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Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) 1st July – 3rd August 2022

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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 2022 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 now consists of seven years (2016-2022).

The survey coverage area included in calculations of the mackerel index was 2.9 million km^2 in 2022, which is 32% larger coverage compared to 2021. Survey coverage was increased in the western areas (Iceland and Greenland waters) compared to in 2021. Furthermore, 0.28 million km^2 was surveyed in the North Sea in July 2022, but those stations are excluded from the mackerel index calculations.

The total swept-area mackerel index in 2022 was 7.37 million tonnes in biomass and 17.51 billion in numbers, an increase by 43% for biomass and 43% for abundance compared to 2021. In 2022, the most abundant year classes were 2020, 2019, 2010, 2011, respectively. The cohort internal consistency improved compared to last year, particularly for ages 5-8 years.

Most of the surveyed mackerel still appears to be in the Norwegian Sea. The mackerel were more westerly distributed than in the last 2 years.

The zero-line was reached south and north of Iceland and in the west in Greenland waters. It was not reached in the north-western and north-eastern part of the Norwegian Sea but given that the polar front with water too cold for mackerel is usually found close to the northwesternmost catches, we assume that the zero-line was practically reached here as well. Towards the Barents Sea the zero-line was not reached but considered of less quantitative importance based on low catch rates. The zero-line was not reached on the European shelf, where mackerel are present west of the British Isles and in the southern North Sea

Total number of NSSH recorded during IESSNS 2022 was 25.0 billion and the total biomass index was 7.14 million tonnes, or 22% (abundance) and 17% (biomass) higher than in 2021. The 2016 year-class (6-year-olds completely dominated in the stock and contributed to 58% and 56% to the total biomass and total abundance, respectively, whereas the 2013 year-class (9-year-olds) contributed 8% and 7% 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 2022 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.

Total biomass of blue whiting registered during IESSNS 2022 was 2.2 million tons, which is to the same as in 2021. Estimated stock abundance (ages 1+) was 27.5 billion compared to 26.2 billion in 2021. Age 1 and 2 respectively, dominated the estimate in 2022 as they contributed to 44% and 33% (abundance) and 30% and 33% (biomass), respectively. The group considered the acoustic biomass estimate of blue whiting to be of good quality in the 2022 IESSNS as in the previous survey years.

As in previous years, there was overlap in the spatio-temporal distribution of mackerel and herring. This overlap occurred between mackerel and North Sea herring in the North Sea and partly in the southernmost part of the Norwegian Sea. There were also some overlapping distributions of mackerel and Norwegian spring-spawning herring (NSSH) particularly in the western, north-western part of the Norwegian Sea.

Other fish species also monitored are lumpfish (*Cyclopterus lumpus*) and Atlantic salmon (*Salmo salar*). Lumpfish was caught at 71% of surface trawl stations distributed across the surveyed area from southwestern part of Iceland, central part of North Sea to southwestern part of the Svalbard. Abundance was greater north of latitude 72°N compared to southern areas. A total of 60 North Atlantic salmon were caught in 38 stations both in coastal and offshore areas from 61°N to 76°N in the upper 30 m of the water column. The salmon ranged from 0.028 kg to 4.1 kg in weight, dominated by post-smolt and 1 sea-winter individuals. We caught from 1 to 6 salmon during individual surface trawl hauls. The length of the salmon ranged from 15 cm to 74 cm, with the highest fraction between 20 cm and 30 cm

Satellite measurements of sea surface temperature (SST) in the Northeast Atlantic in July 2022 show that parts of central Norwegian Sea and areas east and north of Iceland were slightly cooler than the long-term average for July 1990-2009. The northern regions of the Nordic Seas were slightly warmer than the average while the East Greenland Current was cooler that the long-term average. The SST in the Irminger Sea and Iceland Basin were slightly warmer than the average.

The zooplankton biomass varied between areas with a patchy distribution throughout the area. In the Norwegian Sea areas, the average zooplankton biomass was at similar level as last year, slightly lower in Icelandic waters, and higher in Greenlandic waters.

2 Introduction

During approximately four weeks of survey in 2022 (1st of July to 3rd of August), six vessels; the M/V "Eros" and M/V "Vendla" from Norway, "Jákup Sverri" operating from Faroe Islands, the R/V "Árni Friðriksson" from Iceland; R/V "Tarajoq" from Greenland 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. 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 from Norway, Iceland, 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).

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. Greenland did not participate in 2021 but was back in 2022 with their new research vessel R/V "Tarajoq".

The North Sea was included in the survey area for the fifth time in 2022, 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 - 2021 results).

3 Material and methods

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

Overall, the weather conditions were rougher than usual for the Norwegian vessels in the first part of the survey. However, in the second part, the weather conditions and progress were good. The Icelandic vessel, operating in Icelandic waters, experienced calm weather for duration of the survey with no survey delay, and no CTD or WP2-net sampling was skipped due to high winds. The weather was worse than what is has been previous years for the Faroese vessel which operated in Faroese and Icelandic waters. This resulted in slow progression and the Icelandic vessel had to cover the northernmost transect line for R/V Jakup Sverri. The chartered vessel Ceton had good weather conditions throughout the survey.

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 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 2022. 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	4-21/7	4082	48/46	46	46
Jákup Sverri	1-17/7	2768	33/27	28	28
Ceton	3-12/7	1905	38/34	34	-
Vendla	5/7-3/8	5369	74/60	59	59
Eros	5/7-3/8	5233	67/57	56	56
Tarajoq	21/7-1/8	1522	19/19	19	19
Total	1/7-3/8	20879	275/247	242	208

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. Tarajoq used a SEABIRD SBE 19plus. Ceton used a Seabird SeaCat offline CTD. The CTD-sensors were used for recording temperature, salinity, and pressure (depth) from the surface down to 210 m, or to the bottom when at shallower depths.

Zooplankton was sampled with a WP2-net on 4 of 5 vessels, excluding Ceton which operates in the North Sea. Mesh sizes were 180 µm (Eros and Vendla) and 200 µm (Árni Friðriksson, Jákup Sverri and Tarajoq). 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).

Two planned CTD and plankton stations 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. 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 Icelandic and 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). 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 2018, 2019, 2020, 2021 and 2022.

Table 2. Trawl settings and operation details during the international mackerel survey in the Nordic Seas from 1st July to 3rd August 2022. 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	Tarajoq	Influ-ence
Trawl producer	Hampiðjan new 2017 trawl	Egersund Trawl AS	Egersund Trawl AS	Vónin	Egersund Trawl AS	Hampiðjan	0
Warp in front of doors	Dynex-34 mm	Dynex -34 mm	Dynex	Dynex – 38 mm	Dynex-34 mm	Dynex-34 mm	+
Warp length during towing	350	350	290-305	350	350-400	350	0
Difference in warp length port/starb. (m)	16	2-10	10	0-7	5-10	10-20	0
Weight at the lower wing ends (kg)	2×400 kg	2×400	2×400	2×400	2×400	2×500	0
Setback (m)	14	6	6	6	6	6	+
Type of trawl door	Jupiter	Seaflex 7.5 m² adjustable hatches	Thybron type 15	Vónin Twister	Seaflex 7.5 m² adjustable hatches	T-20vf Flipper	0
Weight of trawl door (kg)	2200	1700	1970	1650	1700	2000	+
Area trawl door (m²)	6	7.5 with 25% hatches (effective 6.5)	7	4.5	7 with 50% hatches (effective 6.5)	7 with 50% hatches (effective 6.5)	+
Towing speed (knots) mean (min-max)	5.3 (4.6-5.7)	4.6 (4.1-5.5)	5.1 (4.5-5.6)	4.4 (3.6-6)	4.7 (4.1-5.725)	4.9 (4.4-5.4)	+
Trawl height (m) mean (min-max)	32 (26-41)	28-37	30 (25-35)	43 (35–50)	25-32	-	+
Door distance (m) mean (min-max)	107 (95 - 115)	121.8 (118-126)	131.2 (126-137)	115 (107 – 135)	135 (113-140)	105.4 (92-109)	+
Trawl width (m)*	63.75	63.8	72.0	63.4	67.5	61.4	+
Turn radius (degrees)	5-10	5-12	5-10	5 BB turn	5-8 SB 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)	3-21, 4-8	6-22, 8-23	6-15, 8-20	7-26, 7-20	(6-20)	-	+
Headline depth (m)	0	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 on each wingtip	Kite + 2 buoy on each wingtips	Kite + 1 buoy on each wingtips	+

Weighing of catch	All weighted	All weighted	All weighted	Catch < 12 tonnes weighed	All weighted	All weighted	+

* calculated from door distance (Table 6)

Table 3. Protocol of biological sampling during the IESSNS 2022. Numbers denote the maximum number of individuals sampled for each species for the different determinations.

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

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 20th 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.

Underwater camera observations during trawling

M/V "Eros" 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 night-time when there was midnight sun and good underwater visibility. Video recordings were collected at 70 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 5th July and 2nd August 2022 onboard M/V "Eros" and M/V "Vendla", and onboard R/V Árni Friðriksson from 4th until 21st July 2022. On board Jákup Sverri (1st – 17th 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" and R/V Tarajoq 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 Vendla and Eros were calibrated 4th July 2022 for 18, 38, 70, 120 and 200 kHz. Árni Friðriksson was calibrated 28th of May 2022 for frequencies 18, 38, 70, 120 and 200 kHz. Jákup Sverri was calibrated on 24th April 2022 for 18, 38, 120, 200 and 333 kHz. Tarajoq was calibrated on 20th May 2022 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). 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 2022.

	R/V Árni Friðriksson	M/V Vendla	Jákup Sverri	Eros	Tarajoq*
Echo sounder	Simrad EK80	Simrad EK60	Simrad EK80	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	18, **38**, 70, 120, 200, 333
Primary transducer	ES38-7	ES38B	ES38-7	ES38B	ES38-7
Transducer installation	Drop keel	Drop keel	Drop keel	Drop keel	Drop keel
Transducer depth (m)	9.6	8	6-9	6	7
Upper integration limit (m)	15	15	15	15	
Absorption coeff. (dB/km)	10.5	9.9	9.5	9.3	
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.43	3.064	2.43	
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	18	21.90	21.9	21.9	
2-way beam angle (dB)	-20.30	-20.70	-20.6	-20.7	
TS Transducer gain (dB)	27.03	25.22	27.27	25.22	
s_A correction (dB)	-0.04	-0.73	-0.01	-0.72	
3 dB beam width alongship:	6.43	6.88	6.86	6.85	
3 dB beam width athw. ship:	6.43	6.76	6.89	6.79	
Maximum range (m)	500	500	500	500	750
Post processing software	LSSS v.2.12.0	LSSS 2.12.0	LSSS 2.12.0	LSSS 2.12.0	LSSS 2.12.0

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

*Acoustic data collected but not post-processed at the time of report writing.

Multibeam sonar

Both M/V Eros 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 Eros 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 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 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 2022 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.

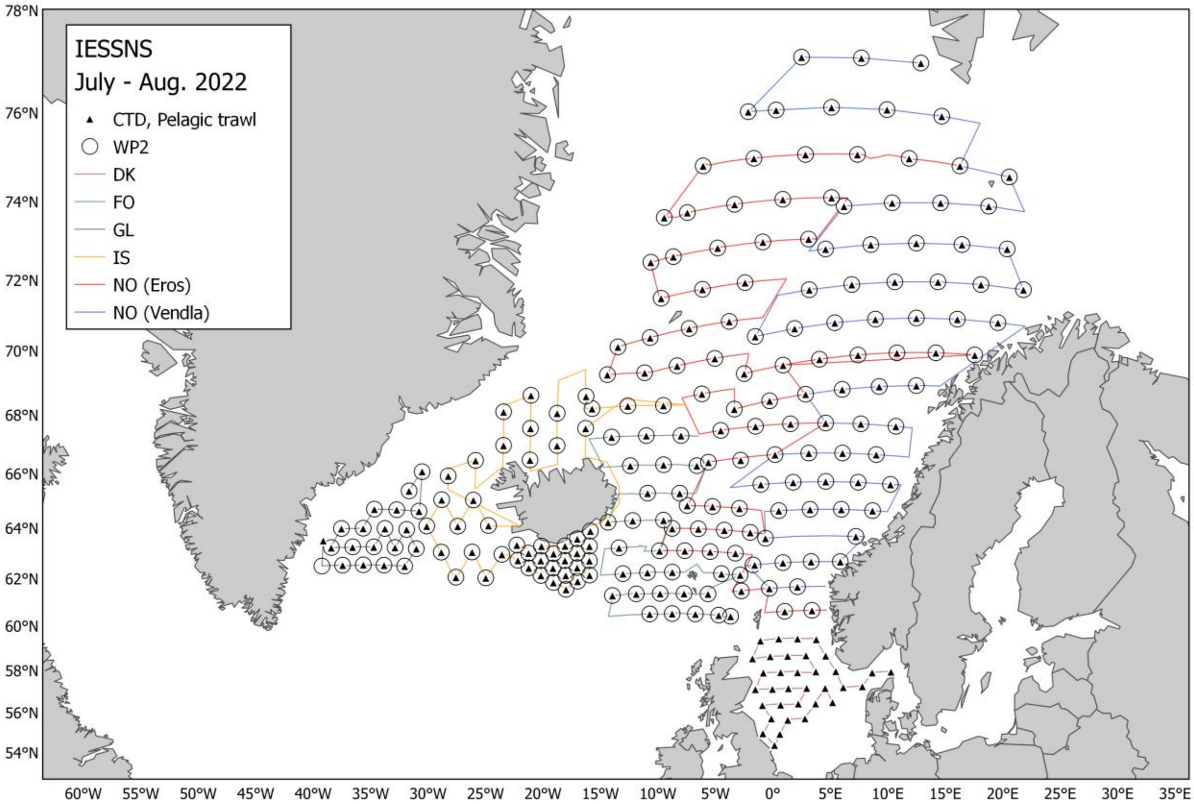

Figure 1. Fixed predetermined trawl stations (shown for CTD and WP2) included in the IESSNS from July 1st to August 3rd 2022. At each station a 30 min surface trawl haul, a CTD station (0-500 m) and WP2 plankton net samples (0-200 m depth) was performed.

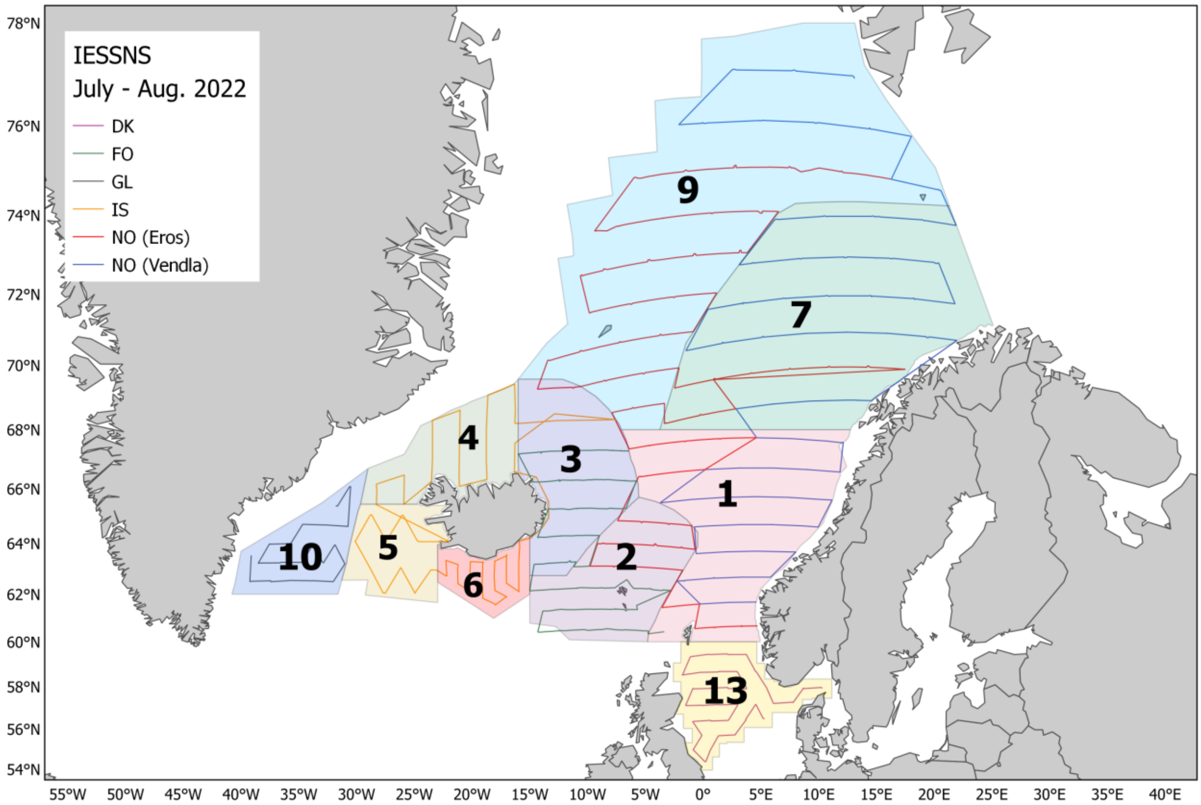

Figure 2. Permanent and dynamic strata used in StoX for IESSNS 2022. The survey area is split into 10 strata, of which 6 are permanent (1, 2, 3, 7, 10 and 13) and four dynamic (4, 5, 6 and 9). The former stratum 8 (along the Norwegian coast) was merged into adjacent strata 1 and 7. The former stratum 11 (southern Greenland) has not been surveyed the last few years. 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).

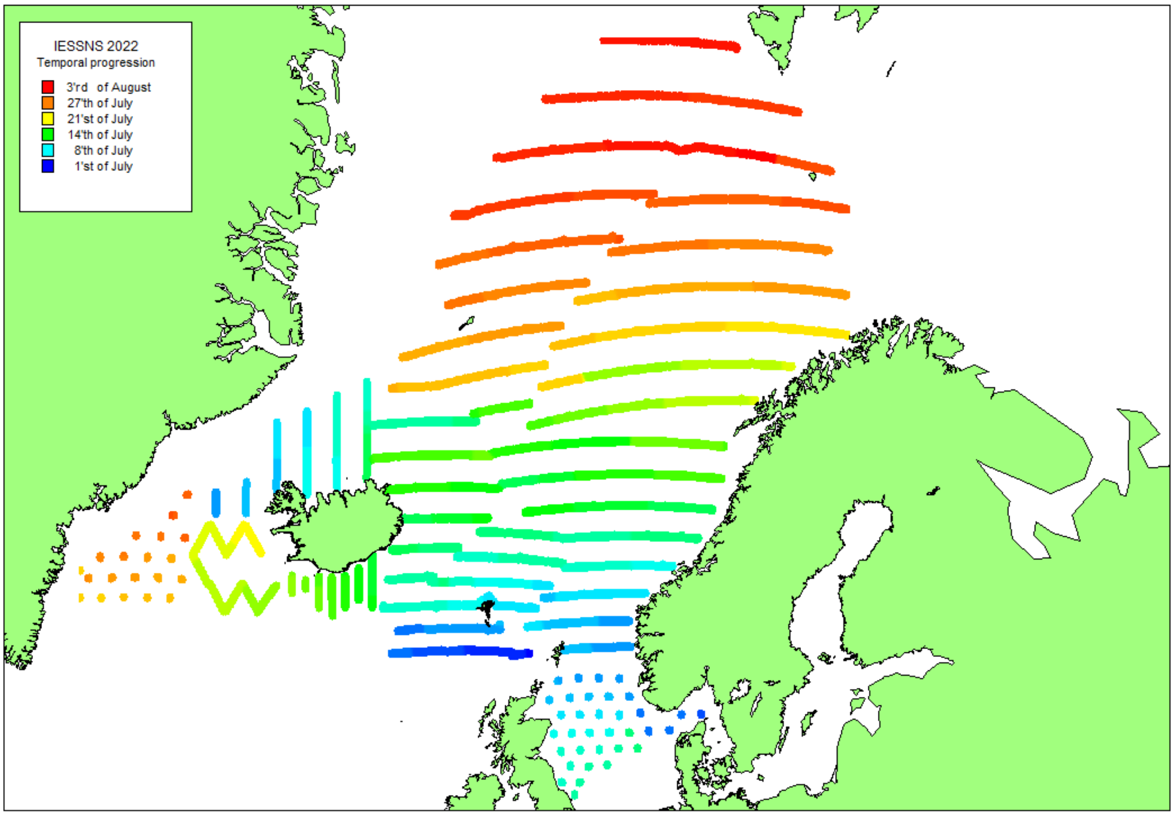

Figure 3. Temporal survey progression by vessel along the cruise tracks during IESSNS 2022: Blue represents effective survey start (1'st of July) progressing to red representing a five-week span (survey ended 3rd of August). As Ceton and Tarajoq did not submit acoustics, they have been represented by 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 3.5.0. The herring and blue whiting acoustic abundance indices were calculated using StoX version 3.4.0.

3.7 Swept area index and biomass estimation

This year the input data for the swept area calculations were taken from the ICES database in contrast to previous years where 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 2022. 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 2022 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	Tarajoq
Trawl doors horizontal spread (m)						
Number of stations	27	44	57	60	34	19
Mean	115	107	122	112	131.2	105.4
max	125	115	136	120	136.7	109.4
min	107	95	115	100	126.4	92.4
st. dev.	4.1	3.9	4.8	4.0	2.7	
Vertical trawl opening (m)						
Number of stations	27	45	59	60	34	-
Mean	43	31.7	35	32.5	29.5	-
max	47	25.8	33	37.0	35.5	-
min	35	41.3	25	18.8	24.9	-
st. dev.	3.8	3.0	2.9	4.33	2.2	-
Horizontal trawl opening (m)						
Mean	63.4	63.75	67.5	63.8	72.0	61.4
Speed (over ground, nmi)						
Number of stations	27	45	57	60	34	19
Mean	4.4	5.3	4.5	4.7	5.1	4.9
max	6	5.7	5.3	5.6	5.6	5.4
min	3.4	4.6	3.0	4.1	4.5	4.4
st. dev.	0.5	0.2	0.5	0.3	0.2	0.2

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

Towing speed 4.5 knots: Horizontal opening (m) = 0.441 * 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 knots. 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	56.6	57	57.2	57.7	58.2	58.7	59.2	59.7	60.2	60.7	61.1	61.6	62.1
101	56.9	57.3	57.6	58.1	58.6	59.1	59.6	60.1	60.6	61.1	61.5	62	62.4
102	57.3	57.7	58.1	58.6	59	59.5	60	60.5	60.9	61.4	61.9	62.4	62.8
103	57.7	58.1	58.5	59	59.5	59.9	60.4	60.9	61.3	61.8	62.3	62.7	63.2
104	58.2	58.6	59	59.4	59.9	60.3	60.8	61.3	61.7	62.2	62.6	63.1	63.5
105	58.6	59	59.4	59.9	60.3	60.8	61.2	61.7	62.1	62.6	63	63.5	63.9
106	59	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	62.5	62.9	63.3	63.8	64.2	64.6
108	59.9	60.3	60.7	61.1	61.6	62	62.4	62.9	63.3	63.7	64.1	64.6	65
109	60.4	60.8	61.2	61.6	62	62.4	62.8	63.2	63.7	64.1	64.5	64.9	65.3
110	60.8	61.2	61.6	62	62.4	62.8	63.2	63.6	64.1	64.5	64.9	65.3	65.6
111	61.3	61.6	62	62.4	62.8	63.2	63.6	64	64.4	64.8	65.2	65.6	66
112	61.7	62.1	62.5	62.9	63.3	63.7	64	64.4	64.8	65.2	65.6	66	66.3
113	62.2	62.5	62.9	63.3	63.7	64.1	64.4	64.8	65.2	65.6	65.9	66.3	66.6
114	62.6	63	63.4	63.7	64.1	64.5	64.9	65.2	65.6	66	66.3	66.6	67
115	63.1	63.5	63.8	64.2	64.5	64.9	65.3	65.6	66	66.3	66.7	67	67.3
116	63.6	63.9	64.3	64.6	65	65.3	65.7	66	66.4	66.7	67	67.3	67.6
117	64	64.4	64.7	65	65.4	65.7	66.1	66.4	66.8	67.1	67.4	67.7	68
118	64.5	64.8	65.1	65.5	65.8	66.1	66.5	66.8	67.2	67.5	67.8	68	68.3
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	68.6
120	65.4	65.7	66	66.3	66.6	67	67.3	67.6	67.9	68.2	68.5	68.7	68.9
121	65.8	66.1	66.5	66.8	67.1	67.4	67.7	68	68.3	68.6	68.8	69	69.3
122	66.2	66.5	66.9	67.2	67.5	67.8	68.1	68.4	68.7	69	69.1	69.4	69.6

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 2022 were slightly cooler than the long-term average for July 1990-2009 based on SST anomaly plots (Figure 4). The northern regions of the Nordic Seas were slightly warmer than the average while the East Greenland Current was cooler that 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 4-5). However, since the anomaly is based on the average for the whole month of July, it should give representative results of the surface temperature.

In situ measurements from the survey showed that the upper layer (10 m depth) in 2022 generally was slightly cooler than 2021, except for the northern areas with slightly warmer surface layer (Figure 5, upper left panel). However, in the deeper layers (50 m and deeper; Figure 5, upper right panel and bottom panels), the hydrographical features in the area were similar to previous years. The increased presence of the East Icelandic Current visible in the surface might be due to the relatively cold July month in 2022 with less summer stratification in the that area. 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.

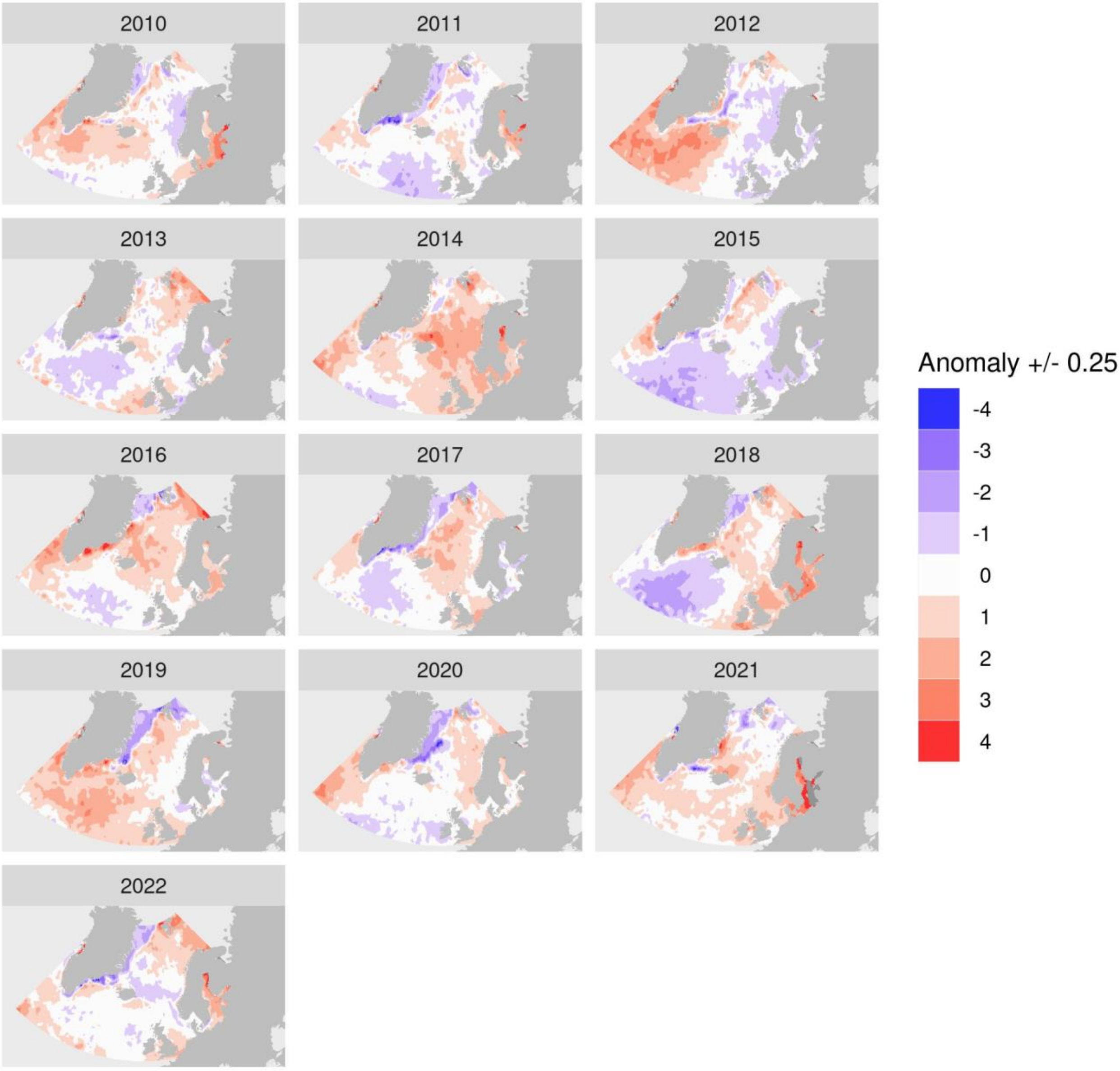

Figure 4. Annual sea surface temperature anomaly (-4 to +4°C) in Northeast Atlantic for the month of July from 2010 to 2022 showing warm and cold conditions in comparison to the average for July 1990-2009. Based on monthly averages of daily Optimum Interpolation Sea Surface Temperature (Ver. 2.1 NOAA OISST, AVHRR-only, Banzon et al. 2016, https://www.ncdc.noaa.gov/oisst).

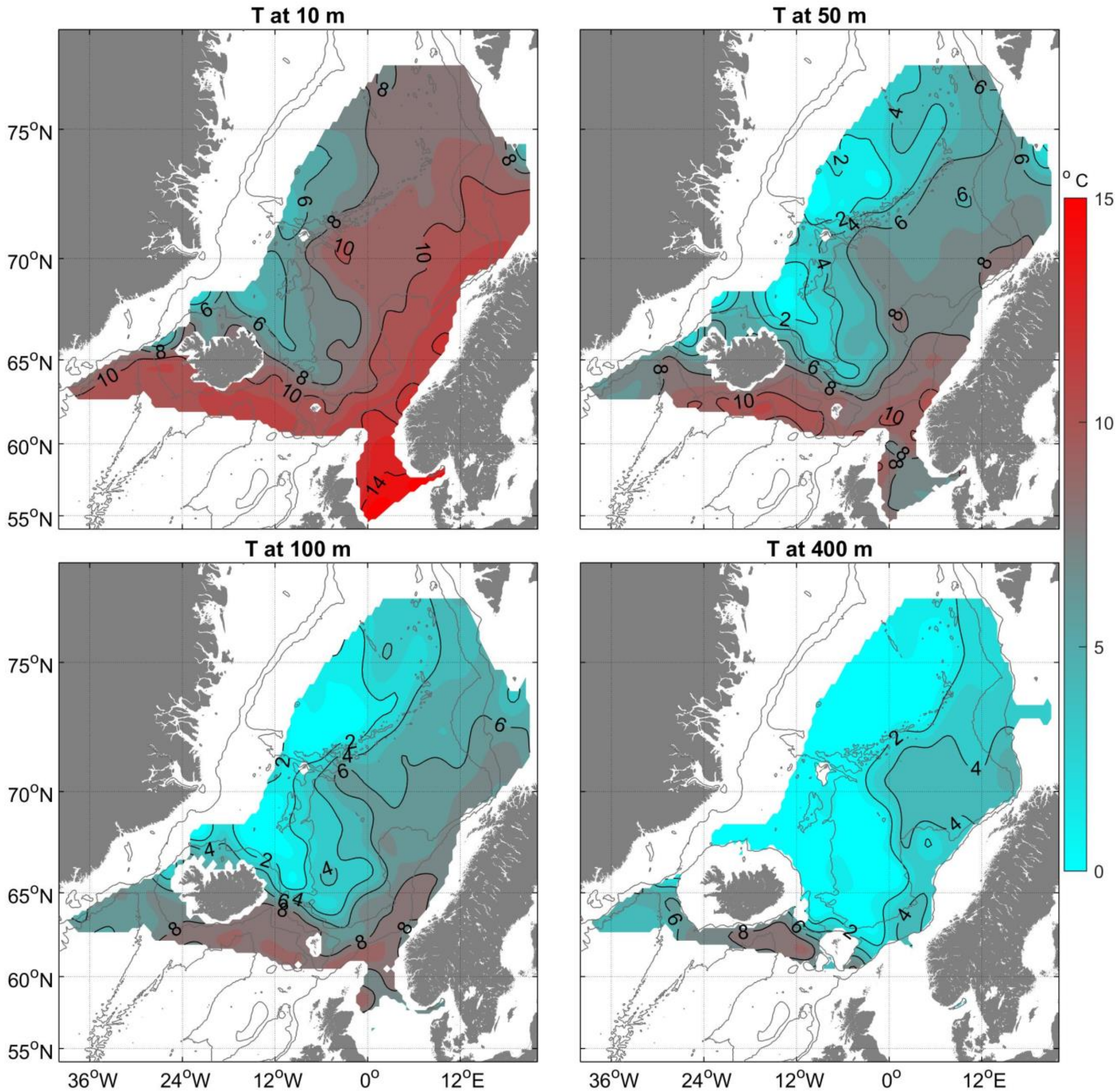

Figure 5. Temperature (°C) at 10, 50, 100 and 400 m depth in Nordic Seas and the North Sea in July-August 2022. 500 m and 2000 m depth contours are shown in light grey.

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 at the same level as last year.

The time-series of average zooplankton biomass averaged by three subareas: Greenland region, Iceland region and the Norwegian Sea region is shown in Figure 6b (see definitions in legend). In the Greenland area an increase was observed in 2022 compared to the low 2020 value (not surveyed in 2021). In the Icelandic region the level was the same as in 2021. The Greenland and Iceland time-series co-vary (2014-2020, 2022 r = 0.89). The biomass index in the Norwegian Sea varied less compared to the other two indices, and showed a slight decrease in 2022 from a relatively stable level since 2013 (Figure 6b). The lower variability 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.

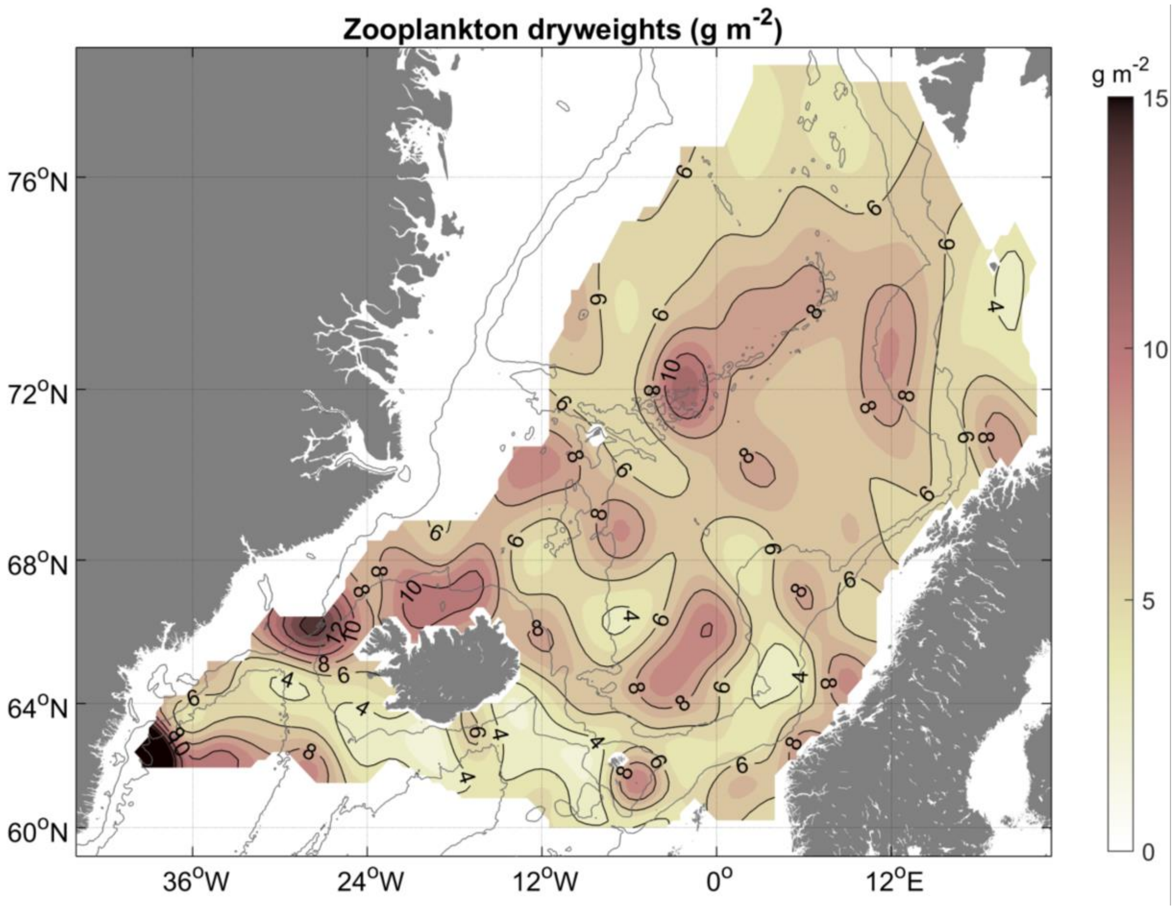

Figure 6a. Zooplankton biomass (g dw/m2, 0-200 m) in Nordic Seas in July-August 2022. 500 m and 2000 m depth contours are shown in light grey.

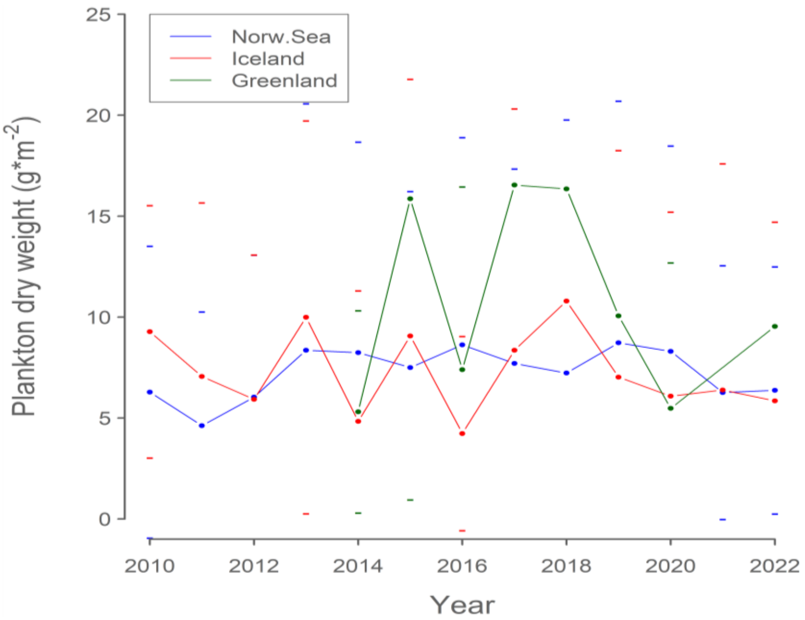

Figure 6b. Zooplankton biomass indices (g dw/m2, 0-200 m). Time-series (2010-2022) of mean zooplankton biomass for three subareas within the survey range: Norwegian Sea (between 14°W-17°E & north of 61°N), Icelandic waters (14°W-30°W) and Greenlandic waters (2014-2022, west of 30°W).

4.3 Mackerel

The total swept-area mackerel index in 2022 was 7.37 million tonnes in biomass and 17.51 billion in numbers, an increase of 43% for biomass and 43% for abundance compared to 2021. The survey coverage area (excl. the North Sea, 0.28 million km²) was 2.9 million km² in 2022, which is 32% larger compared to 2021. The mackerel catch rates varied from zero to 103 tonnes/km² (mean = 2.3 tonnes/km², with two very large values (70 and 103, see CPUE by station in Figure 7 together with the mean catch rates per 2° lat. x 4° lon. rectangles). These two hauls contributed with 33% of the total biomass index (Appendix 3). This is also explains the very high uncertainty of the estimate. It is worth noting that western part of the northern Norwegian Sea (stratum 9) was oversampled as three surface trawl stations were added, at the dynamic stratum boundary, at only half the distance from next station, 35 nm instead of 70 nm. Mackerel was caught at all these station and max catch per station was about one ton. All three stations were included in the index calculations and the dynamic stratum boundary extended 35 nm westward of these three stations.

Most of the surveyed mackerel still appears to be in the Norwegian Sea. The mackerel were more westerly distributed than in the last 2 years.

The zero-line was reached south and north of Iceland and in the west in Greenland waters. It was not reached in the northwestern and northeastern part of the Norwegian Sea but given that the polar front with water too cold for mackerel is usually found close the northwestern most catches, we assume that the zero-line was practically reached here as well. Towards the Barent Sea the zero-line was not reached but considered of less quantitative importance based on low catch rates. The zero-line was not reached on the European shelf, where mackerel are present west of the British Isles and in the southern North Sea (Campbell, 2021).

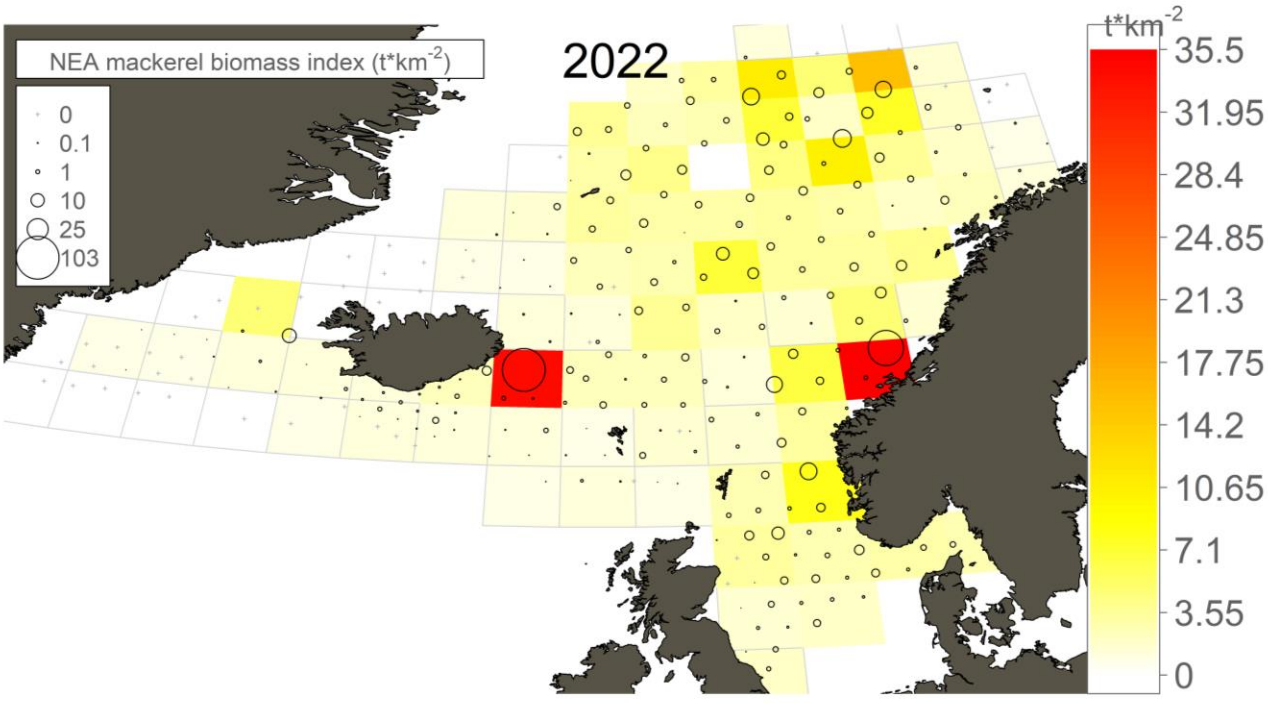

Figure 7. Mackerel catch rates by Multpelt 832 pelagic trawl haul at predetermined surface trawl stations (circle areas represent catch rates in kg/km²) overlaid on mean catch rates per standardized rectangles (2° lat. x 4° lon.) in Nordic Seas in July-August 2022.

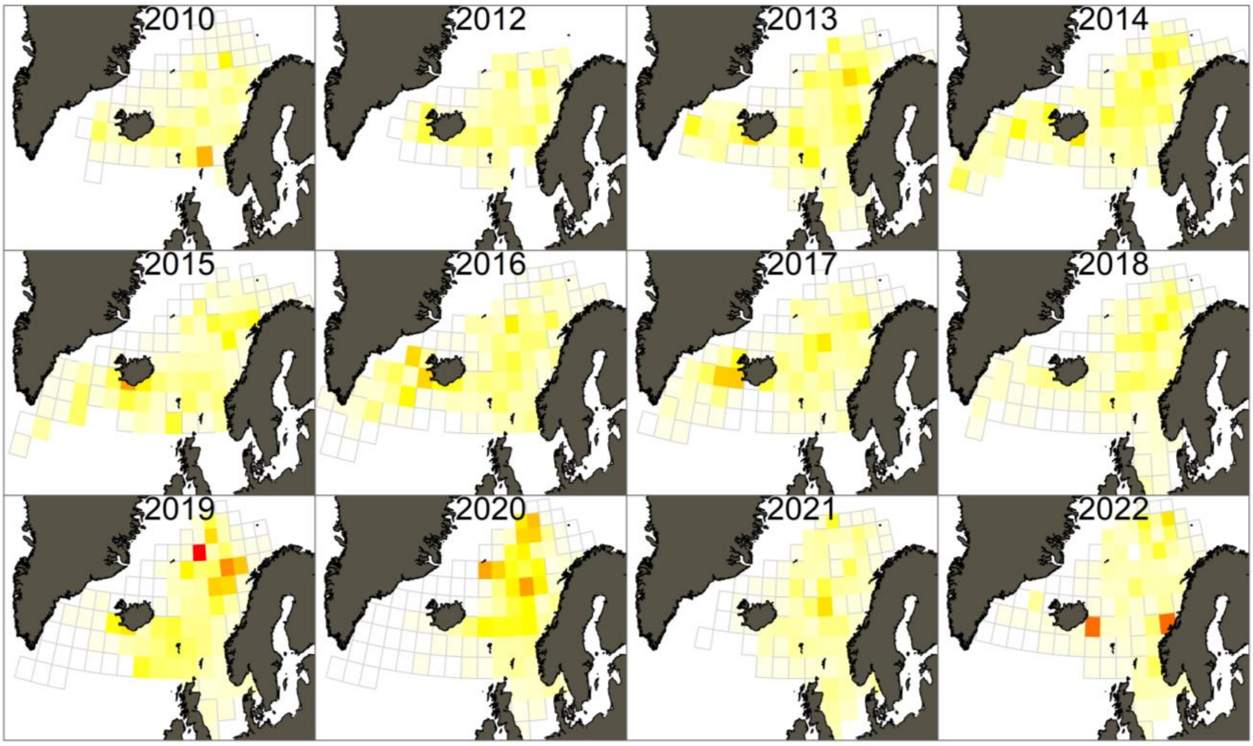

Figure 8. Annual distribution of mackerel proxied by the absolute distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations in Nordic Seas in June-August 2010-2022. Colour scale goes from white (= 0) to red (= maximum value for the highest year).

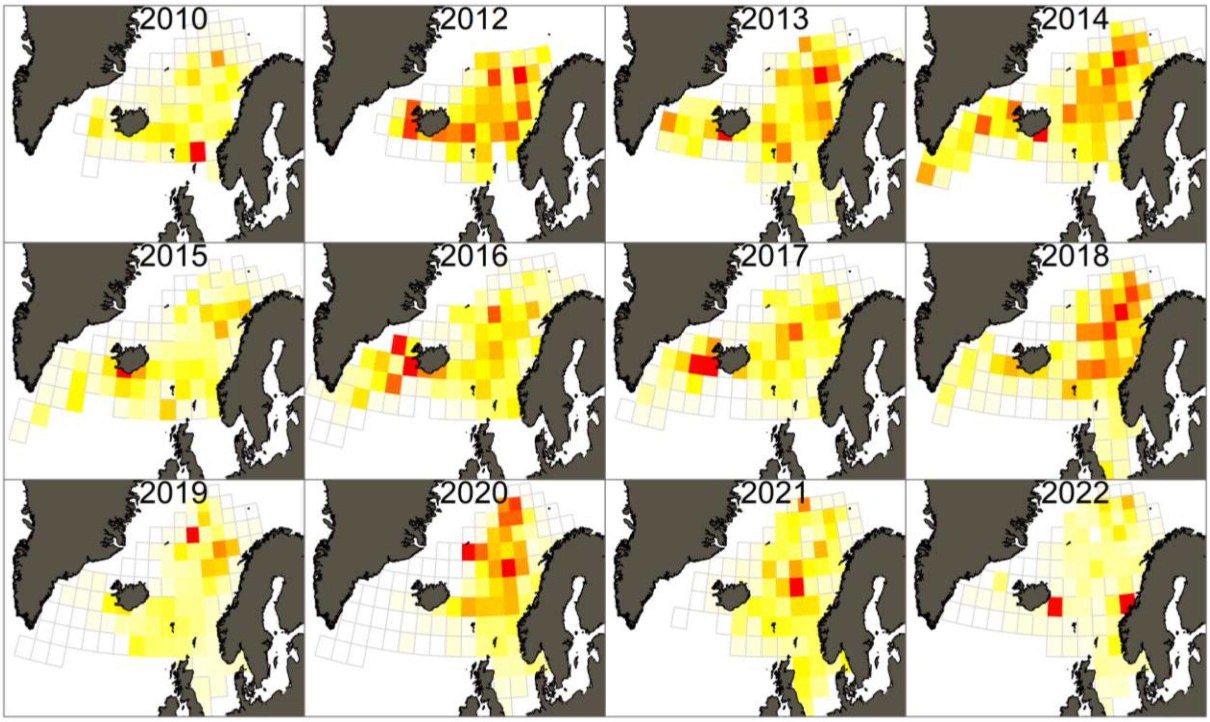

Figure 9. Annual distribution of mackerel proxied by the relative distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations stations in Nordic Seas in June-August 2010-2022. Colour scale goes from white (= 0) to red (= maximum value for the given year).

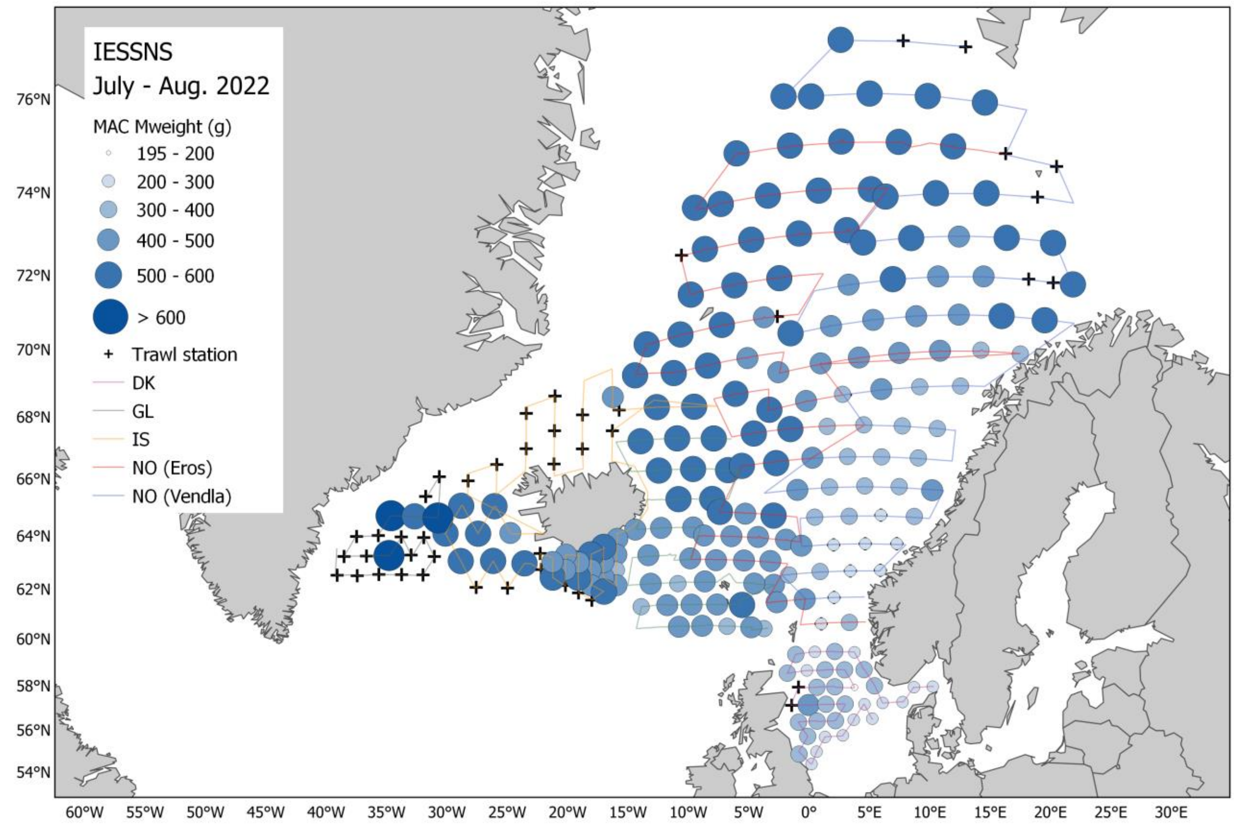

Figure 10. Average weight of mackerel at predetermined surface trawl stations during IESSNS 2022.

The mackerel weight varied between 48 to 872 g with an average of 388 g. The length of mackerel caught in the pelagic trawl hauls onboard the five vessels varied from 18 to 46 cm, with an average of 33 cm. Individuals in the length range 30-31 cm and 36-40 cm dominated in numbers and biomass. 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 2022 according to surface trawl catches is shown in Figure 11.

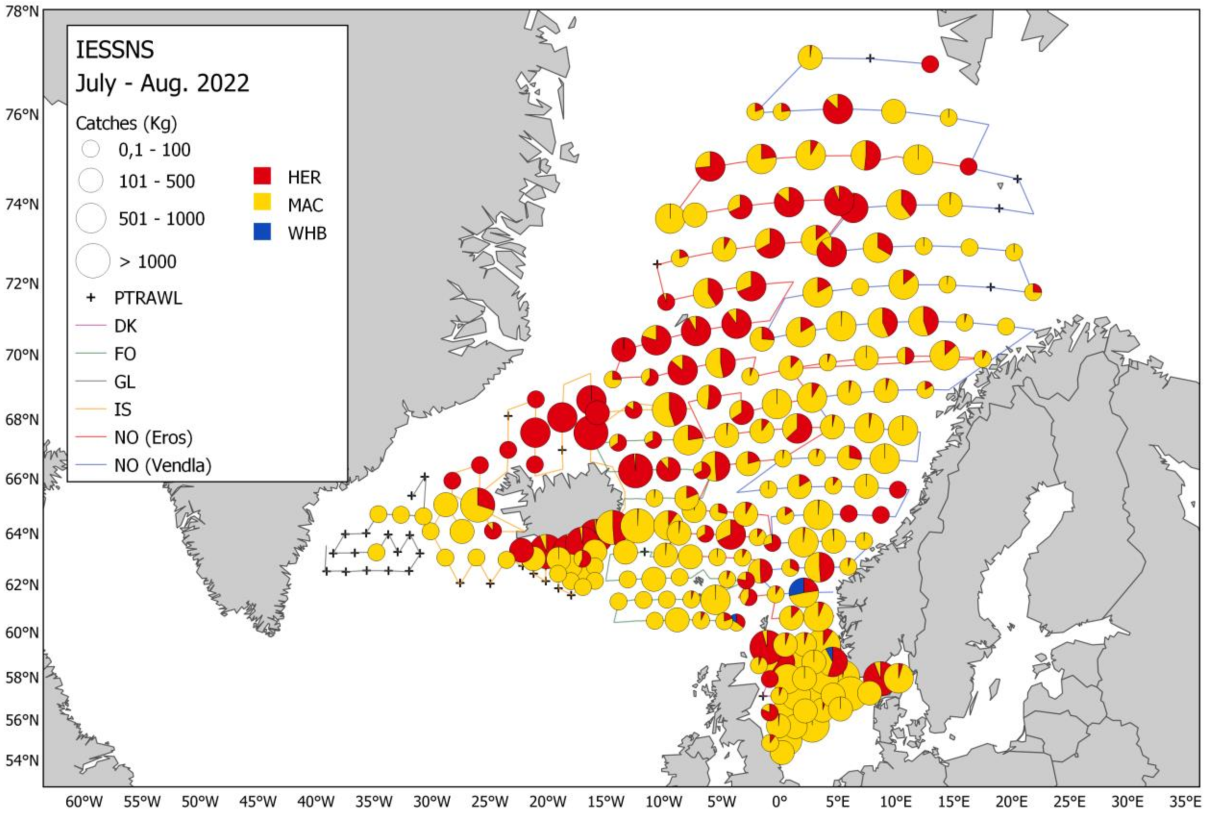

Figure 11. Distribution and spatial overlap between mackerel, herring, and blue whiting, at all surface trawl stations during IESSNS 2022. Vessel tracks are shown as continuous lines and predetermined surface trawl stations with no catch of the three species is displayed as +.

Swept area analyses from standardized pelagic trawling with Multpelt 832

The swept area estimates of mackerel biomass from the 2022 IESSNS were based on abundance of mackerel per stratum (see strata definition in Figure 2) and calculated in StoX version 3.5.0. Mackerel abundance index in 2022 was slightly lower than the time series mean of 18.9 billion (Table 7a; Figure 12) and the biomass index was slightly higher than the mean of 7.28 million tons (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 2022, the most abundant year-classes were respectively 2020 (age 2), 2019 (age 3), 2012 (age 10), and 2011 (age 11) (Figure 13). Mackerel of age 1, 2 and to some extent also age 3 are not completely recruited to the survey (Figure 15), information on recruitment is therefore uncertain. Variance in age index estimation is provided in Figure 14.

The overall internal consistency was slightly improved 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 0.70 and 0.91. However, the internal consistency is more variable between age 5 to 9, with r=0.43 between 5 and 6 years (r=0.43) and r=0.22 between 7 and 8 years. The reason for the relatively low consistency for these year groups are not clear.

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).

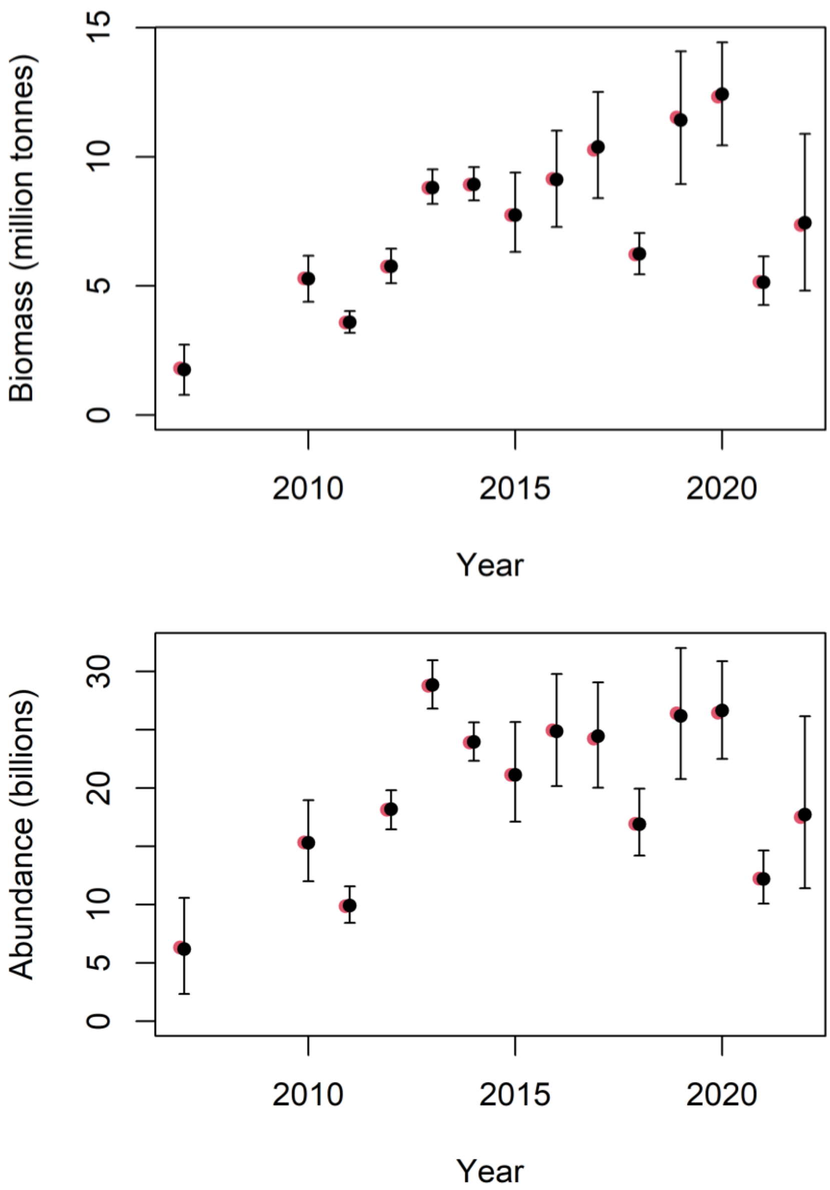

Figure 12. Estimated total stock biomass (upper panel) and total stock numbers (lower panel) of mackerel from StoX for the years 2007 and from 2010 to 2022. The red dots are baseline estimates, the black dots are mean of 1000 bootstrap replicates while the error bars represent 90 % confidence intervals based on the bootstrap.

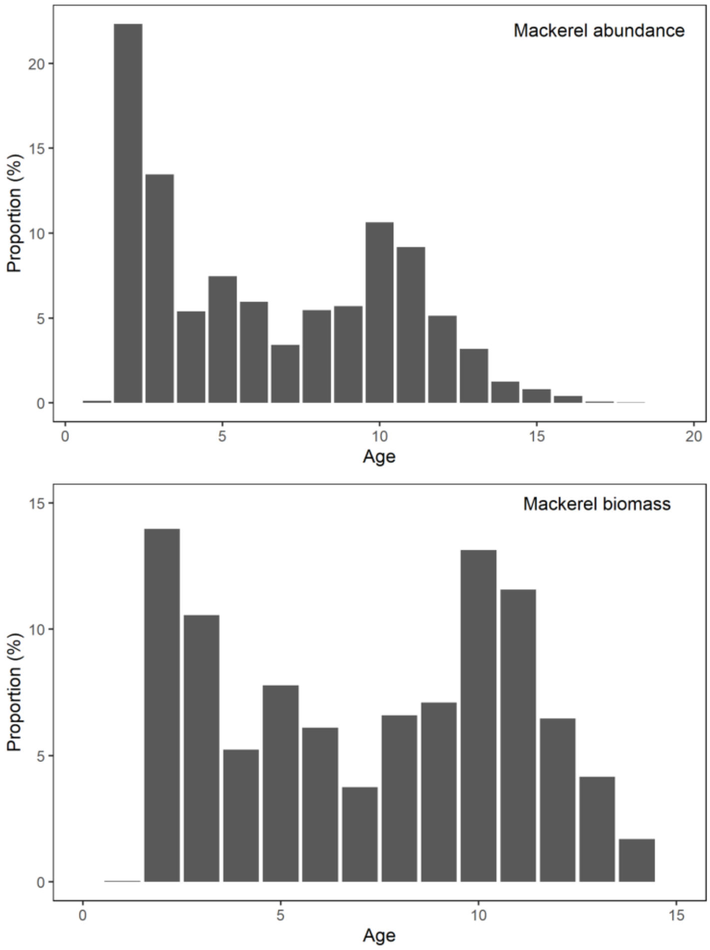

Figure 13. Mackerel age distribution in numbers (%) and in biomass (%) from IESSNS 2022.

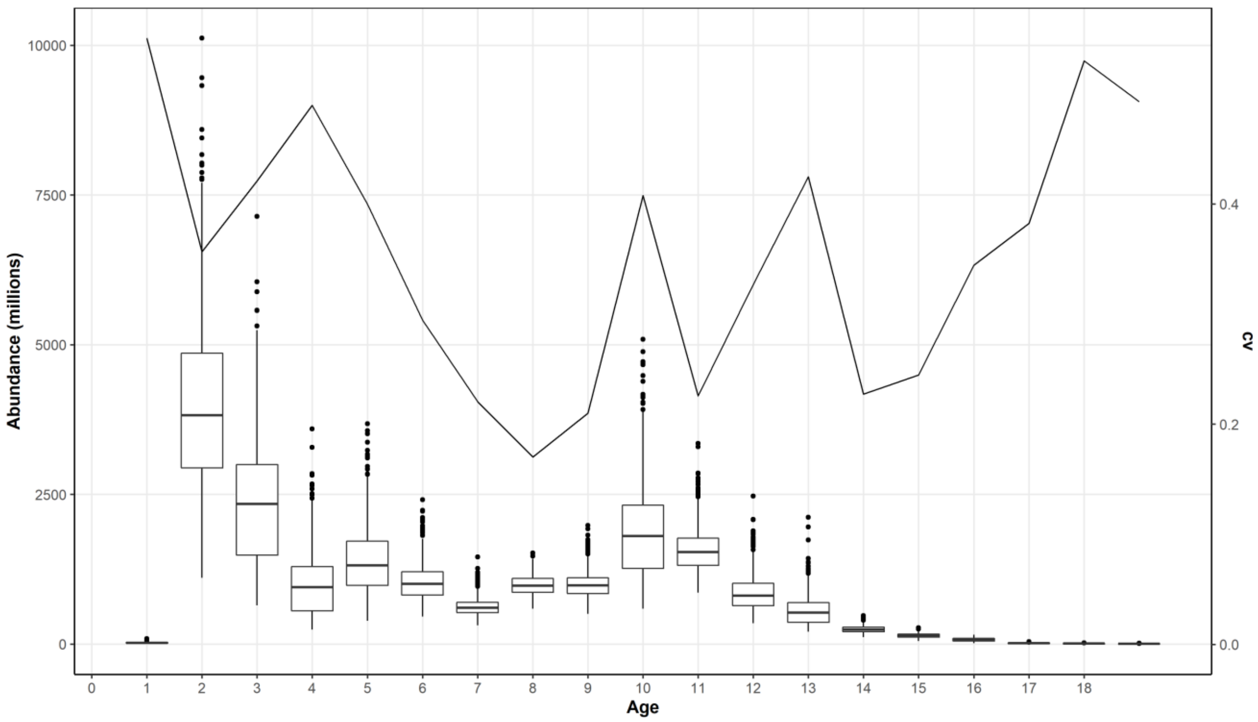

Figure 14. Number by age for mackerel in 2022. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

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 2022, 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

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

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

d)	Age in years (year class)														Number	Biomass	Mean
Length	1	2	3	4	5	6	7	8	9	10	11	12	13+	NA			weight
(cm)	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010			(10^6)	(10^6 kg)	(g)
18-19	1														1	0	46.7
19-20	8														8	0	58.1
20-21	3														3	0	66.4
21-22	3														3	0	74.5
22-23														0	0	0	88.0
23-24															0	0	
24-25														0	0	0	126.0
25-26															0	0	
26-27	0														0	0	166.0
27-28															0	0	
28-29	8	64													72	15	214.4
29-30		805	30	3											838	200	239.1
30-31		1 809	9		4	3									1 825	471	258.1
31-32		993	353	2	34	5									1 386	390	281.7
32-33		178	637	25	5	5									851	265	311.5
33-34		34	711	96	43	10	3		0	0					896	301	336.3
34-35	0	16	384	95	133	52	0					0			681	248	363.6
35-36		3	204	70	104	279	125	13	7	3	2				808	313	387.6
36-37			26	477	219	236	77	38	1	17	26	0	4		1 120	471	420.5
37-38		4	1	168	439	269	153	127	84	403	97	43	11		1 799	835	464.1
38-39			1	7	171	161	158	461	195	435	527	295	226		2 639	1321	500.5
39-40		4	0	1	157	17	41	198	511	465	497	301	188		2 382	1256	527.5
40-41					0	3	28	111	174	493	341	159	297		1 606	910	566.5
41-42				0		4	12	4	19	40	98	82	203		464	280	606.3
42-43								2	5	6	17	8	56		94	61	642.4
43-44								3			1	9	21		33	22	687.6
44-45													3		3	2	704.0
45-46														1	1	1	803.8
46-47														0	0	0	872.0
TSN(mill)	23.4	3 909.5	2 355.9	944.4	1 307.8	1 043.4	598.2	956.1	995.9	1 862.0	1 605.7	897.6	1 011.3	2.2	17 513.5	7365	
TSB(1000 t)	2.9	1 028.7	777.1	385.4	572.3	449.4	276.5	485.8	522.7	967.2	851.5	476.6	567.8	1.4	7 365.3		
Mean length(cm)	22.7	30.2	32.7	35.5	36.4	36.2	37.1	38.2	38.8	38.6	38.9	39.0					
Mean weight(g)	125	263	330	408	438	431	462	508	525	519	531	531					

Table 8. Bootstrap estimates from StoX (based on 1000 replicates) of mackerel in 2022. 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	3.9	20.3	41.5	21.3	12.0	0.56
2	1945.0	3822.1	6590.4	3974.3	1416.0	0.36
3	1019.0	2341.4	4200.5	2384.2	1002.9	0.42
4	382.1	950.4	1858.6	988.8	483.8	0.49
5	575.8	1311.0	2357.8	1380.1	551.4	0.40
6	617.4	1006.7	1609.3	1043.2	306.7	0.29
7	434.8	602.8	845.6	618.9	136.3	0.22
8	704.6	972.9	1250.1	980.5	166.5	0.17
9	696.4	977.0	1367.3	991.6	207.9	0.21
10	874.3	1801.7	3269.0	1872.5	763.0	0.41
11	1068.4	1534.8	2206.6	1567.8	353.6	0.23
12	487.9	808.9	1340.7	849.8	277.5	0.33
13	283.9	522.3	983.6	556.4	236.2	0.42
14	162.4	241.0	343.9	245.3	55.7	0.23
15	88.7	141.7	201.7	142.8	34.9	0.24
16	33.6	78.2	112.2	74.5	25.6	0.34
17	6.5	14.1	25.4	14.8	5.6	0.38
18	1.1	6.0	12.7	6.6	3.6	0.55
19	0.0	2.5	7.6	2.7	2.7	1.03
TSN	11388	17196	26156	17719	4558	0.26
TSB	4.82	7.23	10.89	7.44	1.87	0.25

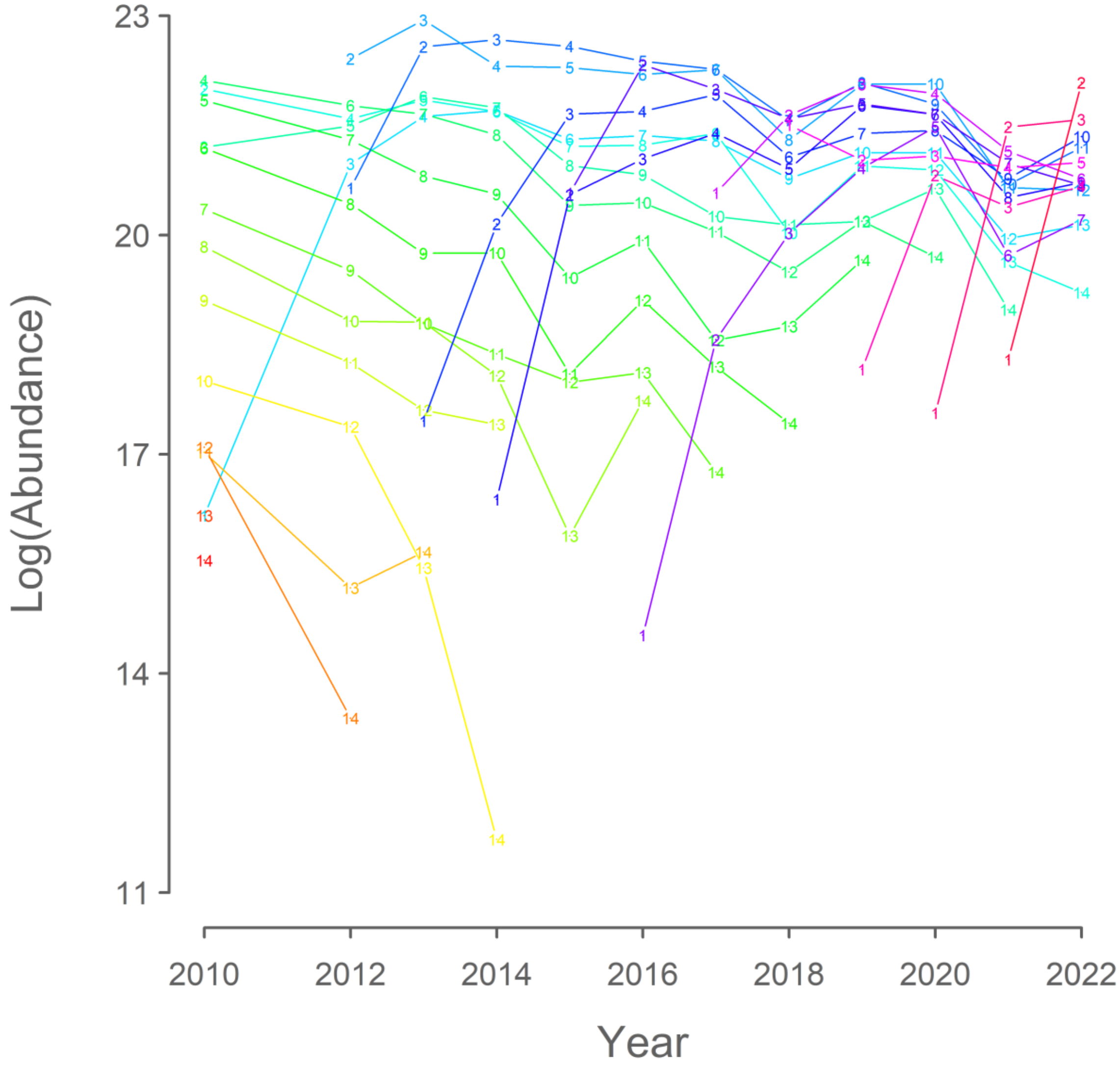

Figure 15. Catch curves for the years 2010; 2012-2022. Each cohort of mackerel is marked by a uniquely coloured line that connects the estimates indicated by the respective ages.

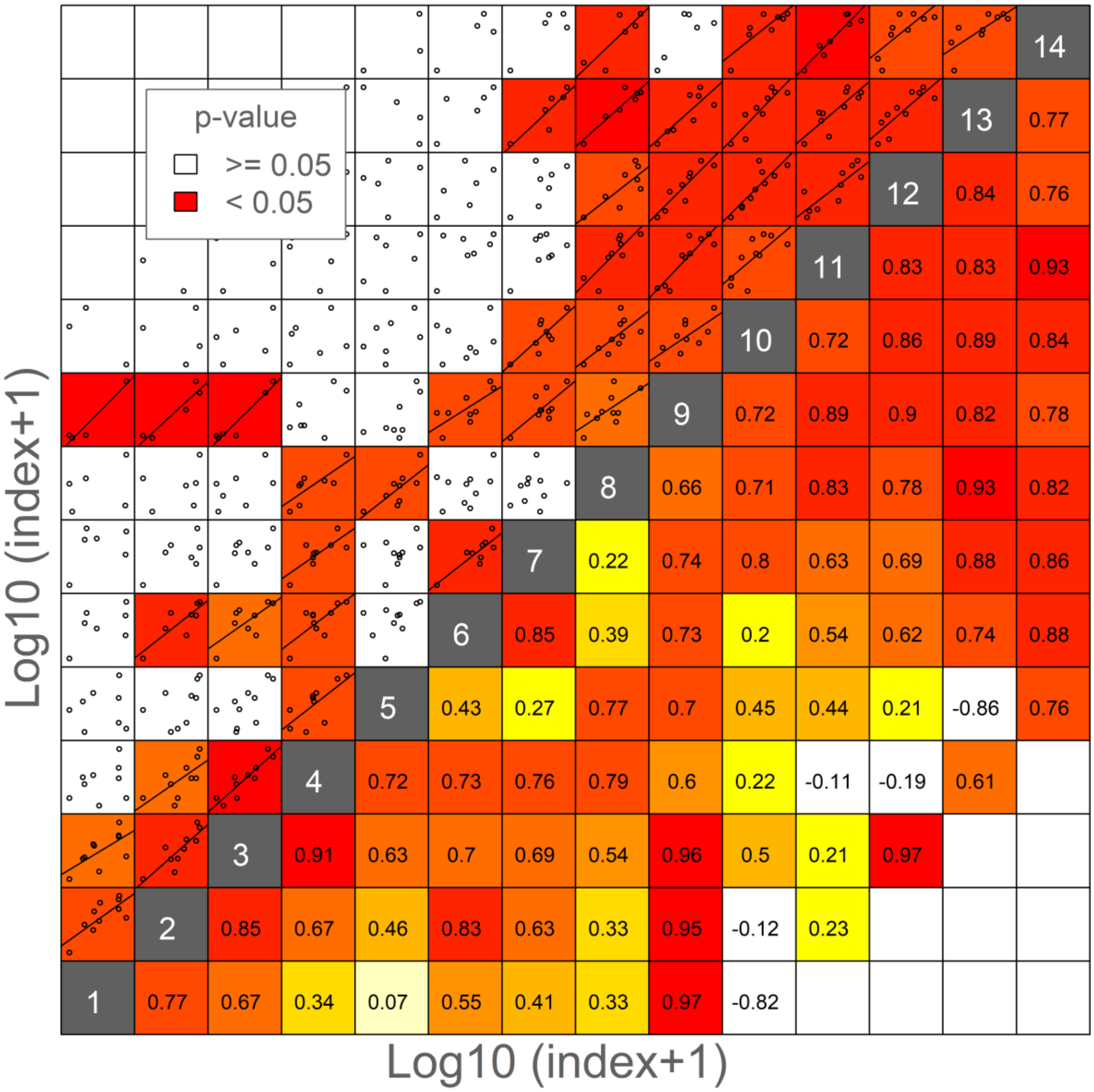

Figure 16 Internal consistency of the of mackerel density index from 2012 to 2022. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations ($p<0.05$) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given 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 56.6.5-75.4 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 in July 2022. A relatively large part of the adult NSSH stock was distributed north of 68°N (Figure 17a). 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, except some putative North Sea herring in the southeastern area north of Shetland (Figure 17b).

The total number of NSSH recorded during IESSNS 2022 was 25.0 billion and the total biomass index was 7.14 million tonnes, or 22% (abundance) and 17% (biomass) higher than 2021 (Table 10 and 11).

The 2016 year-class (6 year-olds) completely dominated in the stock and contributed 58% and 56% to the total biomass and total abundance, respectively, whereas the 2013 year-class (9 year-olds) contributed 8% and 7% to the total biomass and total abundance, respectively (Figure 18 and Table 9). The 2016 year-class is fully recruited to the adult stock.

Bootstrap estimates of numbers by age are shown in Figure 18. The uncertainty (CV) around the age disaggregated abundance indices from the 2022 survey was very low, except for the highly dominating 6 year-olds (2016 year class) (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 0-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 2022 to be of the similar quality as in the previous survey years.

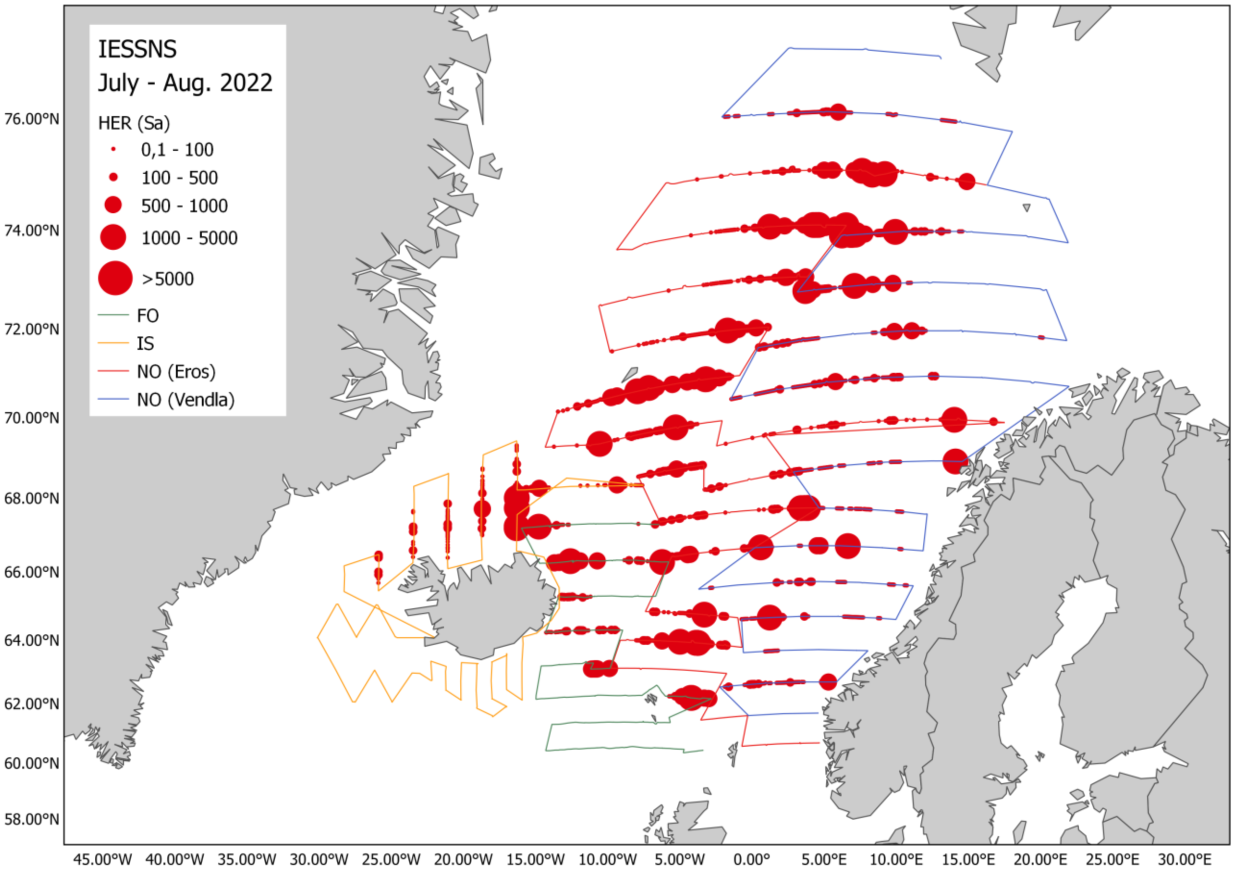

Figure 17a. The sA/Nautical Area Scattering Coefficient (NASC) values of herring along the cruise tracks in 2022 presented as contour lines. Values north of 62ºN, and east of 14ºW, are considered to be Norwegian spring-spawning herring. South and west of this area the herring observed are other stocks, *i.e.* Icelandic summer spawners, Faroese autumn spawners and North Sea herring in the southeast.

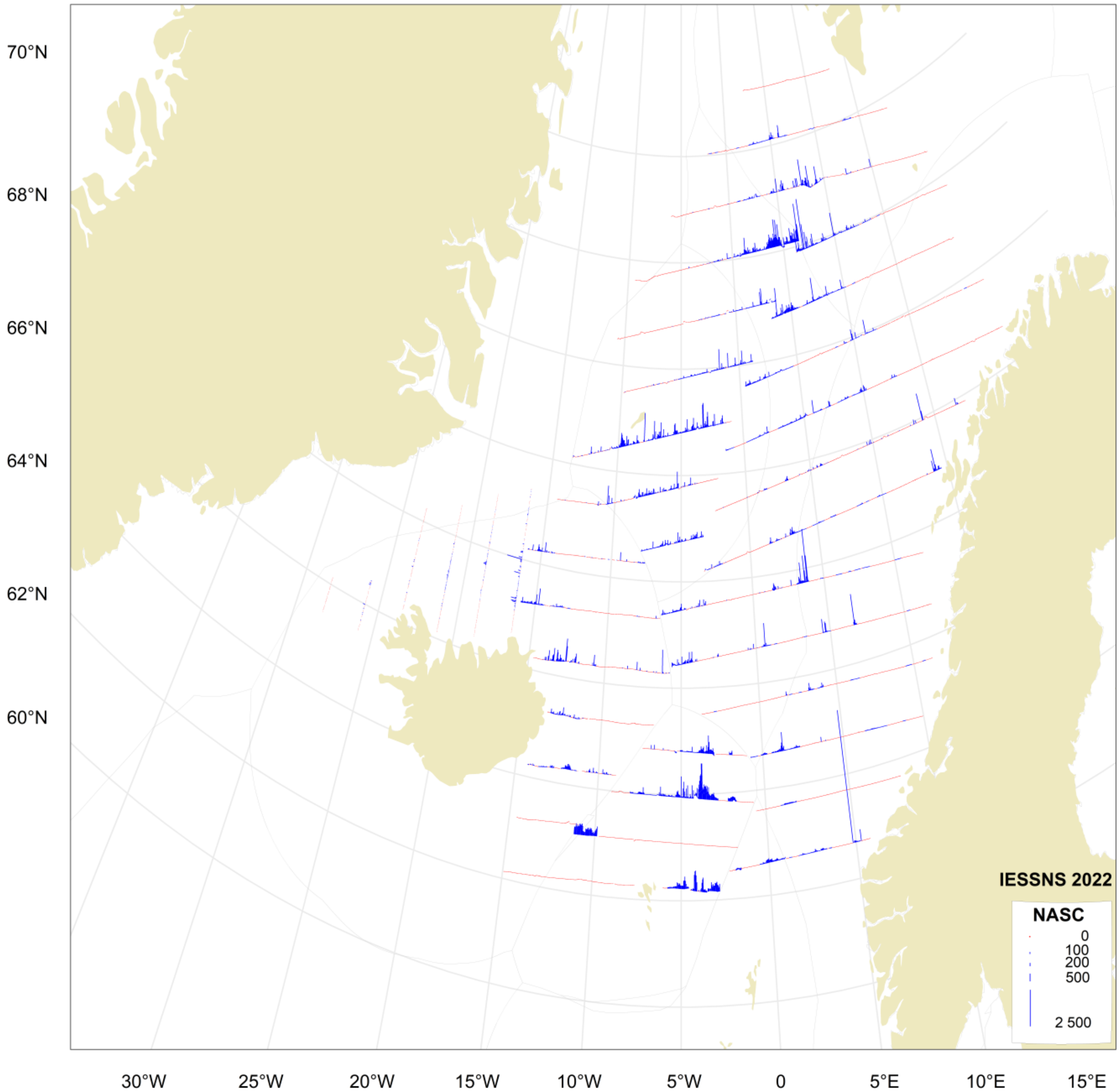

Figure 17b. The sA/Nautical Area Scattering Coefficient (NASC) values of Norwegian spring-spawning herring along the cruise tracks in 2022, presented as bar plot.

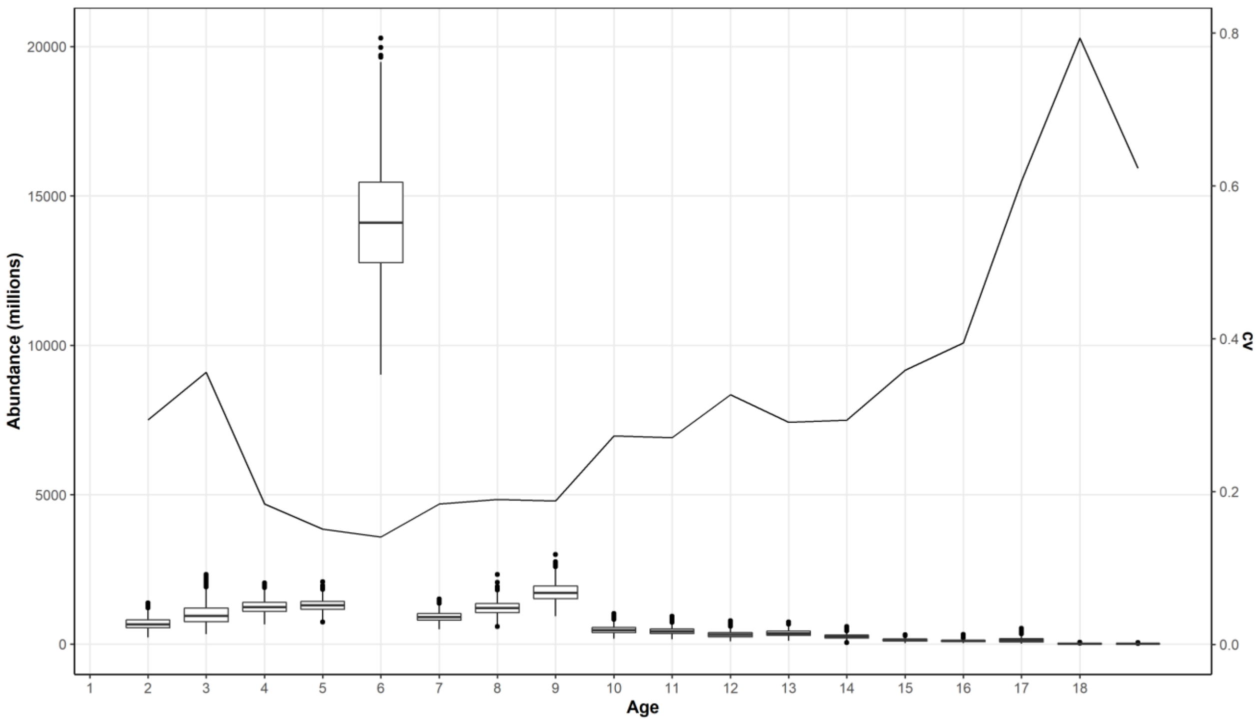

Figure 18. Abundance by age for Norwegian spring-spawning herring during IESSNS 2022. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 9. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring based on calculation in StoX (bootstrap) for IESSNS 2022.

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)
15-16																					
16-17																					
17-18																					
18-19																					
19-20			30.1																30.1	2.6	85.0
20-21		17.7	26.7																44.3	3.4	70.7
21-22		9.0	82.6																91.6	8.5	89.6
22-23		149.0	45.6																194.6	19.5	100.4
23-24		217.2	143.0	4.4															364.6	41.6	114.8
24-25		156.8	55.5	9.6															221.9	29.1	131.1
25-26		86.0	108.8	93.4	7.4														295.7	44.7	150.2
26-27		45.4	68.8	222.9	73.2														410.4	68.6	167.1
27-28			70.3	225.9	57.9	51.9			6.5										412.5	78.5	186.4
28-29			143.3	228.1	113.2	67.0	24.1	15.3	60.7	22.7									674.2	145.7	213.0
29-30			135.9	191.7	141.3	117.0	43.6	3.6	218.8	3.1		11.8							866.9	207.5	238.7
30-31			39.4	127.1	337.6	857.1	24.2	42.5	141.5	55.1	47.3	21.1	12.3	24.7	10.5				1 740.3	454.0	259.0
31-32			55.8	119.6	264.1	3301.7	37.3	94.8	82.4	73.6	32.6	19.9	3.5						4 085.2	1142.3	278.0
32-33				23.2	252.2	5232.2	134.8	120.5	46.7	28.4	36.0	2.2		21.8					5 898.0	1748.0	296.1
33-34			2.3		49.8	3249.0	217.9	184.0	58.5	14.7	10.8			21.2	11.0				3 819.3	1199.2	313.1
34-35				4.8		1107.3	259.0	355.6	371.5	45.6	21.3		17.0			10.5			2 192.5	738.5	335.9
35-36						141.1	126.0	300.9	448.1	48.4	40.3	20.8	47.7	22.1		12.2	2.2		1 209.8	440.0	361.7
36-37					4.2		22.7	84.2	233.8	112.1	88.3	24.7	81.9	65.7	5.3	5.0	3.4		731.3	278.8	376.2
37-38						10.8	13.0	9.3	65.6	61.7	109.1	91.8	136.5	25.6	47.1	29.3	22.2	5.1	627.2	251.8	402.4
38-39							11.6			11.7	33.8	90.9	48.1	37.3	41.8	43.4	48.8	4.8	372.2	156.9	422.0
39-40											13.8	19.3	12.6	16.5	19.1	5.3	43.8	4.1	134.6	60.5	445.9
40-41												12.7	3.6	18.3	6.3		5.3		46.2	20.7	454.9
41-42																1.1	4.8		5.9	20.7	489.3
42-43																		0.6	0.6	2.8	510.9
TSN(mill)		681.2	1008.0	1250.7	1301.0	14135.1	914.3	1210.8	1734.0	477.1	433.3	315.1	363.1	253.2	141.1	106.9	130.5	14.6	25 009.4		
cv (TSN)		0.29	0.36	0.18	0.15	0.14	0.18	0.19	0.19	0.27	0.27	0.33	0.29	0.29	0.36	0.39	0.61	0.82	0.12		
TSB(1000 t)		82.2	171.4	262.4	332.5	4 190.8	294.3	399.0	571.1	161.4	158.4	121.4	141.4	95.8	55.4	42.4	57.2	6.4	7 143.4		
cv (TSB)		0.29	0.29	0.18	0.15	0.14	0.19	0.20	0.20	0.26	0.29	0.34	0.30	0.30	0.37	0.40	0.61	0.80	0.13		
Mean length(cm		23.5	26.1	28.3	30.1	32.1	33.4	33.8	33.9	34.9	35.2	37.1	36.5	37.0	37.2	37.3	38.2	39.1			
Mean weight(g)		123.3	175.1	215.6	256.3	296.6	324.3	330.7	341.4	363.0	367.3	400.8	393.0	402.9	401.2	406.3	437.4	480.0			

Table 10. IESSNS bootstrap time series (mean of 1000 replicates) from 2016 to 2022. 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	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

Table 11. IESSNS baseline time series from 2016 to 2022. 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
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

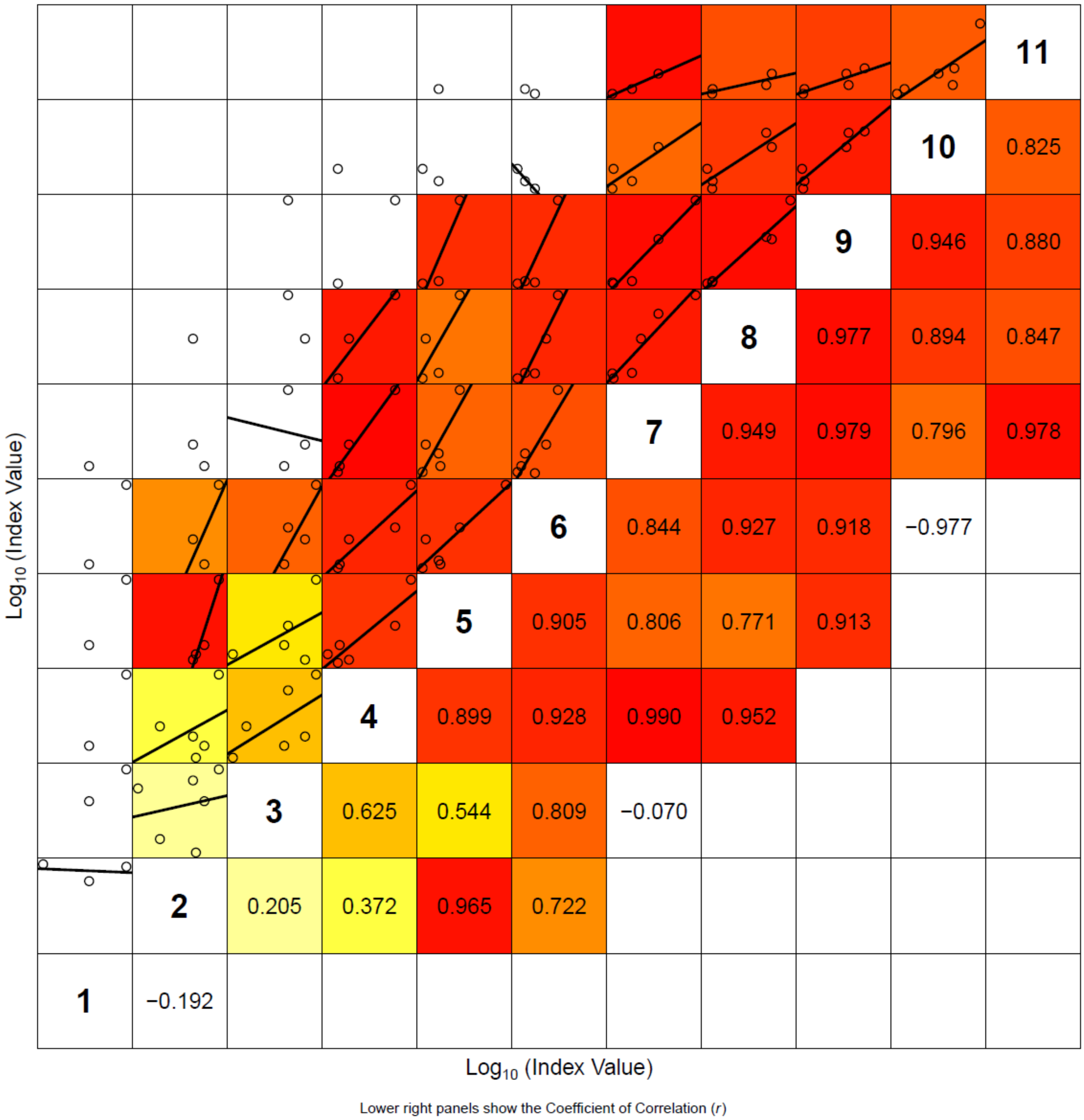

Figure 19. Internal consistency for Norwegian spring-spawning herring within the IESSNS 2022. The upper left part of the plots shows the relationship between log index-at-age within a cohort. Linear regression line shows the best fit to the log-transformed indices. The lower-right part of the plots shows 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 (72 °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 (age2+) were low, and they were mainly observed on the continental slopes, both in the eastern and the southern part of the Norwegian Sea (Figure 20). The distribution in 2022 is comparable to the last two years with juvenile blue whiting recorded south and southwest of Iceland. As in previous years no blue whiting was registered in the cold East Icelandic Current, between Iceland and Jan Mayen.

The total biomass of blue whiting registered during IESSNS 2022 was 2.2 million tons (Table 12), which is about the same level as in 2021. Estimated stock abundance (ages 1+) was 27.5 billion compared to 26.2 billion in 2021. Age 1 and 2 respectively, dominated the estimate in 2022 as they contributed to 44% and 33% (abundance) and 30% and 33% (biomass), respectively.

Bootstrap estimates of numbers by age, with uncertainty estimates, for blue whiting during IESSNS 2022 are shown in Figure 21. The baseline point estimates from 2016-2022 are shown in Table 13. The internal consistency among year classes is shown in Figure 22 and indicates very good internal consistency for ages 3-5, and moderate to good fit for other ages.

The group considered the acoustic biomass estimate of blue whiting to be of good quality in the 2022 IESSNS as in the previous survey years.

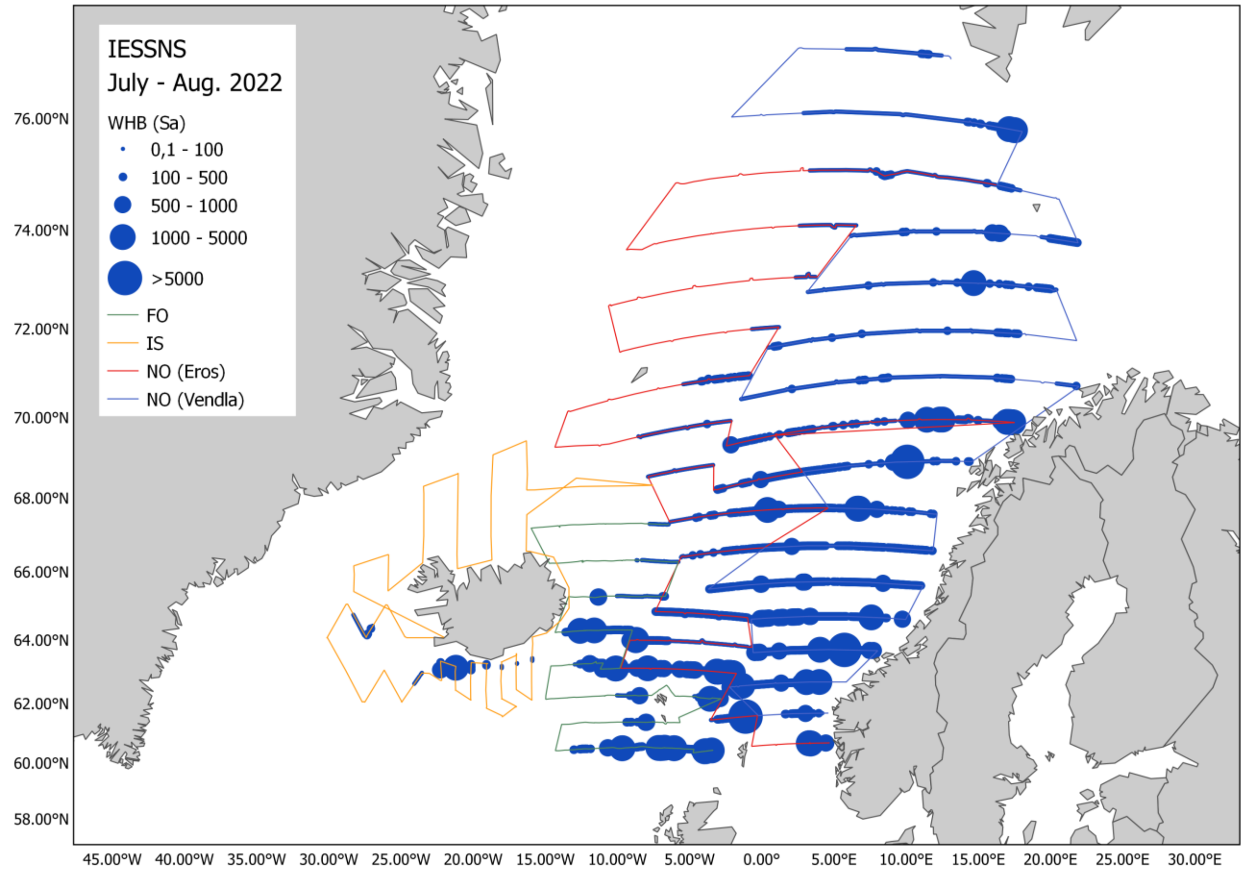

Figure 20a. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2022.

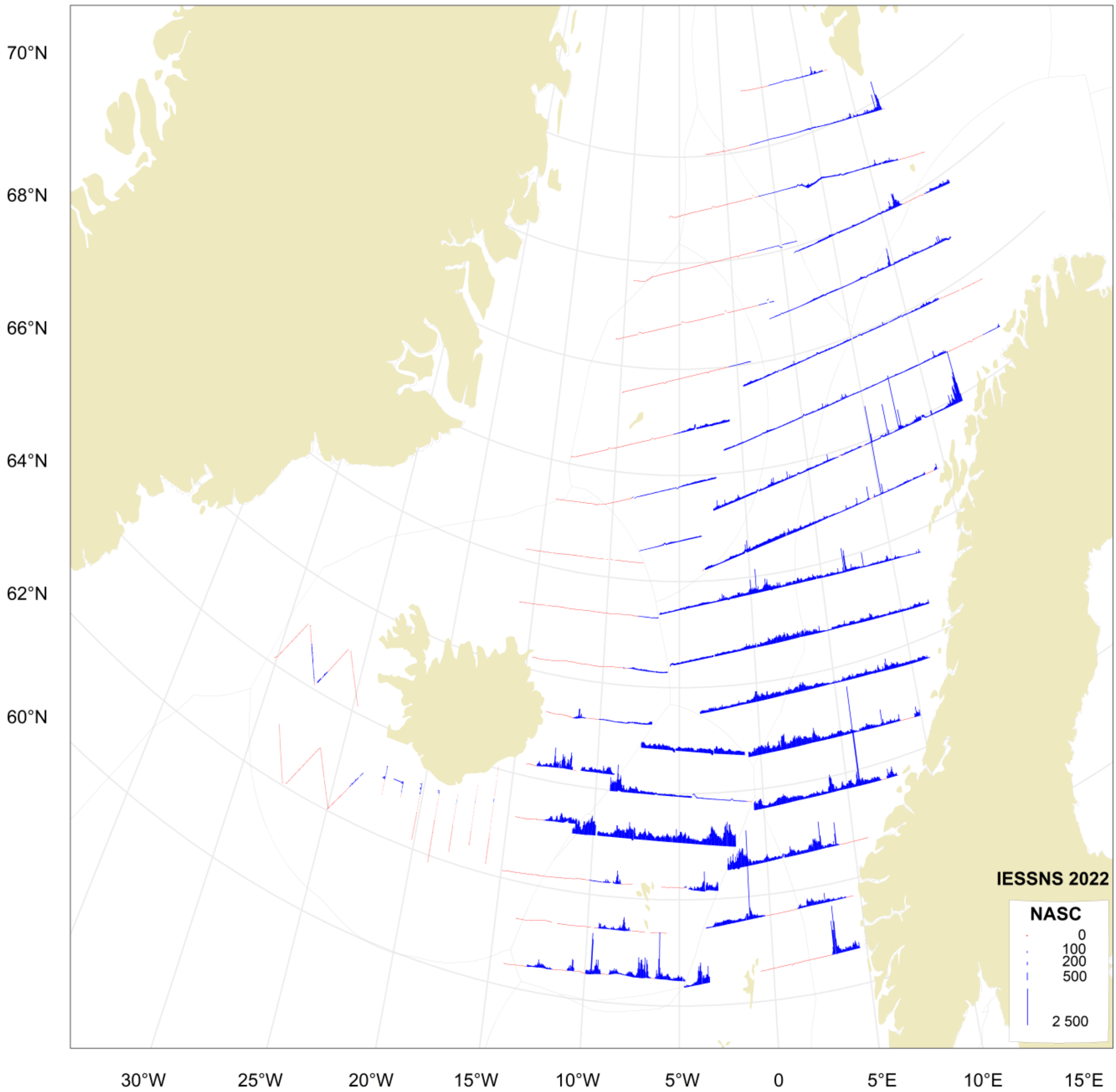

Figure 20b. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2022. Presented as bar plot.

Table 12. Estimates of abundance, mean weight and mean length of blue whiting based on calculation in StoX (bootstrap) for IESSNS 2022.

	Age in years (year class)											Number	Biomass	Mean
Length	0	1	2	3	4	5	6	7	8	9	10			weight
(cm)	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	(10^6)	(10^6 kg)	(g)
10-11														
11-12	135.2											135.2	1.1	8.2
12-13	414.1											414.1	4.7	11.3
13-14	236.6											236.6	3.5	14.9
14-15	169.0											169.0	2.9	17.1
15-16													0.2	22.0
16-17														
17-18													0.4	30.0
18-19		152.9										152.9	6.2	37.2
19-20		1567.2										1 567.2	68.3	44.1
20-21		4498.5										4 498.5	225.8	50.8
21-22		4136.4	277.3	44.9								4 458.5	251.9	57.1
22-23		1687.7	902.5									2 590.2	166.9	64.0
23-24		484.9	2723.7	21.6								3 230.2	244.4	76.6
24-25		84.2	2921.4	101.8								3 107.4	263.9	85.7
25-26		5.9	1837.0	336.5								2 179.4	207.8	95.5
26-27		4.0	729.4	396.6	19.4	6.8						1 156.3	121.6	106.5
27-28			243.2	564.3	144.2	6.5						958.2	107.7	115.1
28-29		1.1	99.4	437.5	151.5	11.7		46.8	26.3			774.4	95.5	127.3
29-30				81.2	240.6	34.8	67.3	65.6	101.5	54.1	54.1	699.3	90.1	133.3
30-31			14.4	190.4	8.9	19.7	125.3	43.1	249.8			651.7	96.1	154.1
31-32					174.0	26.1	178.4	36.0	64.3	74.0		552.8	89.0	167.6
32-33					97.6	43.9	53.9	26.7	145.2			367.3	66.5	187.2
33-34					47.2	65.8	66.9	35.7	72.8		6.4	294.8	58.3	200.8
34-35						64.9	7.0	49.6	18.4			139.8	29.7	221.0
35-36						24.4	10.9		11.9			47.2	11.8	244.2
36-37						7.8				19.5	6.4	33.7	8.7	267.6
37-38														
38-39													0.5	285.0
39-40									0.7			0.7	0.2	282.6
TSN(mill)	955	12623	9748	2175	883	313	510	303	691	148	67	28 503.1		
cv (TSN)	1.04	0.18	0.17	0.27	0.35	0.36	0.37	0.34	0.34	0.50	0.79	0.11		
TSB(1000 t)	12.2	683.9	826.3	240.1	127.5	58.4	81.9	48.5	111.4	22.9	9.0	2 223.7		
cv (TSB)	1.04	0.18	0.17	0.27	0.36	0.38	0.37	0.35	0.34	0.46	0.71	0.12		
Mean length(cm)	12.5	21.3	24.0	26.8	29.6	32.0	31.0	31.1	31.0	31.6	32.3			
Mean weight(g)	13	60	87	114	152	190	167	173	167	168	180			

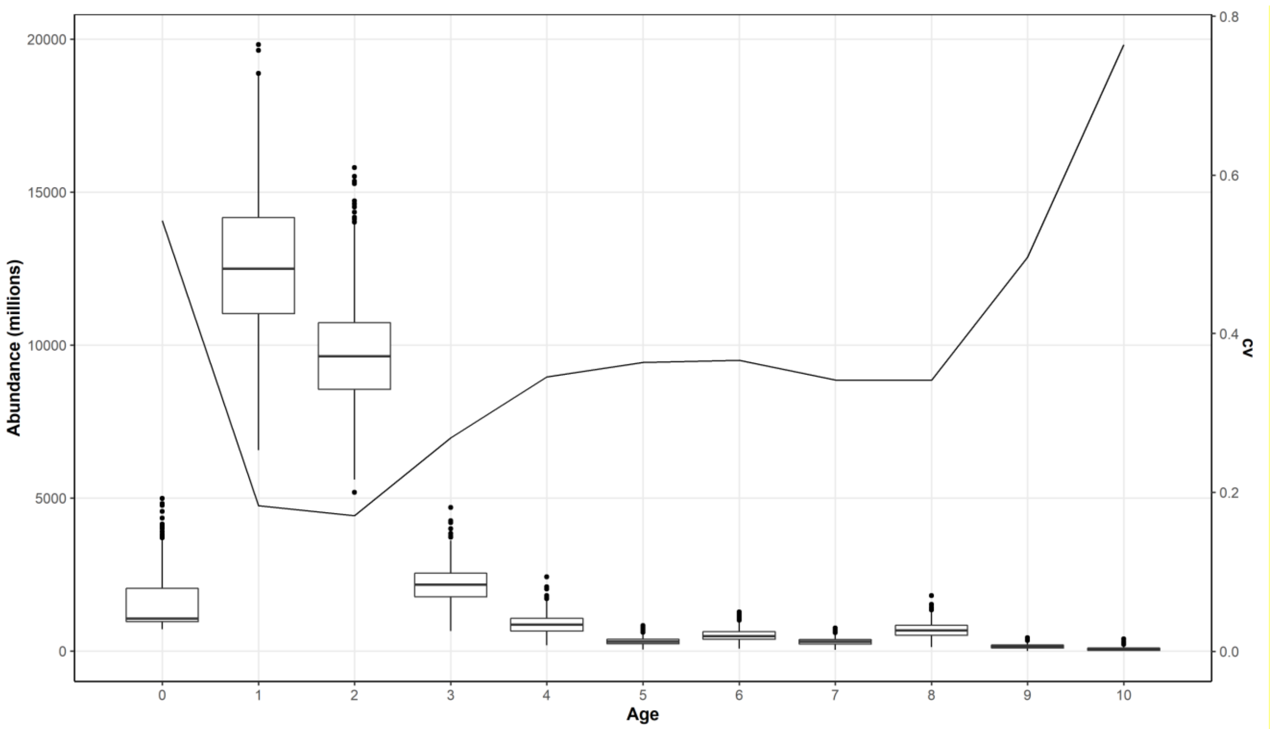

Figure 21. Number by age with uncertainty for blue whiting during IESSNS 2022. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

Table 13. IESSNS baseline time series from 2016 to 2022. 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
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

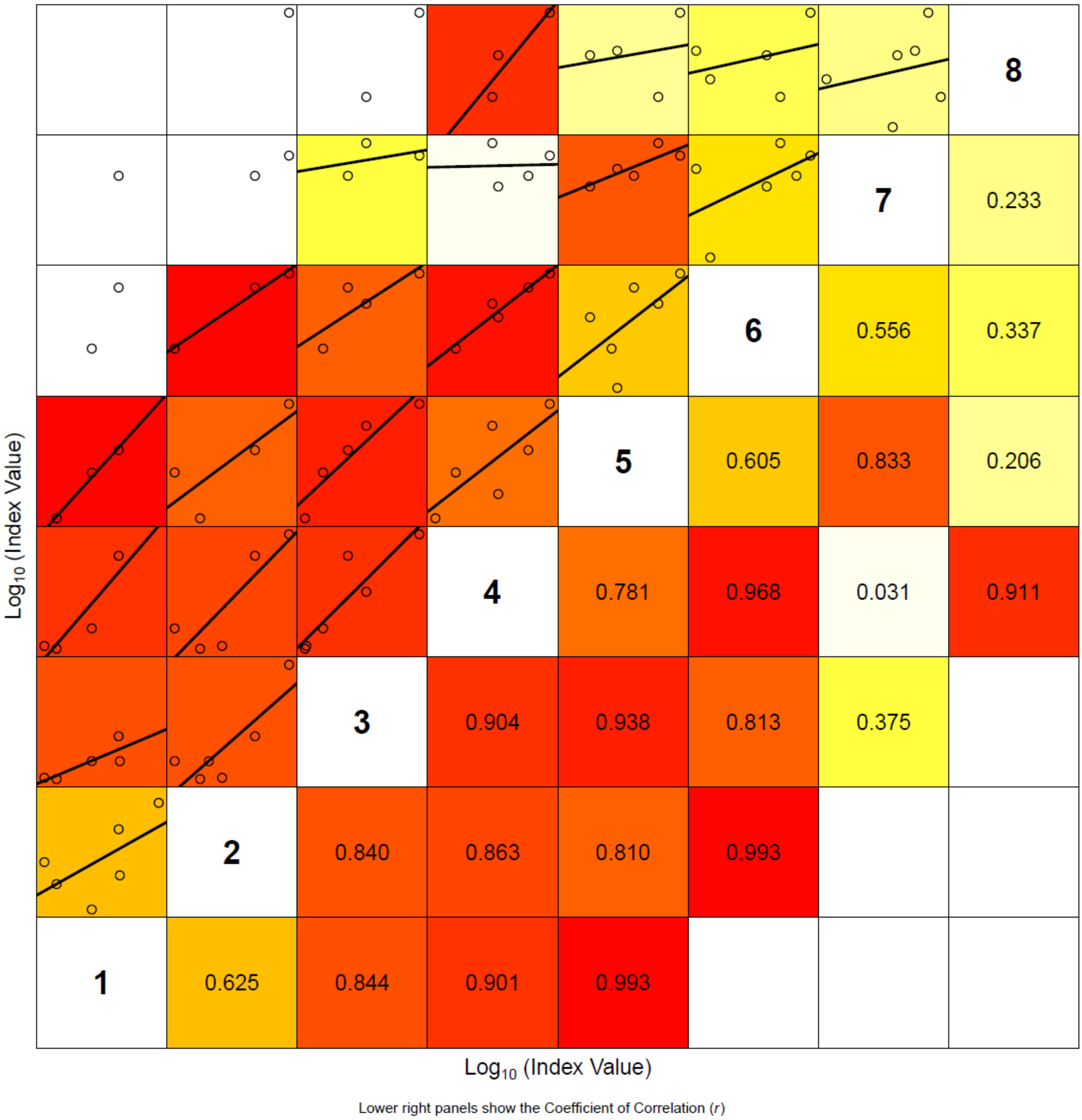

Figure 22. Internal consistency for blue whiting within the IESSNS. The upper left part of the plots shows the relationship between log index-at-age within a cohort. Linear regression line shows the best fit to the log-transformed indices. The lower-right part of the plots shows the correlation coefficient (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 71% of trawl stations across the five vessels (Figure 23) and where lumpfish was caught, 69% of the catches were ≤10kg. Lumpfish was distributed across the entire survey area, from east of Greenland to the Barents Sea in the northeast 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 southwest of the survey so it is likely that the distribution of lumpfish extends beyond the survey coverage. The length of lumpfish caught varied from 5 to 51 cm with a bimodal distribution with the left peak (5-20 cm) likely corresponding to 1-group lumpfish and the right peak consisting of a mixture of age groups (Figure 24). For fish ≥20 cm in which sex was determined, the males exhibited a unimodal distribution with a peak around 25-27 cm. The females also exhibited a bimodal distribution but with a peak around 24-30 cm and another around 35-45 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 294 fish (67 by R/V "Árni Friðriksson", 83 by M/V "Eros", 96 by M/V Vendla and 48 by Tarajoq) between 5 and 52 cm were tagged during the survey (Figure 25).

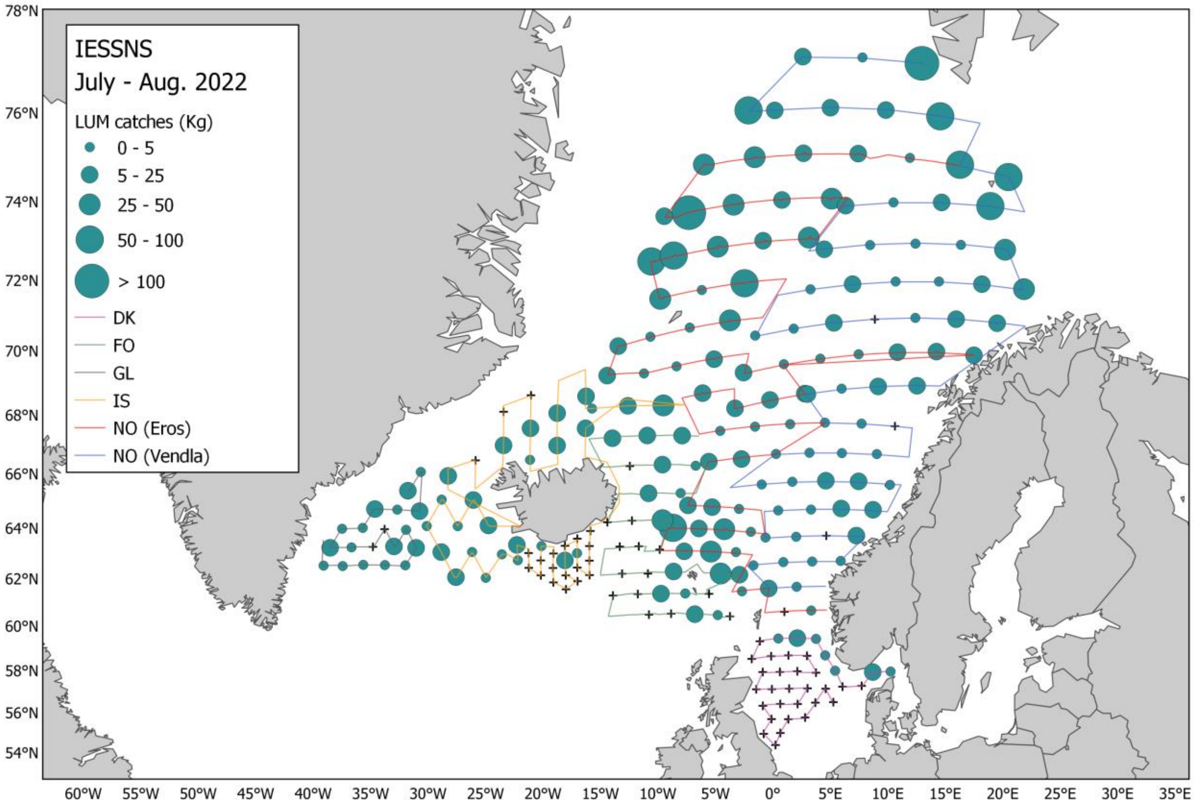

Figure 23. Lumpfish catches at surface trawl stations during IESSNS 2022.

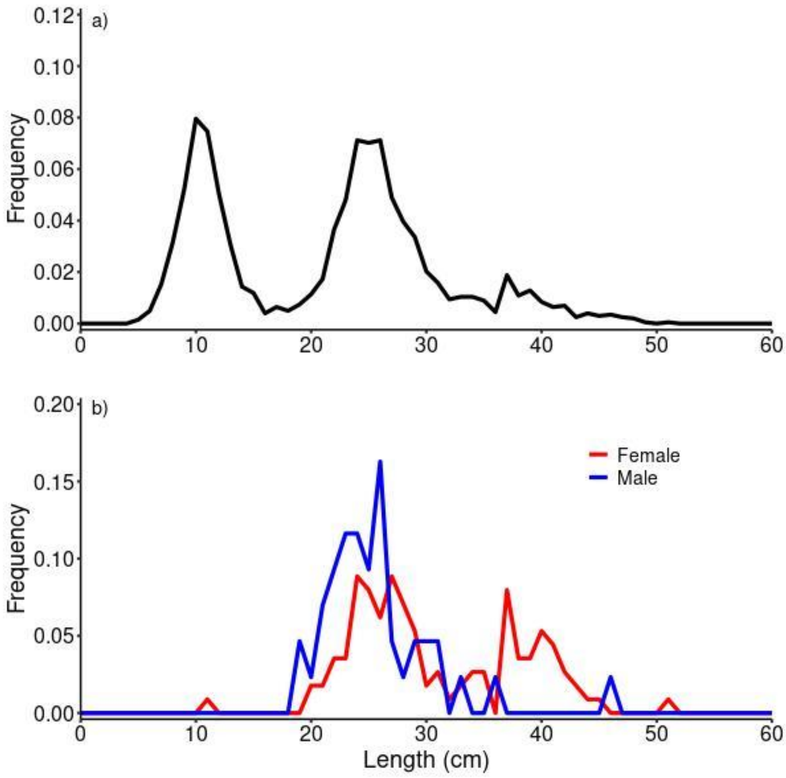

Figure 24. Length distribution of a) all lumpfish caught during the survey and b) length distribution of fish in which sex was determined.

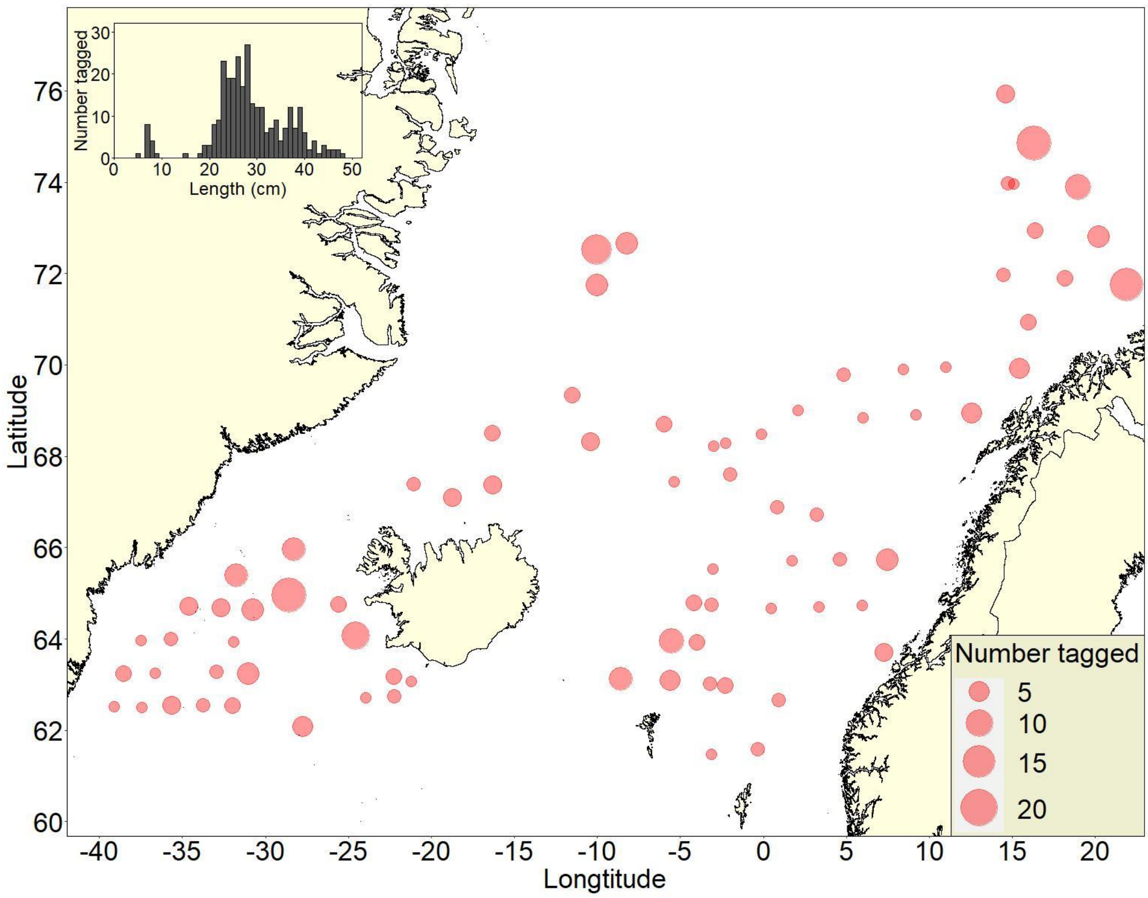

Figure 25. Number tagged, and release location, of lumpfish. Insert shows the length distribution of the tagged fish.

Salmon (*Salmo salar*)

A total of 60 North Atlantic salmon were caught in 38 stations both in coastal and offshore areas from 61°N to 76°N in the upper 30 m of the water column during IESSNS 2022 (Figure 26). The salmon ranged from 0.028 kg to 4.1 kg in weight, dominated by post-smolt and 1 sea-winter individuals. We caught from 1 to 6 salmon during individual surface trawl hauls. The length of the salmon ranged from 15 cm to 74 cm, with the highest fraction between 20 cm and 30 cm.

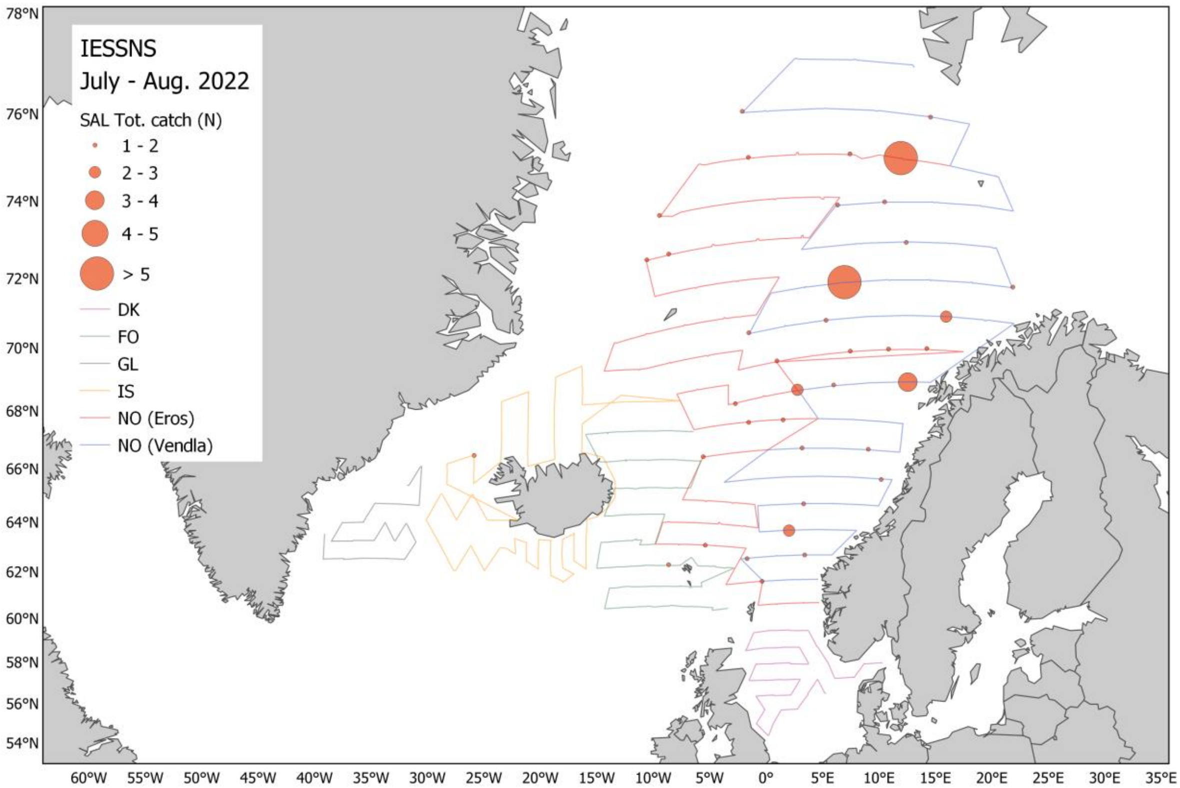

Figure 26. Catches of salmon at surface trawl stations during IESSNS 2022.

Capelin (*Mallotus villosus*)

Capelin was caught in the surface trawl on 22 stations primarily along the cold fronts: Between East Greenland and Iceland, west and North of Jan Mayen and at the entrance to the Barents Sea (Figure 27). This is 10 stations more than in 2021 partly because of the lack of Greenland coverage in 2021 and partly because of more stations with capelin around Iceland this year (11 in 2022, 6 in 2021).

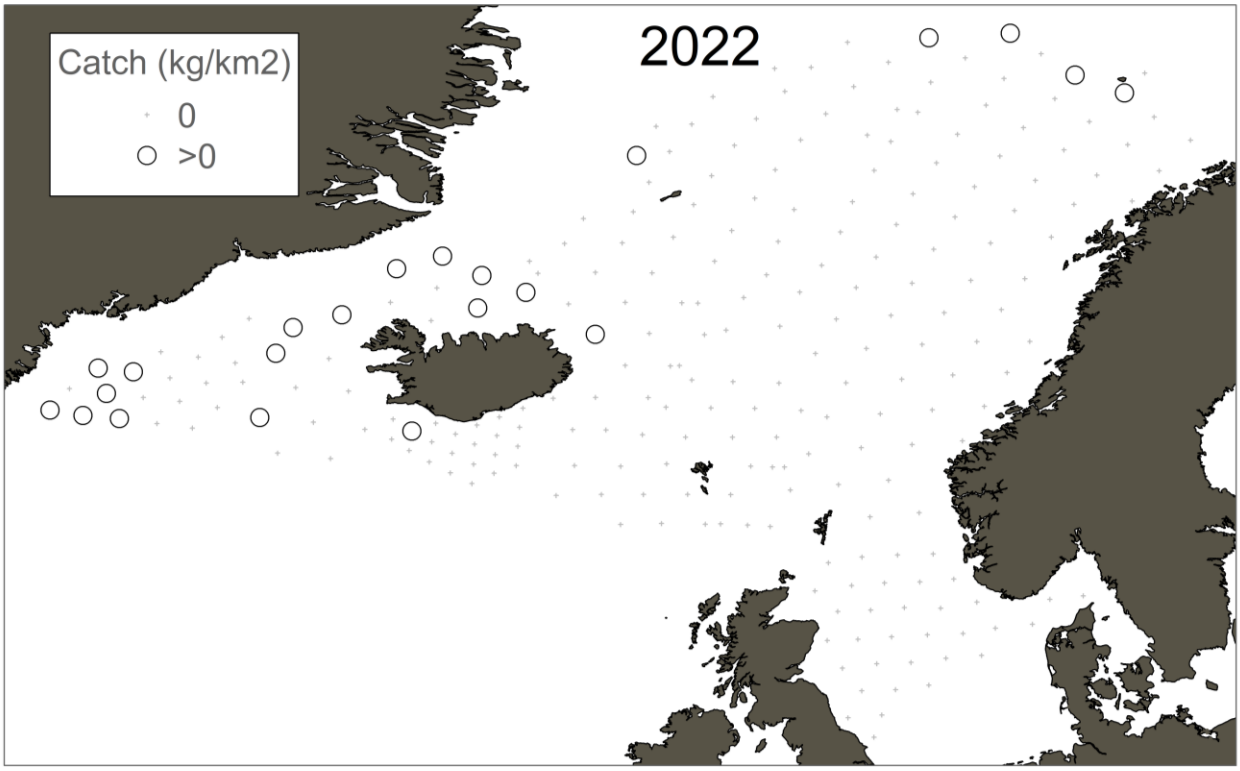

Figure 27. Presence of capelin in surface trawl stations during IESSNS 2022.

4.7 Marine Mammals

Opportunistic whale observations were done by M/V "Eros" and M/V "Vendla" from Norway in addition to R/V "Árni Friðriksson" from Iceland and R/V "Jákup Sverri" from Faroe Islands in from 1st July to 3rd August 2022 (Figure 28). Overall, 711 marine mammals of 11 different species were observed, which was a decrease from an overall 1029 marine mammals and eight species observed in 2021.

The species that were observed included 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*), harbour porpoise (*Phocoena phocoena*). A basking shark (*Cetorhinus maximus*) was also observed during the survey. The dominant number of marine mammal observations were found around Iceland, Faroe Islands and along the continental shelf between the north-eastern part of the Norwegian Sea and in a line between Finnmark to southwest of Svalbard. We observed very few marine mammals in the central part of the Norwegian Sea in July 2022. Fin whales (n = 48, group size = 1-12 (average group size = 2.5)) and humpback whales (n = 44, group size = 1-30 (average group size = 3.9)) dominated among the large whale species, and they were present west and northwest of Iceland and from Norwegian coast outside Finnmark stretching north/northwest via Bear Island to southwest of Svalbard. Very few sperm whales (n = 8, group size = 1 (average group size = 1.0)) where observed. Killer whales (n = 121, group size = 1-30 (average groups size = 10.1)) dominated in the southern, northern and north-eastern part of the Norwegian Sea, partly overlapping and presumably feeding on NEA mackerel in the upper water masses. Pilot whales (n = 30, group size = 5-15 (average groups size = 10)) where mostly observed in Faroese waters during IESSNS 2022. A sei whale and one northern bottlenose whale were observed in Icelandic waters, whereas a basking shark was observed in Faroese waters. White beaked dolphins (n = 229, group size = 1-22 (average groups size = 8.5)) were present in the northern part of the Norwegian Sea. Two pods of white sided dolphins (group size = 15) were observed in the southern part of the Norwegian Sea. Minke whales (n = 53, group size = 1-10 (average group size = 1.7)) were distributed over large areas from western coast of Norway to western part of Iceland, and from 60°N to 75°N, including overlapping and likely feeding on NSS herring in the upper 40 m of the water column. There is available a new 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)

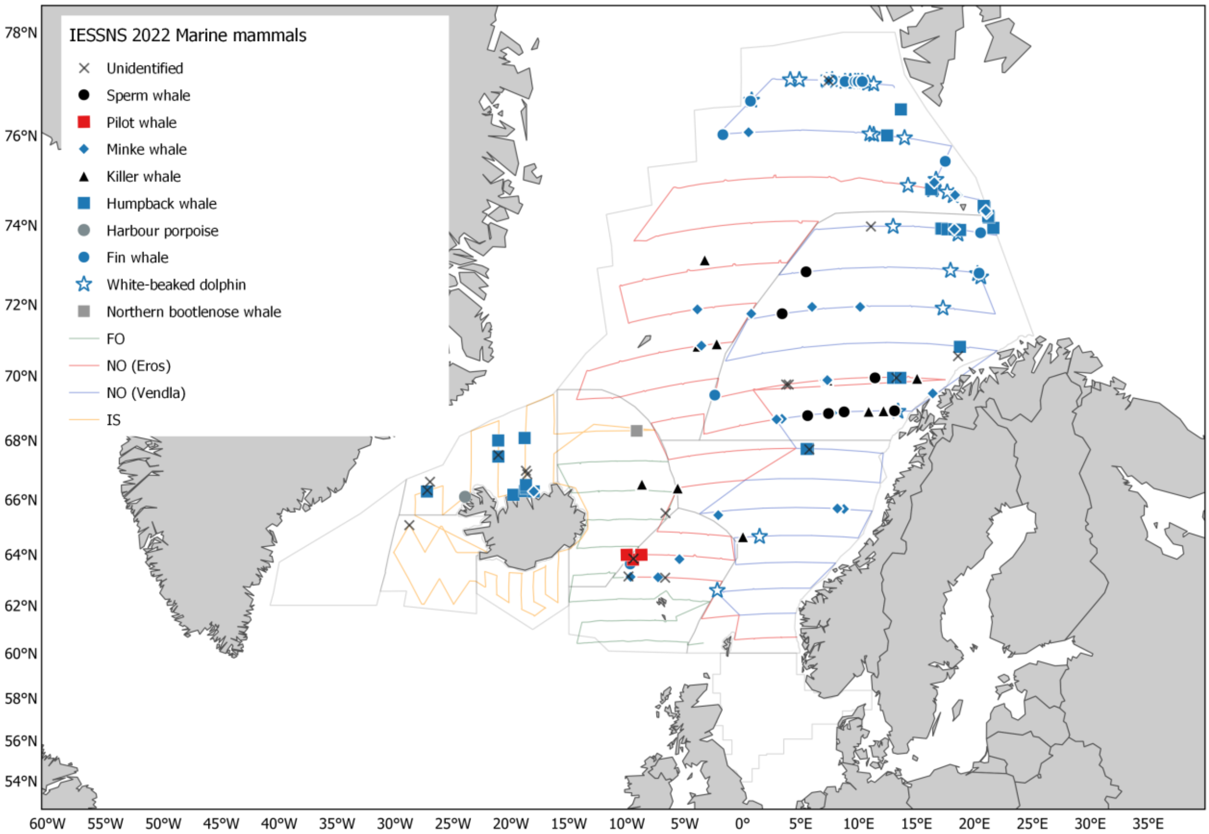

Figure 28. Overview of all marine mammals sighted during IESSNS 2022.

5 Recommendations

The group suggested the following recommendation from WGIPS	To whom
The occasional large catches of mackerel have a relatively large impact on the overall results and possibly bias the stock indices. WGIPS recommends that the ability of the present and alternative methods (such as more advanced statistical models) to represent this overdispersion is evaluated, preferably at the WGISDAA meeting 25.-27.October, 2022.	National institutes and WGISDAA
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
It is recommended that WGIPS contacts the country representatives for the IESSNS survey to update the respective sections (e.g. trawl performance, trawl station data collection) in the survey manual prior to the WGIPS meeting 23.-27.January 2023.	WGIPS

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
All survey participants are encouraged to continue the international tagging of lumpfish.	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 2022 the IESSNS survey in the North Sea has been conducted for five consecutive years (2018-2022). 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 the internal consistency between years in the survey for selected age groups is also evaluated. 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)

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8 Acknowledgements

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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.

In 2022, 34 stations were taken (PT and CTD. 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. However, due to shortage of available survey time only 34 out of the planned 38 stations were covered.

Average mackerel catch in 2022 amounted 1689 kg/km^2, which was considerably lower than in the previous year (2021: 2429 kg/km^2) but higher or similar than in the period 2018-2020 (2020: 1318 kg/km^2, 2019: 1009 kg/km^2, 2018: 1743 kg/km^2). The length and age composition indicate a relative low amount of small (< 25 cm) individuals whereas the abundance of older (≥ age 2) mackerel was on a similar level than in the previous year (Fig. A.1.).

StoX (version 3.5.0) estimate of mackerel biomass in the North Sea for 2022 is 471 948 tonnes (Table A1-1) which is the second highest biomass values in the time series. The biomass and abundance estimates are based on a preliminary defined polygon for the surveyed area covered in all years since 2018 in which the northern border was set to 60 °N (border to stratum 1; Fig. 2), and the eastern, southern, and western limits were either the coastline or extrapolated using half the longitudinal or latitudinal distance between the adjacent stations. The area of this polygon is 278 525 km^2.

For 11 out of 35 individuals in the size range of 18 to 20 cm the first wintering was not visible applying the standard age reading procedure. These fish should be attributed to the 2021-year class rather than be treated as 0-group fish considering the spawning period of mackerel in the North Sea. However, the aspect of the non-visible first age ring, which might be related to the presently prevailing warm winter conditions in the North Sea, warrants further investigations.

Based on the experiences made in the previous years, new limits for the stratum in the North were defined which shall be used for the station allocation for future surveys (Fig. A2). 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 were 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.

Table A1-1. StoX (version 3.5.0) baseline estimates of age segregated and length segregated mackerel indices for the North Sea in 2022.

Length	Age in years / Year class															Number	Biomass	Mean weight
(cm)	0 2022	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	(10^6)	(ton)	(g)
17-18		0.1														0.1	4	40
18-19	15.5	15.3														30.8	1488	48
19-20	36.3	87.1														123.4	6753	55
20-21	1.8	120.4														122.1	8024	66
21-22		42.0														42.0	3162	75
22-23		12.6														12.6	1153	92
23-24		11.3														11.3	1237	109
24-25		26.7														26.7	3318	124
25-26		12.6														12.6	1747	139
26-27		7.4														7.4	1161	157
27-28		15.3								0.8						16.1	3013	187
28-29		147.9	23.2													171.1	36138	211
29-30		496.5	23.2													519.7	126715	244
30-31		204.9	160.3													365.2	97338	266
31-32		26.2	134.1	13.3												173.6	49252	284
32-33			103.7	13.1	0.6											117.4	36622	312
33-34			35.2	30.1	5.4	0.6										71.3	23661	332
34-35			3.6	29.6	18.9	2.3										54.3	19943	367
35-36				5.7	13.5	7.6	6.6	4.4								37.8	14858	393
36-37				0.7	8.9	11.3	7.1	0.2	0.5	0.8						29.5	12106	410
37-38					1.5	6.3	9.4	3.9	0.1							21.1	9138	433
38-39						1.2	0.7	4.1	2.4	0.5						8.9	4416	498
39-40					1.1	4.2	2.5	0.7	0.9	0.5						9.8	4963	504
40-41						1.1	0.8	1.3	0.5	0.3	0.7					4.6	2537	549
41-42								1.1		0.1						1.3	699	542
42-43								0.4					0.4		0.1	1.0	648	675
43-44										1.8						1.8	1250	682
44-45							1.3									1.3	1281	950
TSN (mill)	53.6	1226.4	483.3	92.4	49.8	34.4	28.5	16.3	4.3	4.8	0.7	0.0	0.4	0.0	0.1	1,995	472626	
TSB (ton)	2913	242385	136351	30981	19206	14533	13103	7731	2195	2535	345	0	259	0	90	472,626		
Mean length (cm)	18.7	26.8	30.8	33.0	34.7	36.3	36.9	37.4	38.2	38.1	40.0		42.0		42.0			
Mean weight (g)	54	198	282	335	385	422	460	474	511	525	525		638		746			

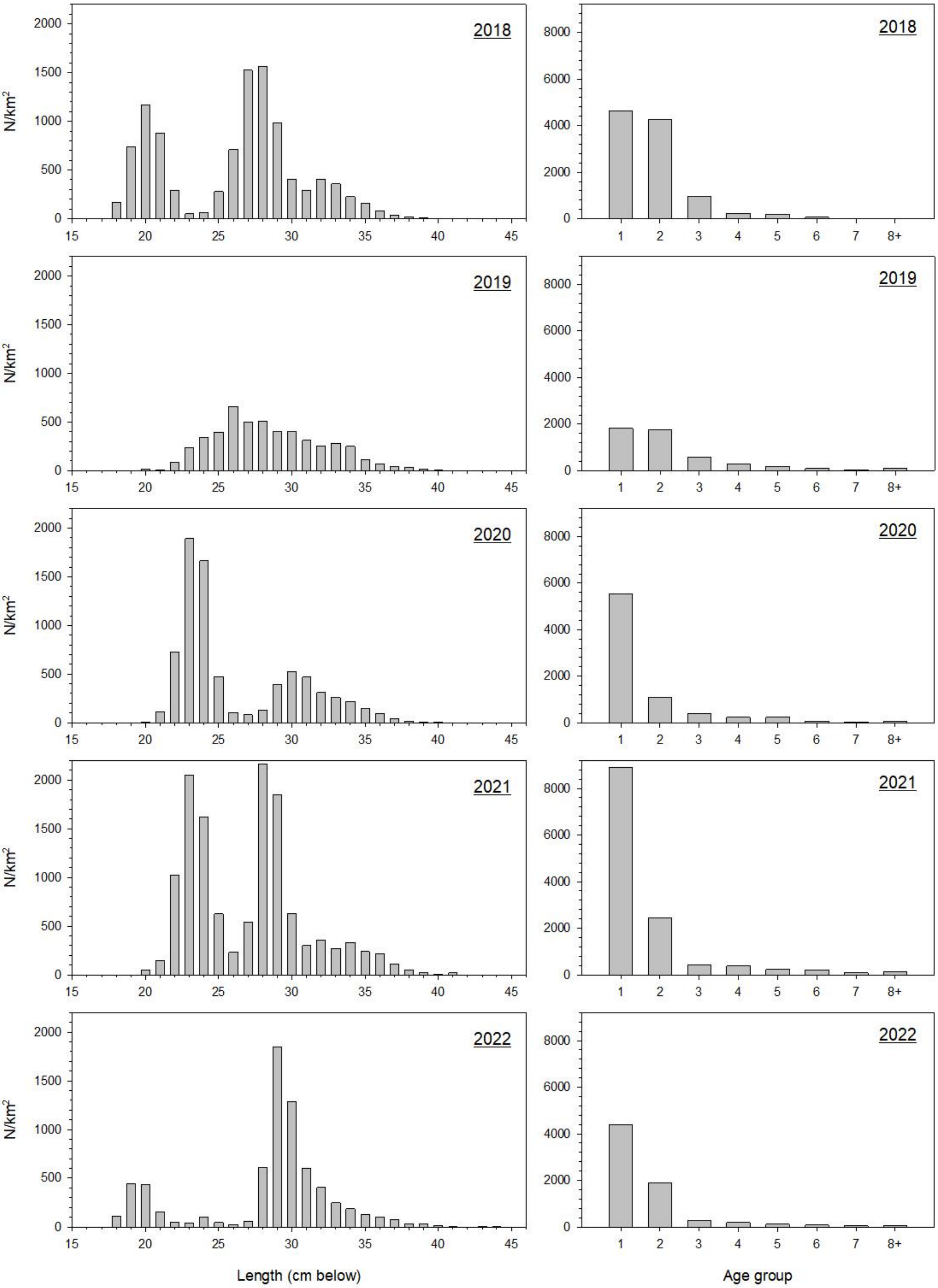

Fig. A1-1. Comparison of length and age distribution of mackerel in the North Sea 2018 to 2022.

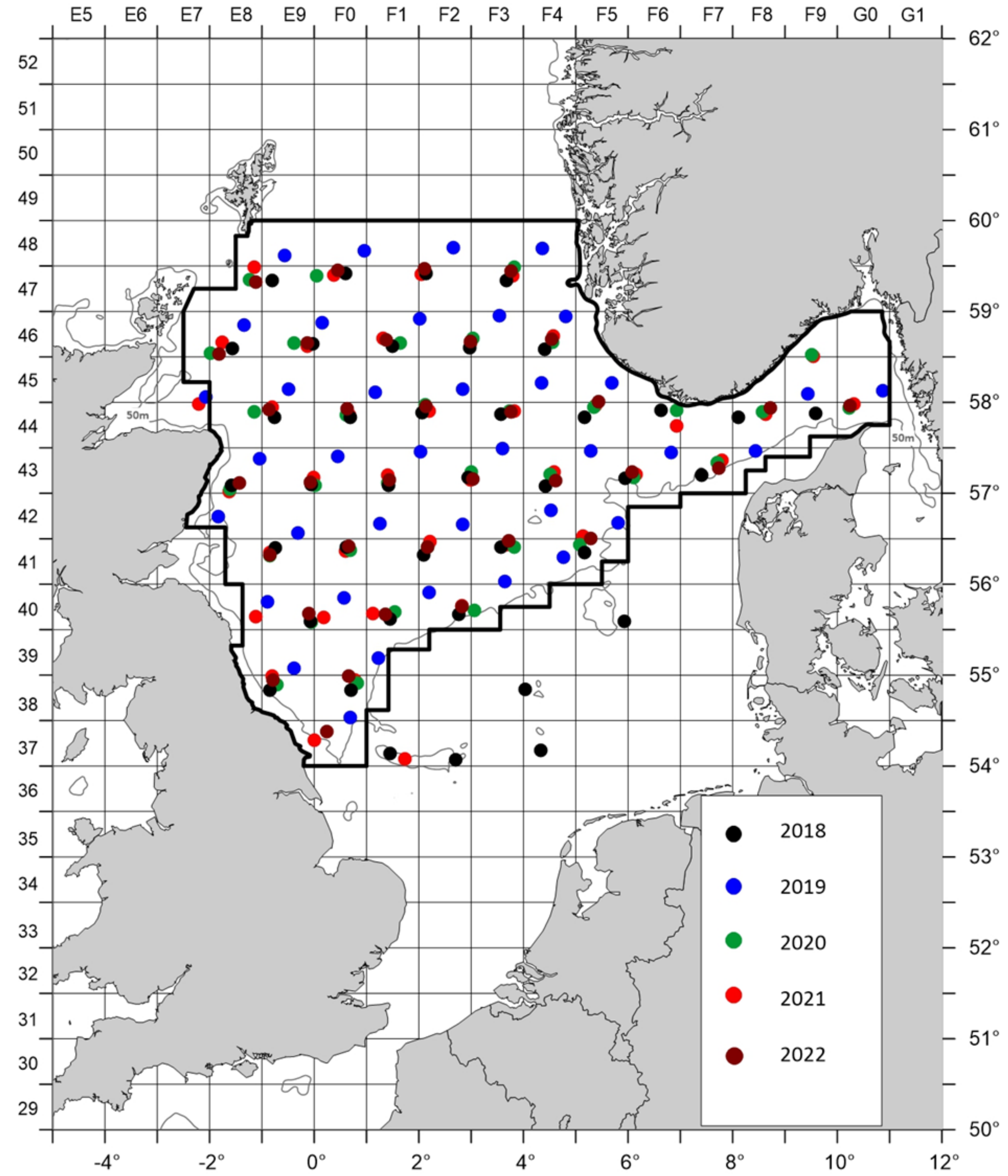

Fig. A1-2. Limits of the North Sea stratum for future surveys and sampling positions achieved in the period 2018-2022.

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 2022 (Table A2-1). Map of included and excluded trawl stations displayed in Figure A2-1.

Table A2-1: Trawl station exclusion list and average horizontal trawl opening per vessel for IESSNS 2022 for calculating the mackerel abundance index.

Vessel	Country	Horizontal trawl opening (m)	Exclusion list Cruise	Stations
Vendla	Norway	67.5	2022816	60, 75, 80, 82, 85, 88, 90, 91, 95, 104, 109, 113, 120, 124
Eros	Norway	63.5	2022817	28, 30, 44, 46,51, 55, 59, 63, 72, 73, 91
R/V Árni Friðriksson	Iceland	63.75	A8-2022	295, 311
R/V Jákup Sverre	Faro Islands	63.4	2230	5, 23, 24, 35, 46, 61*
R/V Tarajoq	Greenland	61.4	TA-2022-04	none
Ceton	Denmark	72.0	IESSNS2022	none

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

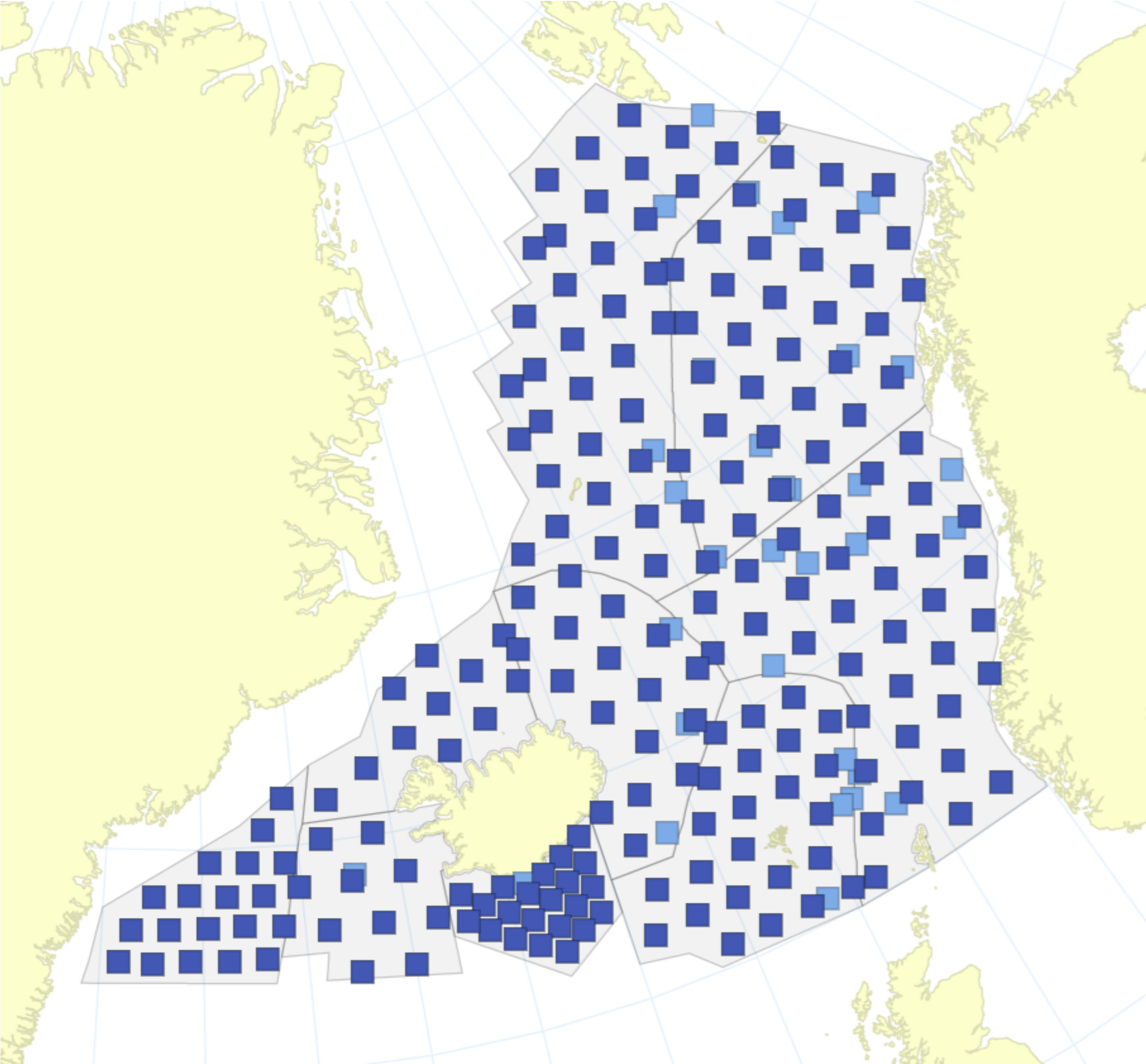

Figure A2-1. IESSNS 2022. Surface trawl stations included (filled dark blue rectangle) and excluded (filled light blue rectangle) in calculations of mackerel age segregated index used in the assessment. Strata boundary also displayed (grey solid lines).

Appendix 3: Impact of large hauls on abundance and biomass estimates

In 2022 there were two large mackerel hauls. In order to investigate the effect of these on the StoX estimates, an additional run of StoX was made without these hauls (Figure A3-1).

If the two stations with the highest catches (slightly above 20 tons on each) are removed, the baseline estimate of total abundance is reduced by 34 % and the baseline estimate of total biomass is reduced by 33 % (from 7.37 to 4.91 million tons). Moreover, the relative standard error of total abundance from 1000 bootstrap replicates is 26 % when all stations are used, while becomes reduced to 12 % when the two highest stations are removed. The relative standard error of total biomass from 1000 bootstrap replicates is 25 % when all stations are used, while becomes reduced to 11 % when the two highest stations are removed.

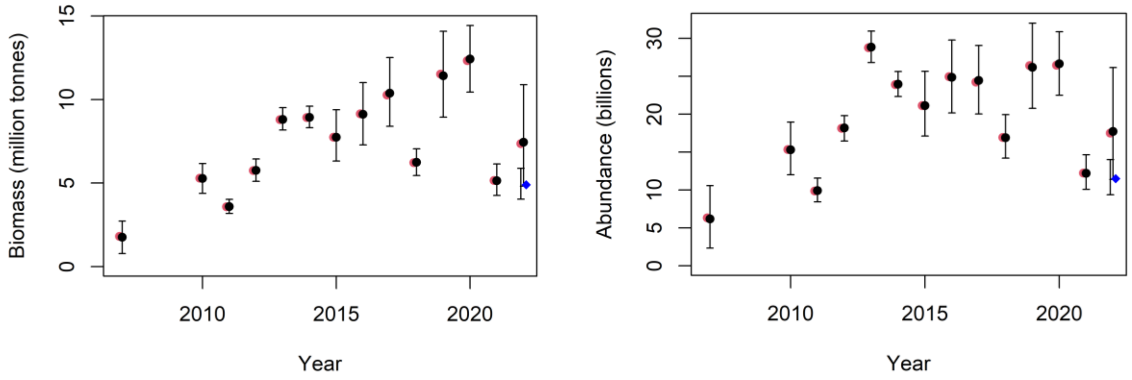

Figure A3-1. StoX runs with (black/red 2022 dot) and without (blue 2022 dot) large hauls. Biomass (left panel) and abundance (right panel).

Appendix 4:

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.

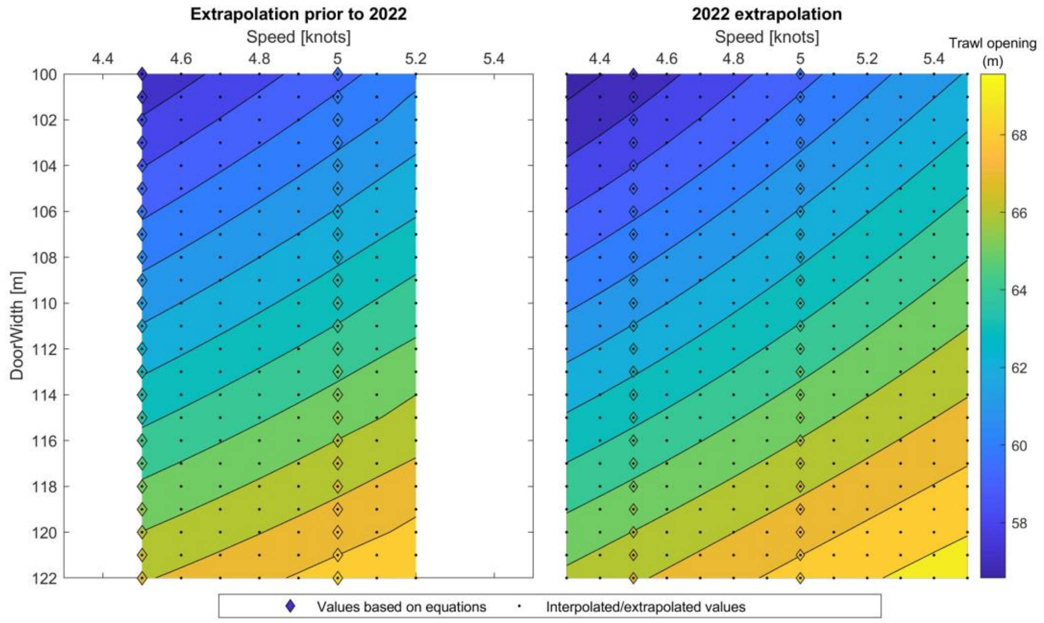

Figure A3-1. Table 6 in the report shown as a plot.