WORKING GROUP OF INTERNATIONAL PELAGIC SURVEYS (WGIPS)

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International Council for the Exploration of the Sea
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H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Editors

Michael O'Malley • Bram Couperus

Authors

Michael O'Malley • Bram Couperus • Urbano Auton • Florian Berg • Benoit Berges • Sigurvin Bjarnason
Fabio Campanella • Pablo Carrera • Solva Karadottir Eliasen • Edward Farrell • Eydna Homrum
Åge Høines • Arne Johannes Holmin • Jan Arge Jakobsen • Espen Johnsen • Ruth Kelly
Alexander Krysov • Cecilie Kvamme • Susan Mærsk Lusseau • Steven Mackinson • Gavin McNeill
Colin Millar • Leif Nøttestad • Steven O'Connell • Ciaran O'Donnell • Anna H Olafsdottir • Hjalte Parner
Mark Payne • Maxim Rybakov • Are Salthaug • Matthias Schaber • Erling Kåre Stenevik • Aleksei Stesko
Jeroen van der Kooji • Sindre Vatnehol • Alina Wieczorek

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i Executive summary

The core objectives of The Working Group of International Pelagic Surveys (WGIPS) are to combine and review results of annual pelagic ecosystem surveys to provide indices for the stocks of herring, sprat, mackerel, boarfish, and blue whiting in the Northeast Atlantic, Norwegian Sea, North Sea, and Western Baltic; and to coordinate timing, coverage and methodologies for upcoming surveys. Results from all WGIPS surveys as well as coordination plans for multinational pelagic acoustic surveys and individual surveys were the primary focus at meetings over the past 3 years (2019-2021).

WGIPS discussed developments and experiences with the ICES database and the survey analysis software StoX. WGIPS recommends that all surveys use StoX as the primary method for biomass and abundance estimation, and this has been a welcome improvement in the overall working of the group for the surveys that use StoX. Harmonising procedures across surveys increases transparency and promotes understanding and sharing of survey methods within the group. In 2021, a session was held to begin the process of moving surveys onto the Transparent Assessment Framework (TAF). Some surveys had started the TAF process before the meeting and their progress was presented to the group. WGIPS will work with the ICES Data Centre to produce a workflow and/or documentation to assist with the transition to TAF.

Harmonising surveying techniques that measure other aspects of the marine ecosystem has been flagged as requiring attention. As such, the group annually assessed auxiliary pelagic ecosystem surveying techniques currently used on surveys coordinated by WGIPS. The discussions highlighted the range of additional work being undertaken across the group.

WGIPS has continued to respond to requests from other ICES expert groups and contribute to workshops. In 2021, WGIPS held a subgroup made up of IBWSS participants (NO, FO, NL, IE, ES) to discuss the formulation of scrutiny procedures to harmonise the reporting of mesopelagic acoustic density during future surveys. This was in response to a recommendation from WKMESOMeth. The IBWSS survey participants have agreed to begin the process of providing acoustic data within the agreed criteria and aim to develop biological sampling capacity over time within existing constraints. A review exercise will be conducted during the 2022 WGIPS meeting to review the data and findings of the 2021 survey and refine the protocol. WGIPS is also working on plans to update the Manual for International Pelagic Surveys.

ii Expert group information

Expert group name	Working Group of International Pelagic Surveys (WGIPS)
Expert group cycle	Multiannual
Year cycle started	2019
Reporting year in cycle	3/3
Chair(s)	Bram Couperus, Netherlands
	Michael O'Malley, Ireland
Meeting venue(s) and dates	18 – 22 January, 2021 (36 participants)
	13 – 17 January, 2020 (25 participants)
	14 – 18 January, 2019 (20 participants)

1 Terms of Reference

ToR	Description	Background	Science plan codes	Duration	Expected Deliverables
a (ACOM)	Combine and review annual ecosystem survey data to provide: indices of abundance and spatial distribution for the stocks of herring, sprat, mackerel, boarfish and blue whiting in Northeast Atlantic waters.	a) Advisory Requirements b) Requirements from other EGs	3.2, 5.2	years 1–3	Survey reports containing indices of stock biomass and abundance at age, spatial distributions of stocks and hydrographic conditions. HAWG WGWIDE
b(ACOM)	Coordinate the timing, area and effort allocation and methodologies for individual and multinational acoustic surveys on pelagic resources in the Northeast Atlantic waters covered (Multinational surveys: IBWSS, IESNS, IESSNS, HERAS, and individual surveys: CSHAS, ISAS, PELTIC, GERAS, WESPAS, industry coordinated surveys, CAPS).	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs	3.1	years 1–3	Cruise plans for international and individual surveys. HAWG WGWIDE
c (SCICOM)	Adopt standardized analysis methodology and data storage format utilizing the ICES acoustic database repository for all acoustically derived abundance estimates of WGIPS coordinated surveys	a) Science Requirements b) Advisory Requirements	3.2	years 1–3	Progress on the adaption of standardized analysis methodology and data storage format utilizing the ICES pelagic acoustic database repository for WGIPS coordinated surveys.
d (ACOM)	Periodically review and update the WGIPS acoustic survey manual to address and maintain monitoring requirements for pelagic ecosystem surveys	a) Science requirements b) Advisory requirements	3.1	years 1–3	Updated WGIPS survey manual.
e (ACOM)	Review the work, and report of workshops organised by WGIPS and develop formal ICES recommendations. This should	a) Science requirements b) Advisory requirements	3.1	years 1–3	

	include SISP updates and adopting changes to survey co-ordination where deemed appropriate.				
f (ACOM)	Review and evaluate survey designs across all WGIPS coordinated surveys to ensure the integrity of survey deliverables, including acoustic surveys on spawning aggregations.	a) Science requirements b) Advisory Requirements c) Requirements from other EGs	3.1, 3.3	years 1–3	Optimize and harmonise sampling designs and precision estimates for the different surveys to ensure survey quality. HAWG WGWIDE
g(ACOM)	Assess and compare scrutinisation procedures employed for the analysis of raw acoustic data from WGIPS coordinated surveys	a) Science requirements b) Advisory requirements	3.2, 3.3, 4.2	year 1	Documented standardised scrutinisation recommendations; Update of survey manual to address and maintain monitoring requirements for pelagic ecosystem surveys.
h (SCICOM)	Collaborate with groups wishing to utilize available time-series from WGIPS coordinated surveys.	a) Science requirements	3.2	Years 1-3	Facilitate testing and developing forecast models provided by WGS2D and other groups.
i (SCICOM)	Assess developing pelagic ecosystem surveying technology (e.g. optical technology, multi-beam and wideband acoustics) to: (i) achieve monitoring of different ecosystem components, and/or (ii) give input to the development of ecosystem indicators from surveys covered by WGIPS, (iii) continue to support the development of tools to improve the accuracy and precision of survey estimates.	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs	3.1, 3.3, 4.1	years 1–3	Update ecosystem metrics that are collected by WGIPS coordinated surveys; and protocols/recommendations for practical implementation of new technologies.

2 Summary of Work Plan

Year 1	General meeting, preceded by 3 post-cruise meetings which collate data of multinational surveys. Session to review and evaluate survey designs across all WGIPS coordinated surveys done in Year 1; and coordinate planning and discuss designs for surveys taking place in Year 2. Session to standardize scrutinisation procedures for the International Ecosystem Summer Survey in the Norwegian Sea (IESSNS) covered by the WG (WKSCRUT). Inter-sessional work on the review and updates for the WGIPS acoustic manual, followed by a session during the annual meeting to review and provide possible updates for the WGIPS acoustic survey manual. Harmonize changes amongst the different surveys. Develop survey design protocols for acoustic surveys on spawning aggregations for inclusion in the survey manual. Session (mini symposium) to assess auxiliary pelagic ecosystem surveying technology focusing on methods currently used to monitor different ecosystem components across WGIPS coordinated surveys. Session on the future and development of databases (more specifically the ICES acoustic database and the PGNAPES database)
Year 2	General meeting, preceded by 3 post-cruise meetings which collate data of multinational surveys. Session to review and evaluate survey designs across all WGIPS coordinated surveys done in Year 2, and coordinate planning and discuss designs for surveys taking place in Year 3. Inter-sessional work on the review and updates for the WGIPS acoustic manual, followed by a session during the annual meeting to review and provide possible updates for the WGIPS acoustic survey manual. Harmonize changes amongst the different surveys. Develop survey design protocols for acoustic surveys on spawning aggregations for inclusion in the survey manual. Session to assess progress in the implementation of auxiliary pelagic ecosystem surveying technology and methodology (e.g. optical technology, multi-beam and wideband acoustics) for monitoring components of the wider ecosystem in surveys covered by WGIPS. Session on the future and development of databases (more specifically the ICES acoustic database and the PGNAPES database).
Year 3	General meeting, preceded by 3 post-cruise meetings which collate data of multinational surveys. Session to review and evaluate survey designs across all WGIPS coordinated surveys done in Year 3. Inter-sessional work on the review and updates for the WGIPS acoustic manual, followed by a session during the annual meeting to review and provide possible updates for the WGIPS acoustic survey manual. Harmonize changes amongst the different surveys. Develop survey design protocols for acoustic surveys on spawning aggregations for inclusion in the survey manual. Session to assess progress in the implementation of auxiliary pelagic ecosystem surveying technology and methodology (e.g. optical technology, multi-beam and wideband acoustics) for monitoring components of the wider ecosystem in surveys covered by WGIPS. Session on the future and development of databases (more specifically the ICES acoustic database and the PGNAPES database).

3 Supporting Information

Priority	The Group has a very high priority as its members have expertise in design and implementation of acoustic-trawl surveys, including sampling of additional ecosystem parameters. It will therefore directly contribute to the implementation of integrated pelagic ecosystem monitoring programmes in the ICES area. The Group's core task is the standardisation, planning, coordination, implementation, and reporting of acoustic surveys for the main pelagic fish species including herring, sprat, blue whiting, mackerel, and boarfish in Northeast Atlantic waters. The work provides essential data in the form of survey indices to WGWIDE and HAWG in the aim to perform integrated ecosystem assessment.
Resource requirements	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	The Group is normally attended by some 20–25 members and guests.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	WGWIDE, HAWG
Linkages to other committees or groups	There is a very close working relationship with other groups in EOSG, especially relevant links to WGACEGG, WGALES, WGBIFS, WGFAST, WGFTFB, WGISDAA, WGISUR, WGMEGS, WGTC, WGINOR, WGINOSE, WGIAB, WKEVAL, WKMSMAC2, WKSCRUT, WKSUREQ
Linkages to other organizations	EU H2020 project 'AtlantOS'

4 List of Outcomes and Achievements in this delivery period

Indices for the stocks of herring, sprat, mackerel, boarfish, and blue whiting in Northeast Atlantic waters from annual ecosystem surveys are used as fishery-independent data for analytical assessment purposes in HAWG and WGWIDE. The following outcomes and achievements were obtained during this delivery period (2019-2021):

- North Sea autumn spawning herring numbers, biomass, maturity proportion, mean weight, and length-at-age, from the ICES Coordinated Acoustic Survey in the Skagerrak and Kattegat, the North Sea, West of Scotland, and the Malin Shelf area (HERAS)
- Western Baltic spring-spawning herring numbers, biomass, maturity pro-portion, mean weight, and length-at-age, from the HERAS
- West of Scotland autumn spawning herring numbers, biomass, maturity proportion, mean weight, and length-at-age, from the HERAS
- Malin Shelf herring (areas 6.a/7b,c) numbers, biomass, maturity proportion, mean weight, and length-at-age, from the HERAS
- Sprat in the North Sea (Subarea 4) numbers, biomass, mean weight, and length-at-age, from the HERAS
- Sprat in Skagerrak / Kattegat (Division 3.a) numbers, biomass, mean weight, and length-at-age, from the HERAS
- Norwegian spring-spawning herring numbers, biomass, mean weight, and length-at-age, from the International Ecosystem Survey in the Nordic Sea (IESNS)
- Blue whiting numbers, biomass, mean weight, and length-at-age, from the International Ecosystem Survey in the Nordic Sea (IESNS)
- Mackerel numbers, biomass, mean weight, and length-at-age, from the International Ecosystem Summer Survey in the Nordic Sea (IESSNS)
- Norwegian spring-spawning herring numbers, biomass, mean weight, and length-at-age, from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS)
- Blue whiting numbers, biomass, mean weight, and length-at-age, from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS)
- The Blue Whiting survey did not take place in 2020 due to the global COVID pandemic. Normally this survey would produce blue whiting numbers, biomass, maturity proportion, mean weight, and length-at-age, from the ICES International Blue Whiting Spawning stock Survey (IBWSS)
- Irish Sea and North Channel (area 7.a), autumn spawning herring, numbers, biomass, distribution maturity proportion, mean weight, and length-at-age from the Irish Sea Acoustic Survey (ISAS).
- Irish Sea (area 7.a N), Industry spawning survey of herring biomass and distribution (ISSS)
- Western Baltic Spring-spawning Herring (including and excluding Central Baltic Herring) as well as sprat numbers, biomass, and mean weight-at-age by area for the Western Baltic (ICES Subdivisions 21, 22, 23, and 24) from the German Acoustic Autumn Survey (GERAS) of the Baltic International Acoustic Survey (BIAS)
- Boarfish numbers, biomass, maturity proportion, mean weight, and length-at-age, from the Western European Shelf Pelagic Acoustic Survey (WESPAS)

- Celtic Sea herring numbers, biomass, maturity proportion, mean weight, and length-at-age, from the Celtic Sea herring Acoustic Survey (CSHAS)
- 6.a herring numbers, biomass, maturity proportion, mean weight, and length-at-age, from the industry surveys in 6.a.N and 6.a.S (6aSPAWN)
- The Blue Whiting survey did not take place in 2020 due to the global COVID pandemic. Normally this survey would produce Blue whiting numbers, biomass, maturity proportion, mean weight, and length-at-age, from (IBWSS - PELACUS)

Other ecosystem survey-derived operational products:

- Horse Mackerel numbers, biomass, maturity proportion, mean weight, and length-at-age, from WESPAS
- Zooplankton distribution based on dry weight samples from the IESNS, IESSNS and WESPAS surveys.
- Recorded observations of marine mammals during the IESSNS, CSHAS and WESPAS.
- Recorded observations of seabird abundance and distribution during CSHAS, IBWSS (no survey in 2020) and WESPAS surveys

Other outcomes and achievements:

- Started process of moving some surveys onto TAF with assistance from ICES Data Centre
- Continued development of common code to aid survey planning, formatting, quality check, and plot data from acoustic surveys. Continued used of the WGIPS GitHub repository initiated https://github.com/ices-eg/WGIPS
- Comments and input to development of the ICES Acoustic database; maintained communication between WGIPS and WGAcousticGov
- Overview of new and currently applied auxiliary pelagic ecosystem sampling technologies, including session on ecosystem technologies
- Continued collection of genetic samples on HERAS/WESPAS surveys for splitting of herring stocks
- 2021 survey plans (see Annex 16 for 2021 survey plans)
- Contribution to ICES Annual Science Conference (*ICES ASC postponed in 2020*)
- Contribution to the report on the Topic Group on Collecting Quality Underwater Acoustic Data in Inclement Weather (TGQUAD)
- Review of BIAS survey move to ICES DB and StoX for WGBIFS
- Review of WGACEGG survey manual in TIMES
- Continued adoption of a common survey evaluation tool (StoX) across the surveys coordinated within WGIPS and transition to the use of the ICES acoustic database repository
- Contribution to WKMESOMeth; constructed protocol for testing acoustic and sampling of mesopelagics on IBWSS 2021
- Working document on sensitivity analysis conducted of NSAS/WBSS indices from the HERAS survey (annex 23)
- Working document on stock splitting in HERAS (annex 24)
- Protocols for sampling NSSH otoliths and scales on the IESSNS and IESNS (annex 25)

5 Progress Report on ToRs and work plan

ToR a). Combine and review annual ecosystem survey data to provide: indices of abundance and spatial distribution for the stocks of herring, sprat, mackerel, boarfish and blue whiting in Northeast Atlantic waters.

During the 2019-2021 reporting period WGIPS delivered annual indices of abundance and spatial distribution of stocks of herring, sprat, mackerel, boarfish and blue whiting in Northeast Atlantic waters from four large multinational WGIPS coordinated ecosystem surveys and 8 national surveys. The results from the large international survey were combined and reviewed within separate post-cruise meetings for each survey prior to WGIPS where the final results were presented.

Detailed cruise reports from each survey in 2018 and 2019 are found in the WGIPS interim reports for those years. Details of the 2020 surveys and findings are reported in Annex 3 – 14 in this report.

IBWSS

The IBWSS did not take place in 2020 due to the global COVID pandemic. For the IBWSS 2021 survey, it was agreed that data will be produced so that it can be uploaded to both the ICES DB and PGNAPES DB by all participating countries. This was agreed at the WGIPS 2020 meeting also, but because the IBWSS 2020 survey was cancelled due to the COVID pandemic, this agreement is rolled over to IBWSS 2021. This will enable comparison between StoX projects from both sources and ensure transition to using common formats. Timing, planning, and methods applied for IBWSS surveys were discussed and evaluated during the 2019-2021 reporting period.

IESNS

The survey is considered to contain the distribution area of NSS herring, although in 2019 the zero-line was not fully reached in the north western part of the distribution area, and in 2020 herring were observed on some of the transect ends in the eastern area. NSS herring has mainly been concentrated in the south-western part of the survey area (older herring) and in the north-eastern area (younger herring). In 2020, the distribution of the recruiting 2016 year-class in the eastern part of the Norwegian Sea extended from 70°N south to 64°N. This is different from earlier year-classes recruiting to the Norwegian Sea, which usually do not extend farther south than 69°N. The IESNS also covers the young herring in the Barents Sea by a Russian vessel, but in 2020 there was no coverage in the Barents Sea.

A revision of the strata system in the survey was done in 2020. Information about the distribution of herring since the strata system was made in 2014 showed that the survey had been typically covering areas of very low/zero densities of herring. The strata system was therefore adjusted to account for that. Furthermore, the new system makes it easier to plan the survey and to change plans at short notice. It also improves the synoptic coverage particularly in the south where two of the strata were merged into one.

Since 2015 the Norwegian vessel has surveyed two cross-basin transects in order to sample environmental data, currently not sampled by the other vessels. This has also enabled comparison on e.g. acoustics and biological sampling among vessels in the same region, which is considered as a strength in quality checking data. In, 2020, however, the Norwegian vessel had restrictions on distance from Norwegian harbour (due to COVID-19) preventing such a cross basin transect.

StoX is used for calculating the stock indices of NSS herring and blue whiting.

Details of the 2020 survey and findings are reported in Annex 4b.

HERAS

The HERAS survey is carried out annually and provides abundance indices by age and biological parameters for North Sea Autumn Spawning herring (NSAS), Western Baltic Spring Spawning herring (WBSS), Malin Shelf herring (MSH), sprat in the North Sea, and sprat in Skagerrak-Kattegat to the Herring Assessment Working Group (HAWG).

Indices of abundance from this survey go back to 1991 and the survey went through a change in survey design to be more compatible with the StoX method for estimation in 2015 (WKEVAL: ICES 2015).

StoX continues to be used to estimate the outputs from the survey and disaggregated survey data are uploaded to the ICES trawl acoustic database. In 2020 the computation of the survey indices for WBSS and NSAS was implemented on the ICES TAF system to improve the transparency of the process. The survey group is working towards TAF compliance for all indices produced.

In this reporting period the survey has covered the entire survey area (North Sea, Skagerrak-Kattegat and Malin Shelf) in all years.

Generally trends over the reporting period have been stable for all stocks monitored apart from a steady small decrease year on year in SSB for NSAS.

Several herring stocks occur in the survey area and apart from in those strata covered by Denmark and Norway, the stocks are treated as geographically discrete in the analysis. Large scale investigations into using genetic tools to separate the component stocks in the HERAS indices (and beyond) have been ongoing through this reporting period. Methods are now established and ready to be implemented to separate 6a South and 6a North herring found in mixed aggregations in the Malin Shelf area and efforts are ongoing to standardise genetic methods to be used to separate WBSS and NSAS in the strata covered by Norway and Denmark.

Details of the 2020 survey and findings are reported in Annex 5b.

IESSNS

The International Ecosystem Summer Survey in the Nordic Seas (IESSNS) was performed within approximately 5 weeks from July 1st to August 4th in 2020 using six vessels from Norway (2), Iceland (1), Faroe Islands (1), Greenland (1) and Denmark (1). The main objective is to provide annual age-segregated abundance index, with an uncertainty estimate, for northeast Atlantic mackerel (*Scomber scombrus*). We have also constructed a new time series for blue whiting (*Micromesistius poutassou*) abundance index and for Norwegian spring-spawning herring (NSSH) (*Clupea harengus*) abundance index. This is obtained by utilizing standardized acoustic methods to estimate their abundance in combination with biological trawling on acoustic registrations. The time series for blue whiting and NSSH have now been conducted for five years (2016-2020) and ready for evaluation in ICES.

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

The survey, including all participating vessels, was not negatively impacted to any extent by the international Covid-19 situation in July-August 2020. The survey coverage area was 2.9 million km^2 in 2020, which is similar as in previous years from 2017 to 2019. Furthermore, 0.26 million km^2 was surveyed in the North Sea in July 2020. Distribution zero boundaries were found in majority of the survey area apart from high mackerel abundance in the north-western region of the Norwegian Sea into the Fram Strait west of Svalbard. The mackerel appeared less patchily distributed within the survey area and had a pronounced distribution in the central and northern Norwegian Sea in 2020 compared to previous years. This major difference in distribution consists of a substantial decline of mackerel in the west and corresponding increase in the central and northern part of the Norwegian Sea.

Consequently, the survey strata south of Iceland has now been changed from permanent strata to dynamic strata for IESSNS 2021. The survey strata south of Greenland has been taken out from the survey planned for 2021. The main reason for these changes in survey design is due to a substantial reduction of NEA mackerel during summer in waters off Greenland and Iceland from 2018-2020.

Details of the 2020 survey and findings are reported in Annex 6b.

GERAS

The German Autumn Acoustic Survey (GERAS) is coordinated by ICES WGIPS and the ICES Baltic International Fish Survey Working Group (WGBIFS). During the current reporting cycle, the survey provided the Herring Assessment Working Group (HAWG) and the Baltic Fisheries Assessment Working Group (WGBFAS) with index values for stock sizes of herring and sprat in the Western Baltic area (ICES Subdivisions 21-24). Since 2018, a further distinct decrease in stock biomass and abundance was estimated from survey results, amongst others driven by the continued absence of dense aggregations of old pre-spawning Western Baltic Spring Spawning herring in the Sound (SD 23). Current biomass estimates are the lowest on record.

Details of the 2020 survey and findings are reported in Annex 7b.

ISAS

The Agri-Food and Biosciences Institute (AFBI), continues to provide age stratified data for herring to the HAWG by conducting acoustic surveys of the northern Irish Sea (ICES Area 7aN) throughout the term of the current reporting cycle (2018-2020). A survey design of systematic, parallel transects covers approximately 620 nmi, widely-spaced (8-10 nmi) transects are surveyed around the periphery of the Irish Sea with transect spacing reduced to 2 nmi in strata around the Isle of Man to improve precision of estimates of adult herring biomass. Transect positioning is randomized within +/- 4 nmi of a baseline position each year. Estimates throughout the period of the current reporting cycle remain consistent within the range for the time series. Highest estimates for herring SSB and +1 ringers was observed in the 2020 survey.

Details of the 2020 survey and findings are reported in Annex 8b.

ISSS

The Agri-Food and Biosciences Institute (AFBI) has been conducting an acoustic spawning survey of the northern Irish Sea (ICES Area 7aN) since 2007 and was introduced as a separate survey to the WGIPS portfolio in 2017. The survey design consists of systematic, parallel transects spaced at 2 nmi in strata around the Isle of Man to improve precision of estimates of adult herring biomass. Transect positioning is randomized within +/- 4 nmi of a baseline position each year. Throughout the term of the current reporting cycle (2018-2020), the acoustic spawning survey continues to compliment the main ISAS. Traditionally the ISSS is conducted on board a commercial pelagic fishing vessel but had to be completed on board the RV Corystes in 2020 due to Covid 19 biosecurity concerns.

Details of the 2020 survey and findings are reported in Annex 9b.

CSHAS

The Celtic Sea herring acoustic survey continues to provide annual age stratified biomass and abundance estimates to HAWG. Changes in the behaviour of the stock compounded by a low stock biomass prompted a review of the survey design in 2016. The survey conducts two comparable but independent surveys of the core broad scale distribution area accompanied by focused adaptive surveys. All survey data are uploaded to the ICES trawl acoustic database and the survey is currently working towards TAF compliance. The StoX program is used to calculate annual estimates. The survey routinely reports visual survey effort on marine mammals and seabirds. Hydrographic data which are uploaded to the ICES Oceanographic database.

Details of the 2020 survey and findings are reported in Annex 10.

WEPAS

The WESPAS survey is carried out annually and provides age stratified biomass and abundance estimates for herring, horse mackerel and boarfish. The survey provides synoptic coverage northern Biscay to the north of Scotland. Data are submitted annually to HAWG and WGWIDE. All survey data are uploaded to the ICES trawl acoustic database and the survey is currently working towards TAF compliance. The StoX program is used to calculate annual estimates. The survey routinely reports visual survey effort on marine mammals and seabirds. Hydrographic data which are uploaded to the ICES Oceanographic database.

Details of the 2020 survey and findings are reported in Annex 11.

PELTIC

The 9th Pelagic ecosystem survey in western Channel and eastern Celtic Sea (PELTIC) extended its coverage for the fourth year into French waters of the English Channel, and included, for the first time, the waters of Cardigan Bay (southern Irish Sea). Just under 2000 nautical miles of survey transects were completed. Sprat biomass from Lyme Bay, English Channel, was estimated at 33,798 t and will feed into HAWG to underpin its assessment. Sardine biomass for the whole survey area (excluding Cardigan Bay) was estimated at 332,098 t. The short four-year time series of sardine biomass estimates and biological data (based on the extended PELTIC coverage) will be considered to provide the basis for the first sardine in area 7 stock assessment at a benchmark meeting WKWEST in February 2021. PELTIC provides the only fisheries independent data on sardine in ICES area 7, which, since 2017, has been considered as a separated stock from sardine from ICES area 8. StoX software was used to post-process the acoustic data and provide abundance estimates. Distribution and abundance of other pelagic fish species (anchovy, horse mackerel and mackerel) and boarfish, as well information on top predators, lower trophic levels and physical oceanography were collected.

Details of the 2020 survey and findings are reported in Annex 12.

PELACUS

Blue whiting data from PELACUS has been presented at WGIPS since 2018. Previously, blue whiting data from areas 8c and 9a were presented to WGWIDE. Data from the 2019 survey were included in the survey estimate. The IBWSS-PELACUS did not take place in 2020 due to the global COVID pandemic. Timing, planning, and methods applied for IBWSS-PELACUS surveys were discussed and evaluated during the 2019-2021 reporting period.

6aSPAWN

The 6aSPAWN surveys have been carried by industry vessels annually since 2016 and are developing abundance indices by age and biological parameters for herring in 6aN and separately in 6aS7bc. The survey designs have seen some modifications over time as the work develops, as reported in WKHASS (2019, see summary below under 'Progress by ToRs'). The utility of abundance indices will be evaluated during the 6a7bc herring benchmark process in early 2022. StoX has been used to estimate the abundance indices since the surveys began and acoustic and biological data are stored on the ICES database.

Details of the 2020 survey and findings are reported in Annex 13b.

ToR b: Coordinate the timing, area and effort allocation and methodologies for individual and multinational acoustic surveys on pelagic resources in the Northeast Atlantic waters covered (Multinational surveys: IBWSS, IESNS, IESSNS, HERAS, and individual surveys: CSHAS, ISAS, ISSS, PELTIC, GERAS, WESPAS, 6aSPAWN).

Results of different ecosystem surveys conducted in 2018-2020 were presented at each meeting of the 3 year term. This included results from relevant post-cruise meetings (IBWSS, IESNS, IESSNS, and HERAS). The combined results provided indices of abundance and distribution for stocks of herring, sprat, mackerel, boarfish, and blue whiting in Northeast Atlantic waters.

Timing, planning, and methods applied for coordinated multinational (IBWSS, IESNS, IESSNS, HERAS) and individual surveys (CSHAS, WESPAS, ISAS, ISSS, PELTIC, GERAS and 6aSPAWN) were discussed and evaluated.

IBWSS

The IBWSS survey has been coordinated by Norwegian scientists the last three years and this responsibility will continue. In general, the timing and progression of vessels have been good, and methodology has been according to the survey standard. However, the survey did not take place in 2020 due to the global COVID pandemic.

IESNS

Norwegian scientists have coordinated the IESNS survey the last three years. In general, the timing and progression of vessels have been good, and methodology has been according to the survey standard.

IESSNS

Norwegian scientists have coordinated the IESSNS survey in 2019-2020, whereas Icelandic scientists coordinated the IESSNS survey back in 2018. The timing and temporal progression have been quite optimal in 2018-2020, although there is always room for improvements. The core strata remained unchanged during these last three years, whereas some of the peripheral strata have been changed. Dynamic strata in the south western part of the survey area have been reduced, whereas dynamic strata in the northern part of the survey area have been expanded to follow the overall changes in distribution and densities of mackerel during summers from 2018-2020.

HERAS

Norwegian scientists have coordinated the HERAS survey in 2018-2020. In general, the timing and progression of vessels have been good, and methodology has been according to the survey standard. The responsibility of coordinating the survey is taken over by Germany from 2021.

WESPAS

The 2021 WESPAS survey will take place from the 9th June to the 20th July (42 days) beginning in the south and working progressively northwards. The time frame of the survey is similar to previous years and good geographical, but limited temporal, alignment with surveys to the south (PELGAS) and north (Scottish HERAS).

CSHAS

The 2021 CSHAS will run over 21 days beginning on the 8th October. The survey will use the laddered approach for broad scale areas and adaptive survey effort. Hydrographic, marine mammal and seabird surveys will continue in 2021.

ISAS

The 2021 Irish Sea acoustic survey (ISAS) will be carried out onboard the RV Corystes between August 26th and September 14th 2021. A survey design of systematic, parallel transects will cover approximately 620 nmi and be divided into two parts. Transects around the periphery of the Irish Sea are randomized within +/- 4 nmi of a baseline position each year with spacing set between 8-10 nmi. Transect spacing is reduced to 2 nmi in strata around the Isle of Man to improve precision of estimates of adult herring biomass.

ISSS

The Irish Sea Acoustic Spawning Survey will take place between the 24th of September and the 8th of October 2021. Transect spacing of 2nmi in strata surrounding The Isle of Man. Timing of the survey depends on advice from industry vessels who will notify when spawning is taking place.

PELTIC

The Pelagic ecosystem survey in western Channel and eastern Celtic Sea (PELTIC) went ahead as planned in all three of the reporting years, 2018, 2019 and 2020. All three surveys covered the same, expanded survey design adopted for the first time in 2017, including the waters of the eastern Celtic Sea, from south Wales to the French coast of the western English Channel (ICES areas 7f, e and parts of g and h). The 2018 survey further extended into the Eastern Channel, and the 2020 survey extended further north into Cardigan Bay (southern Irish Sea). While sailing dates were similar for the three surveys (6th, 1st and 3rd of October), their duration varied because of the extensions (36, 28 and 35 days). Efforts to coordinate PELTIC timing and spatial coverage with CSHAS (to the north and west) and JUVENA (to the south), were reasonably successful, achieving wide scale coverage, from the north coast of Spain to the south coast of Ireland. Unfortunately, in 2019, JUVENA was not able to survey the northern part of the Bay of Biscay due to weather constraints. The 2021 Pelagic ecosystem survey in western Channel and eastern Celtic Sea (PELTIC) is scheduled to commence on the 1st to 29th October 2021. The survey area may be extended north into Cardigan Bay subject to approval. It will cover the waters of the eastern Celtic Sea, from south/west Wales to the French coast of the western English Channel (ICES areas 7f, e and parts of g and h). Where possible PELTIC will be coordinated with CSHAS (to the north and west) and JUVENA (to the south), to achieve best possible widescale coverage.

GERAS

GERAS as a national survey represents a part of the ICES Baltic International Acoustic Survey (BIAS) that is coordinated through the ICES Baltic International Fish Survey Working Group (WGBIFS). As GERAS also covers the distribution area of Western Baltic Spring Spawning herring that is also contained in other WGIPS coordinated surveys, both the survey coordination and the presentation of results are conducted under the auspices of both WGIPS and WGBIFS. In the last 3 years, GERAS has been coordinated by the Thünen Institutes of Sea Fisheries and

Baltic Sea Fisheries, TI-SF and TI-OF) and followed a stratified systematic design. Survey timing and effort were comparable throughout the reporting period.

PELACUS

IBWSS - PELACUS is a national survey conducted by Spain. Results from PELACUS - IBWSS is incorporated into IBWSS since 2019.

6aSPAWN

Industry scientists from the Scottish Pelagic Fishermen's Association and Pelagic Freezer Trawler Association have been the lead coordinators of the surveys in 6aN and have worked closely with scientists from Marine Scotland and the Scottish Fishermen's Federation in planning and delivery. Post survey data workshops take place around two months after the survey when data has been collated and summarised. In 6aS7bc, scientists from the Marine Institute in Ireland are responsible for coordination, liaising with a range of industry vessels for implementation.

ToR c: ICES DB and WGAcousticGov

In 2020, WGAcousticGov established an online quarterly meeting schedule and held two meetings in Year 1 (September and December). The Year 1 work plan focused on achieving ToRs a & b. The group undertook the development of a Framework document (ToR a). The document outlined a structured management plan for the development of an effective and efficient data portal for high-quality survey data and how these goals would be achieved. The focus of the group moved to addressing users' needs and working through the current request items. A platform was established within GitHub to receive, record and process user feedback requests (ToR b). The group worked through specific individual requests and established a procedure to address these requests. In 2021 work will continue to support user's requests. The Working Group on Acoustic and Egg Surveys for small pelagic fish in NE Atlantic (WGACEGG) indicated in 2020 that they will begin the process of transition to using the portal as primary survey data repository with assistance and guidance from the ICES data centre and WGAcousticGov.

Within WGIPS, transition has been slow but positive steps were made during this meeting with an indication that Norway will now use the ICES data format for reporting acoustic and biological data going forward and these data will be uploaded to the repository. The developers of StoX have adopted the ICES format for future versions. This represents a significant move for the group proving their commitment to high quality data products and end-to-end transparency in their work flow through the TAF process.

Table 1. Progress of adopting the ICES DB and StoX for the individual surveys

Survey	Database (ICES or other)	Abundance estimation software (StoX or other)
HERAS	Biological and acoustic files in ICES DB	StoX
MSHAS/WoS	Biological and acoustic files in ICES DB	StoX
6aSPAWN	Biological and acoustic files in ICES DB	StoX
GERAS	Access database/uploading files to ICES DB	GERIBAS II
ISSS	National SQL database	R-scripts

ISAS	National SQL database	R-scripts
WESPAS	Biological and acoustic files in ICES DB	StoX
PELTIC	Biological and acoustic files in ICES DB	EchoR, StoX
IBWSS	PGNAPES & ICES Database	StoX
IESSNS	PGNAPES	StoX
IESNS	PGNAPES & ICES Database	StoX
CSHAS	Biological and acoustic files in ICES DB	StoX

A number of WGIPS coordinated and individual acoustic surveys are included in the ICES Acoustic Trawl survey database e.g. HERAS, CSHAS, WESPAS, PELTIC IBWSS (IRL and ND) and 6.a Industry surveys (6.aSPAWN). Under this TOR, the group will keep following the progress for the rest of the surveys coordinated by WGIPS. In 2019, WKHASS recommended that the Irish Sea surveys (ISAS and ISSS) be uploaded to the ICES DB and progress on this is ongoing.

There are on-going compatibility issues with the .xml files that are extracted from both the ICES DB and PGNAPES databases. StoX currently cannot handle .xml files from both databases when combined in one project. It would be preferable if files from either database could be used in the StoX project for the IBWSS, IESNS and IESSNS. It is also important that there is one agreed procedure going forward for all participants of these internationally coordinated surveys. At the IBWSS post-cruise meeting in Galway in 2019 and again at the WGIPS meeting in 2020, it was agreed that all participating countries would upload to the ICES database and the PGNAPES database in 2020. IBWSS 2020 was cancelled due to COVID pandemic, therefore both .xml formats can be used within two StoX projects at the post-cruise meetings in 2021. A comparison can be made between the StoX projects using both formats. There is support within all members of the group that participate in the international surveys to use the ICES database in the future, however, there is still concern about how hydrographic data is stored in and processed from this database. There is also concern about the extra time needed to produce data in the format for the ICES database, which is new to some participants.

ToR d:

WGIPS agreed to work towards putting forward a publication resolution to ICES to update the current version of the SISP 9 Manual for International Pelagic Surveys and publish the manual in the new TIMES format over the coming years. A subgroup of WGIPS members will meet periodically online during 2021 to make progress on the new TIMES format and present an update on progress to WGIPS in 2022.

ToR e:

Annually WGIPS deals with numerous recommendations from other groups, both responding to recommendations to WGIPS and formulating recommendations to other groups on issues as they arise. This is the primary way that WGIPS formally interacts with other groups. Often the group cannot deal with a substantial recommendation at the annual meeting and they can result in the development of workshops. The request from WGWIDE is a case in point, where WGIPS answer to the question of extending the swept area survey was to have a workshop on the issue. WGIPS is waiting for a response from WGWIDE on how to proceed with this. Two workshops were held by WGIPS in 2019 (WKHASS and WKSCRUT2). The results from these workshops were incorporated into the protocols for 6aSPAWN and IESSNS surveys and will become part of the updated manual in the TIMES format that WGIPS will publish in the coming years. WGIPS have continued to respond to requests from other groups and contribute to workshops when required. The response to a recommendation given by WGIPS to WGFAST in 2020 on survey estimates at variable vessel speed on the IESSNS was well received and the results from this work will be used in executing this survey going forward.

ToR f:

The Workshop on Herring Acoustic Spawning Surveys (WKHASS) in 2019 specifically dealt with issues of survey design on the spawning surveys on herring in 6.a and 7.a. WKHASS recommended that the spawning survey on herring in the Irish Sea (7.a) should be included in the SISP 9 Manual for International Pelagic Surveys, because this survey is already used as a biomass index in the Irish Sea herring assessment and thus transparency is required in the calculation of survey indices. The spawning surveys in 6.a. are still undergoing design changes and require further work before being able to provide definitive survey manuals.

To help ensure transparency in the calculation of survey indices and allow for comparison with standard methods WKHASS recommended that the ICES Acoustic trawl surveys database hosts acoustic and biological data from the herring acoustic spawning surveys in 6a and 7a. This is being implemented. WKHASS also suggested that where in-house methods are currently used, the estimations of biomass and abundance should be compared with the WGIPS standard StoX methods. Experience from the Irish Sea spawning surveys (7a) was helpful in thinking about refinements to the 6aN that may help to provide a useful index of herring abundance during spawning time. The suggestions made by WKHASS for future survey design in 6aN and 6aS,7b were implemented in surveys undertaken in 2020, and used to undertake a re-analysis of previous surveys in 6aN, which will be presented as a working document to the 6a,7bc benchmark in 2021. Finally, discussions at WKHASS proposed that as part of quality control, a scrutinisation workshop is carried out to share experience in identifying herring marks during the (pre) spawning period.

ToR g:

A workshop on acoustic scrutinising procedures for the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) was recommended by the WGIPS in 2019 and held in Bergen 17-18 September 2019. Participants (13) from all nations participating in the IESSNS attended the workshop. The IESSNS targets mackerel, herring and blue whiting during their summer feeding migration in the Nordic Seas. However, mackerel is estimated by standardized swept-area trawl method while herring and blue whiting are estimated using standard acoustic methods. Hence the scrutinising of herring and blue whiting were the main focus of the workshop. The group defined three areas with typical and common acoustic backscatter features within the total survey area covered by IESSNS: The Irminger Sea including East Greenland and West Iceland, the Norwegian Sea and adjacent areas including Iceland Sea and the area around the Faroes, and shelf areas. Further, two general procedures were also presented; the first was how to separate herring from plankton (the "threshold" method and the "200 kHz" method), and the second how to deal with the acoustic backscatter in the upper layers in years when strong year-classes of blue whiting occur in the survey area (that resemble herring schools). Several examples were analysed in the report and showed that all participants used the same general procedure during the scrutinising process. However, some minor adjustments were done by individual participants to ensure that a common identical procedure was followed by the whole group, as shown by the examples in the report. In addition, a recommendation from the workshop was that survey leaders trawl as much as possible to ground-truth the acoustic registrations.

ToR h:

WGIPS facilitates testing and developing forecast models provided by WGS2D (blue whiting spawning habitat forecast) using data from the IBWSS. There has been collaboration between WGS2D and WGIPS annually, and the forecasts along with results are presented annually at the WGIPS meeting. In 2021, WGIPS held a subgroup made up of IBWSS participants (NO, FO, NL, IE, ES) to discuss the formulation of scrutiny procedures to harmonise the reporting of mesopelagic acoustic density during future surveys. This was in response to a recommendation from WKMESOMeth. The IBWSS survey participants have agreed to begin the process of providing acoustic data within the agreed criteria and aim to develop biological sampling capacity over time within existing constraints. A review exercise will be conducted during the 2022 WGIPS meeting to review the data and findings of the 2021 survey and refine the protocol.

ToR i: developing pelagic ecosystem surveying technology

Increasingly, complimentary data outside of the more traditional sources such as CTD and supplementary biological data are collected. Visual abundance surveys for marine mammals and seabirds are becoming increasingly common, as are zooplankton sampling (e.g. dry weight), in-trawl optics, broadband acoustic and sonar data. Annually, the group assessed these developments by reporting on these additional data sources within the Ecosystem index overview table and research on these topics is presented during a dedicated ecosystem session during the meeting. Currently such additional data sources are collected in a somewhat ad hoc fashion by national institutes. To provide meaningful on-going ecosystem metrics a more coordinated approach is required within the group. The first part of this process is to identify the end user and specific requirements. For this to be achieved successfully then support from outside this group is required to:

- Determine the final end user group, what is the (primary) use of this data?
- Prioritise data types and metrics
- Determine protocols and methods to provide a coordinated collection program
- Define metadata standards and a data repository for these data
- Identification of the costs, where applicable, and potential funding sources
- Determine feedback process from final end user group

The group recognises their unique position to be able to provide ecosystem data sources alongside more traditional survey outputs and are willing to engage in a structured collection process. To this end the group looks forward to future engagement with other expert groups.

6 Recommendations issued to WGIPS from other Working Groups

Recommendations issued to WGIPS from other working groups in 2020

Recommendation	Addressed to
ID 28 HAWG recommends that stock splitting is taken into account in future analysis and planning of the HERAS summer survey in 6aN and 6aS. This should follow the recommendations from the EASME project which is examining stock separation of herring west of Scotland and Ireland and will allow for separate indices to be delivered for these stocks. The results of this project will be available at the end of 2020.	WGIPS
ID 28 Reply: Annex 18	

Recommendation	Addressed to
ID 29 HAWG recommends that WGIPS investigates possible causes for the deterioration of the internal consistency in the HERAS index and suggest that both the analysis method and the biological sampling methods are scrutinised for issues that could cause the deterioration of the ability of the survey to accurately track cohorts past the age of 6 wr. In addition to investigating the analysis method it is recommended that a thorough review of differences and changes in biological sampling strategy and intensity amongst participating laboratories and over the time series are documented and their potential effect investigated as far back as possible. Finally, it is recommended that consideration is given to how otoliths have been aged by all participating labs over the time series (mounted/unmounted/different mediums etc.) and if / when changes have occurred how such changes might have affected aging results.	WGIPS
ID 29 Reply: Annex 19	

Recommendation	Addressed to
ID 120 It is recommended that an age reading exchange and a following workshop are held for Norwegian spring spawning herring. The work should also deal with issues related to the mixing of NSSH with adjacent herring stocks in the fringes of the distribution area. The workshop participants should be both age readers and participants with statistical, stock identification and stock assessment expertise.	WGWIDE to WGIPS and WGBIOP
ID 120 Reply: Annex 20	

7 Cooperation with Advisory Structures

HAWG

Indices for the stocks of herring and sprat in North-east Atlantic waters from annual ecosystem surveys are used as fishery-independent data for analytical assessment purposes in HAWG. Communication between HAWG and WGIPS is strengthened through overlap in memberships of the two groups as well as the delivery of survey summary tables from WGIPS to stock assessors and the return of these to WGIPS with comments from stock assessors.

WGWIDE

Indices for the stocks of herring, mackerel, boarfish, and blue whiting in North-east Atlantic waters from annual ecosystem surveys are used as fishery-independent data for analytical assessment purposes in WGWIDE. Communication between WGWIDE and WGIPS is strengthened through overlap in memberships of the two groups as well as the delivery of survey summary tables from WGIPS to stock assessors and the return of these to WGIPS with comments from stock assessors.

WKREO

The group considered the preliminary results of Workshop on the Realigning of the Ecosystem Observation Steering Group (WKREO). This group reviewed the current tasks of the multi-annual data collection expert groups, develop options for reorganizing Ecosystem Observation Steering Group (EOSGs) expert groups that can effectively conduct the essential tasks and evaluate different reorganization options for EOSG to identify the potential for issues.

WKREO proposes to realign the EGs on data collection from the current situation – with groups covering specific techniques – towards regional data collection groups that look at specific ecosystems.

WGIPS supports this proposal as in general a greater ecosystem perspective is required. It is in line with the WGIPS recommendation from 2019 to requests guidance from SCICOM to identify ecosystem metrics that can be routinely collected during surveys coordinated by the group. However - in contrast to the expectations as expressed by WKREO in its preliminary report – WGIPS does not expect the proposed scheme will lead to less meetings as international acoustic surveys will require the same planning and coordination as before.

ICES Acoustic Trawl Survey Data Portal

Since 2015 the ICES Data Centre has been developing ICES Acoustic Trawl Survey database and portal http://acoustic.ices.dk as part of the AtlantOS project (2015-2019). WGIPS have been involved in the development by giving input to the data structure and workflow, amongst others through several survey-specific and general work-shops, i.e. the Workshop on Evaluating Current National Abundance Estimation Methods for HERAS Surveys (WKEVAL) and the Workshop on the Review of the ICES acoustic-trawl survey database design (WKIACTDB). The new working group on acoustic governance (WGAcousticGov) has formalised the communication between groups such as WGIPS and the ICES Data Portal. Additional input comes from the annual WGIPS and survey post-cruise meetings. The Acoustic Trawl Survey Data Portal is now being maintained by ICES and several WGIPS coordinated surveys are now actively using the database i.e. HERAS, CSHAS, WESPAS, 6aSPAWN and partly IBWSS and IESNS.

8 Revisions to the Work Plan

Facilitating the adoption of TAF across WGIPS surveys

Support was provided by the ICES data centre at the WGIPS meeting in 2021 for surveys to begin using the ICES Transparent Assessment Framework (ICES TAF) for documenting and archiving the estimation process of indices from the coordinated surveys. WGIPS would like to continue developing this process in the coming years, facilitating the adoption of the ICES TAF for documenting the survey estimates. WGIPS agreed to recommend to the ICES Data Centre that they provide support in the form of workflow packages with training in the system before the next WGIPS meeting (January 2022, Belfast). Continued demonstration and hands-on support to those surveys that are ready to start this process is also appreciated.

Many of the surveys coordinated in WGIPS have already adopted the ICES Acoustic Trawl Survey database for data storage (http://www.ices.dk/marine-data/data-portals/Pages/acoustic.aspx) and the StoX software (https://www.hi.no/hi/forskning/prosjekter/stox) for the estimation process. This makes it an easy step to adopt ICES TAF to fully document all data processing steps from version control of the data extracted from the database to the production of estimates in StoX and any additional data processing performed on data to deliver the final index to the assessment. WGIPS has been discussing the need for a practical, secure and future proof way to archive the final agreed StoX projects from each survey and scripting the full estimation process including StoX estimation on the ICES TAF would address this.

Although not all surveys will be ready to go onto the ICES TAF immediately it would be helpful to get the process started with the aim to get as many of the surveys onto the ICES TAF during the next WGIPS reporting period (2022 - 2024).

A session was held in 2019 to assess auxiliary pelagic ecosystem surveying techniques currently used on surveys coordinated by WGIPS. It was decided that this approach be continued in future meetings during the term whereby results from the auxiliary monitoring of ecosystem components will be presented in a separate session from the standard fishery survey results for the target species. In practice this means that the session planned under TOR h for 2019 was repeated in 2020 and 2021.

Annex 1: List of participants

WGIPS 2021 participants (online meeting)

Name	Institute	Country (of institute)	Email
Bram Couperus (Chair)	Wageningen Marine Research	Netherlands	bram.couperus@wur.nl
Michael O´Malley (Chair)	Marine Institute	Ireland	michael.omalley@marine.ie
Åge Høines	Institute of Marine Research	Norway	aageh@hi.no
Alexander Krysov	Polar branch of Russian Federal Research Institute of Fisheries and Oceanography «VNIRO»(«PINRO»)	Russia	a_krysov@pinro.ru
Alexey Stesko	Polar branch of Russian Federal Research Institute of Fisheries and Oceanography «VNIRO»(«PINRO»)	Russia	stesko@pinro.ru
Alina Wieczorek	Marine Institute	Ireland	Alina.Wieczorek@Marine.ie
Anna H. Olafsdottir	Marine and Freshwater Research Institute	Iceland	Anna.olafsdottir@hafogvatn.is
Arne Johannes Holmin	Institute of Marine Research	Norway	arnejh@hi.no
Are Salthaug	Institute of Marine Research	Norway	are.salthaug@hi.no
Benoit Berges	Wageningen Marine Research	Netherlands	benoit.berges@wur.nl
Cecilie Kvamme	Institute of Marine Research	Norway	cecilie.kvamme@hi.no
Colin Millar	ICES	Denmark	colin.millar@ices.dk
Ciaran O´Donnell	Marine Institute	Ireland	Ciaran.odonnell@marine.ie
Edward Farrell	EDF Scientific Limited	Ireland	edward.d.farrell@gmail.com
Erling Kåre Stenevik	Institute of Marine Research	Norway	erling.stenevik@hi.no

Eydna í Homrum	Faroe Marine Research Institute	Faroe Islands	eydnap@hav.fo
Espen Johnsen	Institute of Marine Research	Norway	espen.johnsen@hi.no
Fabio Campanella	Centre for Environment, Fisheries and Aquaculture Science	England, UK	Fabio.campanella@cefas.co.uk
Florian Berg	Institute of Marine Research	Norway	florian.berg@hi.no
Gavin McNeill	Agri-food and Biosciences Institute	Northern Ireland	gavin.mcneill@afbini.gov.uk
Hjalte Parner	ICES	Denmark	hjalte.parner@ices.dk
Jan Arge Jacobsen	Faroe Marine Research Institute	Faroe Islands	janarge@hav.fo
Jeroen van der Kooij	Centre for Environment, Fisheries and Aquaculture Science	England, UK	jeroen.vanderkooij@cefas.co.uk
Leif Nøttestad	Institute of Marine Research	Norway	leif.noettestad@hi.no
Mark Payne	DTU-Aqua	Denmark	mpay@aqua.dtu.dk
Matthias Schaber	Thünen Institute of Sea Fisheries	Germany	matthias.schaber@thuenen.de
Maxim Rybakov	Polar branch of Russian Federal Research Institute of Fisheries and Oceanography «VNIRO»(«PINRO»)	Russia	fisher@pinro.ru
Pablo Carrera	IEO (Spanish Institute of Oceanography)	Spain	pablo.carrera@ieo.es
Ruth Kelly	Agri-food and Biosciences Institute	Northern Ireland	ruth.kelly@afbini.gov.uk
Sigurvin Bjarnason	Marine and Freshwater Research Institute	Iceland	sigurvin.bjarnason@hafogvatn.is
Sindre Vatnehol	Institute of Marine Research	Norway	sindre.vatnehol@hi.no
Solva Karadottir Eliasen	Faroe Marine Research Institute	Faroe Islands	Solvae@hav.fo
Steven Mackinson	Scottish Pelagic Fishermen's Association	Scotland	steve.mackinson@scottishpelagic.co.uk
Steven O'Connell	Marine Scotland	Scotland	Steven.O'connell@gov.scot

Susan Mærsk Lusseau	DTU-Aqua	Denmark	smalu@aqua.dtu.dk
Urbano Autón	IEO (Spanish Institute of Oceanography)	Spain	urbano.auton@ieo.es

WGIPS 2020 participants (Bergen, Norway)

Name	Institute	Country (of institute)	Email
Bram Couperus (Chair)	Wageningen Marine Research	Netherlands	bram.couperus@wur.nl
Michael O´Malley (Chair)	Marine Institute	Ireland	michael.omalley@marine.ie
Åge Høines	Institute of Marine Research	Norway	aageh@hi.no
Alexander Krysov	Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO)	Russia	a_krysov@pinro.ru
Are Salthaug	Institute of Marine Research	Norway	are.salthaug@hi.no
Cecilie Kvamme	Institute of Marine Research	Norway	cecilie.kvamme@hi.no
Ciaran O´Donnell	Marine Institute	Ireland	Ciaran.odonnell@marine.ie
Erling Kåre Stenevik	Institute of Marine Research	Norway	erling.stenevik@hi.no
Espen Johnsen	Institute of Marine Research	Norway	espen.johnsen@hi.no
Florian Berg	Institute of Marine Research	Norway	florian.berg@hi.no
Gavin McNeill	Agri-food and Biosciences Institute	Northern Ireland	gavin.mcneill@afbini.gov.uk
Hjalte Parner	ICES	Denmark	hjalte.parner@ices.dk
Isidora Katara	Centre for Environment, Fisheries and Aquaculture Science	England, UK	isidora.katara@cefas.co.uk
Jan Arge Jacobsen	Faroe Marine Research Institute	Faroe Islands	janarge@hav.fo
Jeroen van der Kooij	Centre for Environment, Fisheries and Aquaculture Science	England, UK	jeroen.vanderkooij@cefas.co.uk

Karl-Johan Staehr	DTU Aqua – National Institute of Aquatic Resources	Denmark	kjs@aqua.dtu.dk
Leif Nøttestad	Institute of Marine Research	Norway	leif.noettestad@hi.no
Leon Smith	Faroe Marine Research Institute	Faroe Islands	leonsmit@hav.fo
Matthias Schaber	Thünen Institute of Sea Fisheries	Germany	matthias.schaber@thuenen.de
Pablo Carrera	IEO (Spanish Institute of Oceanography)	Spain	pablo.carrera@ieo.es
Sindre Vatnehol	Institute of Marine Research	Norway	sindre.vatnehol@hi.no
Steven Mackinson	Scottish Pelagic Fishermen's Association	Scotland	steve.mackinson@scottishpelagic.co.uk
Steven O'Connell	Marine Scotland	Scotland	Steven.O'connell@gov.scot
Susan Mærsk Lusseau	Marine Scotland Science	Scotland	S.Lusseau@marlab.ac.uk
Urbano Autón	IEO (Spanish Institute of Oceanography)	Spain	urbano.auton@ieo.es

WGIPS 2019 participants (Santa Cruz, Tenerife, Spain)

Name	Institute	Country (of institute)	Email
Bram Couperus (Chair)	Wageningen Marine Research	Netherlands	bram.couperus@wur.nl
Michael O´Malley (Chair)	Marine Institute	Ireland	michael.omalley@marine.ie
Åge Høines	Institute of Marine Research	Norway	aageh@hi.no
Cecilie Kvamme	Institute of Marine Research	Norway	cecilie.kvamme@hi.no
Ciaran O´Donnell	Marine Institute	Ireland	Ciaran.odonnell@marine.ie
Gavin McNeill	Agri-food and Biosciences Institute	Northern Ireland	gavin.mcneill@afbini.gov.uk
Hjálmar Hátún	Faroe Marine Research Institute	Faroe Islands	hjalmarh@hav.fo
Hjalte Parner	ICES	Denmark	hjalte.parner@ices.dk
Jan Arge Jacobsen	Faroe Marine Research Institute	Faroe Islands	janargehav.fo
Jeroen van der Kooij	Centre for Environment, Fisheries and Aquaculture Science	England, UK	jeroen.vanderkooij@cefas.co.uk
Karl-Johan Staehr	DTU Aqua – National Institute of Aquatic Resources	Denmark	kjs@aqua.dtu.dk

Leon Smith	Faroe Marine Research Institute	Faroe Islands	leonsmit@hav.fo
Mathieu Lundy	Agri-food and Biosciences Institute	Northern Ireland	Mathieu.Lundy@afbini.gov.uk
Matthias Schaber	Thünen Institute of Sea Fisheries	Germany	matthias.schaber@thuenen.de
Pablo Carrera	IEO (Spanish Institute of Oceanography)	Spain	pablo.carrera@ieo.es
Serdar Sakinan	Wageningen Marine Research	Netherlands	serdar.sakinan@wur.nl
Steven Mackinson	Scottish Pelagic Fishermen's Association	Scotland	steve.mackinson@scottishpelagic.co.uk
Steven O'Connell	Marine Scotland	Scotland	Steven.O'connell@gov.scot
Susan Mærsk Lusseau	Marine Scotland Science	Scotland	S.Lusseau@marlab.ac.uk
Urbano Autón	IEO (Spanish Institute of Oceanography)	Spain	urbano.auton@ieo.es

Annex 2: Resolutions

Draft resolution for new ToRs for WGIPS 2022-24 has been submitted to ICES for approval.

Annex 3: 2020 IBWSS Survey Summary Table and Survey Report

The IBWSS (annex 3) surveys did not take place in 2020 due to the global COVID pandemic, therefore there is no annex 3 in this report.

Annex 4: 2020 IESNS Survey Summary Table and Survey Report

Document 4a: IESNS 2020 survey summary table

Survey Summary table WGIPS 2021	
Name of the survey (abbreviation):	International Ecosystem Survey in the Nordic Seas (IESNS)
Target Species:	Norwegian spring-spawning herring
Survey dates:	29 April – 2 July
Summary:	
Survey effort, timing and area coverage in 2020 were comparable to previous years in the Nordic Seas. However, due to engine problems of the Russian vessel the Barents Sea was not covered. The zero-line of the distribution of the adult herring was considered to be fully reached in the Nordic Seas, although high concentrations were observed at the easternmost part of the area. One of the vessels steaming towards the Norwegian coast obsereved no herring east of the transect. However, the juveniles in the Barents Sea was not covered in 2020. It is recommended that the results from IESNS 2020 can be used for assessment purpose for the Nordic Seas coverage of the adult herring. As in previous years the size and age of herring were found to increase towards west and south in the Norwegian Sea. Correspondingly, it was mainly older herring that appeared in the southwestern areas, while relatively high concentrations of herring of the 2016 year-class were obseverd in the easternmost part of the survey. The total estimate of herring in the Norwegian Sea from the 2020 survey was 22.8 billion in numbers and the biomass 4.25 million tonnes. This estimate is 13 % decrease from the 2019 survey estimate in biomass and a 15% increase in numbers. The biomass estimate decreased from 2009 to 2012, and has since then been rather stable at 4.2 to 5.9 million tonnes, with the lowest abundance occurring in 2017. Four year old herring (year class 2016) dominated both in terms of number and biomass. Its number at age 4 is at the same level as the 2004 year class at same age.	
	Description
Survey design	Stratified systematic parallel transects design with randomised starting point of the southernmost transect within each strata.
Index Calculation method	StoX (via the PGNAPES database)

Random/systematic error issues	N/A
Specific survey error issues (acoustic)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Bubble sweep down	No problems due to bad weather for acoustic recordings
Extinction (shadowing)	N/A
Blind zone	Upper 8-12 m not covered by acoustics.
Dead zone	N/A
Allocation of backscatter to species	Standard TS for herring and blue whiting
Target strength	Blue whiting: TS = 20 log(L) – 65.2 dB (ICES 2012) Herring: TS = 20.0 log(L) – 71.9 dB
Calibration	OK
Specific survey error issues (biological)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Stock containment	Time series: Considered to have covered the adult stock adequately 2020 survey: the entire adult stock during its migration on the feeding grounds, the adults in the Nordic Seas. The juveniles in the Barents Sea were not covered in 2020.
Stock ID and mixing issues	Yes, some mixing of herring might have occurred in some of the fringe regions: in the Southeastern Icelandic zone some Icelandic summer spawners are probably included in the NSSH estimate. In the southers part of the surey area some herring of the autumn spawning type is probably included in the NSSH estimate. However, these mixing issues are not regareded as serious sources of bias. The problem of herring stock ID is currently being working on and analyses of otholith shape seems lika a promising method.
Measures of uncertainty (CV)	The estimated survey uncertainty for the main age groups in the sestimate was around 0.25
Biological sampling	Sampling was considered representative and the sampling levels as adequate.

	In the recent years there have been concerns regarding age reading of herring, because the age distributions from the different participants have showed differences within the same strata. A scale and otolith exchange are proposed, where scales and otoliths for the same fish have been sampled. On basis of that work, a workshop will be planned..
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole times series or for individual years? (please specify)	No concerns were raised (in addition to those discussed above) regarding the fitness of the survey for use in the assessment.
Did the Survey Summary Table contain adequate information to allow for evaluation of the quality of the survey for use in assessment? Please identify shortfalls	The survey summary table contained adequate information to allow for evaluation of the quality of the survey for use in assessment.

Document 4b: IESNS 2020 survey report

Please see the report on the next page.

IESNS post-cruise meeting, webex 16-18/6 2020

Working Document to

Working Group on International Pelagic Surveys (WGIPS)
Belfast, 18 - 22 January 2021
and
Working Group on Widely Distributed Stocks (WGWIDE)
Copenhagen, 26 August - 1 September 2020

INTERNATIONAL ECOSYSTEM SURVEY IN NORDIC SEA (IESNS) in May – June 2020

Post-cruise meeting on Teams, 16-18 June 2020

Are Salthaug[1], Erling Kåre Stenevik[1], Sindre Vatnehol[1], Åge Høines[1], Valantine Anthonypillai[1], Kjell Arne Mork[1], Cecilie Thorsen Broms[1], Øystein Skagseth[1]
RV G.O. Sars

Kai Wieland[2], Karl-Johan Stæhr[2], Susan Mærsk Lusseau[2], Benoit Berges[3]
RV Dana

Sigurvin Bjarnason[4], Anna Heiða Ólafsdóttir[4]
RV Árni Friðriksson

Sólvá Káradóttir Eliasen[5], Jan Arge Jacobsen[5], Leon Smith[5]
RV Magnus Heinason

[1] Institute of Marine Research, Bergen, Norway
[2] DTU-Aqua, Denmark
[3] Wageningen Marine Research, IJmuiden, The Netherlands
[4] Marine and Freshwater Research Institute, Hafnarfjordur, Iceland
[5] Faroese Marine Research Institute, Tórshavn, Faroe Islands

Introduction

In May-June 2020, four research vessels; R/V Dana, Denmark (joined survey by Denmark, Germany, Ireland, The Netherlands, Sweden and UK. Due to the Covid19 situation in 2020 there was only participation from Denmark in the actual cruise), R/V Magnus Heinason, Faroe Islands, R/V Árni Friðriksson, Iceland and R/V G.O. Sars, Norway participated in the International ecosystem survey in the Nordic Seas (IESNS). The aim of the survey was to cover the whole distribution area of the Norwegian Spring-spawning herring with the objective of estimating the total biomass of the herring stock, in addition to collect data on plankton and hydrographical conditions in the area. The survey was initiated by the Faroes, Iceland, Norway and Russia in 1995. Since 1997 also the EU participated (except 2002 and 2003) and from 2004 onwards it was more integrated into an ecosystem survey. This report represents analyses of data from this International survey in 2020 that are stored in the PGNAPES database and supported by national survey reports from each survey (Dana: Cruise Report R/V Dana Cruise 04/2020. International Ecosystem survey in the Nordic Seas (IESNS) in 2020, Magnus Heinason: IESNS Cruise Report Magnus Heinasen, Eliasen et al, FAMRI 2020, Árni Friðriksson: Óskarsson et al. 2019).

As previous years, it was planned that Russia would cover the Barents Sea. However, due to technical issues with the research vessel, Russia was not able to conduct the survey and thus no IESNS estimates from this area exist for 2020.

Material and methods

Coordination of the survey was done during the WGIPS meeting in January 2020 and by correspondence. Planning of the acoustic transects and hydrographic stations and plankton stations were carried out by using the recently developed survey planner function in the r-package Rstox version 1.11 (see www.imr.no/forskning/prosjekter/stox). The survey planner function generates the survey plan (transect lines) in a cartesian coordinate system, and transforms the positions to the geographical coordinate system (longitude, latitude) using the azimuthal equal distance projection, which ensures that distances, and also equal coverage, if the method used is designed with this prerequisite, are preserved in the transformation. Figure 1 shows the planned acoustic transects and hydrographic and plankton stations in each stratum. Only parallel transects were used this year, however, the transects now follow great circles instead of a constant latitude as before, so they appear bended in a Mercator projection. The participating vessels together with their effective survey periods are listed in the table below:

Vessel	Institute	Survey period
Dana	DTU Aqua - National Institute of Natural Resources, Denmark	01/5-25/5
G.O. Sars	Institute of Marine Research, Bergen, Norway	01/5-02/6
Magnus Heinason	Faroe Marine Research Institute, Faroe Islands	29/4- 11/5
Árni Friðriksson	Marine and Freshwater Research Institute, Iceland	10/5-28/5

Figure 2 shows the cruise tracks, Figure 3a the hydrographic and plankton stations and Figure 3b the pelagic trawl stations. Survey effort by each vessel is detailed in Table 1. Frequent contacts were maintained between the vessels during the course of the survey, primarily through electronic mail. The temporal progression of the survey is shown in Figure 4.

In general, the weather condition did not affect the survey even if there were some days that were not favourable and prevented for example WP2 and Multinet sampling at some stations. The survey was based on scientific echosounders using 38 kHz frequency. Transducers were calibrated with the standard sphere calibration (Foote *et al*., 1987) prior to the survey. Salient acoustic settings are summarized in the text table below.

Acoustic instruments and settings for the primary frequency (boldface).

	Dana	G.O. Sars	Arni Friðriksson	Magnus Heinason
Echo sounder	Simrad EK 60	Simrad EK 80	Simrad EK80	Simrad EK60
Frequency (kHz)	**38**	**38**, 18, 70, 120, 200, 333	**38**, 18, 70, 120, 200	**38**,200
Primary transducer	ES38BP	ES 38B	ES38-7	ES38B
Transducer installation	Towed body	Drop keel	Drop keel	Hull
Transducer depth (m)	5 - 7	8.5	8	3
Upper integration limit (m)	7 - 9	15	15	7
Absorption coeff. (dB/km)	10.1	10.1	10	10.1
Pulse length (ms)	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.43	?	2.425
Transmitter power (W)	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	18	21.9
2-way beam angle (dB)	-20.5	-20.7	-20.3	-20.8
Sv Transducer gain (dB)				
Ts Transducer gain (dB)	25.17	26.05	26.9	25.57
s_A correction (dB)	-0.50	-0.66	-0.02	-0.68
3 dB beam width (dg)				
alongship:	6.96	6.48	6.53	7.17
athw. ship:	6.98	6.22	6.5	7.06
Maximum range (m)	500	500	500	500
Post processing software	LSSS	LSSS	LSSS	LSSS

All participants used the same post-processing software (LSSS) and scrutinization was carried out according to an agreement at a PGNAPES scrutinizing workshop in Bergen in February 2009 (ICES 2009), and "Notes from acoustic Scrutinizing workshop in relation to the IESNS", Reykjavík 3.-5. March 2015 (Annex 4 in ICES 2015). Generally, acoustic recordings were scrutinized on daily basis and species 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. All vessels used a large or medium-sized pelagic trawl as the main tool for biological sampling. The salient properties of the trawls are as follows:

	Dana	G.O. Sars	Arni Friðriksson	Magnus Heinason
Circumference (m)		**496**	**832**	**640**
Vertical opening (m)	**25-35**	**25-30**	**20–35**	**45–55**
Mesh size in codend (mm)	**16**	**24**	**20**	**40**
Typical towing speed (kn)	**3.5-4.0**	**3.0–4.5**	**3.1–5.0**	**3.0–3.5**

Catches from trawl hauls were sorted and weighed; fish were identified to species level, when possible, and other taxa to higher taxonomic levels. A subsample of herring, blue whiting and mackerel were sexed, aged, and measured for length and weight, and their maturity status was estimated using established methods. An additional sample of fish was measured for length. For the Norwegian, Icelandic and Faroese vessel, a smaller subsample of stomachs was sampled for further analyses on land. Salient biological sampling protocols for trawl catches are listed in the table below.

	Species	Dana	G.O. Sars	Arni Friðriksson	Magnus Heinason
Length measurements	Herring	200-300	100	300	100-200
	Blue whiting	200-300	100	50	100-200
	Mackerel	100-200	100	50	100-200
	Other fish sp.	100	30	30	30
Weighed, sexed and maturity determination	Herring	50	25-100	100	50-100
	Blue whiting	50	25-100	50	50-100
	Mackerel	0	25-100	50	50-100
	Other fish sp.	0	0	0	30*
Otoliths/scales collected	Herring	50	25-30	100	50-100
	Blue whiting	50	25-30	50	50-100
	Mackerel	0	25-30	50	50-100
	Other fish sp.	0	0	0	0
Stomach sampling	Herring	0	10	10	5-10
	Blue whiting	0	10	10	5-10
	Mackerel	0	10	10	5-10
	Other fish sp.	0	0	0	0

* Only weighed, not sexed or determination of maturity.

** Will be included in the final report

Acoustic 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. Estimation of abundance from acoustic surveys with StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990). This method requires pre-defined strata, and the survey area was therefore split into 6 strata with pre-defined acoustic transects as agreed during the WGIPS in January 2019. Within each stratum, parallel transects with equal distances were used. The distance between transects was based on available survey time, and the starting point of the first transect in each stratum was randomized. This approach allows for robust statistical analyses of uncertainty of the acoustic estimates. The strata and transects used in StoX are shown in Figure 1. All trawl stations within a given stratum with catches of the target species (either blue whiting or herring) were assigned to all transects within the stratum, and the length distributions were weighted equally within the stratum. The following target strength (TS)-to-fish length (L) relationships were used:

Blue whiting: TS = 20 log(L) – 65.2 dB (ICES 2012)

Herring: TS = 20.0 log(L) – 71.9 dB

The target strength for herring is the traditionally one used while this target strength for blue whiting was first applied in 2012 (ICES 2012).

The hydrographical and plankton stations by survey are shown in Figure 3a. Most vessels collected hydrographical data using a SBE 911 CTD. Maximum sampling depth was 1000 m. Zooplankton was sampled by a WPII on all vessels, according to the standard procedure for the surveys. Mesh sizes were 180 or 200 µm. The net was hauled vertically from 200 m to the surface or from the bottom whenever bottom depth was less than 200 m. All samples were split in two and one half was preserved in formalin while the other half was dried and weighed. The samples for dry weight were size fractionated before drying by sieving the samples through 2000 µm and 1000 µm sieves, giving the size fractions 180/200 – 1000 µm, 1000 – 2000 µm, and > 2000 µm. Data are presented as g total dry weight per m^2. For the zooplankton distribution map, all stations are presented. For the time series, stations in the Norwegian Sea delimited to east of 14°W and west of 20°E have been included. The zooplankton data were interpolated using objective analysis utilizing a Gaussian correlation function to obtain a time-series for four different areas. The results are given as inter-annual indexes of zooplankton abundance in May. This method was introduced at WGINOR in 2015 (ICES, 2016) and the results match the former used average index.

Results and Discussion

Hydrography

The temperature distributions in the ocean, averaged over selected depth intervals; 0-50 m, 50-200 m, and 200-500 m, are shown in Figures 5-7. The temperatures in the surface layer (0-50 m) ranged from below 0°C in the Greenland Sea to 9°C in the southern part of the Norwegian Sea (Figure 5). The Arctic front was encountered below 65°N east of Iceland extending eastwards towards about 2° West where it turned northeastwards to 65°N and then almost straight northwards. This front was well-defined at 200-500 m depth while shallower it was unclear. Further to west at about 8° West another front runs northward to Jan Mayen, the Jan Mayen Front that was most distinct in the upper 200 m. The warmer North Atlantic water formed a broad tongue that stretched far northwards along the Norwegian coast with temperatures >6 °C to the Bear Island at 74,5° N in the surface layer.

Relative to a 25 years long-term mean, from 1995 to 2019, the temperatures at 0-50 m were 0-1 °C below the mean for almost the whole Norwegian Sea (Figure 5). Warmest region is in the eastern Greenland Sea with temperatures 2 °C higher than the mean. This warming can be observed at all depths. At 50-200 m the temperatures were also, in most regions, 0-1 °C lower than the long-term mean. An exception is for the southwestern Norwegian Sea, west of the 0 meridian, where the temperatures were about 0-0,5 °C higher than the mean (Figure 6). At 200-500 m depth, the pattern is more fragmented but in the southwestern region the temperatures were near the long-term mean while in more eastern areas the temperatures were in general lower than the mean (Figure 7).

The temperature, salinity and potential density in the upper 800 m at the Svinøy section in 26-28 April 2020 are shown in Figure 8. Atlantic water is lying over the colder and fresher intermediate layer and reach down to 500 m at the shelf edge and shallower westward. The warmest water, above 8 °C, is located near the shelf edge where the core of the inflowing Atlantic Water is located. Westward, temperature and salinity are reduced due to mixing with colder and less saline water. Compared to a 30 years long-term mean, from 1978 to 2007, the temperatures in 2020 were higher than the mean at the shelf edge but westward the temperatures were both lower and higher than the mean due to meandering or eddies. The salinity was however lower than the long-term mean for the whole section above 400 m with the exception in coastal water.

Two main features of the circulation in the Norwegian Sea, where the herring stock is grazing, are the Norwegian Atlantic Current (NWAC) and the East Icelandic Current (EIC). The NWAC with its offshoots forms the northern limb of the North Atlantic current system and carries relatively warm and salty water from the North Atlantic into the Nordic Seas. The EIC, on the other hand, carries Arctic waters. To a large extent this water derives from the East Greenland Current, but to a varying extent, some of its waters may also have been formed in the Iceland and Greenland Seas. The EIC flows into the southwestern Norwegian Sea where its waters subduct under the Atlantic waters to form an intermediate Arctic layer. While such a layer has long been known in the area north of the Faroes and in the Faroe-Shetland Channel, it is only in the last three decades that a similar layer has been observed all over the Norwegian Sea.

This circulation pattern creates a water mass structure with warm Atlantic Water in the eastern part of the area and more Arctic conditions in the western part. The NWAC is rather narrow in the southern Norwegian Sea, but when meeting the Vøring Plateau off Mid Norway it is deflected westward. The western branch of the NWAC reaches the area of Jan Mayen at about 71°N. Further northward in the Lofoten Basin the lateral extent of the Atlantic water gradually narrows again, apparently under topographic influence of the mid-ocean ridge. It has been shown that atmospheric forcing largely controls the distribution of the water masses in the Nordic Seas. Hence, the lateral extent of the NWAC, and consequently the position of the Arctic Front, that separates the warm North Atlantic waters from the cold Arctic waters, is correlated with the large-scale distribution of the atmospheric sea level pressure. The local air-sea heat flux in addition influence the upper layer and it is found that it can explain about half of the year to year variability of the ocean heat content in the Norwegian Sea.

Zooplankton

The zooplankton biomass (g dry weight m^{-2}) in the upper 200 m is shown in Figure 9. Sampling stations were evenly spread over the area, covering Atlantic water, Arctic water, and the Arctic frontal zone. The highest zooplankton biomasses were not concentrated in a specific area but spread over several locations in the northern part of the sampling area. High biomasses were found in northwestern parts of the central Norwegian Sea, northeast of Iceland and Jan Mayen, and in an area around Lofoten/Vesterålen and north of that area. Lower biomasses were found in the entire southern part of the sampling area, especially in southwest.

Figure 10 shows the zooplankton index given for the sampling area (delimited to east of 14°W and west of 20°E). To examine regional difference in the biomass, the total area where divided into 4 subareas 1) Southern Norwegian Sea including the Norwegian Sea Basin, 2) The Northern Norwegian Sea including the Lofoten Basin, 3) Jan Mayen Arctic front, and 4) East of Iceland. The mean index of subarea 1 and 2 is also given. The zooplankton biomass index for the Norwegian Sea and nearby areas in 2020 was 8.3 g dry weight m^{-2}, which is a decrease from last year. A similar decrease was observed in all sub-areas, except from East of Iceland where an increase was observed.

The zooplankton biomass index for the Norwegian Sea in May has been estimated since 1995. For the period 1995-2002 the plankton index was relatively high (mean 11.5 g) even if varying between years. From 2003-2006, the index decreased continuously and has been at lower levels since then, with a mean of 7.9 g for the period 2003-2020. An increase can be noted in the last part of the low-biomass period. This general pattern applies more or less to all the different sub-areas within the Norwegian Sea. The zooplankton biomass at the Jan Mayen Arctic front was high until 2007 but has since then been at the same level as the Norwegian Sea. The zooplankton biomass East of Iceland was in general higher compared with the other sub-areas until 2015.

The reason for this fluctuation in the zooplankton biomass is not obvious to us. The unusually high biomass of pelagic fish feeding on zooplankton has been suggested to be one of the main causes for the reduction in zooplankton biomass. However, carnivorous zooplankton and not pelagic fish are the main predators of zooplankton in the Norwegian Sea (Skjoldal *et al.*, 2004), and we do not have good data on the development of the carnivorous zooplankton stocks. Timing effects, as match/mismatch with the phytoplankton bloom, can also affect the zooplankton abundance. It is also worth noting that the period with lower zooplankton biomass coincides with lower-than-average heat contents in the Norwegian Sea (ICES 2018) and reduced inflow of Arctic water into the southwestern Norwegian Sea (Kristiansen et al., 2019). More ecological and environmental research to reveal inter-annual variations and long-term trends in zooplankton abundance are recommended.

Norwegian spring-spawning herring

Survey coverage in the Norwegian Sea was considered adequate in 2020. The zero-line was believed to be reached for adult NSS herring in most of the areas. On some of the transects in stratum 2 and 4, however, aggregations of herring were recorded on the easternmost part indicating that the zero-line was not fully reached on those transect although some of the transect were extended. It is, however, recommended that the results from IESNS 2020 can be used for assessment purpose. The herring was primarily distributed in the south-western area where the 2013-year-class dominated, and in the eastern area where the 2016 year-class dominated (Figure 11). It is a commonly observed pattern that the older fish are distributed in the southwest while the younger fish are found closer to the nursery areas in the Barents Sea (Figure 12). The distribution of the recruiting 2016 year-class in the eastern part of the Norwegian Sea extends all the way from 70°N south to 64°N. This is different from earlier year-classes recruiting to the Norwegian Sea, which usually do not extend farther south than 69°N.

Four years old herring (year class 2016) dominated both in terms of number (57%) and biomass (41 %) on basis of the StoX baseline estimates for the Norwegian Sea (Tables 2-4). Its number at age 4 is higher than for the 2004 year class at same age (Figure 13), which puts the size of the 2016 year class into perspective. The large 2004 year class, which has dominated the stock together with the 2002 year class, has contributed significantly to the biomass of older age-groups (see paragraph on issues with age determination below). Herring aged 12-18 years old thus comprised 11% of the numbers and 19% of the biomass. Uncertainty estimates for number at age based on bootstrapping within StoX are shown in Figure 14 and Table 5. The relative standard error (CV) of the total biomass estimate is 15 % and 12 % for the total numbers estimate, and the relative standard error for the dominating age groups is around 30 % (Figure 14 and Table 5).

The total estimate of herring in the Norwegian Sea from the 2020 survey was 22.8 billion in number and the biomass was 4.25 million tonnes. The biomass estimate is 0.62 million tonnes (13 %) lower than the 2019 survey estimate while the estimated number is 15 % higher in 2020. The biomass estimate decreased significantly from 2009 to 2012, and has since then been rather stable at 4.2 to 5.9 million tonnes with similar confidence interval (Figure 15), with the lowest abundance occurring in 2017. Although there is only little change in total abundance and biomass, there is a gradual shift in age and size composition with the 2016 year class becoming more dominant than the older year classes.

In the last 5 years, there have been concerns regarding age reading of herring, because the age distributions from the different participants have showed differences – particularly older specimens appear to have uncertain ages. A scale and otolith exchange has been ongoing for some period, where scales and otoliths for the same fish have been sampled. On basis of that work, a workshop was planned in the spring 2018 to discuss the results. This workshop was postponed indeterminately. The survey group emphasizes the necessity of having this workshop before next year's survey takes place.

With respect to age-reading concerns in the recent years, the comparison between the nations in this year's survey could not been done fully since restrictions on the cruise tracks due to COVID-19 prevented the Norwegian vessel to enter stratum 1 and 3. However, in stratum 2 and 4 there was overlap between the Norwegian vessel and the Danish vessel and the age distributions from those strata seems to be relatively similar between the two vessels (Figure 20).

In the IESNS survey in 2020 some differences regarding the acoustic scrutinizing between neighbouring vessels were observed and discussed. The data where re-scruitinized, and there was a better agreement between the vessel. Still, the difference between the original and the re-scrutinization where small, indicating that the difference where not caused by an scrutinization error. There is a need to further discuss the scrutinizing process before next year's survey. The survey group suggest to have a meeting before next year's survey to discuss the protocol for acoustic scrutinizing in the IESNS survey.

Recently concerns have been raised by the survey groups for the International ecosystem surveys in the Nordic Seas (IESNS and IESSNS) on mixing issues between Norwegian spring-spawning herring and other herring stocks (e.g. Icelandic summer-spawning, Faroese autumn-spawning, Norwegian summer-spawning and North Sea type autumn-spawning herring) occurring in some of the fringe regions in the Norwegian Sea. Until now, fixed cut lines have been used by the survey group to exclude herring of presumed other types than NSS herring, however this simple procedure is thought to introduce some contamination of the stock indices of the target NSS herring.

In the IESNS 2020 survey, all herring in the Stratum 1 was allocated to NSSH, although the southernmost transect east of the Faroes (Figure 11) contained mainly autumn-spawning type herring, probably local Faroese autumn-spawners or North Sea type autumn-spawners. WGIPS noted in their 2019 report that the separation of different herring stock components is an issue in several of the surveys coordinated in WGIPS and the needs for development of standardized stock splitting methods was also noted in the WKSIDAC (ICES 2017).

Blue whiting

The spatial distribution of blue whiting in 2020 was similar to the years before, with the highest abundance estimates in the southern and eastern part of the Norwegian Sea, along the Norwegian continental slope. The main concentrations were observed in connections with the continental slopes of Norway and along the Scotland – Iceland ridge (Figure 16). Blue whiting was distributed similar as last year. The largest fish were found in the western and middle part of the survey area (Figure 17). It should be noted that the spatial survey design was not intended to cover the whole blue whiting stock during this period.

The total biomass index of blue whiting registered during the IESNS survey in 2020 was 0.39 million tonnes, which is a 26 % decrease from the biomass estimate in 2019 (0.53). The abundance index for 2020 was 4.9 billion, which is 21 % lower than in 2019. Age 1 is dominating the acoustic estimate (32.5 % of the biomass and 57% by number). Uncertainty estimates for numbers at age based on bootstrapping with StoX are shown in Figure 18 and Table 6. The relative standard error (CV) of total biomass estimate is 16 % and 17 % for total numbers (Table 6).

In this year's IESNS survey, one-year old blue whiting was at similar level as the estimate of one-year olds in 2019 and more numerous as compared to IESNS 2017 and 2018. The survey group compared age and length distributions by vessel and strata (Figure 20 and 21) and no clear differences were found compared to earlier years.

This year the blue whiting estimate was based on only three of the four vessels. Staffing constraints on Dana due to the Covid-19 situation meant that the survey data was scrutinised after the survey ended rather than during the cruise. This resulted in some discrepancy in the procedure used for scrutinization of blue whiting from Dana. Visual observation of significant inconsistencies between the neighbouring transects of Dana and G. O. Sars lead the survey group to decide to omit the acoustic data from Dana this year. This resulted in a higher total estimate of blue whiting (~21%) but also higher uncertainty. The biological information from Dana was still used.

Mackerel

Trawl catches of mackerel are shown in Figure 22 Mackerel was present in the southern and eastern part of the Norwegian Sea (up to 69°N) in the beginning of May. No further quantitative information can be drawn from these data as this survey is not designed to monitor mackerel.

General recommendations and comments

Recommendation	Adressed to
1. Continue the methodological research in distinguishing between Herring and blue whiting in the interpretation of echograms.	WGIPS
2. It is recommended that a workshop based on the ongoing otolith and scale exchange will take place before next year's IESNS survey.	WGBIOP, WGWIDE
3. It is recommended that the WGIPS meeting in 2021 includes a workshop on how to deal with stock components of herring in the IESNS-survey.	WGIPS
4. It is recommended that the WGIPS meeting in 2021 discusses the possible implementation of sonar observations in IESNS and other acoustic surveys.	WGIPS

Next year's post-cruise meeting

We will aim for next meeting in 15-17 June 2021. The final decision will be made at the next WGIPS meeting.

Concluding remarks

- The sea temperature in 2020 at 0-200 m depth was generally below the long-term mean (1995-2019) in the Norwegian Sea.
- The 2020 index of meso-zooplankton biomass in the Norwegian Sea and adjoining waters decreased a bit from last year.
- The total biomass estimate of NSSH in herring in the Norwegian Sea was 4.25 million tonnes, which is a 13 % decrease from the 2019 survey estimate. The estimate of total number of NSSH was 22.8 billion, which is a 15 % higher than in the 2019 survey. The survey followed the pre-planned protocol and the survey group recommends using the abundance estimates in the analytical assessment.

- The 2016 year class of NSSH dominated in the survey indices both in numbers (57%) and biomass (41%), and it is on the same level as the strong 2004 year class at the same age (in the 2008 survey).
- The biomass of blue whiting measured in the 2020 survey decreased by 26 % from last year's survey and 21 % in terms of numbers. Age 1 (2019 year class) is the dominating year class (32.5 % of the biomass and 57% by number)

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Tables

Table 1. Survey effort by vessel for the International ecosystem survey in the Nordic Seas in May - June 2020.

Vessel	Effective survey period	Effective acoustic cruise track (nm)	Trawl stations	Ctd stations	Aged fish (HER)	Length fish (HER)	Plankton stations
Dana	01/05-25/05	1893	25	29	468	1866	34
Magnus Heinason	29/4-11/5	1319	15	22	394	775	22
Árni Fridriksson	12/5-26/5	3188	14	34	830	2758	30
G.O.Sars	01/5-02/6	3632	73	66	659	2065	60
Total		**10032**	**127**	**151**	**2351**	**7464**	**146**

Table 2. IESNS 2020 in the Norwegian Sea. Baseline estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring.

	age																				
LenGrp	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
14-15	15775	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15775	276.1	17.50
15-16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2379	2379	-	-
18-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8387	8387	385.8	46.00
20-21	20596	46719	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	67315	3942.2	58.56
21-22	-	42542	23662	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	66204	4583.0	69.23
22-23	-	124419	109173	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	233593	18657.3	79.87
23-24	-	63233	286786	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	350019	31906.0	91.16
24-25	-	63676	1122561	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1186237	118331.1	99.75
25-26	-	26921	2767160	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2794080	313130.6	112.07
26-27	-	24267	2575099	7327	-	30359	-	-	-	-	-	-	-	-	-	-	-	-	2637052	323632.1	122.72
27-28	-	96829	1389284	-	3530	24990	14119	-	-	3586	-	-	-	-	-	-	-	-	1532337	213322.6	139.21
28-29	-	5884	1927200	78548	47422	153158	41188	-	-	-	-	-	-	-	-	-	-	-	2253401	357169.5	158.50
29-30	-	-	1929251	84784	114419	415279	144971	45132	13717	-	9145	-	-	-	-	-	-	-	2756696	484901.5	175.90
30-31	-	-	731038	211152	282243	388372	287591	71245	39794	9036	8689	-	-	-	-	-	-	-	2029160	402964.2	198.59
31-32	-	-	89081	163380	260560	238699	50907	90121	78299	101878	27584	11822	-	-	-	-	-	-	1112330	248182.8	223.12
32-33	-	-	11658	22823	165992	404084	14312	30234	42153	49547	-	-	-	-	-	-	-	-	740803	179908.2	242.86
33-34	-	-	18429	2096	63689	517652	52388	40442	19271	2096	12573	-	-	-	-	-	-	-	728636	184875.2	253.73
34-35	-	-	9607	11823	64531	293609	125357	92216	28374	33103	7094	7094	4729	2365	9458	-	-	-	689359	193224.9	280.30
35-36	-	-	-	-	32093	81692	70022	164132	113785	163384	64187	140044	72939	35011	11670	-	-	-	948959	293187.8	308.96
36-37	-	-	-	-	-	25001	25001	44233	58296	211548	92913	180777	278740	115390	38463	17308	-	-	1087672	351837.7	323.48
37-38	-	-	-	-	-	-	2778	25002	27780	104176	57361	141679	255578	230576	137512	25002	-	-	1007445	340918.5	338.40
38-39	-	-	-	-	-	-	-	-	14787	11375	6825	44362	85311	109198	101236	32987	11375	-	417455	148142.6	354.87
39-40	-	-	-	-	-	-	-	-	-	-	-	19266	23799	-	36266	20400	5667	-	105398	39859.4	378.18
40-41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10205	10205	-	-
41-42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1136	1136	-	-
TSN(1000)	36371	494488	12989989	581932	1034479	2572896	828633	602757	436258	689729	286370	545043	721097	492539	334605	95697	17041	22107	22782032	-	-
TSB(1000 kg)	1471.2	47893.6	1755258.9	112070.0	232978.9	593613.9	192408.4	159723.7	119478.0	210165.6	90037.0	177472.5	238730.4	165718.0	116523.5	33343.8	6065.9	385.8	-	4253339.0	-
Mean length (cm)	17.81	23.76	26.86	30.19	31.15	31.50	31.37	33.21	33.68	34.82	35.10	36.18	36.60	36.83	37.25	37.59	38.33	29.75	-	-	-
Mean weight (g)	40.45	96.85	135.12	192.58	225.21	230.72	232.20	264.99	273.87	304.71	314.41	325.61	331.07	336.46	348.24	348.43	355.95	46.00	-	-	186.81

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Table 4. IESNS 2020 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of blue whiting.

LenGrp	age 1	2	3	4	5	6	7	8	10	Number (1E3)	Biomass (1E3kg)	Mean W (g)
16-17	3175	-	-	-	-	-	-	-	-	3175	69.8	22.00
17-18	56465	-	-	-	-	-	-	-	-	56465	1442.4	25.54
18-19	260128	-	-	-	-	-	-	-	-	260128	7978.6	30.67
19-20	895640	-	-	-	-	-	-	-	-	895640	33357.1	37.24
20-21	708352	39471	-	-	-	-	-	-	-	747823	33457.2	44.74
21-22	510440	49345	26468	-	-	-	-	-	-	586253	31207.9	53.23
22-23	267390	91340	18972	-	-	-	-	-	-	377703	23374.3	61.89
23-24	95144	105467	56782	-	-	-	-	-	-	257393	18312.6	71.15
24-25	24788	82626	122028	-	-	-	-	-	-	229442	19304.4	84.14
25-26	-	47957	171008	17439	10899	-	-	-	-	247304	23504.4	95.04
26-27	-	57515	154081	22617	19547	-	-	-	-	253760	26919.0	106.08
27-28	-	6822	31835	6822	9096	2656	11629	-	-	68860	8684.8	126.12
28-29	-	-	51237	24091	44665	79472	10325	9822	-	219613	32134.2	146.32
29-30	-	-	17933	73231	103619	39343	19603	-	-	253729	42296.7	166.70
30-31	-	-	30704	98407	120707	50174	27940	10235	-	338168	59325.9	175.43
31-32	-	-	-	13533	26074	45444	20141	-	-	105191	20992.3	199.56
32-33	-	-	-	-	17544	9029	2567	4695	-	33836	7113.2	210.23
33-34	-	-	-	-	-	2109	-	-	-	2109	493.6	234.00
34-35	-	-	-	-	-	-	-	-	-	-	-	-
36-37	-	-	-	-	-	-	-	-	382	382	113.9	298.20
TSN(1000)	2821522	480543	681050	256141	352152	228228	92204	24752	382	4936973	-	-
TSB(1000 kg)	126992.5	36024.1	68641.8	40862.5	57978.5	39223.4	16101.6	4143.9	113.9	-	390082.3	-
Mean length (cm)	20.09	23.27	25.44	28.95	29.36	29.55	29.59	29.63	36.00	-	-	-
Mean weight (g)	45.01	74.97	100.79	159.53	164.64	171.86	174.63	167.42	298.20	-	-	79.01

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Table 5. IESNS 2020. Bootstrap estimates from StoX (based on 1000 replicates) of Norwegian spring-spawning herring. Numbers by age and total number (TSN) are in millions and total biomass (TSB) in thousand tons.

Age	5th percentile	Median	95th percentile	Mean	SD	CV
2	9.0	40.0	85.4	42.7	24.0	0.563
3	245.8	466.7	714.2	471.9	144.8	0.307
4	10156.8	13067.0	16037.7	13064.5	1826.4	0.140
5	216.9	512.5	808.0	512.7	175.7	0.343
6	528.3	977.8	1585.3	1009.2	317.5	0.315
7	1543.8	2446.6	3602.0	2492.2	633.2	0.254
8	404.4	758.2	1262.3	786.4	263.5	0.335
9	340.3	615.7	965.8	629.4	196.7	0.313
10	219.4	418.0	684.5	433.8	144.0	0.332
11	357.6	678.3	1071.4	694.2	223.6	0.322
12	152.4	311.2	528.3	323.8	113.2	0.349
13	231.7	484.8	843.4	505.1	192.8	0.382
14	356.1	698.5	1166.3	725.6	257.6	0.355
15	228.9	466.9	777.6	483.0	177.6	0.368
16	118.5	292.8	543.5	307.8	133.3	0.433
17	30.7	92.0	175.7	96.6	46.1	0.477
18	0.0	12.7	34.3	14.4	11.1	0.768
Unknown	9.0	21.7	40.8	22.8	10.0	0.439
TSN	18020.8	22708.0	27299.3	22615.9	2795.2	0.124
TSB	3161.1	4206.4	5296.1	4209.9	638.3	0.152

Table 6. IESNS 2020. Bootstrap estimates from StoX (based on 1000 replicates) of blue whiting. Numbers by age and total number (TSN) are in millions and total biomass (TSB) in thousand tons.

Age	5th percentile	Median	95th percentile	Mean	SD	CV
1	1931.0	2777.9	3834.2	2817.2	597.2	0.21
2	319.1	486.1	701.5	492.9	119.6	0.24
3	448.1	667.5	955.3	680.6	156.6	0.23
4	123.3	245.7	398.3	251.6	82.9	0.33
5	174.2	339.8	539.6	345.1	113.0	0.33
6	133.6	235.2	349.8	237.8	68.1	0.29
7	46.4	88.1	151.7	92.3	32.1	0.35
8	7.0	23.0	42.0	23.4	10.5	0.45
10	0.0	0.4	1.3	0.4	0.3	0.81
TSN	3682.9	4928.6	6231.0	4942.5	777.7	0.16
TSB	283.6	391.1	497.5	388.8	64.3	0.17

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Figures

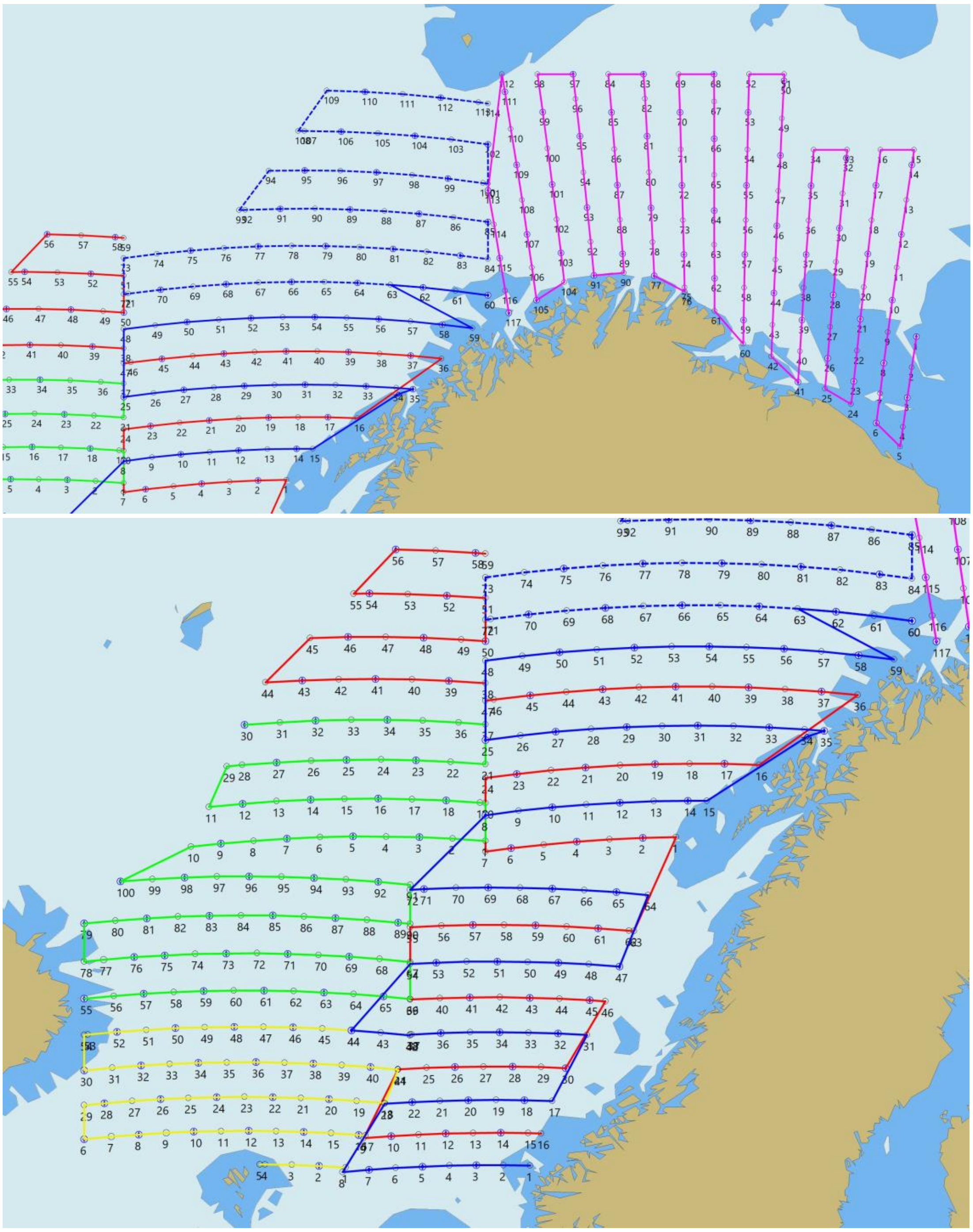

Figure 1. The pre-planned strata and transects for the IESNS survey in 2020 (red: EU, dark blue: Norway, yellow: Faroes Islands, violet: Russia, green: Iceland). Hydrographic stations and plankton stations are shown as blue circles with diamonds. All the transects have numbered waypoints for each 30 nautical mile and at the ends. **Note:** The Russian vessel was not able to conduct the survey planned in the Barents Sea.

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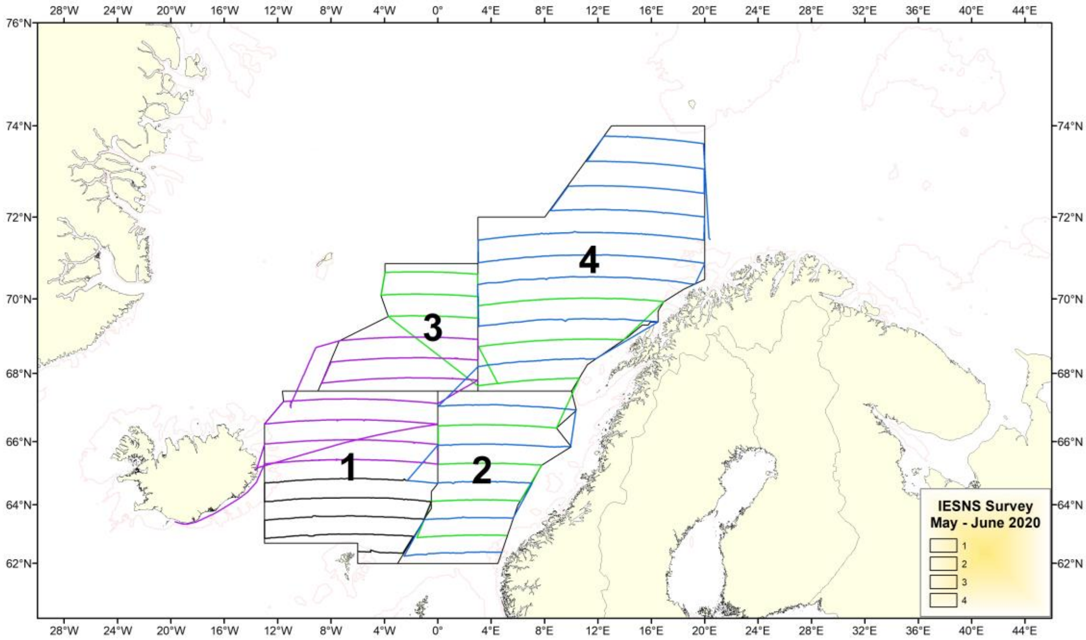

Figure 2. Cruise tracks and strata (with numbers) for the IESNS survey in May 2020.

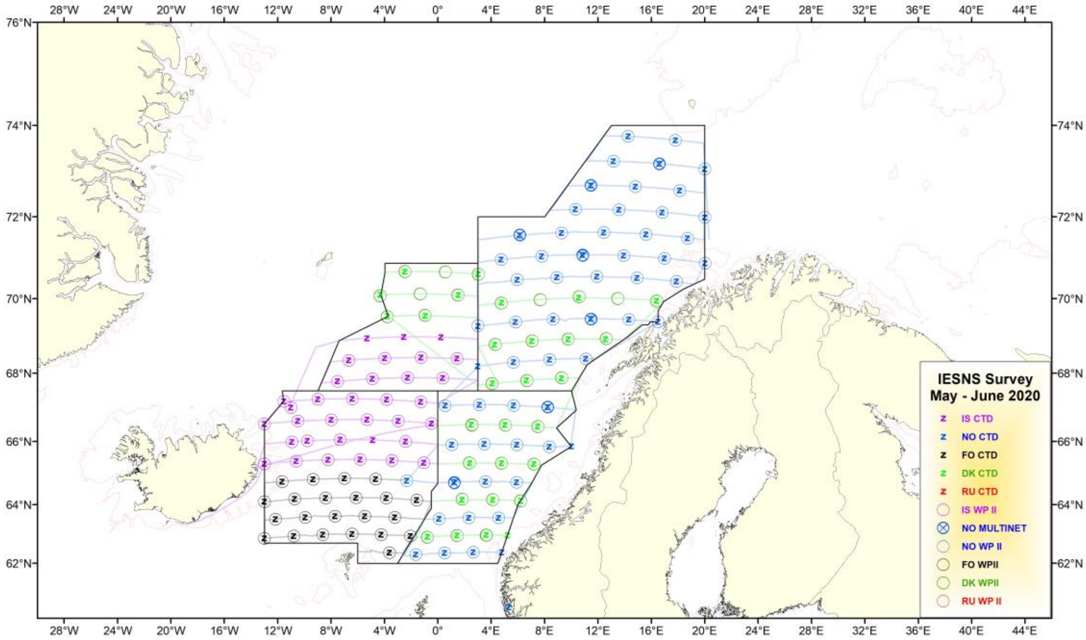

Figure 3a. IESNS survey in May 2020: location of hydrographic and plankton stations. The strata are shown.

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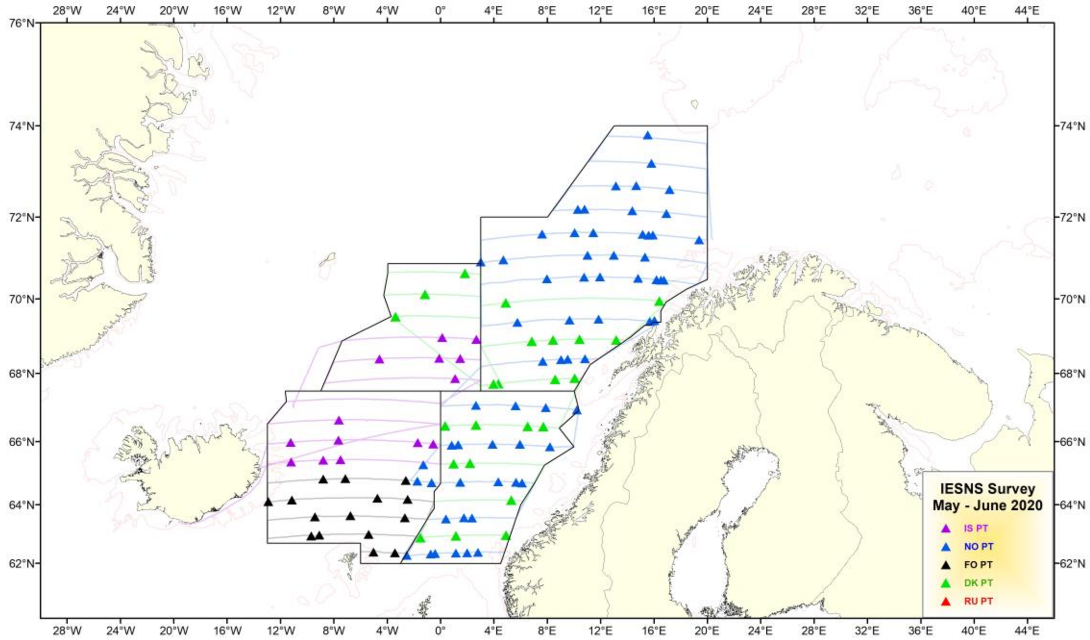

Figure 3b. IESNS survey in May 2020: location of pelagic trawl stations. The strata are shown.

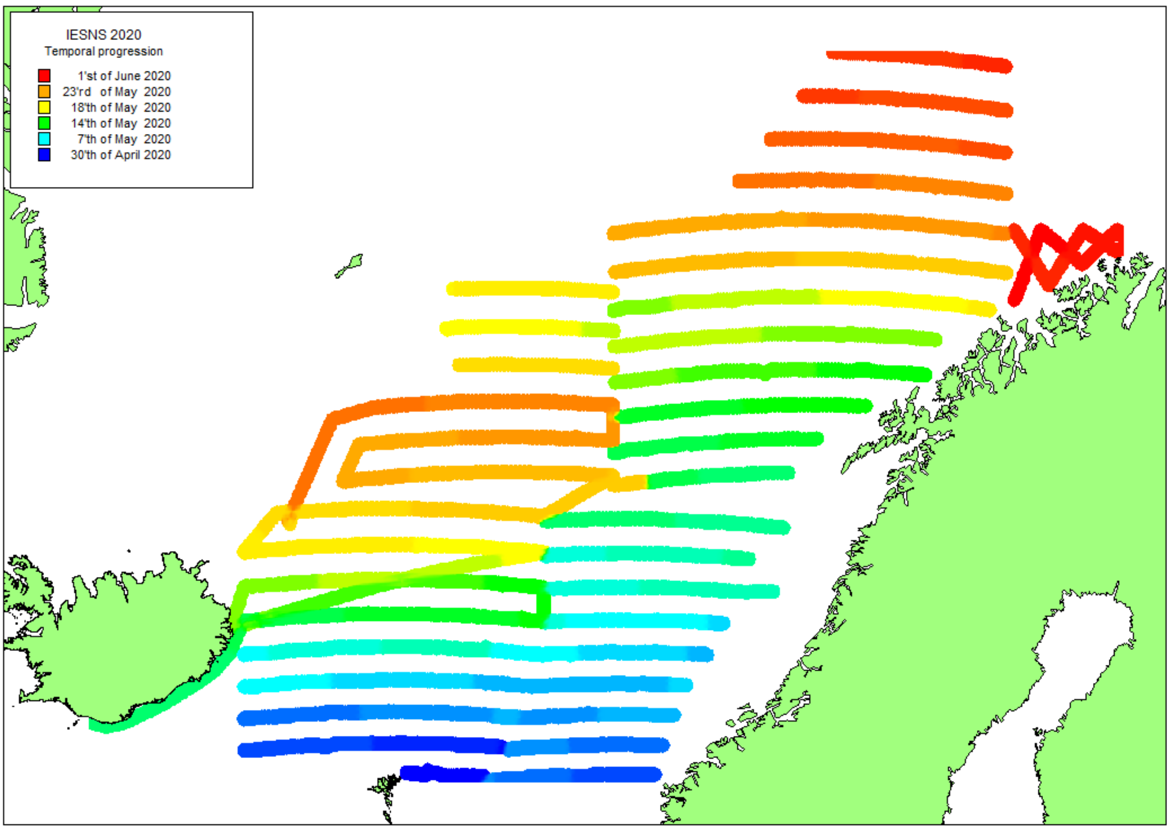

Figure 4. Temporal progression IESNS in May-June 2020.

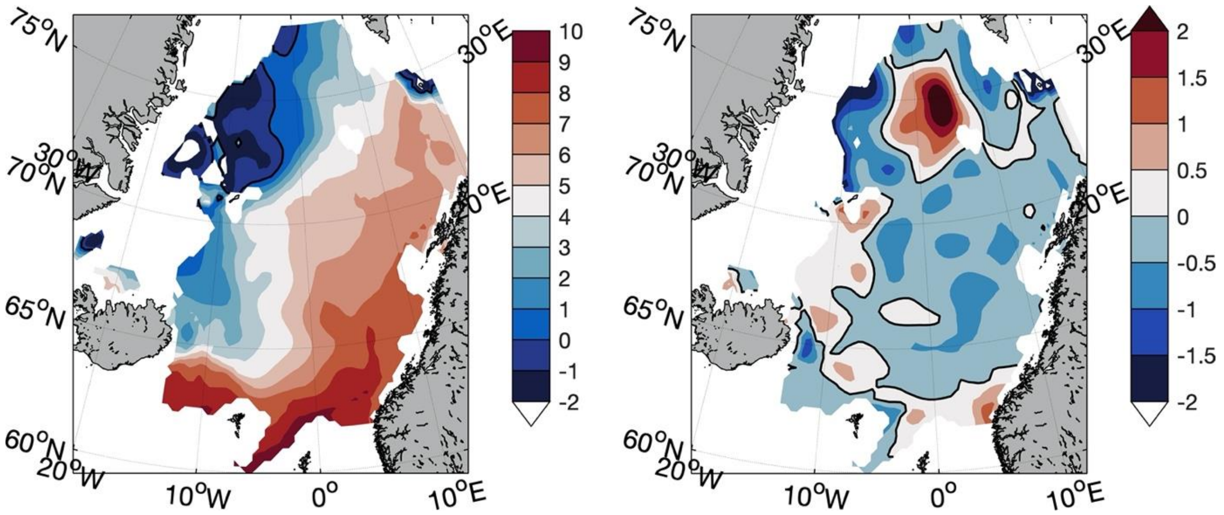

Figure 5. Temperature (left) and temperature anomaly (right) averaged over 0-50 m depth in May 2020. Anomaly is relative to the 1995-2019 mean.

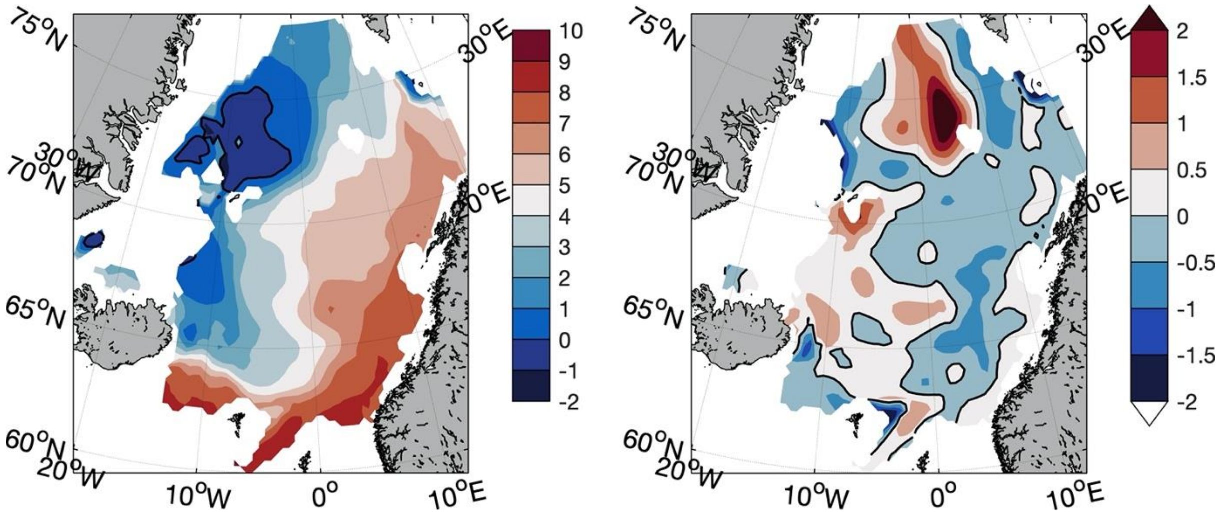

Figure 6. Same as above but averaged over 50-200 m depth.

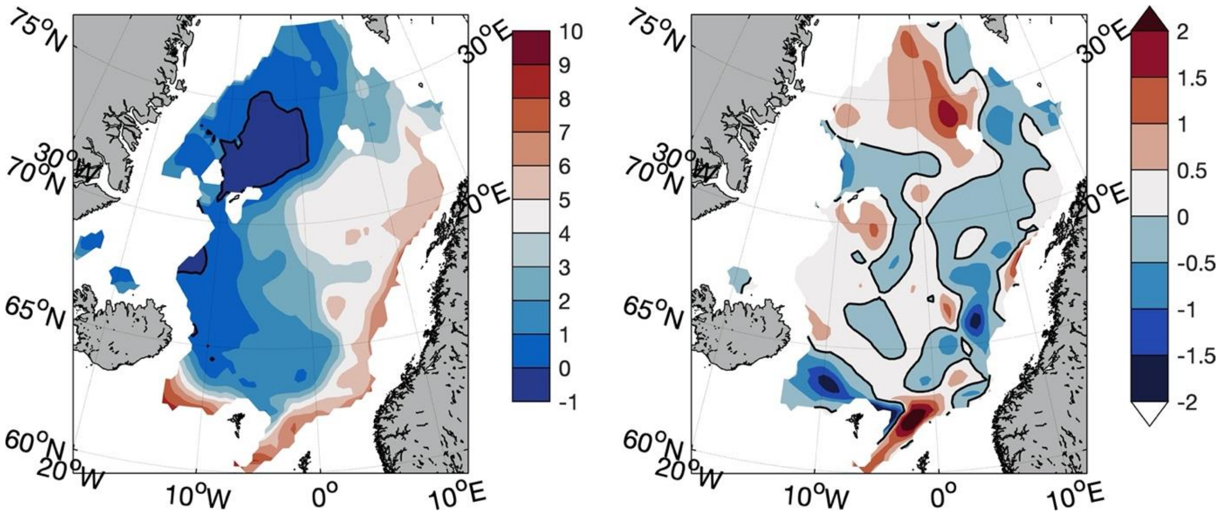

Figure 7. Same as above but averaged over 200-500 m depth.

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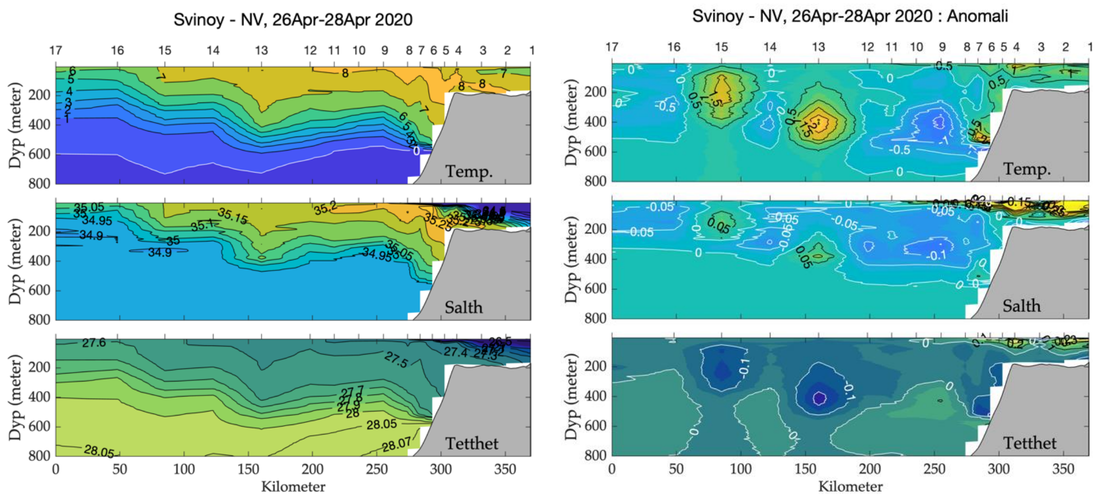

Figure 8. Temperature, salinity and potential density (sigma-t) (left figures) and anomalies (right figures) in the Svinøy section, 26-28 April 2020. Anomalies are relative to a 30 years long-term mean (1978-2007).

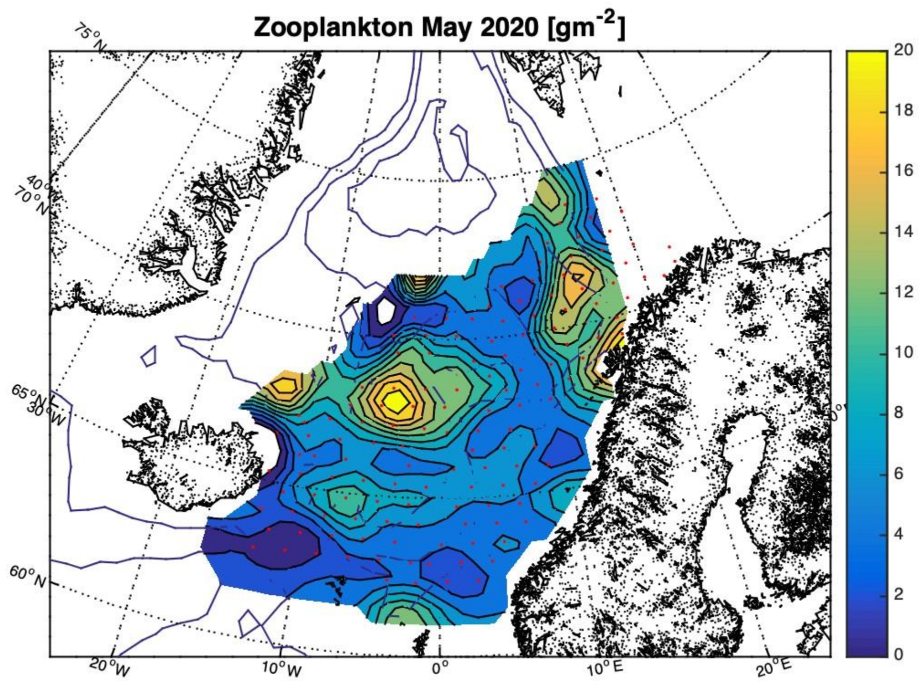

Figure 9. Representation of zooplankton biomass (g dry weight m^{-2}; at 0-200 m depth) in May 2020.

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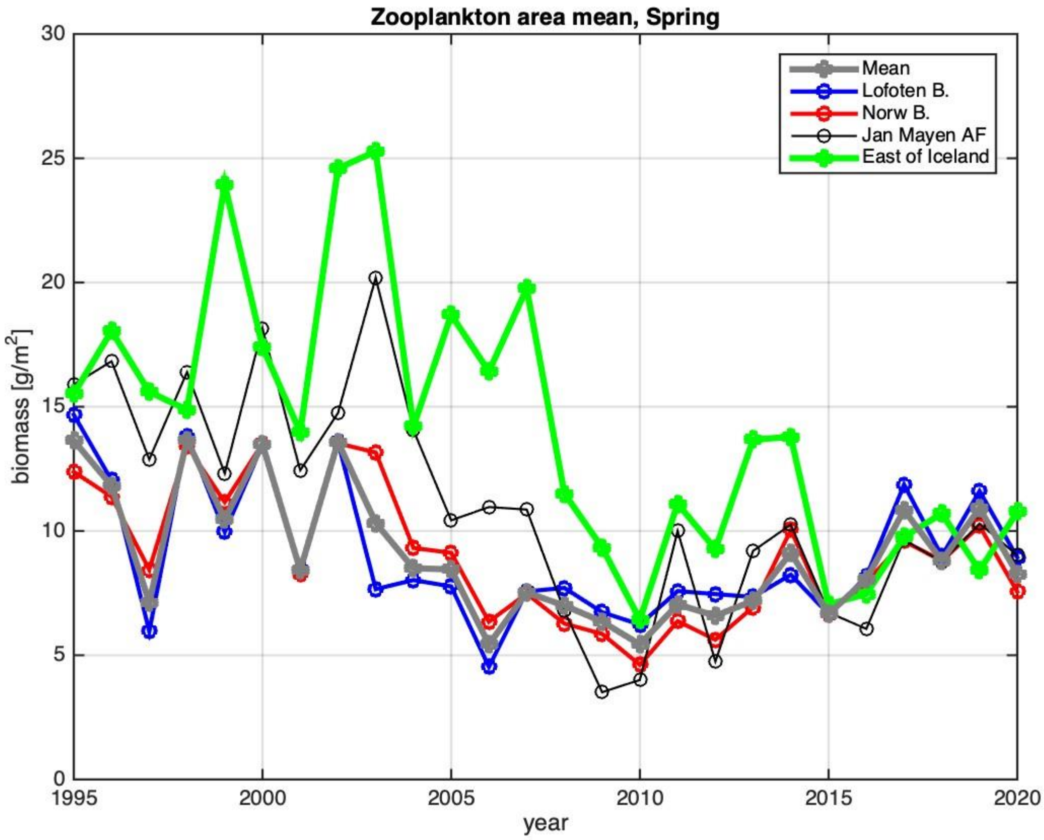

Figure 10. Indices of zooplankton dry weight (g m^{-2}) sampled by WP2 in May in (a) the different areas in and near Norwegian Sea from 1995 to 2020 as derived from interpolation using objective analysis utilizing a Gaussian correlation function (see details on methods and areas in ICES 2016).

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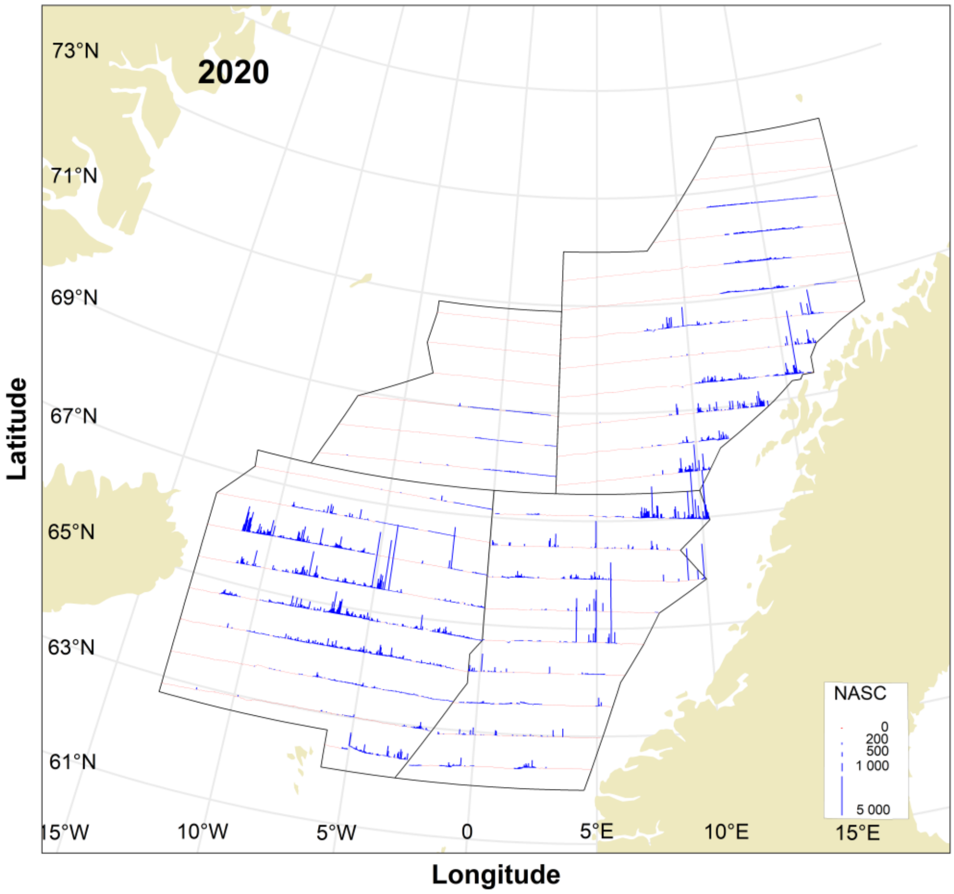
(a)



(b)

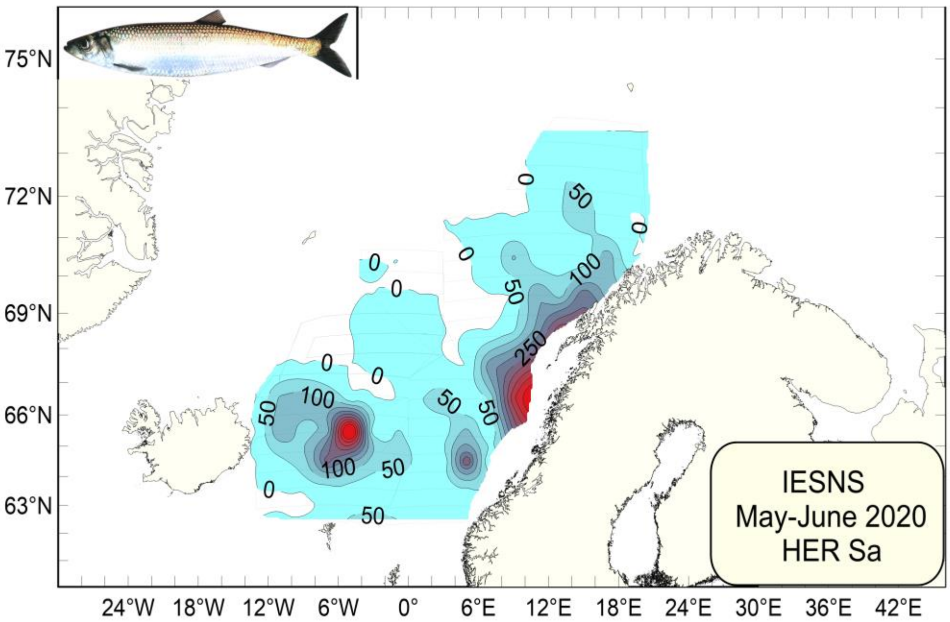


Figure 11. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2020 in terms of NASC values (m²/nm²) averaged for every 1 nautical mile and (b) represented by a contour plot.

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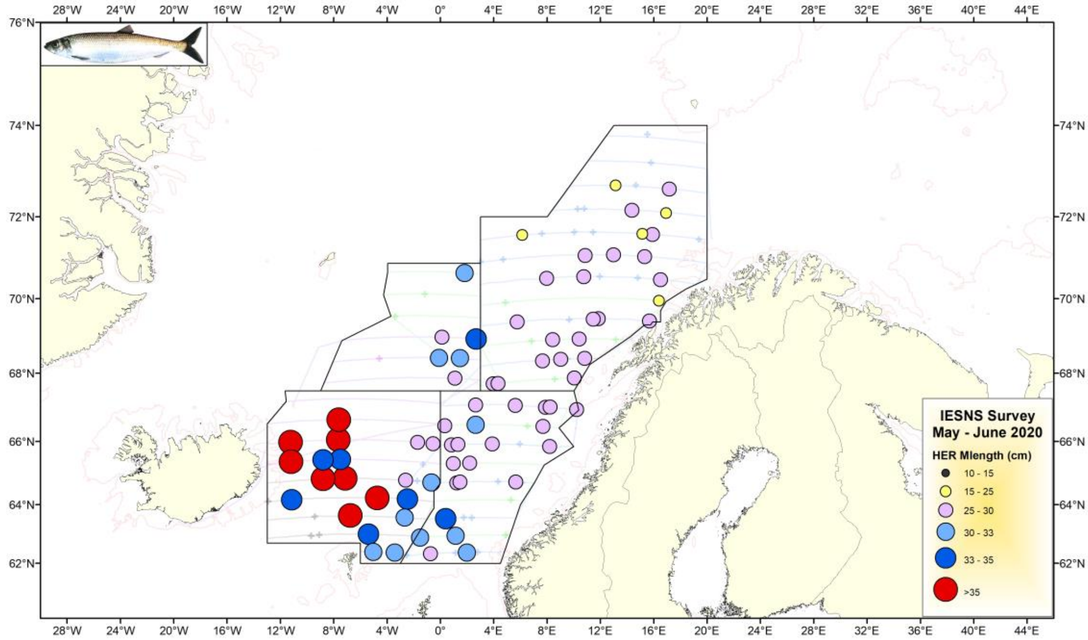

Figure 12. Mean length of Norwegian spring-spawning herring in all hauls in May 2020. The strata are shown.

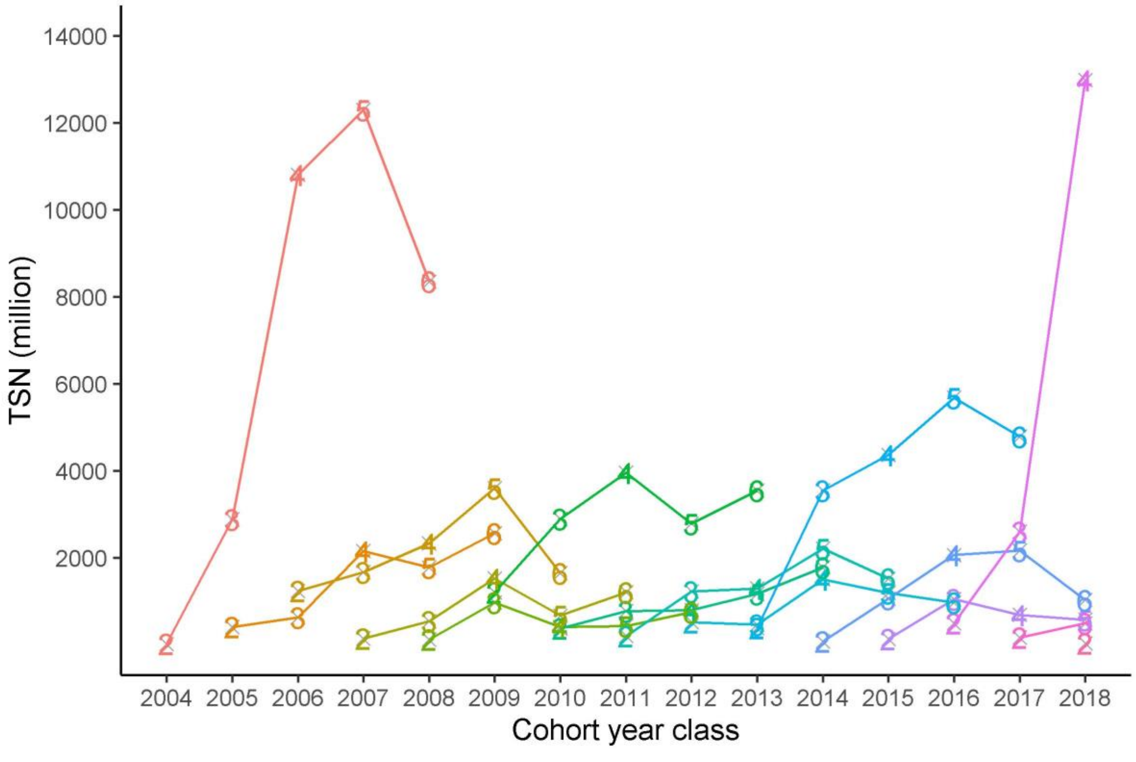

Figure 13. Tracking of the Total Stock Number (TSN, in millions) of Norwegian spring-spawning herring for each cohort since 2004 from age 2 to age 6. From 2008, stock is estimated using the StoX software. Prior to 2008, stock was estimated using BEAM.

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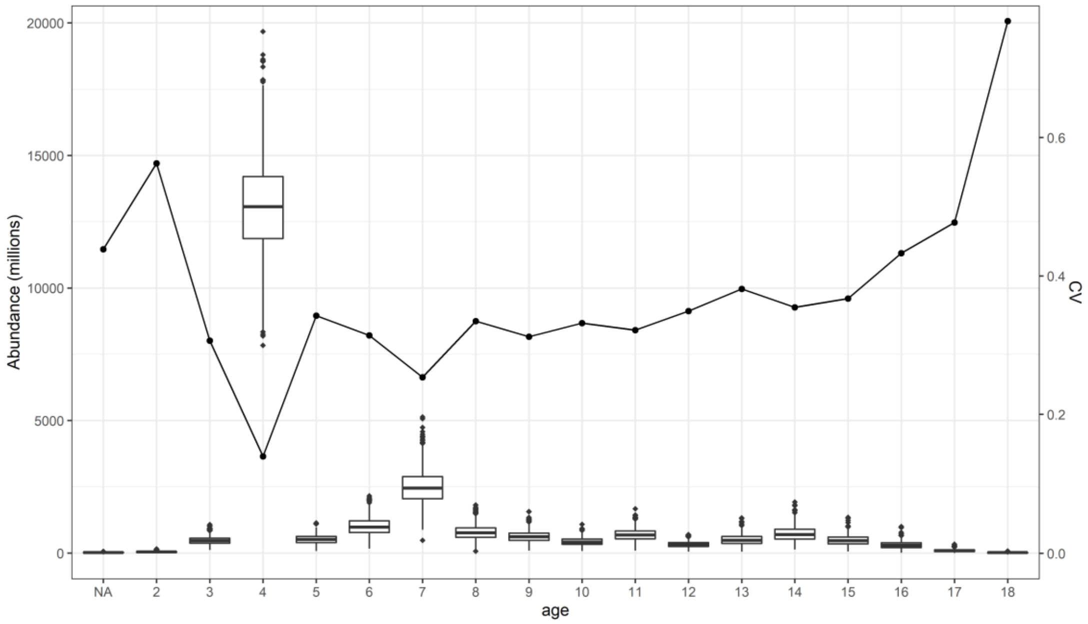

Figure 14. Norwegian spring-spawning herring in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

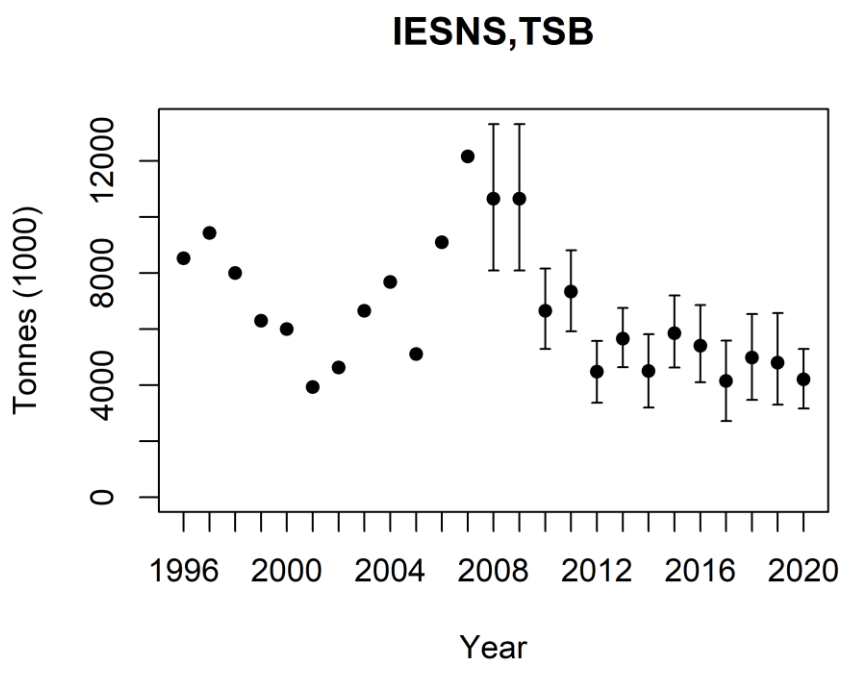

Figure 15. Biomass estimates of Norwegian-spring spawning herring in the IESNS survey (Barents Sea, east of 20°E, is excluded) from 1996 to 2020 as estimated using BEAM (1996-2007; calculated on basis of rectangles) and as estimated with the software StoX (2008-2020; boostrap means with 90% confidence interval; calculated on basis of standard stratified transect design).

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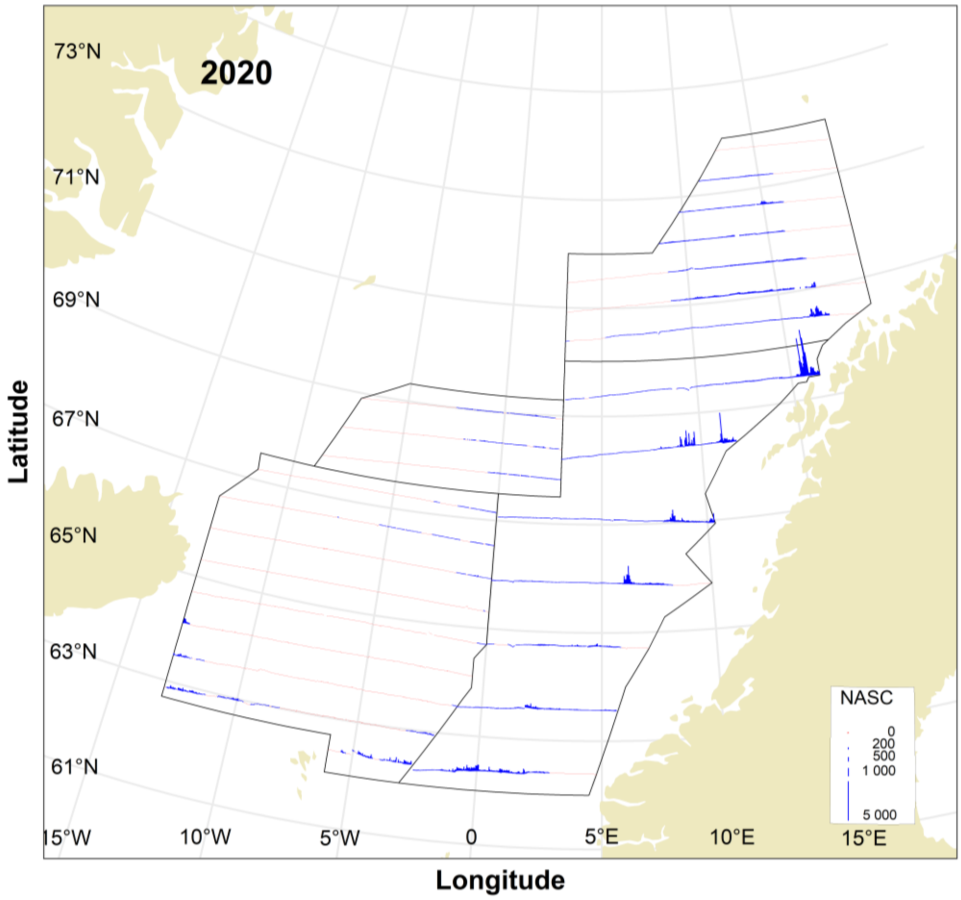
(a)



(b)

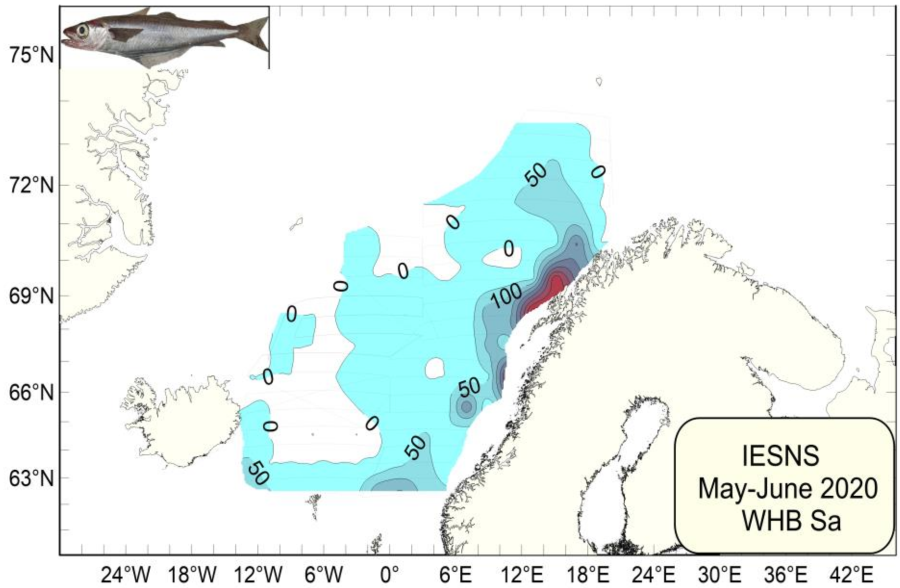


Figure 16. Distribution of blue whiting as measured during the IESNS survey in May 2020 in terms of NASC values (m²/nm²) (a) averaged for every 1 nautical mile and (b) represented by a contour plot.

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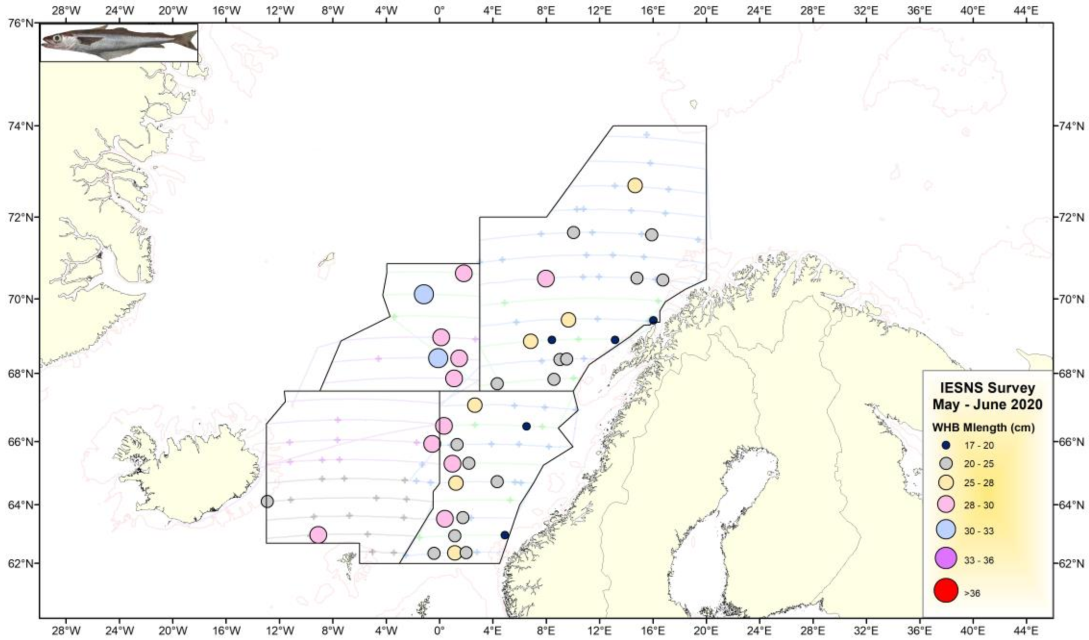

Figure 17. Mean length of blue whiting in all hauls in IESNS 2020. The strata are shown.

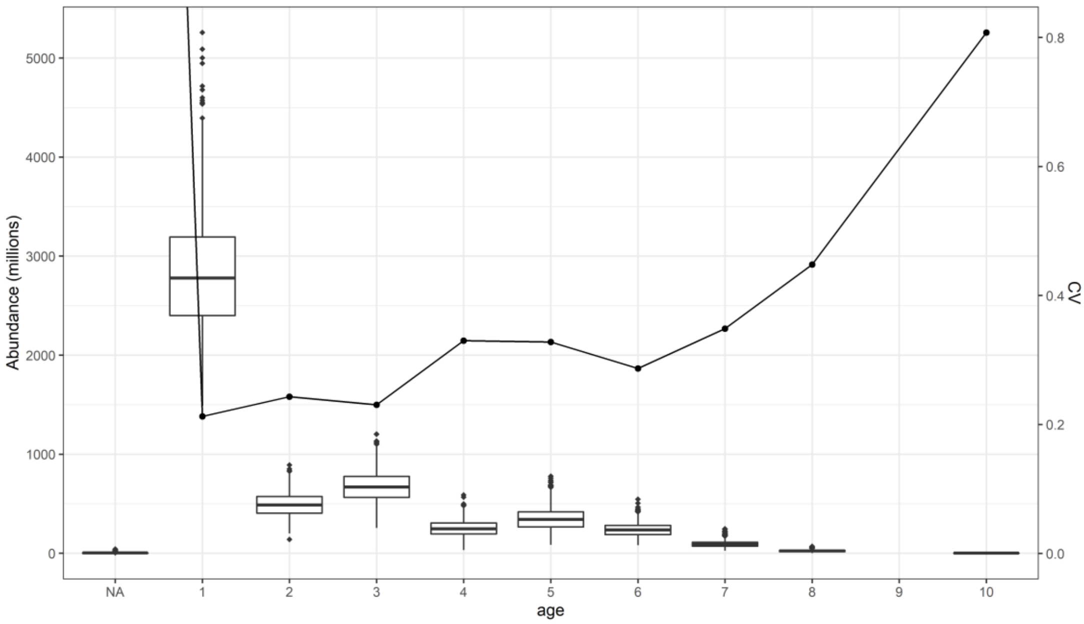

Figure 18. Blue whiting in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

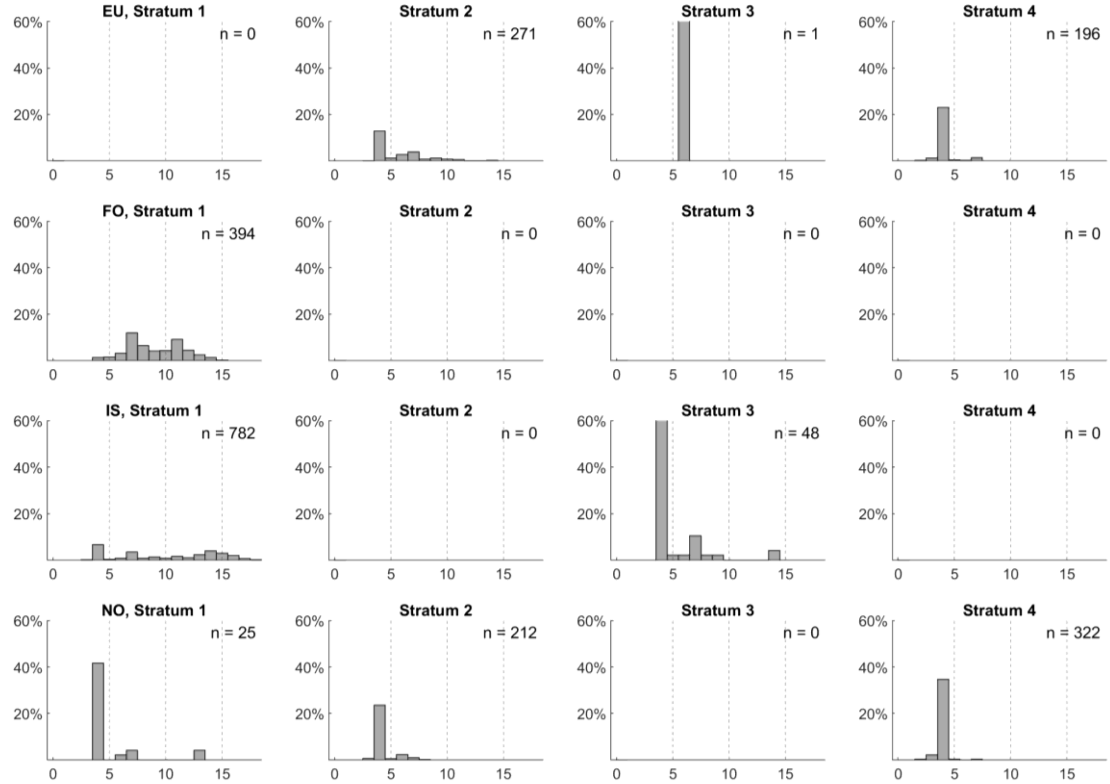

Figure 19. Comparison of the age distributions of NSS-herring by stratum and country in IESNS 2020. The strata are shown in Figure 3.

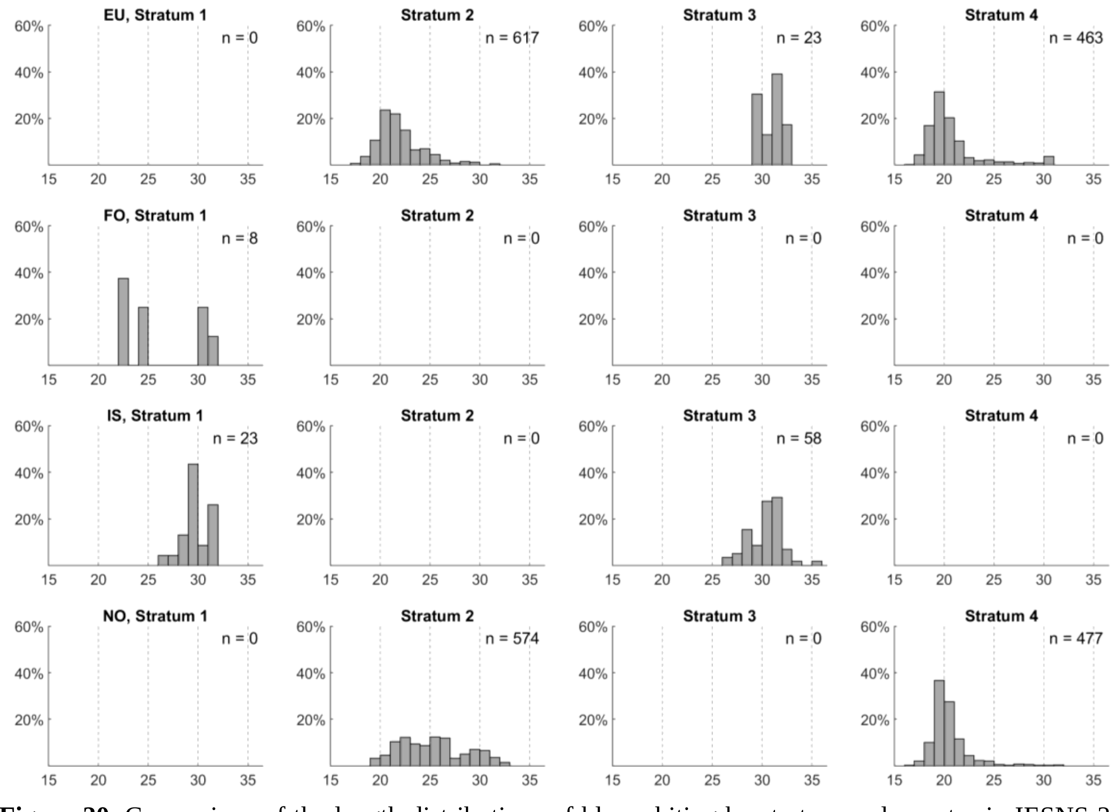

Figure 20. Comparison of the length distributions of blue whiting by stratum and country in IESNS 2020. The strata are shown in Figure 3.

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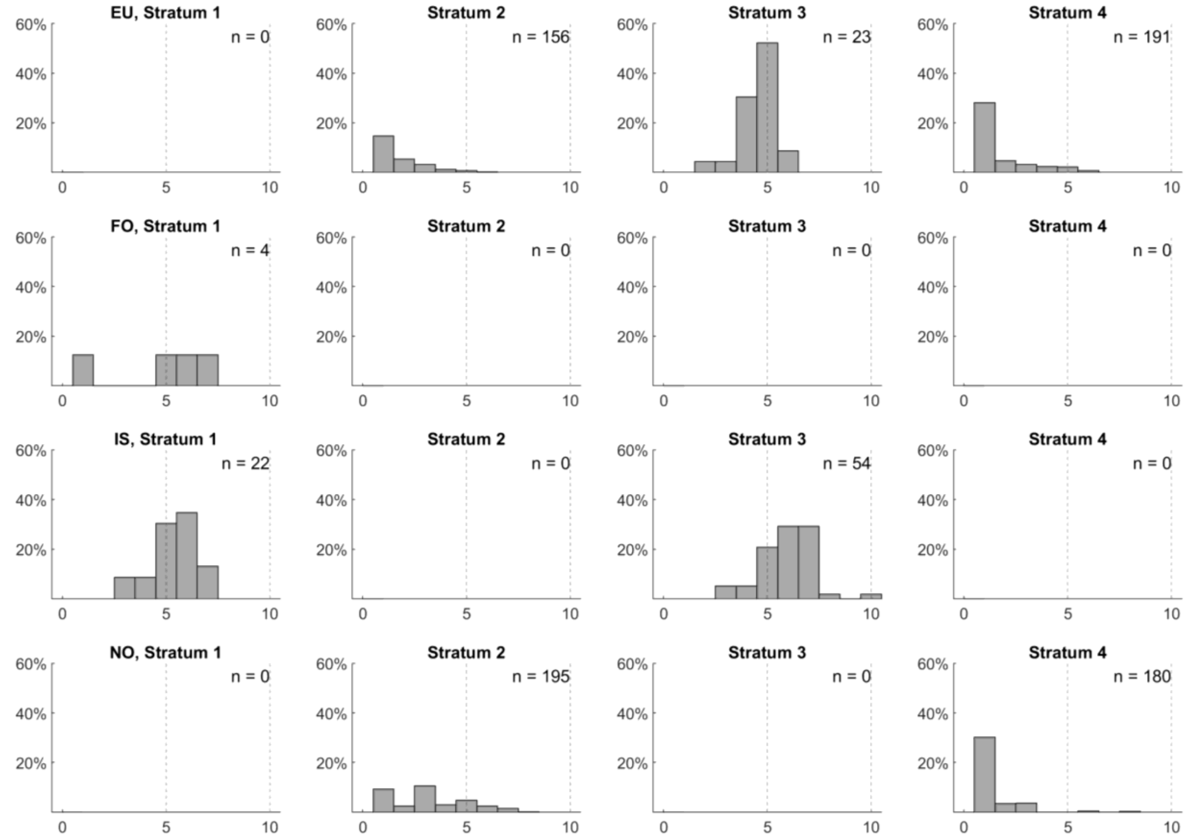

Figure 21. Comparison of the age distributions of blue whiting by stratum and country in IESNS 2020. The strata are shown in Figure 3.

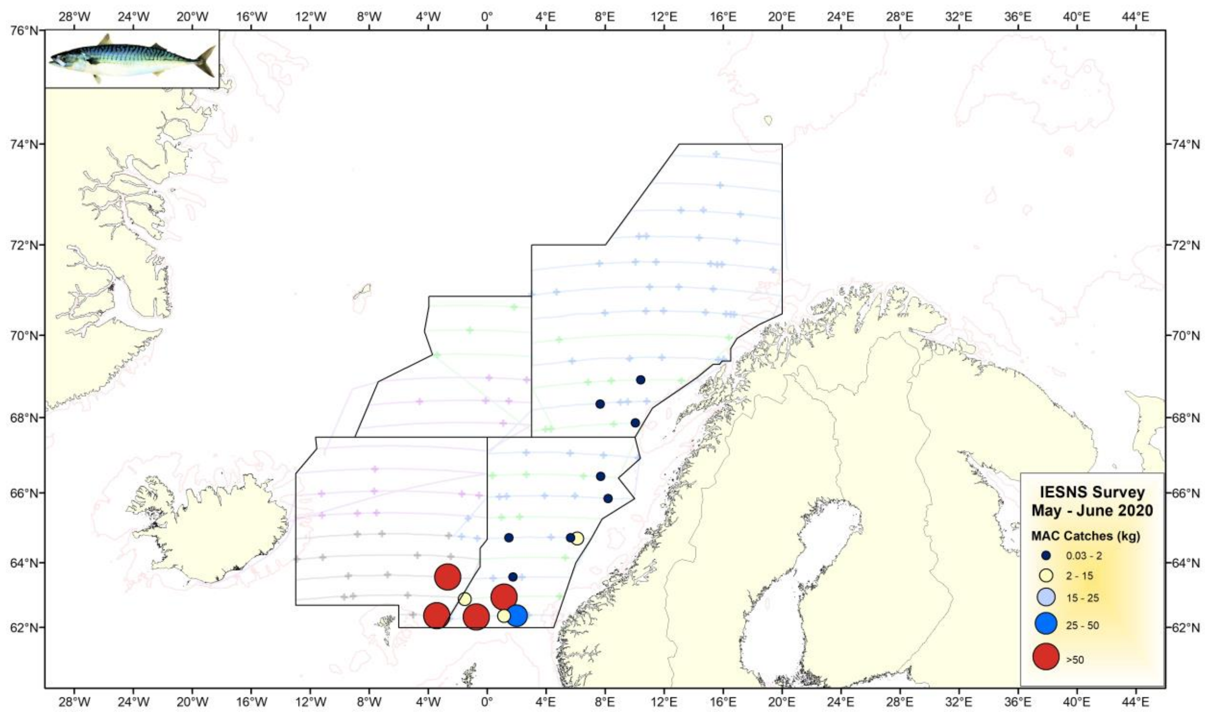

Figure 22. Pelagic trawl catches of mackerel in IESNS 2020. The strata are shown.

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Appendix A

Distribution of NASC in the IESNS survey in the period 2014 – 2019.

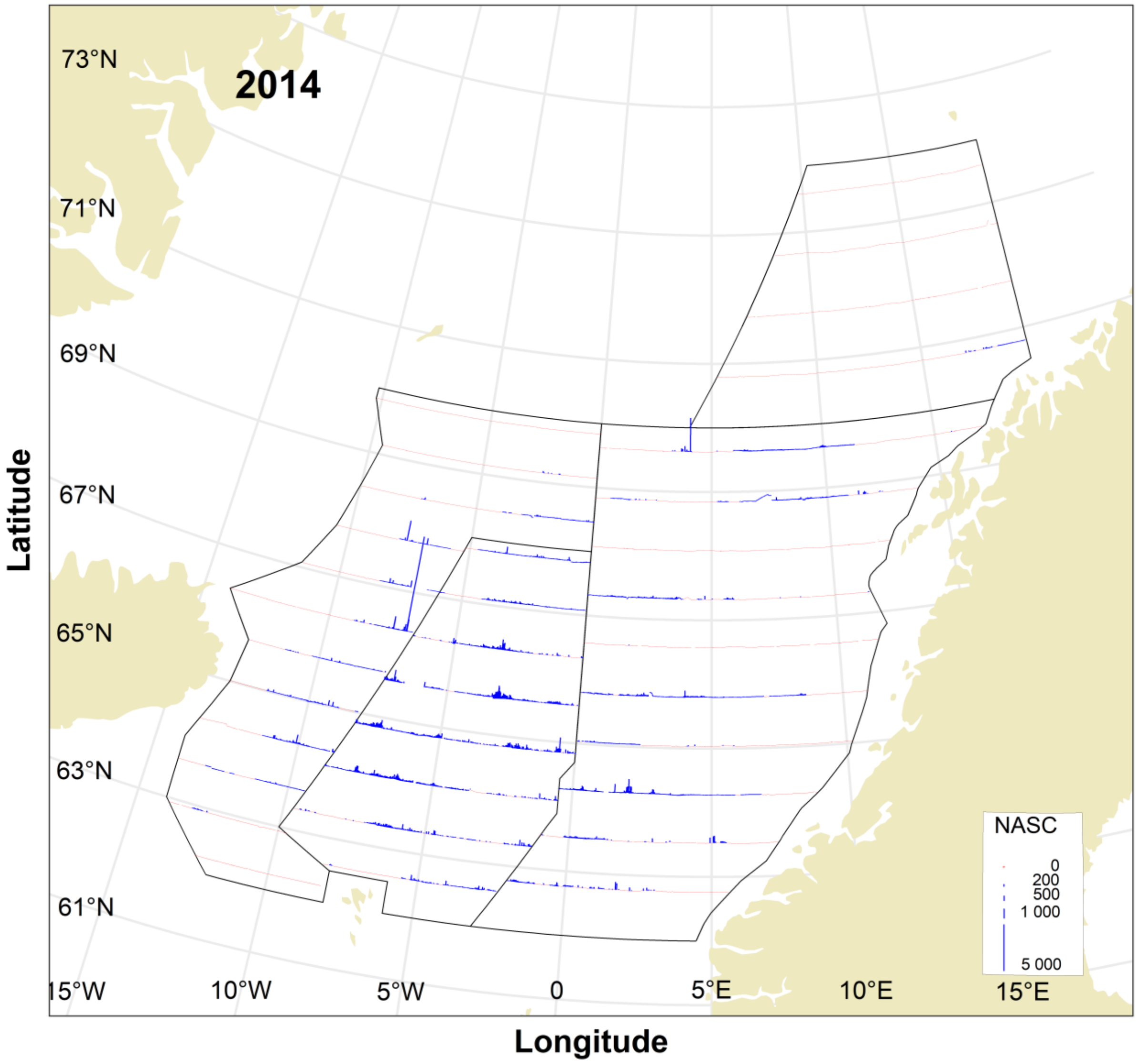

Figure A1. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2014 in terms of NASC values (m^2/nm^2) (a) averaged for every 1 nautical mile

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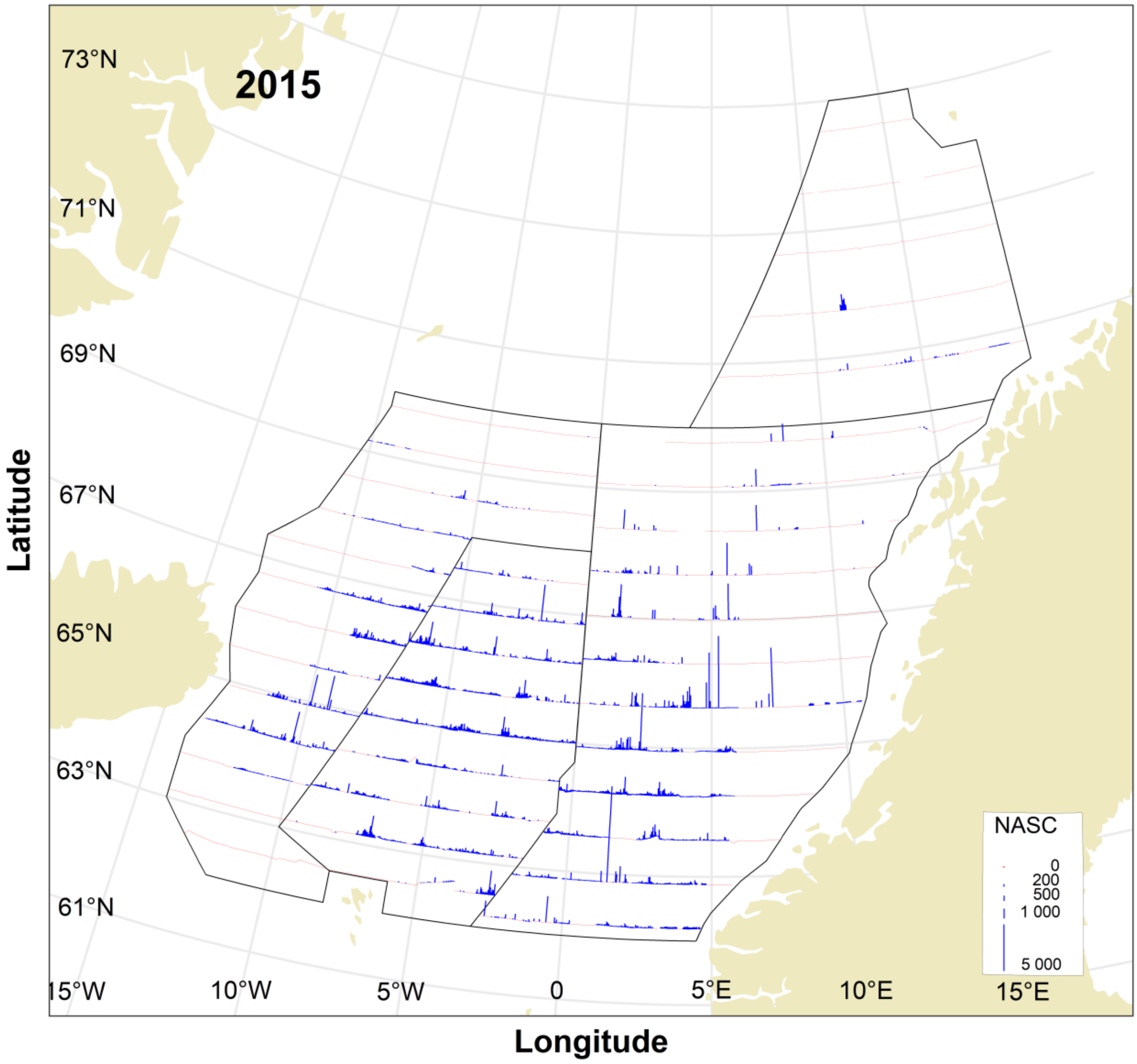

Figure A2. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2015 in terms of NASC values (m^2/nm^2) (a) averaged for every 1 nautical mile

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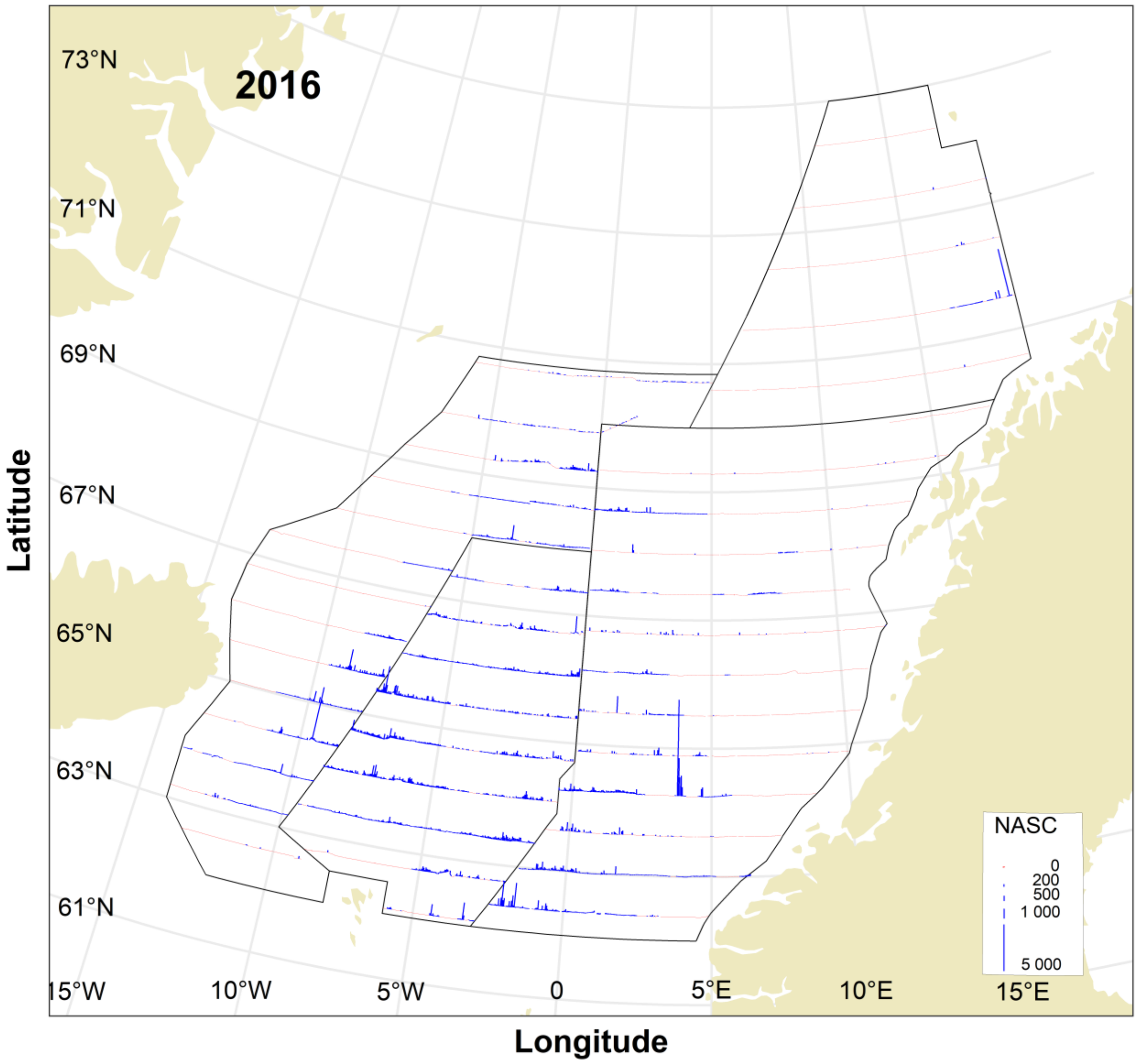

Figure A3. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2016 in terms of NASC values (m^2/nm^2) (a) averaged for every 1 nautical mile

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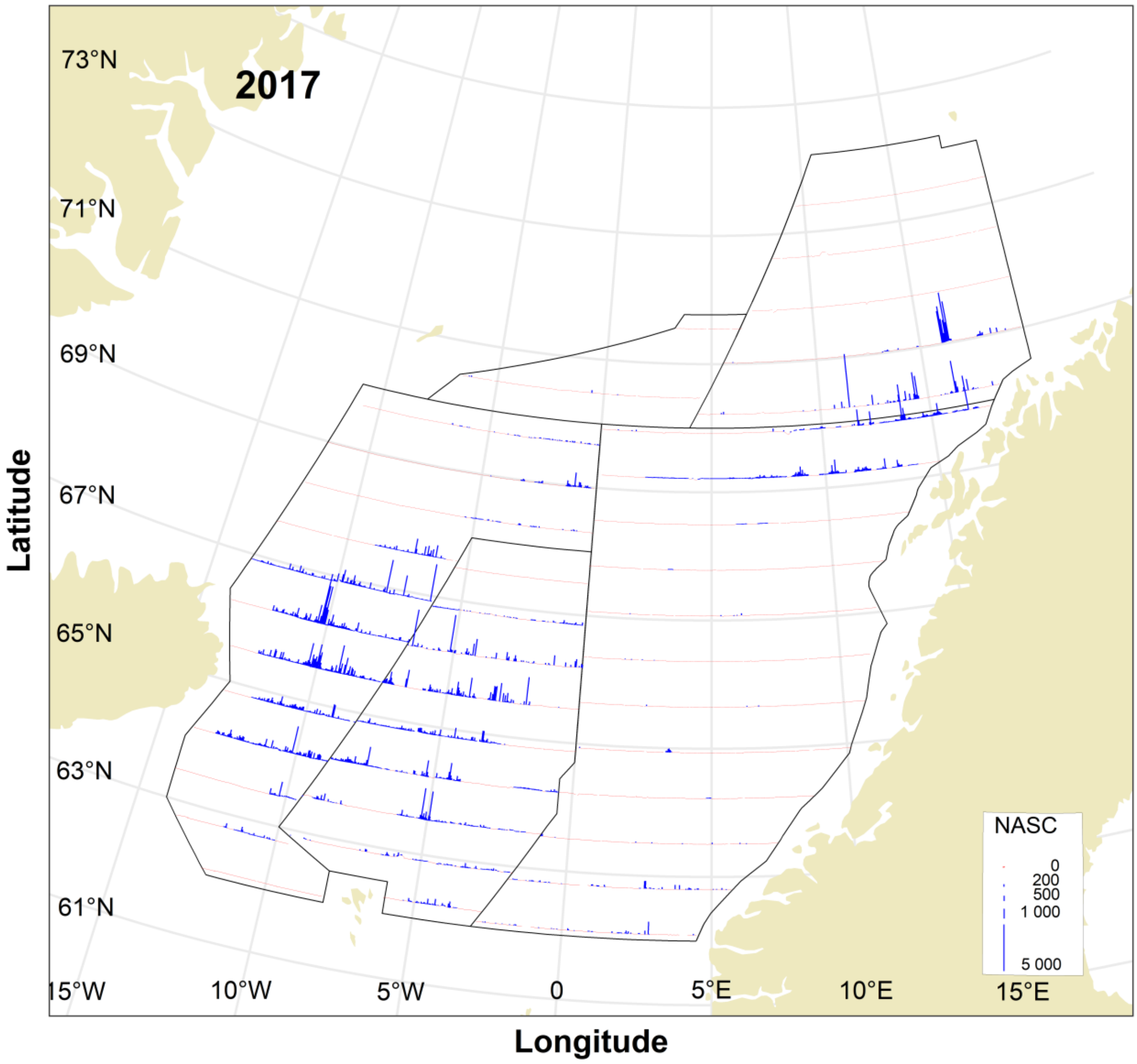

Figure A4. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2017 in terms of NASC values (m^2/nm^2) (a) averaged for every 1 nautical mile

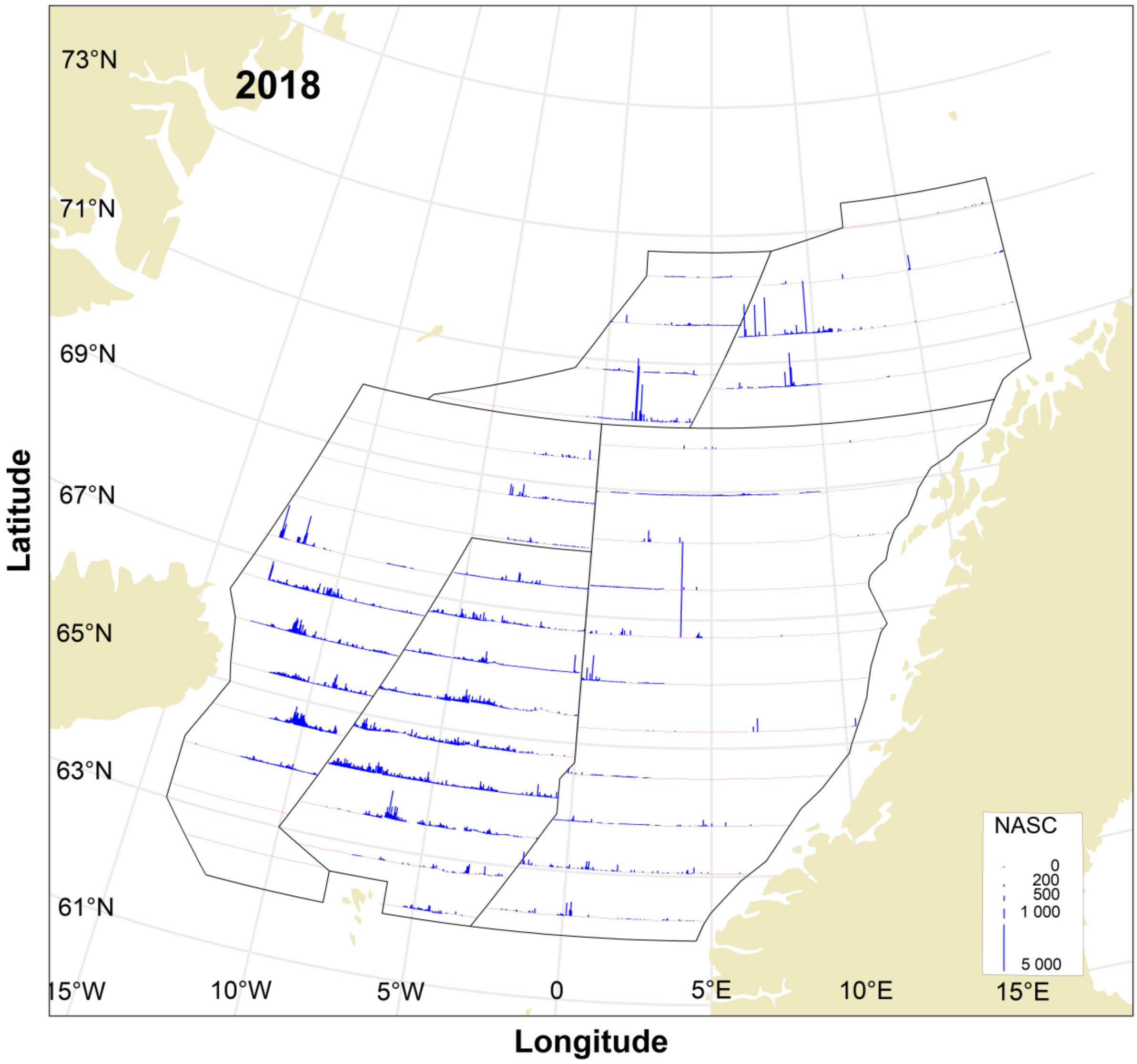

Figure A5. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2018 in terms of NASC values (m^2/nm^2) (a) averaged for every 1 nautical mile

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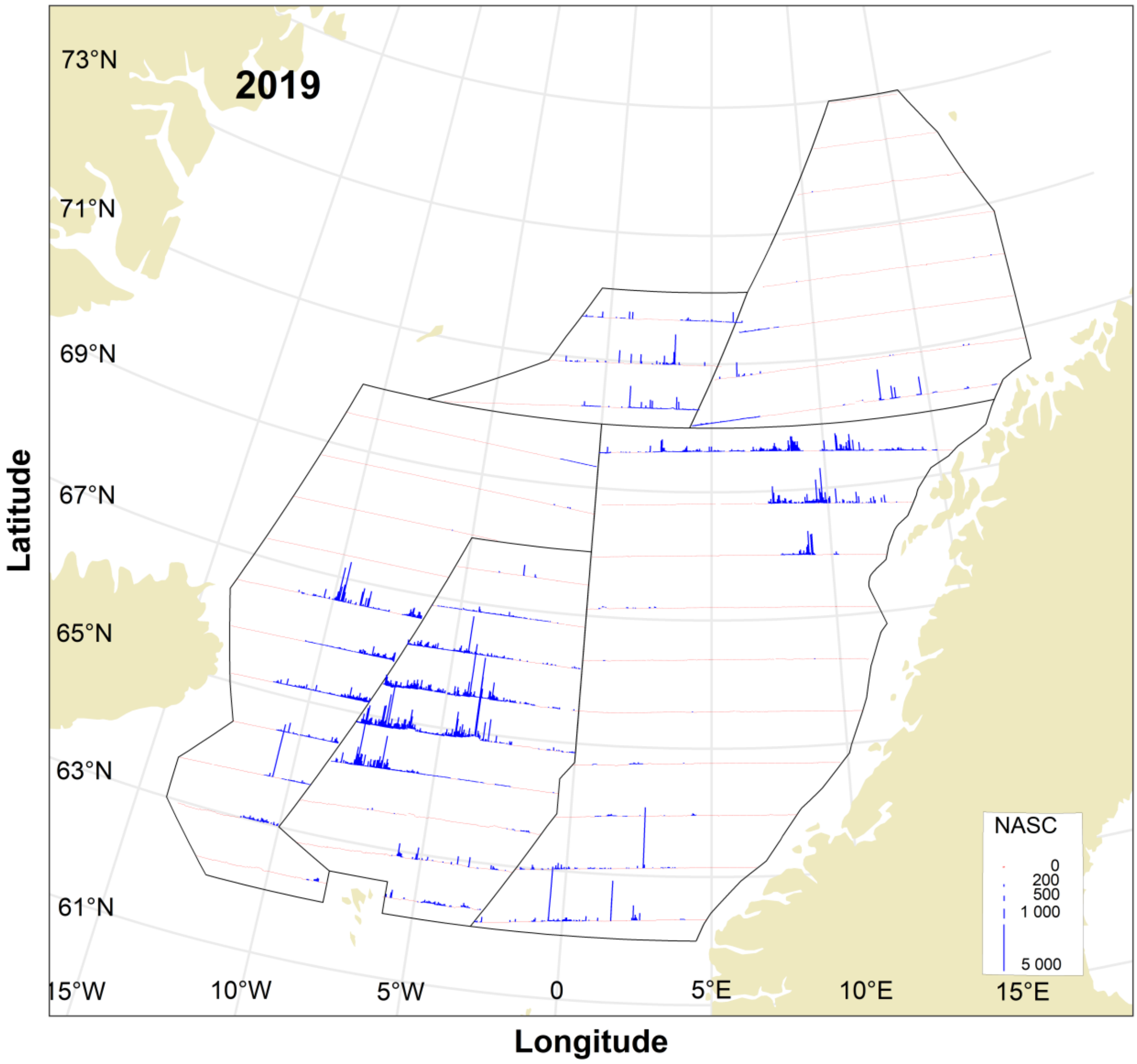

Figure A6. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2019 in terms of NASC values (m^2/nm^2) (a) averaged for every 1 nautical mile.

Appendix B

Vertical distribution of herring from omni directional fisheries sonar during international ecosystem survey in Nordic SEA (IESNS) in May – June 2020

Héctor Peña
Marine ecosystem acoustic group
Institute of Marine Research, Bergen, Norway

Introduction

The biomass estimation method using hull mounted echo sounder has two sources of bias related to the collection of the acoustic backscattering of the target species: i) fish present in the echo sounder blind zone, and ii) fish avoidance to the surveying vessel. Omni directional fisheries sonars can potentially provide with data to investigate when these biases occur and its magnitude along an acoustic surveying.

Since 2017, the collection and scrutinizing of sonar data has been an additional activity in the IESNS survey carried out by the Institute of marine research. Experience gained will help to evaluate feasibility and benefits of using sonar in a routine basis during acoustic pelagic trawling surveys.

The main goal of the present study was to use the omni sonar SU90 onboard RV "G. O. Sars" to quantify the fraction of NSS herring in the upper 60 m during the IESNS survey in the Nordic sea. Sonar vertical distribution of fish abundance will be compared with the distribution from echo sounder.

Methods

Sonar set up

The horizontal beams from the sonar onboard RV "G. O. Sars" was previously calibrated prior to the survey on May 1st in Bergen bay. Calibration using a reference target was done at 26 kHz frequency, FM normal transmission mode and narrow beam. Attempt to calibrate vertical beams was unsuccessful because of high noise levels, which not allowed visualization the calibration sphere. Echoes from bottom may be the reason and in future is planned to perform calibration in deeper waters.

During the survey (1st May to 03rd June), the sonar was set up to achieve a high ping rate operating at a range of 600 m. The sonar was synchronized with the EK80 echo sounder and

MS70 scientific sonar to avoid interference, which resulted in a ping rate of the horizontal beams between 4 to 5 seconds.
A tilt of 5 deg was set for the horizontal beams with a theoretical upper depth of the beam of 8 m at 50 m range and lower depth of the beam of 90 m at the maximum operational range. Experienced showed that shallower tilt angles (i.e. 1 or 2 deg) can affect severely data acquisition, which is subject to noise produced by air bubbles swept down by waves, that in high winds (>25 knots) can reach up to 50 m below the surface. The vessel roll contained in the echo sounder data was used as an indicator of bad sonar conditions (high wind and high waves), not processing sonar data with absolute roll angles larger than 2.5 deg.
The 180° vertical beam fan was set perpendicular to the vessel track with a horizontal range of 600 m and a vertical range of 600 m.
All the sonar filters (AGC, RCG, Ping to ping) were set to the default values, except for the "Noise filter", which was disabled because it alters the values of exported raw data.

PROFOS settings

The Processing system for omni directional fisheries sonar (Profos) module of the LSSS software was used for the data replay and school segmentation. The automatic school detection functionality was used, with a posterior manual quality control of the segmented school. The segmentation settings most commonly used were: 12 dB above the background level, minimum surface of 300 m^2, maximum surface of 7000 m^2, two missing pings, at least 10 pings schools, and a ratio of 10 between length and school width. The output from LSSS contained school descriptors and vessel navigation information for each ping de the school was detected.

Vertical distribution of sonar and echo sounder

School descriptors from sonar data were used to compute the nautical area scattering coefficient (S_A, m^2 nmi^{-2}) by 1 nmi distance and depth channels of 10 m, from surface up to 60 m. Similar integration criteria was used with the echo sounder data resulted from the official survey scrutiny. Data was sorted by transects and vertical distributions of S_A were generated. A correlation analysis was done to compare the standardized NASC form sonar and echosounder by 10 m depth channels.
Because different ensonification angle of the two instruments used (vertical for echo sounder and horizontal for sonar) the S_A values are not directly comparable, and a conversion factor was used to upscale the lower sonar S_A values, and facilitate the visual comparison. The conversion factor used was 2.5. This value corresponds to the linear difference of 4 dB between the lower horizontal mean target strength compared with the mean vertical target strength.

Results

Predominant NSS herring from 2016-year class was found mostly as well defined small (ca. 10 m diameter) and medium size (ca. 100 m diameter) schools in the upper 100 m.

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Conditions for sonar operation were optimal almost during the whole survey with few periods of bad weather which impeded good sonar data.

The sum of the herring NASC from 0 to 60 m depth by transects for sonar showed a similar spatial distribution as the NASC from the echo sounder from transect 1 to 8 (Figure 1). Only in the western part of transect 4, more schools were detected by the sonar. In the northern transects (9 to 12), herring was distributed disperse and not as schools or dense layers, and therefore only observed by the echo sounder. In transects with higher herring NASC values (i.e. transects 3 to 7), schools were observed in the eastern end towards the Norwegian coast.

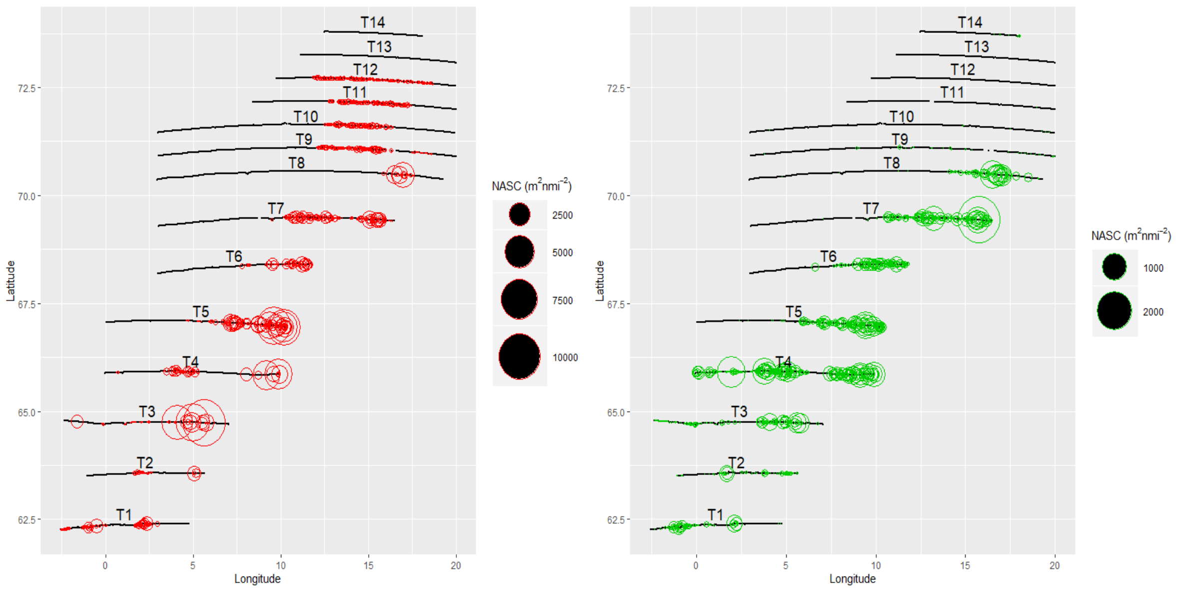

Figure 1. Herring NASC from 0 to 60 m by transects for echo sounder (left panel) and sonar (right panel).

In this region, presence of herring schools was found until the eastern border (end of transects 4 and 6, start of transect 5) of transects towards the coast, indicating that the zero line was not reached (Figure 2 and 3). Transects 4 and 5 were extended during the survey towards east from its original design, but not enough to reach areas with no herring. During surveying, sonar information was valuable to evaluate the presence of schools ahead of the vessel track, and the need to establish criteria to extend a transect (when zero line has not been reached), based in sonar observations, was suggested in the post-cruise meeting.

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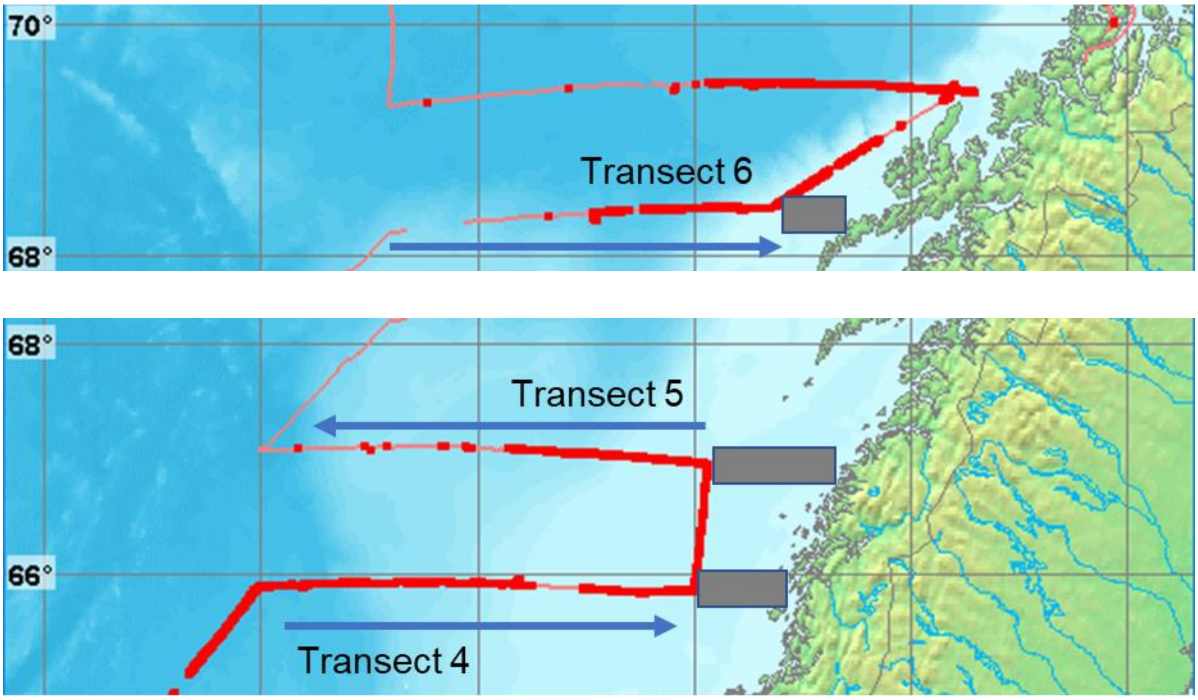

Figure 2. Detail of transects 4, 5 and 6 showing the schools detected by sonar as red dots along the survey pink line. Blue arrows indicate vessel direction and grey boxes regions towards the east that were not covered by the transects along the coast.

Examples of the different herring schools observed by echo sounder and sonar displayed in LSSS are shown in Figure 3. In general, larger schools were observed in transects 3 to 5, and smaller and denser in the region off Loffoten and Vesterålen (transects 6 to 8).

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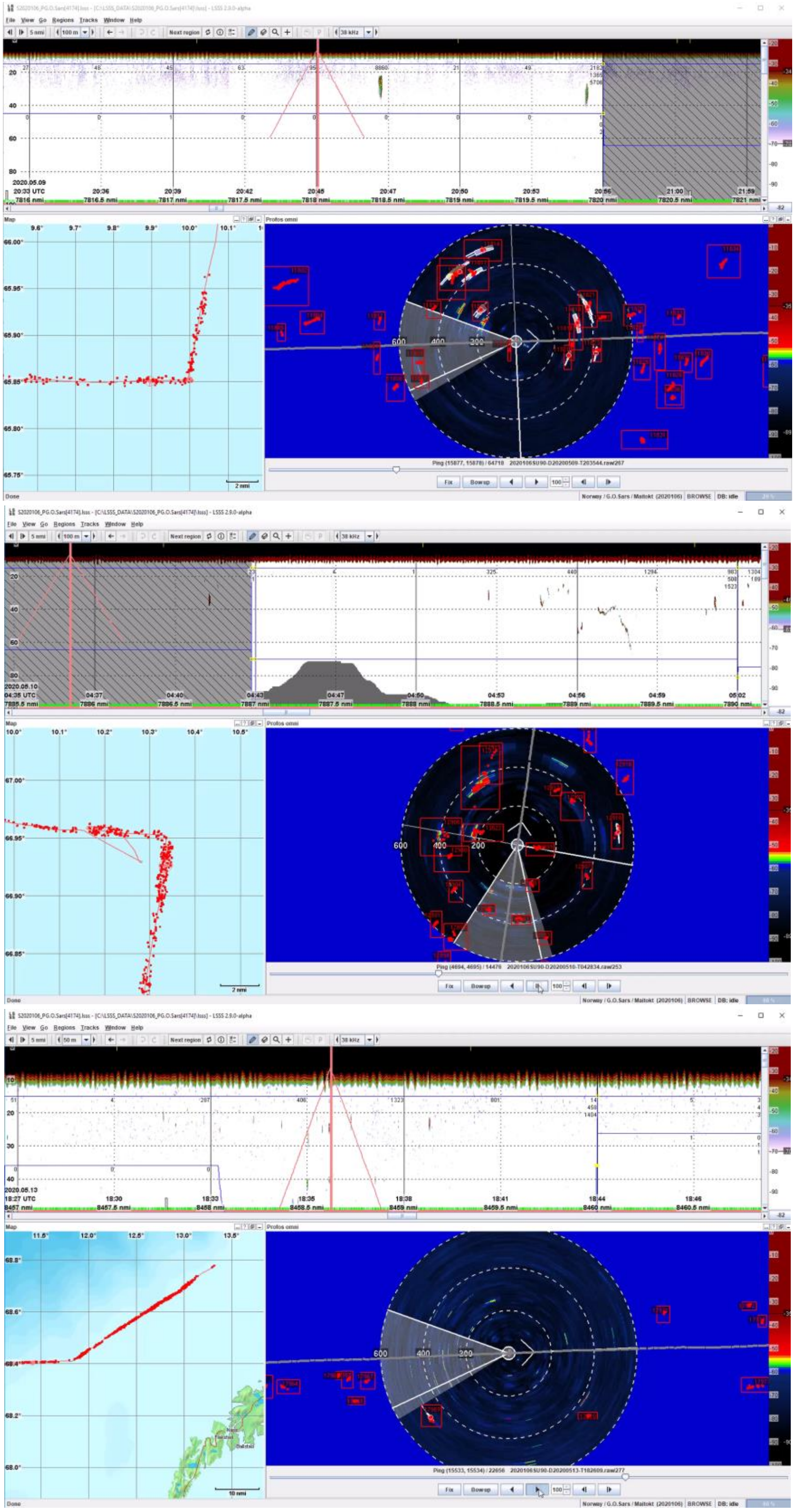

Figure 3. Image of LSSS display showing typical herring aggregations from echo sounder and sonar in transects 4 (Top), 5 (middle) and 6 (bottom). Larger and more distant schools in transect 4, smaller and more dense schools in transects 5 and 6.

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No statistical differences were found between the standardized NASC by 10 m depth channels from echo sounder and sonar in any of the transects where herring was observed (*i.e.* transects 1 to 8) (Figure 4)

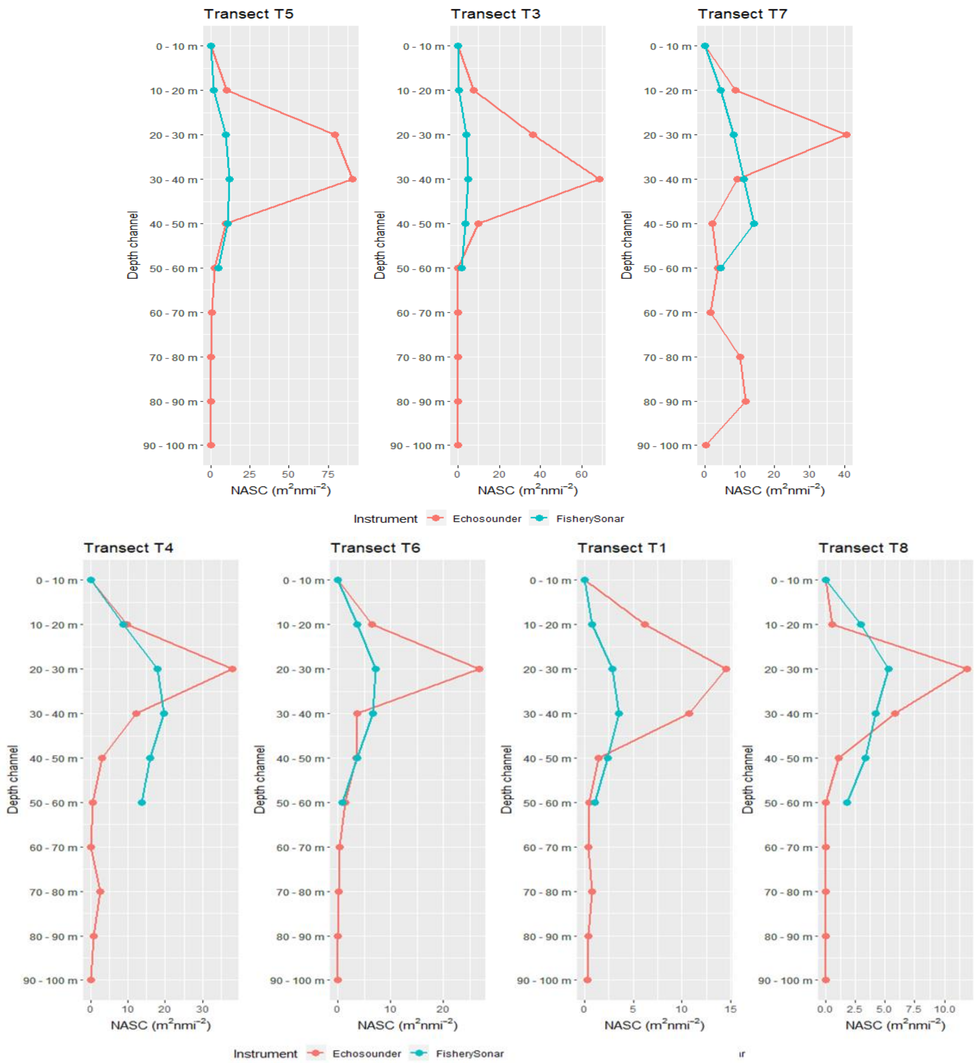

Figure 4. Vertical distribution of herring NASC values from echo sounder and sonar for transects in decreasing order of contribution of NASC from echo sounder measurements (top left to bottom right).

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Discussion

NSS herring 2016-year class was predominant in the sonar measurements in the upper 60 m in the 2020 IESNS survey. Well defined schools and general good weather conditions conditioned good quality sonar data.

Abundant schools were measured with the sonar in the eastern end of transects 4 to 6, not reaching the zero line. Even though a reduced transect extension was implemented, it was not enough. The need to establish a criterion based in the sonar measurement, when these situations occurs, was indicated in the post-cruise meeting. For example, the absence of schools in the sonar for 10 nmi after the end of a transect could be a rule to decide stop surveying along that transect and continue with the next one.

The similar spatial distribution of herring from echo sounder and sonar is a good indicator that both acoustic systems are detecting the presence of herring in the layer up to 60 m depth, when herring was aggregated in schools (transect 1 to 8). In the northern area (transects 8 to 12), herring was present as disperse fish, and not detected by the sonar.

The analysis of the vertical distribution of herring between echo sounder and sonar indicate no statistical differences between distributions on depth and levels of NASC. The relative contribution of NASC by depth channels from the sonar data, don't show higher levels in the 10 to 20 m depth, similar observed in echo sounder distribution, which indicate no bias of the echo sounder in this depth layer.

Current analysis of data series from 2017 to 2020 aim to evaluate if the current scaling factor between the sonar and echo sounder NASC is appropriate or need to be modified.

In summary, the vertical distribution of herring from sonar indicates no bias from the measurements of the echo sounder from depths from 10 to 60 m during the IESNS 2020 survey. In three transects the zero line was not reached, and a procedure to use the sonar information to avoid this problem is indicated.

Appendix C

Vertical distribution of herring from sonars during international ecosystem survey in Nordic seas (IESNS) in May 2020

Rolf Korneliussen and Arne Johannes Holmin
Research group Ecosystem acoustics
Institute of Marine Research, Norway

Introduction

The biomass estimation method using hull mounted echosounders only, have at least two sources of bias related to the collection of the acoustic backscattering of the pelagic target species: i) fish present in the echosounder blind zone close to the sea surface, and ii) fish avoidance to the surveying vessel. Horizontally oriented sonars can potentially provide data to investigate those biases.

During the last three years, the collection and scrutinizing of sonar data has been an additional activity in the IESNS survey carried out by the Institute of Marine Research (IMR). Experience gained will help to evaluate feasibility and benefits of using sonar in a routine basis during acoustic pelagic trawling surveys.

Two classes of sonars were used; an omnidirectional fisheries sonar (SU90), and a scientific matrix sonar (MS70). The SU90 sonar can be run in two modes: either by measuring in a 360 degrees dish, or in a vertical slice. The SU90 is similar to sonars common on many fishing vessels and has the advantage of being available on many fishing vessels, while MS70 is currently only available onboard RV “G.O. Sars”. The MS70 points port and use a mesh containing 25 x 20 beams = 500 beams covering 60 degrees (horizontally) by 45 degrees (vertically) in. Thus, the MS70 sonar has a better spatial resolution, but a poorer horizontal coverage than SU90. MS70 provides data both at horizontal ranges from the ship and also vertically.

The main goal of the present study was to use the sonars onboard RV “G. O. Sars” to quantify the fraction of NSS herring in the upper depths of 60 m during the IESNS survey in the Nordic seas. SU90 can cover the upper 60 m, and MS70 was used to investigate the upper 200 m. The vertical distribution of fish abundance by means of SU90 and MS70 will be compared with the distribution from echo sounder. In this document we concentrate on the MS70 sonar, while the SU90 comparison is mainly covered in another document.

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Methods

MS70 was calibrated at the survey operation mode with for the first time in 2019 with the highest frequency in the top fan. New integrated electronic cards were installed in MS70 in 2020, and MS70 sonar was calibrated prior to the 2020 survey.

The MS70 scientific matrix sonar

Setup

MS70 was set up to cover a horizontal distance of 250 m (i.e. range 410 m) and to ping at least every second EK80 ping (1 ping per 2 seconds). The highest frequency (112 kHz) closest to the surface with centre of beams parallel to the surface, and the lowest beams (75 kHz) was pointing 45 degrees down. The highest frequencies were used at the top to have the narrowest beams in the vertical direction in order to get as close to the surface as possible. The MS70 transducer were mounted on a protrudable instrument keel, with the centre of the transducer at 7.5 m below the sea surface.

Data preprocessing

The MS70 data were preprocessed by means of LSSS-PROMUS (Processing system for advanced multibeam sonar). A brief description of the preprocessing is as follows:

1) Spatial and temporal spikes were detected and replaced median of the surrounding data.
2) Ambient noise was estimated for each of the 500 beams and then each sample was corrected for ambient noise.
3) Data were collected to a range of 500 m. Data closer to the ship than 20 m were removed. Data at larger horizontal range from the ship than 250 m were removed.
4) Data closer to the surface than 2.5 m were removed. This implies that at least the two uppermost fans were cut at ranges where the upper edge of beam is closer to the surface than 2.5 m. The vertical extent of the fans is a source of uncertainty: we used the nominal vertical beamwidth multiplied by 1.65.
5) Data more than 200 m below the surface were removed. This implies that at least the two uppermost fans were cut at ranges where the upper edge of beam is closer to the surface than 2.5 m. The vertical extent of the fans is a source of uncertainty, but unlike the uppermost beams the lowermost beams were cut by using used the nominal vertical (i.e. the beamwidth multiplied by 1.0).
6) Data were thresholded, so that all S_v-samples weaker than -70 dB and stronger than -5 dB were removed (set to -120 dB).
7) Data were compressed by removing data where 20 samples in a row were weaker than -70 dB. This reduced the data volume by 85%.

Pre-scrutiny

School-candidates were automatically detected from preprocessed data according to specified criteria. The most important of those were:

1) The school seed-point needed to be between -30 and -60 dB.
2) The maximum grow-depth of the centre of the beam was 200 m (although the lower edge of the beam could be deeper). This means that at depths deeper than 200 m, the data are not trusthworthy.

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3) The minimum grow-depth depended on the weather. It mostly varied between 2.5 and 15 m below the sea surface, but it could be as deep as 25 – 30 m.

Data interpretation (scrutiny)
The EK80 data were scrutinized by the cruise leader and the chief instrument engineer some hours after the data were collected. The MS70 data were scrutinized by a single scientist (Rolf Korneliussen). MS70-data collected after May 20 were scrutinized a few hours after the EK80 data. Data collected from May 1 were scrutinized after May 20. All scrutiny finished by the end of the survey.
No data with central axis deeper than 200 m was stored. Thus, the data deeper than 200 m is not representative
MS70 data were scrutinizing by first removing outliers of the school-candidates. Then the school-candidates were scrutinized in pretty much the same way as the EK80 data, i.e. by considering scattering strength, shape of school (in 4 dimensions), biological samples, and by conferring the results of the EK80-data scrutiny. Scrutinization of 24 hours of MS70 data took typically 20 minutes.
Data were stored in a database as volume backscattering data and were exported to files to be processed in external systems. The data were averaged to over the same distance (1 nmi) as the EK80 data, and in range-cells of 10 m, and at its native beam resolution. Thus, each database cell is an average of typically 4500 MS70-samples. Note that MS70-data and database storage cells are natively shaped as sphere-sectors, and that the data used here are converted to cartesian coordinates.
Scrutinization of the fishery sonar and MS70 sonar differ from that of the echosounder in that they consider schools of a minimum volume 250 m^3. This represents a potential source of bias in the comparison between the instruments, as a layer of small schools or individual fish can contribute significantly to the echosounder NASC while being excluded from the sonar NASC.

Results

Figure 1 shows the 2020106 survey. The cruise started in south. After the “official” cruise tracks shown, there was additional triangular shaped cruise-lines in north-west (not shown).

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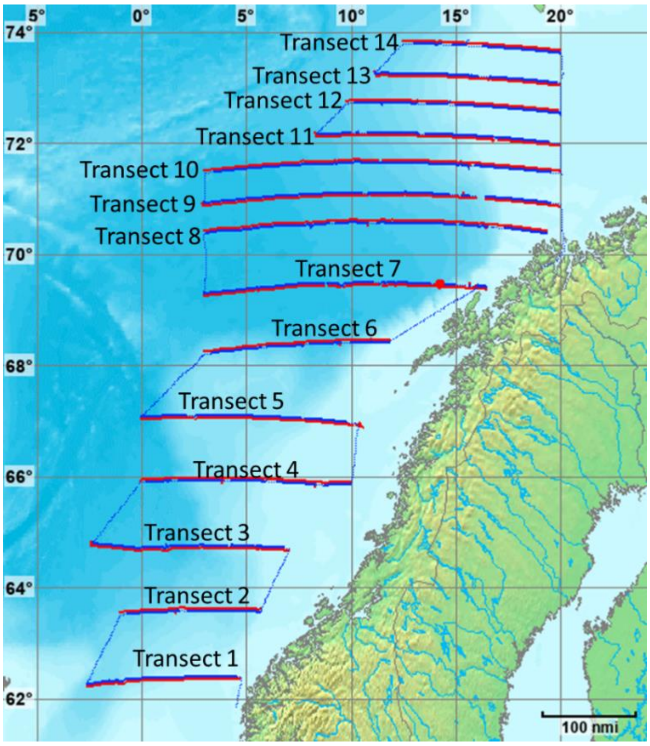

Figure 1. Cruise tracks of survey 2020106. Transects started in south and ended in north.

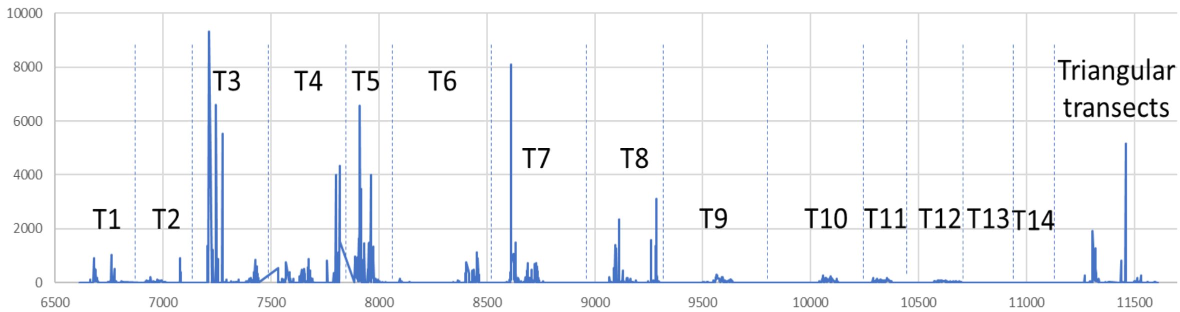

Figure 2. Herring scrutinized on survey 2020106, 38 kHz CW EK80 data. Transects are named "Transect N" or TN. After Transect 14, there were some triangular shaped cruise lines that was not a part of the official survey.

Comparison between echosounder and sonar cannot be done directly as the database contains NASC for the echosounder and s_V for the sonars. $s_V = 4\pi 1852^2 s_V$, so the difference between NASC = s_A and s_V is multiplication by the vertical extent of the depth channel, which in this case is 10 m for the EK80 data. Furthermore, the frequencies of the sonar MS70 is 75 – 112 kHz, i.e. approximately 90 kHz on average, while it is 38 kHz for EK80. For herring, measured frequency response measured by means of echosounder data indicate that NAASC is approximately 50% stronger at 38 kHz than at 90 kHz. In addition to this, dorsal tilt distribution is much smaller than the horizontal direction. Theoretical estimations indicate approximately 4.5 dB difference between herring measured dorsally and horizontally at the same frequency. Thus, the frequency and horizontal measurements is expected to be approximately a factor 4 (2.8 x 1.5 = 4.2 ≈ 4) weaker. In total, the s_V measured horizontally at 90 kHz by MS70 needs to be multiplied by (approximately) 10 (m) x 4 = 40. Figure 3 shows vertical distribution from the 2020 survey, and Figure 4 similar vertical distributions from three selected transects of the 2019 survey for comparison.

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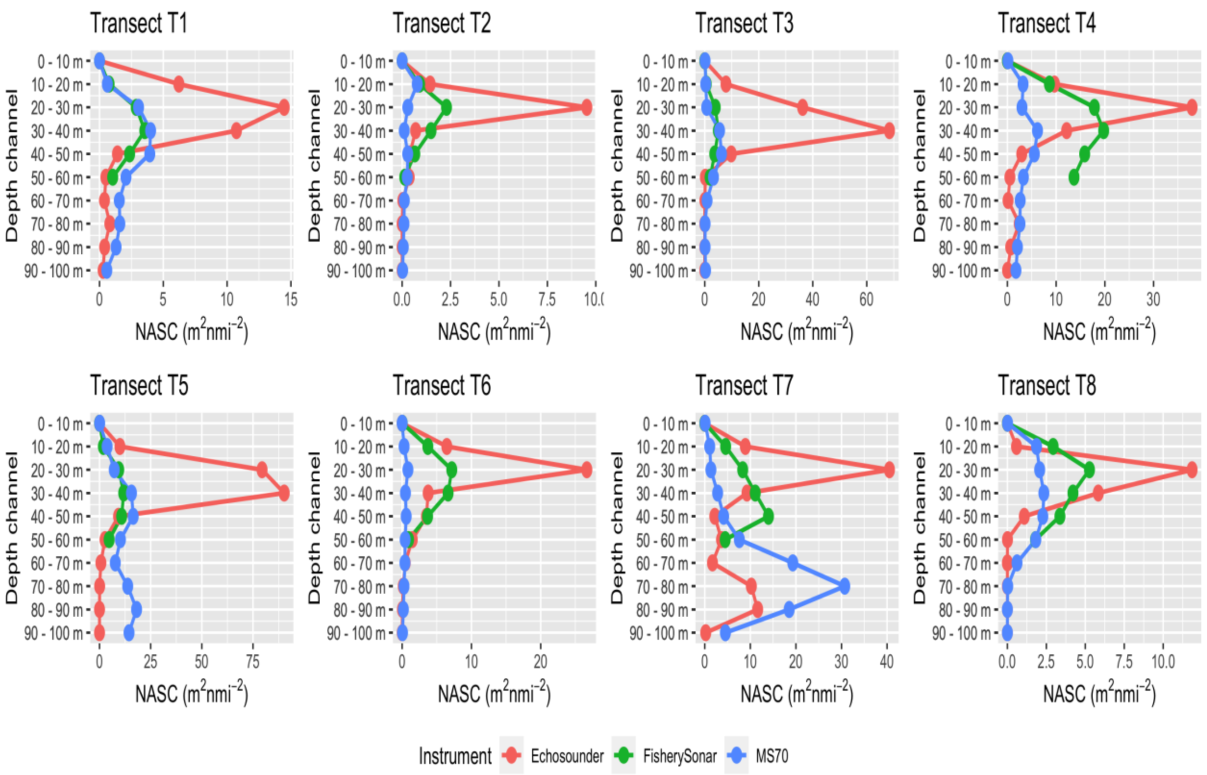


Figure 3. Vertical distribution of Transects T1 – T8 from the 2020106 Norwegian Sea ecosystem survey for echosounder (EK80 - red), fishery sonar (SU90 – green), matrix sonar (MS70 – blue).

Figure 2 was used to select transect with large herring abundance. Figure 4 shows the vertical distribution from surface down to 200 m depth. The horizontal distance from the ship is 50 – 200 m. The integrated acoustic abundance (integral under the curves) are not very different, but MS70 finds most of the abundance deeper than the EK80. This is somewhat surprising as the MS70 is designed to detect schools all the way up to the surface.

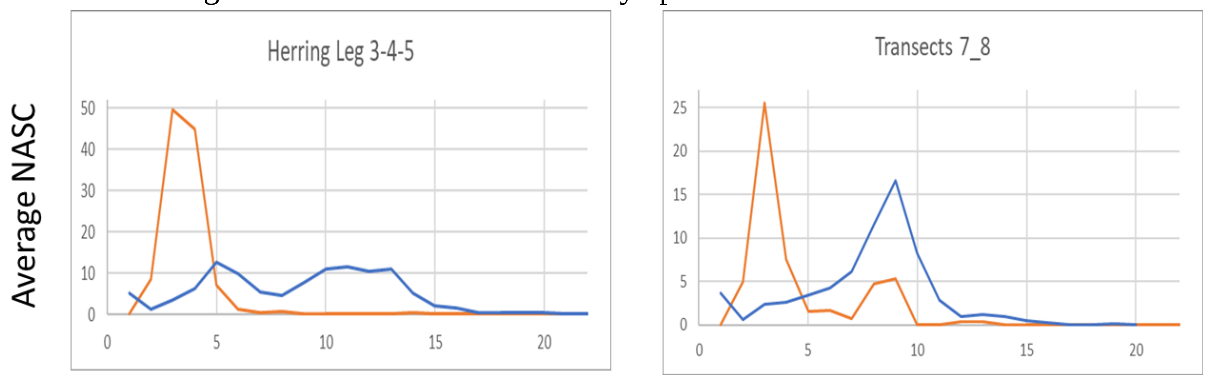


Figure 4. Survey 2020106. Vertical distribution of herring NASC values from echo sounder (red) and MS70 sonar (blue) for transects 3-5 (left panel), 7-8 (right panel). Depth channel 1 (horizontal axis) is 0 – 10 m below sea surface, depth channel 2 is 10 – 20 m (and so on). The MS70 data is based on data from 50 m – 200 m horizontally from the ship, and down to 200 m depth (centre beam).

As a reminder from previous Ecosystem surveys from the Norwegian Sea, Figure 5 shows the vertical distribution from 3 selected transects, and Figure 6 visualize an image from MS70. Figures 5 and 6 shows that MS70 should be able to see schools of fish close to the surface. As shown in Figure 5 (2019 survey), the surface noise on the MS70 sonar propagates below 20 m depth in transect S2019107-T10 (red layer in the lower panel, frame "MS70-Phantom"), intersecting with the large peak in the vertical distribution of the echosounder. In transect S2019107-T8 the surface noise is negligible.

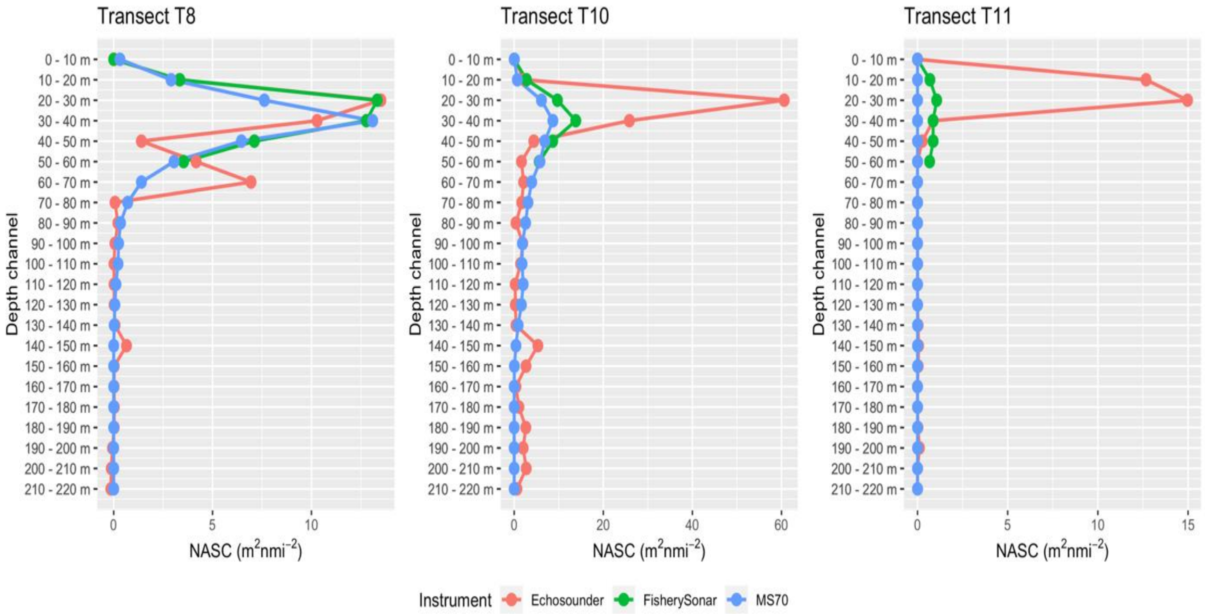
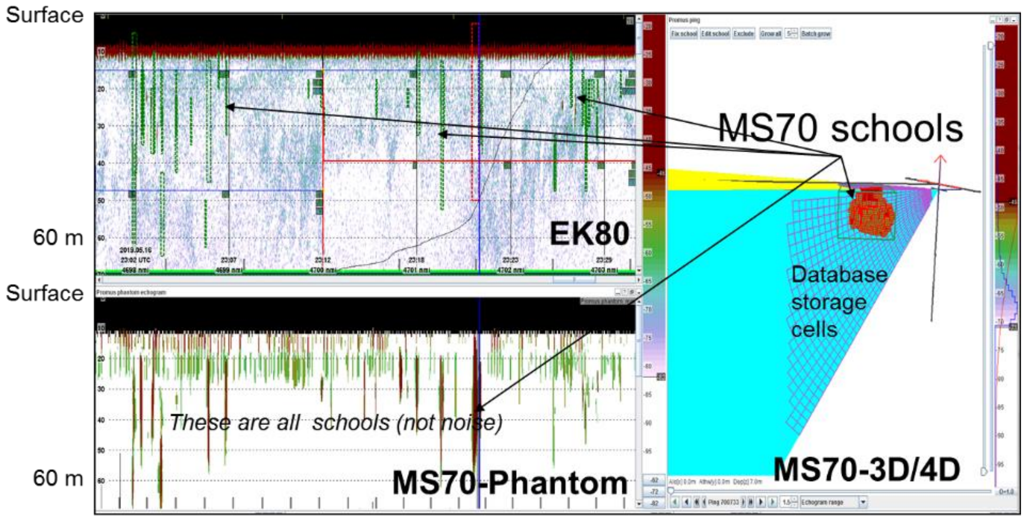


Figure 4. Survey 2019107. Vertical distribution of herring NASC values from echo sounder (red), fishery sonar (green) and MS70 sonar (blue) for transects 8 (left panel), 10 (middle panel), 11 (right panel).



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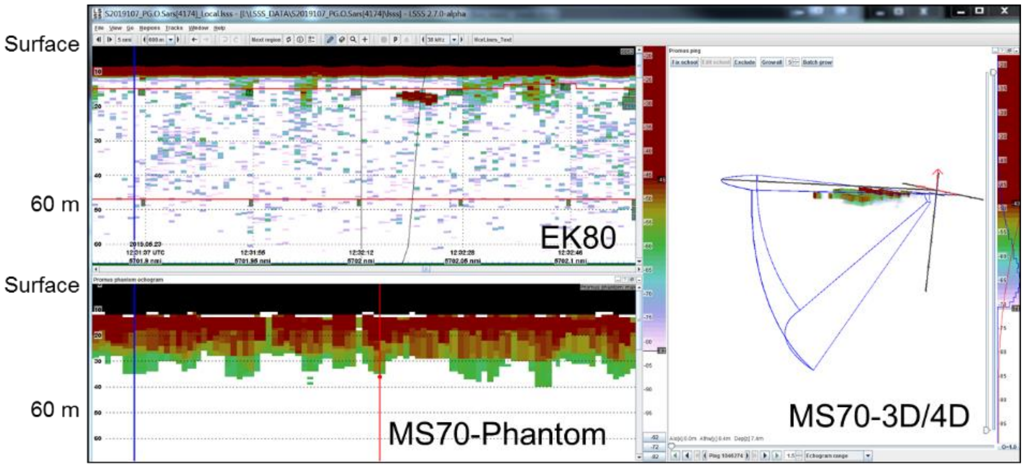

Figure 5. From survey S2019106. Screen dump from the Large Scale Survey System (LSSS), showing echosounder echogram (upper left frame), MS70 phantom echogram (lower left frame) and 3-D view of the MS70 sonar (right frame) of transect T8 (upper panel) and T10 (lower panel). In T8 there were some schools found in EK80, and many in MS70 (some "onto" the surface). In T10, the weather was bad, so the upper school detection depth was 20m. In T10, the weather was very bad, which explains very few detections of MS70.

Discussion

The vertical distribution from echosounder and the fishery sonar and MS70 sonar showed discrepancies in the level depending on the transects. On average the sonars fail to return a peak at the same level as the echosounder. This discrepancy illustrates a fundamental issue with sonar data, which is related to the width of the sonar beams. When observing a near surface school, separation of school and surface noise can be challenging, which could result in exclusion of these schools from the vertical distribution

The sonar data were scrutinized in terms of schools of a required size. The echosounder data can in contrast include all data down to single targets, as long as the data are categorized in acoustic categories representing species. If there are aggregations of individual fish and small schools at certain depths, this difference in post-processing can lead to bias in the vertical distribution from the sonars. This can in particular be a problem close to the surface, where small schools are more likely to be excluded from the sonar scrutinization than larger schools.

The vertical distribution from the echosounder did not show any strong signs of avoidance to the vessel in this survey, with a peak in the vertical distribution starting at 10 m depth and reaching a maximum in the interval 20 to 30 m depth. As such, these data serve as a useful example to comparing vertical distribution from the different instruments, as the avoidance, which is generally unknown, will not affect the comparison. Given that the echosounder performs equally well or better than the sonars as indicator of biomass in the upper 30 meters, there is no strong cause for using sonar to assist the survey estimation. Note, however, that the school depths found by the sonars are estimated from the centre of the beam. Although this is a good estimate of depth for most beams, it also prevents registering schools at the shallowest depths. For MS70, the two uppermost beams were cut at some range, so that a school on the surface 150 m from the transducer would be registered at 20 m depth. Results from calmer weather during this survey showed that MS70 could in fact measure schools onto the surface. Thus, methods to visualize shallow schools need to be developed.

IESNS post-cruise meeting, webex 16-18/6 2020

The methods presented in this study for estimating vertical distribution from sonars can be applied to other surveys where reactions to the research vessel may be stronger than in the IESNS survey from 2019 used in this study. In calm weather the sonars appear to compare well to the echosounder in terms of vertical distribution. In rough weather scrutinization of sonar can however be challenging, and further development should focus on improving separation of fish and noise in these conditions.

Difference in scrutiny of EK80 and MS70

Is the difference in depth distribution close to the surface measured with EK80 and MS70 be due to how data are scrutinized or the ability to measure, or is there maybe another reason? Is the difference in depth distribution at depths 50 – 100 m as measured with EK80 and MS70 due to how data are scrutinized or the ability to measure? These are not easy questions to answer.

1) The EK80 data were scrutinized by the cruise-leader and the instrument engineer close to the time of data collection, all in accordance with procedure for interpreting acoustic data.
2) The MS70 data were scrutinized by one scientist. From May 20, the data were scrutinized shortly after collection, while data prior to May 20 were scrutinized after May 20.
3) Candidates for schools measured by means of MS70 was automatic detected. There were a set of criteria for detection of schools, e.g. a minimum size of schools. The data were inspected by the scrutinizer. Herring was expected to dominate the abundance of schools at shallow depths, and down to 200 m. A criterium for allocating acoustic values to herring was scattering strength, but it turned out to be surprisingly difficult to identify which schools were herring, from what was thought to be likely zooplankton. The sonar does not measure relative frequency response.
4) The EK80 data close to the surface were to a large extent layers, i.e. not schools. They were not seen clearly on the echogram but were still interpreted to be herring due to catches.
5) Catches could be directed by EK80, but in practice not by MS70.

Annex 5: 2020 HERAS Survey Summary Table and Survey Report

Document 5a: HERAS 2020 survey summary table

Survey Summary table WGIPS 2021	
Name of the survey (abbreviation):	HERAS
Target Species:	Herring and sprat
Survey dates:	22 June – 25 July 2020
Summary:	

The 2020 survey covered planned strata and survey effort, timing and coverage were mainly comparable to previous years and all main aggregations of sprat and herring are considered to have been sampled sufficiently. The German survey areas were not covered in full in strata 51, 71 and 131, as one transect had to be dropped in each strata. This was due to adverse weather conditions. The transect distance was increased in these strata to ensure uniform coverage, and this did not affect the StoX analysis and subsequent abundance estimation significantly as the CVs were in accordance with earlier years.

Comprehensive trawling was carried out over the course of the survey providing good confidence in school recognition and supporting biological data for age stratified abundance estimation of the target species in almost all strata. With the low stock size in the western area it has been difficult to secure catches in this area in recent years and this could potentially affect the accuracy of the stock composition estimates for West of Scotland and Malin Shelf herring.

Distribution of herring in the North Sea area is similar to that seen in 2017-2019 though it did not extend as far south as in the years prior to 2017. Abundance of NSAS herring was slightly lower compared to recent surveys in the North Sea area. The abundance of the 2016 year class (age 3 winter ring) of herring continues to be very low. The maturity level of age 2 wr increased from a very low level (37% and 59%) in 2018-2019 to 75% in 2020, which is above average.

The WBSS herring abundance estimate was 16% higher than last year's estimate, but is still among the lowest estimates of the time series. More biological sampling was achieved in the Malin Shelf survey area in 2020, an improvement on recent years. There was herring found in all strata. There were samples obtained in all strata apart from the Minch, including genetic sampling which may be used for stock splitting in the future. The CV on the estimate for the Malin Shelf survey in 2020 was 0.23, an improvement on the 2019 estimate of 0.41. There was an increase in juvenile/immature herring estimate in this area in 2020, however these are not considered reliably estimated in this survey. Increased trawling overall in 2020 provided good confidence in school recognition and supporting biological data for age stratified abundance estimation of herring in most strata, however there were still low numbers of hauls in some strata. With the very low stock size in recent years in the Malin Shelf area it has been more difficult to secure catches, potentially affecting the accuracy of the stock composition estimates for West of Scotland and Malin Shelf herring. Sprat was also encountered within the expected areas. Abundance estimates in the North Sea were lower than in 2019, whereas in Div. 3.a at a similar level and in both areas above the long-term average. The estimates derived from the 2020 survey are considered to be valid for most stocks and consistent with those in each time series.	

	Description
Survey design	Stratified systematic parallel design with randomised starting point within each stratum.
Index Calculation method	StoX (via ICES database) is used to provide indices of abundance. StoX calculated abundances in strata covered by Norway (strata11 and 141) are split by proportion WBSS and NSAS following the Norwegian national method that has been used for the whole time series before being combined with StoX calculated abundances from all other strata.
Random/systematic error issues	No specific issues for this survey outside of those described for standardised acoustic surveys.

Specific survey error issues (acoustic)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Bubble sweep down	2020: OK Not generally an issue. During severe weather survey effort was paused in most strata until conditions improved.
Extinction (shadowing)	2020: OK Target species not thought to aggregate in dense enough schools to produce extinction effects.
Blind zone	2020: OK Target species typically not found in large quantities this close to the surface in this area (herring and sprat). It could be a problem in the Norwegian strata where small feeding schools are found high in the water column and when surveying 24h (NOR, DK). This has been consistent throughout the time series and should thus not be a problem for the indices.
Dead zone	2020: OK Target species (herring and sprat) typically not distributed tight to seabed, and thus not a problem.
Allocation of backscatter to species	2020: OK Species composition verified by directed trawling. Allocation of backscatter to species mainly using multifrequency algorithms in LSSS and Echoview.
Target strength	2020: OK Standard agreed (TS = 20 log L - 71.2 dB herring and sprat)

Calibration	2020: OK Survey frequencies calibrated during survey according to SISP and results within recommended tolerances.
Specific survey error issues (biological)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Stock containment	2020: OK Other surveys often see herring slightly north of our survey area in small amounts. This could be North Sea autumn spawning herring but assumed not to influence our indices significantly. This is evaluated annually by data from the other surveys.
Stock ID and mixing issues	2020: OK WBSS and NSAS herring mix in the North Sea and Skagerrak-Kattegat, and the stocks are split east of 2°E and north of 56°N. Some WoS and Norwegian spring spawning herring might also be found the North Sea. Work is progressing to develop practical methods for assigning each individual to the correct stock that can be standardised across the survey area.
Measures of uncertainty (CV)	MSHAS – 0.23
Biological sampling	2020: OK The number of trawl stations are considered sufficient. Herring and sprat were measured and aged at a similar level as the past few years. Recent results from the herring assessment working group indicate that this may not be adequate for herring.
Were any concerns raised during the meeting regarding the fitness of the	*To be answered by Assessment Working Group*

survey for use in the assessment either for the whole times series or for individual years? (please specify)	
Did the Survey Summary Table contain adequate information to allow for evaluation of the quality of the survey for use in assessment? Please identify shortfalls	*To be answered by Assessment Working Group*

Document 5b: HERAS 2020 survey report

Please see the report on the next page.

The 2020 ICES Coordinated Acoustic Survey in the Skagerrak and Kattegat, the North Sea, West of Scotland and the Malin Shelf area

Susan Mærsk Lusseau[6], Steven O'Connell[1], Bram Couperus[2], Benoit Berges[2], Michael O'Malley[3], Norbert Rohlf[4], Matthias Schaber[4], Cecilie Kvamme[5], Florian Berg[5] and Karl-Johan Staehr[6]

[1] Marine Scotland Science, Marine Laboratory, Aberdeen, Scotland, UK
[2] Wageningen Marine Research, IJmuiden, The Netherlands
[3] Marine Institute, Galway, Ireland
[4] Thünen Institute of Sea Fisheries, Bremerhaven, Germany
[5] Institute of Marine Research, Bergen, Norway
[6] DTU-Aqua, Hirtshals, Denmark

Six surveys were carried out during late June and July covering most of the continental shelf in the North Sea, West of Scotland and the Malin Shelf. The surveys are presented here as a summary in the report of the ICES Working Group for International Pelagic Surveys (WGIPS) and component survey reports are available individually on request. The global estimates of herring and sprat from these surveys are reported here. The global survey results provide spatial distributions of herring and sprat and total abundance by number and biomass at age as well as mean weight and fraction mature at age.

The estimate of North Sea Autumn Spawning herring spawning stock biomass is lower than previous year at 1.7 million tonnes (2019: 1.9 million tonnes) due to a decrease in the number of fish (2019: 10 295 million fish, 2020: 8 915 million fish).

The 2020 estimate of Western Baltic Spring Spawning herring 3+ group is 103 000 tonnes and 667 million. This is an increase of 39% and 16%, respectively, compared to the 2019 estimates of 74 000 tonnes and 574 million fish.

The West of Scotland herring estimate (6.a.N) of SSB is 158 000 tonnes and 943 million individuals, a large increase compared to the 76 000 tonnes and 406 million herring estimate in 2019.

The 2020 SSB estimate for the Malin Shelf area (6.a and 7.b, c combined) is 226 000 tonnes and 1 435 million individuals. This is higher than the 2019 estimates (128 000 tonnes and 740 million herring). There were again low numbers of herring found in the northern strata (to the north of Scotland and east to the 4˚W line) in 2020, which is similar to 2019. There were significant numbers of herring distributed south of 56°N again in 2020, dominated by immature herring.

For consistency, the survey results continue to be presented separately for sprat the North Sea and Skagerrak-Kattegat in this report although these two stocks were combined in a benchmark in 2018 (ICES 2018).

The total abundance of North Sea sprat (Subarea 4) in 2020 was estimated at 67 055 million individuals and the biomass at 531 000 tonnes (Table 5.10). This is a decrease from last year, but slightly above the long-term average of the time series, in terms of both abundance and biomass. The stock is dominated by 1- and 2-year-old sprat (92% in biomass). The estimate includes 0-group sprat (19% in numbers, and 2% in biomass), which only occasionally is observed in the HERAS survey.

In Div. 3.a, the sprat abundance in 2020 is estimated at 4 282 million individuals and the biomass at 39 900 tonnes. This is the second highest estimate of the time series in terms of biomass, and well above the long-term average both in terms of abundance (107%) and biomass (52%). The stock is dominated by 1-year-old sprat.

1 Introduction

Six surveys were carried out during late June and July covering most of the continental shelf north of 52°N in the North Sea and to the west of Scotland and Ireland to a northern limit of 62°N. The eastern edge of the survey area was bounded by the Norwegian, Danish, Swedish and German coastline and to the west by the shelf edge at around 200 m depth. Individual survey reports from participants are available on request from the nation responsible. The vessels, areas and dates of cruises are given in Table 5.1 and in Figure 5.1.

Table 5.1. Vessels, areas and cruise dates during the 2020 herring acoustic surveys.

VESSEL	PERIOD	CONTRIBUTING TO STOCKS	STRATA
Celtic Explorer (IRL) EIGB	22 June - 12 July	MSHAS, WoS	2, 3, 4, 5, 6
Scotia (SCO) MXHR6	3 July – 25 July	MSHAS, WoS, NSAS, Sprat NS	1, 91 (north of 58°30'N), 111, 121
Johan Hjort (NOR) LDGJ	27 June – 14 July	NSAS, WBSS, Sprat NS	11, 141
Tridens (NED) PBVO	25 June - 12 July	NSAS, Sprat NS	81, 91 (south of 58°30'N), 101
Solea (GER) DBFH	29 June – 19 July	NSAS, Sprat NS	51, 61, 71, 131
Dana (DEN) OXBH	25 June – 09 July	NSAS, WBSS, Sprat NS, Sprat 3.a	21, 31, 41, 42, 151, 152

2 Methods

Survey design and acoustic data collection

The acoustic surveys were carried out and analysed in accordance with the ICES survey manual for International Pelagic Surveys (ICES 2015) using Simrad EK60 and EK80 echosounders with transducers mounted either on the hull, drop keel or in towed bodies. Only data gathered at 38kHz was used for the analysis. Data collected at other frequencies was used for target discrimination. Echo integration and further data analyses were carried out using either LSSS (Large Scale Survey System; Korneliussen et al., 2006), Echoview (Echoview Software Pty Ltd, Hobart, Australia) or Ev2Akubio software (local DTU Aqua software).

The survey is designed to be analysed using StoX (Johnsen et al 2019) with a set of strata surveyed with a grid of evenly spaced parallel transects (Figure 5.1-5.2). The survey area is divided into 23 strata with randomized starting point for the grid of transects within each stratum and with transects running perpendicular to lines of bathymetry where possible (Figure 5.1 and 5.2). The transect spacing in the strata ranges from 10 to 30 nautical miles (nmi.) (Table 5.18). The relative effort (and therefore the transect spacing) in each stratum was determined based on the mean abundance and variance in each of the strata during surveys in the most recent 10 years prior to the new design being implemented (2005 – 2015) and the strata classed as high, medium and low effort (ICES 2016).

A total of 9553.5 n.mi of track covered during the survey was used in the acoustic analysis, achieving good coverage of the entire survey area. Due to a loss of survey time through inclement weather at several instances, the overall transect length had to be reduced in the strata 51, 71 and 131 covered by Germany. One transect in each of these strata was dropped and the reduced number of transects were spaced evenly in each stratum. This allowed full and even coverage in each of the affected strata but with increased transect spacing.

Scrutiny of acoustic data

In the Dutch, Irish, Norwegian and Scottish survey, scrutiny of hydroacoustic data during post-processing is done to individual species level and species-specific NASC values are uploaded to the ICES database[1]. In the German survey area, clupeids usually do not occur in single species schools but in comparatively clearly distinguishable mixed aggregations. Post-processing of hydroacoustic data is therefore based on an aggregated CLU category, except for regional occurrences of "clean" schools (e.g. of sardine) or mixed catches of such together with other species (horse mackerel, mackerel, other clupeids) as verified by trawl catches. In these cases, a species-specific (e.g. PIL) or a combined MIX category is allocated to the respective echoes. Accordingly, depending on regional observations and catch composition, also clupeid species can be included in a MIX category. The allocation of spatially limited observations and catches of e.g. sardines and anchovies to a species-specific or a combined category is followed to avoid overestimating the contribution of these species in the stratum in including them in the CLU category.

In the Danish survey it is only distinguished between fish and no fish in the post-processing of hydroacoustic data. A corresponding MIX category is allocated to all fish-echo traces and disaggregation of hydroacoustic data is based on total catch composition on a transect level.

The composition of both the MIX categories in the Danish and German surveys and the CLU category in the German survey vary according to catch composition on the corresponding transects. All disaggregation steps of mixed acoustic categories to individual species in the German and Danish data are conducted using a Split-NASC project/module in the StoX software (Johnsen et al 2019), where all categories employed are clearly defined. The resulting NASC values attributed to herring and sprat are subsequently included in the overall analysis.

For both splitting/disaggregating of hydroacoustic data as well as further analyses of disaggregated data (stock estimates), the following target strengths were used for clupeids (ICES, 2015):

Herring, sprat, sardine, anchovy TS = 20 log L - 71.2 dB

Data analysis

The 2020 disaggregated biological and acoustic data were delivered to the acoustic survey database[1] held at the ICES data centre and the data was analysed using the StoX analysis software (Johnsen et al 2019).

Acoustic and biological data were combined to provide an overall global estimate. Estimates of numbers-at-age, maturity stage and mean weights-at-age were calculated by individual survey stratum (Figure 5.1). The data were combined to provide estimates of the North Sea Autumn Spawning herring, Western Baltic Spring Spawning herring, West of Scotland (6.a.N) herring and Malin Shelf herring stocks (6.a.N-S and 7.b-c) as well as sprat in the North Sea and 3.a.

1 https://www.ices.dk/marine-data/data-portals/Pages/acoustic.aspx

3 Stock definitions

North Sea Autumn Spawning herring (NSAS)

Includes all herring encountered in the North Sea between 4°W and 2°E and south of 56°N [56.5°N between 2-6°E] (strata 71, 81, 91, 101, 111, 121 in Figure 5.1). East of 2°E and north of 56°N [56.5°N between 2-6°E], in strata 11, 141, 151, 152, 41, 42, 31 and 21, herring is split into North Sea Autumn Spawning herring and Western Baltic Spring Spawning herring (Figure 5.1). In strata 11 and 141 this is based on analysis of number of vertebrae and in strata 21, 31, 41, 42, 151 and 152, otolith shape analysis.

Western Baltic Spring Spawning herring (WBSS)

The allocation to the Western Baltic Spring Spawning herring stock is partly a geographical assignment and partly a biological assignment based on the vertebrae and otolith shape analysis mentioned above. The geographic limits of the stock in this survey are defined as strata 11, 21, 31, 41, 42, 141, 151 and 152 and the stock splitting methodologies are only applied within these strata (Figure 5.1).

Malin Shelf Herring (MSHAS)

Includes all herring in the stock complex located in ICES areas 6.a and 7.b, c. The survey area is bounded in the west and north by the 200m depth contour, in the south by the 53.5°N latitude, and in the east by the 4°W longitude (strata 1 - 6 in Figure 5.1). The survey targets herring of 6.a.N and 6.a.S spawning origin in mixed feeding aggregations on the Malin Shelf. Work is being concluded to split the abundance and biomass estimates by spawning origin (6.a.N vs 6.a.S). The differentiation between 6.a herring and North Sea herring across the 4°W line of longitude is purely based on geography.

West of Scotland herring (6.a.N)

This is a subset of the Malin Shelf herring abundance\biomass estimate based purely on geographical location (strata 1 - 4 in Figure 5.1). All herring recorded north of the 56°N line of latitude are reported as West of Scotland (6.a.N). This distinction is kept to maintain a comparable time series of herring abundance to the West of Scotland. The area North of the 56°N line of latitude has been covered annually since 1991 whereas the extended area (MSHAS index) has been covered since 2008.

North Sea and Div. 3a sprat

The sprat benchmark in November 2018 (ICES 2018) decided that sprat in these two areas should be assessed as one stock from now. In this survey report, the results are still presented separately for these two areas for consistency. The indices should be summed for use in the sprat assessment.

All sprat recorded in the North Sea geographical area (ICES Subarea 4) are included in the North Sea sprat survey estimate. Sprat is however very rarely recorded in the northern part (strata 11, 91, 111, 121 and 141 in Figure 5.1).

Sprat in 3.a. All sprat in strata 21, 31, 41 and 42 are included in this index.

The border between ICES Div. 3.a and Subarea 4 was revised in 2015. The new border has been used for index calculation since 2015, but prior to this the old border was used to delineate the stocks.

4 Acoustic Survey Results for 2020

The survey strata used for the analysis are shown in Figure 5.1. The area covered during the national acoustic surveys is given in Figure 5.2, and magnitudes of acoustic herring and sprat detections (NASC, Nautical Area Scattering Coefficients) for 5 nmi. intervals are given in Figures 5.3 and 5.4, respectively. The survey provides numbers at age for the different herring and sprat stocks (North Sea Autumn Spawning herring, Western Baltic Spring Spawning herring, West of Scotland herring, Malin Shelf herring, sprat in the North Sea and Div. 3.a) and the time series of these are given in Figures 5.5-5.10. The time series of abundance for the four herring stocks (North Sea Autumn Spawning herring, Western Baltic Spring Spawning herring, West of Scotland and Malin Shelf herring) are given in Tables 5.6 – 5.9 and illustrated in Figures 5.11 - 5.14, respectively. The time series of abundance for sprat in the North Sea and Div. 3.a are given in Tables 5.11 and 5.13. In each of them, a 3-year running mean is included to show the general trend more clearly.

Herring

The NASC values attributed to herring throughout the HERAS survey are shown in Figure 5.3.

The largest aggregations of adult herring in the North Sea was concentrated in the areas to the east of the Shetland Isles, extending south between 2°W and 2°E to app 58.25°N (Figure 5.3). Adult herring was also encountered in concentrations in the deeper parts of Skagerrak. This distribution is similar to that seen since 2017 and does not extend as far south as was the norm in the years prior to 2017. This year the aggregations were further concentrated in the main area with very little herring encountered to the north and west of the Shetland isles. Juvenile herring were seen primarily in the usual distribution in the eastern parts of the North Sea and in the western Skagerrak and Kattegat as well as in the central North Sea.

The estimate of **North Sea** Autumn Spawning herring spawning stock biomass has decreased again by 11% from 1.9 million tonnes in 2019 to 1.7 million tonnes this year (Table 5.6, Figure 5.11).

The abundance of mature fish has decreased from 10 295 million in 2019 to 8 915 in 2020 (Table 5.2). The mean weight of mature fish is similar to last year at 192.6 g and the decrease in biomass follows directly from a decrease in numbers. The 2012- and 2013- year classes (age 6 and 7 winter ring now) continues to be stronger than the long-term average. The 2014-year class (5 wr in 2020) has been estimated to be well below average so far and this year, at age 5 wr in 2020, it is of average size. The 2016-yearclass (3-wr in 2020) continues to be very weak with abundance at only 37% of the long-term average level.

The abundance of immature fish in the stock has decreased from 15 265 million in 2019 to 14 851 million this year. In recent years 2 winter ring fish have contributed substantially to the abundance of immature fish. However, this year the maturity level was high for this age group (75% mature in 2020; 59% mature in 2019) and although the abundance of 2 winter ringers was twice the abundance in 2019, the high maturity level meant this age group contribute mainly to the mature fish abundance this year. (Table 5.6, Figure 5.5).

The proportion mature at 2 winter rings this year at 75% is at the high end in the time series. Maturity of 2 winter ringers was at an all-time low in 2018 at 37%. Maturities for ages 3 and above were comparable to the long-term average, with 98% of 3 winter ringers and 99% or higher maturity for all ages 4 and above (Table 5.2). Since 2015 observed maturities are reported for all age groups, previously maturity was fixed at 100% for ages above 4 wr.

The 2020 estimate of **Western Baltic** Spring Spawning herring 3+ group is 103 000 tonnes and 667 million herring (Table 5.3). This is an increase of 11% compared to 2019, but still below the average from 2009 onwards (716 million herring). The 2019 estimate was 574 million, whereas the 2017 estimate was the highest level observed since 2008 (1 353 million) and comparable to the stock size prior to the low levels observed after 2008. The stock is dominated by 1 and 2 winter ring fish (Table 5.7, Figure 5.6). The numbers of older herring (3+

group) accounts for 38% of the total stock. This is comparable to the period 2009 to 2019 where the 3+ group on average accounted for 37% of the stock. Mean weights were between 21% to 69% higher for ages 1 to 5 wr in 2020 compared to 2019, but more similar to 2019 for older fish.

The **Malin Shelf** (6.a.S) herring estimate of SSB is 226 000 tonnes and 1 435 million individuals (Table 5.5), an increase compared to the 128 000 tonnes and 740 million individual herring estimate in 2019. The estimate is the largest since 2015 when it was 430 000 tonnes (Table 5.9, Figure 5.14). In 2020, 60% of the total biomass (TSB) was observed north of 56°N (the geographic area included in the West of Scotland (6.a.N) index) and 70% of the SSB. Herring were again more widely distributed throughout the survey area in 2020, similar to the distribution seen in 2019. The **West of Scotland** (6.a.N) herring estimate of SSB is 158 000 tonnes and 943 million individuals (Table 5.4), a significant increase compared to the 76 000 tonnes and 406 million herring estimate in 2019. The time-series of indices of abundance per age class for West of Scotland herring are provided in Table 5.8 and Figure 5.7.

There was an increase in the 2020 estimates for the **Malin Shelf (6.a.S) and West of Scotland** (6.a.N) herring compared to 2019, but the estimates since 2016 are still the lowest in the time series. The distribution of herring schools was similar to 2019 with more herring distributed south of 56°N line of latitude (Figure 5.3a). There were also some strong herring marks found to the west and northwest of the Outer Hebrides and around St. Kilda in 2020. Large amounts of juvenile herring were found north of Malin Head and northwest of the Outer Hebrides. Adult herring schools were found in deeper water west of Malin Head, around Stanton Bank and west of the Outer Hebrides. Most of the herring in Stratum 1 were found in the North East of the stratum. Herring has in the past been found in high densities to the east of the 4°W line to the north of Scotland in association with a specific bathymetric feature and the occurrence of these herring west of the line in some years has the ability to strongly influence the annual estimate of abundance of the Malin Shelf/West of Scotland estimates. There is some evidence that this was the case in 2020. It appears that the increase in estimates since 2016 were a result of a greater spread in the distribution of herring rather than distributions occurring around the 4°W line a similar pattern seems to have occurred in 2020.

The Malin Shelf survey estimate was dominated by 1- and 2- winter ringers (2019 and 2018 year classes), making up 66% of the total abundance and 51% of the total biomass. Immature herring made up 45% of the total biomass. The 2014-year class (6 winter rings in 2020) is still strong in the stock and comprised 6% of total abundance and 10% of the biomass. Age disaggregated survey abundance indices for Malin Shelf herring since 2008 are given in Table 5.9 and Figure 5.8.

Sprat in the North Sea and Div. 3.a

In the North Sea, sprat data were available from strata 51, 61, 71, 81, 91, 101, 131, 141 and 151 (Table 5.17). Highest sprat densities were measured in the southern part of the survey area (51 and 61), with the highest abundances and biomass in an area below 54.5° N. The southern limit of the surveyed area is at 52° N. There is no indication that the southern limit of the sprat stock distribution has been reached; it is likely that sprat can be found even further south in the English Channel.

The sprat distribution in the North Sea and Div. 3.a in terms of abundance and biomass per stratum is shown in Table 5.17. The NASC values attributed to sprat in the survey are shown in Figure 5.4.

The total abundance of sprat in the North Sea (Subarea 4) in 2020 was estimated at 67 055 million individuals and the biomass at 531 000 tonnes (Table 5.10). This is slightly above the long-term average of the time series in terms of both abundance and biomass. Compared to the 2019 estimate, abundance and biomass are 46% and 40% lower, respectively (Table 5.11, Figure 5.9). The estimate was dominated by 1- and 2-year-old sprat (92% of biomass), and 60% of the sprat were found to be mature (Table 5.10). The 2020 estimate is above (14%) the long-term average for the survey (Table 5.11).

An age-disaggregated time-series of abundance and biomass of sprat in the North Sea (ICES Subarea 4), as obtained from the acoustic survey, is given in Table 5.11.

In Div. 3.a, sprat in stratum 21 (Kattegat) dominated the estimate (62% of the abundance, and 60% of the biomass), but sprat were also found in strata 31 and 42 in the Skagerrak area (strata 31, 41 and 42). In 2018 and 2013, sprat were only found in the Kattegat. The abundance is estimated at 4 282 million individuals, 62% higher than the 2 645 million individuals in 2019 (Tables 5.12-5.13). The biomass was 4% higher than in 2019, at 39 900 tonnes. 1-year-old sprat dominate the stock (86% in numbers and 79% in biomass). The age-disaggregated time-series of sprat abundance and biomass in Div. 3.a are given in Table 5.13 and Figure 5.10. The sprat distribution in the North Sea and Div. 3.a in terms of abundance and biomass per stratum is shown in Table 5.17. The NASC values attributed to sprat in the survey are shown in Figure 5.4.

5 Quality considerations

The 2020 HERAS global survey estimates of abundance were calculated using StoX (Johnsen et al., 2019), with input files (XML) mostly generated via the ICES Acoustic database[2]. The delivery of disaggregated acoustic and biological data to the group continues to be considered an improvement to the survey analysis as it allows a level of transparency and discussion on data collection and standardisation issues not readily achieved before.

The 2020 survey covered planned strata and survey effort, timing and coverage were mainly comparable to previous years and all main aggregations of sprat and herring are considered to have been sampled sufficiently.

In strata 51, 71 and 131, covered by Germany, one planned transect in each had to be dropped due to survey time constraints caused by several days of inclement weather. However, in increasing the transect spacing accordingly a full and consistent coverage of the corresponding strata was achieved. Since the distribution patterns of clupeids in these strata (based on spatial echo intensity measured) was similar and comparable to the measurements recorded in previous years, and since the pattern observed in general corresponded with the expected distribution based on long term observations from the survey time-series, stock containment was expected to remain achieved in these strata and no adjustments were made. Increasing transect distance does not appear to have affected the StoX analysis and subsequent abundance estimation significantly, as the CVs were in accordance with earlier years (Figure 5.18).

More biological sampling was achieved in the Malin Shelf survey area in 2020, an improvement on recent years. There were samples obtained in all the relevant strata, including genetic sampling which may be used for stock splitting in the future. The CV on the estimate for the Malin Shelf survey in 2020 was 0.23, an improvement on the 2019 estimate of 0.41. There was an increase in juvenile/immature herring estimate in this area in 2020, however these are not considered reliably estimated in this survey.

Stock containment

In recent years, herring has been observed in the most northern HERAS transects, suggesting that North Sea herring may now be distributed further north than the area covered by the HERAS survey, but the amount is not currently significant. Other surveys covering the area north of the HERAS area have also detected small amounts of herring in recent years. Genetics sampling of herring in the Norwegian Sea surveys in May and July has also confirmed the presence of NSAS herring north of 62°N. To ensure containment of North Sea herring in the northern part of the HERAS survey we suggest using data from summer surveys covering the most northern part of the North Sea and areas further north. In particular, the Norwegian acoustic saithe survey (NORACU) where the first part co-occurs with the Norwegian part of HERAS, and the second part covers the area between 59-62°N and 1°W to 2°E. NORACU allocate herring for the acoustics, but since herring is not the target species there are no targeted hauls. The trawl hauls targeting saithe though occasionally have good samples of herring, and this survey thus can be used to add an exploratory stratum North of the northern boundary of if the HERAS to monitor the containments (or lack thereof) of North Sea herring. Continued work to include genetic sampling in HERAS as well as adjacent surveys should also be considered.

Good stock containment was achieved in the Malin Shelf area in 2020, biomass that is sometimes observed straddling the 4˚W line was not a significant issue in 2020.

2 https://www.ices.dk/marine-data/data-portals/Pages/acoustic.aspx

Stock splitting methods

At present two different methods are used within the survey to assign herring in the splitting area (otolith microstructure and shape: strata 21, 31, 41, 42, 151, 152, vertebrae count: 11, 141) to the North Sea Autumn Spawning herring stock or the Western Baltic Spring Spawning herring stock. For strata 11 and 141 genetic data for individual herring is available but has not been used this year to split the acoustic abundances. The advantage of genetic data is a more fine-scale discrimination down to the population level compared to the currently used methods. Both methods, otolith microstructure / shape and vertebrae count, are only able to split two stocks. For the next year (2021), all herring in strata 11 and 141 will be split by genetics. The genetic methods need to be standardised and agreed among all nations. The current methods have been developed independently within national laboratories but have not been calibrated against each other so far.

Occasionally, Germany has also conducted analysis of otoliths to deduct stock membership of herring in strata 51, 61, 71 and 131. Only very small amounts of spring spawning herring have been found during this exercise (2 in 2015, 1 in 2016, 3 in 2017, 1 each in 2018, 2019 and 2020, most in strata 71 or bordering it). Historically in the HERAS survey splitting has not been carried out in these strata, and given the very small amount of spring spawning herring detected since the start of this investigation in 2015 no splitting of the acoustic abundances are conducted in the southern area.

The vertebrae count method used by Norway to date does not provide stock information at the individual fish level and it is therefore not possible presently, to analyse the Norwegian component of the survey within an overall StoX project for the two herring stocks. This means that until the genetic splitting method has been fully tested and agreed upon it is still not possible to routinely produce uncertainty estimates for the abundance indices for the WBSS and NSAS herring stocks.

6.a.N and 6.a.S: Work has been ongoing for several years to split the Malin Shelf herring survey into 6.a.N and 6.a.S spawning components using morphological (body and otolith) differences. To date, the successful classification rate has been unsatisfactory using morphometrics, so both stocks of herring are reported as one from this survey. Genetic techniques are presently being investigated to facilitate this split and the emerging results should be considered when ready (EASME, 2020).

Finally, Norwegian Spring Spawning herring is occasionally encountered in the most northern part of the survey area. The genetic techniques used to separate WBSS and NSAS herring in the area can also identify these to stock and Norwegian Spring Spawning herring need consideration in a future splitting scenario.

Survey uncertainty

The use of the StoX software for survey abundance estimation, concurrent availability of disaggregated survey data, and application of a transect-based approach allows for an estimate of survey uncertainty. However, the stock splitting in strata 11 and 141 enforces the use of two separate StoX projects. Deriving StoX uncertainty therefore require the combination of two StoX projects which could not be done with the manual procedure as implemented to date. With the development of automatic routines, it is now possible to estimate CV for abundance at age in each stratum. Such results are shown for the period 2017-2020 for the NSAS and WBSS herring estimates in Figure 5.18 and 5.19, respectively. Overall, there is consistency in CV estimates since 2017 for both NSAS and WBSS herring.

Biological sampling

Increased trawling overall in 2020 provided good confidence in school recognition and supporting biological data for age stratified abundance estimation of herring in most strata, however there were still low numbers of hauls in some strata. With the very low stock size in recent years in the Malin Shelf area has been more difficult to secure catches, potentially affecting the accuracy of the stock composition estimates for West of Scotland and Malin Shelf herring.

The biological sampling strategy (how many individual fish of the target species are measured and aged and how they are selected) is not standardised amongst participants in the HERAS survey, mainly due to historical differences in analysis methods used to work up the partial results from each area. The strategies vary, with some collecting a fixed total number of fish from the catch to sample for age, maturity and stockID, for others a fixed number of fish from each length class are sampled (either the same across the length distribution, or further stratified by length class with a larger number (but still pre-determined) selected from the larger lengths to resolve the age structure better (see Table 5.19 for an overview of sampling strategies used in HERAS).

There is concern that biological sampling effort in some strata is inadequate to satisfy the increasing demands on the survey to provide results for an increasing number of sub-categories with the increased focus on stock splitting using genetic results.

We suggest that a review of the different strategies used and an analysis is carried out in the survey group to determine the effect of the different strategies on the accuracy and precision of the final results (the abundance indices delivered to the assessment process of the stocks). Furthermore, it should be explored what the optimal sampling strategy and level is, given the present situation, but also what is needed with the increased demand for splitting the survey results in the near future.

We suggest a workshop with the nations participating in the HERAS survey as a way forward on this issue.

Scrutiny of acoustic data

In the Dutch, Irish, Norwegian and Scottish survey, scrutiny of hydroacoustic data during post-processing is taken to species level. Based on scattering characteristics of echo-traces as well as catch composition of corresponding targeted trawl catches, a robust allocation of e.g. herring and sprat to echoes originating from detected fish schools and aggregations is feasible. Accordingly, the acoustic categories HER (herring) and SPR (sprat) are allocated to these echo-traces and corresponding NASC values are exported from integration results.

In the German survey area, clupeids mostly occur in mixed schools of "typical" appearance that based on hydroacoustic characteristics and corresponding catch composition from trawl haul rarely allows allocation of a single species category to echo-traces. However, clupeid schools in the area are comparatively clearly distinguishable and an allocation of a general aggregated CLU (clupeid) category is typically feasible. Where Clupeids are found in aggregations with other species a category of MIX is assigned in the database, the precise mix of species being determined from the composition of relevant trawl hauls. The allocation of trawl hauls to acoustic samples are documented in the final StoX split-NASC project for Germany. Finally, a category of echo-traces that are not thought to contain clupeids (UNK) has been used in 2020. This approach is considered to give a robust estimate of the disaggregated, species-specific clupeid NASC distribution in the German survey area.

In the Danish survey scrutiny is only taken to the level of distinguishing between fish or not fish. The echo traces attributed to fish are uploaded to the ICES Acoustic database as the acoustic category MIX and partitioned to species level based on the composition of trawl catches in StoX using the Split-NASC functionality. This approach is not compatible with best practice anymore and it should be possible together with more directed trawling effort to use modern acoustics species discrimination techniques to apply a more detailed allocation. The group notes that issues such as different catchability of species, height of trawl compared to thickness of the water column sampled and the validity of the TS values for some of the less studied species all add to the uncertainty in partitioning the echoes and this method should only be used when there is no other alternative, i.e. when species level scrutiny is not possible due to herring and sprat occurring in truly inseparable mixed aggregations with other species.

Maturity

Since the 2015 survey no assumptions have been made about expected full maturity above a certain age and those actually observed in the surveys are reported in this report. In the past (prior to 2015), fish 5-wr or older were all assumed mature by definition in the reported result. This is a decision that should be made in the assessment working group for each assessment, as the underlying data should be collected and reported as actually observed.

From 2017 the proportion mature at age of WBSS is not reported. Due to the timing of the survey in relation to the spawning time of this spring spawning stock, it would be erroneous to calculate SSB based on observations at this time of the year.

EK80 vs EK60

During this survey, three vessels used the EK80 system in Continuous Wave mode (CW, i.e. narrow band): RV Solea from Germany, RV Johan Hjort from Norway and Tridens II from the Netherlands. The EK80 CW is the successor of the EK60 which was used routinely for acoustic surveys since the 2000s. The system was introduced in 2015 commercially and underwent careful scrutiny by various institutes. Research showed that the results from the EK60 and the EK80 CW are comparable (Demer et al. 2017, ICES 2017a, MacAulay et al 2018, Sakinan and Berges 2020). Macaulay et al. (2018) investigated in depth the performances of the EK60 and the EK80 CW. This was done using ping to ping data collected in 2016 by FRV Tridens II and FRV G.O. SARS (Norway) during the IBWSS survey (Blue Whiting). This work shows that the magnitude of variability between the two systems are smaller than the stochastic variation expected from echosounders. Further investigations have been carried out from the data collected by FRV Tridens II during the HERAS 2017 and 2018 surveys were no significant differences were found in the results from the two systems (Sakinan and Berges 2020). It is important to keep monitoring thoroughly the quality of the results produced by the EK80 system as the system is still relatively new. Despite being available in the market since 2015, the EK80 and associated software still undergo bug fixes (e.g. a bug in the calibration software was fixed in December 2019[3]). The performance of each system used during the HERAS survey was evaluated by considering the consistency of the calibration using the standard spheres method (Demer et al. 2015, Foote et al. 1987). The rms error during the calibration trials is small (< 1dB) and the S_a correction was minor for all systems.

3 https://www.simrad.online/ek80/swrn/ek80_swrn_current_en_a4.pdf

6 Further improvements to survey

1) Efforts to further standardise the HERAS survey should continue.
    a. Scrutinisation in the Danish survey should be reviewed and where possible brought into line with the procedures used by the rest of the survey group.
    b. Assess the various biological sampling strategies used in the survey by different laboratories and develop commonly agreed strategy to achieve adequate resolution of stock, age and maturity composition
2) Continue monitoring of stock containment to the north of stratum 111. This informs whether it is necessary to expand the survey area further north.
3) Provide Sardine and anchovy occurrence at the south of the survey coverage.
4) Extensive check of the national data to be performed prior to the post-cruise meeting in 2021.
5) Work to incorporate genetic sampling and analysis of herring throughout the HERAS area to facilitate splitting the survey estimates into the component stocks using a commonly agreed set of techniques and procedures. This will require extra resources from national laboratories and possibly a series of workshops to agree on methods for collecting and analysing genetics as well as agreements on sampling levels needed to achieve adequate precision.

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Tables and Figures

Table 5.2. Total numbers (millions) and biomass (thousands of tonnes) of North Sea Autumn Spawning herring in the area surveyed in the acoustic surveys June - July 2020. Mean weights, mean length and fraction mature by age winter ring.

Age (ring)	Numbers	Biomass	Maturity	Weight(g)	Length (cm)
0	7178	27	0.00	3.8	8.3
1	7130	315	0.03	44.1	17.5
2	2736	340	0.75	124.3	23.9
3	1156	183	0.98	158.7	26.0
4	1371	261	1.00	190.7	27.4
5	1674	371	1.00	221.9	28.8
6	1666	389	1.00	233.4	29.1
7	504	124	0.99	246.8	29.7
8	164	42	0.99	255.6	30.2
9+	188	50	1.00	268.3	30.7
Immature	14851	387		26.0	13.4
Mature	8915	1717		192.6	27.1
Total	23766	2104	0.38	88.5	18.5

Table 5.3. Total numbers (millions) and biomass (thousands of tonnes) of Western Baltic spring spawning herring in the area surveyed in the acoustic surveys June-July 2020. Numbers, biomass, mean weights and mean length and by winter ring.

Age (ring)	Numbers	Biomass	Weight (g)	Length (cm)
0	9	0	4.6	9.0
1	815	35	43.2	17.4
2	274	23	85.2	21.4
3	225	29	127.0	24.1
4	180	26	145.2	25.1
5	74	13	178.5	26.9
6	77	13	171.9	26.7
7	64	13	201.0	28.4
8+	46	9	198.7	28.2
3+	667	103	154.9	25.7
Total	1764	162	91.7	21.1

Table 5.4. Total numbers (millions) and biomass (thousands of tonnes) of autumn spawning West of Scotland herring in the area surveyed in the acoustic surveys July 2020. Mean weights, mean lengths and fraction mature by winter ring.

Age (ring)	Numbers	Biomass	Maturity	Weight (g)	Length (cm)
0	0	0.0	0.00	0.0	0.0
1	657	41.9	0.00	63.7	19.4
2	579	73.2	0.46	126.3	24.1
3	274	41.3	0.75	150.5	25.3
4	150	25.6	1.00	170.7	26.4
5	83	15.3	1.00	184.3	27.1
6	178	36.0	1.00	201.9	28.0
7	38	8.1	1.00	214.6	28.5
8	13	2.8	1.00	216.5	28.8
9+	10	2.4	1.00	231.1	29.6
Immature	1039	88		85.2	21.0
Mature	943	158		167.4	26.2
Total	1982	246	0.48	124.3	23.5

Table 5.5. Total numbers (millions) and biomass (thousands of tonnes) of Malin Shelf herring (6.a.N-S, 7.b,c) June-July 2020. Mean weights, mean lengths and fraction mature by winter ring.

Age (ring)	Numbers	Biomass	Maturity	Weight (g)	Length (cm)
0	0	0.0	0.00	0.0	0.0
1	1175	68.1	0.00	58.0	19.0
2	1226	142	0.32	115.8	23.4
3	609	85.6	0.68	140.5	24.9
4	235	38.3	1.00	163	26.2
5	110	19.6	1.00	178.4	27.0
6	209	41.1	1.00	196.9	27.8
7	42	8.9	1.00	211.5	28.5
8	18	3.8	1.00	214.2	28.4
9+	10	2.4	1.00	231.1	29.6
Immature	2199	184		83.6	21.0
Mature	1435	226		157.4	25.7
Total	3634	410	0.39	112.8	22.9

Table 5.6. Estimates of North Sea Autumn Spawning herring (millions) at age and SSB from acoustic surveys, 1986–2020. For 1986 the estimates are the sum of those from the Div. 4.a summer survey, the Div. 4.b autumn survey, and the Div. 4.c, 7.d winter survey. The 1987 to 2020 estimates are from summer surveys in Div. 4.a-c and 3.a excluding estimates of Western Baltic Spring Spawning herring. For 1999 and 2000, the Kattegat was excluded from the results because it was not surveyed. Total numbers include 0-ringers from 2008 onwards.

Years / Age (rings)	1	2	3	4	5	6	7	8	9+	Total	SSB ('000t)
1986	1,639	3,206	1,637	833	135	36	24	6	8	7,542	942
1987	13,736	4,303	955	657	368	77	38	11	20	20,165	817
1988	6,431	4,202	1,732	528	349	174	43	23	14	13,496	897
1989	6,333	3,726	3,751	1,612	488	281	120	44	22	16,377	1,637
1990	6,249	2,971	3,530	3,370	1,349	395	211	134	43	18,262	2,174
1991	3,182	2,834	1,501	2,102	1,984	748	262	112	56	12,781	1,874
1992	6,351	4,179	1,633	1,397	1,510	1,311	474	155	163	17,173	1,545
1993	10,399	3,710	1,855	909	795	788	546	178	116	19,326	1,216
1994	3,646	3,280	957	429	363	321	238	220	132	13,003	1,035
1995	4,202	3,799	2,056	656	272	175	135	110	84	11,220	1,082
1996	6,198	4,557	2,824	1,087	311	99	83	133	206	18,786	1,446
1997	9,416	6,363	3,287	1,696	692	259	79	78	158	22,028	1,780
1998	4,449	5,747	2,520	1,625	982	445	170	45	121	16,104	1,792
1999	5,087	3,078	4,725	1,116	506	314	139	54	87	15,107	1,534
2000	24,735	2,922	2,156	3,139	1,006	483	266	120	97	34,928	1,833
2001	6,837	12,290	3,083	1,462	1,676	450	170	98	59	26,124	2,622
2002	23,055	4,875	8,220	1,390	795	1,031	244	121	150	39,881	2,948
2003	9,829	18,949	3,081	4,189	675	495	568	146	178	38,110	2,999
2004	5,183	3,415	9,191	2,167	2,590	317	328	342	186	23,722	2,584
2005	3,113	1,890	3,436	5,609	1,211	1,172	140	127	107	16,805	1,868
2006	6,823	3,772	1,997	2,098	4,175	618	562	84	70	20,199	2,130
2007	6,261	2,750	1,848	898	806	1,323	243	152	65	14,346	1,203
2008	3,714	2,853	1,709	1,485	809	712	1,749	185	270	20,355	1,784
2009	4,655	5,632	2,553	1,023	1,077	674	638	1,142	578	31,526	2,591
2010	14,577	4,237	4,216	2,453	1,246	1,332	688	1,110	1,619	43,705	3,027
2011	10,119	4,166	2,534	2,173	1,016	651	688	440	1,207	25,524	2,431
2012	7,437	4,718	4,067	1,738	1,209	593	247	218	478	23,641	2,269
2013	6,388	2,683	3,031	2,895	1,546	849	464	250	592	36,484	2,261
2014	11,634	4,918	2,827	2,939	1,791	1,236	669	211	250	61,339	2,610
2015	6,714	9,495	2,831	1,591	1,549	926	520	275	221	24,508	2,280
2016	9,034	12,011	5,832	1,273	822	909	395	220	146	51,686	2,648
2017	3,054	1,761	6,095	3,142	787	365	298	153	140	30,055	1,943
2018	9,938	4,254	1,692	5,150	2,440	719	529	293	111	32,606	2,337
2019	10,146	1,303	2,345	1,212	3,506	1,657	395	252	172	25,560	1,919
2020	7,130	2,736	1,156	1,371	1,674	1,666	504	164	188	23,766	1,717

Table 5.7. Numbers at age (millions) of Western Baltic Spring Spawning herring at age (winter rings) from acoustic surveys 1992 to 2020. The 1999 survey was incomplete due to the lack of participation by RV "Dana".

Year/Age	1	2	3	4	5	6	7	8+	Total	3+ group
1992	277	2,092	1,799	1,593	556	197	122	20	10,509	4,287
1993	103	2,768	1,274	598	434	154	63	13	5,779	2,536
1994	5	413	935	501	239	186	62	34	3,339	1,957
1995	2,199	1,887	1,022	1,270	255	174	39	21	6,867	2,781
1996	1,091	1,005	247	141	119	37	20	13	2,673	577
1997	128	715	787	166	67	69	80	77	2,088	1,245
1998	138	1,682	901	282	111	51	31	53	3,248	1,428
1999	1,367	1,143	523	135	28	3	2	1	3,201	691
2000	1,509	1,891	674	364	186	56	7	10	4,696	1,295
2001	66	641	452	153	96	38	23	12	1,481	774
2002	3,346	1,576	1,392	524	88	40	18	19	7,002	2,081
2003	1,833	1,110	395	323	103	25	12	5	3,807	864
2004	1,668	930	726	307	184	72	22	18	3,926	1,328
2005	2,687	1,342	464	201	103	84	37	21	4,939	910
2006	2,081	2,217	1,780	490	180	27	10	0.1	6,791	2,487
2007	3,918	3,621	933	499	154	34	26	14	9,200	1,661
2008	5,852	1,160	843	333	274	176	45	44	8,839	1,715
2009	565	398	205	161	82	85	39	65	1,602	638
2010	999	511	254	115	65	24	28	34	2,030	519
2011	2,980	473	259	163	70	53	22	46	4,067	614
2012	1,018	1,081	236	87	76	33	14	60	2,605	505
2013	49	627	525	53	30	12	8	15	1,319	643
2014	513	415	176	248	28	37	26	42	1,798	556
2015	1,949	1,244	446	224	171	82	89	115	4,322	1,127
2016	425	255	381	99	40	40	12	28	1,483	600
2017	696	424	661	401	94	53	52	92	2,474	1,353
2018	106	224	271	175	169	50	35	44	1,075	745
2019	418	591	315	109	67	52	19	13	1,585	574
2020	815	274	225	180	74	77	64	46	1,764	667

Table 5.8. Numbers at age (millions) and SSB (thousands of tonnes) of West of Scotland herring at age (winter rings) from acoustic surveys 1993 to 2020. In 1997 the survey was carried out one month early in June as opposed to July when all the other surveys were carried out. A revision of the period 1991 to 2007 was carried out in 2010 and is incorporated in this table (Hatfield and Simmonds 2010).

Year/Age	1	2	3	4	5	6	7	8	9+	SSB:
1993	2	579	690	689	565	900	296	158	161	845
1994	494	542	608	286	307	268	407	174	132	534
1995	441	1,103	473	450	153	187	169	237	202	452
1996	41	576	803	329	95	61	77	78	115	370
1997	792	642	286	167	66	50	16	29	24	175
1998	1,222	795	667	471	179	79	28	14	37	376
1999	534	322	1,388	432	308	139	87	28	35	460
2000	448	316	337	900	393	248	200	95	65	445
2001	313	1,062	218	173	438	133	103	52	35	359
2002	425	436	1,437	200	162	424	152	68	60	549
2003	439	1,039	933	1,472	181	129	347	114	75	739
2004	564	275	760	442	577	56	62	82	76	396
2005	50	243	230	423	245	153	13	39	27	223
2006	112	835	388	285	582	415	227	22	59	472
2007	0	126	294	203	145	347	243	164	32	299
2008	48	233	912	669	340	272	721	366	264	788
2009	346	187	264	430	374	219	187	500	456	579
2010	425	489	398	150	143	95	63	48	188	253
2011	22	185	733	451	204	220	199	113	263	458
2012	792	179	729	471	241	107	107	56	105	375
2013	0	137	320	600	162	69	61	24	37	256
2014	1,031	243	218	469	519	143	30	19	11	272
2015	0	122	325	650	378	442	83	23	2	387
2016	0	30	108	88	112	79	62	6	1	88
2017	0	22	324	144	97	109	44	18	5	139
2018	964	323	92	331	153	51	72	27	13	152
2019	3	50	77	41	137	86	14	16	20	76
2020	657	579	274	150	83	178	38	13	10	158

Table 5.9. Numbers at age (winter rings, millions) and SSB (thousands of tonnes) of the Malin Shelf acoustic survey (6.a.N-S, 7.b,c) time series from 2008 to 2020. This table was been revised in 2015, details can be found in Lusseau et al 2015.

Year/Age	1	2	3	4	5	6	7	8	9+	SSB:
2008	50	267	996	720	363	331	744	386	274	845
2009	773	265	274	444	380	225	193	500	456	592
2010	133	375	374	242	173	146	102	100	297	370
2011	63	257	900	485	213	228	205	113	264	498
2012	796	548	832	517	249	115	111	57	105	434
2013	0	209	434	672	195	71	61	29	37	284
2014	1012	278	242	502	534	148	33	19	13	280
2015	0	212	397	747	423	476	90	24	2	430
2016	0	30	108	88	112	79	62	6	1	88
2017	0	25	339	155	106	110	47	13	5	145
2018	1289	447	106	343	153	52	72	27	13	159
2019	24	231	225	123	169	95	14	17	21	128
2020	1175	1226	609	235	110	209	42	18	10	226

Table 5.10. Sprat in the North Sea (ICES Subarea 4): Abundance, biomass, mean weight and mean length by age and maturity (i = immature, m = mature) from the summer 2020 North Sea acoustic survey (HERAS).

Age	Abundance (million)	Biomass (1000 t)	Mean weight (g)	Mean length (cm)
0i	12 869	12.8	1.0	5.4
1i	13 034	82.6	6.3	9.2
1m	21 683	195.8	9.0	10.3
2i	793	6.3	8.0	10.0
2m	16 713	201.6	12.1	11.3
3i	0	0	-	-
3m	1 539	23.9	15.5	12.5
4m	385	7.0	18.2	13.4
5m	31	0.6	19.5	13.8
6m	7	0.1	19.0	13.5
Immature	**26 696**	**101.7**	**3.8**	**7.4**
Mature	**40 358**	**429.0**	**10.6**	**10.8**
Total	**67 055**	**530.7**	**7.9**	**9.5**

Table 5.11. Sprat in the North Sea (ICES Subarea 4): Time-series of abundance and biomass as obtained from the summer North Sea acoustic survey (HERAS) time series 2000-2020. The surveyed area has expanded over the years. Only figures from 2004 and onwards are broadly comparable. In 2003, information on sprat abundance is available from one nation only.

	Abundance (million)					Biomass (1000 t)				
Year/Age	0	1	2	3+	Sum	0	1	2	3+	Sum
2020	12 869	34 717	17 505	1 963	**67 055**	13	278	208	32	**531**
2019	574	93 503	26 512	4 410	**124 999**	0	413	393	74	**880**
2018	3 409	107 083	9 061	588	**120 141**	1	717	106	10	**834**
2017	2 941	38 124	3 518	1 374	**45 956**	2	280	48	24	**354**
2016	24 792	58 599	33 318	7 880	**124 588**	24	500	453	141	**1118**
2015	198	26 241	22 474	9 799	**58 711**	0	239	312	161	**712**
2014	5 828	58 405	20 164	3 823	**88 219**	9	429	228	62	**728**
2013	454	9 332	6 273	1 600	**17 660**	2	71	74	25	**172**
2012	7 807	21 912	12 541	3 205	**45 466**	27	177	150	55	**409**
2011	0	26 536	13 660	2 430	**42 625**	0	212	188	44	**444**
2010	1 991	19 492	13 743	798	**36 023**	22	163	177	14	**376**
2009	0	47 520	16 488	1 183	**65 191**	0	346	189	21	**556**
2008	0	17 165	7 410	549	**25 125**	0	161	101	9	**271**
2007	0	37 250	5 513	1 869	**44 631**	0	258	66	29	**353**
2006*	0	21 862	19 916	760	**42 537**	0	159	265	12	**436**
2005*	0	69 798	2 526	350	**72 674**	0	475	33	6	**513**
2004*	17 401	28 940	5 312	367	**52 019**	19	267	73	6	**366**
2003*	0	25 294	3 983	338	**29 615**	0	198	61	6	**266**
2002	0	15 769	3 687	207	**19 664**	0	167	55	4	**226**
2001	0	12 639	1 812	110	**14 561**	0	97	24	2	**122**

2000	0	11 569	6 407	180	**18 156**	0	100	92	3	**196**

*** re-calculated using FishFrame**

Table 5.12. Sprat in ICES Div. 3.a: Abundance, biomass, mean weight and length by age and maturity from the summer 2020 North Sea acoustic survey (HERAS).

Age	Abundance (million)	Biomass (tonnes)	Mean weight (g)	Mean length (cm)
0i	2.7	8	2.8	7.2
0m	0.7	2	3.3	8.0
1i	547.6	3 564	6.5	9.3
1m	3 150.6	28 103	8.9	10.2
2i	0	0	-	-
2m	488.1	6 530	13.4	12.0
3m+	92.1	1 649	17.9	13.5
Immature	550.3	3 571	6.5	9.3
Mature	3 731.6	36 285	9.7	10.5
Total	4 281.9	39 856	9.3	10.4

Table 5.13. Sprat in ICES Div. 3.a: Time-series of sprat abundance and biomass as obtained from the summer North Sea acoustic survey (HERAS) time series 2006-2020.

	Abundance (million)					Biomass (1000 t)				
Year/Age	0	1	2	3+	Sum	0	1	2	3+	Sum
2020	3.5	3698.2	488.1	92.1	4 281.9	0.0	31.7	6.5	1.6	39.9
2019	0.7	271.5	1 508.0	865.1	2 645.3	0.0	2.7	19.8	16.0	38.4
2018	98.2	2 096.9	1 051.6	191.0	3 437.7	0.3	17.7	11.7	3.7	33.4
2017	0.0	10.9	146.3	90.5	247.7	0.0	0.1	2.3	1.7	4.1
2016	0.0	5.4	671.2	280.0	956.5	0.0	0.0	8.7	4.8	13.5
2015	0.3	840.8	202.0	342.6	1 385.8	0.0	9.6	2.7	6.2	18.5
2014	29.6	614.5	109.8	159.4	913.3	0.1	4.8	1.8	3.4	10.1
2013	1.4	14.5	68.8	448.6	533.3	0.0	0.2	1.2	9.6	10.9
2012	0.3	123.9	290.1	1 488.0	1 902.3	0.0	1.2	5.0	31.4	37.6
2011	0.0	45.4	546.9	981.9	1 574.2	0.0	0.5	9.1	17.8	27.5
2010	0.0	836.1	343.8	376.3	1 556.2	0.0	7.3	4.9	6.4	18.6
2009	0.0	169.5	432.4	1 631.9	2 233.8	0.0	1.8	6.5	28.3	36.6
2008	0.0	23.0	457.8	291.2	772.0	0.0	0.2	6.3	5.8	12.3
2007	0.0	5 611.9	323.9	382.9	6 318.7	0.0	47.9	3.8	6.5	58.2
2006	86.0	61.3	1 451.9	653.0	2 252.2	0.3	0.6	21.2	11.5	33.6

Table 5.14. North Sea Autumn Spawning herring. Total abundance, biomass, mean weight and percent mature (in numbers) by stratum, last year and present survey. Stratum numbers correspond to numbering in Figure 5.1.

	2019				2020			
Strat.	Abundance (mill)	Biomass (kt)	Mean weight (g)	Proportion mature	Abundance (mill)	Biomass (kt)	Mean weight (g)	Proportion mature
11	169	32	188.9	0.91	492	115	233.7	0.98
21	1306	15.9	12.2	0.01	1096	25	22.9	0.03
31	785	40.7	51.9	0.01	991	22	22.7	0.02
41	326	28.7	87.9	0.20	758	61	80.8	0.34
42	466	31.1	66.7	0.09	1081	37	34.4	0.02
51	1925	5.0	2.6	0.00	3021	12	4.0	0.00
61	1365	3.7	2.7	0.00	2931	12	4.1	0.00
71	5	0.1	13.9	0.00	452	14	30.0	0.02
81	48	2.4	50.8	0.20	156	21	133.6	0.80
91	3300	473.8	143.6	0.93	3421	430	125.8	0.70
101	299	10.5	35.2	0.00	12	1	43.6	0.02
111	5326	1129.8	212.1	1.00	5234	1135	216.9	1.00
121	1536	275.7	179.4	1.00	144	26	181.8	1.00
131	454	6.5	14.4	0.01	981	32	32.7	0.02
141	7820	285	36.5	0.00	2479	135	54.4	0.05
151	240	10.1	41.9	0.06	345	11	32.2	0.01
152	192	16.2	84.7	0.16	172	14	81.2	0.39

Table 5.15. Western Baltic Spring Spawning herring. Total abundance, biomass and mean weight by stratum. Stratum numbers correspond to numbering in Figure 5.1.

	2019			2020		
Stratum	Abundance (mill)	Biomass (kt)	Mean weight (g)	Abundance (mill)	Biomass (kt)	Mean weight (g)
11	87	14	164.2	8	2	194.4
21	471	23.6	50.2	286	12	41.2
31	202	13.0	64.3	189	9	47.9
41	204	21.0	102.9	373	39	103.5
42	124	11.0	88.6	243	11	47.2
141	246	35	144.2	484	78	160.5
151	102	6.2	60.8	100	3	33.8
152	148	13.7	92.6	81	8	102.6

Table 5.16. Malin shelf and West of Scotland (6.a.N) herring. Total abundance, biomass, mean weight and percent mature by stratum. Stratum numbers correspond to numbering in Figure 5.1. The 6.a.N herring geographic subset is comprised of strata marked with *.

	2019				2020			
Stratum	Abundance (mill)	Biomass (kt)	Mean weight (g)	% Mature	Abundance (mill)	Biomass (kt)	Mean weight (g)	% Mature
1*	299	57.7	193.1	1.00	639	84.3	131.8	0.52
2*	0	0.0	-	-	156	11.5	73.3	0.03
3*	136	21.6	158.2	0.74	584	90.7	155.3	0.69
4*	10	1.4	140.2	0.72	603	60.0	99.5	0.34
5	408	57.1	140.0	0.70	1549	153.3	99.0	0.30
6	67	9.4	139.6	0.71	103	10.1	98.1	0.24

Table 5.17. Sprat in the North Sea and Div. 3.a. Total abundance, biomass, mean weight and percent mature by stratum. Stratum numbers correspond to numbering in Figure 5.1.

		2019				2020			
ICES area	Stratum	Abundance (mill)	Biomass (t)	Mean Weight (g)	% Mature	Abundance (mill)	Biomass (t)	Mean Weight (g)	% Mature
Div. 3.a	21	2 532	36 630	14.5	96%	2 643	23 937	9.1	90%
	31	0	0	-	-	912	7 321	8.0	74%
	41	0	0	-	-	0	0	-	-
	42*	113	1 791	15.8	100%	722	8 597	11.8	92%
North Sea	11	0	0	-	-	0	0	-	-
	51	21 315	140 678	6.6	54%	37 268	268 133	7.2	57%
	61	18 521	108 888	5.9	38%	19 714	151 297	7.7	46%
	71	4 717	44 675	9.5	98%	732	7 964	10.9	89%
	81	67 486	459 089	6.9	38%	2 699	21 967	8.1	99%
	91	502	4 310	8.6	100%	3 051	34 442	11.3	100%
	101	330	2 311	7.0	100%	128	1 026	8.0	100%
	111	0	0	-	-	0	0	-	-
	121	0	0	-	-	0	0	-	-
	131	11 834	116 028	9.8	91%	2 100	26 782	12.8	98%
	141	265	4 028	15.2	84%	1 109	15 905	14.3	100%
	151	29	384	13.3	100%	253	3 180	12.6	90%
	152*	0	0	-	-	0	0	-	-

* New strata from 2017, 42 and 152 was part of strata 41 and 151, respectively, in 2016

Table 5.18. Length of track used in analysis, number of fish ages used in estimates and transect spacing for each stratum in the 2019 and 2020 survey. Number of ages cannot be summed for all strata to give total number of ages for the survey as haul information may have been used in more than one stratum. * zig zag.

	2019				2020			
Stratum	Total transect length (nmi.)	Herring ages	Sprat ages	Transect spacing (nmi.)	Total transect length (nmi.)	Herring ages	Sprat ages	Transect spacing (nmi.)
1	481	222		15	486	285	-	15
2	154	122	-	-	145	201	-	*
3	302	122	-	15	299	341	-	15
4	261	130	-	15	241	462	-	15
5	360	130	-	15	400	581	-	10
6	196	130	-	15	216	461	-	15
11	959	520	-	15	964	462	-	15
51	599	432	1018	25	492	186	164	30
61	244	253	415	23	236	222	112	23
71	317	192	166	17.5	232	274	283	23
81	447	309	188	~40	526	262	59	*
91	1645	1244	107	15	1622	734	95	15
101	62	65	47	15	51	100	29	15
111	849	1252	-	15	821	1427	-	15
121	484	619	-	15	477	386	-	15
131	367	234	436	30	466	305	240	40
141	990	588	58	18.75	964	567	49	18.75
21	177	858	471	13	199	1059	885	13
31	146	394	-	10	159	898	490	10
41	140	911	-	17.5	172	396	133	17.5
42	62	469	64	17.5	93	663	214	17.5
151	307	473	146	15	363	561	337	15
152	59	356	-	15	99	303	13	15

Table 5.19. Biological sampling of trawl hauls in the HERAS survey by country and species.

Country	Species	Full sample	Length and weight	Total
SCO	Herring	2 per 0.5 cm class below 22 cm, 5 per 0.5 cm class from 22.5-27.5 cm and ten per 0.5 cm class for 28.0 cm and above	400-500	400-500
SCO	Sprat	5 per 1/2 cm length group from the pool that are length measured	150	150
NL	Herring	5 per 1/2 cm length group from the pool that are length measured	150	150
NL	Sprat	5 per 1/2 cm length group from the pool that are length measured	150	150
IRL	Herring	50 random fish aged, length, weight, sex, maturity. Additional 100 random fish for length and weight only. Length frequency only continued until 60 individuals is reached in one length class.	150 (length and weight). Up to 600 lengths	600
IRL	Sprat	100 random fish for length and weight. Length frequency only continued until 60 individuals is reached in one length class.	100 (length and weight) 200-300 lengths	200-300
GER	Herring	10 fish per ½ cm length group per stratum from length frequency measurements. Sampling from length measurements continued until length group sample is full.	>750 (all strata combined)	Catches allowing, a sample of at least 200 fish is measured (length frequency) per haul
GER	Sprat	10 fish per ½ cm length group per stratum from length frequency measurements. Sampling from length measurements continued until length group sample is full.	>750 (all strata combined)	Catches allowing, a sample of at least 200 fish is measured (length frequency) per haul
DK	Herring	6 per ½ cm length group from the pool that are length measured	450-500	450-500
DK	Sprat	10 per ½ cm length group from the pool that are length measured	200	200
NOR	Herring	50, random	50, random	100
NOR	Sprat	30, random	70, random	100

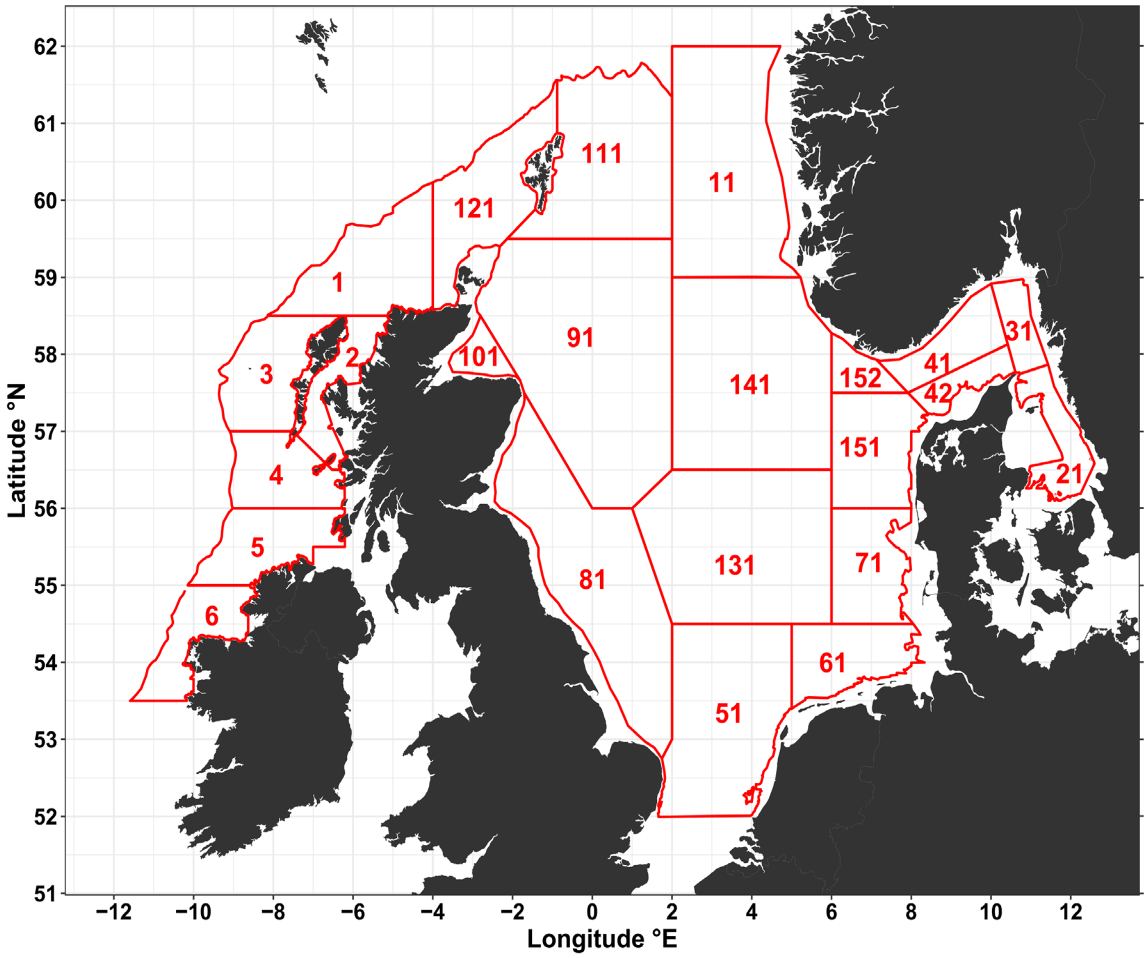


Figure 5.1. Strata used in the HERAS survey 2020.

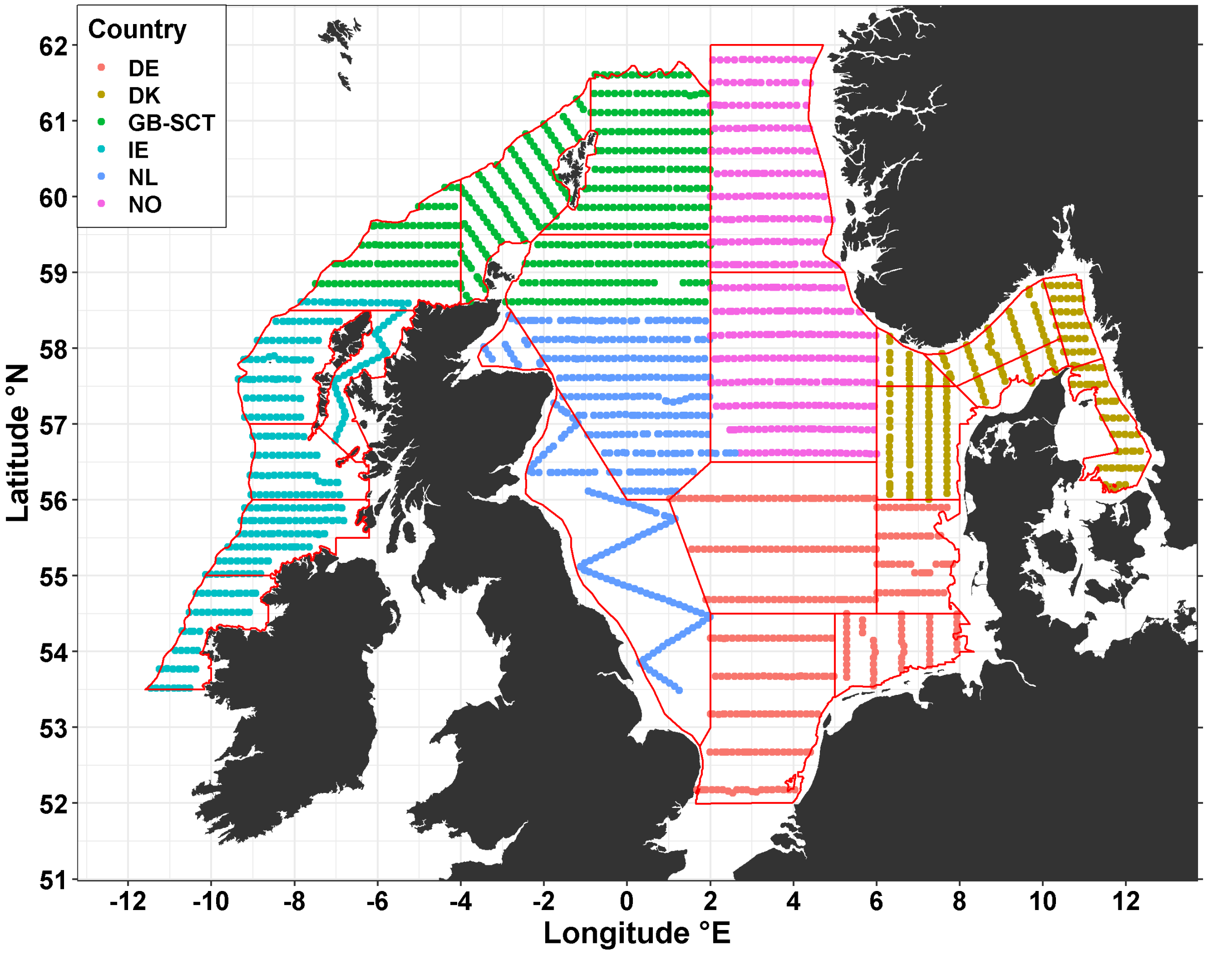


Figure 5.2. Survey area coverage in the HERAS survey in 2020 and individual vessel tracks by nation.

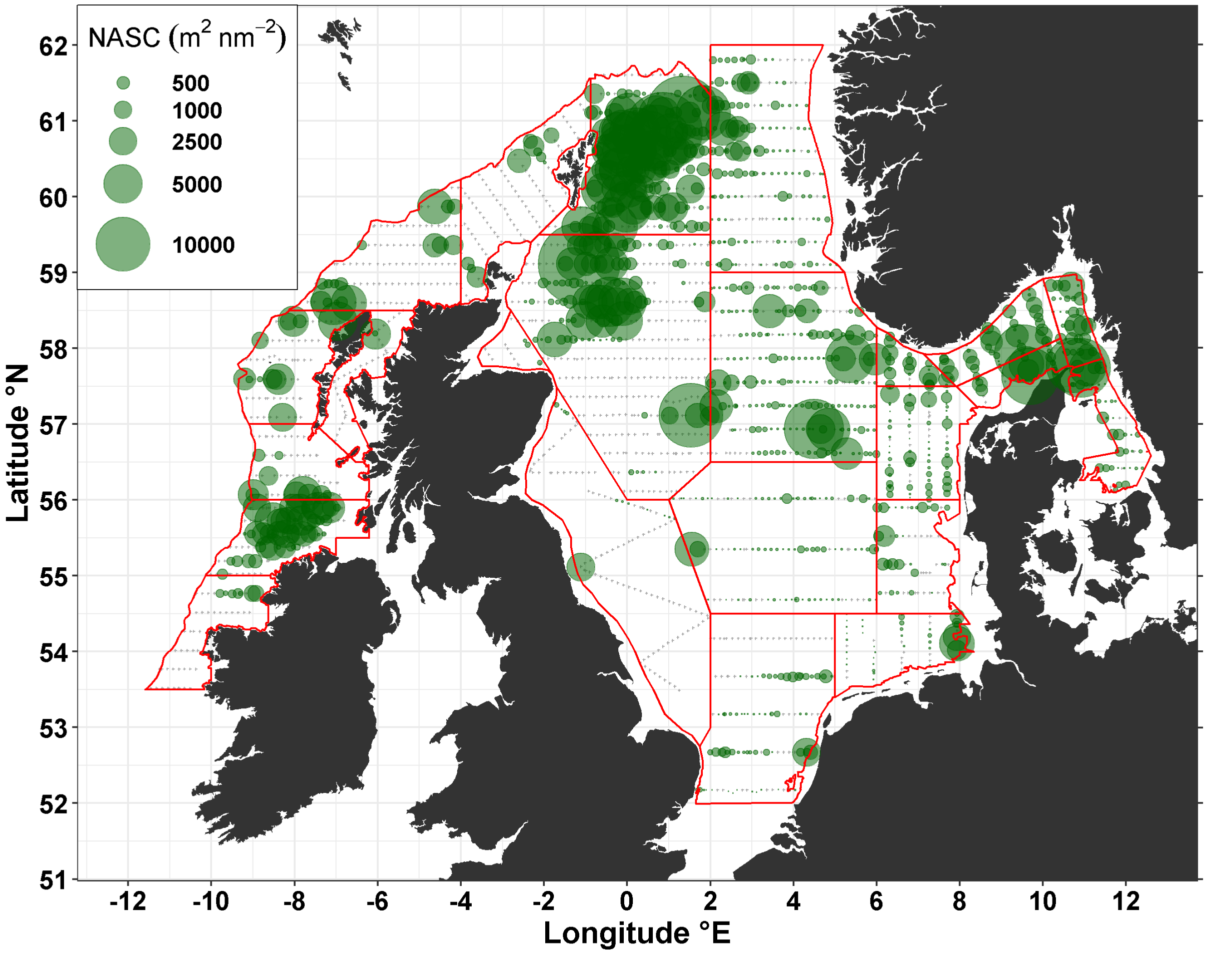


Figure 5.3. Distribution of NASC attributed to herring in HERAS in 2020. Acoustic intervals represented by light grey dot with green circles representing size and location of herring aggregations. NASC values are resampled at 5 nmi. intervals along the cruise track. The red lines show the strata system.

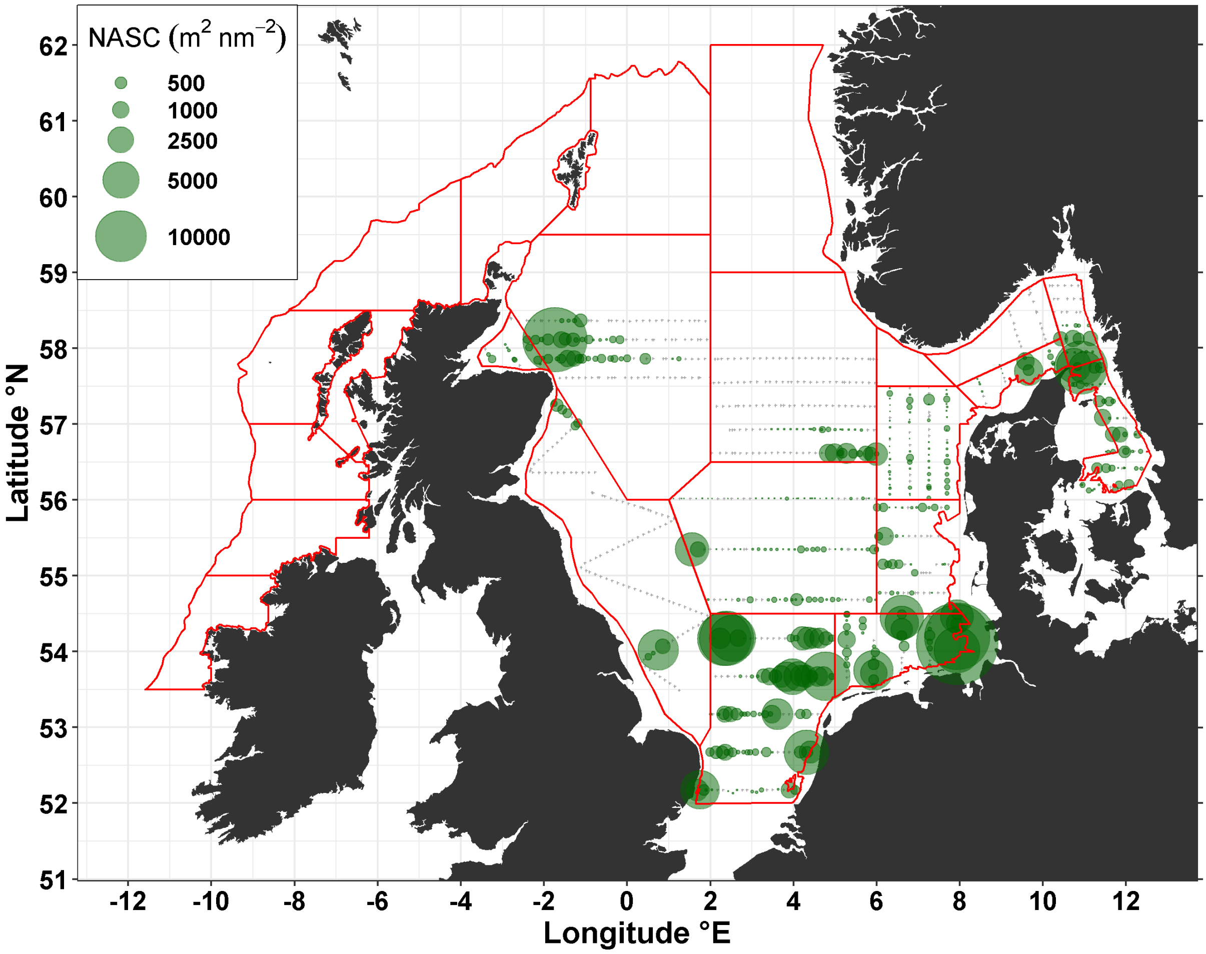


Figure 5.4. Distribution of NASC attributed to sprat in HERAS in 2020. Acoustic intervals represented by light grey dot with green circles representing size and location of sprat aggregations. NASC values are resampled at 5 nmi. intervals along the cruise track. The red lines show the strata system.

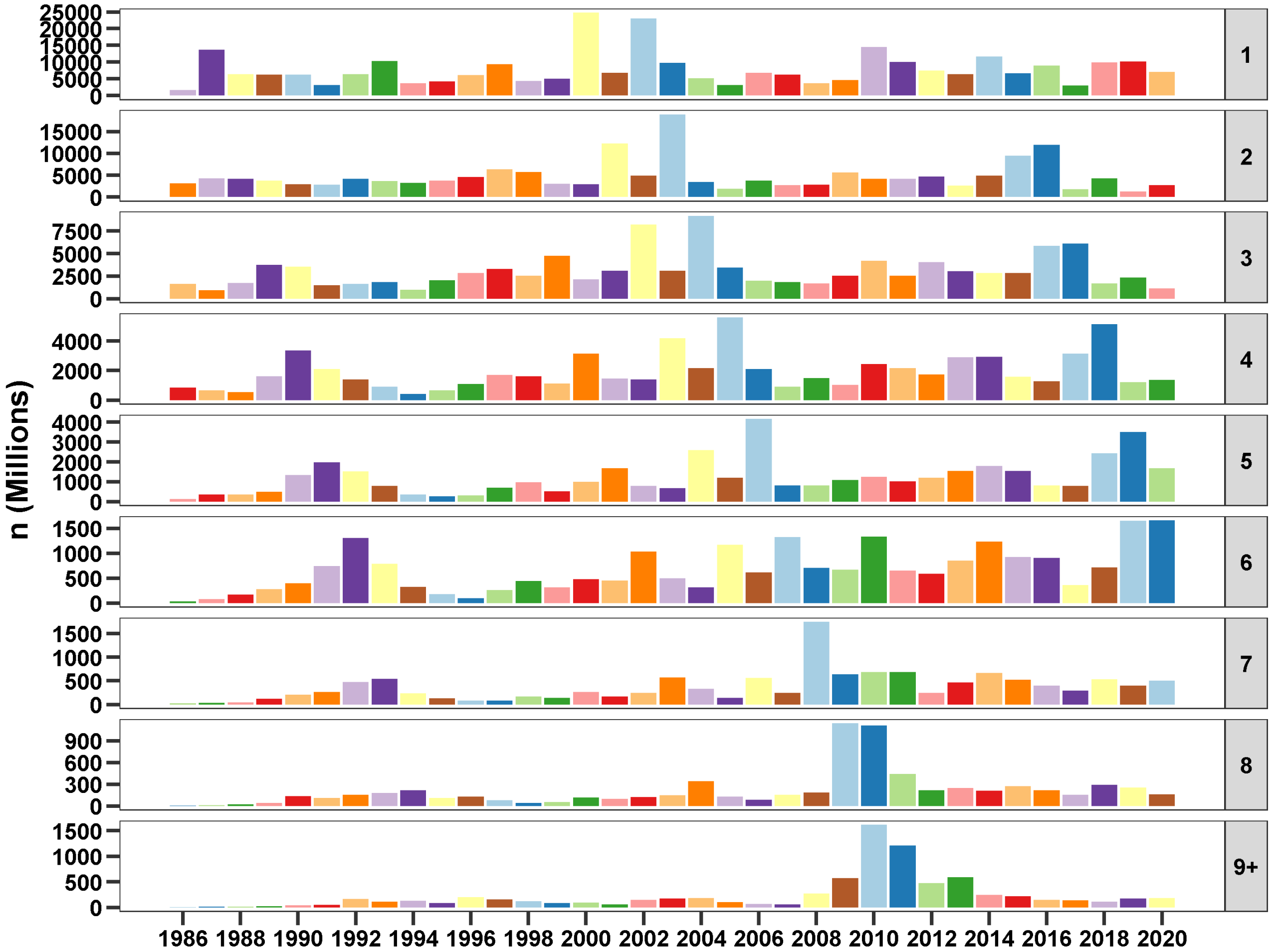


Figure 5.5. North Sea Autumn Spawning herring: HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 1986-2020. Note diverging scales of abundance between ages.

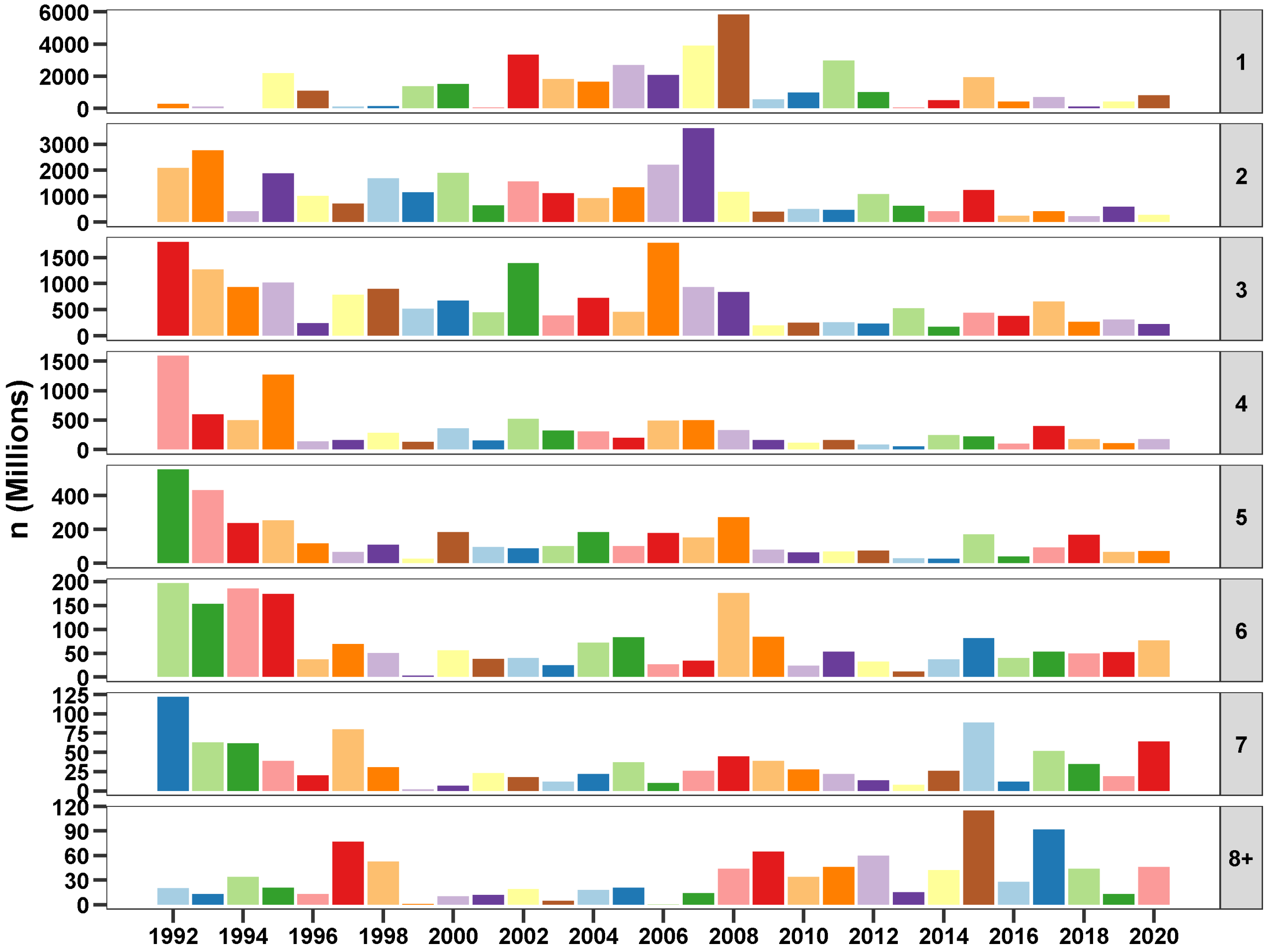


Figure 5.6. Western Baltic Spring Spawning herring: HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 1992-2020. Note diverging scales of abundance between ages.

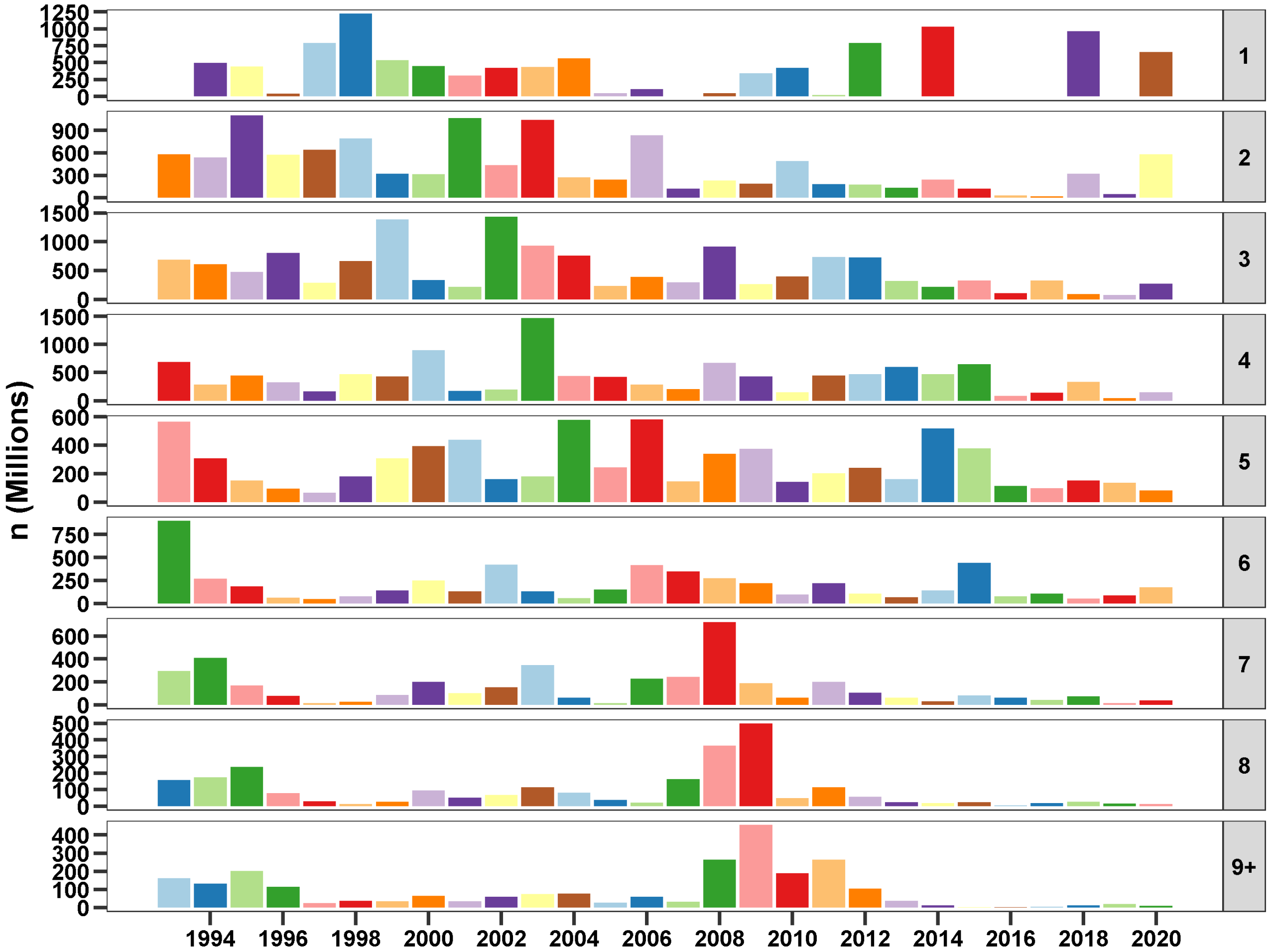


Figure 5.7. West of Scotland (6.a.N) herring: HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 1993-2020.

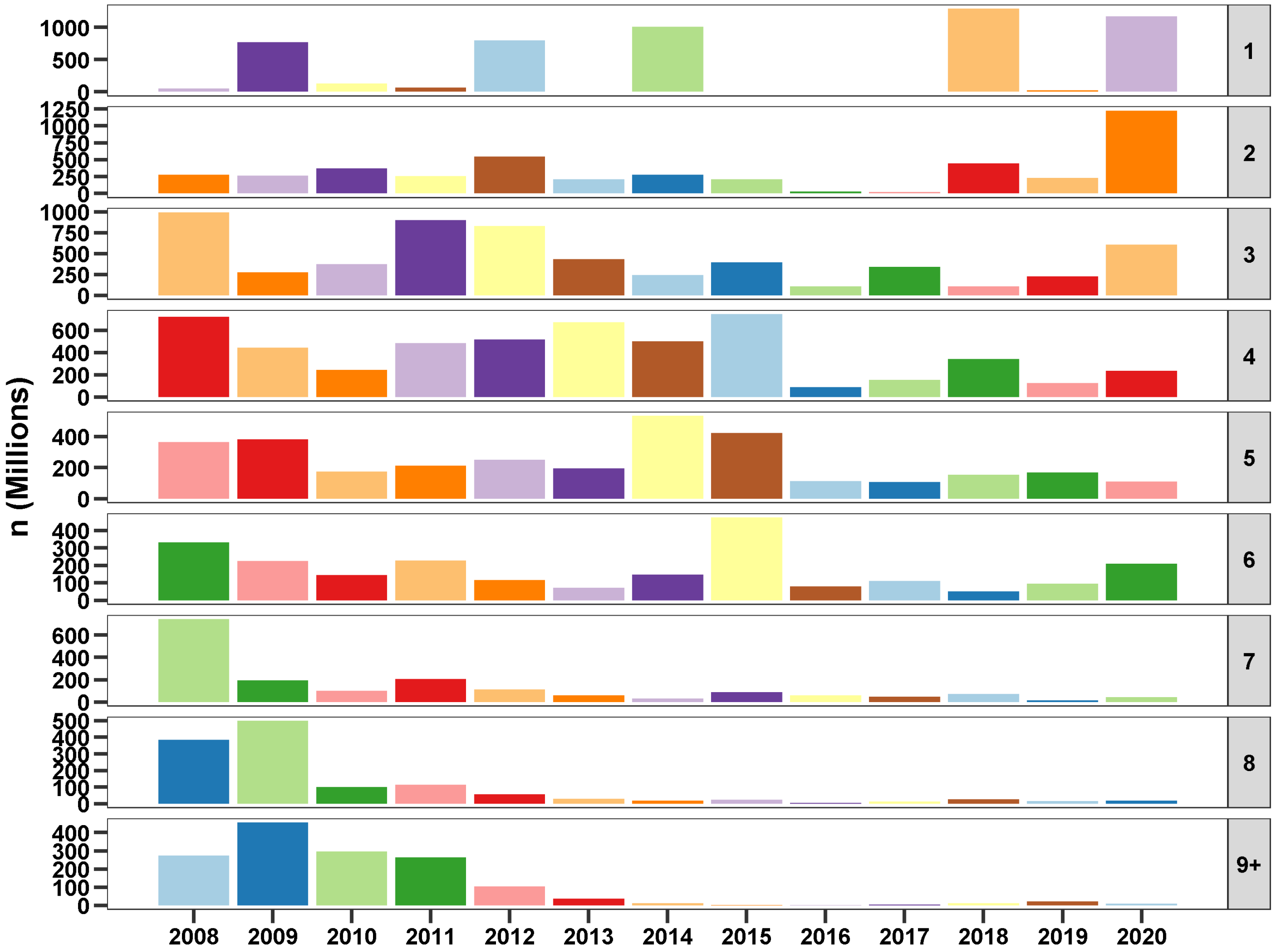


Figure 5.8. Malin Shelf Herring (6.a.N-S, 7.b,c): HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 2008-2020.

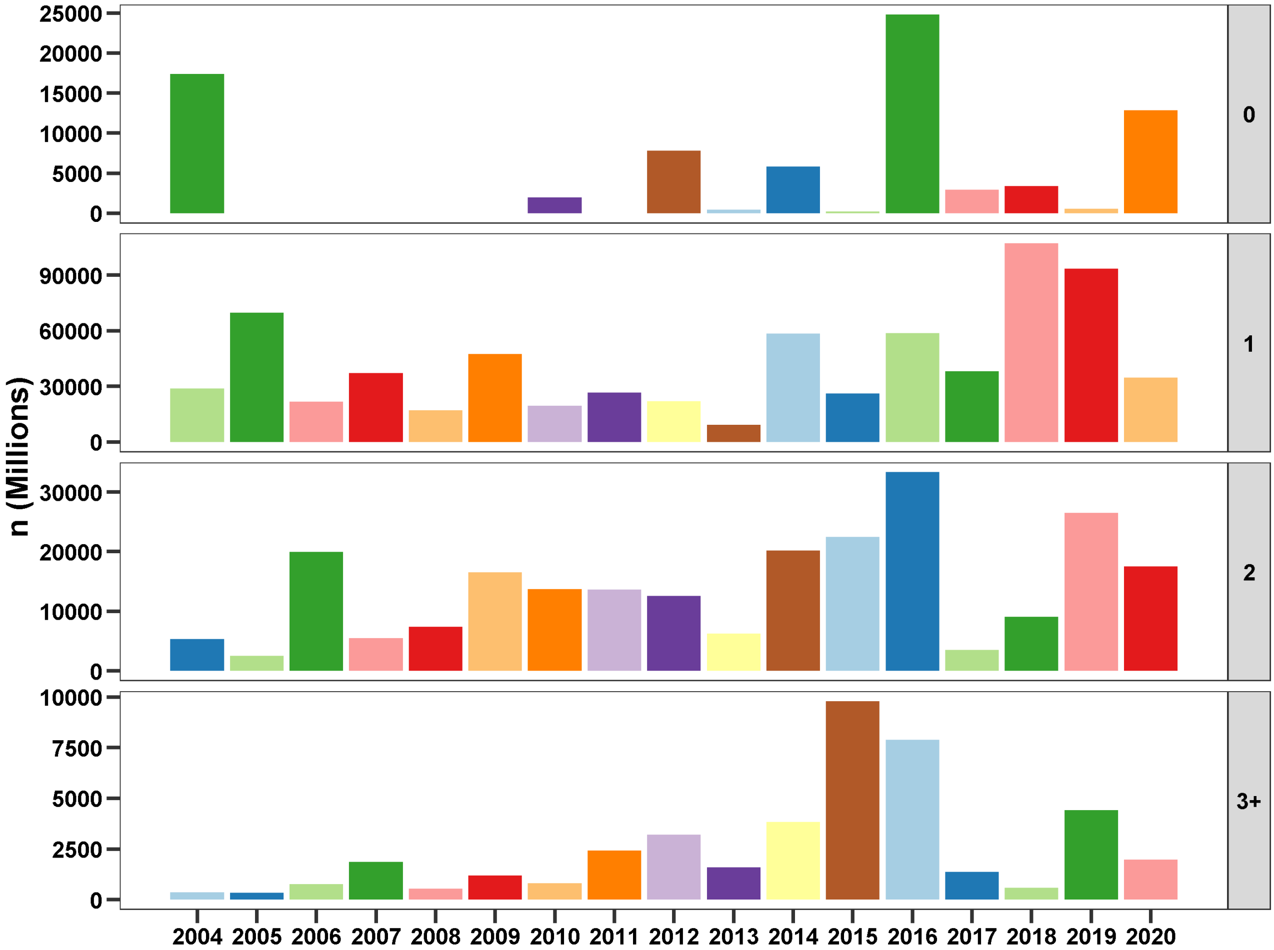


Figure 5.9. North Sea Sprat (ICES Subarea 4): HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 2004-2020. Note diverging scales of abundance between ages.

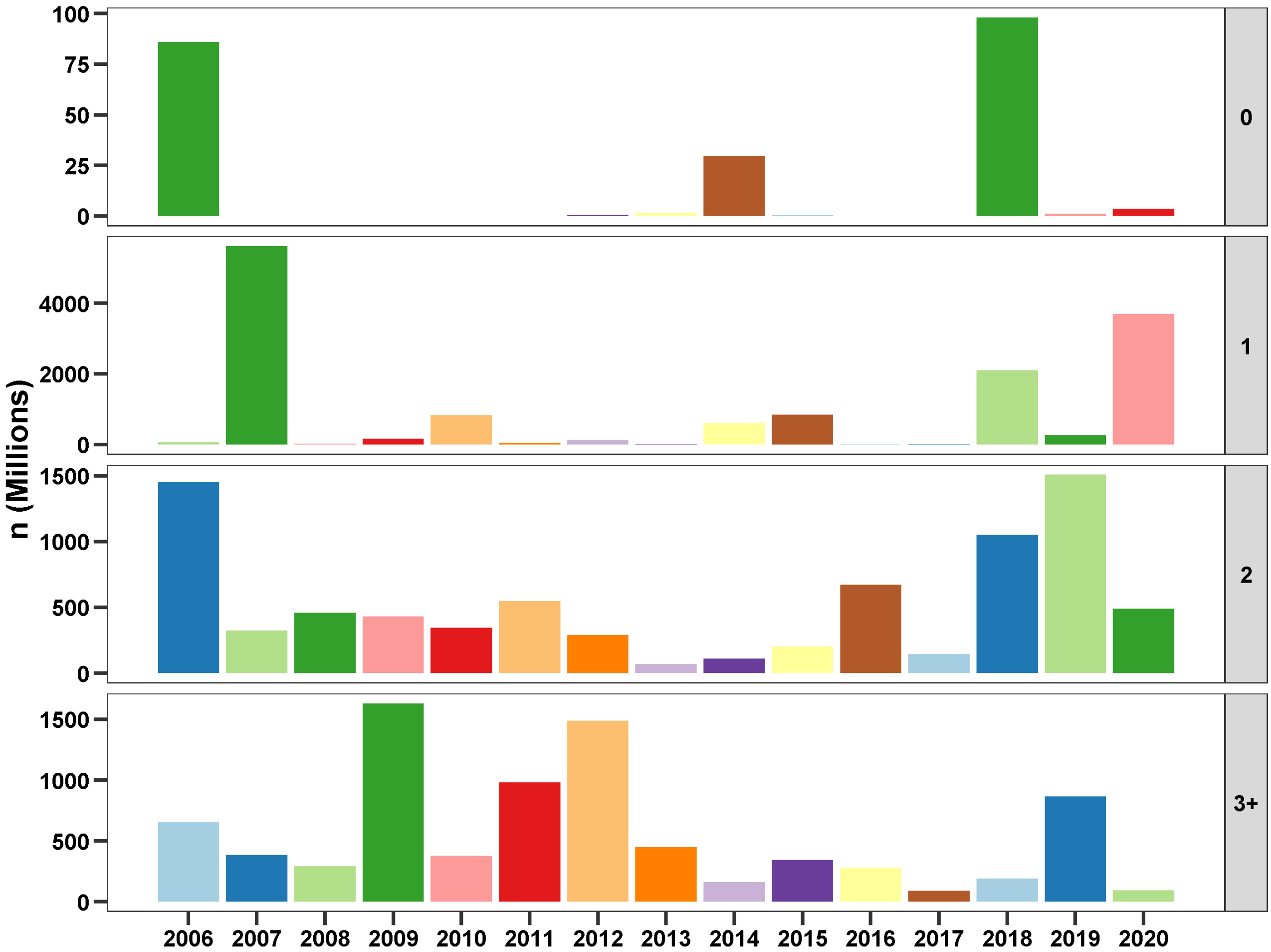
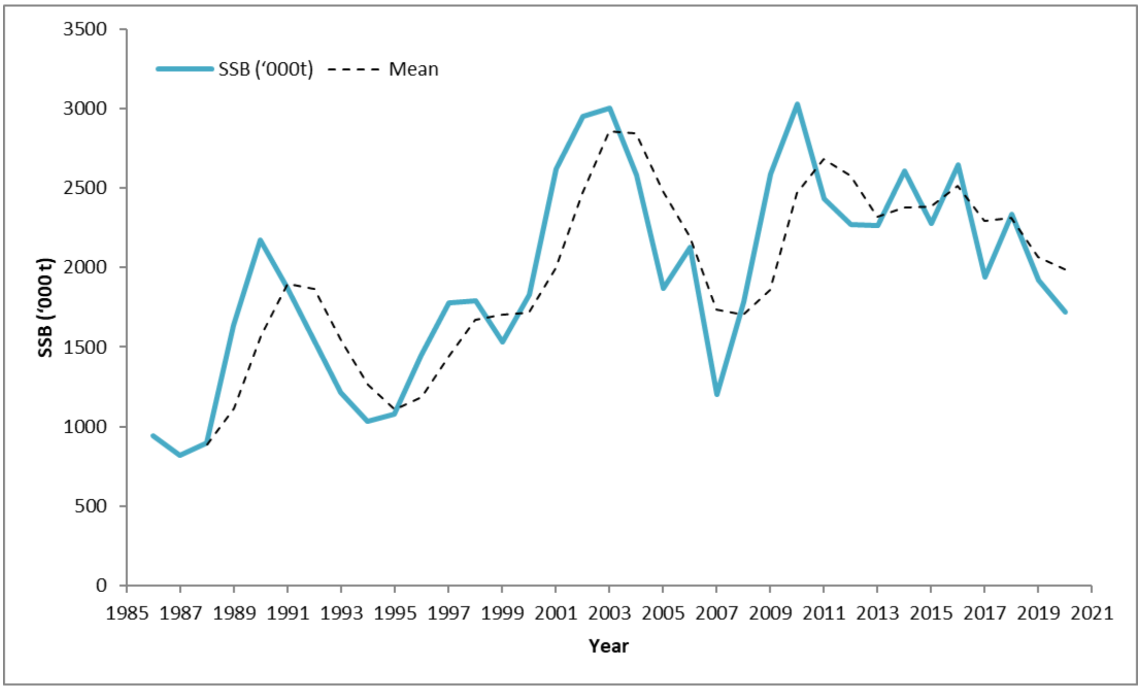


Figure 5.10. Sprat in Div. 3.a: HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 2006-2020. Note diverging scales of abundance between ages.

(a)



(b)

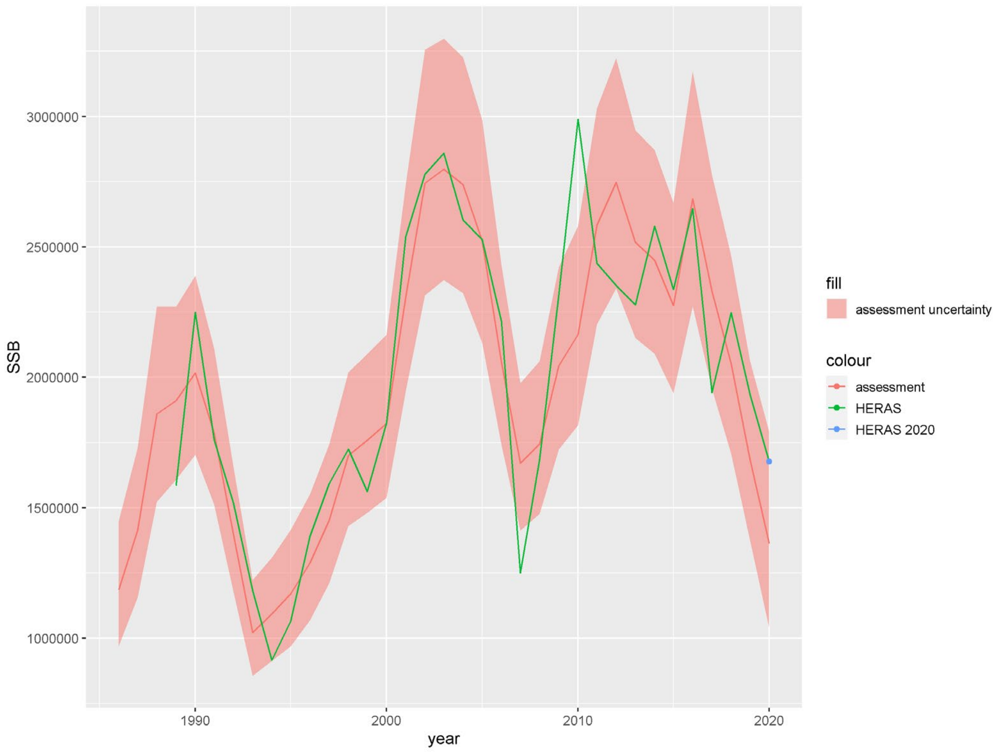


Figure 5.11. Time series of SSB of North Sea Autumn Spawning herring. (a) HERAS SSB since 1986 with three year running mean. (b) Comparison of the HERAS index with the 2020 NSAS herring assessment.

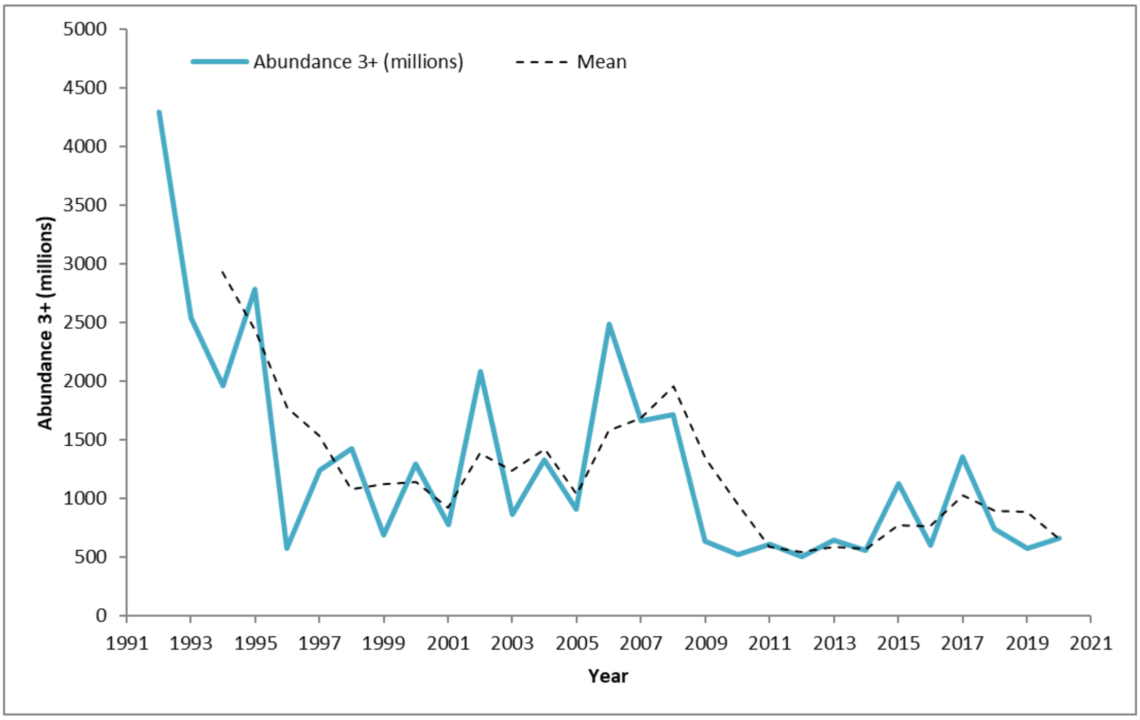


Figure 5.12. Time series of 3+ abundance of Western Baltic Spring Spawning herring with three year running mean.

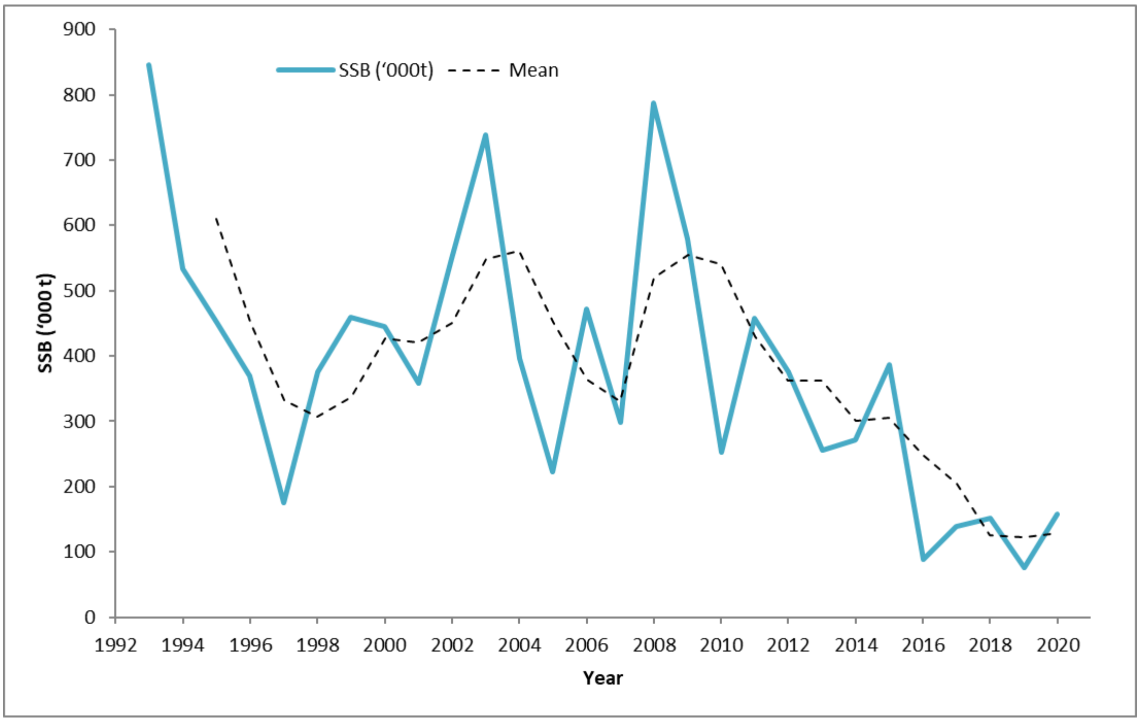


Figure 5.13. Time series of SSB of West of Scotland herring (geographical subset of Malin Shelf herring) with three year running mean.

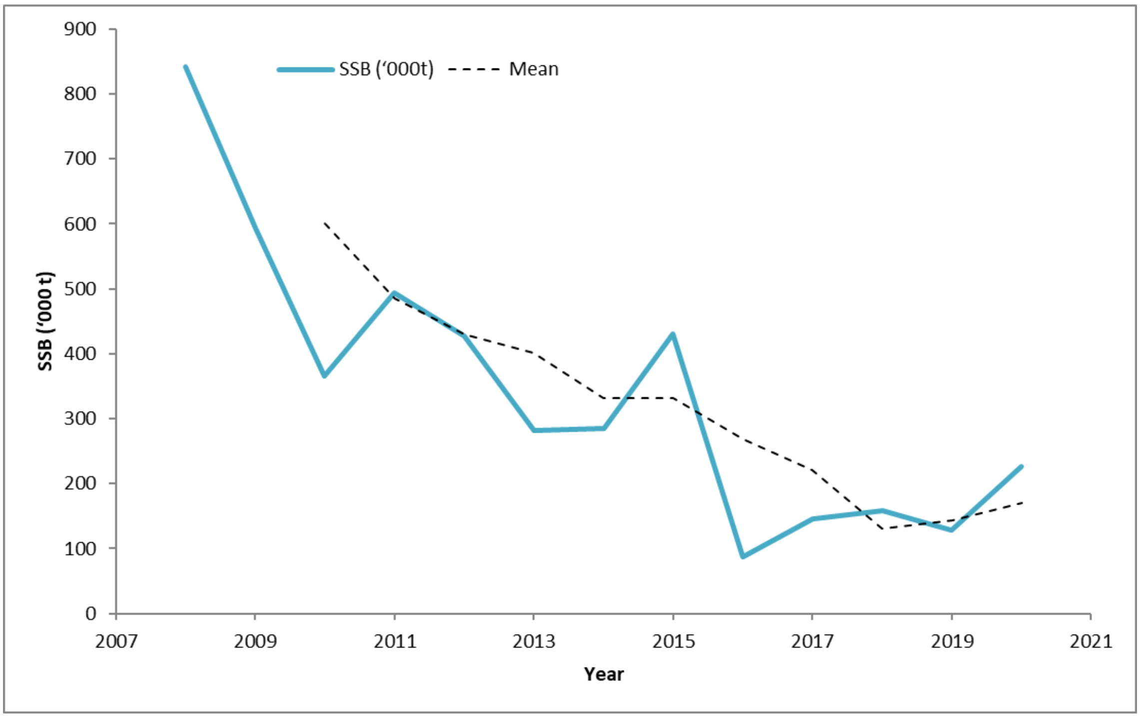


Figure 5.14. Time series of SSB of Malin Shelf herring with three year running mean.

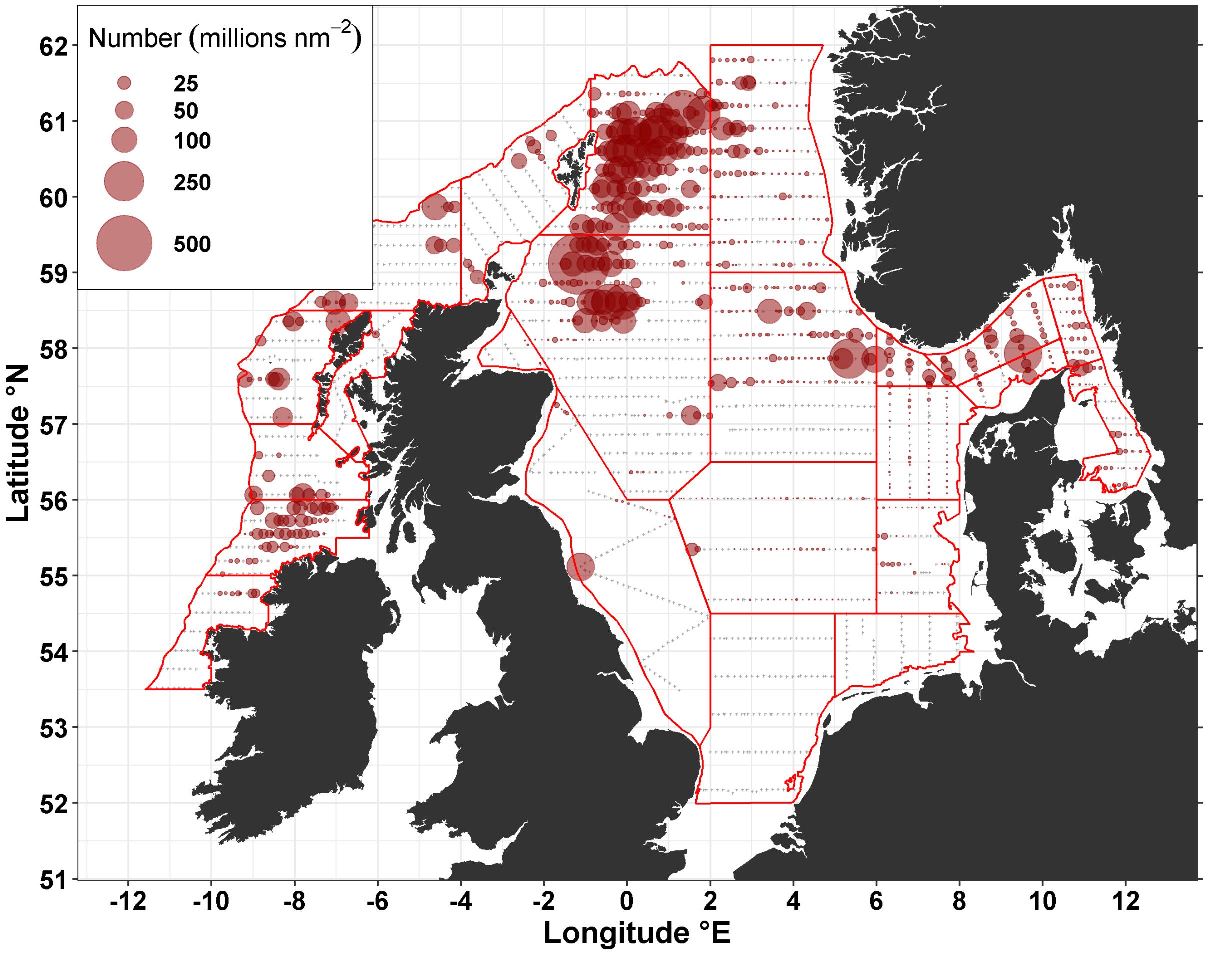


Figure 5.16. Distribution of mature herring in 2020 (n in millions). The NASC values per interval within each stratum were split into mature and immature following the proportion mature for the stratum.

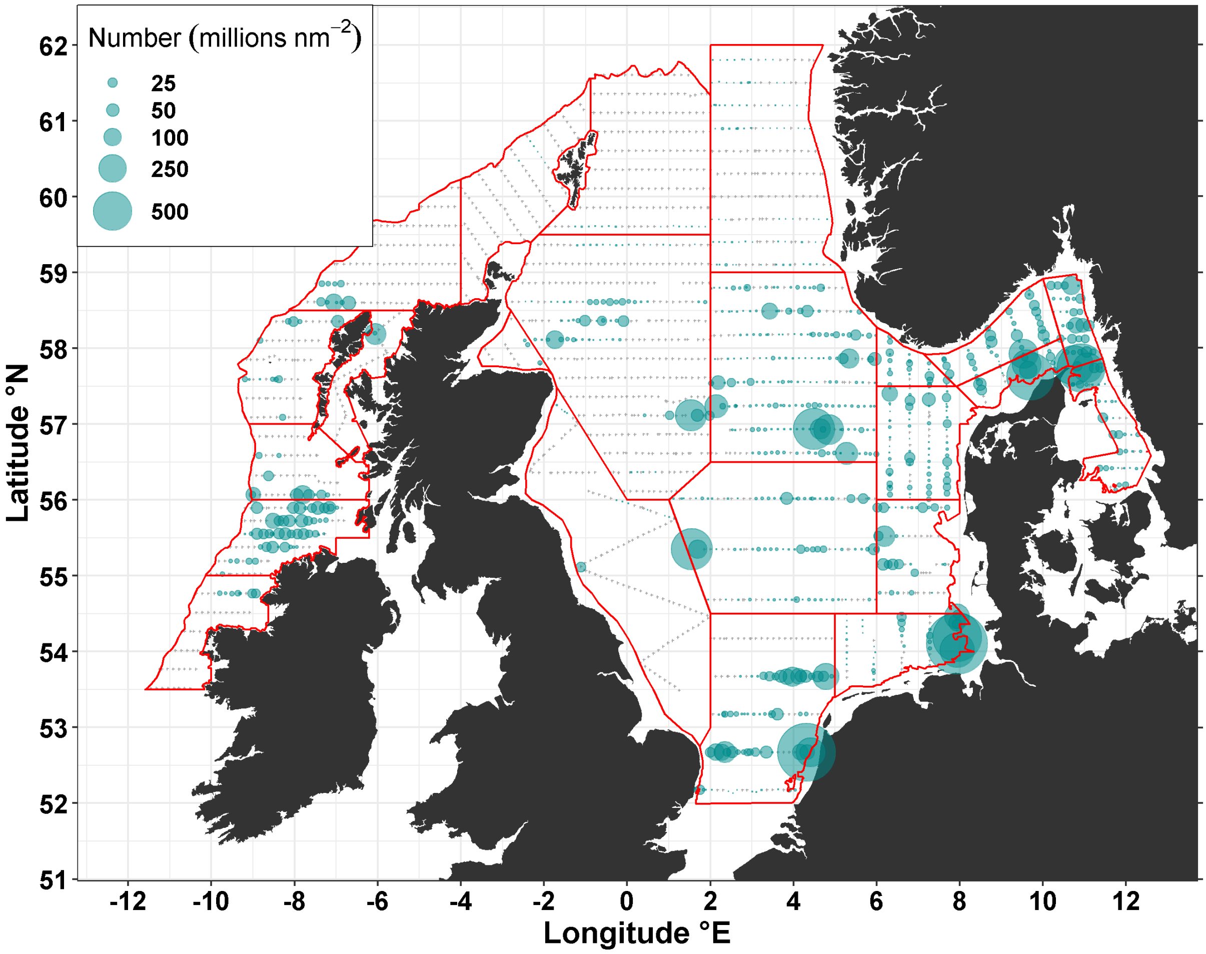


Figure 5.17. Distribution of immature herring in 2020 (n in millions). The NASC values per interval within each stratum were split into mature and immature following the calculated proportion mature for the stratum.

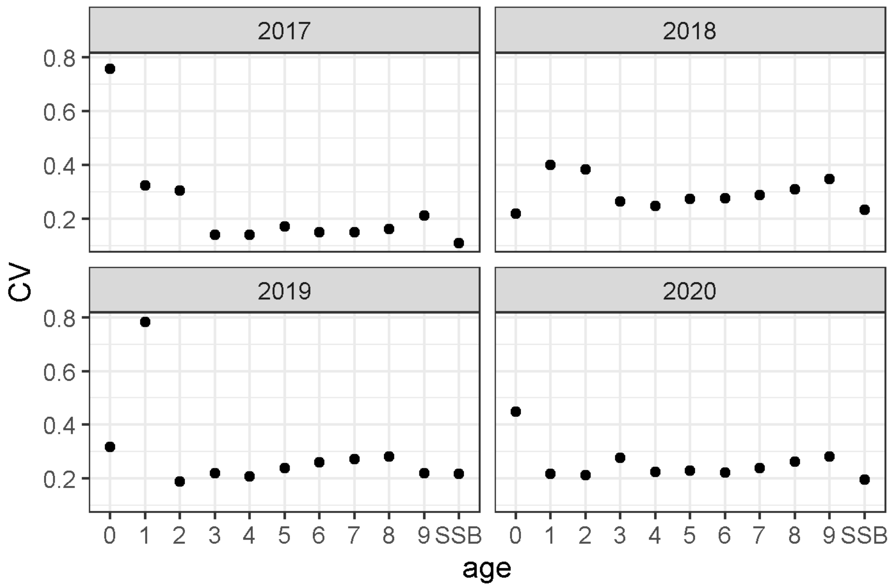


Figure 5.18. NSAS herring Coefficient of Variation (CV) for abundance at age and SSB as estimated using bootstrapping results from StoX. Data are shown for the 2017-2020 period for comparison.

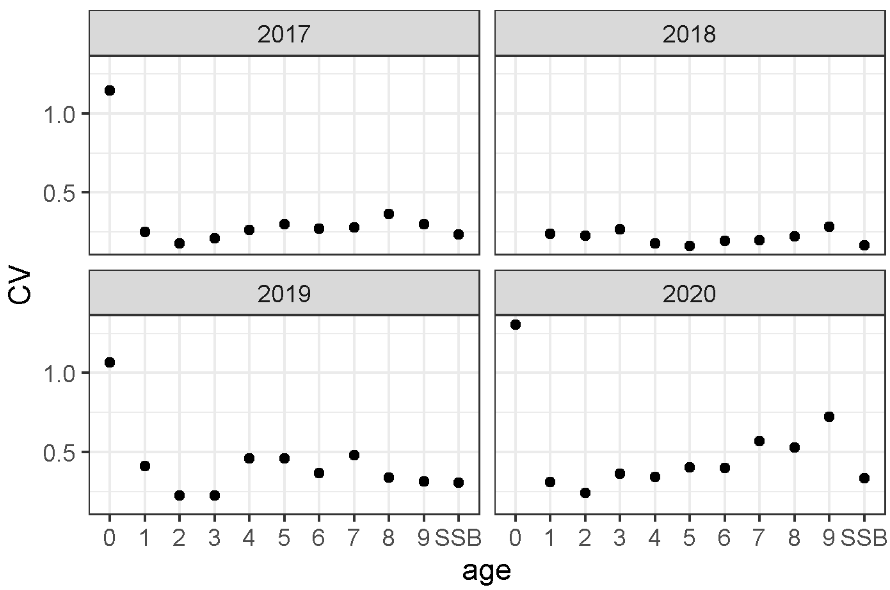


Figure 5.19. WBSS herring Coefficient of Variation (CV) for abundance at age and SSB as estimated using bootstrapping results from StoX. Data are shown for the 2017-2020 period for comparison.

Annex 6: 2020 IESSNS Survey Summary Table and Survey Report

Document 6a: IESSNS 2020 survey summary table

Survey Summary Table WGIPS 2021	
Name of the survey (abbreviation):	International Ecosystem Summer Survey in the Nordic Seas (IESSNS)
Target Species:	NEA mackerel (and five year timeseries for blue whiting and Norwegian spring-spawning (NSS) herring, 2016-2020.
Survey dates:	1 July-4 August 2020
Summary: Swept Area Survey	

The International Ecosystem Summer Survey in the Nordic Seas (IESSNS) was performed within approximately 5 weeks from July 1st to August 4th in 2020 using six vessels from Norway (2), Iceland (1), Faroe Islands (1), Greenland (1) and Denmark (1). The survey was carried out as planned.

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

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

Norwegian spring spawning herring and blue whiting are also being investigated using acoustic methods, but these indices are currently not used in the assessment.

	Description
Survey design	Swept-area systematic trawl survey with a random starting point and fixed spacing between stations in each stratum. Eight permanent and three dynamic strata. Each stratum has a random starting point and fixed spacing between stations. Permanent strata are constant between years and cover the core mackerel distribution area in

	the Norwegian Sea and in the Icelandic EEZ. The dynamic zones are located at westward and northward mackerel distribution range periphery. Effort varies between strata. A combination of spatial variance in mackerel abundance, in years 2010-2014, and available survey time determines effort. Effort increases as spatial variability in abundance increases.
Index Calculation method	Age-segregated swept-area trawl index for NEA mackerel is calculated using stratified approach. StoX (via the PGNAPES database)
Random/systematic error issues	N/A
Specific survey error issues (acoustic)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Bubble sweep down	N/A
Extinction (shadowing)	N/A
Blind zone	N/A
Dead zone	N/A
Allocation of backscatter to species	N/A
Target strength	N/A
Calibration	N/A
Specific survey error issues (biological)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Stock containment	Time series: 2010-2020. The covered area increased from 2010 to 2014, after which the surveyed area has been ~3 million km^2 . 2020 survey: Considered to have covered the adult spawning stock adequately
Stock ID and mixing issues	Time series: 2020 survey:

	N/A for mackerel
Measures of uncertainty (CV)	The estimated survey uncertainty for the main age groups in the estimate was around 0.2-0.25
Biological sampling	Time series: 2010-2020 2020 survey: Sampling levels were considered representative. Catch curves for the most recent cohorts did not show a decreasing trend as expected for the older age groups.
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole times series or for individual years? (please specify)	*To be answered by Assessment Working Group*
Did the Survey Summary Table contain adequate information to allow for evaluation of the quality of the survey for use in assessment? Please identify shortfalls	*To be answered by Assessment Working Group*

Document 6b: IESSNS 2020 survey report

Please see the report on the next page.

Working Document to

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

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

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

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

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

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

Kai Wieland
National Institute of Aquatic Resources, Denmark

Contents

1 Executive summary

The International Ecosystem Summer Survey in the Nordic Seas (IESSNS) was performed within approximately 5 weeks from July 1st to August 4th in 2020 using six vessels from Norway (2), Iceland (1), Faroe Islands (1), Greenland (1) and Denmark (1). The main objective is to provide annual age-segregated abundance index, with an uncertainty estimate, for northeast Atlantic mackerel (*Scomber scombrus*). The index is used as a tuning series in stock assessment according to conclusions from the 2017 and 2019 ICES mackerel benchmarks. A standardised pelagic swept area trawl method is used to obtain the abundance index and to study the spatial distribution of mackerel in relation to other abundant pelagic fish stocks and to environmental factors in the Nordic Seas, as has been done annually since 2010. Another aim is to construct a new time series for blue whiting (*Micromesistius poutassou*) abundance index and for Norwegian spring-spawning herring (NSSH) (*Clupea harengus*) abundance index. This is obtained by utilizing standardized acoustic methods to estimate their abundance in combination with biological trawling on acoustic registrations. The time series for blue whiting and NSSH have now been conducted for five years (2016-2020).

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

The survey coverage area was 2.9 million km² in 2020, which is similar as in previous years from 2017 to 2019. Furthermore, 0.26 million km² was surveyed in the North Sea in July 2020. Distribution zero boundaries were found in majority of the survey area with an exception of high mackerel abundance in the northwestern region of the Norwegian Sea into the Fram Strait west of Svalbard. The mackerel appeared less patchily distributed within the survey area and had a pronounced distribution in the central and northern Norwegian Sea in 2020 compared to previous years. This major difference in distribution consists of a substantial decline of mackerel in the west and corresponding increase in the central and northern part of the Norwegian Sea.

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

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

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

Other fish species also monitored are lumpfish (*Cyclopterus lumpus*) and Atlantic salmon (*Salmo salar*). Lumpfish was caught at 74% of surface trawl stations distributed across the surveyed area from Cape

Farwell, Greenland, to western part of the Barents Sea. Abundance was greater north of latitude 66 °N compared to southern areas. A total of 54 Atlantic salmon were caught in 30 stations both in coastal and offshore areas from 60°N to >77°N in the upper 30 m of the water column. The salmon ranged from 0.084 kg to 2.73 kg in weight, dominated by postsmolt weighing 100-180 grams and 1 sea-winter individuals weighing 1-2 kg.

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

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

2 Introduction

During approximately five weeks of survey in 2020 (1st of July to 4th of August), six vessels; the M/V "Kings Bay" and M/V "Vendla" from Norway, and M/V "Tróndur í Gøtu" operating from Faroe Islands, the R/V "Árni Friðriksson" from Iceland, the M/V "Eros" operating in Greenland waters and M/V "Ceton" operating in the North Sea by Danish scientists, participated in the International Ecosystem Summer Survey in the Nordic Seas (IESSNS).

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

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

The North Sea was included in the survey area for the third time in 2020, following the recommendations of WGWIDE. This was done by scientists from DTU Aqua, Denmark. The commercial fishing vessels "Ceton S205" was used, and in total 35 stations (CTD and fishing with the pelagic Multpelt 832 trawl) were successfully conducted. No problems applying the IESSNS methods were encountered. Area coverage, however, was restricted to the northern part of the North Sea at water depths deeper than 50 m and no plankton samples were taken (see Appendix 1 for comparison with 2018 and 2019 results).

3 Material and methods

Coordination of the IESSNS 2020 was done during the WGIPS 2020 meeting in January 2020 in Bergen, Norway, and by correspondence in spring and summer 2020. The participating vessels together with their effective survey periods are listed in Table 1.

Overall, the weather conditions were calm with good survey conditions for all six vessels for oceanographic monitoring, plankton sampling, acoustic registrations and pelagic trawling. However, several of the vessels experienced more wind than in previous years. The weather was fairly good and calm for the two Norwegian vessels except for a few days of fog in the northernmost part of the Norwegian Sea influencing the visual observations. The Icelandic vessel, operating in Icelandic waters, the Iceland basin and the Irminger Sea, encounter unusually many stormy days with a total of 6 days where wind conditions hampered plankton sampling and demanded reduced sailing speed for acoustic recordings. The weather was mostly calm for the Faroese vessel operating mainly in Faroese waters. The chartered vessel Ceton had excellent weather throughout the survey.

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

Table 1. Survey effort by each of the five vessels during the IESSNS 2020. The number of predetermined ("fixed") trawl stations being part of the swept-area stations for mackerel in the IESSNS are shown after the total number of trawl stations (* including 2 days of capelin study).

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

3.1 Hydrography and Zooplankton

The hydrographical and plankton stations by all vessels combined are shown in Figure 1. Árni Friðriksson was equipped with a SEABIRD CTD sensor with a water rosette that was applied during the entire cruise. Tróndur í Gøtu was equipped with a mini SEABIRD SBE 25+ CTD sensor, Kings Bay and Vendla were both equipped with Seabird CTD sensors. Eros used a SEABIRD 19+V2 CTD sensor. Ceton used a Seabird SeaCat 4 CTD. The CTD-sensors were used for recording temperature, salinity and pressure (depth) from the surface down to 500 m, or to the bottom when at shallower depths.

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

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

3.2 Trawl sampling

All vessels used the standardized Multpelt 832 pelagic trawl (ICES 2013a; Valdemarsen et al. 2014; Nøttestad et al. 2016) for trawling, both for fixed surface stations and for trawling at greater depths to confirm acoustic registrations. Standardization of trawl deployment was emphasised during the survey as in previous years (ICES 2013a; ICES 2014b; ICES 2017). Sensors on the trawl doors, headrope and ground rope of the Multpelt 832 trawl recorded data, and allowed live monitoring, of effective trawl width (actually door spread) and trawl depth. The properties of the Multpelt 832 trawl and rigging on each vessel is reported in Table 2.

Trawl catch was sorted to the highest taxonomical level possible, usually to species for fish, and total weight per species recorded. The processing of trawl catch varied between nations as the Norwegian, Icelandic and Greenlandic vessels sorted the whole catch to species but the Faroese vessel sub-sampled the catch before sorting. Sub-sample size ranged from 60 kg (if it was clean catch of either herring or mackerel) to 150 kg (if it was a mixture of herring and mackerel), however, all lumpfish were picked out from the total catch. The biological sampling protocol for trawl catch varied between nations in number of specimens sampled per station (Table 3).

Table 2. Trawl settings and operation details during the international mackerel survey in the Nordic Seas from 1st July to 4th August 2020. The column for influence indicates observed differences between vessels likely to influence performance. Influence is categorized as 0 (no influence) and + (some influence).

Properties	Kings Bay	Árni Friðriksson	Vendla	Ceton	Tróndur í Gøtu	Eros	Influ-ence
Trawl producer	Egersund Trawl AS	Hampiðjan new 2017 trawl	Egersund Trawl AS	Egersund Trawl AS	Vónin	Hampiðjan	0
Warp in front of doors	Dynex–34 mm	Dynex-34 mm	Dynex -34 mm	Dynex	Dynema – 30 mm	Dynex-34 mm	+
Warp length during towing	350	350	350	300-350	350	340-347	0
Difference in warp length port/starb. (m)	2-10	16	2-10	10	0-15	10-20	0
Weight at the lower wing ends (kg)	2×400	2×400 kg	2×400	2×400	2×400	2×500	0
Setback (m)	6	14	6	6	6	6	+
Type of trawl door	Seaflex 7.5 m^2 adjustable hatches	Jupiter	Seaflex 7.5 m^2 adjustable hatches	Thybron type 15	Injector F-15	T-20vf Flipper	0
Weight of trawl door (kg)	1700	2200	1700	1970	2000	2000	+
Area trawl door (m^2)	7.5 with 25% hatches (effective 6.5)	6	7.5 with 25% hatches (effective 6.5)	7	6	7 with 50% hatches (effective 6.5)	+
Towing speed (knots) mean (min-max)	4.72 (4.3-5.3)	5.1 (4.5-5.8)	4.89 (4.1-5.5)	4.8 (4.0-5.3)	4.9 (4.4-5.4)	4.9 (4.1-5.9)	+
Trawl height (m) mean (min-max)	28-40	36 (28-45)	28-37	31 (24-39)	45.5 (40.5-49.5)	-	+
Door distance (m) mean (min-max)	118.3 (115-120)	101.3 (90 - 113)	121.8 (118-126)	127 (115-139)	99.1 (94 – 104)	118 (113-121)	+
Trawl width (m)*	65.8	60.6	68.0	70.54	57.2	66.5	+
Turn radius (degrees)	5-10	5	5-12	5-10	5-10 BB turn	6-8 SB turn	+
Fish lock front of cod-end	Yes	Yes	Yes	Yes	Yes	Yes	+
Trawl door depth (port, starboard, m) (min-max)	5-15, 7-18	12-12, 4-31	6-22, 8-23	4-16	4-20, 5-19	(11.4-11)	+
Headline depth (m)	0	0	0	0	0	0-1	+
Float arrangements on the headline	Kite with fender buoy +2 buoys on each wingtip	Kite + 2 buoys on wings	Kite with fender buoy +2 buoys on each wingtip	Kite with fender buoy + 2 buoys on each wingtip	Kite with fender buoy + 1 buoy on each wingtip	Kite + 1 buoy on each wingtips	+
Weighing of catch	All weighted	All weighted	All weighted	All weighted	All weighed	All weighted	+

* calculated from door distance

Table 3. Protocol of biological sampling during the IESSNS 2020. Numbers denote the maximum number of individuals sampled for each species for the different determinations.

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

*Length measurements / weighed individuals
**Sampled at every third station
*** One fish per cm-group ≤ 25 cm and two fish > 25 cm from each station was weighed and aged.
^All live lumpfish were tagged and released, only otoliths taken from fish which were dead when brought aboard

Underwater camera observations during trawling

M/V "Kings Bay" and M/V "Vendla" employed an underwater video camera (GoPro HD Hero 4 and 5 Black Edition, www.gopro.com) to observe mackerel aggregation, swimming behaviour and possible escapement from the cod end and through meshes. The camera was put in a waterproof box which tolerated pressure down to approximately 100 m depth. No light source was employed with cameras; hence, recordings were limited to day light hours. Some recordings were also taken during nighttime when there was midnight sun and good underwater visibility. Video recordings were collected at 89 trawl stations. The camera was attached on the trawl in the transition between 200 mm and 400 mm meshes.

3.3 Marine mammals

Opportunistic observations of marine mammals were conducted by scientific personnel and crew members from the bridge between 3rd July and 2nd August 2020 onboard M/V "Kings Bay" and M/V "Vendla". Marine mammal observations were conducted, during the day (weather permitting), by a dedicated whale observer aboard R/V Árni Friðriksson from 1st until 13th July 2020. Opportunistic observations were also done from the bridge by crew members between 1st and 30th July 2020.

3.4 Lumpfish tagging

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

3.5 Acoustics

Multifrequency echosounder

The acoustic equipment onboard Kings Bay and Vendla were calibrated 2nd July 2020 for 18, 38, 70, 120 and 200 kHz. Onboard Kings Bay there were permanent noise challenges on the multifrequency acoustics including the 38kHz transducer during the entire survey. This noise problem predominantly influenced waters deeper than 200 m and could not be solved during the survey. The noise problem was much less at low speed (<5 knots) compared to high cruising speed (10 knots). Árni Friðriksson was calibrated in early May 2020 for the frequencies 18, 38, 70, 120 and 200 kHz. On Árni, EK80 transceivers were installed recently, there were some unusual noise problems in the backscatter and intermittent technical problems which prevented acoustic recordings a few times when vessel was on transport transect causing lack of acoustic track. Tróndur í Gøtu was calibrated on 26th June 2020 for 38 kHz and due to noise problems the first week; it was again calibrated 8th July after the issue had been resolved. Because of the noise issues, data from Tróndur í Gøtu south of Faroes were only usable down to 150 m. Calibration of the acoustic equipment onboard Eros was done after the cruise on the 2nd of August. All frequencies were calibrated successfully. Ceton did not conduct any acoustic data collection because no calibrated equipment was available. All the other vessels used standard hydro-acoustic calibration procedure for each operating frequency (Foote 1987). CTD measurements were taken in order to get the correct sound velocity as input to the echosounder calibration settings.

Acoustic recordings were scrutinized to herring and blue whiting on daily basis using the post-processing software (LSSS, see Table 4 for details of the acoustic settings by vessel). Acoustic measurements were not conducted onboard Ceton in the North Sea. Species were identified and partitioned using catch information, characteristic of the recordings, and frequency between integration on 38 kHz and on other frequencies by a scientist experienced in viewing echograms.

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

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

Table 4. Acoustic instruments and settings for the primary frequency (38 kHz) during IESSNS 2020.

	M/V Kings Bay	R/V Árni Friðriksson	M/V Vendla	M/V Tróndur í Gøtu 250620	M/V Tróndur í Gøtu 080720	Eros
Echo sounder	Simrad EK80	Simrad EK 80	Simrad EK 60	Simrad EK 60	Simrad EK 60	Simrad EK 80
Frequency (kHz)	18, 38, 70, 120, 200	18, 38, 70, 120, 200	18, 38, 70, 120, 200	38,120, 200	38,120, 200	18, 38, 70, 120, 200, 333
Primary transducer	ES38-7	ES38-7	ES38B	ES38B	ES38B	ES38B
Transducer installation	Drop keel	Drop keel	Drop keel	Hull	Hull	Hull
Transducer depth (m)	9	8	9	7	7	8
Upper integration limit (m)	15	15	15	Not used	Not used	15
Absorption coeff. (dB/km)	9.6	10.0	10.1	9.7	9.7	9.3
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.43		2.43	2.43	2.43	2.43
Transmitter power (W)	2000	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.90	18	21.90	21.9	21.9	21.9
2-way beam angle (dB)	-20.70	-20.3	-20.70	-20.6	-20.6	-20.7
TS Transducer gain (dB)	26.33	26.9	25.46	23.44	24.09	25.50
s_A correction (dB)	-0.03	-0.02	-0.02	-0.65	-0.65	-0.6
alongship:	-0.28	6.53	0.19	7.42	7.20	6.86
athw. ship:	0.00	6.5	0.08	7.09	7.03	7.05
Maximum range (m)	500	500	500	500	500	750 for 18 and 38 kHz 500 for 70, 120 and 200 kHz
Post processing software	LSSS v.2.8.1	LSSS v.2.8	LSSS v.2.8.1	LSSS 2.8.0	LSSS 2.8.0	LSSS v.2.8

* No acoustic data collection

Multibeam sonar

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

Cruise tracks

The six participating vessels followed predetermined survey lines with predetermined surface trawl stations (Figure 1). Calculations of the mackerel index are based on swept area approach with the survey area split into 13 strata, permanent and dynamic strata (Figure 2). Distance between predetermined surface trawl stations is constant within stratum but variable between strata and ranged from 35-90 nmi. The survey design using different strata is done to allow the calculation of abundance indices with uncertainty estimates, both overall and from each stratum in the software program StoX (see Salthaug et al. 2017). Temporal survey progression by vessel along the cruise tracks in July-August 2020 is shown in Figure 3. The cruising speed was between 10-12 knots if the weather permitted otherwise the cruising speed was adapted to the weather situation.

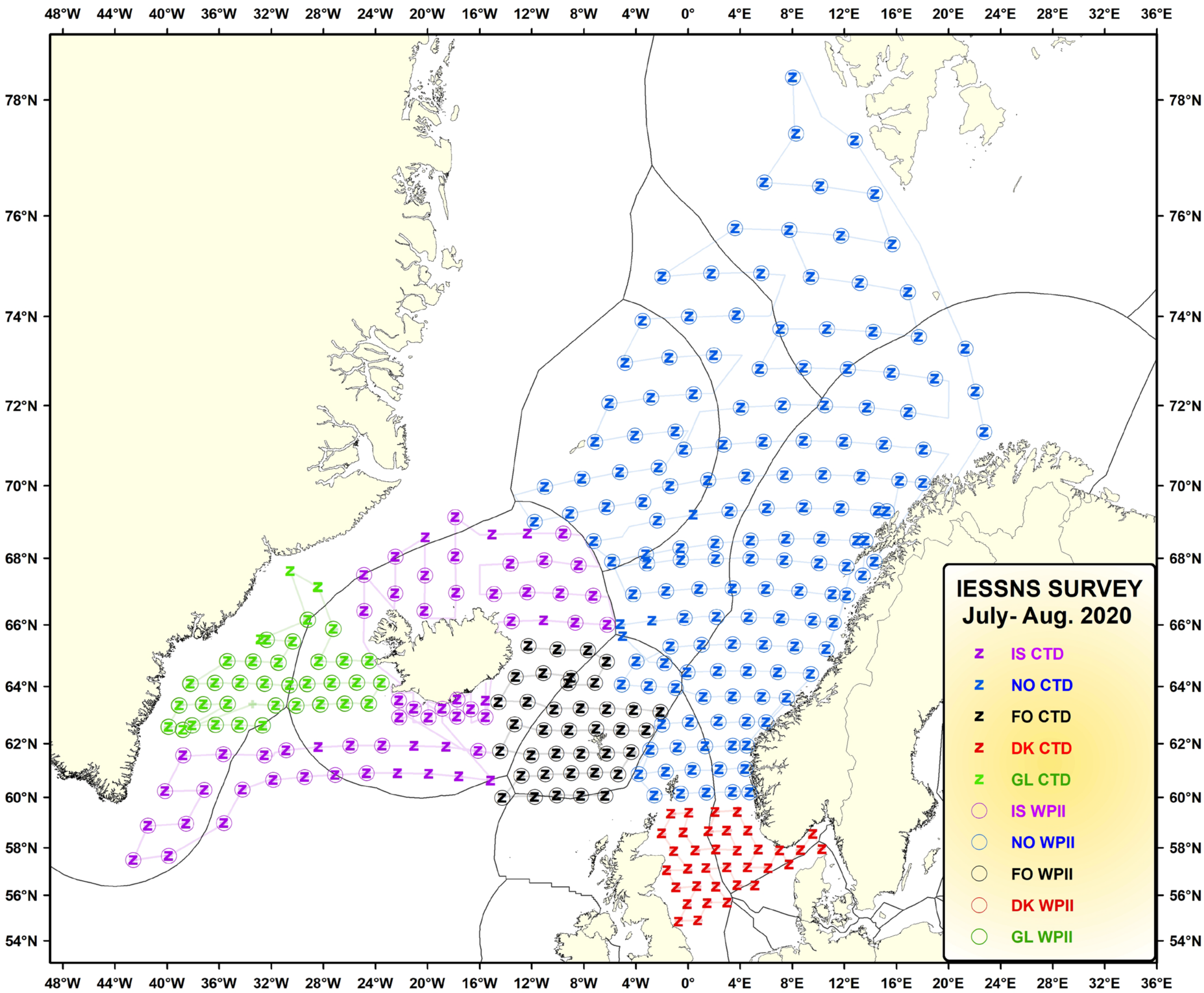


Figure 1. Fixed predetermined trawl stations (shown for CTD and WP2) included in the IESSNS 1st July – 4th August 2020. At each station a 30 min surface trawl haul, a CTD station (0-500 m) and WP2 plankton net samples (0-200 m depth) was performed. The colour codes, Árni Friðriksson (purple), Tróndur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

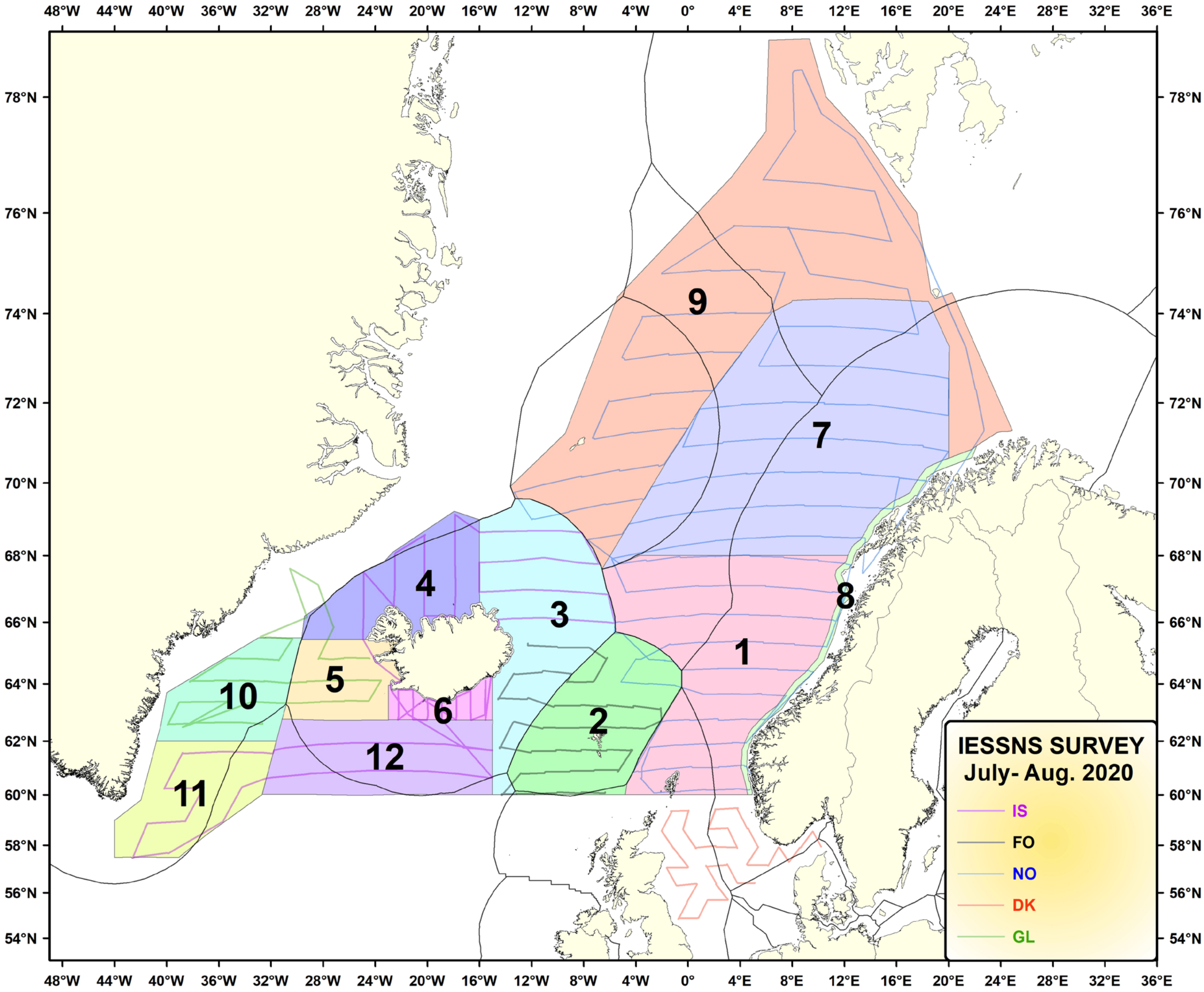


Figure 2. Permanent and dynamic strata used in StoX for IESSNS 2020. The dynamic strata are: 4, 9 and 11.

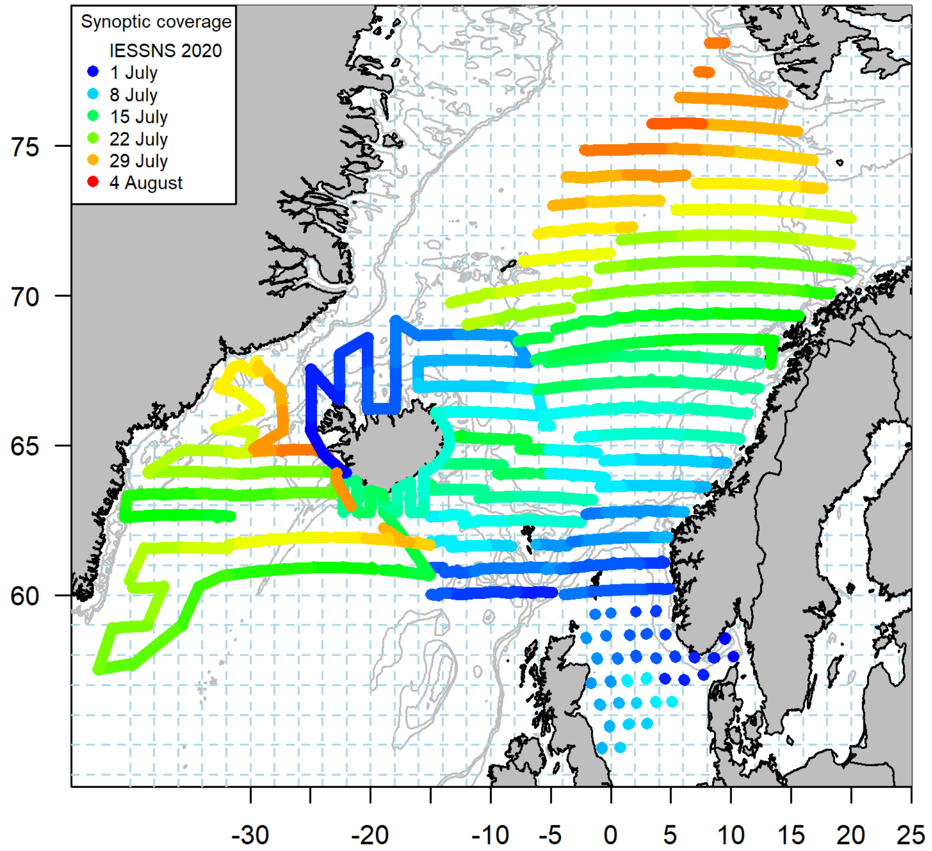


Figure 3. Temporal survey progression by vessel along the cruise tracks during IESSNS 2020: blue represents effective survey start (1st of July) progressing to red representing a five-week span (survey ended 4th of August). As Ceton did not record acoustics, they have been represented by station positions.

3.6 StoX

Stox is open source software developed at IMR, Norway to calculate survey estimates from acoustic and swept area surveys. A description of Stox can be found in Johnsen et al. (2019). The software, with examples and documentation, can be found at: http://www.imr.no/forskning/prosjekter/stox/nb-no. The program is a stand-alone application built with Java for easy sharing and further development in cooperation with other institutes. The underlying high-resolution data matrix structure ensures future implementations of e.g. depth dependent target strength and high-resolution length and species information collected with camera systems. Despite this complexity, the execution of an index calculation can easily be governed from user interface and an interactive GIS module, or by accessing the Java function library and parameter set using external software like R. Various statistical survey design models can be implemented in the R-library, however, in the current version of StoX the stratified transect design model developed by Jolly and Hampton (1990) is implemented. Mackerel, herring and blue whiting indices were calculated using the StoX software package (version 2.7).

3.7 Swept area index and biomass estimation

The swept area age segregated index is calculated separately for each stratum (see stratum definition in Figure 2). Individual stratum estimates are added together to get the total estimate for the whole survey area which is approximately defined by the area between 55°N and 79°N and 43°W and 23°E in 2020. The density of mackerel on a trawl stations is calculated by dividing the total number caught by the assumed area swept by the trawl. The area swept is calculated by multiplying the towed distance by the horizontal opening of the trawl. The horizontal opening of the trawl is vessel specific, and the average value across all hauls is calculated based on door spread (Table 5 and Table 6). An estimate of total number of mackerel in a stratum is obtained by taking the average density based on the trawl stations in the stratum and multiplying this with the area of the stratum.

Table 5. Descriptive statistics for trawl door spread, vertical trawl opening and tow speed for each vessel during IESSNS 2020. Number of trawl stations used in calculations is also reported. Horizontal trawl opening was calculated using average vessel values for trawl door spread and tow speed (details in Table 6).

	Tróndur í Gøtu	RV Árni Friðriksson	Kings Bay	Vendla	Eros	Ceton
Trawl doors horizontal spread (m)						
Number of stations	37	58	74	78	33	35
Mean	99.1	101.3	118.3	121.8	115.2	127
max	104	113	135	129	134	139
min	94	90	110	107	100	114
st. dev.	2.2	5.1	2.84	4.6	5.2	5.7
Vertical trawl opening (m)						
Number of stations	37	58	74	78	33	35
Mean	45.5	36.4	33.6	30.3	34.9	31
max	49.5	45.0	40	40	44.8	39
min	40.5	27.5	29	25	29.2	24
st. dev.	2.0	3.8	2.9	3.0	3.2	3.9
Horizontal trawl opening (m)						
mean	57.2	60.6	65.8	68.0	67.4	70.5
Speed (over ground, nmi)						
Number of stations	38	58	74	78	33	35
mean	4.55	5.1	4.72	4.89	4.9	4.8
max	4.8	4.5	5.7	5.7	5.4	5.3
min	4.3	5.8	4.1	4.4	4.4	4.0
st. dev.	0.1	0.2	0.30	0.29	0.3	0.3

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

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

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

Table 6. Horizontal trawl opening as a function of trawl door spread and towing speed. Relationship based on simulations of horizontal opening of the Multpelt 832 trawl towed at 4.5 and 5 knots, representing the speed range in the 2014 survey, for various door spread. See text for details. In 2017, the towing speed range was extended from 5.0 to 5.2, and in 2020 the door spread was extended to 122 m.

	Towing speed							
Door spread(m)	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2
100	57.2	57.7	58.2	58.7	59.2	59.7	60.2	60.7
101	57.6	58.1	58.6	59.1	59.6	60.1	60.6	61.1
102	58.1	58.6	59.0	59.5	60.0	60.5	61.0	61.4
103	58.5	59.0	59.5	59.9	60.4	60.9	61.3	61.8
104	59.0	59.4	59.9	60.3	60.8	61.3	61.7	62.2
105	59.4	59.9	60.3	60.8	61.2	61.7	62.1	62.6
106	59.8	60.3	60.7	61.2	61.6	62.1	62.5	62.9
107	60.3	60.7	61.2	61.6	62.0	62.5	62.9	63.3
108	60.7	61.1	61.6	62.0	62.4	62.9	63.3	63.7
109	61.2	61.6	62.0	62.4	62.8	63.2	63.7	64.1
110	61.6	62.0	62.4	62.8	63.2	63.6	64.1	64.5
111	62.0	62.4	62.8	63.2	63.6	64.0	64.4	64.8
112	62.5	62.9	63.3	63.7	64.0	64.4	64.8	65.2
113	62.9	63.3	63.7	64.1	64.4	64.8	65.2	65.6
114	63.4	63.7	64.1	64.5	64.9	65.2	65.6	66.0
115	63.8	64.2	64.5	64.9	65.3	65.6	66.0	66.3
116	64.3	64.6	65.0	65.3	65.7	66.0	66.4	66.7
117	64.7	65.0	65.4	65.7	66.1	66.4	66.8	67.1
118	65.1	65.5	65.8	66.1	66.5	66.8	67.1	67.5
119	65.6	65.9	66.2	66.6	66.9	67.2	67.5	67.9
120	66.0	66.3	66.6	67.0	67.3	67.6	67.9	68.2
121	66.5	66.8	67.1	67.4	67.7	68.0	68.3	68.6
122	66.9	67.2	67.5	67.8	68.1	68.4	68.7	69.0

4 Results and discussion

4.1 Hydrography

Satellite measurements of sea surface temperature (SST) in the eastern part of the Norwegian Sea in July 2020 was slightly higher (0.5-1°C) compared to the average for July 1990-2009 based on SST anomaly plot (Figure 4). Surface temperature in the western part of the Norwegian Sea in July 2020 was broadly similar compared to the average (Figure 4). The coastal regions of Greenland were 1-2°C warmer than the average while in the waters south of Iceland, in the Irminger Sea and around the Faroe islands, the SST was similar to the average for July 1990-2009 (Figure 4). This contrasts with the situation in 2019 when SST in the coastal areas of Greenland were 2-3°C warmer and the waters south of Iceland, in the Irminger Sea and around the Faroe islands were 1-2°C warmer than the average. The pattern of anomalies of Sea Surface Temperature in July 2020 was quite different from the other years in the time series from 2010 to 2019.

It must be mentioned that the NOAA SST are sensitive to the weather condition (i.e. wind and cloudiness) prior to and during the observations and do therefore not necessarily reflect the oceanographic condition of the water masses in the areas, as seen when comparing detailed in situ features of SSTs between years (Figures 5-8). However, since the anomaly is based on the average for the whole month of July, it should give representative results of the surface temperature.

In situ measurements showed the upper layer (10 m depth) was 1.0-2.0°C colder in 2020 compared to 2019 in most of Icelandic and Greenland waters but 1.0-2.0°C warmer in 2020 compared to 2019 along the Norwegian coast (Figure 5). The temperature in the upper layer was higher than 8°C in most of the surveyed area, except along the north-western fringes of the surveyed areas north of Iceland where it was lower. In the deeper layers (50 m and deeper; Figure 6-8), the hydrographical features in the area were similar to the last four years (2014-2018) except around the Faroe Islands where temperature at 100 m depth was about 1°C warmer. At all depths there were a clear signal from the cold East Icelandic Current, which originates from the East Greenland Current.

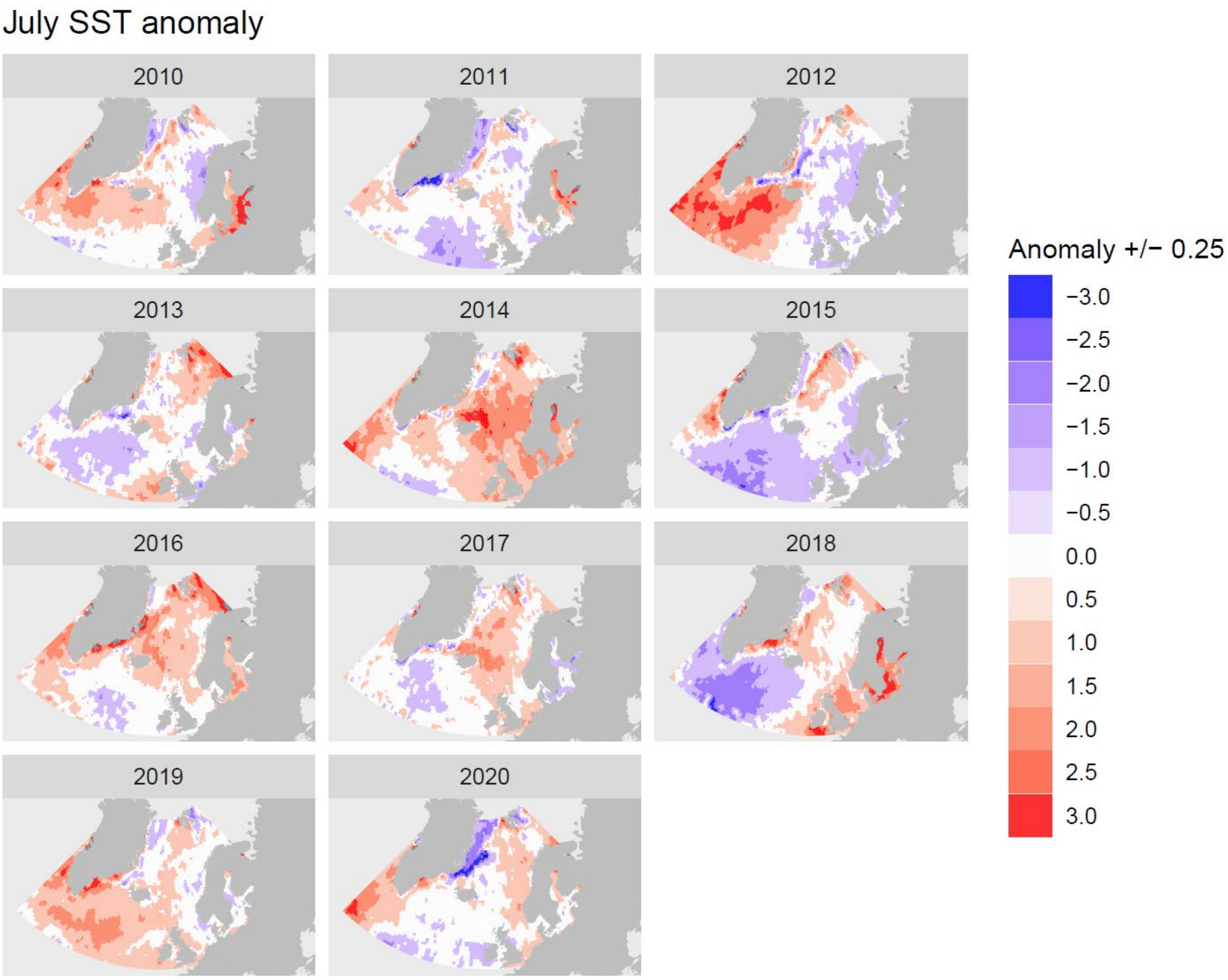


Figure 4. Annual sea surface temperature anomaly (°C) in Northeast Atlantic for the month of July from 2010 to 2020 showing warm and cold conditions in comparison to the average for July 1990-2009. Based on monthly averages of daily Optimum Interpolation Sea Surface Temperature (OISST, AVHRR-only, Banzon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

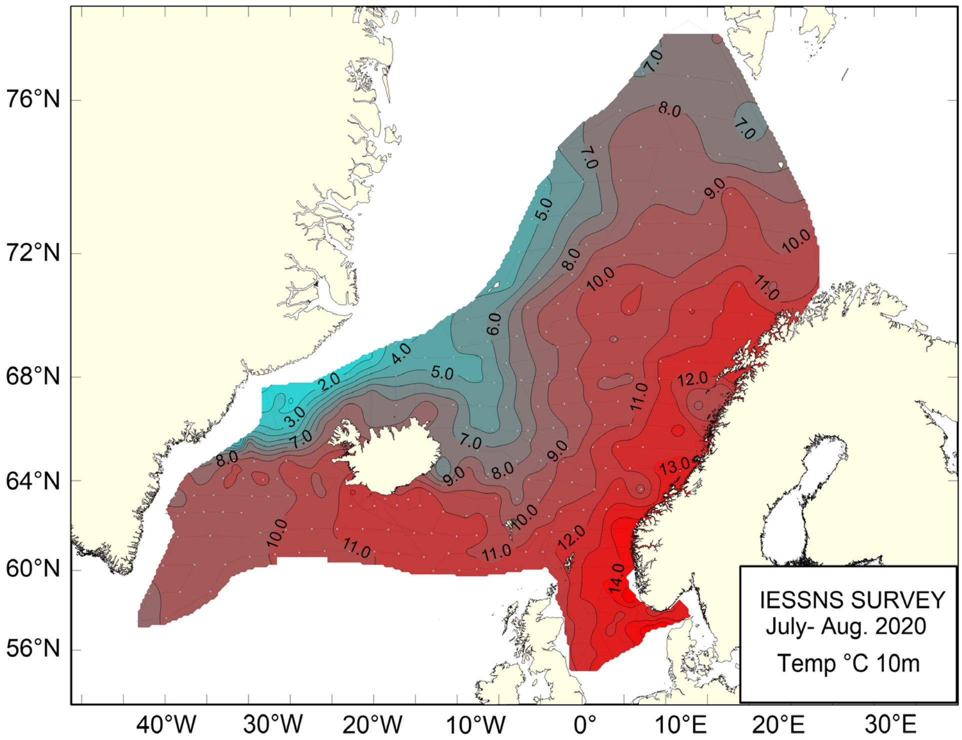


Figure 5. Temperature (°C) at 10 m depth in Nordic Seas and the North Sea in July-August 2020.

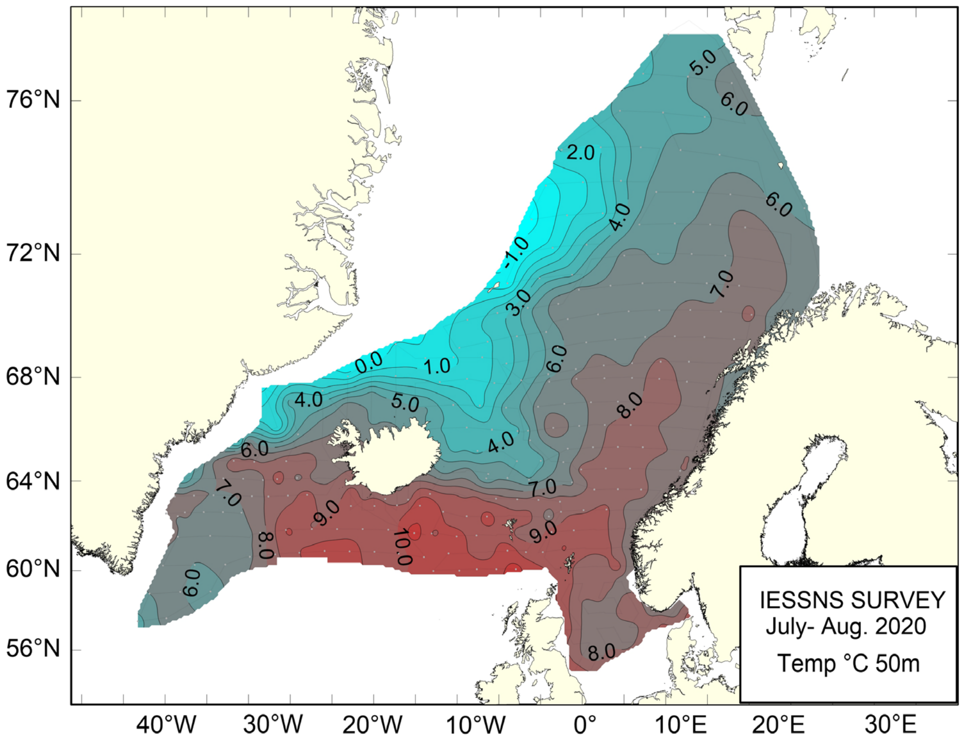


Figure 6. Temperature (°C) at 50 m depth Nordic Seas and the North Sea in July-August 2020.

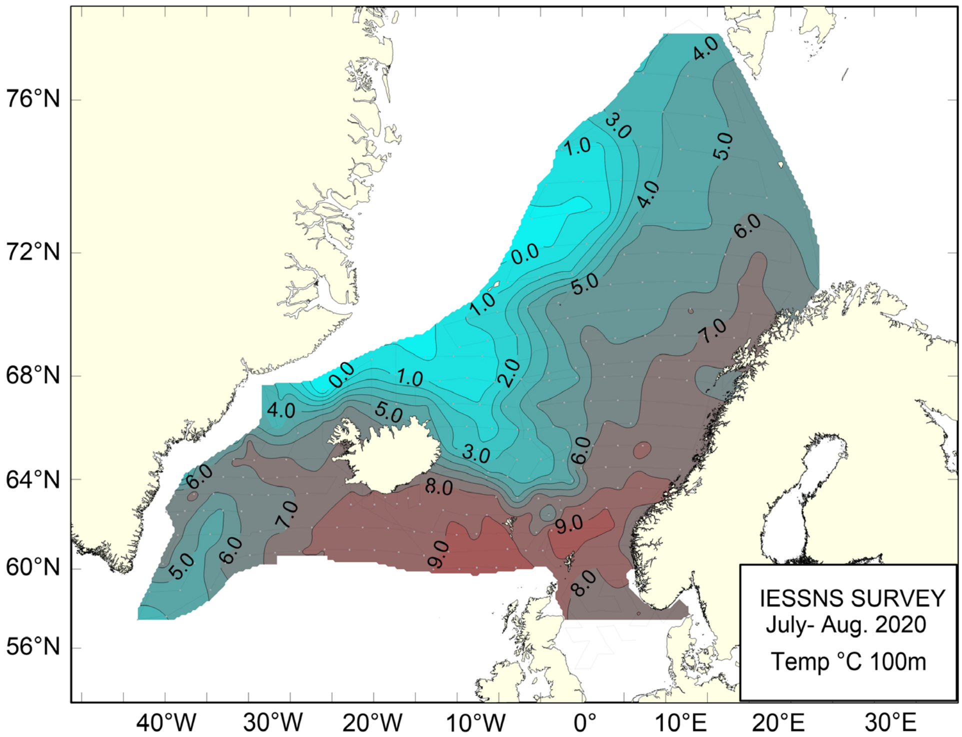


Figure 7. Temperature (°C) at 100 m depth in Nordic Seas and the North Sea in July-August 2020.

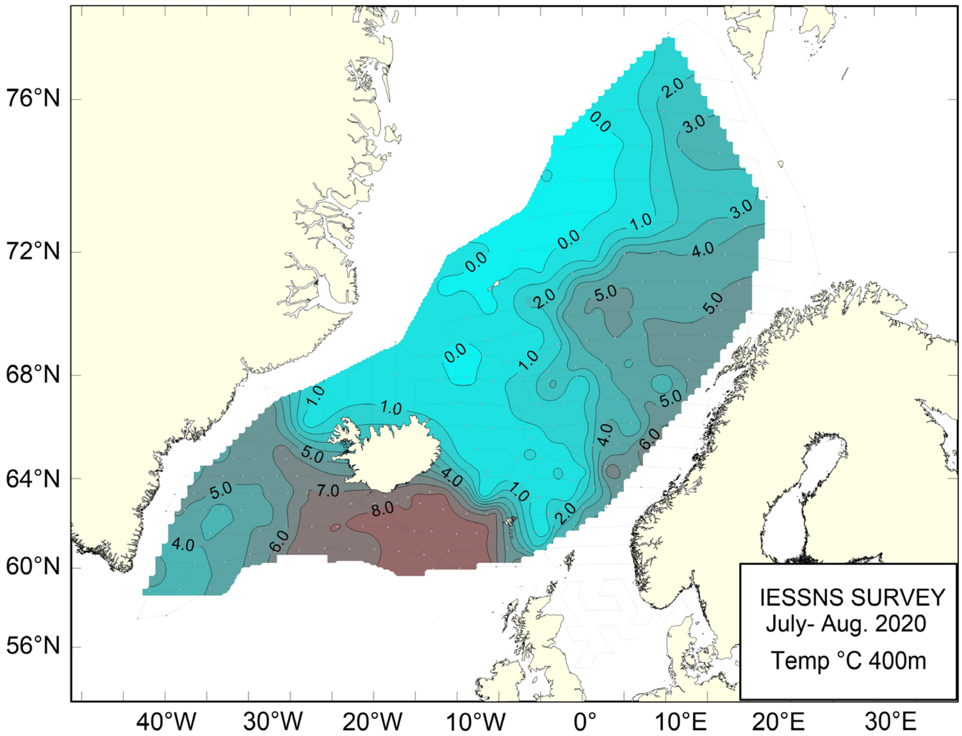


Figure 8. Temperature (°C) at 400 m depth in Nordic Seas and the North Sea in July-August 2020.

4.2 Zooplankton

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

The average zooplankton biomass in Norwegian waters was similar to the average biomass in 2019. In this relatively short time-series, there is greater fluctuations and year-to-year variability (cyclical patterns) in Icelandic and Greenlandic waters compared to the Norwegian Sea. This might in part be explained by both more homogeneous oceanographic conditions in the area defined as Norwegian Sea.

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

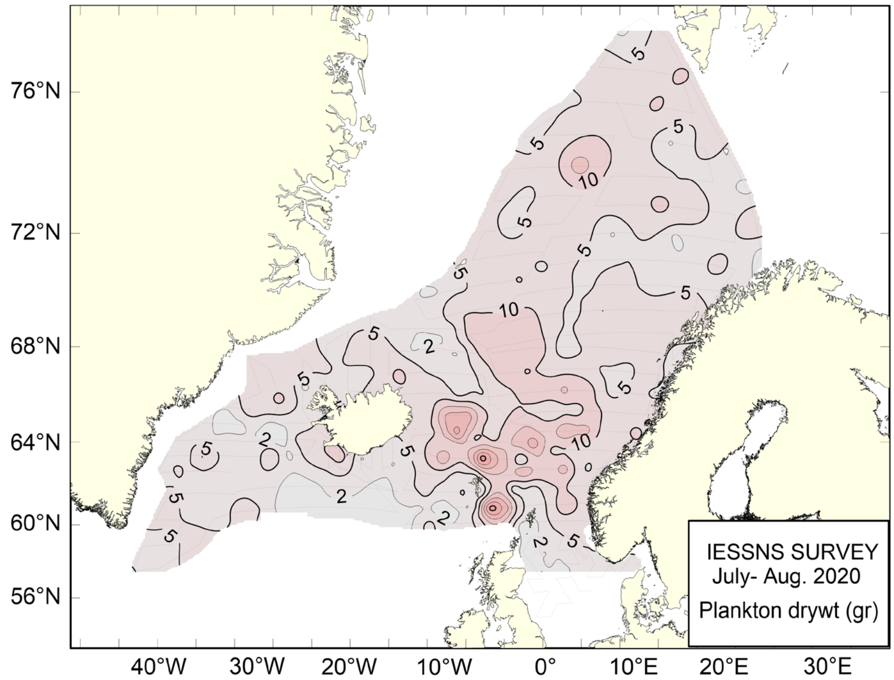


Figure 9a. Zooplankton biomass indices (g dw/m², 0-200 m) in Nordic Seas in July-August.

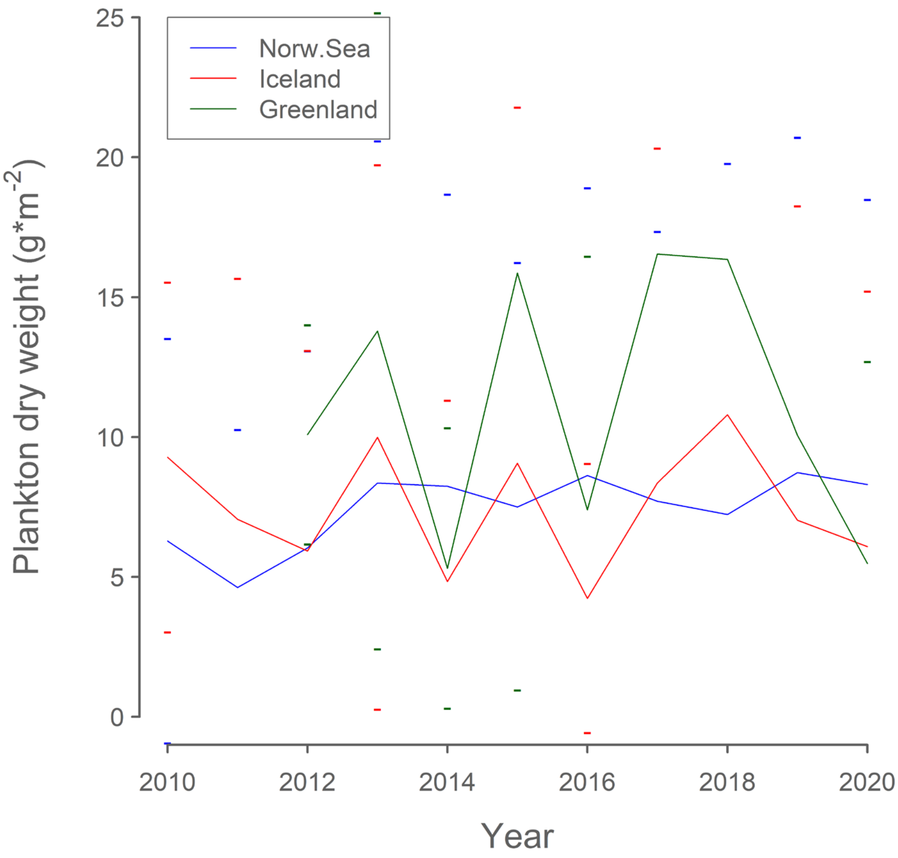


Figure 9b. Zooplankton biomass indices (g dw/m², 0-200 m). Time-series of mean zooplankton biomass for three subareas within the survey range: Norwegian Sea (between 14°W-17°E & north of 61°N), Icelandic waters (14°W-30°W) and Greenlandic waters (west of 30°W).

4.3 Mackerel

The mackerel biomass index i.e. catch rates by trawl station (kg/km²) measured at predetermined surface trawl stations is presented in Figure 10 together with the mean catch rates per 2° lat. x 4° lon. rectangles. The map shows large variations in trawl catch rates throughout the survey area from zero to 62 tonnes/km² (mean = 4.0). High density areas were found in the central and northern Norwegian Sea in 2020, with very small concentrations of mackerel in the western part compared to previous years (Figure 11 & 12). This was both apparent in Greenland waters with no mackerel catches taken and a large decline of mackerel catches in Icelandic waters.

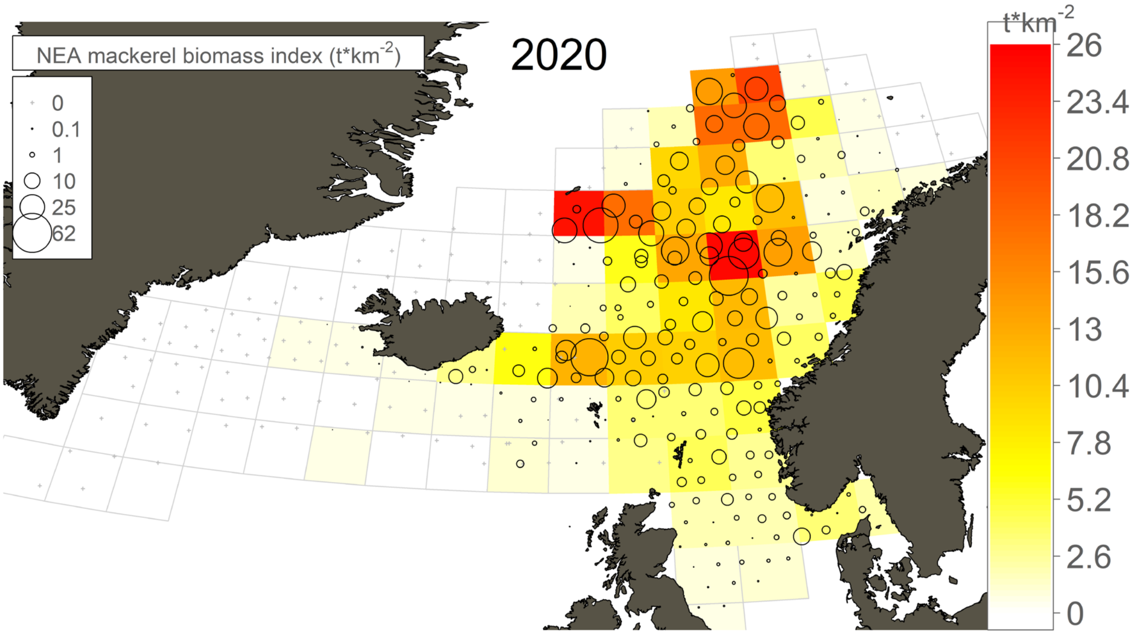


Figure 10. Mackerel catch rates by Multpelt 832 pelagic trawl haul at predetermined surface trawl stations (circle areas represent catch rates in kg/km²) overlaid on mean catch rates per standardized rectangles (2° lat. x 4° lon.).

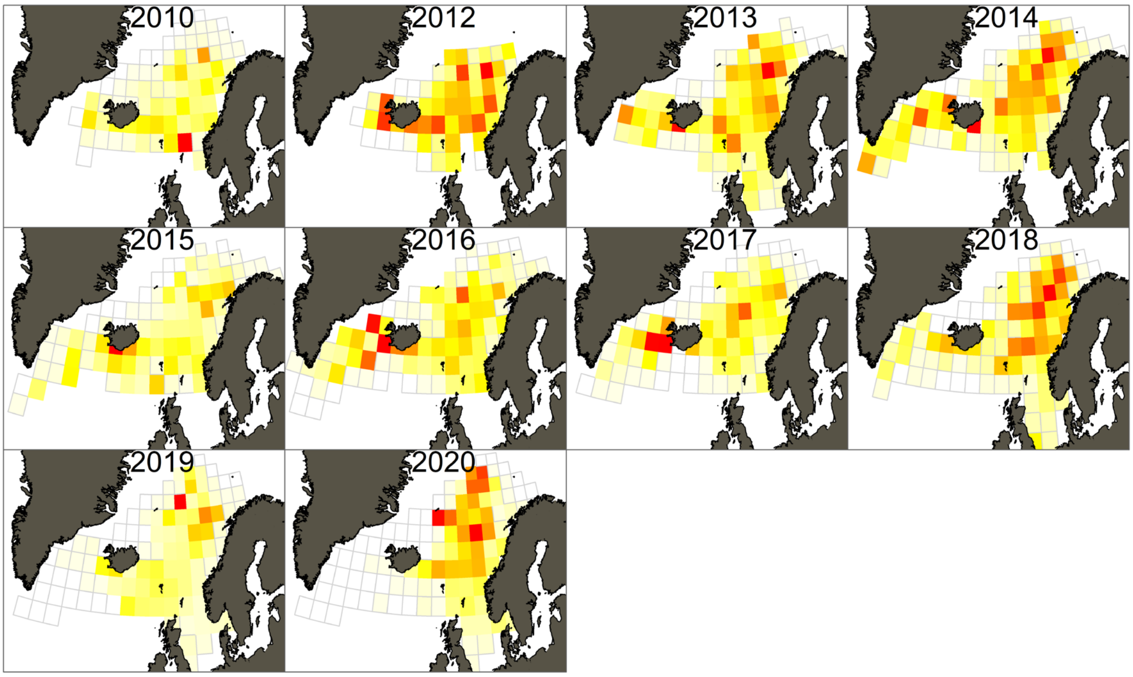


Figure 11. Annual distribution of mackerel proxied by the absolute distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations. Colour scale goes from white (= 0) to red (= maximum value for the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

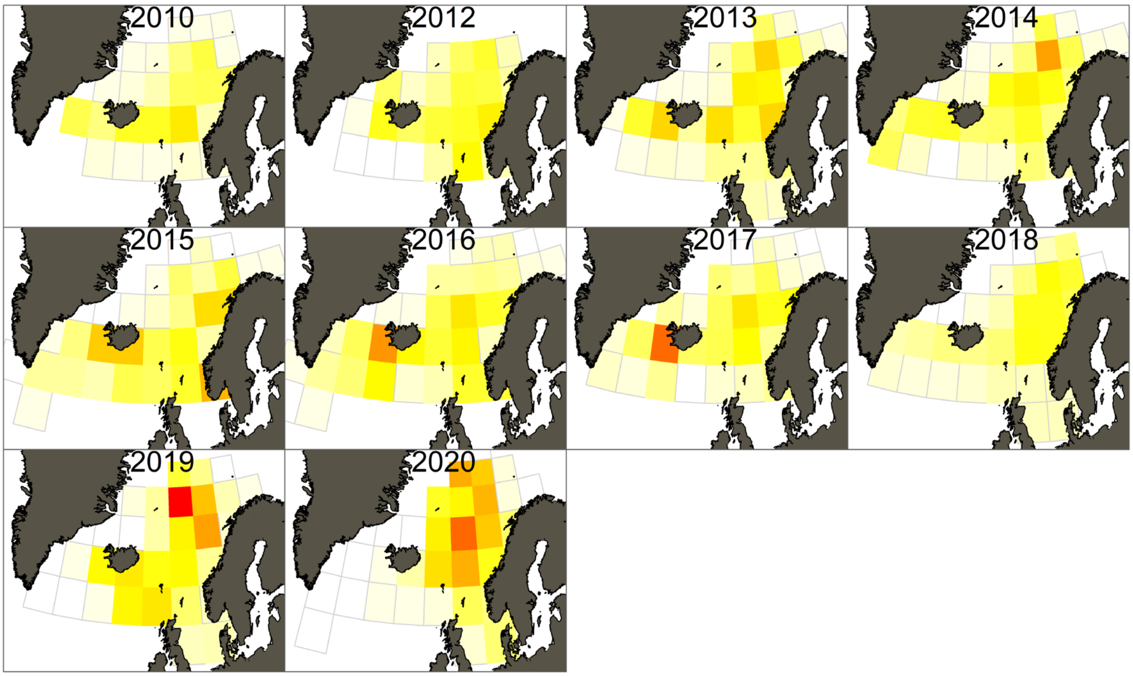


Figure 12. Annual distribution of mackerel proxied by the relative distribution of mean mackerel catch rates per standardized rectangles (4° lat. x 8° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations. Colour scale goes from white (= 0) to red (= maximum value for the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

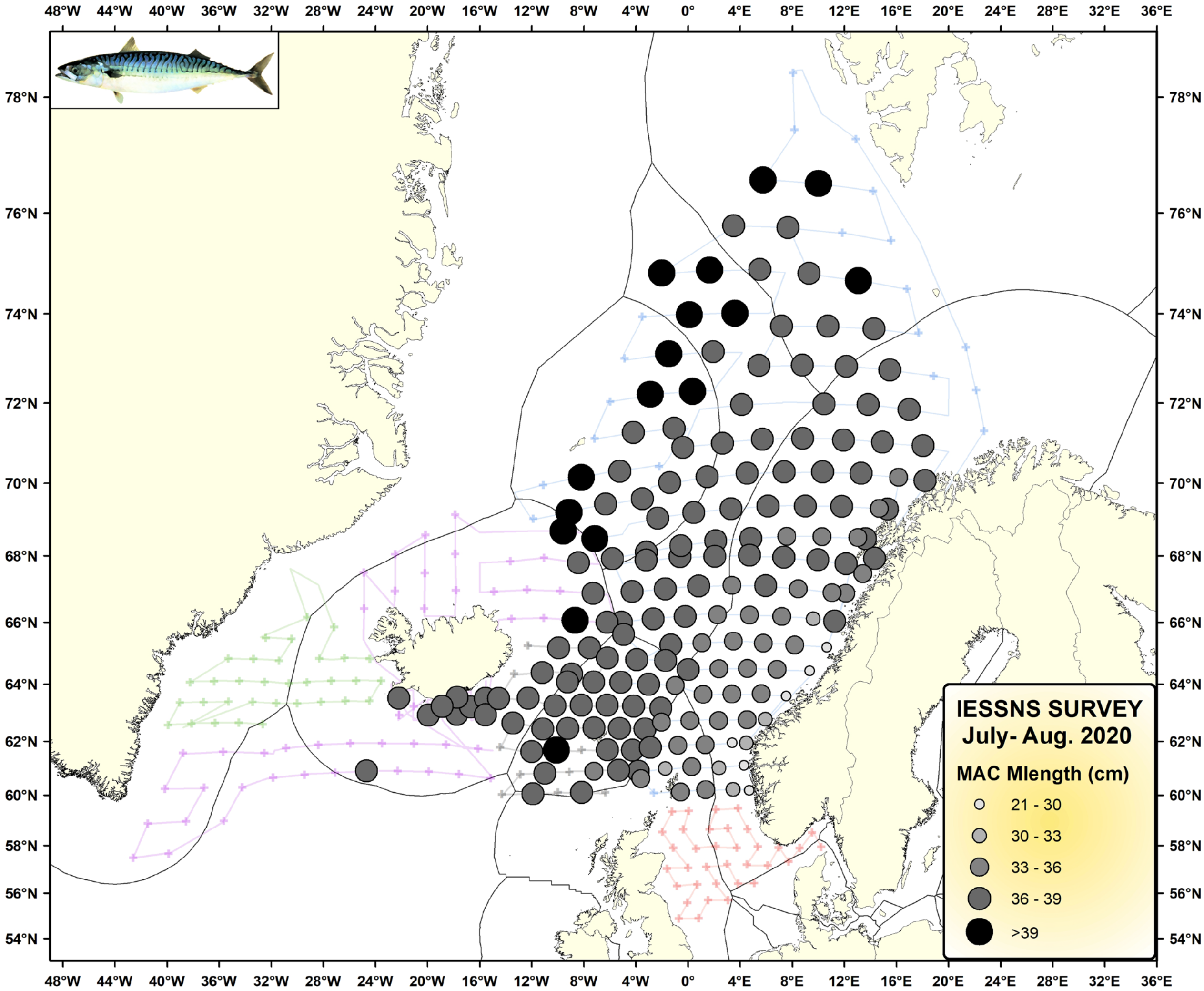


Figure 13. Average length of mackerel at predetermined surface trawl stations during IESSNS 2020.

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

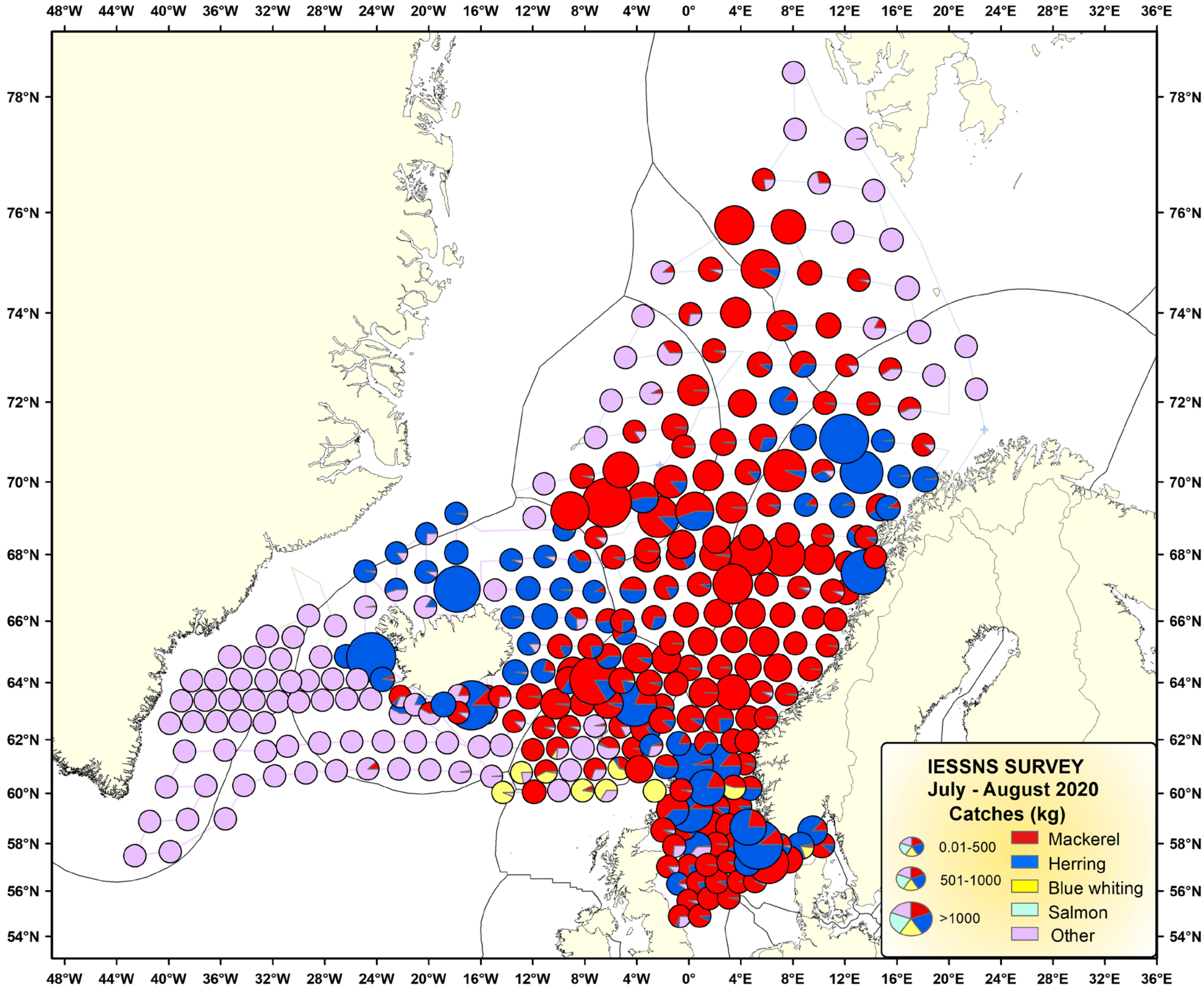


Figure 14. Distribution and spatial overlap between various pelagic fish species (mackerel, herring, blue whiting, salmon, and other (lumpfish)) in 2020 at all surface trawl stations. Vessel tracks are shown as continuous lines.

Swept area analyses from standardized pelagic trawling with Multpelt 832

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

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

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

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

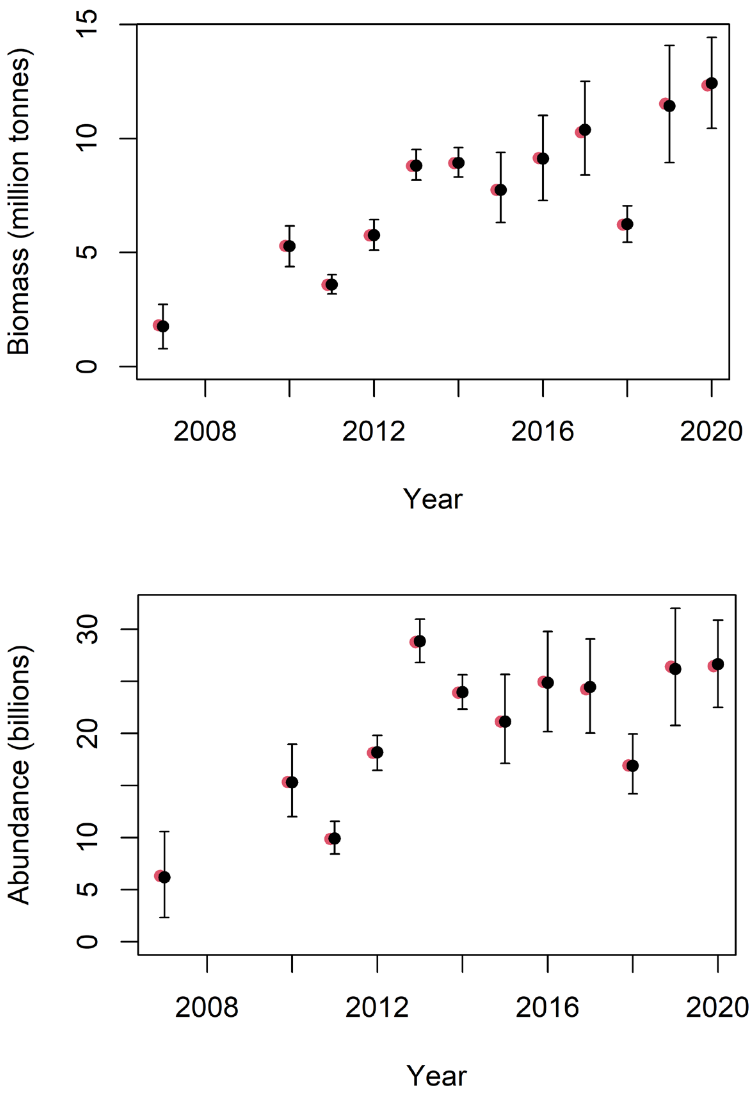


Figure 15. Estimated total stock biomass (upper panel) and total stock numbers (lower panel) of mackerel from StoX . The red dots are baseline estimates, the black dots are mean of 1000 bootstrap replicates while the error bars represent 90 % confidence intervals based on the bootstrap.

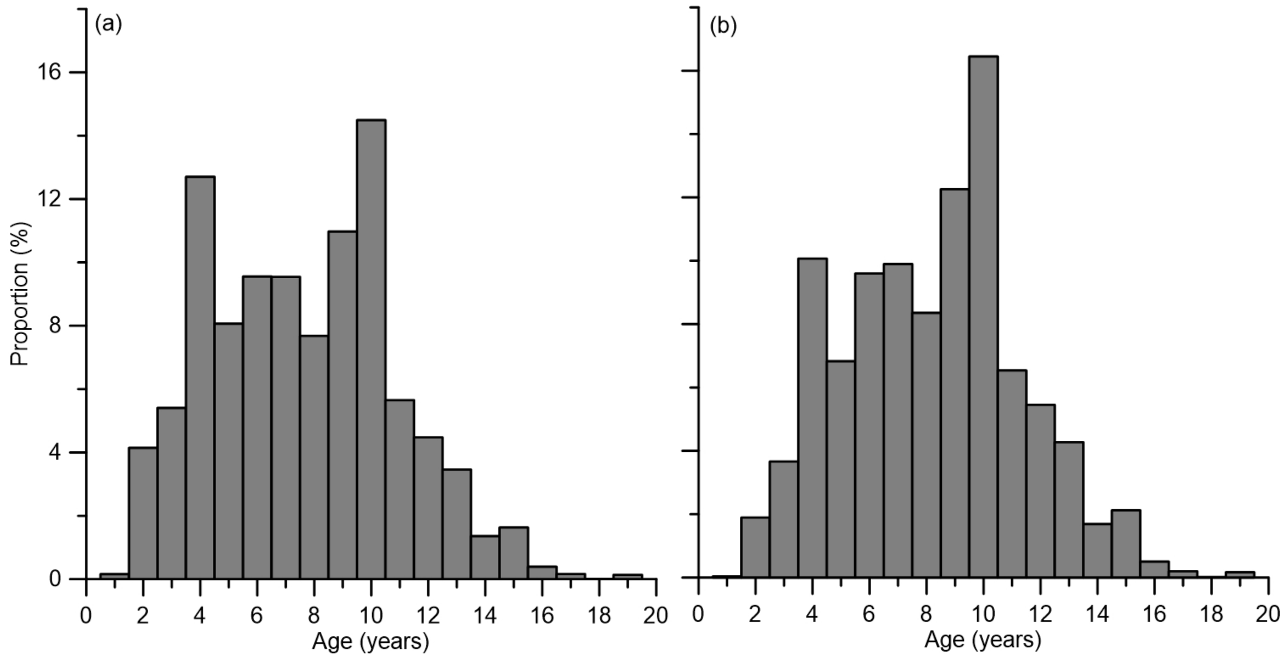


Figure 16. Age distribution in proportion represented as a) % in numbers and b) % in biomass of Northeast Atlantic mackerel in 2020.

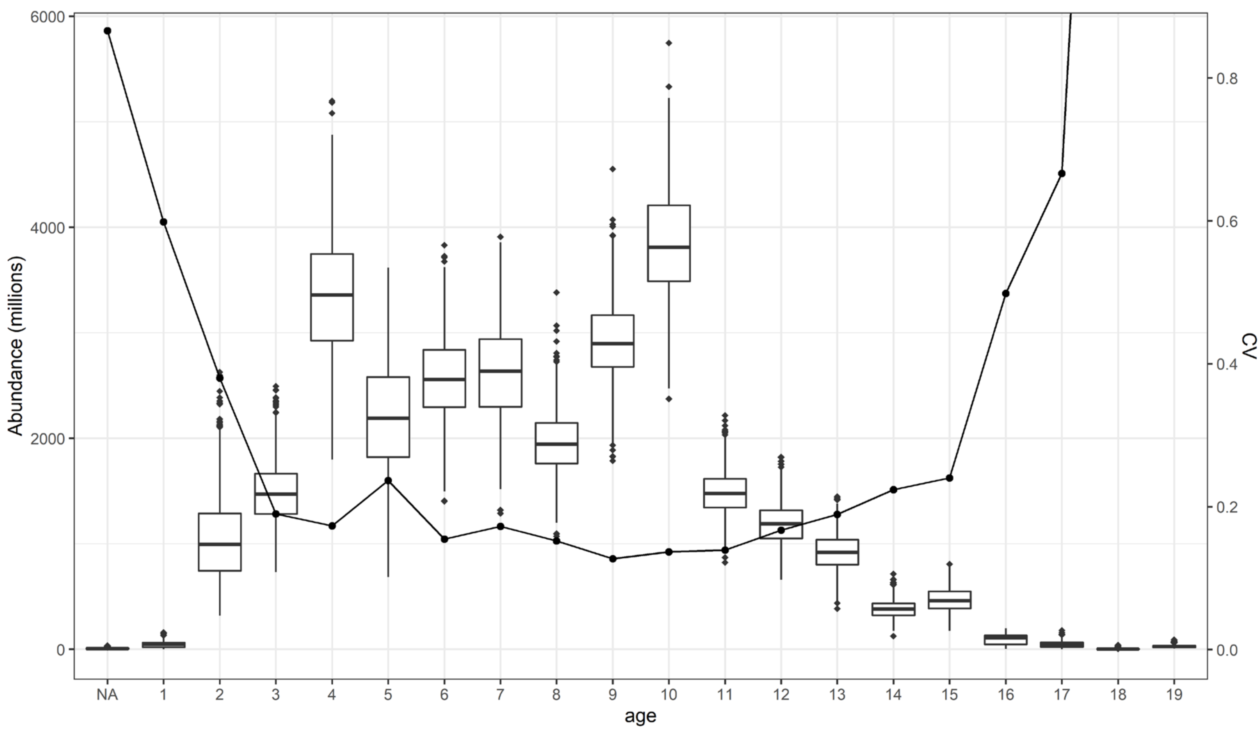


Figure 17. Number by age for mackerel. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 7. a-d) StoX baseline time series of the IESSNS showing (a) age-disaggregated abundance indices of mackerel (billions), (b) mean weight (g) per age and (c) estimated biomass at age (million tonnes) from 2007 to 2020. d) Output from StoX.

a)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)	Tot N
2007	1.33	1.86	0.90	0.24	1.00	0.16	0.06	0.04	0.03	0.01	0.01	0.00	0.01	0.00	5.65
2010	0.03	2.80	1.52	4.02	3.06	1.35	0.53	0.39	0.20	0.05	0.03	0.02	0.01	0.01	13.99
2011	0.21	0.26	0.87	1.11	1.64	1.22	0.57	0.28	0.12	0.07	0.06	0.02	0.01	0.00	6.42
2012	0.50	4.99	1.22	2.11	1.82	2.42	1.64	0.65	0.34	0.12	0.07	0.02	0.01	0.01	15.91
2013	0.06	7.78	8.99	2.14	2.91	2.87	2.68	1.27	0.45	0.19	0.16	0.04	0.01	0.02	29.57
2014	0.01	0.58	7.80	5.14	2.61	2.62	2.67	1.69	0.74	0.36	0.09	0.05	0.02	0.00	24.37
2015	1.20	0.83	2.41	5.77	4.56	1.94	1.83	1.04	0.62	0.32	0.08	0.07	0.04	0.02	20.72
2016	<0.01	4.98	1.37	2.64	5.24	4.37	1.89	1.66	1.11	0.75	0.45	0.20	0.07	0.07	24.81
2017	0.86	0.12	3.56	1.95	3.32	4.68	4.65	1.75	1.94	0.63	0.51	0.12	0.08	0.04	24.22
2018	2.18	2.50	0.50	2.38	1.20	1.41	2.33	1.79	1.05	0.50	0.56	0.29	0.14	0.09	16.92
2019	0.08	1.35	3.81	1.21	2.92	2.86	1.95	3.91	3.82	1.50	1.25	0.58	0.59	0.57	26.4
2020	0.04	1.10	1.43	3.36	2.13	2.53	2.53	2.03	2.90	3.84	1.50	1.18	0.92	0.98	26.47

b)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)
2007	133	233	323	390	472	532	536	585	591	640	727	656	685	671
2010	133	212	290	353	388	438	512	527	548	580	645	683	665	596
2011	133	278	318	371	412	440	502	537	564	541	570	632	622	612
2012	112	188	286	347	397	414	437	458	488	523	514	615	509	677
2013	96	184	259	326	374	399	428	445	486	523	499	547	677	607
2014	228	275	288	335	402	433	459	477	488	533	603	544	537	569
2015	128	290	333	342	386	449	463	479	488	505	559	568	583	466
2016	95	231	324	360	371	394	440	458	479	488	494	523	511	664
2017	86	292	330	373	431	437	462	487	536	534	542	574	589	626
2018	67	229	330	390	420	449	458	477	486	515	534	543	575	643
2019	153	212	325	352	428	440	472	477	490	511	524	564	545	579
2020	99	213	315	369	394	468	483	507	520	529	539	567	575	593

c)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)	Tot B
2007	0.18	0.43	0.29	0.09	0.47	0.09	0.03	0.02	0.02	0.01	0.01	0.00	0.01	0.00	1.64
2010	0.00	0.59	0.44	1.42	1.19	0.59	0.27	0.20	0.11	0.03	0.02	0.01	0.01	0.00	4.89
2011	0.03	0.07	0.28	0.41	0.67	0.54	0.29	0.15	0.07	0.04	0.03	0.01	0.01	0.00	2.69
2012	0.06	0.94	0.35	0.73	0.72	1.00	0.72	0.30	0.17	0.06	0.03	0.01	0.00	0.00	5.09
2013	0.01	1.43	2.32	0.70	1.09	1.15	1.15	0.56	0.22	0.10	0.08	0.02	0.01	0.01	8.85
2014	0.00	0.16	2.24	1.72	1.05	1.14	1.23	0.80	0.36	0.19	0.05	0.03	0.01	0.00	8.98
2015	0.15	0.24	0.80	1.97	1.76	0.87	0.85	0.50	0.30	0.16	0.04	0.04	0.02	0.01	7.72
2016	<0.01	1.15	0.45	0.95	1.95	1.72	0.83	0.76	0.53	0.37	0.22	0.10	0.04	0.04	9.11
2017	0.07	0.03	1.18	0.73	1.43	2.04	2.15	0.86	1.04	0.33	0.28	0.07	0.05	0.03	10.29
2018	0.15	0.57	0.16	0.93	0.50	0.63	1.07	0.85	0.51	0.26	0.30	0.16	0.08	0.05	6.22
2019	0.01	0.29	1.24	0.43	1.25	1.26	0.92	1.86	1.87	0.77	0.65	0.33	0.32	0.32	11.52
2020	<0.01	0.23	0.45	1.24	0.84	1.18	1.22	1.03	1.51	2.03	0.81	0.67	0.53	0.58	12.33

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

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

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

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

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

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

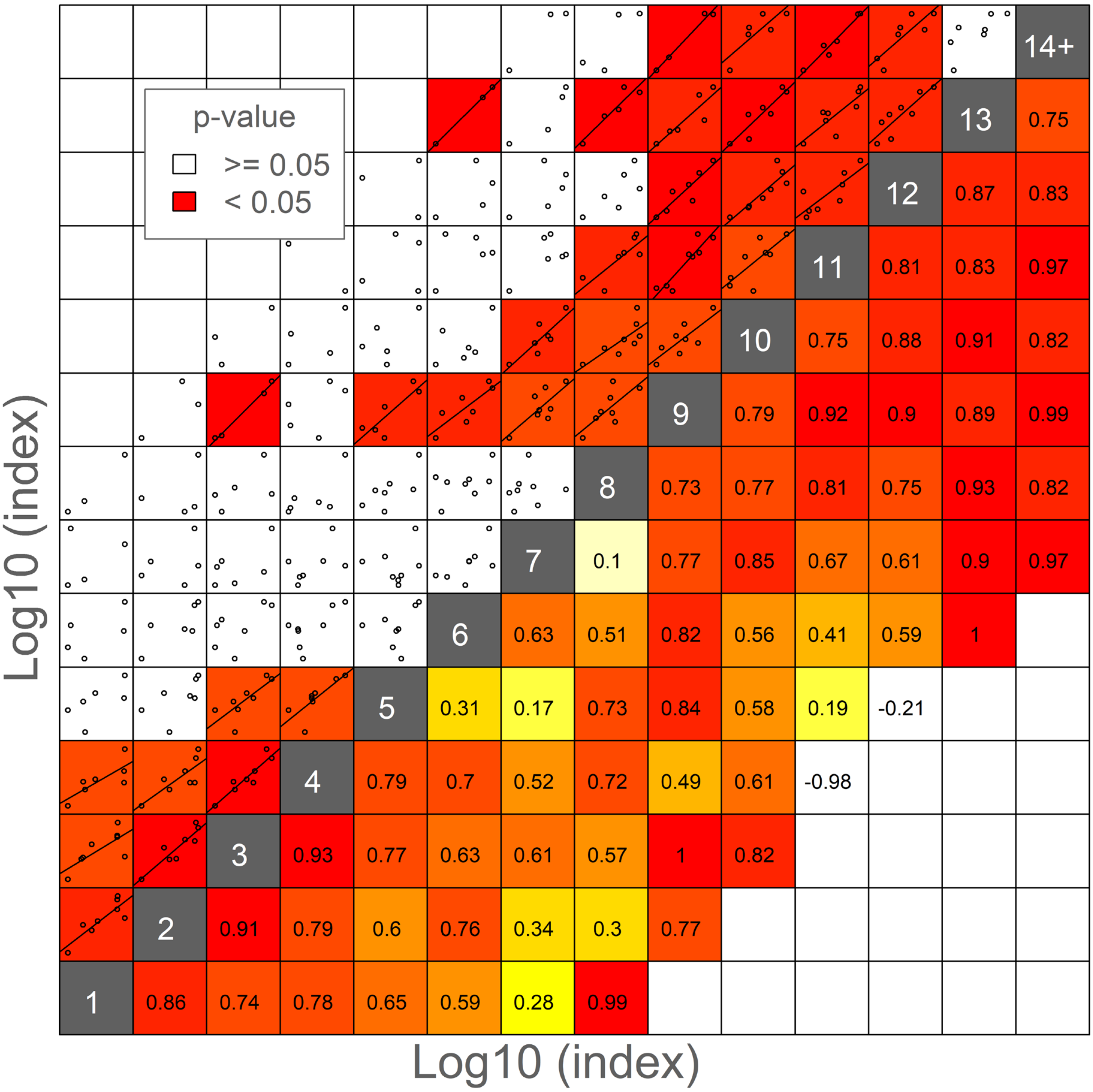


Figure 19. Internal consistency of the of mackerel density index from 2012 to 2020. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given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

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

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

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

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

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

The swept-area estimate was, as in previous years, based on the standard swept area method using the average horizontal trawl opening by each participating vessel (ranging 57.2.5-70.5.4m; Table 5), assuming that a constant fraction of the mackerel inside the horizontal trawl opening are caught. Further, that if mackerel is distributed below the depth of the trawl (footrope), this fraction is assumed constant from year to year.

Results from the survey expansion southward into the North Sea is analysed separately from the traditional survey grounds north of latitude 60°N as per stipulations from the 2017 mackerel benchmark meeting (ICES 2017). We have now available IESSNS survey data from 2018, 2019 and 2020 for the northern part of the North Sea.

This year's survey was well synchronized in time and was conducted over a relatively short period (less than 5 weeks) given the large spatial coverage of around 2.9 million km^2 (Figure 1). This was in line with recommendations put forward in 2016 that the survey period should be around four weeks with mid-point around 20. July. The main argument for this time period was to make the survey as synoptic as possible in space and time, and at the same time be able to finalize data and report for inclusion in the assessment for the same year.

4.4 Norwegian spring-spawning herring

Norwegian spring-spawning herring (NSSH) was recorded in the southern (north of the Faroes and east and north of Iceland) and northern part of the Norwegian Sea basin (Figure 20). The fish in the northeast consisted of young adults (mainly 4 year olds) while the fish further southwest are a range of age groups, although also in this southwestern area significant amounts of the 4- year old as well as 7- year old herring were present. Herring registrations south of 62°N in the eastern part were allocated to a different stock, North Sea herring while the herring closer to the Faroes south of 62°N were Faroese autumn spawners.

Also, herring to the west in Icelandic waters (west of 14°W south of Iceland) were allocated to Icelandic summer-spawners. The abundance and biomass of NSSH was distributed with slightly more than half of the biomass in the north-eastern part (mainly young herring) and slightly less than half in the south-western area. The 0-boundary of the distribution of the adult part of NSSH was considered to be reached in all directions. However, the most abundant year class in the survey estimate, the 2016- year class (4- year olds) may not be fully covered in this survey. Some of this young year class may still not be fully recruited to the survey area.

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

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

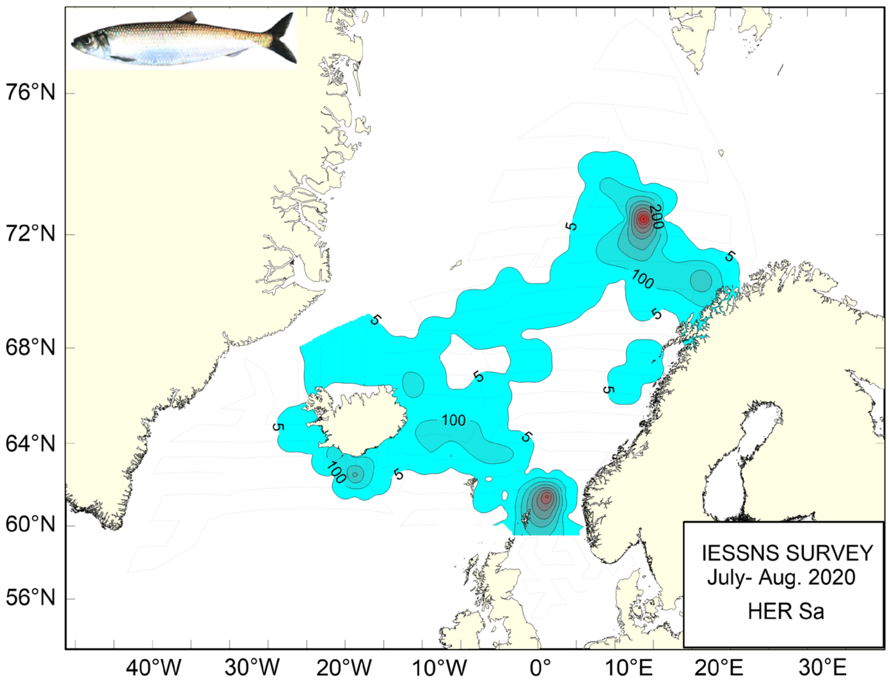


Figure 20a. The sA/Nautical Area Scattering Coefficient (NASC) values of herring along the cruise tracks in 2020. Presented as contour lines. Values north of 62ºN, and east of 14ºW, are considered to be Norwegian spring-spawning herring. South and west of this area the herring observed are other stocks,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

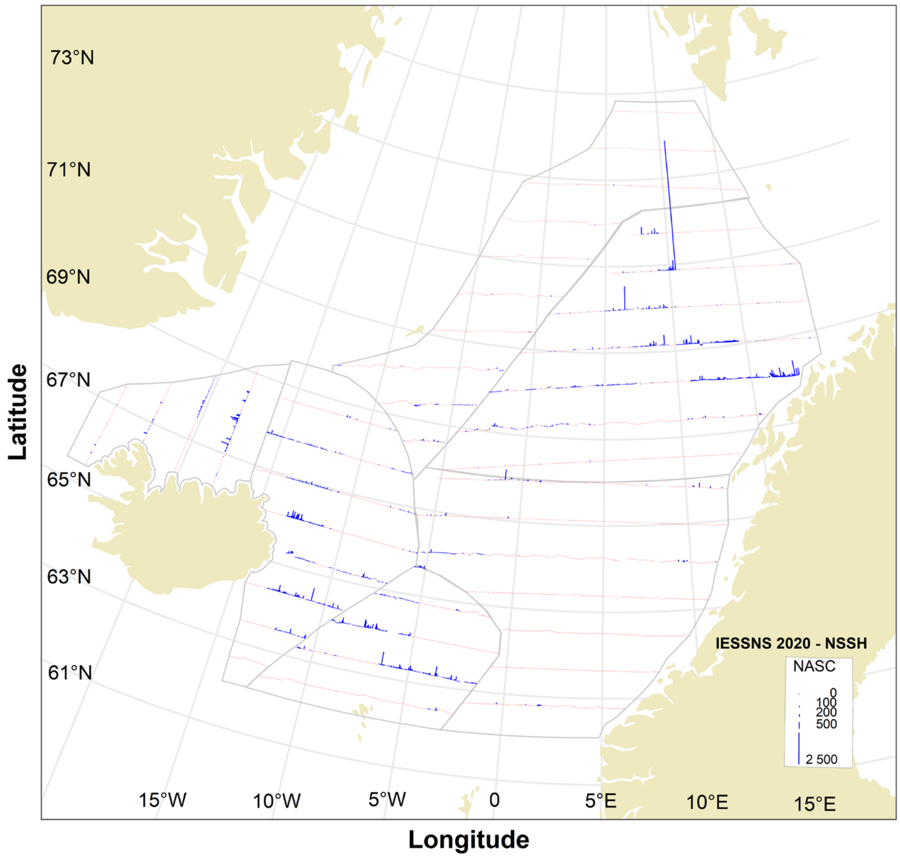


Figure 20b. The sA/Nautical Area Scattering Coefficient (NASC) values of herring along the cruise tracks in 2020. Presented as bar plot. Values north of 62ºN, and east of 14ºW, are considered to be Norwegian spring-spawning herring. South and west of this area the herring observed are other stocks, *i.e.*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

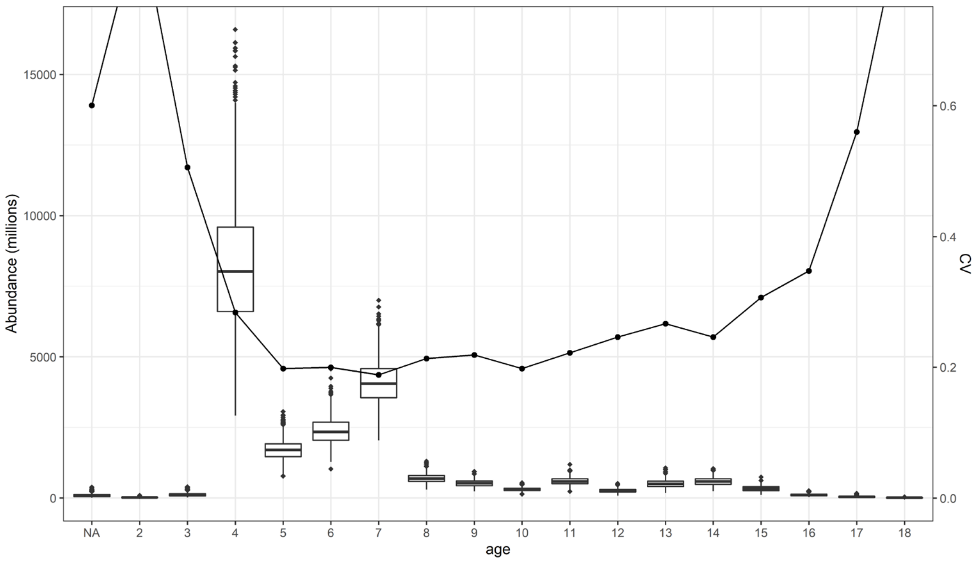


Figure 21. Number by age for Norwegian spring-spawning herring during IESSNS 2020. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

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

LenGrp	age 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
23-24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8096	8096	1214.4	150.00
24-25	-	8096	1245	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9341	1213.7	129.93
25-26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	78567	78567	12099.8	154.01
26-27	3375	27307	351715	-	11208	-	-	-	-	-	-	-	-	-	-	-	-	-	393604	68895.1	175.04
27-28	-	24446	836562	99166	3492	-	-	-	-	-	-	-	-	-	-	-	-	-	963667	181071.1	187.90
28-29	3379	16894	1117284	63398	-	25315	3361	6758	7283	-	-	-	-	-	-	-	-	-	1243672	258390.6	207.76
29-30	-	27259	1659886	40066	7109	13661	5715	-	11105	-	-	-	-	-	-	-	-	-	1764802	412482.5	233.73
30-31	-	7425	2265337	210515	57260	24416	30560	3439	3595	17197	-	-	3595	-	-	-	-	-	2623338	672023.4	256.17
31-32	-	-	1490880	466629	293454	133664	19253	2627	6213	2102	2627	-	-	-	525	-	-	-	2417976	667635.7	276.11
32-33	-	-	256258	656657	1062980	820021	49599	25652	2447	9536	15645	979	1958	3789	3789	-	-	-	2909309	867854.8	298.30
33-34	-	-	51102	141466	649300	1796292	167355	22699	9237	18390	5873	-	-	-	-	-	-	-	2861712	910369.8	318.12
34-35	-	-	39963	5198	182740	1064853	186269	87278	9070	56884	10899	598	465	3859	-	-	-	-	1648074	553397.8	335.78
35-36	-	-	-	12888	59750	213889	219024	134632	37843	92581	8328	52787	20612	32823	-	11277	-	-	896432	321715.6	358.88
36-37	-	-	-	1485	7364	9469	29872	134729	126028	200909	66365	190091	201609	68316	2763	-	-	-	1039001	394231.3	379.43
37-38	-	-	11302	-	-	-	1295	65134	63493	156242	106558	182404	228486	58252	54793	2182	-	-	930141	370334.6	398.15
38-39	-	-	-	-	-	-	2049	7654	17207	35751	30464	66722	107175	100662	37800	29396	5000	-	439879	185616.9	421.97
39-40	-	-	-	-	-	-	-	-	-	-	1368	12316	28053	48916	12316	-	-	-	102969	46454.8	451.15
40-41	-	-	-	-	-	-	-	-	-	-	-	-	5170	-	4579	654	-	-	10402	5147.3	494.83
TSN(1000)	6754	111426	8081535	1697468	2334655	4101580	714352	490601	293521	589590	248127	505896	597123	316616	116565	43509	5000	86663	20340981	-	-
TSB(1000 kg)	1263.0	21354.6	1942260.4	465900.3	711503.7	1307705.0	236374.2	174051.4	108720.0	222214.0	93474.7	199884.1	234966.8	129554.8	47528.2	17760.3	2319.5	13314.2	-	5930149.1	-
Mean length (cm)	27.25	27.60	29.56	31.29	32.52	33.24	33.87	35.09	35.50	35.84	36.24	36.64	36.87	37.19	37.53	37.33	38.00	25.08	-	-	-
Mean weight (g)	187.01	191.65	240.33	274.47	304.76	318.83	330.89	354.77	370.40	376.90	376.72	395.11	393.50	409.19	407.74	408.20	463.95	153.63	-	-	291.54

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

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

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

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

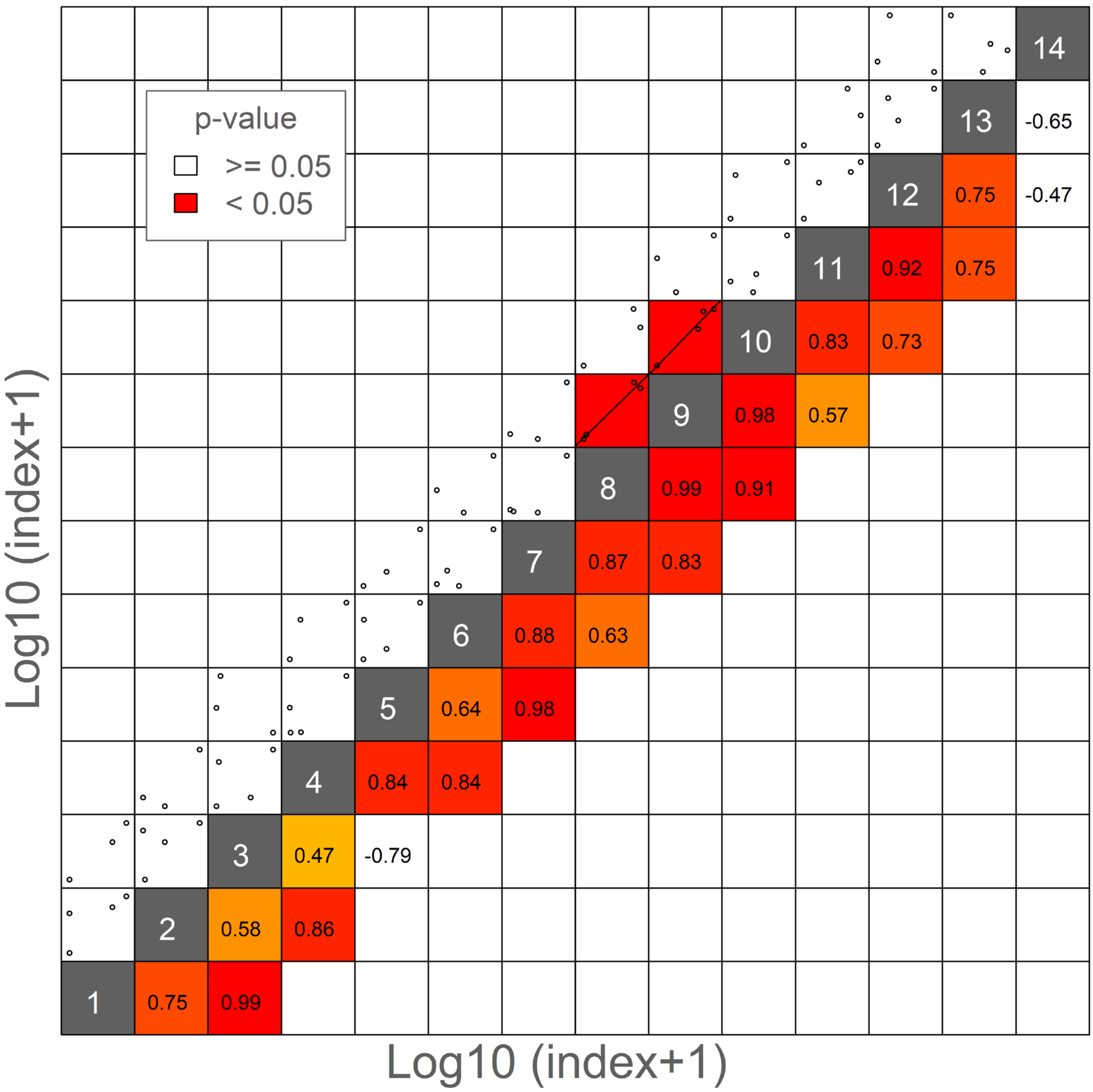


Figure 22. Internal consistency for Norwegian spring-spawning herring within the IESSNS. The upper left part of the plots shows the relationship between log index-at-age within a cohort. Linear regression line shows the best fit to the log-transformed indices. The lower-right part of the plots shows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

4.5 Blue whiting

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

The total biomass of blue whiting registered during IESSNS 2020 was 1.8 million tons (Table 12), a decrease compared to 2019 (2.0 mill tons). The stock estimate in number for 2019 is 16.5 billion compared to 16.2 billion of age groups 1+ in 2019. Age group 1 is dominating the estimate in 2020 (22% and 35% of the biomass and by numbers, respectively, looking at age groups 1+). A good sign of recruiting year class (0-group) was also seen in the survey this year.

Number by age, with uncertainty estimates, for blue whiting during IESSNS 2020 is shown in Figure 24.

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

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

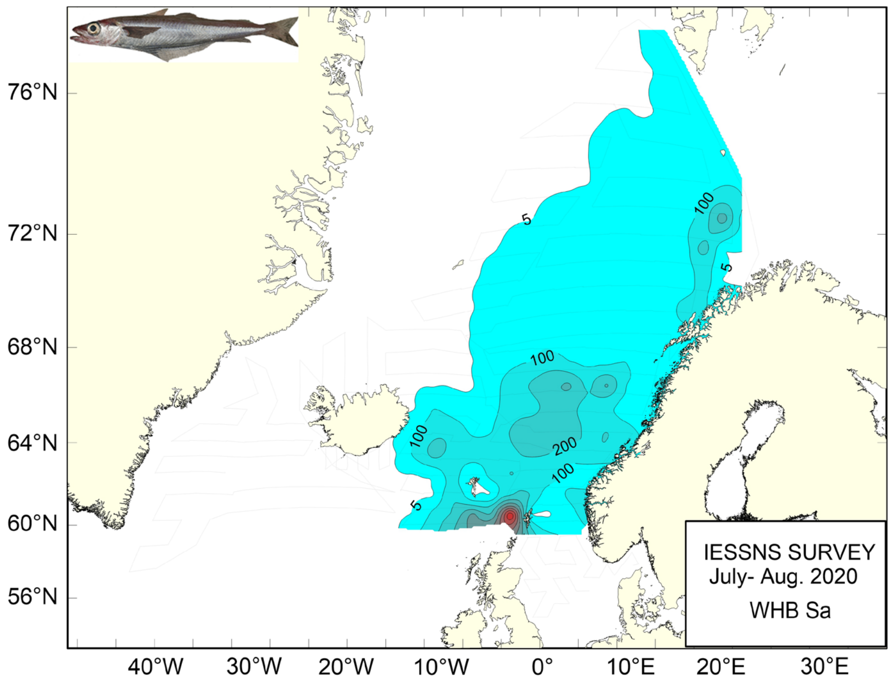


Figure 23a. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2020. Presented as contour lines.

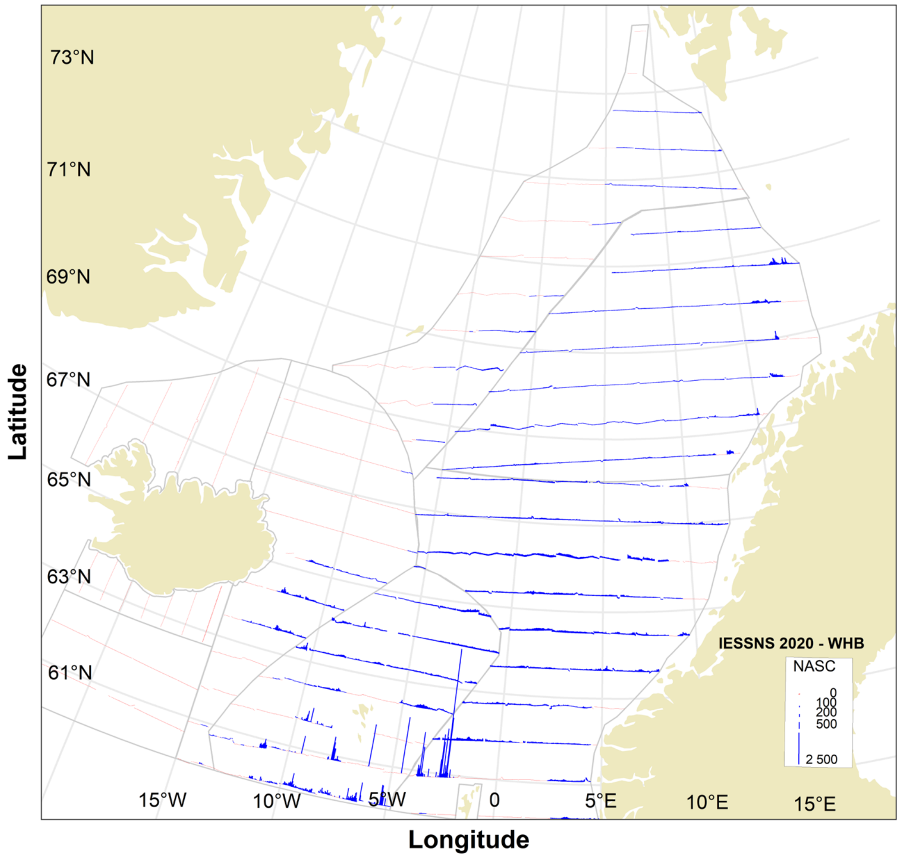


Figure 23b. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2020. Presented as bar plot.

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

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

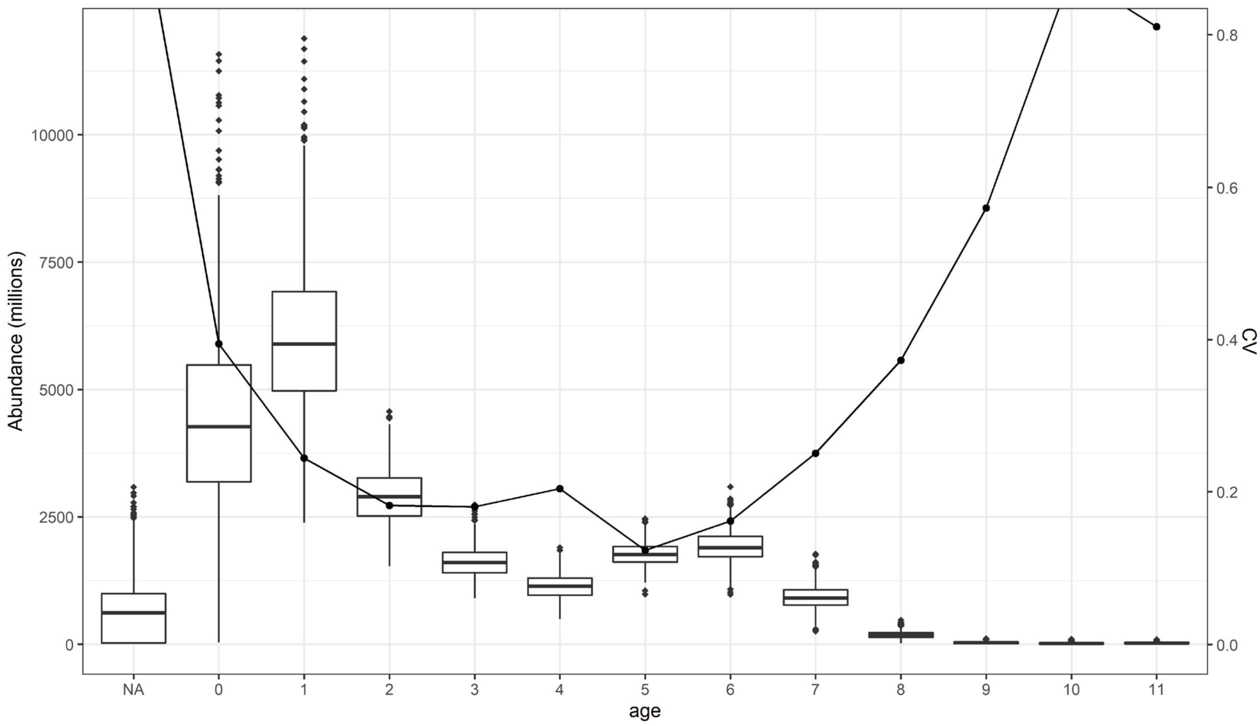


Figure 24. Number by age with uncertainty for blue whiting during IESSNS 2020. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

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

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

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

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

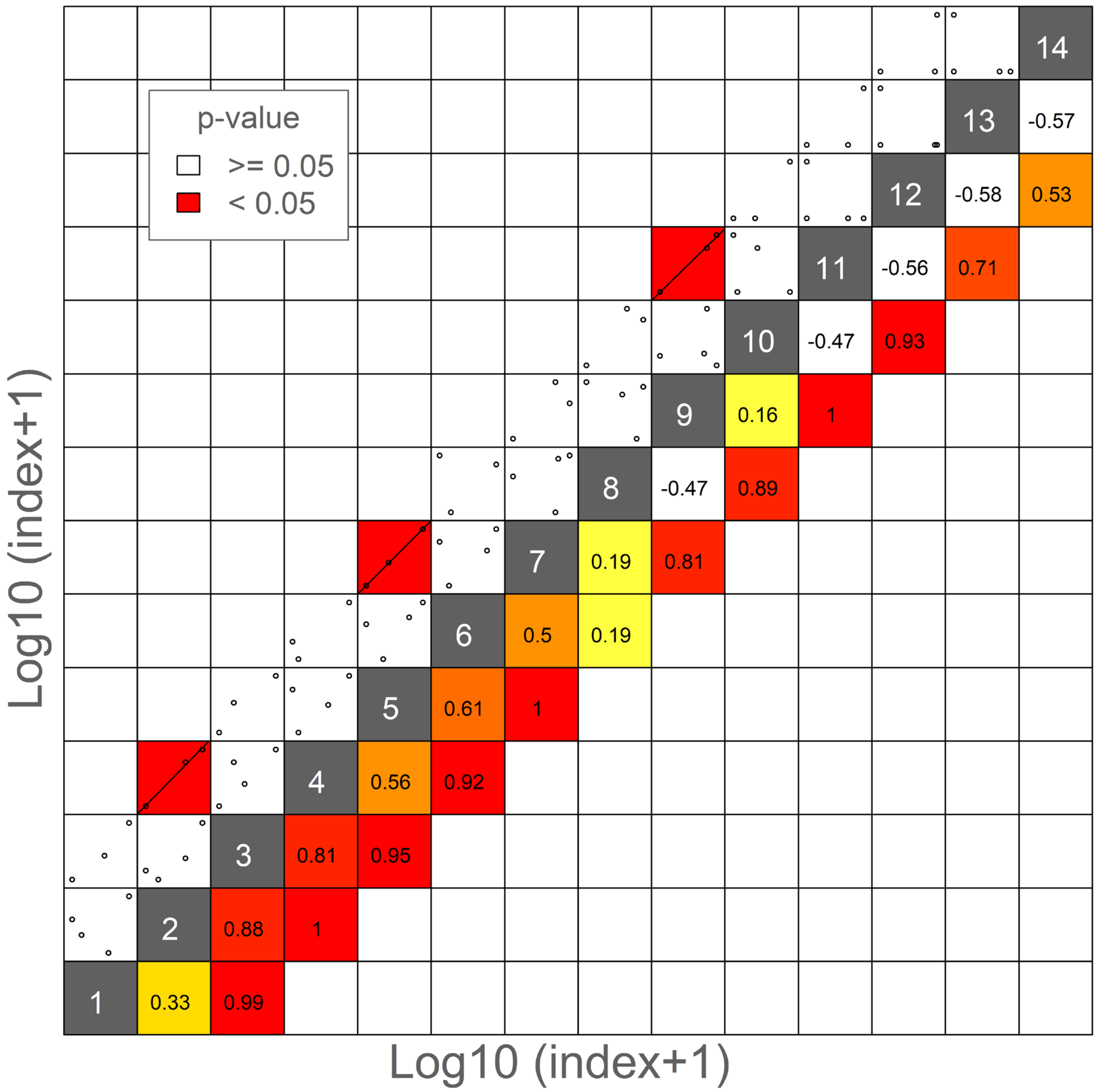


Figure 25. Internal consistency for blue whiting within the IESSNS. The upper left part of the plots shows the relationship between log index-at-age within a cohort. Linear regression line shows the best fit to the log-transformed indices. The lower-right part of the plots shows the correlation coefficient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

4.6 Other species

Lumpfish (*Cyclopterus lumpus*)

Lumpfish was caught in approximately 74% of trawl stations across the six vessels (Figure 26) and where lumpfish was caught, 72% of the catches were ≤10kg. Lumpfish was distributed across the entire survey area, from west of Cape Farwell in Greenland in the southwest to the central Barents Sea in the northeast part of the covered area. Of note, in previous years aboard the Faroese vessel, a subsample of 50 kg to 200 kg of the total catch was processed. Therefore, small catches (<10 kg) of lumpfish may have been missed, however in 2020, all lumpfish were sorted from the catch and weighed.

Abundance was greatest north of 66°N, and lowest directly south of Iceland, and western side of the North Sea. The zero line was not hit to the north, northwest and southwest of the survey so it is likely that the distribution of lumpfish extends beyond the survey coverage. The length of lumpfish caught varied from 2 to 50 cm with a bimodal distribution with the left peak (5-20 cm) likely corresponding to 1-group lumpfish and the right peak consisting of a mixture of age groups (Figure 27). For fish ≥20 cm in which sex was determined, the males exhibited a unimodal distribution with a peak around 25-27 cm. The females also exhibited a unimodal distribution but with a peak around 27-30 cm which was positively skewed. Aboard the Norwegian vessels, of the fish which were sexed, the ratio of females to males was approximately 4.4:1. Generally, the mean length and mean weight of the lumpfish was highest in Faroese waters and the coastal waters and along the shelf edges of Norway and lowest in the central and northern Norwegian Sea.

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

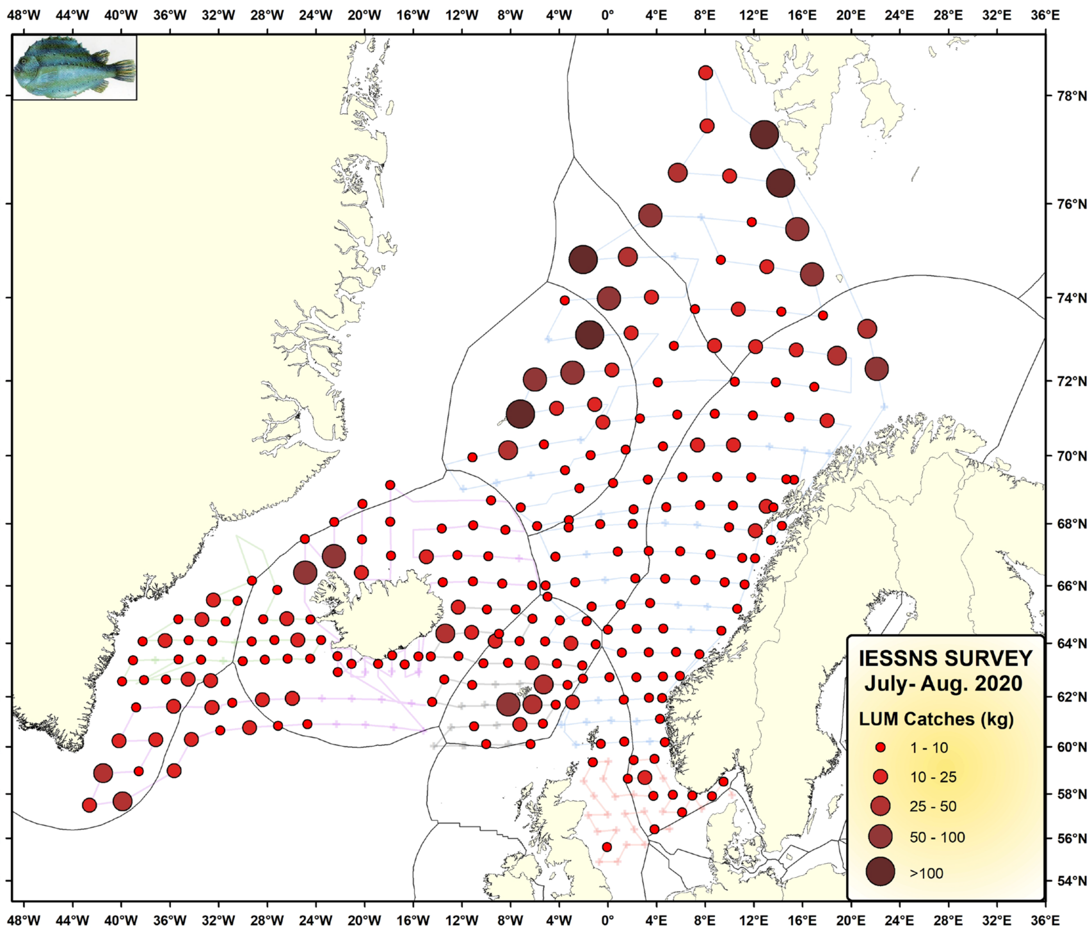


Figure 26. Lumpfish catches at surface trawl stations during IESSNS 2020.

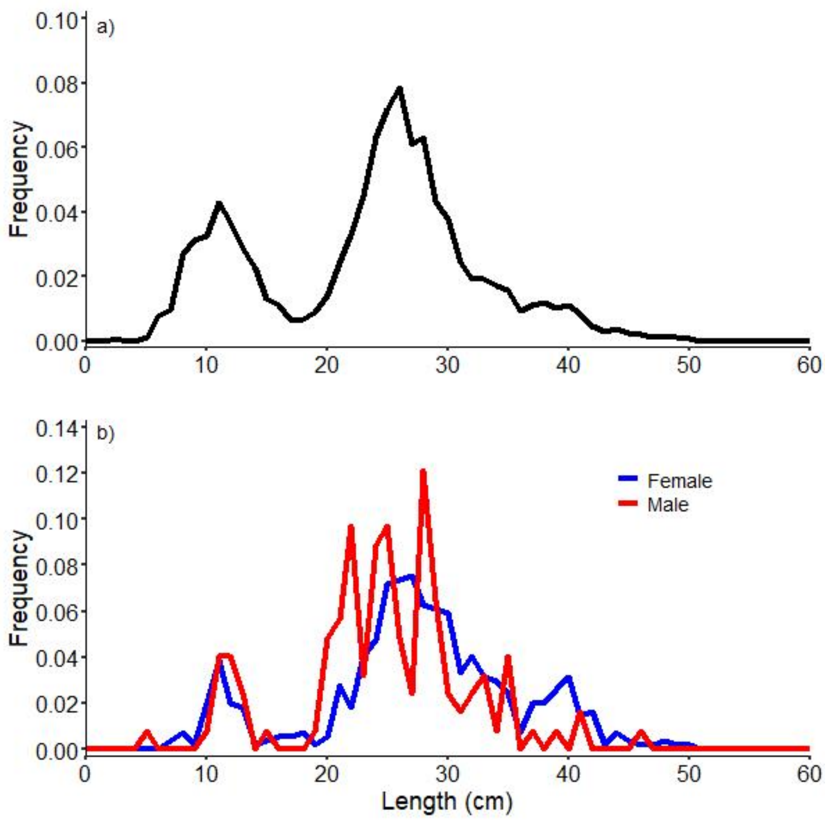


Figure 27. Length distribution of a) all lumpfish caught during the survey and b) length distribution of fish in which sex was determined.

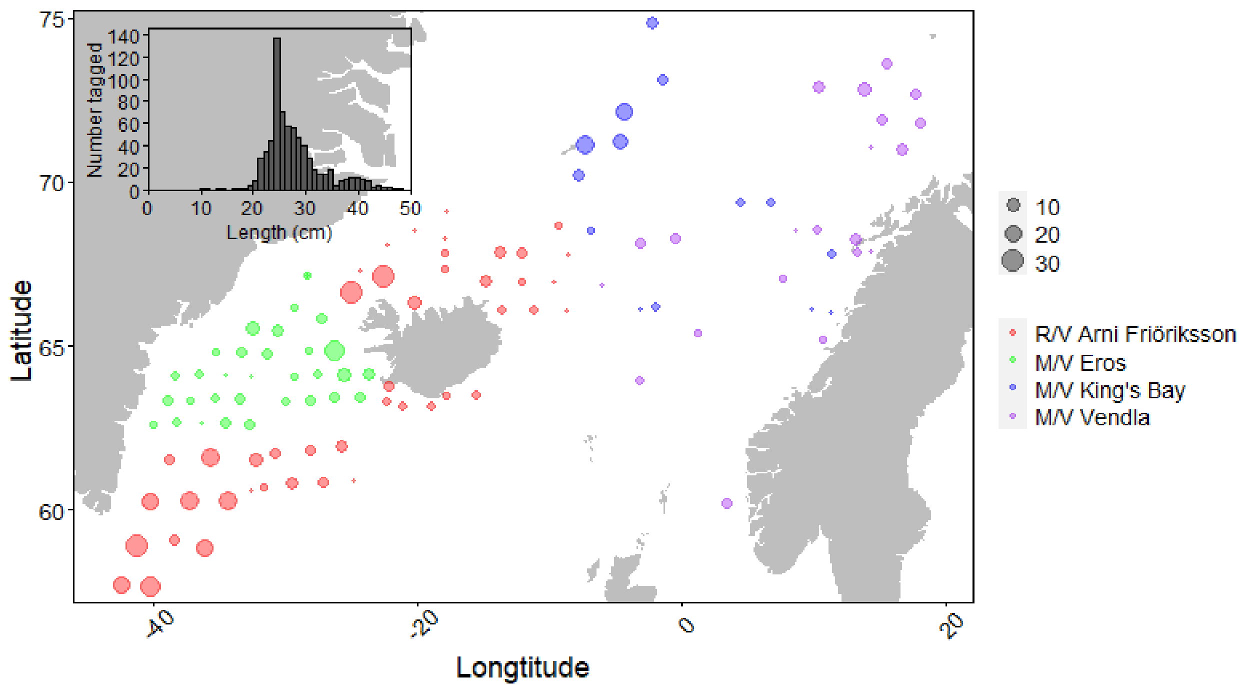


Figure 28. Number tagged, and release location, of lumpfish. Insert shows the length distribution of the tagged fish. Location of fish tagged aboard King's Bay was not available at time of writing.

Salmon (*Salmo salar*)

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

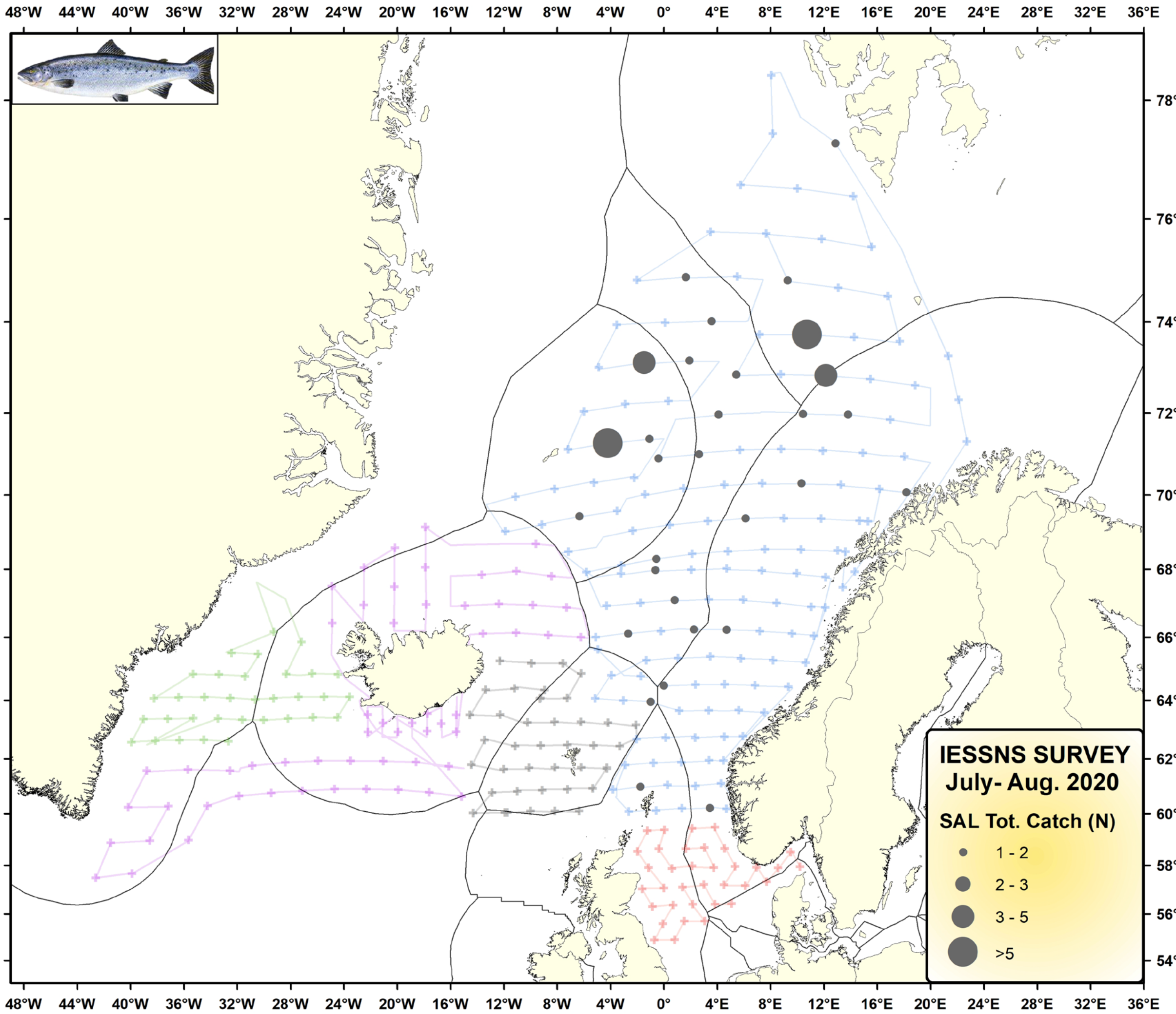


Figure 29. Catches of salmon at surface trawl stations during IESSNS 2020.

Capelin (*Mallotus villosus*)

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

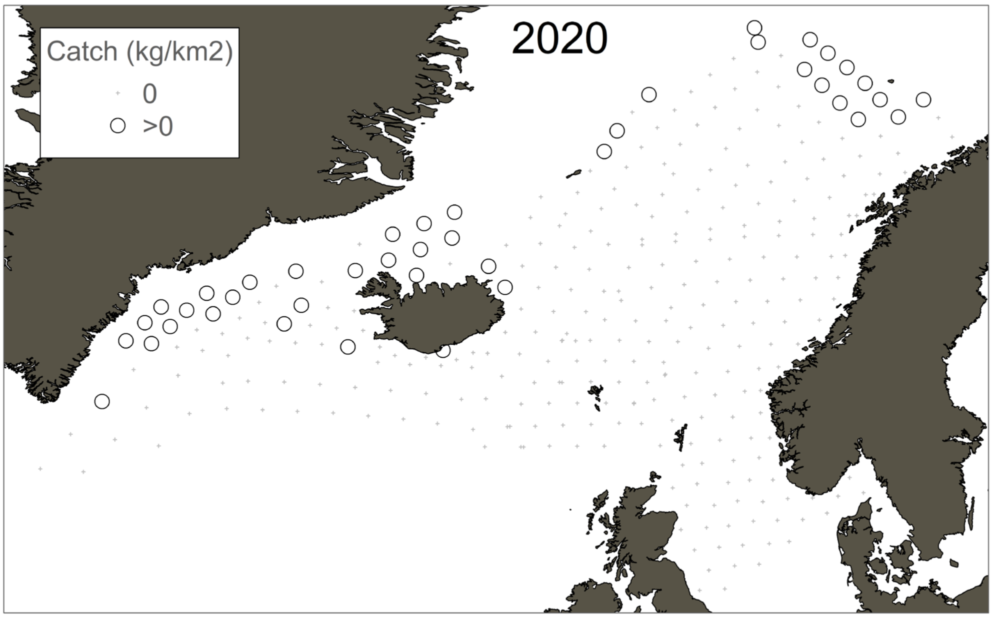


Figure 30. Presence of capelin in surface trawl stations.

4.7 Marine Mammals

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

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

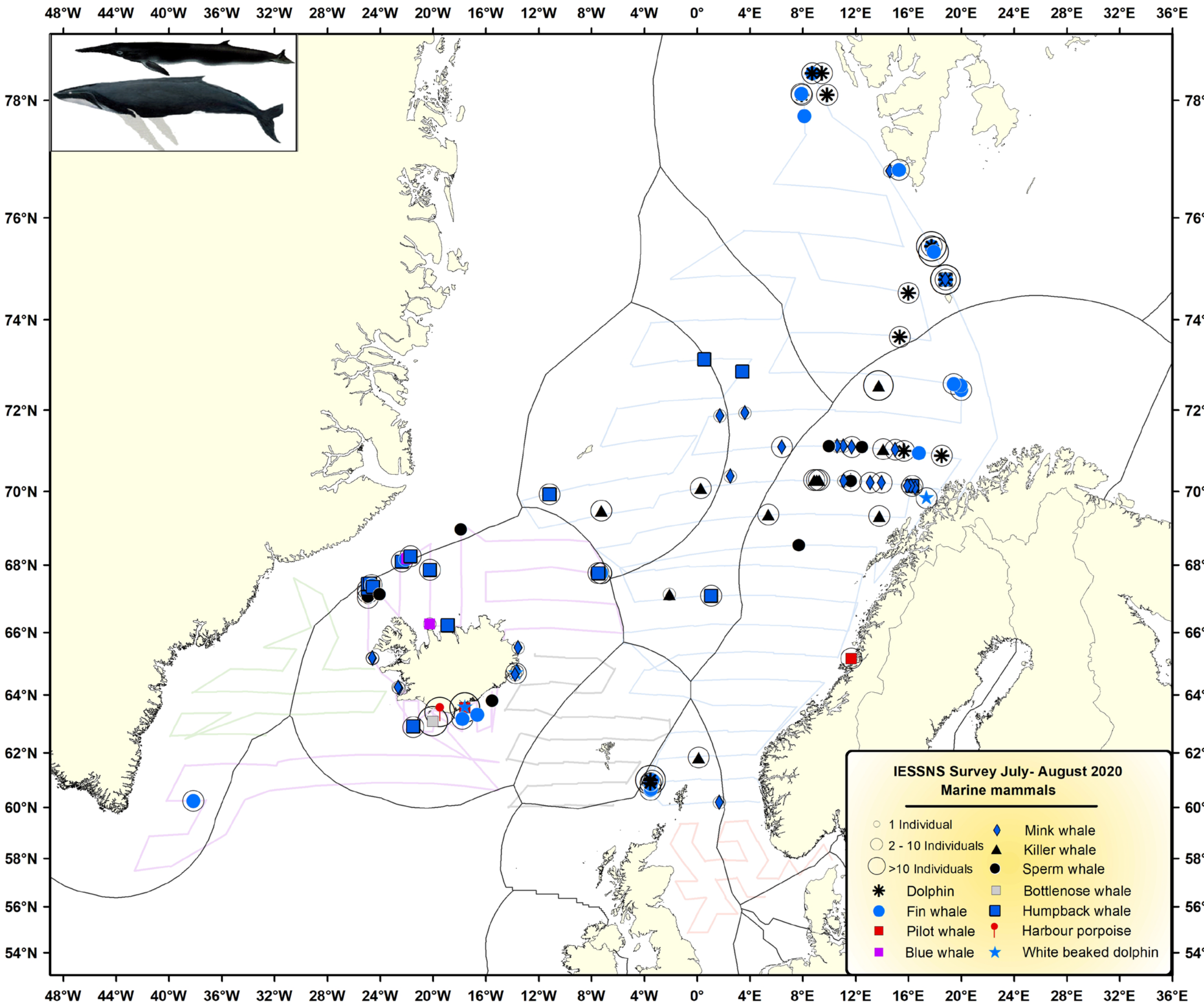


Figure 31. Overview of all marine mammals sighted during IESSNS 2020.

5 Recommendations

Recommendation	To whom
WGIPS recommends that the IESSNS extension to the North Sea should continue for establishing a time series suitable for assessing the part of the NE Atlantic Mackerel stock in the North Sea. The surveys conducted by Denmark in 2018, 2019 and 2020 have demonstrated that the IESSNS methodology works also for the northern North Sea (i.e. north and west from Doggerbank) and the Skagerrak for the area that is deeper than 50 m. The survey provides essential fishery-independent information on the stock during its feeding migration in summer and WGIPS recommends that the Danish survey should continue as a regular annual survey.	WGWIDE, RCG NANSEA

6 Action points for survey participants

Action points
The guidelines for trawl performance should be revised to reflect realistic manoeuvring of the Multpelt832 trawl.
Criteria and guidelines should be established for discarding substandard trawl stations using live monitoring of headline, footrope and trawl door vertical depth, and horizontal distance between trawl doors. For predetermined surface trawl station, discarded hauls should be repeated until performance is satisfactory. Explicit guideline for incomplete trawl hauls is to repeat the station or exclude it from future analysis. It is not acceptable to visually estimate mackerel catch, it must be hauled onboard and weighed. If predetermined trawl hauls are not satisfactory according to criteria the station will be excluded from mackerel index calculations, i.e. treated as it does not exist, but not as a zero mackerel catch station.
Tagging of lumpfish should be initiated or continue on all vessels.
We recommend that observers collect sighting information of marine mammals on all vessels.
Table 3 – biological sampling - needs to be changed to reflect what is sampled on the different vessels.
We should consider calculating the zooplankton index from annually gridded field polygons to extract area-mean time-series.
For next year’s survey, the group should consider having the strata Greenland South and Iceland south offshore (Strata numbers 11 and 12) as dynamic Strata given the absence of mackerel in these strata the last two years.
For next year’s survey, the group should consider distributing transects differently among vessels, such that synoptic coverage becomes better than this year and survey time is optimally used.

7 Survey participants

M/V "Vendla":

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

M/V "Kings Bay":

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

R/V "Árni Friðriksson":

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

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

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

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

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

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1 Appendix 1:

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

Denmark joined the IESSNS again in 2020 using the same vessel. 35 stations were taken (PT and CTD, no plankton and no appropriate acoustic equipment available). The locations of stations differed slightly from the previous year focussing on the area north and west of Doggerbank and extended into the eastern Skagerrak.

Average mackerel catch in 2020 was higher than in 2019 (1318 kg/km^2 compared to 1009 kg/km^2 in 2019 and 1743 kg/km^2 in 2018). The length and age composition indicate a relative high amount of small (< 25 cm) individuals (Tab. A.1) whereas the abundance of older (≥ age 6) mackerel was similar to the two previous years (Fig. A.1.).

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

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

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

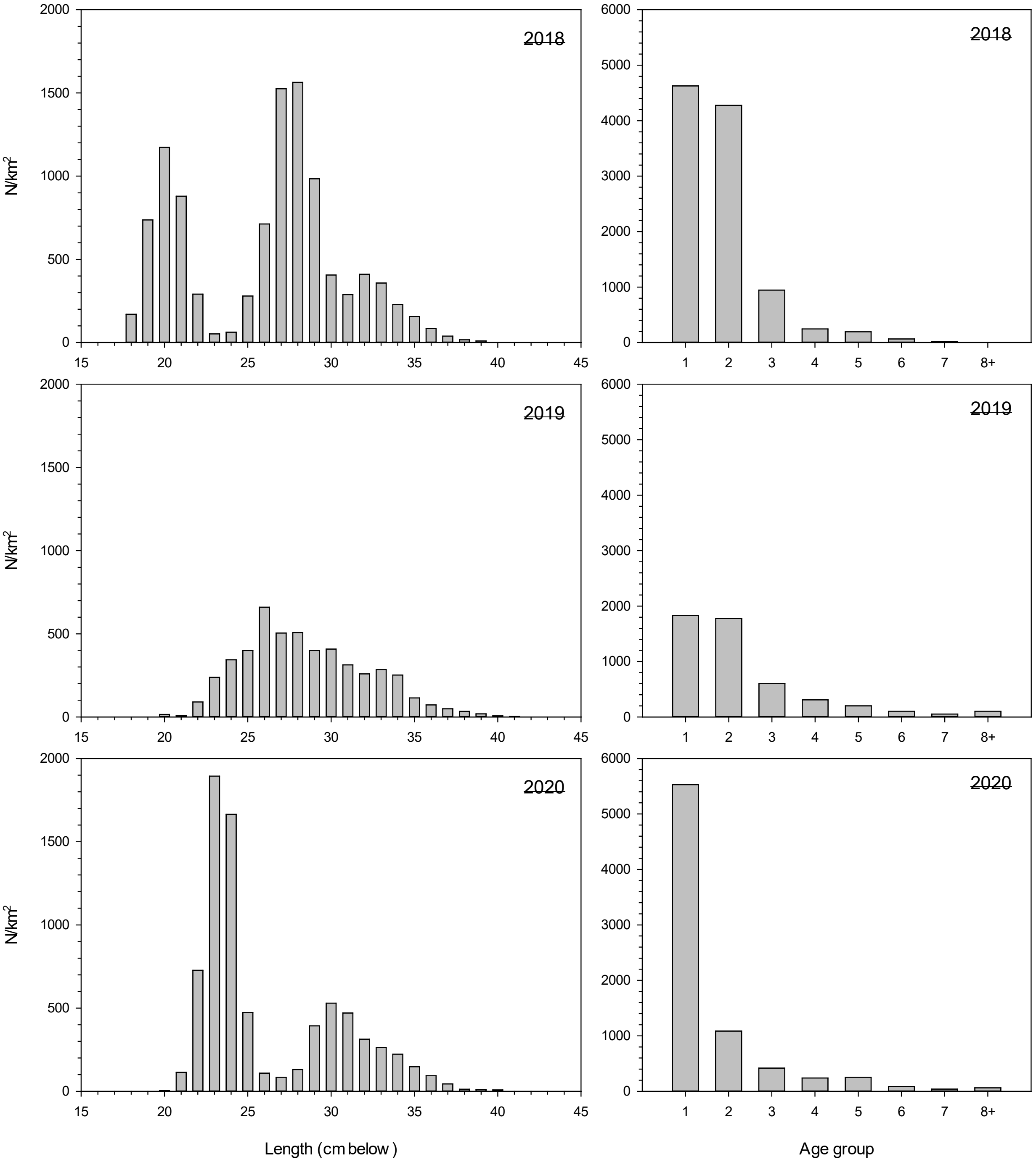

Fig. A1. Comparison of length and age distribution of mackerel in the North Sea 2018, 2019 and 2020.

2 Annex 2:

The mackerel index is calculated on all valid surface stations. That means, that invalid and potential extra surface stations and deeper stations need to be excluded. Below is the exclusion list used when calculating the mackerel abundance index for IESSNS 2020.

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

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

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

Annex 7: 2020 GERAS Survey Summary Table and Survey Report

Document 7a: GERAS 2020 survey summary table

Survey Summary Table WGIPS 2021	
Name of the survey (abbreviation):	GERAS / BIAS (GER) (FRV "Solea" SB783)
Target Species:	Herring (*Clupea harengus,* Western Baltic Spring Spawning Herring WBSSH; Central Baltic Herring CBH), Sprat (*Sprattus sprattus*) Anchovy (*Engraulis encrasicolus*), Sardine (*Sardina pilchardus*)
Survey dates:	02-21 Oct 2020
Summary:	

The objectives of the survey were carried out successfully and as planned in all of the covered ICES Subdivisions.

Altogether, 1204 nautical miles of hydroacoustic transects (plus 41 nmi daytime transects for comparison) were covered (2019: 1124 nmi). For species allocation and identification as well as to collect biological data for an age stratified abundance estimation of the target species herring and sprat, altogether 55 fishery hauls were conducted. Vertical hydrography profiles were measured on 98 stations.

In the majority of all sampled rectangles, mean NASC values per nautical mile were –often distinctly- lower than the values measured in 2019. Compared to the long-time survey mean since 1991, mean NASC values were lower in all rectangles covered. On ICES subdivision scale, mean NASC values were overall distinctly lower than in the previous year in all subdivisions but SD23, where the mean NASC measured had almost doubled compared to 2019.

After excluding the Central Baltic Herring fraction from the estimates via the Separation Function, the present Western Spring Spawning Herring biomass estimate despite distinct increases in SD 21 and SD 23 (compared to 2019) represents the lowest recorded value in the whole time series since 1993.

	Description
Survey design	Stratified systematic (parallel where applicable) design. Start point not randomized. ICES statistical rectangles used as strata for all ICES subdivisions

Index Calculation method	GERIBAS II Software. Index based on mean NASC per ICES statistical rectangle.
Random/systematic error issues	Survey design and transects restricted by area topography. No fully systematic coverage of survey area possible. Indications of large herring aggregations outside the surveyed transects/time period are regularly registered.
Specific survey error issues (acoustic)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Bubble sweep down	Bubble sweep down due to adverse weather conditions occurred and required interruption of survey operations (SD 21). Due to the continuation of the survey in improved conditions, this is not considered to affect integration results.
Extinction (shadowing)	No particular issues as targets are scattered in loose aggregations in most of the surveyed areas during the survey operations.
Blind zone	Due to the night-time distribution of clupeids also in surface layers, registrations of clupeids occur in the blind zone but are not quantified (integration start depth 10 m). In some parts of the survey area, the blind zone exclusion exceeds more than half of the total water column.
Dead zone	No particular issue as clupeids are mostly distributed pelagically and away from seafloor during night-time survey operations.
Allocation of backscatter to species	Directed trawling. Mixed species category applied throughout survey. Species allocations and splitting of NASC values based on combined trawl haul composition per ICES statistical rectangle.
Target strength	Clupeids: TS = 20 log10 (L) - 71.2 Gadids: TS = 20 log10 (L) - 67.5 Mackerel: TS = 20 log10 (L) – 84.9 see SISP Survey manual (ICES, 2017). Clupeid TS allocated to other species included in analysis (see above).
Calibration	All survey frequencies calibrated and results within recommended tolerances (Demer et al., 2015).
Specific survey error issues (biological)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Stock containment	Time series: It is assumed that WBSSH (primary target species) is contained within the survey area. An unquantified but assumedly low degree of mixing of WBSSH and CBH (Central Baltic Herring) can occur outside of the survey area (east of SD 24). Due to transects often determined by topography/bathymetry, aggregations of WBSSH in shallower areas not sampled by the survey may have been missed.

	2020 survey: Survey area was covered as planned resulting in a full sampling of all rectangles/Subdivisions and the standard area of the GERAS-Index for HAWG.
Stock ID and mixing issues	Time series: WBSSH and CBH mix at varying degrees in different parts of the survey area (especially in SD 24). Separation of stocks is achieved through application of an age-growth based stock separation function (SF) (Gröhsler et al. 2013). 2020 survey: The present results support the continued applicability of the SF despite repeated occurrence of some CBH in the GERAS baseline samples of WBSSH in SDs 21 and 23. CBH were identified in herring samples from throughout the survey area, but only in SD 24 contributed significantly to the overall herring abundance (ca. 50% !). Mean weights became distinctly more typical for the growth pattern of WBSSH after removal of CBH, and peaks in abundance of year classes 3-6 also vanished through removal of CBH by the SF.
Measures of uncertainty (CV)	none
Biological sampling	Time series: Based on survey design restrictions, comprehensive sampling is not feasible in all statistical rectangles surveyed. Biological information from neighboring rectangles is used for generating estimates in these cases. This mostly applies to rectangles with low abundance. 2020 survey: Biological information for ICES statistical rectangles 37G3, 37G4 (SD 24), 39G2 (SD 23), 40F9, 40G1 (SD 22) and 43G1 (SD 21) used/amended from neighbouring rectangles.
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole times series or for individual years? (please specify)	*To be answered by Assessment Working Group*
Did the Survey Summary Table contain adequate information to allow for	*To be answered by Assessment Working Group*

evaluation of the quality of the survey for use in assessment? Please identify short-falls	

Document 7b: GERAS 2020 survey report

Please see the report on the next page.

Federal Research Institute for Rural Areas, Forestry and Fisheries

Thünen Institute of Sea Fisheries (TI-SF)[1]
Thünen Institute of Baltic Sea Fisheries (TI-OF)[2]

Survey Report FRV “Solea” SB783

German Acoustic Autumn Survey (GERAS)

01 – 21 October 2020

Matthias Schaber[1] & Tomas Gröhsler[2]

1 INTRODUCTION

1.1 Background

The cruise was part of an international hydroacoustic survey providing information on stock parameters of small pelagics in the Baltic Sea, coordinated by the ICES Working Group of International Pelagic Surveys (WGIPS) and the ICES Baltic International Fish Survey Working Group (WGBIFS). Further WGBIFS contributors to the Baltic survey are national fisheries research institutes of Sweden, Poland, Finland, Latvia, Estonia and Lithuania. FRV "Solea" participated for the 33rd time. The survey area covered the western Baltic Sea including Kattegat, Belt Sea, Sound and Arkona Sea (ICES Subdivisions (SD) 21, 22, 23 and 24).

1.2 Objectives

The survey has the main objective to annually assess the clupeid resources of herring and sprat in the Baltic Sea in autumn. The reported acoustic survey is conducted every year to supply the ICES Herring Assessment Working Group for the Area South of 62°N (HAWG) and Baltic Fisheries Assessment Working Group (WGBFAS) with an index value for the stock size of herring and sprat in the Western Baltic area (Kattegat/Subdivisions 21 and Subdivisions 22, 23 and 24).

The following objectives were planned for SB783:

- Hydroacoustic measurements for the assessment of small pelagics in the Kattegat and western Baltic Sea including Belt Sea, Sound and Arkona Sea (ICES Subdivisions 21, 22, 23 and 24)
- (Pelagic) trawling according to hydroacoustic registrations
- Hydrographic measurements on hydroacoustic transects and after each fishery haul
- Identification and recording of species- and length-composition of trawl catches
- Collection of biological samples of herring, sprat and additionally sardine, European anchovy and cod for further analyses

1.3 Survey summary

The objectives of the survey were carried out successfully and as planned in all of the covered ICES Subdivisions.

Altogether, 1204 nautical miles of hydroacoustic transects (plus 41 nmi daytime transects for comparison) were covered. For species allocation and identification as well as to collect biological data for an age stratified abundance estimation of the target species herring and sprat, altogether 55 fishery hauls were conducted. Vertical hydrography profiles were measured on 98 stations.

In the majority of all sampled rectangles, mean NASC values per nautical mile were –often distinctly- lower than the values measured in 2019. Compared to the long-time survey mean since 1991, mean NASC values were lower in all rectangles covered. On ICES subdivision scale, mean NASC values were overall distinctly lower than in the previous year in all subdivisions but SD23, where the mean NASC measured had almost doubled compared to 2019.

2 SURVEY DESCRIPTION & METHODS APPLIED

2.1 Cruise narrative

The 783rd cruise of FRV "Solea" represents the 33rd subsequent GERAS survey. Due to a delay in the transit of "Solea" to Kiel harbor because of shipping impairments in the Kiel Channel, the begin of the cruise had to be postponed. Equipment of the vessel as well as calibration of echosounders took place on October 3rd, and survey operations commenced on October 4th in SD 24 (Arkona Sea).

Generally, survey operations were conducted during nighttime to account for the more pelagic distribution of clupeids during that time. Weather conditions at the beginning of the survey allowed to start survey operations in the Arkona Sea. Due to a prescheduled change in the scientific crew a few days after the survey begin, surveying of SD 24 was interrupted after largely accomplishing the southern part of the Arkona Sea, and survey operations continued in SD 22 (Mecklenburg Bight, Kiel Bight), where the crew change took place on October 9th (Kiel harbor). Afterwards, SD 22 was accomplished before FRV "Solea" continued monitoring unfinished transects in SD 24 (north). Due to deteriorating weather, it was decided to continue the survey in the comparatively sheltered Sound (SD 23) before accomplishing SD 24. Afterwards, survey operations commenced in SD 21 (Kattegat) but had to be interrupted for one night due to prevailing inclement weather. On October 15th, survey work commenced in SD 21 and was accomplished on October 18th. Afterwards, the remaining unfinished transects in SD 24 were sampled. Survey operations were accomplished on October 20th. A second calibration of the hydroacoustic equipment was conducted on October 21st. After the calibration, FRV "Solea" entered Rostock port, where the survey ended.

Altogether, the following survey schedule was accomplished:

Arkona Sea	(SD 24)	04. - 07.10. & 12.-13.10 & 19.-20.10.
Belt Sea	(SD 22)	07. - 11.10.
Sound	(SD 23)	13. - 14.10.
Kattegat	(SD 21)	15. - 18.10.

Total survey time	17 nights (incl. 1 day loss due to bad weather)
Fishery hauls	55
CTD-casts	98
Hydroacoustic transects	1204 nmi (+ 41 nmi daytime transects for comparison)

2.2 Survey design

ICES statistical rectangles were used as strata for all Subdivisions (ICES, 2017). The area was limited by the 10 m depth line. The survey area in the Western Baltic Sea is characterized by a number of islands and sounds. Consequently, parallel transects would lead to an unsuitable coverage of the survey area. Therefore a zig-zag track was adopted to cover all depth strata regularly and sufficiently. Overall, the covered regular cruise track length was 1204 nautical miles (2019: 1124 nmi) (Figure 1).

2.3 Acoustic data collection

All acoustic investigations were performed during night time to account for the more pelagic distribution of clupeids during that time. Hydroacoustic data were recorded with a Simrad EK80 scientific echosounder with hull-mounted 38, 70, 120 and 200 kHz transducers at a standard ship speed of 10 kn. Post-processing and analysis of hydroacoustic data were conducted with Echoview 11 software (Echoview Software Pty Ltd, 2020). Mean volume back scattering values (S_v) were integrated over 1 nmi intervals from 10 m below the surface to ca. 0.5 m over the seafloor. Interferences from surface turbulence, bottom structures and scattering layers were removed from the echogram. The transducer settings applied were in accordance with the specifications provided in ICES (2015, 2017).

2.4 Calibration

All transducers (38, 70, 120 and 200 kHz) were calibrated prior to the beginning of the survey in suboptimal weather conditions from a drifting vessel in Howacht Bight, southwest of Fehmarn Island (Strande Bay/Kiel Bight (54°23.4 N, 10°52.9 E) on October 3rd. Overall calibration results were considered acceptable based on calculated RMS values. However, a second calibration in good weather conditions was conducted after accomplishing survey operations on October 21st, again from a drifting vessel off Kühlungsborn in the Mecklenburg Bight (54°14.5 N, 11°46.2 E). Resulting transducer parameters were applied for the post-processing of hydroacoustic survey data. Calibration results for the 38 kHz transducer are given in Table 1.

2.5 Biological data – trawl hauls

Trawl hauls were conducted with a pelagic gear "PSN388" in midwater layers as well as near the seafloor. Mesh size in the codend was 10 mm. It was planned to carry out at least two hauls per ICES statistical rectangle. Both trawling depth and net opening were continuously controlled by a netsonde during fishing operations. Trawl depth was chosen in accordance with echo distributions on the echogram. Normally, a vertical net opening of about 6-8 m was achieved. The trawling time usually lasted 30 minutes but was shortened when echograms and netsonde indicated large catches. To validate and allocate echorecordings, altogether 55 fishery hauls were conducted (Figure 1). From each haul sub-samples were taken to determine length and weight of fish. Samples of herring, sprat, sardine and anchovy were frozen for additional investigations (e.g. determining sex, maturity, age).

2.6 Hydrographic data

Hydrographic conditions were measured after each trawl haul and in regular distances on the survey transect. On each corresponding station, vertical profiles of temperature, salinity and oxygen concentration were measured using a "Seabird SBE 19 plus" CTD. Water samples for calibration purposes (salinity) were taken on every station. Altogether, 98 CTD-profiles were measured (Figure 8).

2.7 Data analysis

All data analyses were conducted using GERIBAS II software (Arivis, 2014) and Microsoft Office.

The pelagic target species sprat and herring are often distributed in mixed layers together with other species. Thus, echorecordings cannot be allocated to a single species. Therefore the species composition allocated to echorecordings was based on corresponding trawl catch results. For each rectangle, species composition and length distributions were determined as the unweighted mean of all trawl results in this rectangle. From these distributions the mean acoustic cross section σ was calculated according to the following target strength-length (TS) relation:

	TS	References
Clupeids	= 20 log L (cm) - 71.2	ICES (1983)
Gadids	= 20 log L (cm) - 67.5	Foote et al. (1986)
Scomber scombrus	= 20 log L (cm) - 84.9	ICES (2017)

All other species that were included in the analysis based on their contribution to the catches per rectangle were allocated the clupeid TS (see table above).

The total number of fish (total N) in one rectangle was estimated as the product of the mean Nautical Area Scattering Coefficient (NASC; S_A) and the rectangle area, divided by the corresponding mean cross section σ. The total number was separated into the categories mentioned above and further into herring and sprat according to the mean catch composition.

All calculations performed were in accordance with the guidelines in the "SISP Manual of International Baltic Acoustic Surveys (IBAS)" (ICES, 2017).

Hauls with very low catches in terms of numbers and biomass as well as hauls conducted with unclear fishing gear were rendered invalid for further analyses. Based on survey design restrictions, comprehensive sampling is not feasible in all statistical rectangles surveyed. Biological information from neighboring rectangles is used for generating estimates in these cases. This mostly applies to rectangles with low abundance as well as to rectangles where low catch hauls and invalid hauls need to be omitted.

<u>Stock splitting / Application of the separation function (SF):</u>

In the western Baltic, the distribution areas of two stocks, the Western Baltic Spring Spawning herring (WBSSH) and the Central Baltic herring (CBH) overlap. Survey results from recent years indicated that in SD 24, which is part of the WBSSH management area, a considerable fraction of CBH is present and correspondingly erroneously allocated to WBSSH stock indices (ICES, 2013). Accordingly, a stock separation function (SF) based on growth parameters derived from 2005 to 2010 has been developed to quantify the proportion of CBH and WBSSH in the area (Gröhsler et al., 2013; Gröhsler et al., 2016). The estimates of the growth parameters from baseline samples of WBSSH and CBH in 2011-2018 and

2020 support the applicability of the SF (Oeberst et al., 2013; Oeberst et al., 2014, 2015, 2016, 2017; Gröhsler and Schaber, 2018, 2019, 2021).

The ICES Herring Assessment Working Group for the area south of 62° N (HAWG)) is yearly supplied with an index for this survey (GERAS), which since 2005 excludes CBH and in general covers the total standard survey area, excluding ICES rectangles 43G1 and 43G2 in SD 21 and 37G3 and 37G4 in SD 24, which were not covered in 1994-2004.

3 RESULTS

3.1 Hydroacoustic data (M. Schaber)

Figure 2 depicts the spatial distribution of mean NASC values (5 nmi intervals) measured on the hydroacoustic transects covered in 2020. In general, the majority of these NASC measurements can be allocated to clupeids. Altogether, 27 ICES statistical rectangles were covered in the survey 2020 (25 in 2019). In 5 of those, the mean NASC was higher than in 2019 (partly significantly), in one rectangle mean NASC was in the range of 2019. In the 19 other rectangles, mean NASC values were partly well below the comparatively low values measured in 2019. In all rectangles, the mean NASC measured in 2020 was below the long term survey mean (1991-2019). On ICES subdivision scale, mean NASC values were distinctly lower than in the previous year in all subdivisions but SD 23 (the Sound).

In the rectangles covered both in 2020 and 2019 in SD 21, overall NASC values measured were mostly lower than those measured in the previous year. Only in one rectangle (42G1), mean NASC per 1 nmi EDSU was about twice as high as those measured in 2019. Highest NASC-levels in SD 21 were measured in the northernmost part of SD21 (43G1, unsampled in 2019). As in previous years, aggregations were mostly patchy along the cruisetrack.

In SD 22, mean overall NASC values recorded were lower than in 2019 in 10 out of 11 rectangles surveyed. Only in one rectangle (39G0), mean NASC was increased. This originated from rather unusual aggregations of herring in the northern part of the Great Belt. Subdivision 22 is usually characterized by rather low NASC levels, but in comparison with the long term survey mean, mean NASC was even lower in all of the sampled rectangles.

As in the previous years, the large aggregations of big herring that usually could be observed in SD 23 in the Sound were not present in autumn 2020 to the extent observed prior to 2016. However, mean NASC values in rectangle 40G2 were distinctly higher than the levels measured in 2017-2019 (but still well below the survey mean). In the southern part and northern parts of the Sound (39G2, 41G2), NASC levels however were even lower than the 2019 measurements.

In SD 24, mean NASC values were comparable (1) or distinctly lower (7) than the levels measured in 2018 in 8 out of 9 rectangles. Only in rectangle 37G3 (east of Rügen Island, Sassnitz Trench), a noteworthy (but not significant) increased of NASC was measured. As in the years before, somewhat notable aggregations (including the rectangle with the higher 2020 NASC) were detected around Rügen Island.

3.2 Biological data (T. Gröhsler)

Fishery hauls according to ICES Subdivision (Figure 1):

SD	Hauls (n)
21	14
22	16
23	4
24	21

Altogether, 1 718 individual herring, 943 sprat, 301 European anchovies and 7 sardines were frozen for further investigations (e.g. determining sex, maturity, age). Results of catch compositions by Subdivision are presented in Tables 2-5. Altogether, 36 different species were recorded. Herring were caught in 54, sprat in 53 hauls. SD 23, which is typically characterized by the highest mean herring catch rates per station (kg 0.5 h^{-1}), showed the third lowest value in the data series since 2002. Sardines (*Sardina pilchardus*) only appeared in catches from SD 21, whereas they were caught in SD 22 and SD 23 in 2019. As in previous years, anchovy (*Engraulis encrasicolus*) were present in the whole survey area.

Altogether, the following fish species were sampled and processed:

Species	Length measurements (n)	Prevalence (n of hauls)
Belone belone	4	4
Clupea harengus	10,092	54
Crystallogobius linearis	124	14
Ctenolabrus rupestris	14	6
Cyclopterus lumpus	3	3
Engraulis encrasicolus	1,577	33
Eutrigla gurnardus	11	9
Gadus morhua	123	23
Gasterosteus aculeatus	836	30
Gobius niger	50	7
Limanda limanda	376	29
Merlangius merlangus	362	32
Merluccius merluccius	5	3
Platichthys flesus	50	21
Pleuronectes platessa	14	8
Pomatoschistus minutus	76	24
Scomber scombrus	301	15
Sprattus sprattus	7,533	53
Syngnathus typhle	3	3
Trachinus draco	580	18
Trachurus trachurus	67	21
Others	24	-

Figure 3 depicts the catch (CPUE) of clupeid fishes sampled during the 2020 survey. Figures 4 and 5 show relative length-frequency distributions of herring and sprat in ICES subdivisions 21, 22, 23 and 24 for the years 2019 and 2020. Compared to results from the previous survey in 2019, the following conclusions for **herring** can be drawn (Figure 4):

- In 2020 catches in SD 21 were dominated by the incoming year class (ca. ≤15 cm) with a mode at 13.75 cm. These catches further showed some contribution of larger herring >15 cm. This is in contrast to the results in 2019, which showed a bimodal distribution with modes at 15.25-15.75 cm and 18.75 cm.
- Catches in SD 22, which were dominated by the incoming year class (ca. ≤15 cm) with a mode at 12.75-13.25 cm in 2019 were dominated by larger herring >15 cm in 2020 with a mode at 22.25-22.75 cm.
- In contrast to the years 2016-2019, where larger herring (>20 cm) were almost absent from catches conducted in SD 23, catches in 2020 now showed at least some contribution of these larger length classes. Catches in 2019 showed a bimodal distribution with modes at 14.25 cm and 18.75 cm, whereas in 2020 catches constituted of herring >15 cm - 32.25 cm with a mode at 19.25 cm.
- Catches in SD 24 showed a similar bimodal distribution with modes at 13.25-14.25 cm and 17.75-18.75 cm in both years, accompanied by a virtual absence of herring larger than ca. 23 cm.

Relative length-frequency distributions of **sprat** in the years 2019 and 2020 (Figure 5) can be characterized as follows:

- In SD 21 catches of the incoming year class (ca. ≤10 cm) were virtually absent in 2019, whereas only some contributed to the catches in 2020. The catches were dominated by larger sprat in both years with a mode of 12.25-13.25 cm in 2019 and 11.25 cm in 2020, respectively.
- Catches in SD 22 were dominated in 2019 by the incoming year class (ca. ≤10 cm, mode at 9.75 cm). This is contrast to the results in 2020, where catches showed a bimodal distribution of both the incoming year class (ca. ≤10 cm, mode at 6.75 cm) and of larger sprat (>10 cm, mode at 11.25 cm).
- In SD 23, the catches in 2019 showed a bimodal distribution with a higher contribution of the incoming year class (ca. ≤10 cm, mode at 8.75 cm) compared to lower amounts of larger sprat (>10 cm, mode at 12.15 cm). This is in contrast to the results in 2020 where catches almost exclusively consisted of larger sprat (>10 cm).
- The catches In SD 24 were characterized by a bimodal length-frequency distribution with a lower contribution of the incoming year class (ca. ≤10 cm, mode at 8.75 cm) and higher contribution of larger older sprat (>10 cm, mode at 13.75 cm) in 2019. In contrast, the results in 2020 also almost exclusively consisted of larger sprat (>10 cm) in that subdivision.
- Altogether, the present contribution of the incoming year class (ca. ≤10 cm) seemed to be lower than the one observed in 2019.

For abundance and biomass estimates, the following considerations and calculation steps were included in the analysis:

<u>Fish species considered:</u>

Herring	(*Clupea harengus*)
Crystal goby	(*Crystallogobius linearis*)
European anchovy	(*Engraulis encrasicolus*)
Cod	(*Gadus morhua*)
Three-spined stickleback	(*Gasterosteus aculeatus*)
Whiting	(*Merlangius merlangus*)
Mackerel	(*Scomber scombrus*)
Sprat	(*Sprattus sprattus*)
Greater weever	(*Trachinus draco*)
Poor cod	(*Trisopterus minutus*)

<u>Exclusion of trawl hauls with very low catches:</u>

Haul No.	Rectangle	Subdivision (SD)
2	38G2	24
5	38G4	24
11	37G1	22
27	39G4	24
48	42G2	21

Inclusion of hauls with low catches:

Despite low catches of both herring and sprat, the following hauls were not excluded from the analysis as they were the only trawl hauls conducted in the corresponding rectangles and thus provided the only available information on species composition in the following rectangles:

Haul No.	Rectangle	Subdivision (SD)
1	37G2	24
11, 12, 13	37G1	22
14	38G1	22
15	37G0	22
16, 17	38G0	22
18	39F9	22
41	42G2	21

Usage of neighboring trawl information for rectangles which contain only acoustic investigations:

Rectangle/SD to be filled	with Haul No.	of Rectangle/SD
37G3/24	6, 7	38G3/24
37G4/24	6, 8	38G3/24, 38G4/24
39G2/23	31	39G2/24
40F9/22	19	40G0/22
40G1/22	21	40G0/22
43G2/21	42	43G1/21

3.3 Stock Splitting / Application of the Separation Function

The age-length distribution of herring in SDs 21 and in SD 23 in 2020 indicated also some contribution of fish of CBH origin. Besides the standard procedure to use the SF in SD 24 and in SD 23/39G2 (since biological samples of that rectangle were also used to raise the corresponding mean NASC values in the SD 24 area of the rectangle), the SF was accordingly also applied in SD 21 in 2020.

The applicability of the SF, which is checked by analyzing the growth parameters based on baseline samples of WBSSH in SDs 21 and 23 (GERAS) and SDs 27-29 (GERBASS), was also tested in 2020. Despite some degree of mixing of CBH/WBSSH in SDs 21 and 23, results showed applying the SF for splitting of WBSSH and CBH stocks was feasible (Gröhsler & Schaber, 2021).

3.4 Biomass and abundance estimates

The total abundance of herring and sprat is presented in Table 6. Estimated numbers of herring and sprat by age group and SD/rectangle are given in Table 7 and Table 10. Corresponding mean weights by age group and SD/rectangle are shown in Table 8 and Table 11. Estimates of herring and sprat biomass by age group and SD/rectangle are summarized in Table 9 and Table 12.

3.4.1 Herring incl. Central Baltic Herring (CBH)

The total herring stock in Subdivisions 21-24 was estimated to be 2.5 x 10^9 fish (Table 7) or 73.2 x 10^3 tons (Table 9). For the included area of Subdivisions 22-24 the number of herring was calculated at be 1.8 x 10^9 fish or 60.7 x 10^3 tons.

3.4.2 Herring excl. Central Baltic Herring (CBH)

Estimated numbers of herring excluding CBH in SDs 21-24 by age group and SD/rectangle for 2020 are given in Table 13. Corresponding herring mean weights by age group and SD/rectangle are shown in

Table 14. Estimates of herring biomass excluding CBH by age group and SD/rectangle are summarized in Table 15.

Removal of the CBH fraction in different SDs (total survey area) yielded the following results:

Numbers (millions)	Total	excluding CBH in SD:	
	incl. CBH	24 & 23(39G2)	24 & 23(39G2) and 21
SDs 21-24	2 532.2	1 896.9	1 888.7
Percentage of Total	100.0%	74.9%	74.6%
Difference		-25.1%	-25.4%
Biomass (t)	Total	excluding CBH in SD:	
	incl. CBH	24 & 23(39G2)	24 & 23(39G2) and 21
SDs 21-24	73 157.7	46 561	45 885
Percentage of Total	100.0%	63.6%	62.7%
Difference		-36.4%	-37.3%

Removal of the CBH fraction in SDs 21-24 from the herring HAWG-GERAS index of the standard area (excluding 43G1/43G2 in SD 21 and 37G3/37G4 in SD 24) in 2020 also resulted in biomass reductions of 37 % with corresponding reductions in numbers of 27 % (2019: -36 % and -24 %, 2018: -20 % and -11 %, respectively (Figure 6).

The time series of (WBSSH) HAWG-GERAS indices (standard area) is depicted in Figure 7.

3.4.3 Sprat

The estimated sprat stock in Subdivisions 21-24 was 2.6 x 10^9 fish (Table 10) or 25.7 x 10^3 tons (Table 12). For the included area of Subdivisions 22-24 the number of sprat was calculated at 1.9 x 10^9 fish or 19.1 x 10^3 tons. The overall abundance estimate in 2020 was dominated by one year old sprat (Figure 6 and Table 10).

3.5 Hydrography

Vertical profiles of temperature, salinity and oxygen concentration were measured with a SeaBird SBE CTD-probe on a station grid covering the whole survey area. Hydrography measurements were either conducted directly after a trawl haul or, in case of no fishing activity, in regular intervals along the cruise track. Altogether, 98 CTD casts were conducted during this survey (Figure 5).

Surface temperatures were comparatively high and ranged from ca. 12°C in the northern Kattegat area (SD 21) to > 16°C in the eastern Arkona Basin (SD 24). Bottom temperatures showed a higher variability due to thermohaline layering and were lowest in the deep parts of the Bornholm Basin area in SD 24 (ca. 7°C) and the northern Kattegat (ca. 9°C) but distinctly higher in the shallower areas of SD 21-24. Also in the central parts of the Arkona Sea, bottom temperatures were relatively high at almost 16 °C and exceeded surface temperatures.

As usual, due to the hydrographic nature of the western Baltic Sea, surface salinities showed a large gradient (from ca. 7.5 PSU in the southeastern Arkona Sea to > 21 PSU in the Kattegat). Unlike the previous years, surface salinities in the Western Baltic were not particularly high and mostly were around 15 PSU or lower south of the Belt Sea. Salinity near the seafloor ranged from 8 PSU in the Arkona Sea to ca. 35 PSU in the deep parts of the Kattegat. Especially in the Sound (SD 23), a very strong stratification with steep salinity gradients was observed.

Surface waters were well oxygenated throughout the survey area. In contrast, oxygen depletion was measured in the Mecklenburg Bight (SD 22) and the western SD 22 area between the Little Belt and Kiel Bight. In those regions, lowest oxygen concentrations measured near the seafloor were below 0.5 ml/l and around 0.7 ml/l, respectively.

4 DISCUSSION

Compared to 2019, the present estimates of herring **incl. CBH** show a decrease in stock biomass and abundance estimate (ICES rectangles 43G1 and 43G2 in SD21 were removed in 2020 for comparison):

Herring (incl. CBH)	Difference compared to 2019	
Area	Numbers (%)	Biomass (%)
Subdivisions 21-24	-35	-26

This present decrease of 35 % in numbers and 26 % biomass was mainly driven by distinctly lower estimates in SD 22 (-73 % in numbers and -54 % in biomass) and SD 24 (-30 % in numbers and -25 % in biomass) as compared to 2019.

Compared to 2019, the present estimates of herring **excl. CBH** now show a significant decrease in stock biomass and abundance values (ICES rectangles 43G1 and 43G2 in SD21 were removed in 2020 for comparison):

Herring (excl. CBH)	Difference compared to 2019	
Area	Numbers (%)	Biomass (%)
Subdivisions 21-24	-38	-28

The application of the Separation Function to remove CBH from the index calculation yields robust results, even though the actual applicability of the SF could not be tested in 2020 due to a lack of "clean" baseline samples from SDs 21 and in 23 (39G2). However, several issues were resolved and results corroborated after applying the SF and removing CBH from the samples from in SD 21, SD 23 (39G2) and SD 24 in 2020: Mean weights of different age groups that prior to removal showed somewhat untypical growth pattern for WBSSH became distinctly more realistic for older age groups after removing the CBH fraction. Additionally, a conspicuous peak of abundance of 6 years old herring that otherwise could not be explained vanished after removing the CBH fraction. The 2014 year class represents only a weak year class in the WBSSH assessment (ICES, 2020a). The assumption of this peak originating from CBH is realistic, since latest assessment results for CBH show a very strong (strongest in the time series) 2014 year class (ICES, 2020b).

After over 5 years of consecutive decline, the present Western Spring Spawning Herring biomass estimate (HAWG-GERAS Index) represents the lowest recorded value in the whole time series since 1993 (Figure 7).

Prior to 2016, high numbers of large herring were usually and regularly recorded in SD 23 (the Sound), which is considered an important transition and aggregation area for the WBSSH stock during its spawning migration (Nielsen, 1996). In 2020, after several years of supposed absence, some of those fishes were present in catches from the Sound again. The reason for this re-appearance or for the previous absence in survey hauls can so far not be identified. The lack of large, adult herring in the Sound in previous years has been explained by a possibly delayed immigration of WBSSH from the feeding areas in the Skagerrak. The exceptionally low numbers of large and older herring 2016-2020 could also be explained by the very low recruitment, which was recorded through the N20 larval survey index during the last years. The sustained downward trend in recruitment could explain the further disappearance of older herring in time. A strong correlation of the N20 index with the 1-age group of the GERAS index (Polte and Gröhsler, 2020) supports this assumption. Methodological biases leading to presence or absence large herring in the catches can again not be ruled out, but at least in terms of overall acoustic detections of clupeids seem not likely. Possible shifts in the spatial or diurnal distribution of herring aggregations towards shallower areas would be undetected by the current survey and cannot be disregarded. In indication for such possible shifts was detected during a 2019 parallel survey of the inner Sound transect with FRV "Solea" and FRV "Clupea", when length distributions of herring caught differed between night- and daytime with larger herring in the daytime catches. Additionally, also in 2020 large - assumed clupeid - aggregations were detected in shallower areas of SD 23 while steaming to the starting point of the transect.

Migrations of herring out of the sound can be triggered by hydrographic conditions in a way that barotropic inflow events in late summer and early autumn prevent deoxygenation in the Sound. This leads to prolonged aggregations of herring in the Sound (Miethe et al., 2014). In 2020, no such migration could be assumed since no older and bigger herring were detected in corresponding areas of the adjacent SD 24, nor was there an indication of according hydrographic conditions driving herring out of the Sound.

5 SURVEY PARTICIPANTS

Name	Function	Institute
Dr. M. Schaber (9.-21.10.)	Cruise Leader (Hydroacoustics, Hydrography)	TI-SF
L. Hartkens (2.-9.10.)	Cruise Leader (Hydroacoustics, Hydrography)	TI-SF
M. Koth	Fishery biology	TI-OF
A. Georgi	Fishery biology	TI-OF
A. Fiek	Fishery biology	TI-SF
I. Kratzer	Fishery biology	DTU-Aqua (DK)

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7 FIGURES

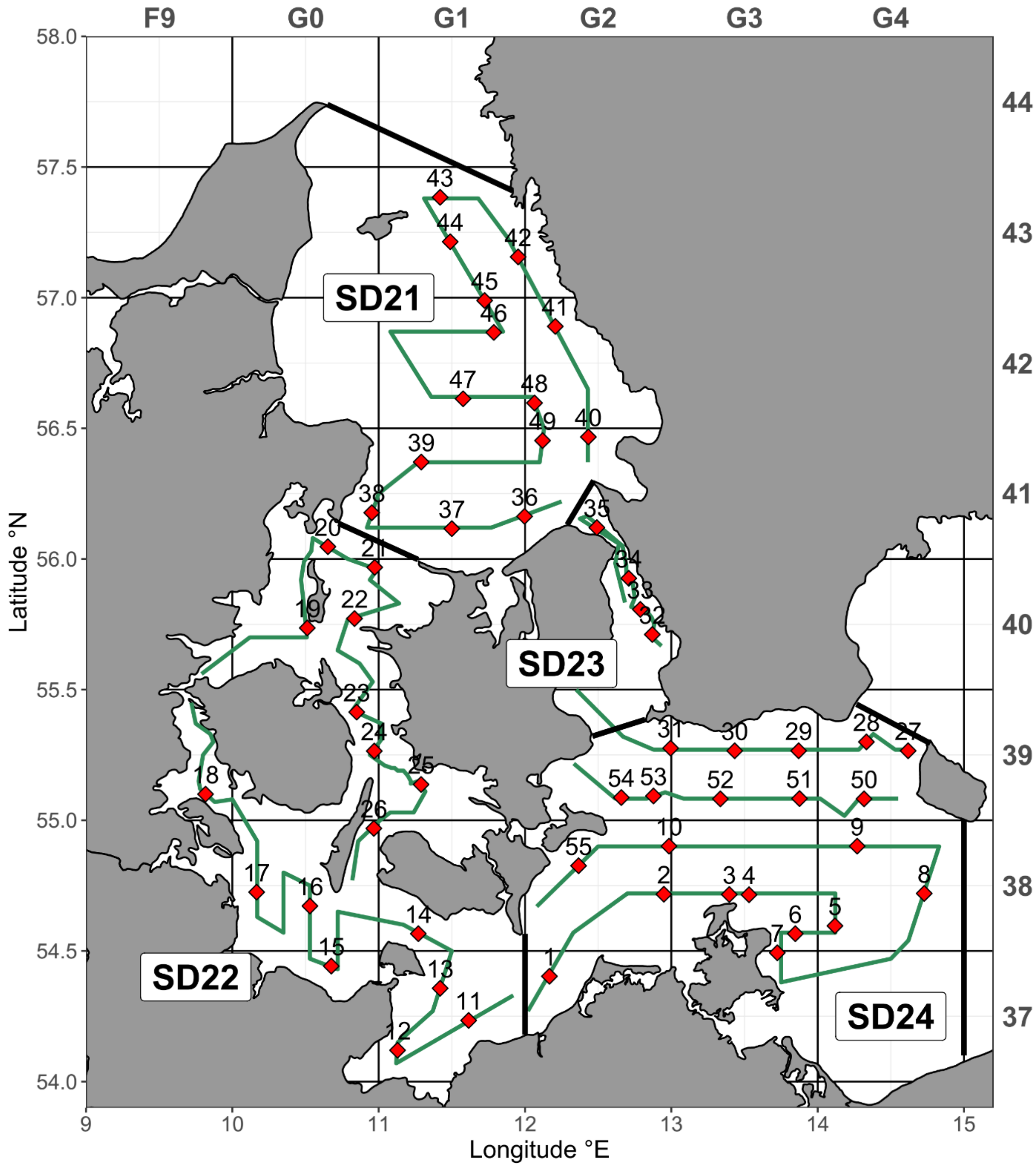


Figure 1: FRV "Solea" cruise 783/2020. Cruise track (dark green lines) and fishery hauls (red diamonds). ICES statistical rectangles are indicated in the top and right axis. Thick black lines separate ICES subdivisions (SD).

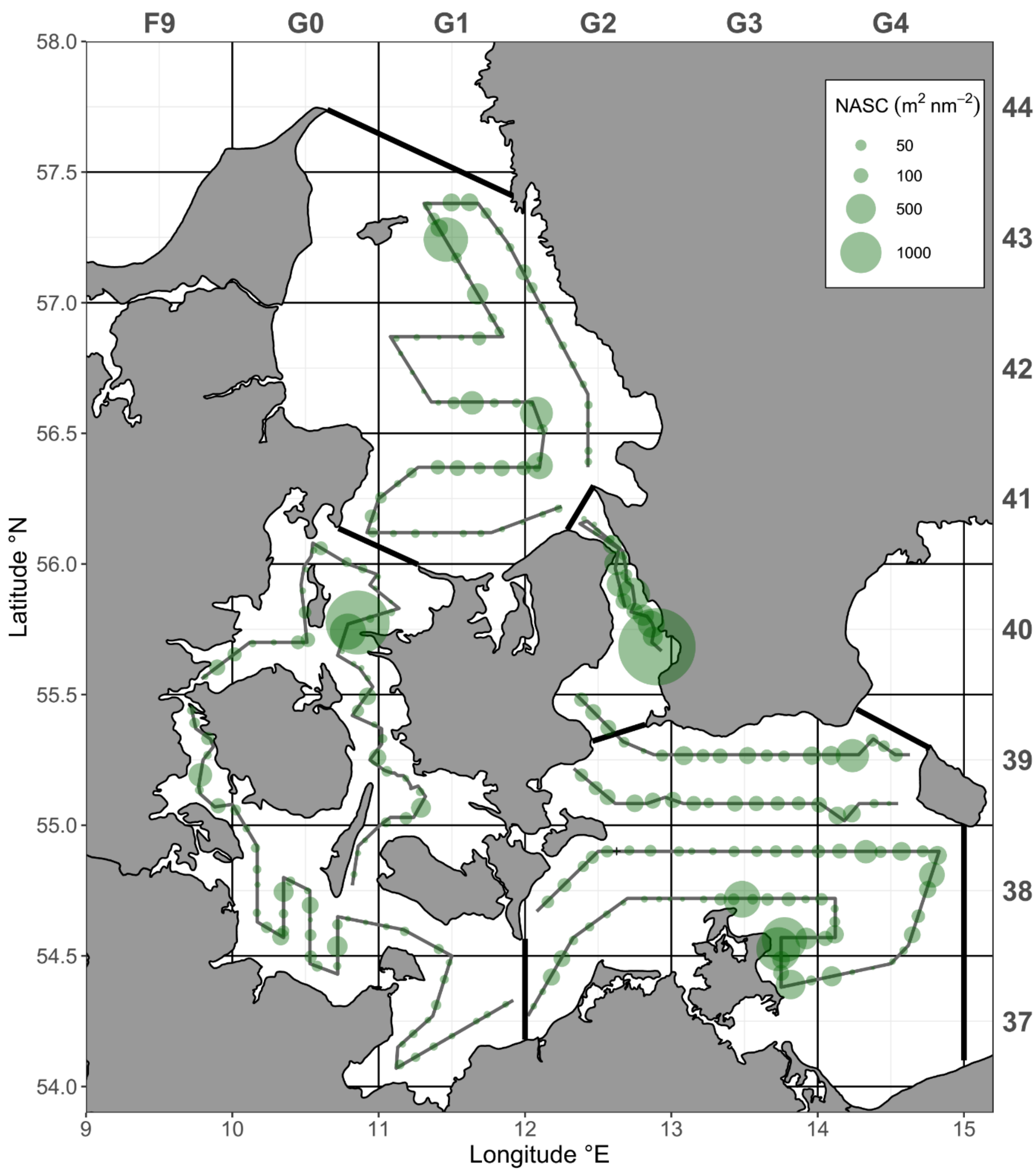


Figure 2: FRV "Solea" cruise 783/2020. Cruise track (thin grey lines) and mean NASC (5 nmi intervals, dots). ICES statistical rectangles are indicated in the top and right axis. Thick black lines separate ICES subdivisions.

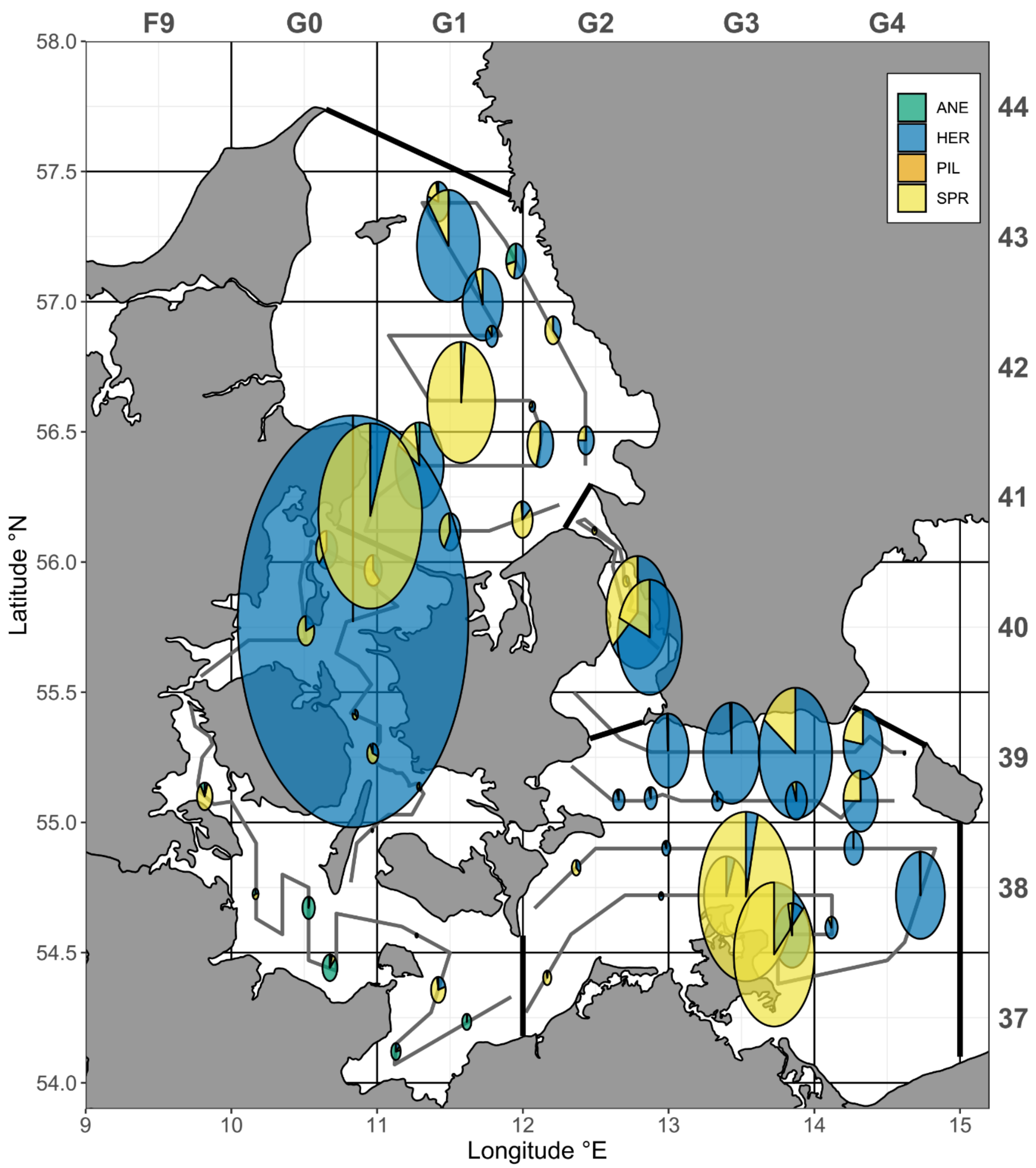


Figure 3: FRV "Solea" cruise 783/2020. Clupeid catch per haul (kg 30min^{-1}). ANE = European anchovy (*Engraulis encrasicolus*), HER = Herring (*Clupea harengus*), PIL = Sardine (*Sardina pilchardus*), SPR = Sprat (*Sprattus sprattus*). ICES statistical rectangles are indicated in the top and right axis. Thick black lines separate ICES subdivisions. Thin grey lines indicate cruise track.

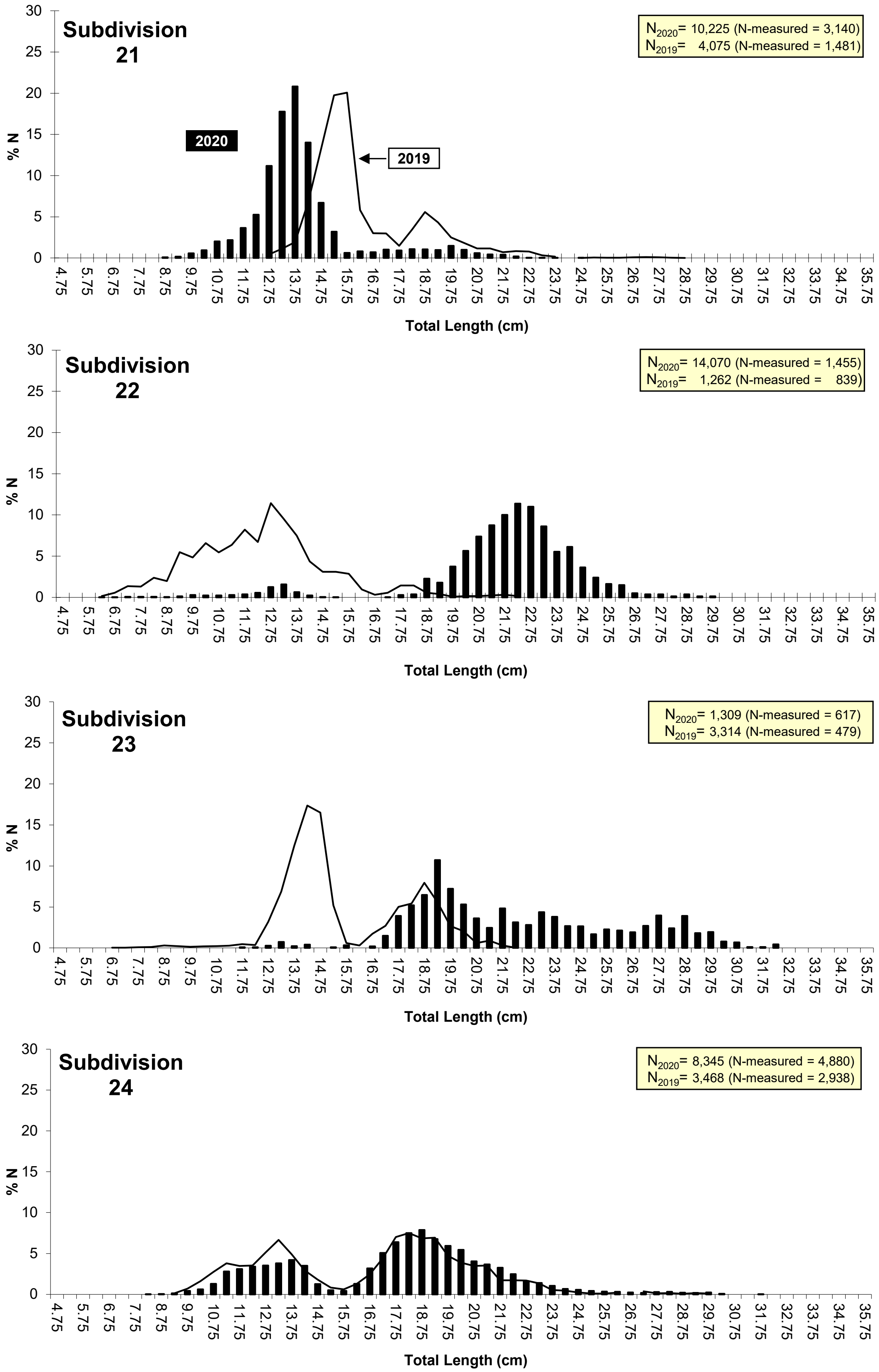


Figure 4: FRV "Solea" cruise 783/2030. Herring (*Clupea harengus*) length-frequency distribution (bars) compared to the previous year (cruise 768/2019, lines).

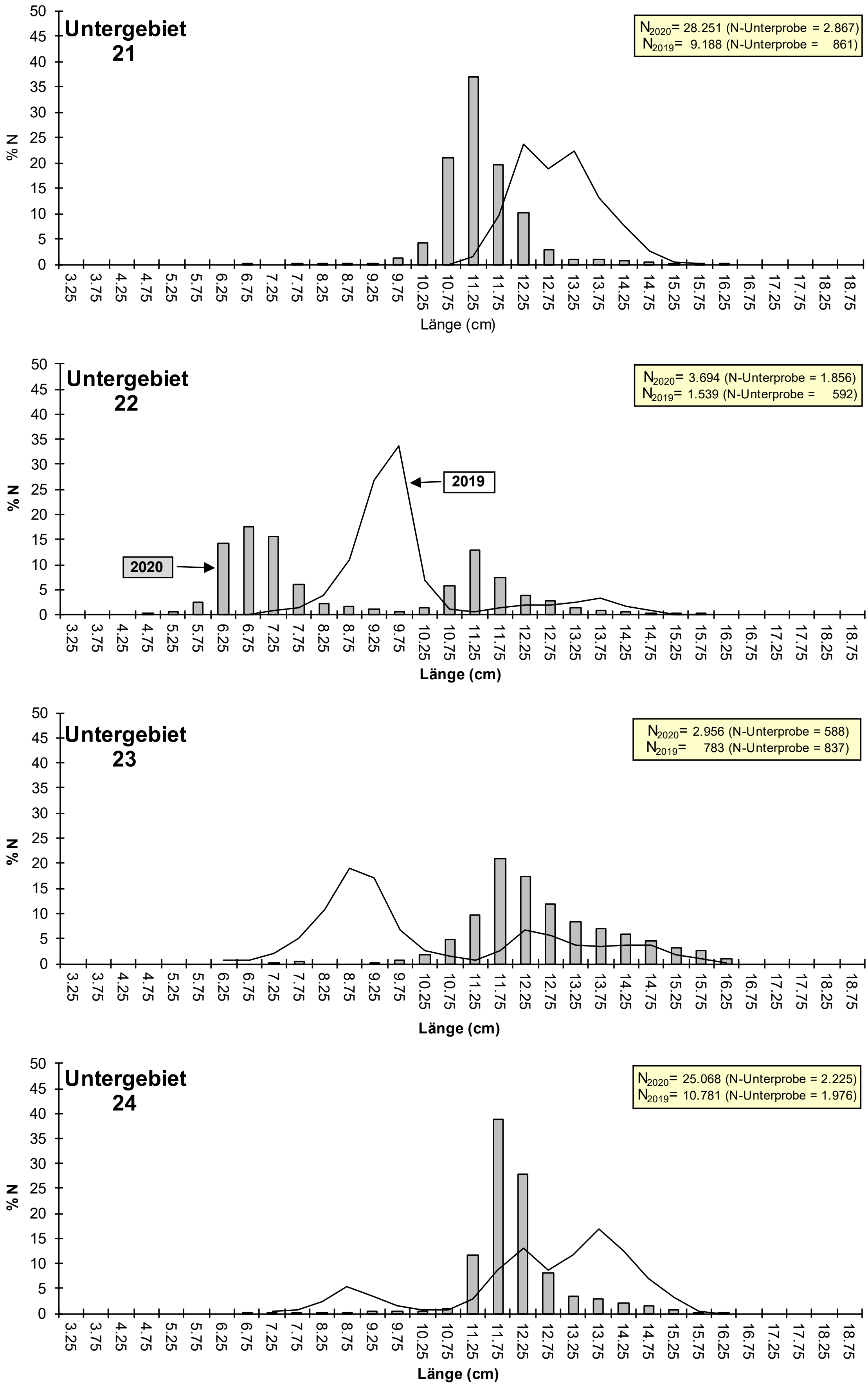


Figure 5: FRV "Solea" cruise 783/2020. Sprat (*Sprattus sprattus*) length-frequency distribution (bars) compared to the previous year (cruise 768/2019, lines).

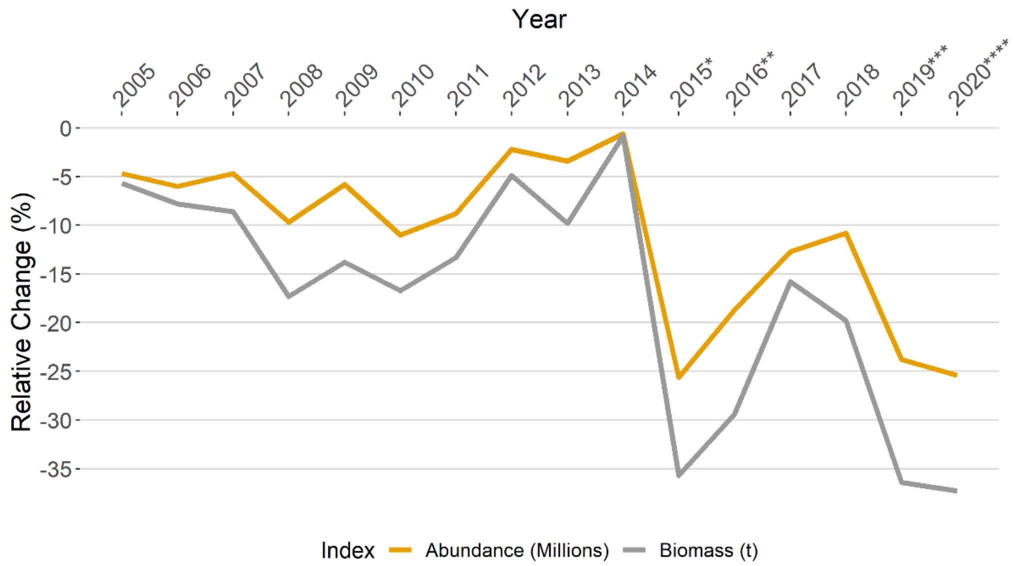


Figure 6: Relative changes in abundance and biomass of Western Baltic Spring Spawning herring in ICES Subdivisions 21-24 (2005-2020) after application of the stock Separation Function (SF, Gröhsler et al., 2013) to the abundance and biomass index generated from German acoustic survey data (GERAS) from SD24 and SD23/39G2. ** excl. of CBH in SD 22 and mature herring (stages ≥6) in SD 23, ** excl. of CBH in SD 22; *** excl. of CBH in SDs 21-23, **** excl. of CBH in SDs 21.*

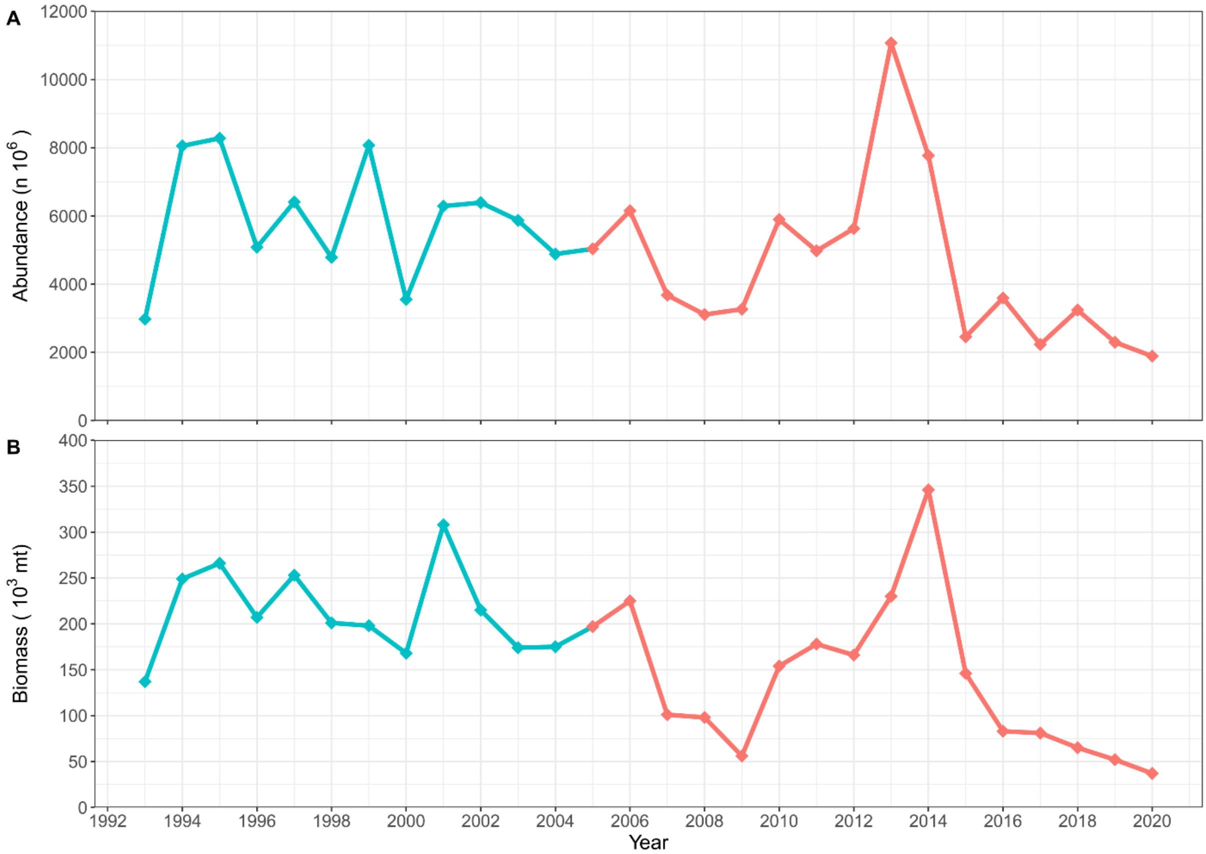


Figure 7: Time series of GERAS survey indices for Western Baltic Spring Spawning Herring (WBSSH) age groups 0-8+. A) Abundance and B) Biomass of herring in ICES Subdivisions 21 (Southern Kattegat, ICES statistical rectangles 41G0 - 42G2) – 24 (excl. ICES statistical rectangles 37G3 & 37G4). Blue line (until 2005): WBSSH including Central Baltic Herring fraction; Red line (from 2005): WBSSH after application of Separation Function (SF).

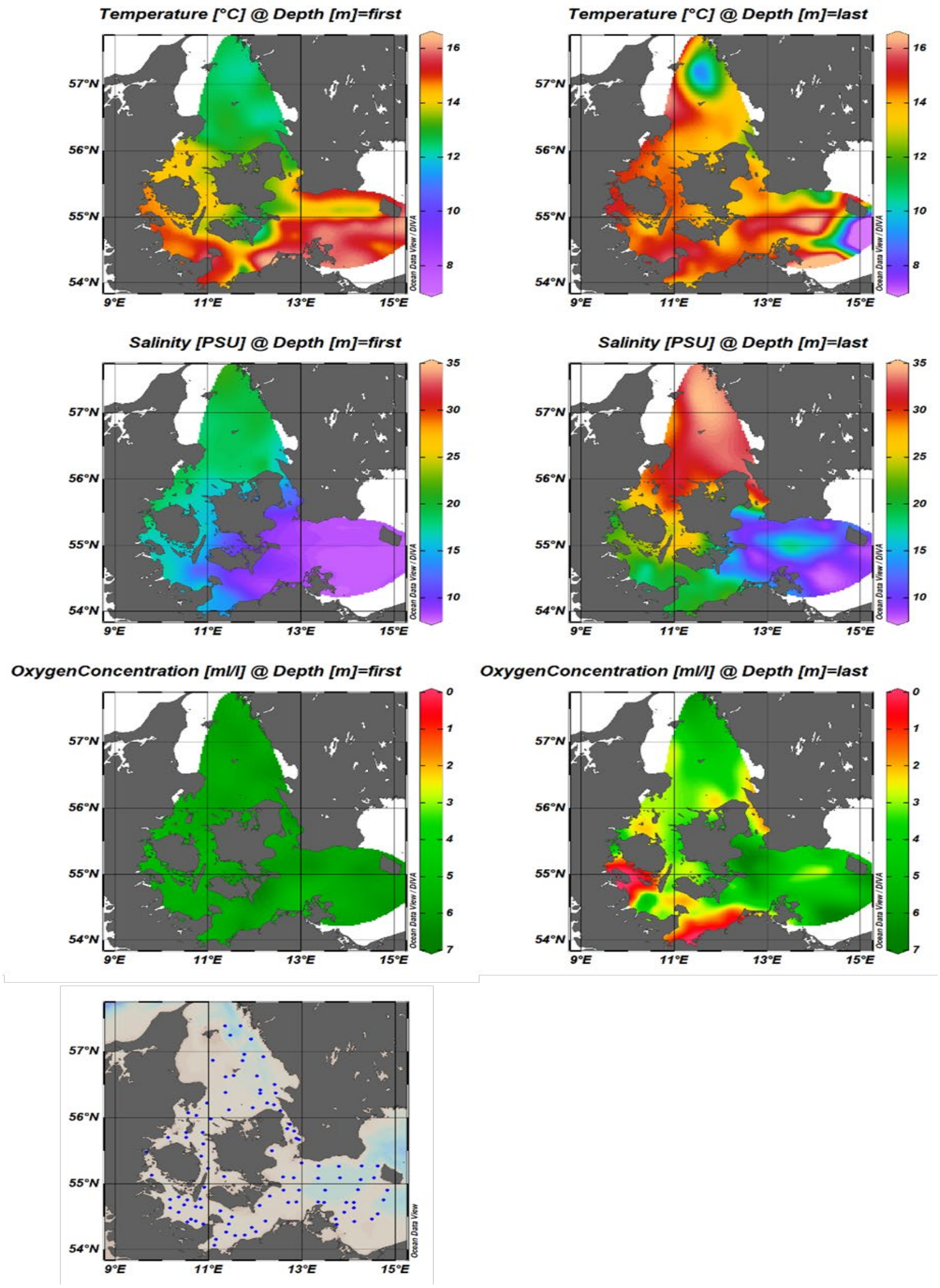


Figure 8: FRV "Solea" cruise 783/2020: Hydrography. CTD stations are depicted as blue dots in the area map. Temperature (°C, top panels), salinity (PSU, middle panels and oxygen concentration (ml/l, lower panels) at the surface (left) and near the seafloor (right).

8 TABLES

Table 1: FRV “Solea” cruise 783/2020: Simrad EK80 calibration report (38 kHz Transducer). Parameters for this transducer were retrieved from the second calibration at the end of the survey.

Date:	21.10.2020		
Calibration Site:	Kühlungsborn/Mecklenburg Bight (54°14.5 N, 11°46.2 E)		
Transceiver Type:	WBT		
Software Version:	EK80 1.12.4.0		
Reference Target:	Tungsten (WC-Co) 38.1 mm		
Transducer:	ES38-7 Serial No. 147		
Frequency:	38000 Hz	Beamtype:	Split/Narrow
Gain:	26.65 dB	Equivalent Beam Angle:	-20.7 dB
Beamwidth Athw.:	6.35 deg	Beamwidth Along.:	6.27 deg
Offset Athw.:	0.33 deg	Offset Along.:	-0.26 deg
Depth:	4.20 m		
Pulse Duration:	1.024 ms		
Power:	2000 W		
TS Detection:			
Min. Value:	-50.0 dB	Min. Spacing:	0.0
Max. Gain Comp.:	3.0 dB	Min. Echolength:	0.8
Max. Echolength:	1.8		
Environment:			
Absorption Coeff.:	0.004934	Sound Velocity:	1483.45m/s
Temperature:	14.1 °C	Salinity:	17.0 PSU
Calibration results:			
Transducer Gain:	27.11 dB	SaCorrection:	-0.1008 dB
Beamwidth Athw.:	6.48 deg	Beamwidth Along.:	6.60 deg
Offset Athw.:	0.07 deg	Offset Along.:	-0.18 deg
RMS-Error:	0.08		

Table 2: FRV "Solea" cruise 783/2020: Catch composition (kg 0.5 h^{-1}) by haul in SD 21.

Haul No.	36	37	38	39	40	41	42	43	44	45	46	47	48
Species/ICES Rectangle	41G1	41G1	41G0	41G1	41G2	42G2	43G1	43G1	43G1	42G1	42G1	42G1	42G2
BELONE BELONE								0.03		0.34			
CLUPEA HARENGUS	1.19	4.89	12.68	36.24	3.56	1.67	3.88	7.43	65.92	28.60	2.32	1.65	0.45
CRANGON CRANGON		+		+		+	0.01						
CRYSTALLOGOBIUS LINEARIS	+	+	+	+	0.01	+	+						
ENGRAULIS ENCRASICOLUS	0.14	0.12	0.20	1.31		0.01	2.03	0.29		0.02	0.01	0.21	
EUTRIGLA GURNARDUS	0.05	0.06	0.20	0.03	0.13	+							
GADUS MORHUA	0.01	0.08											
GASTEROSTEUS ACULEATUS		+	+	+							+		
LIMANDA LIMANDA	0.22	0.13	8.27	0.14	0.20		0.02	0.05					
LOLIGO	0.01	0.13	0.11	0.05	0.02	0.07	0.02	0.09	0.01	0.03	0.16	0.02	0.01
MERLANGIUS MERLANGUS	+	+	0.16		1.00	0.07	0.46	0.21	0.29	0.15	0.09	0.19	0.19
MERLUCCIUS MERLUCCIUS					0.05				0.17	+			
NEPHROPS NORVEGICUS					0.20								
PLATICHTHYS FLESUS													
PLEURONECTES PLATESSA			0.34	0.06									
POMATOSCHISTUS MINUTUS				+	+	+		+		+			+
PSETTA MAXIMA	0.16												
SARDINA PILCHARDUS							0.04						
SCOMBER SCOMBRUS		0.02		1.93		1.43		15.50	1.01	3.24	0.91	0.86	8.88
SEPIOLA							0.01				+	0.01	
SPRATTUS SPRATTUS	6.56	3.27	189.85	6.20	1.18	2.94	1.30	1.65	8.20	1.77	0.32	84.68	0.19
TRACHINUS DRACO	1.21	2.40	1.74	1.17	0.28	0.18		0.10	0.05	0.02	0.61	5.14	2.08
TRACHURUS TRACHURUS	0.02	0.06	0.18	0.07		+		0.04	0.17		0.01	0.01	0.01
TRISOPTERUS MINUTUS							0.01		0.01				
Total	**9.57**	**11.16**	**213.73**	**47.20**	**6.63**	**6.37**	**7.78**	**25.39**	**75.83**	**34.17**	**4.43**	**92.77**	**11.81**
Medusae	0.02	0.05	0.00	0.00	0.33	0.79	1.43	0.48	0.08	0.00	0.00	0.00	0.26

Haul No.	49	Total
Species/ICES Rectangle	41G2	
BELONE BELONE		**0.37**
CLUPEA HARENGUS	6.91	**177.39**
CRANGON CRANGON		**0.01**
CRYSTALLOGOBIUS LINEARIS		**0.01**
ENGRAULIS ENCRASICOLUS		**4.34**
EUTRIGLA GURNARDUS	+	**0.47**
GADUS MORHUA		**0.09**
GASTEROSTEUS ACULEATUS		**+**
LIMANDA LIMANDA	0.08	**9.11**
LOLIGO	0.06	**0.79**
MERLANGIUS MERLANGUS	0.01	**2.82**
MERLUCCIUS MERLUCCIUS		**0.22**
NEPHROPS NORVEGICUS		**0.20**
PLATICHTHYS FLESUS	0.27	**0.27**
PLEURONECTES PLATESSA		**0.40**
POMATOSCHISTUS MINUTUS	+	**+**
PSETTA MAXIMA		**0.16**
SARDINA PILCHARDUS		**0.04**
SCOMBER SCOMBRUS		**33.78**
SEPIOLA		**0.02**
SPRATTUS SPRATTUS	5.61	**313.72**
TRACHINUS DRACO	2.32	**17.30**
TRACHURUS TRACHURUS	0.05	**0.62**
TRISOPTERUS MINUTUS		**0.02**
Total	**15.31**	**562.15**
Medusae	0.00	3.44

+ = < 0.01 kg

Table 3: FRV “Solea” cruise 783/2020: Catch composition (kg 0.5 h^{-1}) by haul in SD 22.

Haul No. Species/ICES Rectangle	11 37G1	12 37G1	13 37G1	14 38G1	15 37G0	16 38G0	17 38G0	18 39F9	19 40G0	20 41G0	21 40G0	22 40G0	23 39G0
AGONUS CATAPHRACTUS													
BELONE BELONE													
CLUPEA HARENGUS	0.02	0.24	0.83	0.02	0.21	0.06	0.15	0.26	1.00	5.25	2.05	1000.62	0.20
CRANGON CRANGON										+			
CRYSTALLOGOBIUS LINEARIS										+			
CTENOLABRUS RUPESTRIS			+										
CYCLOPTERUS LUMPUS										0.15			
ENGRAULIS ENCRASICOLUS	1.51	1.32	0.12	0.08	3.64	2.83	0.22	0.42	0.04	0.02	0.03	0.04	0.12
GADUS MORHUA		2.62	0.12	0.32	3.01					0.08	0.06		
GASTEROSTEUS ACULEATUS	+	+		+	2.20	0.06	0.16	0.08	0.03	0.02	+		
GOBIUS NIGER				0.01				0.01					+
LIMANDA LIMANDA		0.15	6.49	0.44	0.34	0.43	0.05	0.49	0.02	0.24	0.37	0.20	0.07
LOLIGO										0.06	0.02		+
LUMPENUS LAMPRETAEFORMIS			0.05										
MERLANGIUS MERLANGUS			1.17		0.10		0.08				0.07		0.01
MYOXOCEPHALUS SCORPIUS				0.02									
NEOGOBIUS MELANOSTOMUS													
PLATICHTHYS FLESUS	0.57	0.31	1.47	0.17		0.20							
PLEURONECTES PLATESSA			0.48							0.22	0.07		
POMATOSCHISTUS MINUTUS			+										
PSETTA MAXIMA	0.58												
SCOMBER SCOMBRUS										0.80	0.17	0.16	
SPRATTUS SPRATTUS	0.02	0.13	3.03	0.01	0.33	0.01	0.30	3.81	4.11	3.16	3.53		0.24
SYNGNATHUS ROSTELLATUS		+											
SYNGNATHUS TYPHLE	+							+	+				
TRACHINUS DRACO										0.52	1.34	0.67	0.03
TRACHURUS TRACHURUS				0.03	0.08					0.02	0.09	0.04	0.01
Total	**2.70**	**4.77**	**13.76**	**1.10**	**9.91**	**3.59**	**0.96**	**5.07**	**5.20**	**10.54**	**7.80**	**1001.73**	**0.68**
Medusae	0.27	0.82	0.43	0.70	0.65	0.38	0.63	0.88	0.34	0.00	0.00	0.00	1.14

Haul No. Species/ICES Rectangle	24 39G0	25 39G1	26 38G0	Total
AGONUS CATAPHRACTUS			0.02	**0.02**
BELONE BELONE	0.05		0.05	**0.10**
CLUPEA HARENGUS	0.70	0.23		**1011.84**
CRANGON CRANGON		+	+	**+**
CRYSTALLOGOBIUS LINEARIS	+	+	0.01	**0.01**
CTENOLABRUS RUPESTRIS	0.02	0.03	+	**0.05**
CYCLOPTERUS LUMPUS				**0.15**
ENGRAULIS ENCRASICOLUS	0.17	+	0.03	**10.59**
GADUS MORHUA	0.04			**6.25**
GASTEROSTEUS ACULEATUS	0.01	0.17	0.03	**2.76**
GOBIUS NIGER	+	+	+	**0.02**
LIMANDA LIMANDA	0.12	+	1.09	**10.50**
LOLIGO	0.01	0.01	0.02	**0.12**
LUMPENUS LAMPRETAEFORMIS				**0.05**
MERLANGIUS MERLANGUS				**1.43**
MYOXOCEPHALUS SCORPIUS				**0.02**
NEOGOBIUS MELANOSTOMUS		+	+	**+**
PLATICHTHYS FLESUS		0.09		**2.81**
PLEURONECTES PLATESSA				**0.77**
POMATOSCHISTUS MINUTUS		+	0.01	**0.01**
PSETTA MAXIMA				**0.58**
SCOMBER SCOMBRUS	1.02			**2.15**
SPRATTUS SPRATTUS	1.48	0.17	0.03	**20.36**
SYNGNATHUS ROSTELLATUS				**+**
SYNGNATHUS TYPHLE				**+**
TRACHINUS DRACO				**2.56**
TRACHURUS TRACHURUS			0.01	**0.28**
Total	**3.62**	**0.70**	**1.30**	**1073.43**
Medusae	0.08	1.08	2.57	9.97

+ = < 0.01 kg

Table 4: FRV “Solea” cruise 783/2020: Catch composition (kg 0.5 h^{-1}) by haul in SD 23.

Haul No. Species/ICES Rectangle	32 40G2	33 40G2	34 40G2	35 41G2	Total
APHIA MINUTA	0.01				**0.01**
CLUPEA HARENGUS	60.97	48.36	0.26	0.05	**109.64**
CRANGON CRANGON			+		**0.00**
ENGRAULIS ENCRASICOLUS				+	**0.00**
EUTRIGLA GURNARDUS	43.50		16.59		**60.09**
GADUS MORHUA			0.41		**0.41**
GASTEROSTEUS ACULEATUS		+	+	0.01	**0.01**
LIMANDA LIMANDA	0.19	1.43	0.31		**1.93**
LOLIGO		+			**0.00**
MELANOGRAMMUS AEGLEFINUS	1.28				**1.28**
MERLANGIUS MERLANGUS	15.27	26.38	0.44	0.30	**42.39**
MYSIDACEA				0.15	**0.15**
POMATOSCHISTUS MINUTUS	0.03		+		**0.03**
Total	**121.25**	**76.17**	**18.01**	**0.51**	**215.94**
Medusae	0.03	0.00	0.00	0.87	**0.90**

+ = < 0.01 kg

Table 5: FRV "Solea" cruise 783/2020: Catch composition (kg 0.5 h^{-1}) by haul in SD 24.

Haul No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**27**	**28**	**29**
Species/ICES Rectangle	**37G2**	**38G2**	**38G3**	**38G3**	**38G4**	**38G3**	**38G3**	**38G4**	**38G4**	**38G2**	**39G4**	**39G4**	**39G3**
CLUPEA HARENGUS	0.03	0.36	2.37	6.82	2.56	23.62	9.90	44.53	6.48	1.80	0.06	74.38	25.09
CRANGON CRANGON	+									0.00		+	
CRYSTALLOGOBIUS LINEARIS	+												
CTENOLABRUS RUPESTRIS	+												
CYCLOPTERUS LUMPUS			0.25									0.09	
ENGRAULIS ENCRASICOLUS	0.03		0.04							0.03			
EUTRIGLA GURNARDUS		0.06											
GADUS MORHUA			0.20	0.03	3.84	12.69	14.16	+				11.15	1.24
GASTEROSTEUS ACULEATUS		0.15	0.25	0.15	0.08	0.01	+			+			
GOBIUS NIGER	0.07												
LEANDER	+												
LIMANDA LIMANDA	2.81	0.14								0.15			
MERLANGIUS MERLANGUS							1.30		0.68			0.97	1.55
PLATICHTHYS FLESUS	0.37	0.44	1.24				0.34		0.67	0.21		0.32	0.71
PLEURONECTES PLATESSA	0.25		0.14										
POMATOSCHISTUS MINUTUS	+	+	+					+		0.02		+	
SCOMBER SCOMBRUS													
SOLEA VULGARIS		0.07											
SPRATTUS SPRATTUS	1.16	+	35.24	162.61	0.26	0.86	63.55	0.26	0.02	0.13		14.63	7.46
TRACHURUS TRACHURUS	+												
Total	**4.72**	**1.22**	**39.73**	**169.61**	**6.74**	**37.18**	**89.25**	**44.79**	**7.85**	**2.34**	**0.06**	**101.54**	**36.05**
Medusae	10.89	3.11	10.46	1.68	57.04	39.42	26.23	4.70	5.38	1.90	6.15	1.56	1.96

Haul No.	**30**	**31**	**50**	**51**	**52**	**53**	**54**	**55**	**Total**
Species/ICES Rectangle	**39G3**	**39G2**	**39G4**	**39G3**	**39G3**	**39G2**	**39G2**	**38G2**	
CLUPEA HARENGUS	59.73	32.14	16.63	7.91	2.11	2.72	2.38	0.50	**322.12**
CRANGON CRANGON					0.02	0.01	+		**0.03**
CRYSTALLOGOBIUS LINEARIS						+	+		**+**
CTENOLABRUS RUPESTRIS									**+**
CYCLOPTERUS LUMPUS									**0.34**
ENGRAULIS ENCRASICOLUS			0.06		0.03	0.11	0.05		**0.35**
EUTRIGLA GURNARDUS									**0.06**
GADUS MORHUA	3.51			+			0.13	0.01	**46.96**
GASTEROSTEUS ACULEATUS			1.94	0.22	0.07	0.34	0.12	0.19	**3.52**
GOBIUS NIGER									**0.07**
LEANDER									**+**
LIMANDA LIMANDA					0.08			0.16	**3.34**
MERLANGIUS MERLANGUS	0.21	0.06	0.33	0.42	0.05		0.04	0.03	**5.64**
PLATICHTHYS FLESUS		0.15	0.17	0.18	0.38	0.72		2.65	**8.55**
PLEURONECTES PLATESSA							0.18		**0.57**
POMATOSCHISTUS MINUTUS	+	+		0.01	+	+	+	+	**0.03**
SCOMBER SCOMBRUS					0.62				**0.62**
SOLEA VULGARIS									**0.07**
SPRATTUS SPRATTUS	0.60	0.21	5.43	0.53	0.04	0.08	0.13	0.92	**294.12**
TRACHURUS TRACHURUS									**+**
Total	**64.05**	**32.56**	**24.56**	**9.27**	**3.40**	**3.98**	**3.03**	**4.46**	**686.39**
Medusae	5.94	4.42	6.48	4.34	4.81	1.51	10.15	23.36	**231.49**

+ = < 0.01 kg

Table 6: FRV "Solea", cruise 783/2020. Survey statistics by area.

Sub-division	ICES Rectangle	Area (nm²)	Sa (m²/NM²)	Sigma (cm²)	N total (million)	Herring (%)	Sprat (%)	NHerring (million)	NSprat (million)
21	41G0	108.1	32.0	1.249	27.70	4.53	94.92	1.25	26.29
21	41G1	946.8	47.6	2.072	217.51	41.45	44.49	90.15	96.77
21	41G2	432.3	51.8	1.758	127.38	49.66	38.81	63.25	49.44
21	42G1	884.2	53.1	1.913	245.43	51.59	38.38	126.63	94.20
21	42G2	606.8	66.1	1.287	311.65	19.64	70.31	61.22	219.13
21	43G1	699.0	153.7	1.560	688.69	56.34	22.51	388.00	155.06
21	43G2	107.0	34.8	1.441	25.84	38.24	20.45	9.88	5.28
21	Total	3,784.2			1644.20			740.38	646.17
22	37G0	209.9	30.0	0.665	94.69	1.25	1.71	1.18	1.62
22	37G1	723.3	21.4	1.795	86.23	15.28	39.09	13.18	33.71
22	38G0	735.3	54.8	0.752	535.83	4.09	16.79	21.89	89.97
22	38G1	173.2	28.2	1.954	25.00	3.13	3.13	0.78	0.78
22	39F9	159.3	101.4	0.469	344.41	2.33	89.44	8.01	308.04
22	39G0	201.7	72.3	1.271	114.74	17.71	49.69	20.32	57.01
22	39G1	250.0	69.0	0.435	396.55	2.59	25.39	10.27	100.68
22	40F9	51.3	93.8	1.282	37.53	19.02	75.87	7.14	28.47
22	40G0	538.1	116.6	2.079	301.79	48.91	46.28	147.60	139.67
22	40G1	174.5	12.3	1.789	12.00	27.86	62.98	3.34	7.56
22	41G0	173.1	21.8	1.571	24.02	52.39	40.67	12.58	9.77
22	Total	3,389.7			1972.79			246.29	777.28
23	39G2	130.9	118.5	2.974	52.16	96.35	3.55	50.26	1.85
23	40G2	164.0	619.6	6.438	157.84	27.66	64.16	43.66	101.27
23	41G2	72.3	45.6	1.929	17.09	8.33	80.56	1.42	13.77
23	Total	367.2			227.09			95.34	116.89
24	37G2	192.4	85.2	1.627	100.75	4.60	89.66	4.63	90.33
24	37G3	167.7	229.6	2.583	149.07	47.49	51.21	70.79	76.34
24	37G4	875.1	57.4	3.604	139.37	93.40	5.38	130.17	7.49
24	38G2	832.9	42.8	1.077	330.99	51.61	29.99	170.84	99.25
24	38G3	865.7	166.9	1.850	781.00	25.48	72.45	199.02	565.82
24	38G4	1034.8	123.7	4.112	311.30	97.53	1.23	303.61	3.82
24	39G2	406.1	93.8	1.713	222.37	69.12	3.19	153.70	7.08
24	39G3	765.0	106.6	2.434	335.04	73.95	12.67	247.77	42.45
24	39G4	524.8	179.1	2.405	390.82	43.41	30.33	169.65	118.54
24	Total	5,664.5			2,760.71			1450.18	1011.12
22-24	Total	9,421.4			4,960.59			1791.81	1905.29
21-24	Total	13,205.6			6,604.79			2532.19	2551.46

Table 7: FRV “Solea”, cruise 783/2020. Numbers (millions) of herring incl. CBH by age/W-rings and area.

Sub-division	Rectangle/ W-rings	0	1	2	3	4	5	6	7	8+	Total
21	41G0	1.19	0.06								1.25
21	41G1	79.60	8.99	0.64	0.34	0.23	0.05	0.30			90.15
21	41G2	61.95	1.15	0.09	0.02	0.02	0.01	0.01			63.25
21	42G1	119.03	7.34	0.04	0.06	0.06	0.02	0.09			126.64
21	42G2	52.32	7.62	0.46	0.28	0.21	0.10	0.23			61.22
21	43G1	344.20	37.94	1.97	1.05	1.45	0.19	1.20			388.00
21	43G2	9.81	0.06								9.87
21	Total	668.10	63.16	3.20	1.75	1.97	0.37	1.83	0.00	0.00	740.38
22	37G0	1.15	0.03								1.18
22	37G1	13.00	0.18								13.18
22	38G0	21.41	0.48								21.89
22	38G1	0.78									0.78
22	39F9	8.01									8.01
22	39G0	15.32	3.06	0.98	0.76		0.10	0.10			20.32
22	39G1	5.77	0.39	2.46	1.23		0.21	0.21			10.27
22	40F9	6.74	0.29	0.08	0.02	0.01					7.14
22	40G0	90.90	25.93	21.38	5.59	2.57	0.84	0.32	0.07		147.60
22	40G1	3.01	0.31	0.01							3.33
22	41G0	11.47	1.05	0.03	0.03						12.58
22	Total	177.56	31.72	24.94	7.63	2.58	1.15	0.63	0.07	0.00	246.28
23	39G2	11.70	7.06	3.00	7.66	6.45	5.34	6.87	0.99	1.19	50.26
23	40G2	12.58	9.29	7.5	5.21	3.46	3.12	1.25	0.94	0.3	43.65
23	41G2	0.95	0.44	0.03							1.42
23	Total	25.23	16.79	10.53	12.87	9.91	8.46	8.12	1.93	1.49	95.33
24	37G2	4.63									4.63
24	37G3	26.61	8.39	3.20	7.05	7.52	6.21	8.96	1.44	1.42	70.80
24	37G4	7.43	21.74	9.34	20.83	20.59	17.81	24.35	4.00	4.08	130.17
24	38G2	161.42	2.91	0.23	1.87	1.41	1.12	1.53	0.19	0.16	170.84
24	38G3	91.04	21.62	6.96	18.00	18.95	14.86	21.20	3.31	3.08	199.02
24	38G4	2.61	42.60	27.77	54.42	48.70	47.60	55.44	13.52	10.94	303.60
24	39G2	97.00	11.93	3.89	11.06	9.31	7.54	9.98	1.43	1.57	153.71
24	39G3	113.20	26.31	12.13	22.31	21.06	19.53	24.95	4.08	4.22	247.79
24	39G4	42.04	17.47	9.92	29.20	21.03	20.35	20.13	5.20	4.31	169.65
24	Total	545.98	152.97	73.44	164.74	148.57	135.02	166.54	33.17	29.78	1,450.21
22-24	Total	748.77	201.48	108.91	185.24	161.06	144.63	175.29	35.17	31.27	1,791.82
21-24	Total	1,416.87	264.64	112.11	186.99	163.03	145.00	177.12	35.17	31.27	2,532.20

Table 8: FRV “Solea”, cruise 783/2020. Mean weight (g) of herring incl. CBH by age/W-rings and area.

Sub-division	Rectangle/ W-rings	0	1	2	3	4	5	6	7	8+	Total
21	41G0	13.45	41.47								14.79
21	41G1	15.39	44.38	56.42	49.42	50.90	42.48	52.89			18.93
21	41G2	13.61	39.23	71.94	46.03	38.63	42.48	34.31			14.18
21	42G1	16.40	32.13	32.59	37.73	39.21	42.48	37.28			17.36
21	42G2	14.41	44.14	54.21	47.75	48.03	42.48	55.78			18.88
21	43G1	13.03	40.19	60.48	46.21	74.19	42.48	51.94			16.38
21	43G2	13.61	33.37								13.73
21	Total	14.08	40.30	58.74	46.79	67.26	42.48	51.76			16.84
22	37G0	10.39	12.88								10.45
22	37G1	8.74	13.44								8.80
22	38G0	8.94	14.97								9.07
22	38G1	15.19	0.00								15.19
22	39F9	5.30	0.00								5.30
22	39G0	9.82	42.30	90.82	97.19		119.05	119.05			22.96
22	39G1	10.04	12.97	95.67	107.36		119.05	119.05			46.78
22	40F9	9.77	25.62	72.22	47.73	49.89					11.28
22	40G0	11.33	48.34	79.33	98.01	107.53	135.62	151.35	175.67		33.73
22	40G1	12.91	23.10	48.83							13.97
22	41G0	13.50	17.15	91.70	91.70						14.18
22	Total	10.53	45.10	81.37	99.28	107.31	131.15	135.46	175.67		26.85
23	39G2	14.59	36.04	42.70	39.75	39.99	45.43	43.01	47.09	48.57	34.98
23	40G2	14.88	40.19	70.16	128.96	135.39	148.23	170.47	185.07	213.55	71.95
23	41G2	11.56	34.40	34.40							19.12
23	Total	14.62	38.29	62.23	75.86	73.30	83.34	62.63	114.29	81.79	51.67
24	37G2	7.95									7.95
24	37G3	10.23	38.55	47.23	41.13	41.46	45.01	42.47	45.89	46.62	30.24
24	37G4	12.01	38.87	48.13	41.86	41.97	47.05	44.71	49.69	48.08	41.80
24	38G2	9.33	31.70	32.15	30.44	34.64	37.21	37.81	37.90	37.30	10.68
24	38G3	9.56	38.05	43.88	38.15	39.28	42.85	41.59	43.70	44.89	26.28
24	38G4	16.13	39.98	53.51	53.22	48.99	53.94	48.67	58.58	56.24	50.02
24	39G2	12.53	33.89	40.81	37.99	38.95	43.83	42.40	46.00	47.29	22.48
24	39G3	14.56	35.27	45.82	44.20	44.83	50.08	46.82	54.21	50.57	30.84
24	39G4	15.89	35.31	46.55	56.65	58.75	74.34	63.67	81.40	78.96	48.30
24	Total	11.63	37.50	48.69	47.73	46.42	53.21	47.92	57.85	55.40	33.89
22-24	Total	11.47	38.76	57.48	51.80	49.05	55.60	48.91	61.20	56.68	33.87
21-24	Total	12.70	39.13	57.52	51.76	49.27	55.56	48.94	61.20	56.68	28.89

Table 9: FRV "Solea", cruise 783/2020. Total biomass (t) of herring incl. CBH by age/W-rings and area.

Sub-division	Rectangle/ W-rings	0	1	2	3	4	5	6	7	8+	Total
21	41G0	16.0	2.5								18.5
21	41G1	1,225.0	399.0	36.1	16.8	11.7	2.1	15.9			1,706.6
21	41G2	843.1	45.1	6.5	0.9	0.8	0.4	0.3			897.2
21	42G1	1,952.1	235.8	1.3	2.3	2.4	0.9	3.4			2,198.0
21	42G2	753.9	336.4	24.9	13.4	10.1	4.3	12.8			1,155.8
21	43G1	4,484.9	1,524.8	119.2	48.5	107.6	8.1	62.3			6,355.4
21	43G2	133.5	2.0								135.5
21	Total	9,408.7	2,545.6	188.0	81.9	132.5	15.7	94.7	0.0	0.0	12,467.0
22	37G0	12.0	0.4								12.3
22	37G1	113.6	2.4								116.0
22	38G0	191.4	7.2								198.6
22	38G1	11.9									11.9
22	39F9	42.5									42.5
22	39G0	150.4	129.4	89.0	73.9		11.9	11.9			466.6
22	39G1	57.9	5.1	235.4	132.1		25.0	25.0			480.4
22	40F9	65.9	7.4	5.8	1.0	0.5					80.5
22	40G0	1,029.9	1,253.5	1,696.1	547.9	276.4	113.9	48.4	12.3		4,978.3
22	40G1	38.9	7.2	0.5							46.5
22	41G0	154.9	18.0	2.8	2.8						178.4
22	Total	1,869.1	1,430.6	2,029.5	757.49	276.9	150.8	85.34	12.30	0.0	6,611.9
23	39G2	170.7	255.4	127.6	304.6	257.3	242.7	294.3	47.21	58.4	1,758.2
23	40G2	187.2	373.4	526.2	671.9	468.5	462.5	213.1	174.0	64.1	3,140.7
23	41G2	11.0	15.1	1.0							27.2
23	Total	368.9	643.9	654.8	976.4	725.8	705.1	507.4	221.2	122.4	4,926.0
24	37G2	36.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.8
24	37G3	272.2	323.4	151.1	290.0	311.8	279.5	380.5	66.1	66.2	2,140.9
24	37G4	89.2	845.0	449.5	871.9	864.2	838.0	1,088.7	198.8	196.2	5,441.5
24	38G2	1,506.1	92.3	7.4	56.9	48.8	41.7	57.9	7.2	6.0	1,824.2
24	38G3	870.3	822.6	305.4	686.7	744.4	636.8	881.7	144.7	138.3	5,230.8
24	38G4	42.1	1,703.2	1,486.0	2,896.2	2,385.8	2,567.5	2,698.3	792.0	615.3	15,186.3
24	39G2	1,215.4	404.3	158.8	420.2	362.6	330.5	423.2	65.8	74.3	3,454.9
24	39G3	1,648.2	928.0	555.8	986.1	944.1	978.1	1,168.2	221.2	213.4	7,643.0
24	39G4	668.0	616.9	461.8	1,654.2	1,235.5	1,512.8	1,281.7	423.3	340.3	8,194.5
24	Total	6,348.4	5,735.6	3,575.8	7,862.2	6,897.2	7,184.8	7,980.0	1,918.9	1,649.9	49,152.8
22-24	Total	8,586.4	7,810.1	6,260.1	9,596.1	7,899.8	8,040.8	8,572.8	2,152.4	1,772.3	60,690.7
21-24	Total	17,995.0	10,355.7	6,448.0	9,678.0	8,032.3	8,056.5	8,667.5	2,152.4	1,772.3	73,157.7

Table 10: FRV "Solea", cruise 783/2020. Numbers (millions) of sprat by age and area.

Sub-division	Rectangle/ Age group	0	1	2	3	4	5	6	7	8+	Total
21	41G0		25.21	0.63	0.33	0.06	0.06				26.29
21	41G1		69.79	14.02	9.98	1.93	0.99		0.07		96.78
21	41G2	1.16	44.05	1.93	1.88	0.32	0.10				49.44
21	42G1		62.47	15.18	12.20	2.45	1.77		0.12		94.19
21	42G2	1.07	213.54	2.53	1.71	0.24	0.05				219.14
21	43G1	1.47	147.76	2.26	2.58	0.60	0.39				155.06
21	43G2	0.04	5.03	0.09	0.10	0.02					5.28
21	Total	3.74	567.85	36.64	28.78	5.62	3.36	0.00	0.19	0.00	646.18
22	37G0	0.37	0.25	0.30	0.43	0.16	0.12				1.63
22	37G1	12.92	15.42	2.50	1.89	0.70	0.28				33.71
22	38G0	67.78	18.00	3.39	0.60	0.20					89.97
22	38G1		0.34	0.34	0.08	0.03					0.79
22	39F9	307.84	0.20								308.04
22	39G0	10.97	37.25	5.38	2.18	0.96	0.27				57.01
22	39G1	98.21	2.47								100.68
22	40F9	0.71	22.24	3.45	1.33	0.59	0.14				28.46
22	40G0	3.95	116.43	13.07	3.94	1.75	0.53				139.67
22	40G1	0.24	6.70	0.50	0.07	0.03	0.02				7.56
22	41G0	0.15	8.88	0.63	0.07	0.03	0.01				9.77
22	Total	503.14	228.18	29.56	10.59	4.45	1.37	0.00	0.00	0.00	777.29
23	39G2	1.35	0.27	0.09	0.09	0.03	0.02	0.01			1.86
23	40G2	3.09	71.11	11.61	7.16	4.73	2.23	0.45	0.71	0.20	101.29
23	41G2	0.65	12.69	0.36		0.07					13.77
23	Total	5.09	84.07	12.06	7.25	4.83	2.25	0.46	0.71	0.20	116.92
24	37G2	0.77	33.60	18.63	20.02	8.45	6.54	1.62	0.69		90.32
24	37G3	1.82	50.61	11.72	8.67	1.58	1.48	0.40	0.06		76.34
24	37G4	0.01	2.24	1.88	1.84	0.77	0.52	0.18	0.06		7.50
24	38G2	63.78	20.85	6.26	5.86	1.24	1.26				99.25
24	38G3	19.39	413.69	66.25	50.59	7.12	6.71	1.81	0.27		565.83
24	38G4		0.14	0.63	0.91	0.70	1.06	0.26	0.13		3.83
24	39G2	1.79	2.78	1.01	0.91	0.29	0.22	0.07	0.02		7.09
24	39G3		3.47	9.44	15.44	7.37	5.24	0.93	0.54		42.43
24	39G4	0.04	9.98	25.05	39.08	22.23	14.08	5.05	3.04		118.55
24	Total	87.60	537.36	140.87	143.32	49.75	37.11	10.32	4.81	0.00	1,011.14
22-24	Total	595.83	849.61	182.49	161.16	59.03	40.73	10.78	5.52	0.20	1,905.35
21-24	Total	599.57	1,417.46	219.13	189.94	64.65	44.09	10.78	5.71	0.20	2,551.53

Table 11: FRV "Solea", cruise 783/2020. Mean weight (g) of sprat by age and area.

Sub-division	Rectangle/ Age group	0	1	2	3	4	5	6	7	8+	Total
21	41G0		10.32	14.07	16.46	18.84	20.34				10.53
21	41G1		11.66	14.51	16.10	17.93	20.73		22.83		12.76
21	41G2	2.32	9.31	15.10	16.11	16.54	19.81				9.70
21	42G1		11.75	14.82	16.61	18.33	20.98		22.83		13.23
21	42G2	4.16	9.22	14.49	15.94	15.65	18.22				9.32
21	43G1	3.79	8.29	15.02	17.26	17.94	21.50				8.56
21	43G2	4.08	8.62	14.89	16.36	16.35					8.87
21	Total	3.44	9.61	14.69	16.42	17.93	20.88		22.83		10.30
22	37G0	3.18	11.87	14.78	17.08	16.68	17.85				12.67
22	37G1	4.67	10.33	13.55	16.61	16.56	17.31				8.94
22	38G0	2.73	11.81	12.65	12.79	12.79					5.01
22	38G1		12.79	12.79	12.79	12.79					12.79
22	39F9	2.00	5.16								2.00
22	39G0	2.58	11.18	13.33	14.77	14.39	15.43				9.94
22	39G1	3.23	5.92								3.30
22	40F9	7.64	10.65	12.83	14.97	14.45	15.76				11.14
22	40G0	7.45	10.45	12.35	14.95	14.55	16.23				10.75
22	40G1	7.29	10.28	11.48	14.83	15.01	17.14				10.35
22	41G0	7.50	10.54	11.27	14.39	14.20	15.40				10.59
22	Total	2.48	10.64	12.71	15.16	14.80	16.39				5.53
23	39G2	2.94	12.63	14.53	15.88	17.74	16.88	18.20			5.94
23	40G2	7.20	12.93	16.79	19.79	19.08	21.41	19.27	22.51	23.41	14.27
23	41G2	6.70	10.62	9.76	0.00	11.63					10.42
23	Total	6.01	12.58	16.56	19.74	18.96	21.37	19.25	22.51	23.41	13.68
24	37G2	10.68	12.68	15.23	16.26	17.42	17.48	17.59	19.47		14.91
24	37G3	10.79	12.27	14.18	14.53	16.67	15.99	16.55	18.20		12.97
24	37G4	11.32	13.19	15.22	16.11	17.13	16.57	16.87	18.99		15.19
24	38G2	4.65	12.66	14.60	15.42	17.05	16.42				7.90
24	38G3	10.41	12.05	13.76	13.94	16.66	15.98	16.54	18.20		12.48
24	38G4		14.06	16.54	18.13	19.56	20.61	20.26	20.92		18.91
24	39G2	3.20	12.55	14.78	15.69	17.03	16.52	17.02	18.20		11.28
24	39G3		13.68	16.01	16.89	17.48	17.34	18.02	19.23		16.64
24	39G4	11.32	13.69	15.74	17.04	17.91	17.72	18.51	19.27		16.84
24	Total	6.08	12.18	14.57	15.59	17.53	17.26	17.91	19.26		13.01
22-24	Total	3.03	11.81	14.40	15.75	17.44	17.45	17.94	19.69	23.41	10.00
21-24	Total	3.04	10.93	14.45	15.85	17.48	17.72	17.94	19.78	23.41	10.07

Table 12: FRV "Solea", cruise 783/2020. Total biomass (t) of sprat by age and area.

Sub-division	Rectangle/ Age group	0	1	2	3	4	5	6	7	8+	Total
21	41G0		260.3	8.8	5.4	1.1	1.3				276.9
21	41G1		813.7	203.4	160.7	34.6	20.6		1.5		1,234.5
21	41G2	2.7	410.2	29.2	30.3	5.3	1.9				479.6
21	42G1		734.2	225.0	202.6	45.0	37.2		2.8		1,246.7
21	42G2	4.4	1,968.6	36.6	27.3	3.7	0.9				2,041.5
21	43G1	5.6	1,224.7	33.9	44.6	10.7	8.5				1,327.9
21	43G2	0.2	43.4	1.4	1.6	0.3					46.8
21	Total	12.9	5,455.1	538.2	472.5	100.6	70.3	0.0	4.3	0.0	6,653.9
22	37G0	1.2	2.9	4.5	7.3	2.7	2.1				20.5
22	37G1	60.3	159.3	33.9	31.3	11.5	4.9				301.3
22	38G0	185.2	212.7	42.9	7.7	2.6					451.0
22	38G1	0.0	4.3	4.3	1.0	0.3					10.0
22	39F9	614.3	1.0								615.3
22	39G0	28.3	416.4	71.7	32.2	13.9	4.2				566.6
22	39G1	317.5	14.6								332.1
22	40F9	5.4	236.8	44.3	19.9	8.5	2.2				317.2
22	40G0	29.4	1,217.2	161.4	58.9	25.5	8.6				1,501.0
22	40G1	1.7	68.9	5.7	1.1	0.5	0.3				78.2
22	41G0	1.1	93.7	7.1	1.0	0.4	0.1				103.4
22	Total	1,244.4	2,427.7	375.8	160.3	65.9	22.5	0.0	0.0	0.0	4,296.6
23	39G2	4.0	3.4	1.3	1.4	0.5	0.4	0.1			11.0
23	40G2	22.2	919.7	194.8	141.8	90.2	47.7	8.6	15.9	4.6	1,445.5
23	41G2	4.4	134.8	3.5		0.8					143.5
23	Total	30.6	1,057.9	199.6	143.2	91.5	48.0	8.7	15.9	4.6	1,599.9
24	37G2	8.3	426.2	283.6	325.4	147.2	114.4	28.5	13.5		1,347.1
24	37G3	19.6	620.9	166.2	126.0	26.4	23.7	6.7	1.1		990.5
24	37G4	0.1	29.5	28.7	29.6	13.1	8.6	3.0	1.2		113.8
24	38G2	296.7	264.0	91.4	90.4	21.2	20.6				784.2
24	38G3	201.8	4,983.8	911.8	705.3	118.6	107.1	29.9	4.9		7,063.2
24	38G4		1.9	10.5	16.5	13.7	21.8	5.3	2.6		72.2
24	39G2	5.7	34.9	14.9	14.3	4.9	3.7	1.1	0.3		79.8
24	39G3		47.5	151.2	260.9	128.9	90.9	16.7	10.5		706.5
24	39G4	0.4	136.6	394.2	665.9	398.2	249.5	93.4	58.6		1,996.8
24	Total	532.5	6,545.2	2,052.3	2,234.2	872.1	640.3	184.6	92.8	0.0	13,154.0
22-24	Total	1,807.5	10,030.8	2,627.7	2,537.7	1,029.4	710.8	193.3	108.7	4.6	19,050.5
21-24	Total	1,820.4	15,485.9	3,165.9	3,010.2	1,130.0	781.1	193.3	113.0	4.6	25,704.4

Table 13: FRV "Solea", cruise 783/2020. Numbers (m) of herring excl. CBH in SD 21, SD 23/39G2and SD-24 by age/W-rings & area.

Sub-division	Rectangle/ W-rings	0	1	2	3	4	5	6	7	8+	Total	
21	41G0	1.19	0.06	0.002							1.24	
21	41G1	79.60	8.88	0.59	0.05						89.13	
21	41G2	61.95	1.10	0.08							63.13	
21	42G1	119.02	6.55								125.57	excl. CBH
21	42G2	52.31	7.62	0.42							60.35	
21	43G1	344.13	36.36	1.73	0.18	0.54					382.95	
21	43G2	9.81	0.03								9.84	
21	Total	668.02	60.60	2.83	0.23	0.54	0.00	0.00	0.00	0.00	732.22	
22	37G0	1.15	0.03								1.18	
22	37G1	12.94	0.18								13.12	
22	38G0	21.41	0.48								21.89	
22	38G1	0.78									0.78	
22	39F9	8.01									8.01	
22	39G0	15.32	3.06	0.98	0.76		0.10	0.10			20.32	
22	39G1	5.77	0.39	2.46	1.23		0.21	0.21			10.27	
22	40F9	6.74	0.29	0.08	0.02	0.01					7.14	
22	40G0	90.90	25.93	21.38	5.59	2.57	0.84	0.32	0.07		147.60	
22	40G1	3.01	0.31	0.01							3.33	
22	41G0	11.47	1.05	0.03	0.03						12.58	
22	Total	177.50	31.72	24.94	7.63	2.58	1.15	0.63	0.07	0.00	246.22	
23	39G2	11.70	6.54	1.79	1.50	0.39	0.13	0.06	0.01	0.01	22.13	
23	40G2	12.58	9.29	7.5	5.21	3.46	3.12	1.25	0.94	0.3	43.65	
23	41G2	0.95	0.44	0.03							1.42	
23	Total	25.23	16.27	9.32	6.71	3.85	3.25	1.31	0.95	0.31	67.20	
24	37G2	4.63									4.63	
24	37G3	26.61	8.32	2.52	1.50	0.34	0.18	0.04	0.01	0.01	39.53	
24	37G4	7.43	21.70	7.53	5.23	1.08	0.50	0.34	0.06	0.01	43.88	
24	38G2	161.42	2.24	0.04							163.70	
24	38G3	91.04	21.51	4.57	2.81	0.48	0.25	0.06	0.02	0.01	120.75	excl. CBH
24	38G4	2.61	42.60	24.61	28.46	7.22	3.95	1.59	0.47	0.19	111.70	
24	39G2	97.00	9.84	2.05	1.68	0.44	0.18	0.11	0.01	0.01	111.32	
24	39G3	113.20	22.05	9.10	6.28	1.47	1.10	0.64	0.22	0.05	154.11	
24	39G4	42.04	15.37	6.51	12.43	5.56	6.01	3.25	1.47	0.80	93.44	
24	Total	545.98	143.63	56.93	58.39	16.59	12.17	6.03	2.26	1.08	843.06	
22-24	Total	748.71	191.62	91.19	72.73	23.02	16.57	7.97	3.28	1.39	1,156.48	
21-24	Total	1,416.73	252.22	94.02	72.96	23.56	16.57	7.97	3.28	1.39	1,888.70	

Table 14: FRV "Solea", cruise 783/2020. Mean weight (g) of herring excl. CBH in SD 21, SD 23/39G2 and SD 24 by age/W-rings & area.

Sub-division	Rectangle/ W-rings	0	1	2	3	4	5	6	7	8+	Total	
21	41G0	12.89	42.03	52.89							14.29	
21	41G1	14.72	44.73	57.19	56.63						18.02	
21	41G2	13.06	39.94	75.12							13.61	
21	42G1	15.75	33.38								16.67	excl. CBH
21	42G2	13.82	44.54	55.17							17.99	
21	43G1	12.55	41.17	63.66	56.63	113.00					15.67	
21	43G2	13.08	47.00								13.19	
21	Total	13.54	41.25	61.38	56.63	113.00					16.10	
22	37G0	10.39	12.88								10.45	
22	37G1	8.74	13.44								8.80	
22	38G0	8.94	14.97								9.07	
22	38G1	15.19									15.19	
22	39F9	5.30									5.30	
22	39G0	9.82	42.30	90.82	97.19		119.05	119.05			22.96	
22	39G1	10.04	12.97	95.67	107.36		119.05	119.05			46.78	
22	40F9	9.77	25.62	72.22	47.73	49.89					11.28	
22	40G0	11.33	48.34	79.33	98.01	107.53	135.62	151.35	175.67		33.73	
22	40G1	12.91	23.10	48.83							13.97	
22	41G0	13.50	17.15	91.70	91.70						14.18	
22	Total	10.53	45.10	81.37	99.28	107.31	131.15	135.46	175.67		26.85	
23	39G2	13.98	38.85	53.10	71.09	79.94	103.30	101.41	101.57	101.57	30.37	
23	40G2	14.88	40.19	70.16	128.96	135.39	148.23	170.47	185.07	213.55	71.95	
23	41G2	11.56	34.40	34.40							19.12	
23	Total	14.34	39.49	66.77	116.02	129.77	146.43	167.31	184.19	209.94	57.14	
24	37G2	7.80									7.80	
24	37G3	9.78	39.92	51.87	67.05	91.73	102.92	120.10	105.25	101.57	22.27	
24	37G4	11.38	40.06	52.65	66.08	84.55	109.17	155.76	177.54	101.57	43.45	
24	38G2	8.89	37.78	44.67							9.29	
24	38G3	9.15	39.41	51.71	64.90	91.73	102.92	120.10	105.25	101.57	18.05	excl. CBH
24	38G4	15.84	41.12	57.14	70.44	80.27	95.97	122.69	126.33	101.57	57.62	
24	39G2	11.93	38.87	52.96	71.53	81.20	100.51	97.51	101.57	101.57	16.48	
24	39G3	13.95	39.88	52.14	70.83	103.45	129.49	155.63	155.00	148.17	24.74	
24	39G4	15.31	38.76	56.93	90.26	111.44	135.90	158.96	145.20	170.27	53.88	
24	Total	11.12	39.99	54.89	73.99	93.64	119.57	147.10	142.36	154.62	28.04	
22-24	Total	11.09	40.79	63.35	80.52	101.22	125.65	149.50	155.20	166.98	29.48	
21-24	Total	12.24	40.90	63.29	80.44	101.49	125.65	149.50	155.20	166.98	24.29	

Table 15: FRV "Solea", cruise 783/2020. Total biomass (t) of herring excl. CBH in SD 21, SD23/39G2 and SD 24 by age/W-rings & area.

Sub-division	Rectangle/ W-rings	0	1	2	3	4	5	6	7	8+	Total	
21	41G0	15.3	2.4	0.1							17.8	
21	41G1	1,172.0	397.4	34.0	2.6						1,606.0	
21	41G2	809.1	44.0	6.2							859.3	
21	42G1	1,874.5	218.7								2,093.1	
21	42G2	723.0	339.4	23.0							1,085.4	
21	43G1	4,320.5	1,496.9	110.3	10.3	61.4					5,999.4	
21	43G2	128.3	1.5								129.8	
21	Total	9,042.7	2,500.2	173.6	12.9	61.4	0.0	0.0	0.0	0.0	11,790.8	
22	37G0	12.0	0.4								12.3	
22	37G1	113.1	2.4								115.5	
22	38G0	191.4	7.2								198.6	
22	38G1	11.9									11.9	
22	39F9	42.5									42.5	
22	39G0	150.4	129.4	89.0	73.9		11.9	11.9			466.6	
22	39G1	57.9	5.1	235.4	132.1		25.0	25.0			480.4	
22	40F9	65.9	7.4	5.8	1.0	0.5					80.5	
22	40G0	1,029.9	1,253.5	1,696.1	547.9	276.4	113.9	48.4	12.3		4,978.3	
22	40G1	38.9	7.2	0.5							46.5	
22	41G0	154.9	18.0	2.8	2.8						178.4	
22	Total	1,868.6	1,430.6	2,029.5	757.49	276.9	150.8	85.34	12.30	0.0	6,611.4	
23	39G2	163.6	254.1	95.1	106.6	31.2	13.4	6.1	1.02	1.0	672.1	
23	40G2	187.2	373.4	526.2	671.9	468.5	462.5	213.1	174.0	64.1	3,140.7	
23	41G2	11.0	15.1	1.0							27.2	
23	Total	361.7	642.6	622.3	778.5	499.6	475.9	219.2	175.0	65.1	3,839.9	
24	37G2	36.1									36.1	
24	37G3	260.3	332.1	130.7	100.6	31.2	18.5	4.8	1.1	1.0	880.3	
24	37G4	84.6	869.3	396.5	345.6	91.3	54.6	53.0	10.7	1.0	1,906.4	
24	38G2	1,435.0	84.6	1.8							1,521.4	
24	38G3	833.0	847.7	236.3	182.4	44.0	25.7	7.2	2.1	1.0	2,179.5	**excl. CBH**
24	38G4	41.3	1,751.7	1,406.2	2,004.7	579.6	379.1	195.1	59.4	19.3	6,436.4	
24	39G2	1,157.2	382.5	108.6	120.2	35.7	18.1	10.7	1.0	1.0	1,835.0	
24	39G3	1,579.1	879.4	474.5	444.8	152.1	142.4	99.6	34.1	7.4	3,813.4	
24	39G4	643.6	595.7	370.6	1,121.9	619.6	816.8	516.6	213.4	136.2	5,034.6	
24	Total	6,070.3	5,743.1	3,125.1	4,320.2	1,553.5	1,455.2	887.0	321.8	167.0	23,643.1	
22-24	Total	8,300.6	7,816.2	5,776.9	5,856.2	2,330.0	2,082.0	1,191.5	509.0	232.1	34,094.4	
21-24	Total	17,343.3	10,316.4	5,950.5	5,869.1	2,391.3	2,082.0	1,191.5	509.0	232.1	45,885.3	

Annex 8: 2020 ISAS Survey Summary Table and Survey Report

Document 8a: ISAS 2020 survey summary table

Survey Summary table WGIPS 2021	
Name of the survey (abbreviation):	**Irish Sea Acoustic Survey (ISAS)**
Target Species:	**Herring**
Survey dates:	**26th August – 09th September 2020**
Summary:	
The survey started on the peripheral Irish Sea transects to the west of the Solway Firth at 17:45 on the 26th August and continued to completion on 09th September. Sea conditions were variable during the survey; adverse weather between the 01st and 03rd Sept. resulted and in temporary cessations of the survey. Targets were identified by aimed midwater trawls, 34 successful tows were completed in 2020, which is consistant with fishing intensity for survey over time series. Trawling intensity provides good confidence in school recognition and supporting biological data for age stratified abundance estimation of target species (herring and sprat). Herring was fairly widely distributed within mixed schools at low abundance throughout the Irish Sea area, and within fewer localised high abundance schools. The bulk of 1+ herring targets in 2020 were observed west of the Isle of Man and off the Mull of Galloway on the Scottish coast. Cohorts, ages 0 -9 are visible within the survey. The major contribution of age to the total estimates in the 2020 survey is from age 2 accounting for 36% of total estimates by number.	

	Description
Survey design	The survey design of systematic, parallel transects covers approximately 620 nm. The position of the set of widely-spaced (8-10 nm) transects around the periphery of the Irish Sea is randomized within +/- 4 nm of a baseline position each year and transect spacing is reduced to 2 nm in strata around the Isle of Man to improve precision of estimates of adult herring biomass. Survey design and methodology adheres to the methods laid out in the WGIPS acoustic survey manual.

Index Calculation method	Weighted mean TS is applied to the NASC value to give numbers per square nautical mile – further decomposed by age class according to length frequencies in relevant target identified trawls and survey age-length key.
Random/systematic error issues	NA
Specific survey error issues (acoustic)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Bubble sweep down	Sea conditions were variable during the survey; particularly poor weather between the 01st and 03rd resulted in a temporary cessation of the survey in order to eliminate potential sweep down.
Extinction (shadowing)	No perceived issues. Majority of target schools in mid to lower water column. For schools on or just above sea bed, negligible affects discerned.
Blind zone	Sub surface zone of 8 m applied. Majority of target schools in survey within mid to lower water column.
Dead zone	NA
Allocation of backscatter to species	Directed trawling, with 34 successful trawls completed during the course of this survey.
Target strength	Herring, sprat and horse mackerel: TS = 20log(L) -71.2 db Mackerel: TS = 20log(L) -84.9 db Gadoids: TS = 20log(L) -67.5 db
Calibration	The hull mounted Simrad EK60 acoustic system with 38 kHz split-beam was calibrated on the 26th August off Laxey on the east coast of the Isle of Man. Conditions were good and results within parameters.
Specific survey error issues (biological)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Stock containment	Time series: Complete coverage 2020 survey: Complete coverage
Stock ID and mixing issues	Time series: Winter hatched fish, of which the majority are thought to be of Celtic Sea origin, are present in the prespawning aggregations sampled in the Irish Sea during the acoustic survey. The presence of these winter hatched fish

	has implications for the estimates of 1-ringer+ biomass and SSB 2020 survey: No additional issues
Measures of uncertainty (CV)	CV of biomass and numbers at age
Biological sampling	2020 Survey: The biological sampling is deamed to be appropriate for the stock and area. Sampling is in line with historic levels. Biological samples are not available at the time of WGIPS to update biological data. Ages (age-length-key) and maturity data for 2019 are used for initial biomass estimates and population age structure.
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole times series or for individual years? (please specify)	*To be answered by Assessment Working Group*
Did the Survey Summary Table contain adequate information to allow for evaluation of the quality of the survey for use in assessment? Please identify shortfalls	*To be answered by Assessment Working Group*

Document 8b: ISAS 2020 survey report

Please see the report on the next page.

Survey report for RV Corystes

25th August – 11th September 2020

Gavin McNeill Agri-Food and Biosciences Institute (AFBI),

Belfast, Northern Ireland

1. INTRODUCTION

Acoustic surveys of the northern Irish Sea (ICES Area VIIaN) have been carried by the Agri-Food and Biosciences Institute (AFBI), formerly the Department of Agriculture and Rural Development for Northern Ireland (DARD), since 1991. This report covers the routine Irish Sea survey in the autumn.

2. SURVEY DESCRIPTION & METHODS

2.1 Personnel

Gavin McNeill (SIC)
Peter McCorriston
Ian McCausland
Ruth Kelly
Jessica Graham
Aaron Buick

2.2 Narrative

The vessel departed Belfast at 21:00 on the 25^4h^ August and proceeded to the east coast of the Isle of Man for acoustic calibration off Laxey on the 26th August. The survey started on the peripheral Irish Sea transects to the west of the Solway Firth at 17:45 on the 26th August and continued to the completion of transect 109 off Liverpool Bay on the 28th August. From here, the ship made way to the northeast of the Isle of Man and awaited recommencement of the survey at the start of transect 1 on the 28th August at 14:00 and end on transect 81 to the northwest of the Mull of Galloway 31st August. After a brief overnight break, the survey continued along the western Irish Sea peripheral transects 01st Sept at 12:00. Working south along the Northern Ireland coast, additional survey transects in the vicinity of Rig Bank was conducted on 01st September. A mid cruise break took place on the 2nd Sept, corresponding with an anticipated period of inclement weather. The final set of transects for the first phase of the survey ended on transect 108 on 06th September and a further set of transects around the Isle of Man were completed with the survey concluding on 09th September. Sea conditions were variable during the survey; particularly poor weather between the 01st and 03re September resulted in a temporary cessation of the survey.

2.3 Survey design

The survey design of systematic, parallel transects covers approximately 620 nm (Figure 5B.1). The position of the set of widely-spaced (8-10 nm) transects around the periphery of the Irish Sea is randomized within +/- 4 nm of a baseline position each year. Transect spacing is reduced to 2 nm in strata around the Isle of Man to improve precision of estimates of adult herring biomass. Relatively lower effort is deployed around the periphery of the Irish Sea where the acoustic targets comprise mainly extended school groups of sprats and 0-group herring. Although this survey design yields high-precision estimates for these small clupeoids due to their extended distribution, the probability of encountering highly aggregated and patchy schools of larger herring remains low around the periphery of the Irish Sea compared with around the Isle of Man. Survey design and methodology adheres to the methods laid out in the WGIPS acoustic survey manual.

2.4 Calibration

The hull mounted Simrad EK60 acoustic system with 38 kHz split-beam was calibrated on the 25th August off Laxey on the east coast of the Isle of Man. Conditions were good and the calibration results satisfactory. All procedures were according to those defined in the survey manual. Summary of calibration results are presented in Table 5B.1.

2.5 Acoustic data collection

Acoustic data were only collected during 24hrs a day, except in coastal areas on the English and Irish coasts were data collection was restricted to daylight hours (0600-2100). Acoustic data at 38 kHz are collected in 15-minute elementary distance sampling units (EDSU's) with the vessel steaming at 10 knots. A Simrad EK-60 echosounder with hull-mounted split-beam transducer is employed, and data are logged and analysed using SonarData Echoview software. The system settings are given in Table 5B.1.

2.6 Biological data – fishing stations

Targets are identified where possible by aimed midwater trawling fitted with a sprat brailer. The net was fished with a vertical mouth opening of approximately 15m, which was observed using a Scanmar “Trawleye” netsounder. To facilitate determining the position of the net in the water column, a Scanmar depth sensor is also fitted to the headline.

Trawl catches are sorted to species level and then weighted. Depending on the number of fish, the sorted catch is normally sub-sampled for length measurements. Length frequencies are recorded in 0.5 cm length classes. Individual length-weight data are collected for all fish species contributing to the catches. Random samples of 50 herring (1+ gp) are taken from each catch for recording of biological parameters (length, weight, sex and maturity) and removal of otoliths for age determination.

2.7 Hydrographic data

Surface temperature and salinity were recorded using the through-flow thermosalinograph, and logged together with DGPS position at 1-minute intervals.

2.8 Data analysis

EDSUs were defined by 15 minute intervals which represented 2.5 nm per EDSU, assuming a survey speed of 10 knots. The surface-area backscattering (NASC) estimates are calculated for schools, school groups and scattering layers using a threshold of -60 dB. Targets in each 15-minute interval were allocated to species or species mixes by scrutinizing the echo charts together with acoustic records during trawling and maps of NASC values indicating location of trawls relative to school groups. In some cases, trawls with similar species and size composition are combined to give a more robust estimate of population length composition. Data were analysed using quarter rectangles of 15’ by 30’.

The single-species or mixed-species mean target strength (*TS*) is calculated from trawl data for each interval as 10 log $\{(\Sigma_{s,l}\, N_{s,l}.10^{0.1.TS_{s,l}}) \,/\, \Sigma_{s,l}\, N_{s,l}\}$ where $N_{s,l}$ is the number of fish of species *s* in length class *l*. The values recommended by ICES for the parameters *a* and *b* of the length -*TS* relationship $TS = a \log(l) + b$ are used: $a = 20$ (all species); $b = -71.2$ (herring, sprat, horse mackerel), -84.9 (mackerel) and -67.5 (gadoids). The weighted mean *TS* is applied to the NASC value to give numbers per square nautical mile. For herring, this is further decomposed into densities by age class according to the length frequencies in the relevant target-identification trawls and the survey age–length key. Mean weights-at-age, calculated from length-weight parameters for the survey, is used to calculate biomass of herring from the estimated numbers-at-age. The weighted mean fish density is estimated for each survey stratum (Figure 5B.1) using distance covered in each 15-minute EDSU as weighting factors, and raised by stratum surface area. Approximate standard errors are computed for the biomass estimates based on the variation between EDSUs within strata.

3. RESULTS

3.1 Biological data

Sampling intensity was relatively high during the 2020 survey with 34 successful trawls completed Figure 5B.2. Table 5B.2 gives the positions, catch composition and mean length by species for these trawl hauls. Thirty-one hauls contained herring to be used in the analysis. The length frequency distributions of these hauls are illustrated in Figure 5B.3. Length frequency distributions reflect the general juvenile/adult herring distributions within the sampling area. The resulting weight-length relationship for herring was calculated from the sampling information as $W = 0.003017 *L^{3.383}$ (length measured in cm). The preliminary age length key (Table 5B.3) used in the analysis indicate that the population is composed of juveniles and adults fish (age 0-9). Age-length key for herring (Table 5B.3) from which otoliths were removed at sea during the Irish Sea 2019 survey have been included in this report as otoliths from the 2020 survey are still to be analysed. Age-length data will be updated for the 2019 survey upon completion of their analysis.

3.2 Acoustic data

The distribution of the NASC values assigned to herring and to clupeoid mixes (juvenile herring and sprat) are presented in Figure 5B.4. The highest abundance of herring was to the west of the Isle of Man and off the Mull of Galloway on the Scottish coast.

3.3 Biomass estimates

The estimated biomass and number of herring and sprat by strata are given in Table 5B.4. The total number estimate comprises of ~16% age 0, 34% age 1, ~36% age 2, ~6% age 3, ~2% age 4 and 6% age 5+.

4. DISCUSSION

The herring stock estimate in the survey area (Irish Sea/North Channel) was estimated to be 101,253t The major contribution of ages to the total estimates is from age 1 and age 2 fish by number and weight. The herring were fairly widely distributed within mixed schools at low abundance, with a few distinct high abundance areas. The bulk of 1+ herring targets in 2020 were observed west of the Isle of Man and off the Mull of Galloway on the Scottish coast (western side of stratum 7 and southern end stratum 2 respectively; Figure 5B.1), with a fairly scattered lower abundance observed throughout the Irish Sea (Figure 5B.4). The length frequencies generated from these trawls highlight the spatial heterogeneous nature of herring age groups in the Irish Sea (Figure 5B.3). The estimate of herring SSB of 52,656t is within the observed range for the time series and the biomass estimate of 85,517t for 1+ ringers for 2020 also remains within the observed range since 2011. Biomass estimates for herring SSB and herring +1 ringers are higher than observed over the previous three years of the time series.

The survey estimates are influenced by the timing of the spawning migration. The highest proportion of the 1+ biomass estimates were to the west of the Isle of Man (strata 7), and northwest of the Isle of Man, south of the Mull of Galloway (strata 2) which is indicative of a later migration into the Irish Sea.

Sprat and 0-group herring were distributed around the periphery of the Irish Sea, with the most abundance of 0-group herring in the eastern side and in areas along the northern Irish coast to the west.

Results of a successive acoustic survey conducted later in September confirmed similar biomass estimates to the main acoustic survey and to those observed in the last few years. The survey results are within the rage of what has been observed historically.

TABLES AND FIGURES

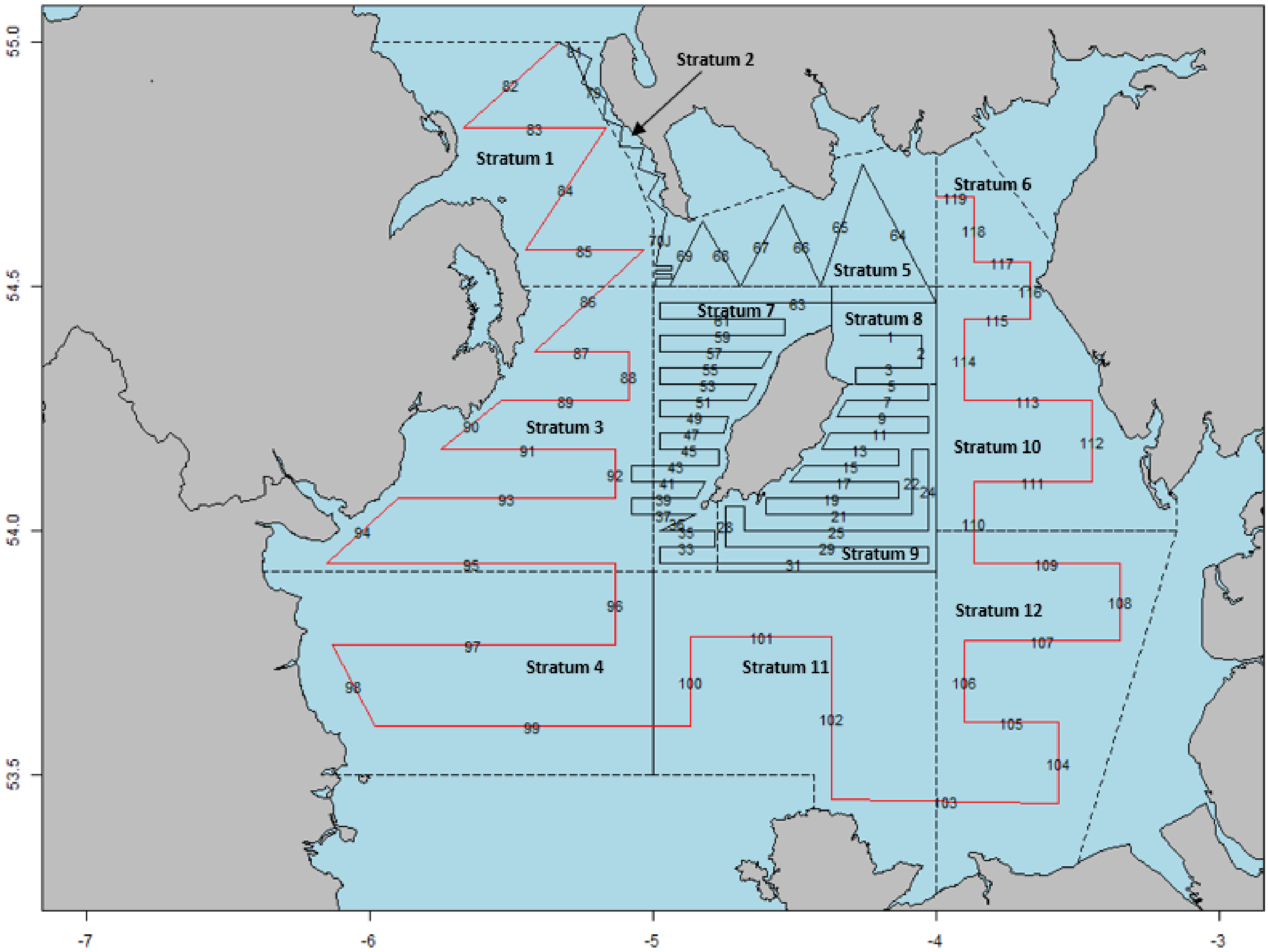


Figure 5B.1: Acoustic survey tracks for the 2020 Irish Sea acoustic survey. Survey design of systematic, parallel transects covers approximately 620 nm

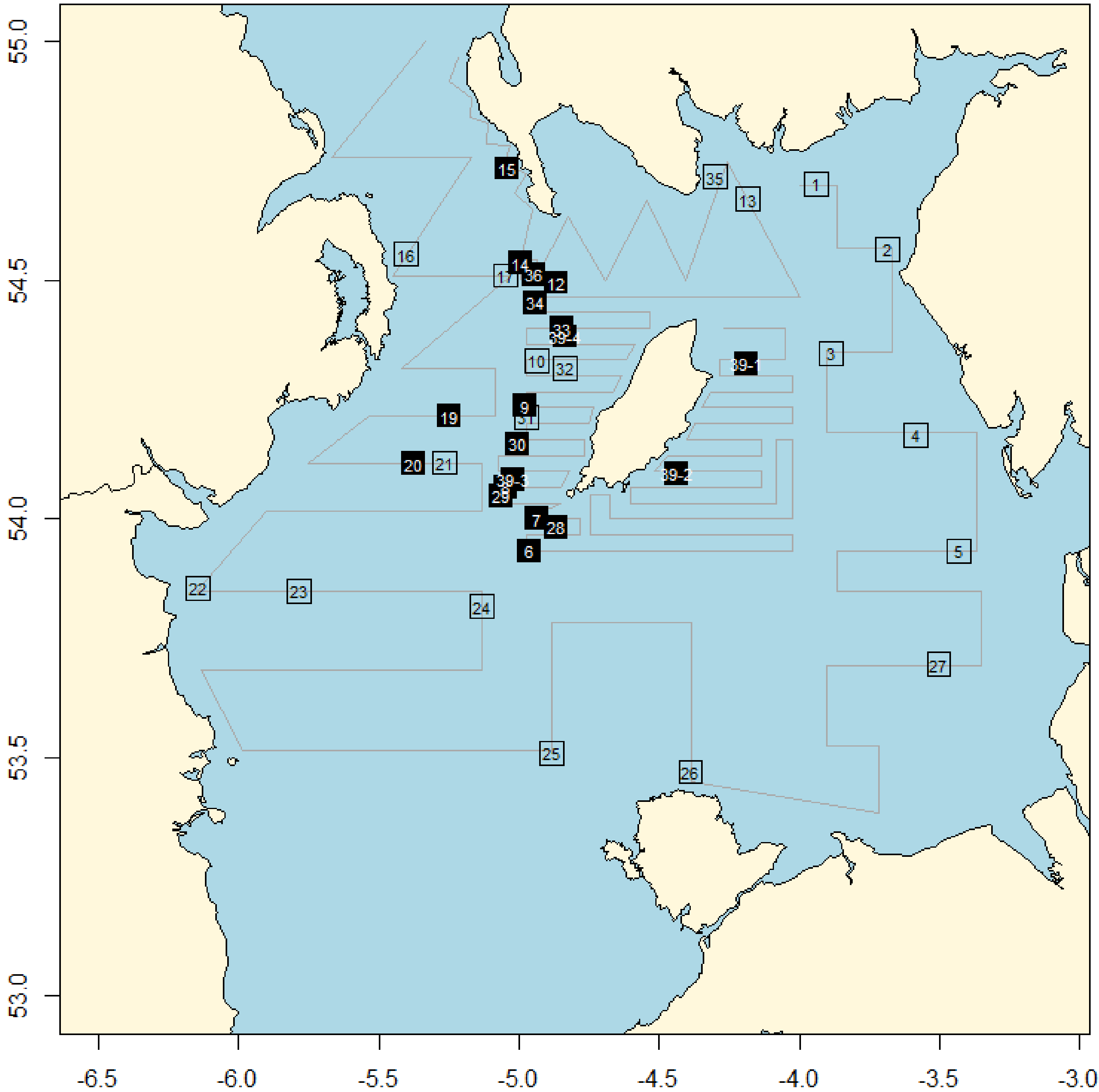
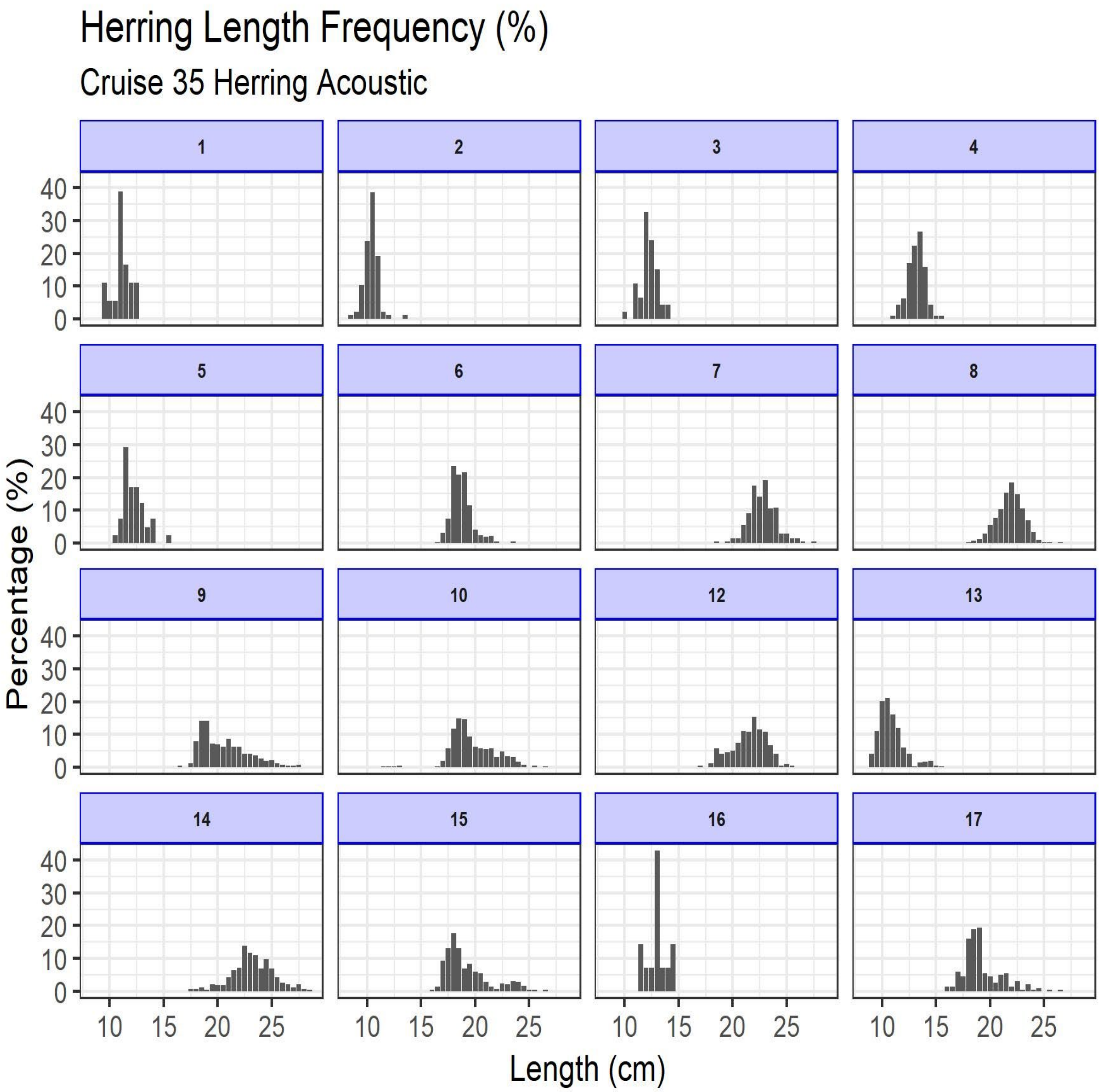


Figure 5B.2 Acoustic survey tracks with trawl positions of the 2020 Irish Sea and North Channel survey on RV "Corystes". Filled squares indicate trawls in which significant numbers of herring were caught or trawls with a high proportion of herring, while open squares indicate trawls with few or no herring.


Herring Length Frequency (%)
Cruise 35 Herring Acoustic
1
2
3
4
5
6
7
8
9
10
12
13
14
15
16
17
Percentage (%)
0
10
20
30
40
10
15
20
25
Length (cm)

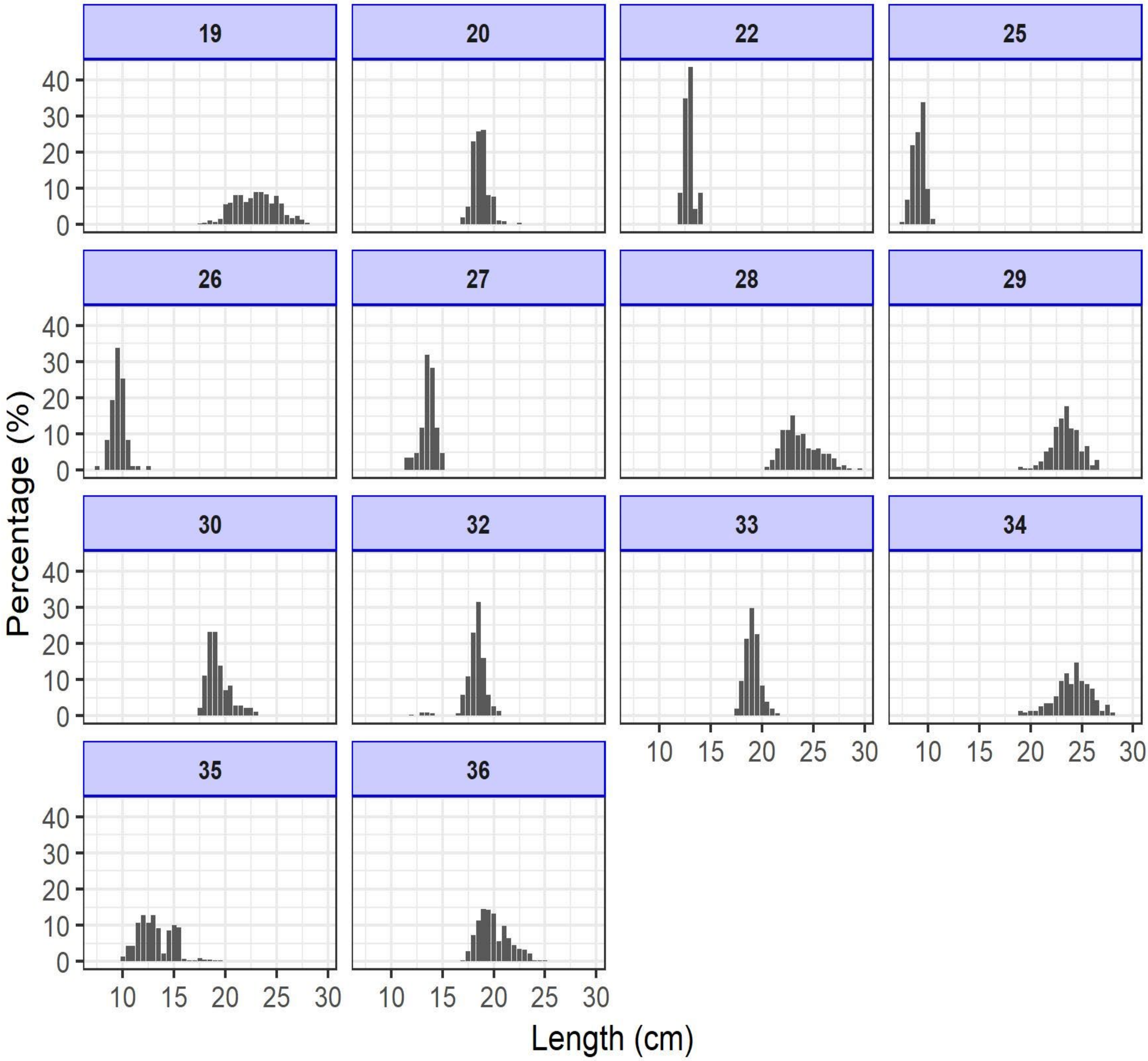


Figure 5B.3: Percentage length compositions of herring in each trawl sample in the 2020 Irish Sea and North Channel acoustic survey on RV "Corystes".

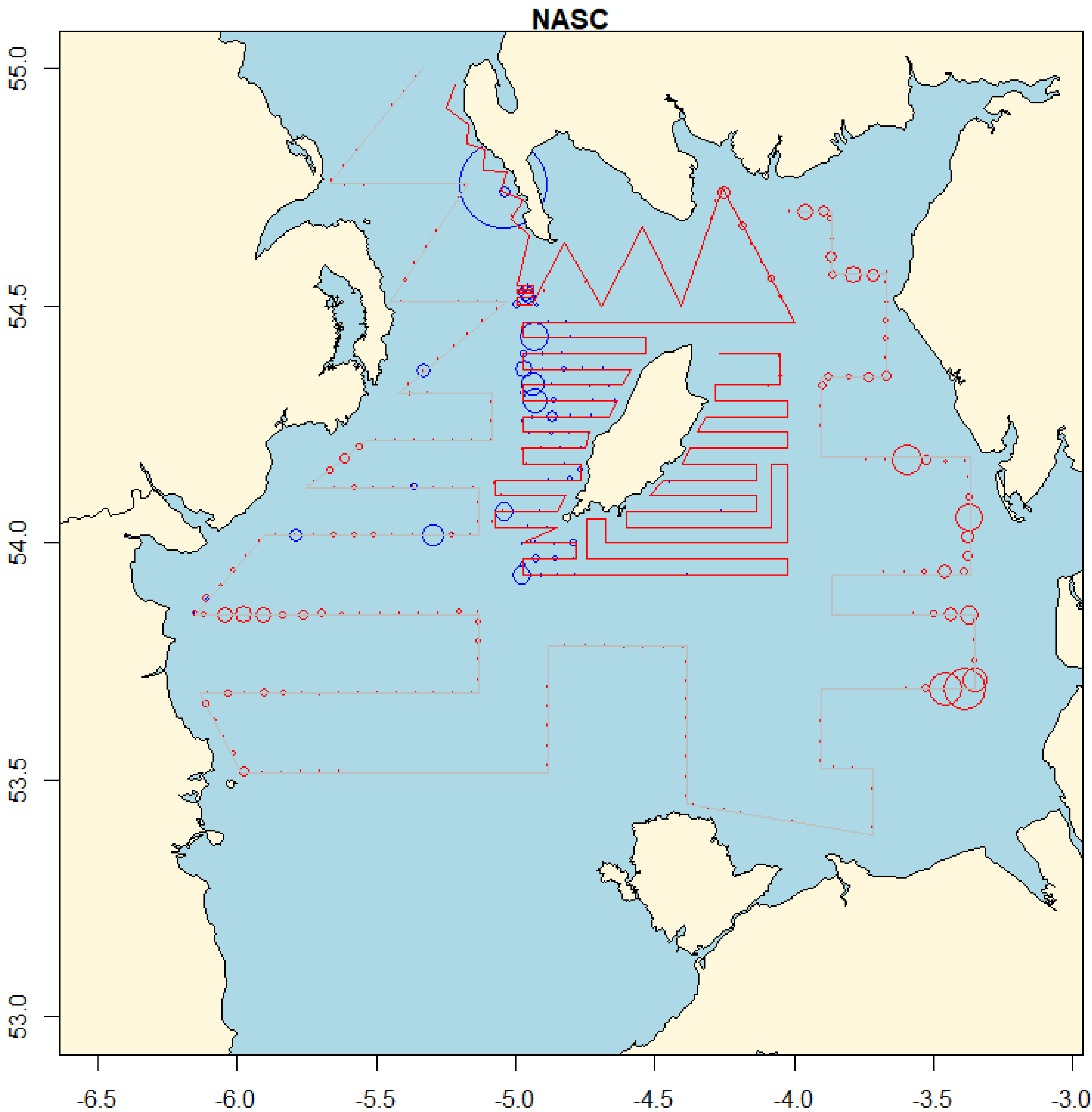


Figure 5B.4: Map of the Irish Sea and North Channel with a post plot showing the distribution of NASC values (size of elipses is proportional to square root of the NASC value per 15-minute interval) obtained during the 2020 acoustic survey on RV "Corystes". (a) Open blue circles are for herring NASC values (maximum value was 18895 and (b) open red circles are for clupeoid mix NASC, which include juvenile herring and sprat (maximum value was 2714).

Table 5B.1: Simrad EK60 and analysis settings used on the 2019 and 2020 Irish Sea and North Channel herring acoustic survey on RV "Corystes"

TRANSCEIVER MENU		
Year	2019	2020
Frequency	38 kHz	38 kHz
Sound speed	1511.8m.s^{-1}	1511.06m.s^{-1}
Max. Power	2000 W	2000 W
Default Transducer Sv gain	26.74 dB	26.65dB
Athw. Beam Angle Athw. Offset Angle Along. Beam Angle Along. Offset Angle	7.04 deg 0.00 deg 6.98 deg 0.12 deg	6.95 deg 0.00 deg 6.90 deg 0.00 deg
Calibration details		
TS of sphere	-33.6 dB	-33.6 dB
Range to sphere in calibration	11.5m	11.5 m
Log Menu		
Integration performed in Echoview post-processing based on 15 minute EDSUs		
Operation Menu		
Ping interval	0.7 s	0.7 s
Analysis settings		
Bottom margin (backstep)	0.5 m	0.5 m
Integration start (absolute) depth	8 m	8 m
Sv gain threshold	-60 dB	-60 dB

Table 5B.2: Catch composition and position of hauls undertaken by the RV *Corystes* during the Irish Sea/North Channel survey, August/September 2020.

Tow	Date	Shooting Details						Total Catch									
		Time	Lat.		Long.		Depth	Kg.	sprat	herring	mackerel	scad	anchovy	whiting	other	sprat	herring
1	26/08/2020	19:58	54	42.1495	3	56.2709	27	190	98.3	0.7	1.0	0.0	0.0	0.0	0.0	8.5	11.1
2	27/08/2020	08:07	54	33.96	3	41.118	20	165	55.3	1.3	0.7	0.0	0.0	0.0	42.8	8.4	10.8
3	27/08/2020	11:20	54	20.8542	3	53.1858	38	222	85.6	13.5	0.8	0.0	0.0	0.0	0.0	9.0	13.1
4	27/08/2020	14:42	54	10.593	3	35.183	25	120	58.7	37.9	1.3	0.0	1.4	0.0	0.7	10.0	14.2
5	27/08/2020	18:41	53	56.0153	3	25.8006	21	102	86.0	5.1	2.6	0.0	0.4	0.0	5.8	9.3	12.9
6	29/08/2020	19:06	53	56.033	4	57.784	72	180	0.0	100.0	0.0	0.0	0.0	0.0	0.0		19.9
7	29/08/2020	21:45	54	0.046	4	56.035	43	65	0.0	100.0	0.0	0.0	0.0	0.0	0.0		23.4
8	29/08/2020	23:26	54	4.076	5	2.769	56	1100	0.0	95.8	4.2	0.0	0.0	0.0	0.0		22.5
9	30/08/2020	08:00	54	14.2086	4	58.6602	83	160	0.0	100.0	0.0	0.0	0.0	0.0	0.0		22.5
10	30/08/2020	12:18	54	19.896	4	56.145	90	678	1.6	98.4	0.0	0.0	0.0	0.0	0.0	10.7	20.6
12	30/08/2020	20:39	54	29.6847	4	52.0008	63	271	0.0	93.6	0.8	0.0	0.0	0.2	5.5		22.0
13	31/08/2020	08:16	54	40.2326	4	10.966	37	162	71.7	26.2	2.0	0.0	0.0	0.0	0.0	10.9	14.4
14	31/08/2020	17:24	54	32.1515	4	59.5344	136	634	0.0	62.9	0.6	0.1	0.0	0.1	36.3		23.7
15	31/08/2020	20:20	54	44.076	5	2.548	54	141	0.0	86.0	14.0	0.0	0.0	0.0	0.0		20.9
16	01/09/2020	12:36	54	33.336	5	24.148	53	177	95.5	1.2	3.4	0.0	0.0	0.0	0.0	11.8	13.1
17	01/09/2020	14:53	54	30.636	5	2.749	121	232	0.3	5.0	4.9	3.0	0.0	85.5	1.2		20.6
19	03/09/2020	08:54	54	12.9622	5	14.8392	81	554	0.0	100.0	0.0	0.0	0.0	0.0	0.0		24.1
20	03/09/2020	12:22	54	6.974	5	22.443	58	305	0.0	100.0	0.0	0.0	0.0	0.0	0.0		19.5
21	03/09/2020	13:57	54	7.097	5	15.744	103	205	100.0	0.0	0.0	0.0	0.0	0.0	0.0	8.6	
22	03/09/2020	19:51	53	51.3358	6	8.696	21	162	96.4	1.8	0.8	0.0	0.0	1.0	0.0	8.9	13.3
23	04/09/2020	08:24	53	50.985	5	47.104	52	113	98.9	0.0	1.1	0.0	0.0	0.0	0.0	9.6	
24	04/09/2020	11:36	53	49.026	5	7.906	69	202	100.0	0.0	0.0	0.0	0.0	0.0	0.0	8.8	
25	05/09/2020	07:20	53	30.544	4	53.07	76	73	92.0	5.4	3.1	0.0	0.0	0.0	0.0	6.9	9.5
26	05/09/2020	12:59	53	28.195	4	23.237	41	47	79.6	20.3	0.0	0.0	0.0	0.0	0.0	7.8	10.2
27	06/09/2020	07:40	53	41.7302	3	30.1502	31	91	87.6	6.3	5.4	0.0	0.4	0.0	0.0	10.1	13.4
28	07/09/2020	21:03	53	58.9936	4	51.9087	58	107	0.0	96.7	3.3	0.0	0.0	0.0	0.0		25.5
29	08/09/2020	01:11	54	2.942	5	3.651	60	817	0.0	97.7	0.1	0.0	0.0	0.4	1.7		23.6
30	08/09/2020	05:00	54	9.48	5	0.16	84	478	0.0	92.1	0.1	0.0	0.0	3.8	4.2		20.1
31	08/09/2020	07:58	54	12.8377	4	58.4989	84	28	98.4	0.0	0.0	0.0	0.0	0.0	0.0	9.2	
32	08/09/2020	14:17	54	19.024	4	50.094	43	241	1.9	98.1	0.0	0.0	0.0	0.0	0.0	12.0	17.9
33	08/09/2020	18:26	54	23.927	4	50.691	40	246	0.0	100.0	0.0	0.0	0.0	0.0	0.0		19.8
34	08/09/2020	22:19	54	27.1814	4	56.4877	60	550	0.0	98.0	0.0	0.0	0.0	0.0	2.0		24.2
35	09/09/2020	06:03	54	43.008	4	17.971	25	153	13.2	86.6	0.0	0.0	0.0	0.0	0.0	10.7	16.6
36	09/09/2020	14:26	54	30.771	4	56.713	80	2100	0.0	100.0	0.0	0.0	0.0	0.0	0.0		22.0

Table 5B.3: Preliminary age-length key for herring from which otoliths were removed at sea during the Irish Sea/North Channel survey 2019. Data are numbers of fish at age in each length class in samples collected from each trawl.

AGE CLASS
(RINGS, OR AGES ASSUMING 1 JANUARY BIRTHDATE)

LENGTH (CM)	0	1	2	3	4	5	6	7	8+	TOTAL
7.5	1	0	0	0	0	0	0	0	0	1
8	1	0	0	0	0	0	0	0	0	1
8.5	1	0	0	0	0	0	0	0	0	1
9	5	0	0	0	0	0	0	0	0	5
9.5	6	0	0	0	0	0	0	0	0	6
10	7	0	0	0	0	0	0	0	0	7
10.5	8	0	0	0	0	0	0	0	0	8
11	9	0	0	0	0	0	0	0	0	9
11.5	8	0	0	0	0	0	0	0	0	8
12	6	0	0	0	0	0	0	0	0	6
12.5	6	0	0	0	0	0	0	0	0	6
13	5	0	0	0	0	0	0	0	0	5
13.5	3	0	0	0	0	0	0	0	0	3
14	3	0	0	0	0	0	0	0	0	3
14.5	4	0	0	0	0	0	0	0	0	4
15	2	0	0	0	0	0	0	0	0	2
15.5	3	0	0	0	0	0	0	0	0	7
16	1	4	0	0	0	0	0	0	0	10
16.5	2	9	0	0	0	0	0	0	0	16
17	0	14	0	0	0	0	0	0	0	34
17.5	0	34	0	0	0	0	0	0	0	31
18	0	31	0	0	0	0	0	0	0	39
18.5	0	39	0	0	0	0	0	0	0	37
19	0	37	0	0	0	0	0	0	0	29
19.5	0	29	0	0	0	0	0	0	0	30
20	0	25	5	0	0	0	0	0	0	29
20.5	0	20	9	0	0	0	0	0	0	33
21	0	21	12	0	0	0	0	0	0	27
21.5	0	10	17	0	0	0	0	0	0	34
22	0	11	23	0	0	0	0	0	0	24
22.5	0	0	24	0	0	0	0	0	0	27
23	0	0	26	1	0	0	0	0	0	31
23.5	0	0	30	0	1	0	0	0	0	24
24	0	0	19	4	1	0	0	0	0	21
24.5	0	0	14	6	0	1	0	0	0	25
25	0	0	12	8	2	3	0	0	0	20
25.5	0	0	2	9	4	4	1	0	0	25
26	0	0	1	11	4	9	0	0	0	20
26.5	0	0	0	2	7	7	4	0	0	18
27	0	0	0	1	3	10	4	2	1	14
27.5	0	0	0	0	2	7	2	2	1	12
28	0	0	1	0	0	6	2	1	0	6
28.5	0	0	0	0	0	3	2	0	1	3
29	0	0	0	0	1	0	1	0	1	1
TOTAL	81	284	195	42	25	50	16	5	4	702

Table 5B.4: Acoustic survey estimates of biomass (t) and numbers ('000) of herring and sprat by survey stratum from the AFBI acoustic surveys in 2020.

Stratum	No. sprat	Biomass sprat	No. Her	Biomass Her
1	159257	1867	114103	8193
2	0	0	180042	10386
3	1626977	17717	498284	35571
4	8998044	53847	70553	3664
5	186077	1352	229356	11247
6	975254	2207	9518	96
7	6308	24	249591	17691
8	61392	191	2446	37
9	0	0	20680	1181
10	11598524	35407	500744	7618
11	2050505	5279	69402	485
12	11353434	38310	337367	5085
Totals	**37015772**	**156200**	**2282088**	**101253**

Annex 9: 2020 ISSS Survey Summary Table and Survey Report

Document 9a: ISSS 2020 survey summary table

<table>
<tr><td colspan="2">Survey Summary table WGIPS 2021</td></tr>
<tr><td>Name of the survey (abbreviation):</td><td>Irish Sea Acoustic Spawning Survey (ISSS)</td></tr>
<tr><td>Target Species:</td><td>Herring</td></tr>
<tr><td>Survey dates:</td><td>05th October – 08th October 2020</td></tr>
<tr><td colspan="2">Summary:</td></tr>
<tr><td colspan="2">The Irish Sea Acoustic Spawning Survey (ISSS) 2020 was conducted on the RV Corystes. The survey started on the Isle of Man grid at the start of transect 1 on 05th October and continued through to the end of transect 82 on the 08th October 2020. Sea conditions were reasonably good during the survey; no weather induced down time was recorded. Targets were identified by aimed midwater trawls, 4 successful tows were completed in 2020, which is consistant with fishing intensity for survey over time series, providing confidence in school recognition and supporting biological data for age stratified abundance estimation of target species (herring).

High abundance schools of Herring were locally distributed. The bulk of 1+ herring targets in 2020 were observed east of the Isle of Man and also along the western coast of the Isle of Man

Cohorts, ages 0 -9 are visible within the survey. The major contribution of age to the total estimates in the 2020 survey is from age 1 accounting for 41% of total estimates by number. It is perceived that the pervelance of 1 and 2 year old emerging year classes (~41% age 1, 36% age 2) will continue to recruit to the SSB over the next 1-2 years.</td></tr>
<tr><td></td><td>Description</td></tr>
<tr><td>Survey design</td><td>The survey design of systematic, parallel transects covers approximately 620 nm. The position of the set of transect with spacing is reduced to 2 nm in strata around the Isle of Man. Survey design and methodology adheres to the repeats the methods laid out in the WGIPS acoustic survey manual.</td></tr>
</table>

Index Calculation method	Weighted mean TS is applied to the NASC value to give numbers per square nautical mile – further decomposed by age class according to length frequencies in relevant target identified trawls and survey age-length key.
Random/systematic error issues	NA
Specific survey error issues (acoustic)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Bubble sweep down	Sea conditions were reasonably good during the survey; no weather induced down time was recorded.
Extinction (shadowing)	No perceived issues. Majority of target schools in mid to lower water column. For schools on or just above sea bed, negligible affects discerned.
Blind zone	Sub surface zone of 8 m applied. Majority of target schools in survey within mid to lower water column.
Dead zone	NA
Allocation of backscatter to species	Four dediacetd trawls were conducted.
Target strength	Herring, sprat and horse mackerel: TS = 20log(L) -71.2 db Mackerel: TS = 20log(L) -84.9 db Gadoids: TS = 20log(L) -67.5 db
Calibration	The hull mounted Simrad EK60 acoustic system with 38 kHz split-beam was calibrated on the 10th September in Brodick bay off the Isle of Arran, in the Firth of Clyde, Scotland Conditions were good and the calibration results satisfactory. All procedures were according to those defined in the survey manual.
Specific survey error issues (biological)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Stock containment	Time series:The survey is focused on spawning aggregations with 75% coverage of main ISAS. 2020 survey: As in previous years, complete coverage.

Stock ID and mixing issues	Time series: Designed to generate an SSB index constituted from herring on or around the Irish Sea spawning ground to reduced stock mixing issues. 2020 survey: No additional issues
Measures of uncertainty (CV)	CV of biomass and numbers at age
Biological sampling	2020 Survey: The biological sampling uses biological sampling for the main Irish Sea acoutiscs survey and is deemed to be appropriate for the stock and area. The sampling levels are in line with historic levels. Biological samples are not available at the time of WGIPS to update biological data. Ages (age-length-key) and maturity data for 2019 are used for initial biomass estimates and population age structure.
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole times series or for individual years? (please specify)	*To be answered by Assessment Working Group*
Did the Survey Summary Table contain adequate information to allow for evaluation of the quality of the survey for use in assessment? Please identify shortfalls	*To be answered by Assessment Working Group*

Document 9b: ISSS 2020 survey report

Please see the report on the next page.

Survey report for RV Corystes

05th October – 08th October 2020

Gavin McNeill Agri-Food and Biosciences Institute (AFBI),

Belfast, Northern Ireland

1. INTRODUCTION

Acoustic surveys of the northern Irish Sea (ICES Area VIIaN) have been carried by the Agri-Food and Biosciences Institute (AFBI), formerly the Department of Agriculture and Rural Development for Northern Ireland (DARD), since 1991. This report covers the Irish Sea commercial survey conducted in the autumn.

2. SURVEY DESCRIPTION & METHODS

2.1 Personnel

Gavin McNeill (SIC)
Peter McCorriston
Ian McCausland

2.2 Narrative

The vessel departed Belfast at 1100 on the 05th October and proceeded to the east coast of the Isle of Man. The survey started on transect 1 to the northeast of The Isle of Man on the 05th October proceeding through to the end of transect 81 on the 08th October. Sea conditions were reasonably good during the survey enabling full completion of survey grid without disruption.

Survey design

The survey design of systematic, parallel transects covers approximately 640 nm (Figure 5B.1). Transect spacing is set to 2 nm in strata around the Isle of Man where adult herring were expected to be most abundant but also to have a very patchy distribution with relatively low probability of encounter. The survey design is based on information on herring distribution in autumn obtained from previous surveys, and from patterns in the commercial fishery showing a concentration of herring in Manx waters at this time. Survey design and methodology adheres to the methods laid out in the WGIPS acoustic survey manual.

2.4 Calibration

The hull mounted Simrad EK60 acoustic system with 38 kHz split-beam was calibrated on the 10th September in Brodick bay off the Isle of Arran, in the Firth of Clyde, Scotland. Conditions were good and the calibration results satisfactory. All procedures were according to those defined in the survey manual. Summary of calibration results are presented in Table 5B.1.

2.5 Acoustic data collection

Acoustic data was collected 24hrs a day at 38 kHz in 15-minute elementary distance sampling units (EDSU's) with the vessel steaming at 10 knots. A Simrad EK-60 echosounder with hull-mounted split-beam transducer is employed, and data is logged and analysed using SonarData Echoview software. The system settings are given in Table 5B.1.

2.6 Biological data – fishing stations

Targets are identified where possible by aimed midwater trawling fitted with a sprat brailer. The net was fished with a vertical mouth opening of approximately 15m, which was observed using a Scanmar “Trawleye” netsounder. To facilitate determining the position of the net in the water column, a Scanmar depth sensor is also fitted to the headline.

Trawl catches are sorted to species level and then weighted. Depending on the number of fish, the sorted catch is normally sub-sampled for length measurements. Length frequencies are recorded in 0.5 cm length classes. Individual length-weight data are collected for all fish species contributing to the catches. Random samples of 50 herring (1+ gp) are taken from each catch for recording of biological parameters (length, weight, sex and maturity) and removal of otoliths for age determination.

2.7 Data analysis

EDSUs were defined by 15 minute intervals which represented 2.5 nm per EDSU, assuming a survey speed of 10 knots. The surface-area backscattering (NASC) estimates are calculated for schools, school groups and scattering layers using a threshold of -60 dB. Targets in each 15-minute interval were allocated to species or species mixes by scrutinizing the echo charts together with acoustic records during trawling and maps of NASC values indicating location of trawls relative to school groups. In some cases, trawls with similar species and size composition are combined to give a more robust estimate of population length composition. Data were analysed using quarter rectangles of 15’ by 30’.

The single-species or mixed-species mean target strength (*TS*) is calculated from trawl data for each interval as 10 log $\{(\Sigma_{s,l}\, N_{s,l}.10^{0.1.TS_{s,l}}) / \Sigma_{s,l}\, N_{s,l}\}$ where $N_{s,l}$ is the number of fish of species *s* in length class *l*. The values recommended by ICES for the parameters *a* and *b* of the length -*TS* relationship $TS = a \log(l) + b$ are used: $a = 20$ (all species); $b = -71.2$ (herring, sprat, horse mackerel), -84.9 (mackerel) and -67.5 (gadoids). The weighted mean *TS* is applied to the NASC value to give numbers per square nautical mile. For herring, this is further decomposed into densities by age class according to the length frequencies in the relevant target-identification trawls and the survey age–length key. Mean weights-at-age, calculated from length-weight parameters for the survey, is used to calculate biomass of herring from the estimated numbers-at-age. The weighted mean fish density is estimated for each survey stratum (Figure 5B.1) using distance covered in each 15-minute EDSU as weighting factors, and raised by stratum surface area. Approximate standard errors are computed for the biomass estimates based on the variation between EDSUs within strata.

3. RESULTS

3.1 Biological data

Sampling intensity was relatively high during the main Irish Sea Acoustic Survey 2020 with 34 successful trawls completed, an additional 4 trawls were successfully completed during the 2020 Irish Sea Acoustic Spawning Survey Figure 5B.2. Table 5B.2 gives the positions, catch composition and mean length by species for the 34 trawl hauls for the main Irish Sea Acoustic Survey and Table 5B.3 shows positions, catch composition and mean length by species for the further 4 hauls completed during the commercial survey. The length frequency distributions of these hauls are illustrated in Figure 5B.3 for the main survey and Figure 5B.4 for the commercial survey. Length frequency distributions reflect the general juvenile/adult herring distributions within the sampling area. The preliminary age length key (Table 5B.4) used in the analysis indicate that the population is composed of juveniles and adults fish (age 0-9).

3.2 Acoustic data

The distribution of the NASC values assigned to herring and to clupeoid mixes (juvenile herring and sprat) and for herring only are presented in Figure 5B.5. The highest abundance of herring was to the east of the Isle of Man and also along the west coast of the Isle of Man

3.3 Biomass estimates

The estimated biomass and number of herring and sprat by strata are given in Table 5B.5. The total herring SSB estimate comprises is 55,418t

4. DISCUSSION

The herring stock estimate for the Irish Sea commercial survey area was estimated to be 89,553t. The major contribution of ages to the total estimates is from ages 1 fish by number and weight. The herring were distributed within a few distinct high abundance areas to the west and east of the Isle of Man. The bulk of 1+ herring targets in 2020 were observed to the south of stratum 8, southwest of stratum 9 and to the offshore ends of transects in stratum 7. Figure 5B.5, shows a further, fairly scattered, lower abundance observed throughout the remainder of the Irish Sea survey area. The length frequencies generated from these trawls highlight the spatial heterogeneous nature of herring age groups in the Irish Sea (Figure 5B.3 & 5B.4). The estimate of herring SSB of 55,418t and biomass estimate of 89,166t for 1+ ringers for 2020 commercial acoustic survey remain within range for the time series. The survey estimates are influenced by the timing of the spawning migration.

5 TABLES AND FIGURES

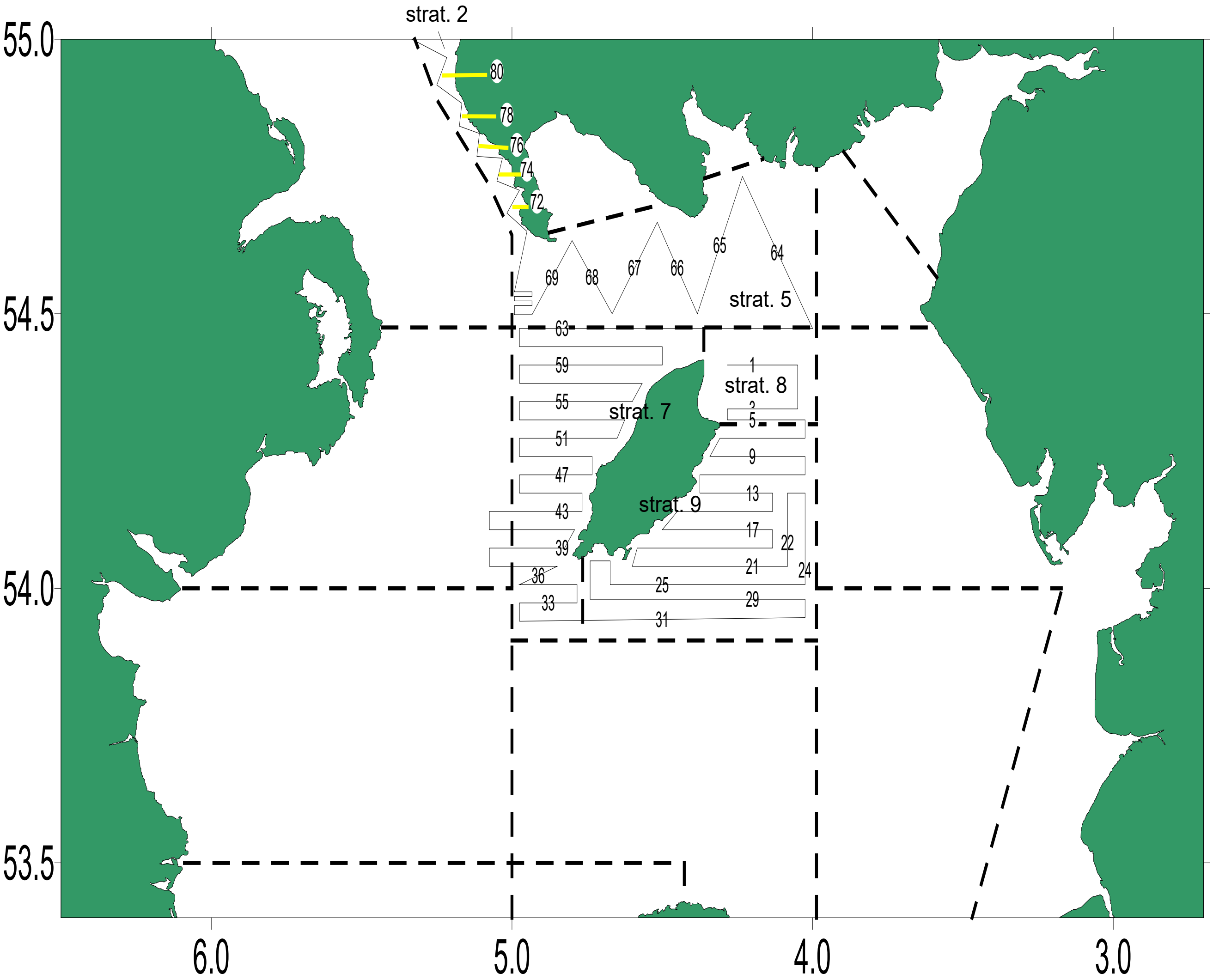


Figure 5B.1: Acoustic survey tracks for the 2020 Irish Sea acoustic survey. Survey design of systematic, parallel transects covers approximately 620nm.

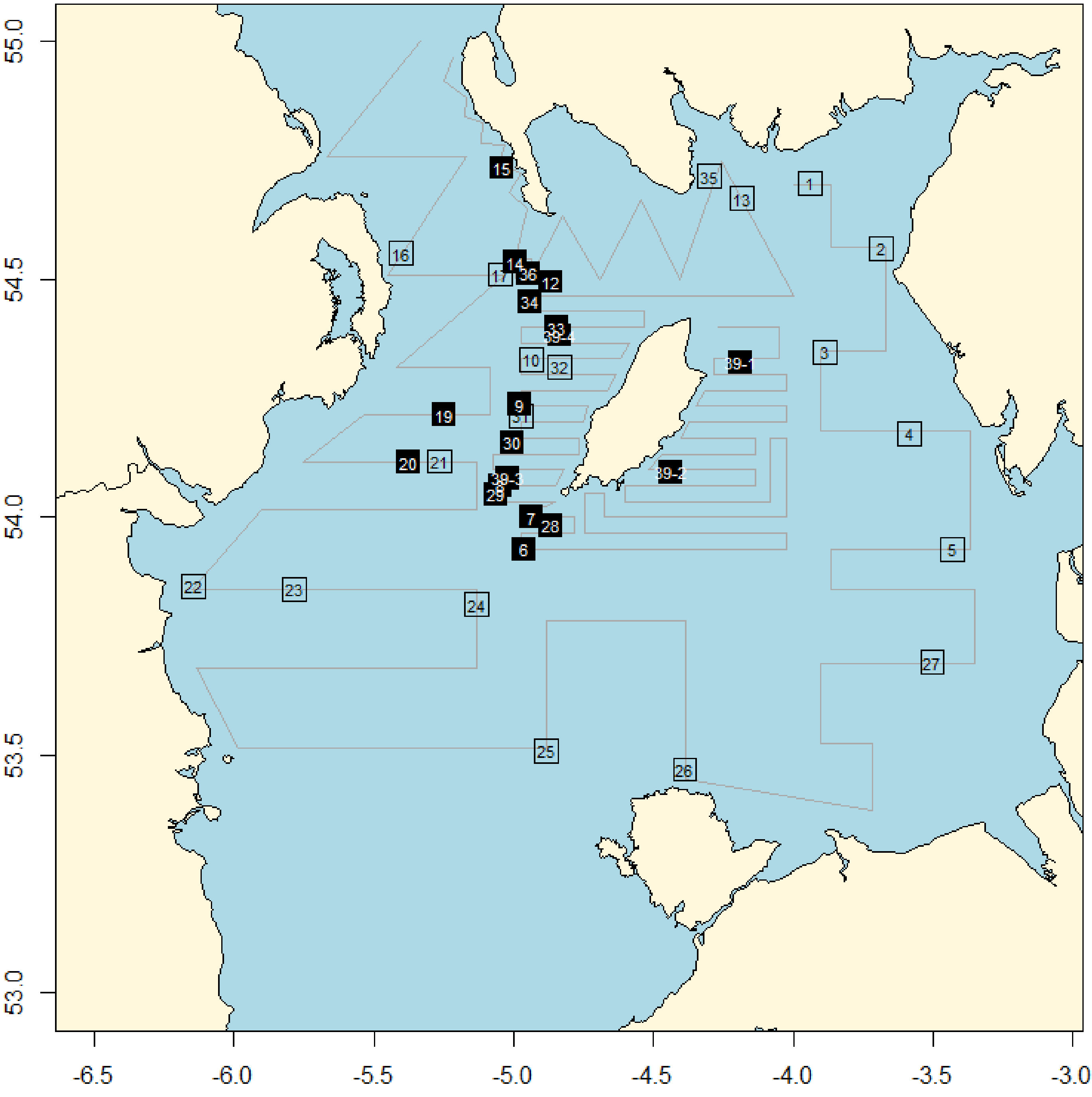
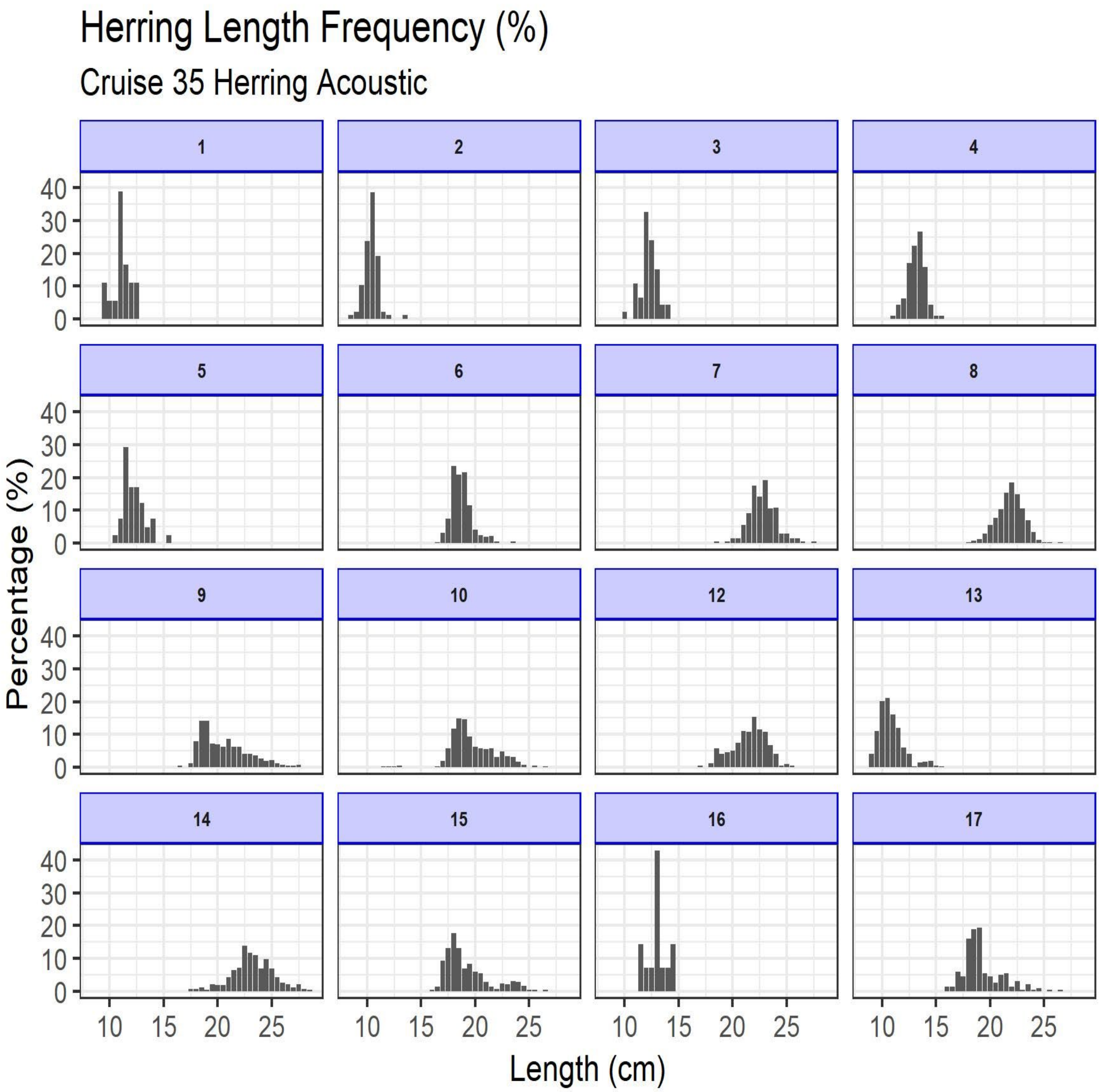


Figure 5B.2 Acoustic survey tracks with trawl positions of the 2020 Irish Sea and North Channel survey on RV "Corystes" and 2020 Irish Sea and North Channel commercial survey on RV "Corystes". Filled squares indicate trawls in which significant numbers of herring were caught or trawls with a high proportion of herring, while open squares indicate trawls with few or no herring.


Herring Length Frequency (%)
Cruise 35 Herring Acoustic
1
2
3
4
5
6
7
8
9
10
12
13
14
15
16
17
Percentage (%)
0
10
20
30
40
10
15
20
25
Length (cm)

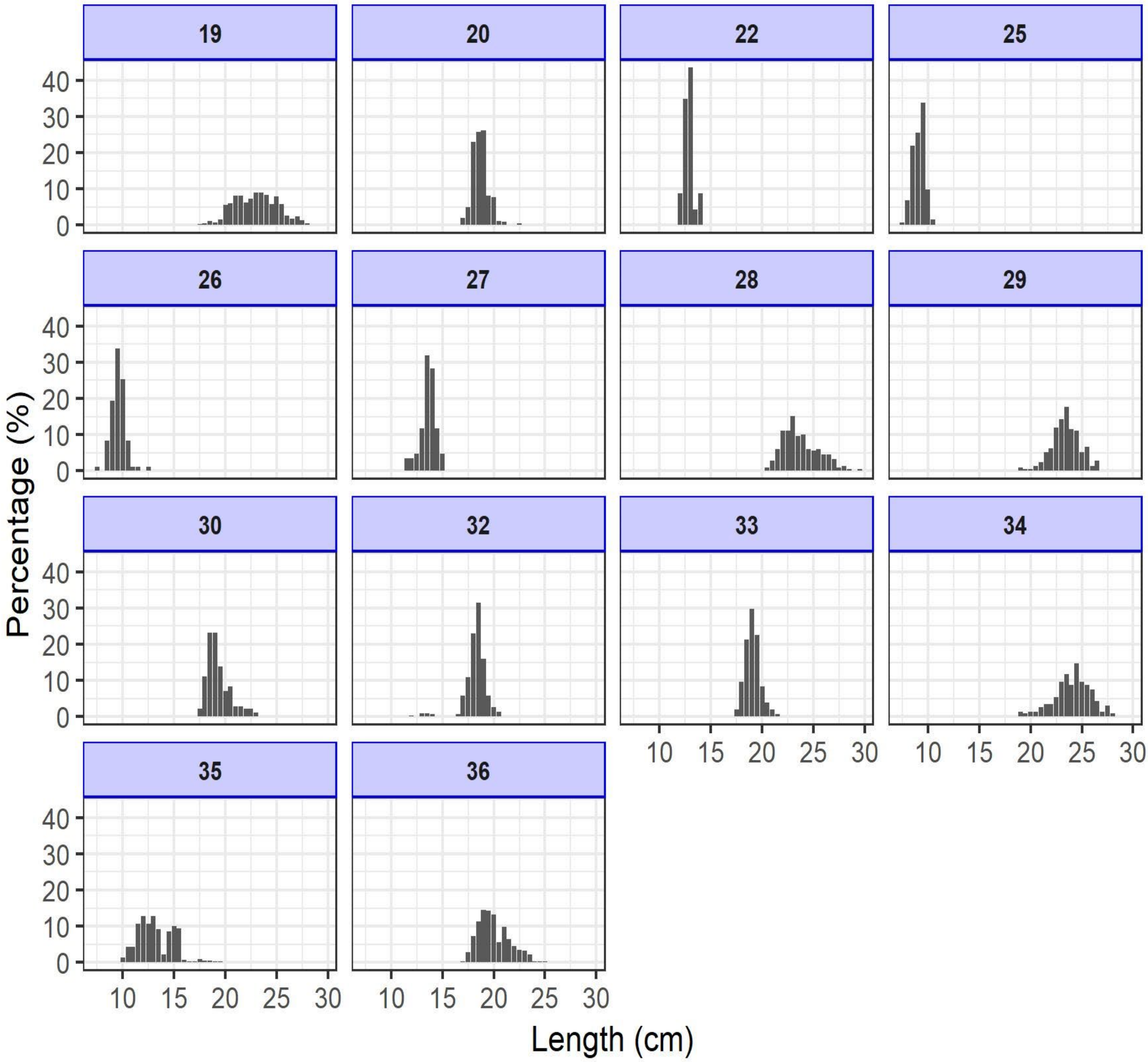


Figure 5B.3: Percentage length compositions of herring in each trawl sample in the August/September 2020 Irish Sea and North Channel acoustic survey on RV "Corystes".

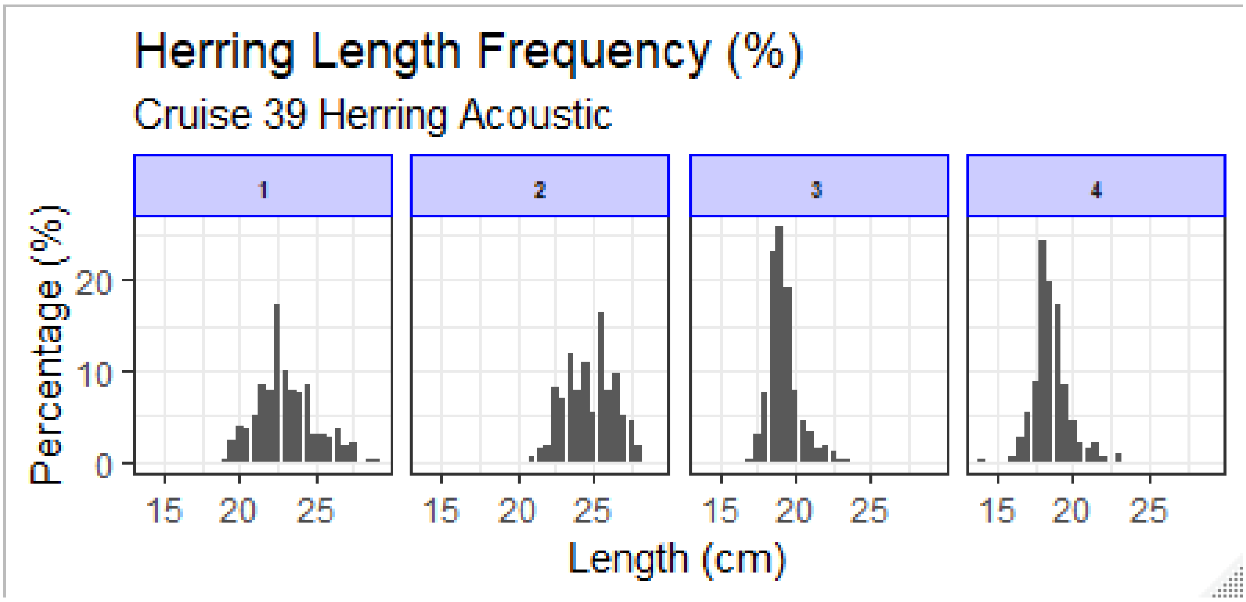


Figure 5B.4: Percentage length compositions of herring in each trawl sample in the 2020 Irish Sea and North Channel commercial acoustic survey on the RV "Corystes".

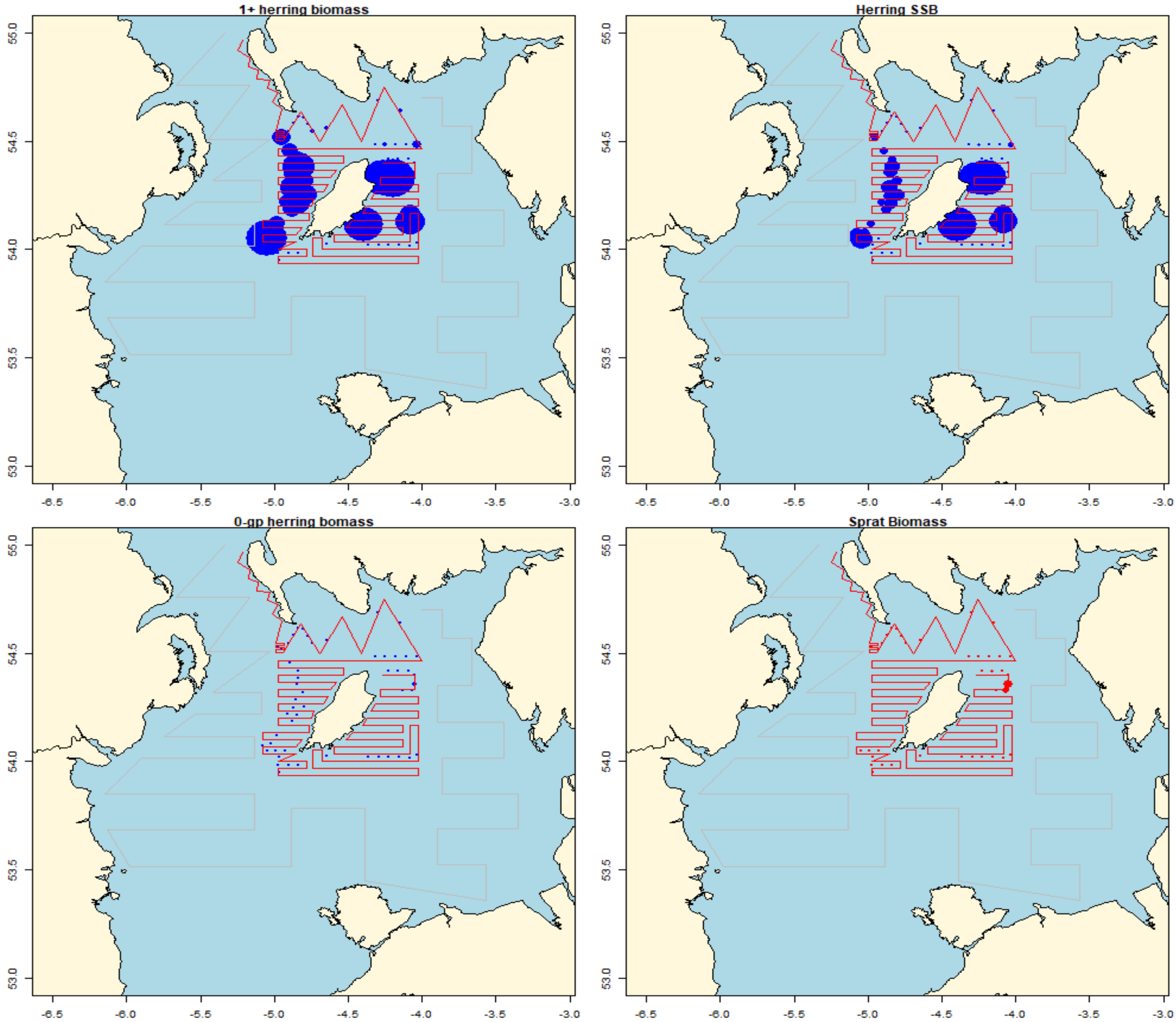


Figure 5B.5: Map of the Irish Sea and North Channel with a post plot showing the distribution of NASC values (size of elipses is proportional to square root of the NASC value per 15-minute interval) obtained during the 2020 commercial acoustic survey on RV "Corystes". (a) Solid blue circles are for herring NASC values and (b) solid red circles are for clupeoid mix NASC, which include juvenile herring and sprat.

Table 5B.1: Simrad EK60 and analysis settings used on the 2019 and 2020 Irish Sea and North Channel herring acoustic survey on FV "Havilah" (2019) and **RV "Corystes" (2020).**

TRANSCEIVER MENU		
Year	2019	2020
Frequency	38 kHz	38 kHz
Sound speed	1510.8m.s^{-1}	1511.06m.s^{-1}
Max. Power	2000 W	2000 W
Default Transducer Sv gain	26.96dB	26.65dB
Athw. Beam Angle Athw. Offset Angle Along. Beam Angle Along. Offset Angle	6.96 deg -0.01 deg 6.95 deg -0.01 deg	6.95 deg 0.00 deg 6.90 deg 0.00 deg
Calibration details		
TS of sphere	-33.6 dB	-33.6 dB
Range to sphere in calibration	11.5m	11.5m
Log Menu		
Integration performed in Echoview post-processing based on 15 minute EDSUs		
Operation Menu		
Ping interval	0.7 s	0.7 s
Analysis settings		
Bottom margin (backstep)	0.5 m	0.5 m
Integration start (absolute) depth	8 m	8 m
Sv gain threshold	-60 dB	-60 dB

Table 5B.2: Catch composition and position of hauls undertaken by the RV Corystes during the Irish Sea/North Channel survey, August/September 2020.

		Shooting Details						Total Catch									
Tow	Date	Time	Lat.		Long.		Depth	Kg.	sprat	herring	mackerel	scad	anchovy	whiting	other	sprat	herring
1	26/08/2020	19:58	54	42.1495	3	56.2709	27	190	98.3	0.7	1.0	0.0	0.0	0.0	0.0	8.5	11.1
2	27/08/2020	08:07	54	33.96	3	41.118	20	165	55.3	1.3	0.7	0.0	0.0	0.0	42.8	8.4	10.8
3	27/08/2020	11:20	54	20.8542	3	53.1858	38	222	85.6	13.5	0.8	0.0	0.0	0.0	0.0	9.0	13.1
4	27/08/2020	14:42	54	10.593	3	35.183	25	120	58.7	37.9	1.3	0.0	1.4	0.0	0.7	10.0	14.2
5	27/08/2020	18:41	53	56.0153	3	25.8006	21	102	86.0	5.1	2.6	0.0	0.4	0.0	5.8	9.3	12.9
6	29/08/2020	19:06	53	56.033	4	57.784	72	180	0.0	100.0	0.0	0.0	0.0	0.0	0.0		19.9
7	29/08/2020	21:45	54	0.046	4	56.035	43	65	0.0	100.0	0.0	0.0	0.0	0.0	0.0		23.4
8	29/08/2020	23:26	54	4.076	5	2.769	56	1100	0.0	95.8	4.2	0.0	0.0	0.0	0.0		22.5
9	30/08/2020	08:00	54	14.2086	4	58.6602	83	160	0.0	100.0	0.0	0.0	0.0	0.0	0.0		22.5
10	30/08/2020	12:18	54	19.896	4	56.145	90	678	1.6	98.4	0.0	0.0	0.0	0.0	0.0	10.7	20.6
12	30/08/2020	20:39	54	29.6847	4	52.0008	63	271	0.0	93.6	0.8	0.0	0.0	0.2	5.5		22.0
13	31/08/2020	08:16	54	40.2326	4	10.966	37	162	71.7	26.2	2.0	0.0	0.0	0.0	0.0	10.9	14.4
14	31/08/2020	17:24	54	32.1515	4	59.5344	136	634	0.0	62.9	0.6	0.1	0.0	0.1	36.3		23.7
15	31/08/2020	20:20	54	44.076	5	2.548	54	141	0.0	86.0	14.0	0.0	0.0	0.0	0.0		20.9
16	01/09/2020	12:36	54	33.336	5	24.148	53	177	95.5	1.2	3.4	0.0	0.0	0.0	0.0	11.8	13.1
17	01/09/2020	14:53	54	30.636	5	2.749	121	232	0.3	5.0	4.9	3.0	0.0	85.5	1.2		20.6
19	03/09/2020	08:54	54	12.9622	5	14.8392	81	554	0.0	100.0	0.0	0.0	0.0	0.0	0.0		24.1
20	03/09/2020	12:22	54	6.974	5	22.443	58	305	0.0	100.0	0.0	0.0	0.0	0.0	0.0		19.5
21	03/09/2020	13:57	54	7.097	5	15.744	103	205	100.0	0.0	0.0	0.0	0.0	0.0	0.0	8.6	
22	03/09/2020	19:51	53	51.3358	6	8.696	21	162	96.4	1.8	0.8	0.0	0.0	1.0	0.0	8.9	13.3
23	04/09/2020	08:24	53	50.985	5	47.104	52	113	98.9	0.0	1.1	0.0	0.0	0.0	0.0	9.6	
24	04/09/2020	11:36	53	49.026	5	7.906	69	202	100.0	0.0	0.0	0.0	0.0	0.0	0.0	8.8	
25	05/09/2020	07:20	53	30.544	4	53.07	76	73	92.0	5.4	3.1	0.0	0.0	0.0	0.0	6.9	9.5
26	05/09/2020	12:59	53	28.195	4	23.237	41	47	79.6	20.3	0.0	0.0	0.0	0.0	0.0	7.8	10.2
27	06/09/2020	07:40	53	41.7302	3	30.1502	31	91	87.6	6.3	5.4	0.0	0.4	0.0	0.0	10.1	13.4
28	07/09/2020	21:03	53	58.9936	4	51.9087	58	107	0.0	96.7	3.3	0.0	0.0	0.0	0.0		25.5
29	08/09/2020	01:11	54	2.942	5	3.651	60	817	0.0	97.7	0.1	0.0	0.0	0.4	1.7		23.6
30	08/09/2020	05:00	54	9.48	5	0.16	84	478	0.0	92.1	0.1	0.0	0.0	3.8	4.2		20.1
31	08/09/2020	07:58	54	12.8377	4	58.4989	84	28	98.4	0.0	0.0	0.0	0.0	0.0	0.0	9.2	
32	08/09/2020	14:17	54	19.024	4	50.094	43	241	1.9	98.1	0.0	0.0	0.0	0.0	0.0	12.0	17.9
33	08/09/2020	18:26	54	23.927	4	50.691	40	246	0.0	100.0	0.0	0.0	0.0	0.0	0.0		19.8
34	08/09/2020	22:19	54	27.1814	4	56.4877	60	550	0.0	98.0	0.0	0.0	0.0	0.0	2.0		24.2
35	09/09/2020	06:03	54	43.008	4	17.971	25	153	13.2	86.6	0.0	0.0	0.0	0.0	0.0	10.7	16.6
36	09/09/2020	14:26	54	30.771	4	56.713	80	2100	0.0	100.0	0.0	0.0	0.0	0.0	0.0		22.0

Table 5B.3: Catch composition and position of hauls undertaken by the RV "Corystes" during the Irish Sea/North Channel commercial survey, October 2020.

Tow	Date	Shooting details.						Total catch	Percentage composition of fish by weight.							Mean length (cm)	
		Time	Lat.		Long.		Depth	Kg.	sprat	herring	mackerel	scad	anchovy	whiting	other fish	herring	sprat
1	06/10/2020	01:55	54	19.58	4	11.3	24	36	0.0	100.0	0.0	0.0	0.0	0.0	0.0	24.0	0.0
2	06/10/2020	20:37	54	5.7603	4	26.378	30	525	0.0	100.0	0.0	0.0	0.0	0.0	0.0	24.5	0.0
3	07/10/2020	11:23	54	4.976	5	1.332	59	15	0.0	100.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0
4	08/10/2020	01:35	54	22.964	4	49.966	37	52	0.0	100.0	0.0	0.0	0.0	0.0	0.0	19.0	0.0

Table 5B.4: Preliminary age-length key for herring from which otoliths were removed at sea during the Irish Sea/North Channel survey 2019. Data are numbers of fish at age in each length class in samples collected from each trawl.

	Age class (rings, or ages assuming 1 January birthdate)									
Length (cm)	0	1	2	3	4	5	6	7	8+	Total
7.5	1	0	0	0	0	0	0	0	0	1
8	1	0	0	0	0	0	0	0	0	1
8.5	1	0	0	0	0	0	0	0	0	1
9	5	0	0	0	0	0	0	0	0	5
9.5	6	0	0	0	0	0	0	0	0	6
10	7	0	0	0	0	0	0	0	0	7
10.5	8	0	0	0	0	0	0	0	0	8
11	9	0	0	0	0	0	0	0	0	9
11.5	8	0	0	0	0	0	0	0	0	8
12	6	0	0	0	0	0	0	0	0	6
12.5	6	0	0	0	0	0	0	0	0	6
13	5	0	0	0	0	0	0	0	0	5
13.5	3	0	0	0	0	0	0	0	0	3
14	3	0	0	0	0	0	0	0	0	3
14.5	4	0	0	0	0	0	0	0	0	4
15	2	0	0	0	0	0	0	0	0	2
15.5	3	0	0	0	0	0	0	0	0	7
16	1	4	0	0	0	0	0	0	0	10
16.5	2	9	0	0	0	0	0	0	0	16
17	0	14	0	0	0	0	0	0	0	34
17.5	0	34	0	0	0	0	0	0	0	31
18	0	31	0	0	0	0	0	0	0	39
18.5	0	39	0	0	0	0	0	0	0	37
19	0	37	0	0	0	0	0	0	0	29
19.5	0	29	0	0	0	0	0	0	0	30
20	0	25	5	0	0	0	0	0	0	29
20.5	0	20	9	0	0	0	0	0	0	33
21	0	21	12	0	0	0	0	0	0	27
21.5	0	10	17	0	0	0	0	0	0	34
22	0	11	23	0	0	0	0	0	0	24
22.5	0	0	24	0	0	0	0	0	0	27
23	0	0	26	1	0	0	0	0	0	31
23.5	0	0	30	0	1	0	0	0	0	24
24	0	0	19	4	1	0	0	0	0	21
24.5	0	0	14	6	0	1	0	0	0	25
25	0	0	12	8	2	3	0	0	0	20
25.5	0	0	2	9	4	4	1	0	0	25
26	0	0	1	11	4	9	0	0	0	20
26.5	0	0	0	2	7	7	4	0	0	18
27	0	0	0	1	3	10	4	2	1	14
27.5	0	0	0	0	2	7	2	2	1	12
28	0	0	1	0	0	6	2	1	0	6
28.5	0	0	0	0	0	3	2	0	1	3
29	0	0	0	0	1	0	1	0	1	1
Total	81	284	195	42	25	50	16	5	4	702

Table 5B.5: Acoustic survey estimates of biomass (t) and numbers ('000) of herring and sprat by survey stratum from the AFBI commercial acoustic survey October 2020.

Stratum	No. sprat	Biomass sprat	No. Her	Biomass Her
5	11830.43	57.13	79896.41	4250.51
7	7653.81	36.36	660927.9	35016.59
8	509746.7	1585.69	386019.5	37892.23
9	6615.95	20.58	101131.7	12394.18
Total	535846.9	1699.76	1227975	89553.51

Annex 10: 2020 CSHAS Survey Summary Table

Survey Summary table WGIPS 2021	
Name of the survey (abbreviation):	Celtic Sea Herring Acoustic Survey (CSHAS) 2020
Target Species:	Herring (7aS, 7g-j) and sprat (7aS, 7g-j)
Survey dates:	04 October – 24 October, 2020
Summary: **Cruise Report Link:** http://hdl.handle.net/10793/1664	
The objectives of the survey were carried out successfully and as planned. Approximately 36 hrs of weather induced downtime was recorded. Planned area coverage was achieved, with additional replicate strata added and off-transect scouting around the Trench area. Geographical coverage was less than 2019 (-18%) as was acoustic sampling effort or survey miles (-32%). Due to the lack of herring observed offshore, survey effort was re-allocated to inshore using adaptive survey effort. This re-allocation and the time lost due to weather account for the effort reduction between years. Offshore hotspots were covered comprehensively, including the western Celtic Deep and Trench area. Mature fish were observed inshore during the survey and this area was the focus of the adaptive survey effort. The age profile of herring taken from the survey catches, albeit in small numbers, were representative of the dominant 2-wr age class. Three winter ring fish are also represented (10.7% of TSB and 6.9% of TSN) and along with the 2-wr fish form the base of the spawning stock. The presence of immature 1-wr ring fish ranked second (27.7% and 41.2% respectively) and likely contains a propor-tion of resident inshore 'harbour fish'. However, as the stock biomass remains low the contribution of these fish can be overrepresented. The biomass of sprat was much reduced from the 2019 estimate and the lowest in the recent time series. That said, the distribution of sprat was also notably different with the concentration of distribution along the shore in the east and a lack of fish in the southwest. Given the inshore distribution observed this year it is possible that the sprat stock was not fully contained within the survey area. The size profile of sprat was dominated by larger fish overall and lacked the spread of cohorts normally observed. This is not considered reflective of the state of the stock but rather a year effect. The 2020 TSB estimate (Pass 1) is 4,716.8 t and 67,368,000 individuals (CV 0.51) and an increase on the 2019 estimate (2,244.5 t and a total abundance of 106,900,000 individuals). The standing stock biomass remains low overall.	

	Description
Survey design	Stratified systematic parallel design with randomised starting point within each stratum.
Index Calculation method	StoX (via ICES database) is used to calculate abundance and biomass.

Random/systematic error issues	Poor state of the stock and lack of schools negatively impacts the ability of the survey to perform effectively.
Specific survey error issues (acoustic)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Bubble sweep down	36 hrs lost due to poor weather and surveying stopped when conditions deteriorated
Extinction (shadow-ing)	NA
Blind zone	NA
Dead zone	High intensity surveys carried out on herring aggregations within <0.5m of the seabed and in the Acoustic deadzone. However, during this years survey no herring were observed offshore
Allocation of backscatter to species	Directed trawling for verification purposes
Target strength	Recommended values for target species: Herring TS = 20log10(L) – 71.2 (38 kHz) Sprat TS = 20log10(L) – 71.2 (38 kHz)
Calibration	All survey frequencies calibrated and results within recommended toler-ances
Specific survey error issues (biological)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Stock containment	It's believed that the bulk of the stock was contained during the survey. However, interplay with the Irish sea can not be ruled out and has yet to be determined. For sprat, inshore containment was a likely issue during this year due to the inshore distribution of the stock.
Stock ID and mixing issues	NA
Measures of uncer-tainty (CV)	Pass 1: 4,716.8 t (CV abundance: 0.51) Pass 2: 13,062.8 t (CV abun-dance: 0.89). Calculation carried out using StoX (V3.5) and R-StoX (V1.1)
Biological sampling	Comprehensive directed trawling carried out on available schools.
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assess-ment either for the whole times series or for individual years? (please specify)	*To be answered by Assessment Working Group*

Did the Survey Summary Table contain adequate information to allow for evaluation of the quality of the survey for use in assessment? Please identify shortfalls	*To be answered by Assessment Working Group*

Annex 11: 2020 WESPAS Survey Summary Table

Survey Summary table WGIPS 2021	
Name of the survey (abbreviation):	WESPAS / MSHAS (IRL)
Target Species:	Herring, boarfish, horse mackerel
Survey dates:	03 June – 12 July, 2020
Summary:	**Cruise Report Link:** http://hdl.handle.net/10793/1659

The objectives of the survey were carried out successfully and as planned. Good weather conditions dominated during the survey. Good trawling was carried out overall (n=35) but down by 22%, compared to 2019, whereas geographical survey coverage was the same (-3%). Reduced trawl numbers can be in part attributed to not being granted access to trawl while in the French EEZ. This caused issue for the southernmost survey transects where a large volume of boarfish marks were located. Identification was not an issue and we condfidently report these fish as boarfish. In recent years this area has proven to be an important nursery area for boarfish as well as being a spawning/feeding zone. Therefore the importance of trawl sampling to determine the maturity and age composition of echotypes is obvious. Biological samples from adjacent areas were applied during the analysis as a stop gap measure but is by no means ideal given the need to track abundance of pre-recruit cohorts in the south.

Malin Shelf herring distribution was concentrated in an area to the north and west of Tory Island and north of the mouth of Lough Swilly/west of Isle of Islay in 6.a.S (south of 56°N) and to the west of the Hebrides in 6.a.N, particularly around St. Kilda. There were good signs of young immature herring overall in the Malin Shelf area, particularly 1-wr and 2-wr herring distributed in 6.a.S in the area to the north of Lough Swilly/west of Islay and in an area to the west of the Butt of Lewis. The age profile of survey samples in 2020 is dominated by 1-wr, 2-wr and 3-wr herring (75% in terms of biomass, and 86% in terms of abundance). The CV estimate for the 2020 survey is lower than in 2019 (0.25 compared to 0.37); more comparable to previous years in the time-series. This was due to an increased and better spread of herring marks across transects and strata in 2020.

Boarfish distribution was similar to previous years. The number of schools and acoustic density were higher than in 2019 and comparible to the earlier time series (2013). The 2020 survey estimate was over double in terms of biomass and abundance for comparable survey effort. Main age cohorts are visible within the survey. The presence of immature continues into the 2020 estimate with 0-3-year-old immature fish accounting for 10.6% of total biomass and over 41% of total abundance.

Horse mackerel were distributed in comparable regions along the Irish west coast and in the Celtic Sea for comparable survey effort. Although the number of allocated schools was similar to 2019, the acoustic density was lower and standing stock biomass was 40% lower as a result. Poor cohort tracking remains an issue for the older year classes. The 2020 estimate is dominated by the 2017 year class (21.8% of biomass and 34.8% of abundance).

Survey effort, timing and area coverage were comparable to previous years and the same vessel and sampling equipment (transducers and trawl) were used.

	Description
Survey design	Stratified systematic parallel design with randomised starting point within each stratum. Zig-zag transects in the Minch strata.
Index Calculation method	StoX (via ICES database) is used to provide indices of abundance.
Random/systematic error issues	NA, outside of those already described in literature for standardised acoustic surveys
Specific survey error issues (acoustic)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Bubble sweep down	NA, good weather dominated the survey
Extinction (shadowing)	Some shelf slope areas
Blind zone	Some shelf slope areas
Dead zone	Some shelf slope areas
Allocation of backscatter to species	Directed trawling for verification purposes
Target strength	Herring TS = 20log10(L) – 71.2 (38 kHz) Boarfish TS = 20log10(L) – 66.2 (38 kHz) Horse Mackerel TS = 20log10(L) – 67.5 (38 kHz)
Calibration	All survey frequencies calibrated and results within recommended tolerances
Specific survey error issues (biological)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Stock containment	Herring; Co-occurring survey effort in 6a with Scotland. Historic issues with herring around the 4˚W line. Unknown whether stock is contained as currently delineated in this area. Boarfish and horse mackerel; no, temporal alignment remains an issue in the southern boundary (Fra: PELGAS) and no survey coverage in the western Channel area.
Stock ID and mixing issues	Malin Shelf herring consists of mixed herring from 6aN, 6aS/7b,c and other areas

Measures of uncertainty (CV)	*CV on abundance* Malin Shelf herring: 0.25 Boarfish: 0.34 Horse mackerel: 0.31 *Calculation carried out using StoX (V3.5) and R-StoX (V1.1)
Biological sampling	Time series: Relatively low numbers of samples of Malin shelf herring in some years 2020 survey: Good sampling of Malin Shelf herring in 2020. Good sampling carried out for boarfish and horse mackerel in most areas except in southernmost area as previously described.
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole times series or for individual years? (please specify)	*To be answered by Assessment Working Group*
Did the Survey Summary Table contain adequate information to allow for evaluation of the quality of the survey for use in assessment? Please identify shortfalls	*To be answered by Assessment Working Group*

Annex 12: 2020 PELTIC Survey Summary Table

Survey Summary table WGIPS 2021	
Name of the survey (abbreviation):	PELTIC20
Target Species:	Sprat, sardine, anchovy (mackerel, horse mackerel, herring)
Survey dates:	3rd October – 7th of November 2020
Summary: https://www.bodc.ac.uk/resources/inventories/cruise_inventory/reports/endeavour16_20.pdf	

Peltic20 constituted the 9th autumn survey on small pelagic fish and their ecosystem in the waters of the western English Channel and eastern Celtic Sea.

For the fourth year, the survey was extended beyond the area covered between 2012 and 2016, which had focussed solely on the Mackerel Box. The 2020 survey coverage included the French waters of western English Channel and for the first time Cardigan Bay in the southern Irish Sea .

The survey commenced on the 3rd of October and ran for 35 effective survey days, starting in the western English Channel working into the Bristol Channel. In total just under 38 hours was lost due to weather and more than 25 hours due to technical issues. The 2019 nautical miles of effective acoustic coverage were supplemented with 36 valid trawls which provided details on species composition and biological information. This time many trawls (particularly in the western Channel) were conducted after sunset which provided more reliable species ratios. Results indicated that oceanographic conditions were similar to the long term average although storms at the end of the survey were thought to mix the waters and provide (premature) winter conditions for the Bristol Channel. Sardine dominated the pelagic ichthyofauna, with the second highest biomass found in the time series (332,098 t, CV 0.21) – notably sardine biomass north of the Cornish Peninsula was lower than in previous few years, possibly due to storms in the latter half of the survey; Anchovy biomass nearly doubled compared to 2019 at 42,998 t (CV 0.43) and this year large numbers (26,163 t) of post-larval anchovy were found in surface schools on the French side of the western Channel – these were thought to be from the Bay of Biscay stock; sprat biomass was similar, albeit slightly lower, than last year (33,798 t, CV 0.25). Sprat was very localised in Lyme Bay and sizes were smaller than in previous years. Sardine egg- and larval maps suggested more westerly location of peak spawning area (and corresponded to the acoustic derived distribution of adults). For the second time since 2012, Atlantic bonito (*Sarda sarda*) were caught in Lyme Bay.

	Description
Survey design	Systematic stratified parallel (5-10 and 15 nmi), perpendicular to bathymetry
Index Calculation method	StoX
Random/systematic error issues	Assumption of survey synopticity may not hold due to storms affecting last two weeks of survey; possible underestimation of Bristol Channel area.
Specific survey error issues (acoustic)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Bubble sweep down	Attenuation filter was applied to remove the pings affected by poor weather/seas and survey was paused where weather was not workable (~38 hours lost)
Extinction (shadowing)	Not an issue (school backscatter explored *in situ* for high values >20,000 NASC)
Blind zone	*Time-series*: survey conducted daylight only to avoid effects of diurnal vertical migration. High pingrate (0.5 s-1) also ensures that surface fish schools just below nearfield are captured acoustically at 10 knots. *2020*: juvenile anchovy schools at surface (on French side) may have been slightly undersampled. Most schools seemed to be below the surface deadzone however (exercise comparing biomass in reduced blindzones from higher frequencies confirmed this).
Dead zone	1m; no known issue for target species and bottom line was adjusted for occasional pelagic schools extending into deadzone
Allocation of backscatter to species	Echotypes which are allocated to trawls based on combination of nearest distance of acoustic data to trawl and expertise
Target strength	Recommended (-71.2 clupeids, -66.2 boarfish; -68.7 horse mackerel; -67.5 gadoids); Mackerel processed at 200 kHz using b20 of 84.03
Calibration	On drift at 0.512 and 0.256 μs for 38, 120 and 200 kHz (333 kHz on axis). Results comfortably within recommended parameters
Specific survey error issues (biological)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*

Stock containment	*Time series*: **sardine** northerly and westerly boundary captured well (combining data with those collected during CSHAS) and since 2017 also southern area of western Channel; area further south (Bay of Biscay) thought to be different stock and is covered by JUVENA survey (AZTI); small numbers of sardine were found in 2018 but bulk of biomass in western English Channel; genetic work ongoing. **Sprat** questions remain about the link of Lyme Bay sprat to other populations in Channel and beyond although seemingly isolated in autumn. Sprat in Celtic Sea not captured as extending further west (covered by MI, Ireland during CSHAS) *2020 survey*: French side remains crucial for sardine and now also Bay of Biscay **anchovy** recruitment as JUVENA doesn't capture northern end of distribution of this stock
Stock ID and mixing issues	*Time series*:Sprat is genetically linked to wider NE Atlantic but population is likely to be split (geographic separation); Sardine is thought to be single stock although likely to be interacting with stocks in Bay of Biscay (growth rate is different though); northern anchovy is separate stock. *2020 survey*: Strong evidence that post-larval anchovy from Bay of Biscay have expanded northwards and may lead to mixing with northern anchovy in the future.
Measures of uncertainty (CV)	StoX derived and both sardine and sprat good (<0.3)
Biological sampling	*Time series*: good *2020 survey*: details provided in report and although numbers are lower than last year they thought to be good across species and sizes

Annex 13: 2020 6aSPAWN Survey Summary Table and Survey Report

Document 13a: 6aSPAWN 2020 survey summary table

Survey Summary table WGIPS 2021	
Name of the survey (abbreviation):	6a7bc herring industry survey (6aSPAWN)
Target Species:	Herring
Survey dates:	31st August 3rd September (Ocean Star). 17th Sept-21st Sept (Alida) (6aN) 7th November (Crystal Dawn), 10th November (Ros Ard), 26th November (Johnny G), 27th November (Abigail S), 12th December (Ros Ard) and 6th January 2021 (St. Catherine)
Summary:	

2020 was the fifth industry-led survey of herring in 6a/7bc. Two industry vessels were used for acoustic surveys in 6aN and five vessels for six surveys in 6aS/7b.

In 6aN, the two vessels were equipped with hull mounted calibrated Simrad EK80 transceivers, FV Alida with 3 frequencies and Ocean Star with one. Both vessels were proven to be very stable platforms for acoustic surveys. Following the guidance arising from WKHASS, the survey area in 6aN focussed on two principal spawning areas, with timing planned to coincide with the known spawning period. The presence of spawning-ready adult herring marks was low, but an abundance of immature, mainly age 1 fish was found in the strata 1 covering the North Minch. In strata 2 on the North coast, very few marks were seen and no samples hauls were made. During the Ocean Star survey, a storm came through requiring the vessel to continue to progress east for shelter, missing the opportunity to do sample hauls on the top 2 transects in the North Minch. The main distribution of acoustic marks, confidently identified as herring, were concentrated in strata 1 running north south at a depth of 90-100m on flat ground, known to be suitable spawning habitat, and seen in both the Ocean Star and Alida surveys. One feature of the 2020 survey was an apparent 'cleaness' or separation of acoustic marks, compared to the mixed assemblages encountered in the previous two years. Discussion over concerns regarding the impact of limited samples from each survey led to the decision to combine the biological samples from both vessels and apply them to acoustic data to estimate abundance and biomass from each survey separately. Accordingly, the total biomass estimates of herring recorded during the survey in 6aN by Ocean Star was 44, 000t (CV= 0.36), 32% immature, and no samples of spawning fish. Total biomass estimates of herring recorded during the survey in 6aN by Alida was 33, 000t (CV= 0.51), 30% immature, and no samples of spawning fish. Following a proposal from industry, no commercial catches were taken in 6aN in 2020, the only removal of herring being sample hauls during the acoustic surveys.

6aS - An acoustic survey of herring was conducted in 6aS/7b in November-December 2020 and January 2021. The 2020 survey was conducted using five vessels: MFVs Crystal Dawn WD201, Ros Ard SO745, Johnny G S653, Abigail S SO354, and St. Catherine D299. The survey design changed in 2020 compared with previous years in that only core areas with prior knowledge of herring distribution from the monitoring fishery were targeted for surveying. This was largely based on the results from ICES WKHASS (ICES 2020) and from lessons learned in the previous surveys in this area from 2016-2019. Approximately 300nmi of survey tracks were completed using 72 transects. This resulted in a total area coverage of approximately 66.26 nmi², a significant reduction compared to previous survey (2016 – 2019). A pole-mounted system attached to the gunwale of each vessel with a combi 38 kHz (split) 200 kHz (single) transducer was used successfully for the survey in 2020. Herring were again distributed inshore, and the improved survey design and use of small vessels for the survey resulted in a good measure of uncertainty (CV). Very strong herring marks were evident in Lough Foyle and Lough Swilly in the channel in marks that extended for many miles. There was also a series of herring marks in Bruckless Bay, Fintra Bay and Inver Bay in discreet areas. There were some small herring marks in the Achill strata. The monitoring fishery was being conducted on smaller boats in the same areas and close to the same time as the survey and biological samples from some of these vessels were used. There was a good spread of length classes in all hauls, with most hauls dominated by larger (> 22 cm) mature fish. Larger fish were particularly evident in Lough Foyle and Lough Swilly. Slightly smaller (mean length) herring were found in hauls from Bruckless and Inver Bay. The 2- and 3-wr age class of herring accounted for 54% of the overall numbers in 2020. The total stock biomass (TSB) estimate of 45,046 tonnes is considered to be a minimum estimate of herring in the 6aS/7b survey area at the time of the survey; all areas were not covered in 2020, and therefore the stock was not overall contained in the wider 6aS/7b survey area. The flexible survey design and focusing on discreet areas was generally successful and should provide a template for future survey designs.

	Description
Survey design	6aN – two strata centred on known spawning areas. Stratified systematic parallel design (2 nmi spacing) with randomised start point. Two vessels surveyed each strata with a 14 day lag in between. 6aS - Stratified systematic parallel design (~1 nmi spacing) with randomised start point. High intensity zig/zag transects in Lough Swilly.
Index Calculation method	6aN and 6aS - StoX (via the ICES acoustic database)
Random/systematic error issues	NA, outside of those already described in literature for standardised acoustic surveys
Specific survey error issues (acoustic)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Bubble sweep down	6aN- Not an issue in FV Ocean Star 2020, managed to stay ahead of impending storm and stabilty of boat aided by filling fish tanks with water. No issue for Alida. 6aS – not an issue with the pole mounted system used in 2020
Extinction (shadowing)	6aN- No ocurrences recorded. Can occur with spawning aggregations, but these were not recorded in 2020. Dense schools on rocky outcroppings can be subject to side lobes, but these were not classified as herring. 6aS – may be an issue with hyper-aggregating schools, particularly in Lough Swilly and Lough Foyle

Blind zone	6aN – Surface exclusion 8-9m applied. Not a problem for herring schools that are found at significant depth, mostly near bottom. Some sprat schools will be partly excluded but these are not quantified in this survey anyway. 6aS - Surface exclusion 3m applied – herring schools generally below this depth
Dead zone	6aN and 6aS - Dense herring schools tight to the bottom in a few places making delineation more difficult, but detailed school by school scrutiny and checking to resolve any issues.
Allocation of backscatter to species	6aN - Directed trawling for verification and species composition purposes and age structure. Lack of marks meant no biological samples obtained in strata 2 from either vessel, so acoustic analyses inferred from samples in strata 1. 6aS – Samples used from the monitoring fishery taking place at same time and in same areas as the survey
Target strength	TS = 20log10(L) – 71.2 (38 kHz)
Calibration	6aN - 38kHz calibrated on all vessels 6aS – 38kHz calibrated on 18/12/2020 in Lough Swilly
Specific survey error issues (biological)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Stock containment	6aN- Following the guidance arising from WKHASS, the survey area in 6aN focussed on two principal spawning areas, with timing planned to coincide with the known spawning period. The estimates of abundance from both vessels are considered a reliable estimate of herring present during the surveys. Survey duration and sampling was limited, leading to decision to combined biological samples for acoustic analyses. No spawning ready fish were caught in samples, but there there was an abundance (~32% of biomass estimate) of immature fish. 6aS - The stock was not overall contained in 2020, particularly in the Donegal Bay area (Bruckless, Inver Bays, etc.) and more effort is required to contain the stock by targeting effort later in December and January when herring appear to show up in these areas in greater numbers. However, the stock was most likely contained inshore in the discreet core areas covered by using smaller vessels in 2020. This was a problem in previous years, particularly 2016-2018, when it proved difficult to survey inshore when larger vessels were used for this survey.the stock appears to have been largely contained by the survey design in these core strata areas, an improvement on previous years. There is a concern regarding containment inshore in areas not covered by the survey and particularly the Malin Beg, Teelin, Bruckless, Inver Bay areas. It would have been preferable if surveys were completed in these areas later in December in 2020. This was not possible due to COVID-19 restrictions.
Stock ID and mixing issues	No issues – both surveys are conducted at times and in areas when both 6aN and 6aS stocks are expected to be geographically separated
Measures of uncertainty (CV)	6aN- CV of biomass used for estimate of herring biomass for Ocean Star was 0.36 overall and 0.51 for Alida. Very few herring marks were seen in strata 2, which had a higher CV. 6aS – CV estimate on abundance estimate for the survey was 0.34. Per strata, the CV estimate was relatively high for the Lough Foyle strata, and

	this had an adverse effect on the overall CV for the survey. The CV on the estimates of abundance was within expected values for an acoustic survey.
Biological sampling	6aN - Biological data to allocate to acoustic marks identified as herring was satisfactory for strata 1, but not for strata 2. But lack of available marks means this was unavoidable. 6aS - Biological data used from the monitoring fishery to allocate to acoustic marks identified as herring was satisfactory in 2020.
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole times series or for individual years? (please specify)	To be answered by Assessment Working Group
Did the Survey Summary Table contain adequate information to allow for evaluation of the quality of the survey for use in assessment? Please identify shortfalls	To be answered by Assessment Working Group

Document 13b: 6aSPAWN 2020 survey report

The 2020 industry–science acoustic survey of herring in the Western British Isles (ICES div 6a, 7b,c)

Steven Mackinson[1], Martin Pastoors[2], Steven O'Connell[3], Benoit Berges[4], James Forbes-Birnie[5], Steven McAulay[5], Katie Brigden[8], Shaun Fraser[8], Michael O'Malley[6], Ed Farrell[7]

[1] Scottish Pelagic Fishermen's Association, Scotland
[2] Pelagic Freezer Trawler Association, Netherlands
[3] Marine Scotland, Scotland
[4] Wageningen Marine Research, Netherlands
[5] Scottish Fishermen's Federation, Scotland
[6] Marine Institute, Ireland
[7] University College Dublin, Ireland
[8] NAFC Marine Centre, Shetland

Charisma (Davie Hutchison), Alida (Bert Plug), Ocean Star (Michael Tait),

Contents

Executive summary

2020 was the fifth consecutive industry-led survey of herring in 6a/7bc. Industry and scientific institutions from Scotland, Netherlands and Ireland successfully carried out scientific surveys with the aim to improve the knowledge base for the herring spawning components in 6aN and 6aS, 7bc, and submit relevant data to ICES to assist in assessing the herring stocks and contribute to establishing a rebuilding plan.

Following agreement on a scientific monitoring fishery TAC of 4 840 t (3 480 t in 6aN and 1 360 t in 6aS/7bc) (EU 2020/123), the scientific survey was designed based on ICES advice, and experience from 2016-18 on the timing, location and number of samples required to collect assessment-relevant data from the monitoring fishery (ICES 2016a).

In 6aN, two industry vessels were used to undertake acoustic surveys on spawning ground in September (the 6aSPAWN survey). Both were equipped with hull mounted calibrated Simrad EK80 transceivers, FV Alida with 3 frequencies and Ocean Star with one. Both vessels were proven to be very stable platforms for acoustic surveys. Following the guidance arising from WKHASS, the survey area in 6aN focussed on two principal spawning areas, with timing planned to coincide with the known spawning period. The presence of spawning-ready adult herring marks was low, but an abundance of immature, mainly age 1 fish was found in the strata 1 covering the North Minch. In strata 2 on the North coast, very few marks were seen and no samples hauls were made. During the Ocean Star survey, a storm came through requiring the vessel to continue to progress east for shelter, missing the opportunity to do sample hauls on the top 2 transects in the North Minch. The main distribution of acoustic marks, confidently identified as herring, were concentrated in strata 1 running north south at a depth of 90-100m on flat ground, known to be suitable spawning habitat, and seen in both the Ocean Star and Alida surveys. One feature of the 2020 survey was an apparent ‘cleanness’ or separation of acoustic mark, compared to the mixed assemblages encountered in the previous two years. Discussion over concerns regarding the impact of limited samples from each survey led to the decision to combine the biological samples from both vessels and apply them to acoustic data to estimate abundance and biomass from each survey separately. Accordingly, the total biomass estimates of herring recorded during the survey in 6aN by Ocean Star was 44, 000t (CV= 0.36), 32% immature, and no samples of spawning fish. Total biomass estimates of herring recorded during the survey in 6aN by Alida was 33, 000t (CV= 0.51), 30% immature, and no samples of spawning fish. Following a proposal from industry, no commercial catches were taken in 6aN in 2020, the only removal of herring being sample hauls during the acoustic surveys.

Coinciding with the 2020 International Herring Acoustic Survey, a 10-day acoustic survey was carried out by FV Charisma in July (Annex 1). The main objective was to increase the

chance of obtaining sufficient biological samples of herring in Strata 1 and 3 of the International Herring Acoustic Survey (HERAS). A secondary objective was to test the effect of transect spacing on estimation of herring abundance. Only two out of ten survey hauls contained herring, and sample sizes were low. Two nets were damaged beyond repair at sea, curtailing any further chances to obtain samples. Analysis of acoustic data was supported using biological sample information from Scotia and Celtic Explorer, noting that these were taken a different times. Estimates of acoustic abundance were lower than those found by the survey vessels, but considered well within the range of variability that could be expected when the surveys did not perfectly coincide.

The 6aS/7b survey design changed in 2020 compared with previous years in that only 6 core areas with prior knowledge of herring distribution from the monitoring fishery were targeted for surveying. This was largely based on the results from ICES WKHASS (ICES 2020) and from lessons learned in the previous surveys in this area from 2016-2019. This design resulted in a much reduced survey area compared to previous years, but with better coverage of most of the important inshore bays where the monitoring fishery takes place. The survey design objective remained the same; to capture the distribution of winter spawning herring in the 6aS/7b area. The timing of surveys in the core areas was flexible from the outset by design. It was decided that greater flexibility would allow for a targeted spatial and temporal approach which avoided the inevitable poor weather that can happen in this area during this time of the year and which lead to reduced survey effort in 2019, but also to some extent in 2017 and 2018. Using smaller vessels allowed surveys to be conducted in shallow inshore areas where herring are known to inhabit during this time of the year. In 6aS/7b herring were distributed similar to the surveys in 2016 - 2019. Herring were again found close inshore with the overall distribution dominated by aggregations of herring in a few discrete areas. The 2- and 3-wr age class of herring accounted for 54% of the overall numbers in 2020. All of the 6 designated core areas of were surveyed, all areas important to the monitoring fishery. Total biomass estimates of herring recorded during the survey in 6aS/7b was 45 046 t. The inshore distribution of herring generally makes containment of the stock difficult in this area, however, the improved survey design, particularly in Lough Swilly resulted in a much lower measure of uncertainty (CV), compared to previous years. The CV on the estimates of abundance and biomass was within expected values for an acoustic survey and has benefitted from the change of survey design used. The flexible survey design and focusing on discreet areas was generally successful and should provide a template for future survey designs.

At the time of publishing this report, no provision has yet been fully agreed for monitoring fishery quota in 2021, but tentative plans are underway for the sixth survey in 2021, taking into account needs for specific data to address issues for the benchmark assessment planned in early 2022.

1 Rationale, aim and objectives

1.1 Rationale

During the ICES benchmark workshop on herring west of the British Isles (ICES 2015a), the stock assessments of 6aN herring and 6aS/7bc herring (Figure 1.1) were merged into one combined assessment. The reason for this is that the summer acoustic surveys and fishery occur at a time when the northern and southern components are mixed, and the baseline morphometric information required to separate the two components was found to be unreliable due to evidence of changes over time. The consequence is that since 2015, ICES has advised a zero TAC, and recommended that a rebuilding plan be developed (ICES 2017a). The ICES HAWG also stated in its March 2015 report that there is a clear need to determine the relative stock sizes (ICES 2015b).

Under the auspices of the Pelagic Advisory Council, this situation catalysed fishing industry associations representing Scottish, English, Dutch, Irish, Northern Irish and German fishery interests to set about providing the much needed evidence required to establish reliable stock assessments for the separate stocks, and develop a rebuilding plan.

In response to the STECF 2015 autumn plenary recommendation that it would be beneficial to maintain an uninterrupted time series of fishery-dependent catch data, and a subsequent special request (to ICES) by the European Commission, ICES provided advice on methods for undertaking a scientific monitoring fishery for the purpose of obtaining relevant data for assessment (ICES 2016a). In particular, the advice referred to collection of data necessary to determine the identity and structure of the two stocks, collected in a way that (i) satisfies standard length, age, and reproductive monitoring purposes by EU Member States for ICES, and (ii) ensures that sufficient spawning-specific samples are available for morphometric and genetic analyses as agreed by the Pelagic Advisory Council monitoring scheme 2016 (Pelagic Advisory Council, 2016).

This advice, and a resulting EU Council regulation (EU 2016/0203) that made provision for a scientific monitoring TAC of 5 800 tonnes (4 170 t in 6aN and 1 630 t in 6aS, 7bc) were the enablers for the industry-led survey to take place. EU Council regulation (EU 2020/123) made a provision for a monitoring TAC of 4 840 t, enabling the fifth survey to take place. However, following a proposal from industry, no commercial catches were taken in 6aN in 2020, the only removal of herring being sample hauls during the acoustic surveys.

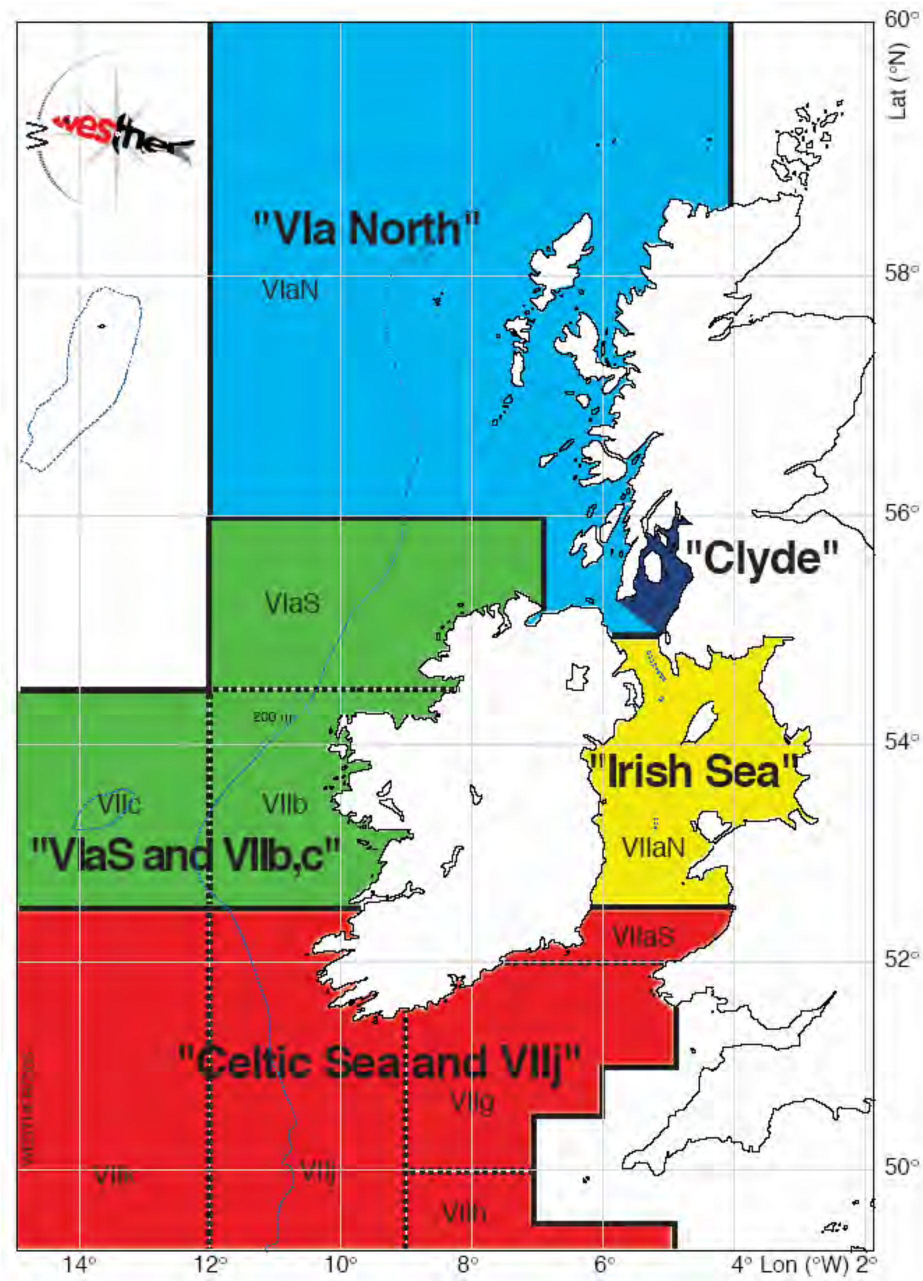


Figure 1.1. Herring stock assessment areas.

1.2 Overall Aim

To improve the knowledge base for the spawning components of herring in 6aN and 6aS/7b, and submit relevant data to ICES to assist in assessing the herring stocks and contribute to establishing a rebuilding plan.

1.3 Objectives

In this report, only information on the methods and results pertaining to objective 1 are documented. A full survey report is available on request.

1. **Abundance estimation**: Collect acoustic data and information on the size and age of herring and use it to generate an age-disaggregated acoustic estimate of the biomass of pre-spawning/ spawning components of herring in 6aN and 6aS/7bc ('Western herring').
2. **Stock identity separation:** Collect morphometric and genetic data to distinguish whether the 6aN stocks are different from the stocks in 6aS, 7bc.
3. **Age composition of the commercial catch:** Collect catch-at-age data from the monitoring fishery to provide continuous fishery-dependent time series required for assessment.
4. **Rationale for continued monitoring:** Use the results of the surveys as evidence for consideration and design of a scientific monitoring fishery in 2019.
5. **Evidence for a rebuilding plan:** Use the results of the surveys to contribute to the scientific basis for development of a rebuilding plan for Western herring.

2 Material and methods

2.1 Research plan

The overall research plan involves the planning, implementation and analysis & reporting stages outlined in Figure 2.1.

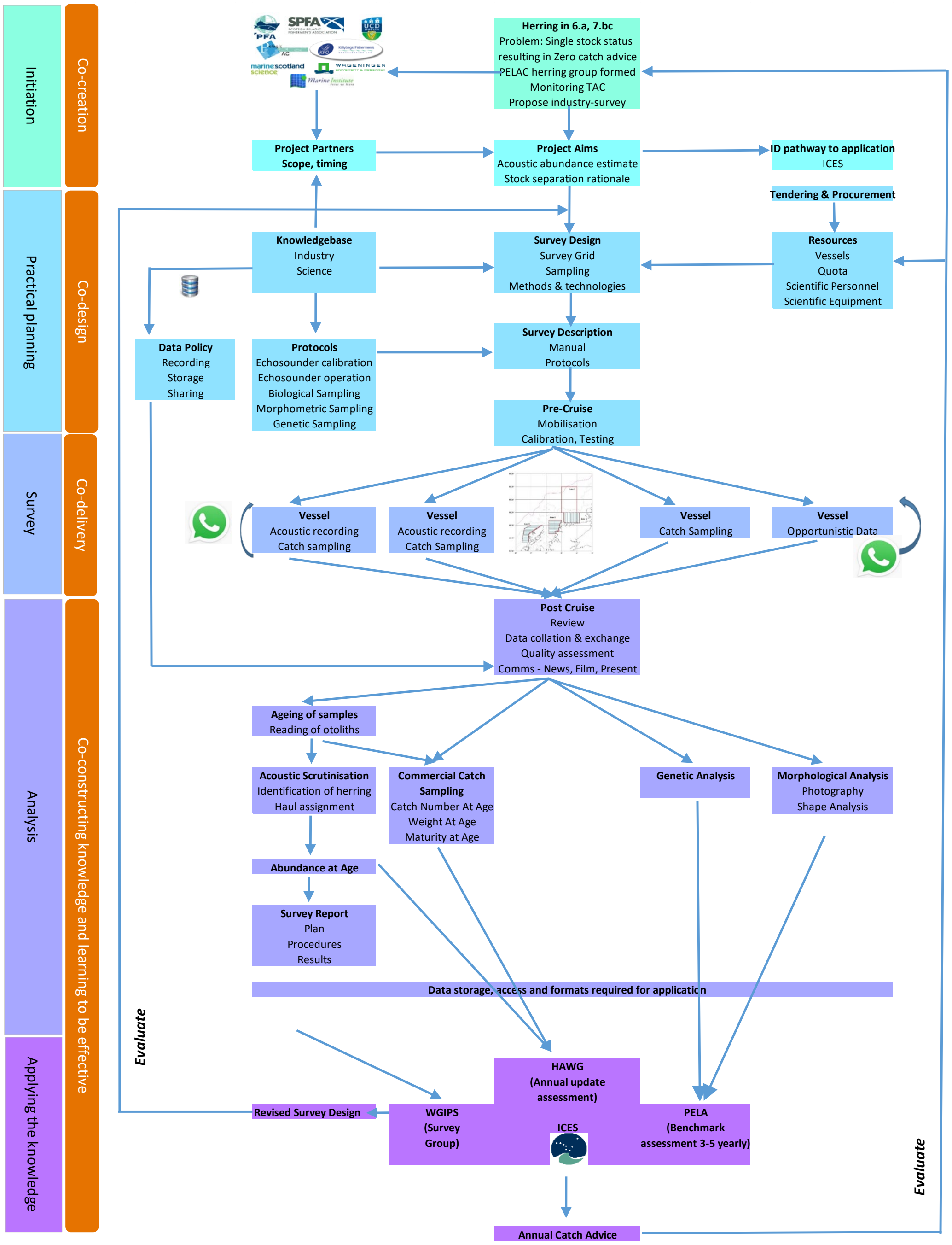


Figure 2.1. Overview of the planning, implementation and analysis stages in the Western herring surveys.

2.1.1 Specific survey objectives

Specific objectives for the field survey followed objectives 1-3, described in section 1.3. Each of the vessels involved were assigned specific objectives and provided with a vessel-specific sailing plan and survey protocol manuals (example available on request). Sections 2.2 to 2.4 describe the survey methods in detail.

2.1.2 Survey areas and timing

The areas of interest for the 6aN surveys have been defined based on the ICES advice on the monitoring fishery (ICES 2016a) and discussions with fishing skippers during the present and past planning meetings.

Prior to the 2020 survey, five areas were selected for surveying in 6aN (Figure 2.2). The areas coincided with the geographic distribution of known active herring spawning areas (Figure 2.3, and observed in previous surveys) and records of commercial catches (Figure 2.4). Areas 2-4 are considered to be active spawning areas and Area 1 a pre-spawning aggregation area that contains an unknown mixture of stocks of Western and North Sea herring, where a large proportion of catches has been taken in recent years (ICES 2015a). Area 5 was added in 2018 and 2019 based on evidence from 2017 and local creel fishermen of herring on the east side of the North Minch. Systematic acoustic surveys (see section 2.2) were conducted only in areas 2-5 in 6aN, but ad-hoc acoustic data was recorded by other vessels also.

Following the guidance arising from WKHASS, the survey area in 6aN focussed on two principal spawning areas (Figure 2.5, 2.6), with timing planned to coincide with the known spawning period. The new strata 1 & 2 are reduced version of previous area 2 and 3 and correspond to regions that have been covered consistently since 2016. Moreover, refocusing the survey to these new strata means that it is now possible to provide a consistency the survey time series, which will be necessary for developing time-series indices relevant for assessment purposes.

In 6aS/7b, the acoustic survey core areas defined as shown in Figure 2.7. These areas correspond to known herring aggregating areas before spawning (Figure 2.8). Spawning time in this area is variable, generally between October and February (Table 2.1).

The timing of surveys in 6aN and 6aS/7b are shown in Table 2.2 and 2.3 respectively.

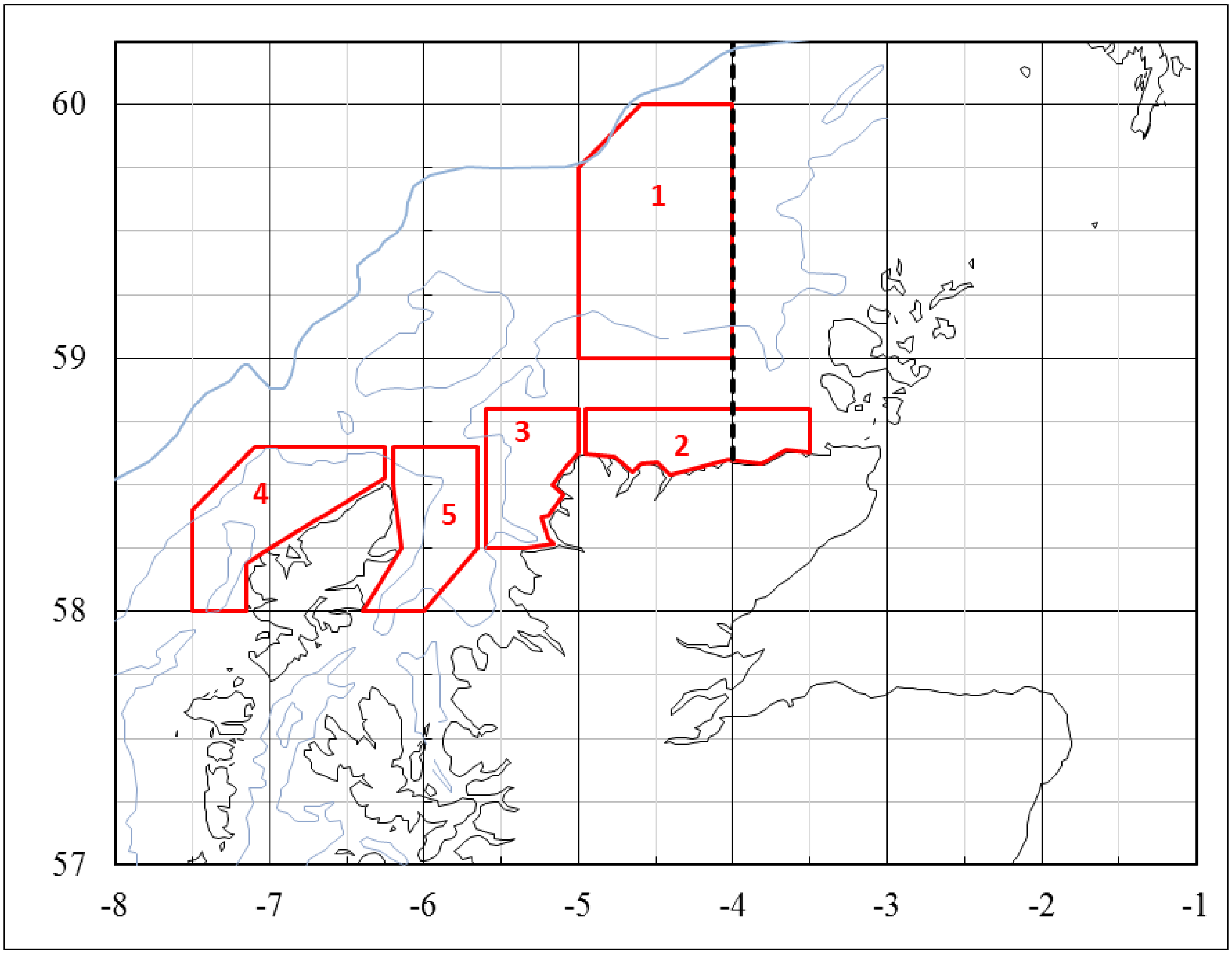


Figure 2.2. Planned survey areas used in the 6aNorth surveys prior to 2020. Area 1- North pre-spawning mixing area, Area 2 -East of cape Wrath, Area 3 – The Minch, Area 4 – Outer Hebrides, Area 5 – east Minch.

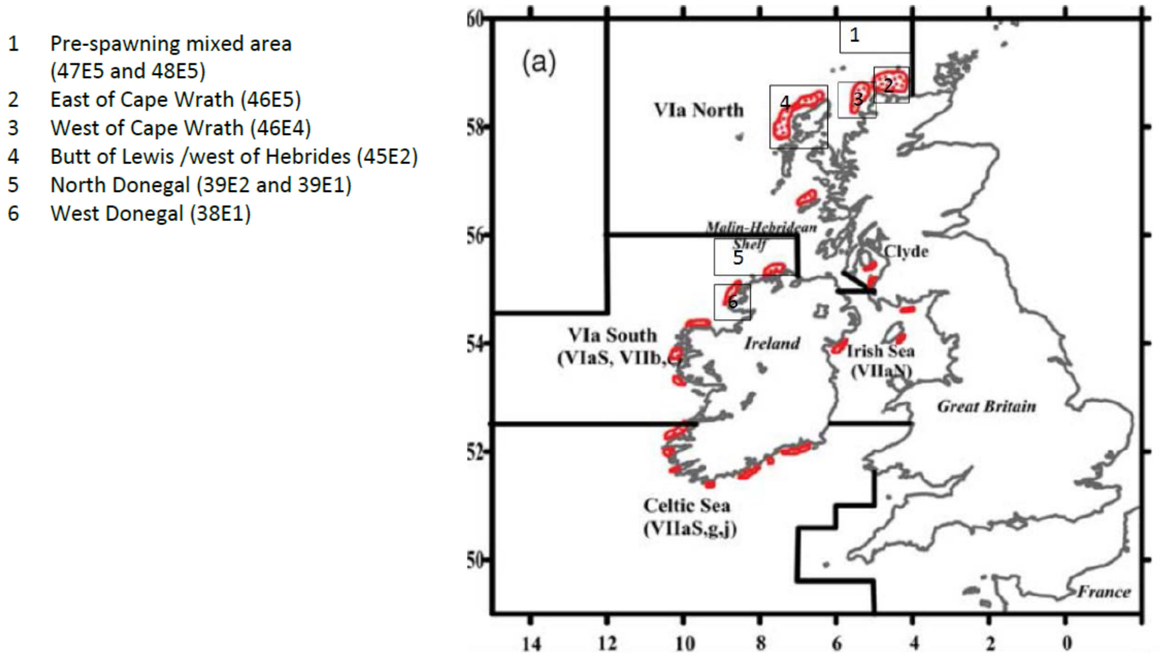


Figure 2.3. Spawning areas for herring in ICES subareas 6 and 7, with currently active spawning areas and pre-spawning aggregation areas for each stock indicated by black rectangles. Used in ICES 2016, redrawn from Geffen *et al.* (2011).

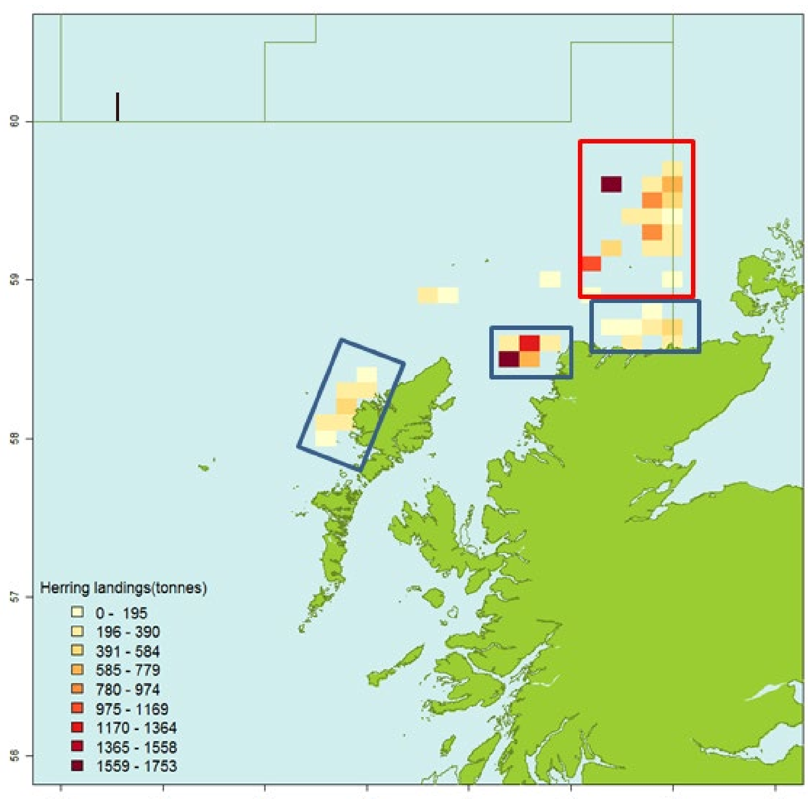


Figure 2.4. Distribution of commercial catches reported in 6aN in 2011.

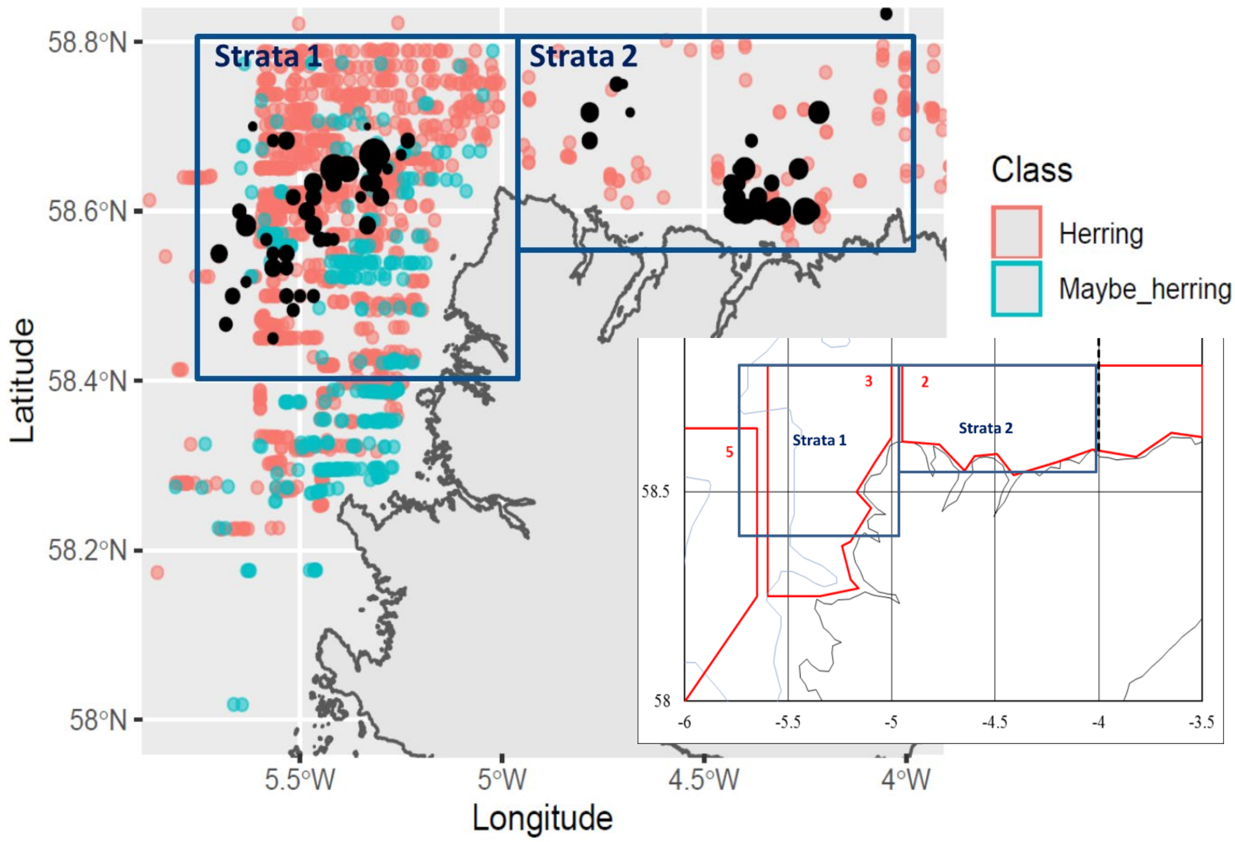
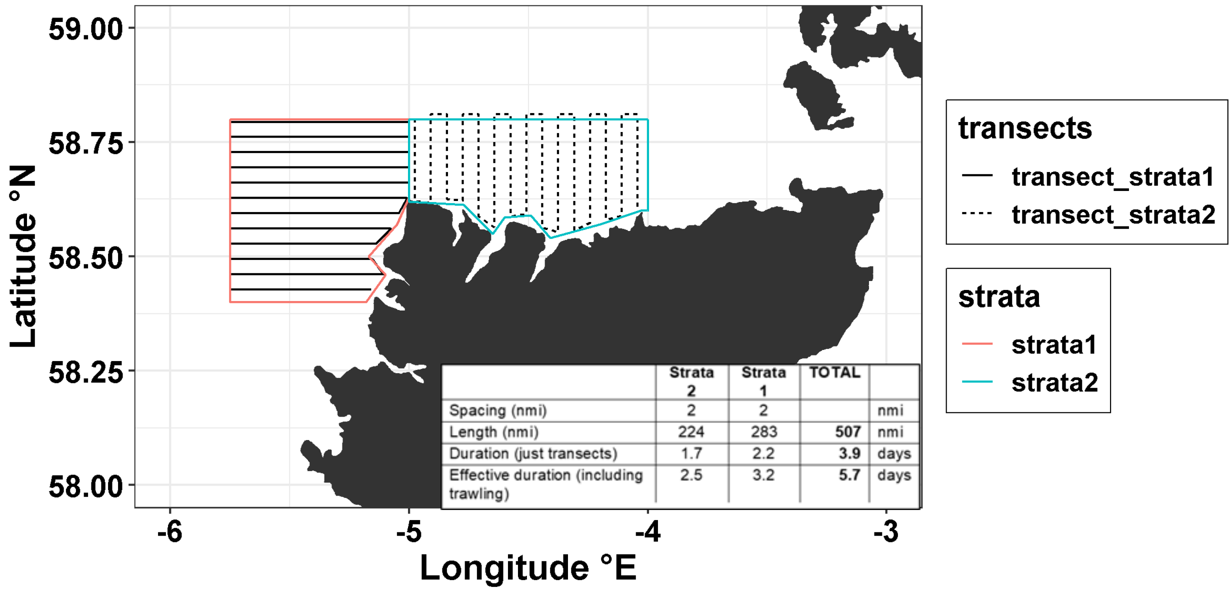


Figure 2.5. Acoustic survey recordings of herring and 'maybe herring' marks and locations of commercial catches 2016-2019 in the newly defined Strata 1 & 2, showing overlap with previous survey Areas 2,3,5 (inset) and noting that the distribution of catches reflect spawning grounds. Catches (black dots) scaled proportionally. Acoustic marks are not scaled and denote location only.



	Strata 2	Strata 1	TOTAL	
Spacing (nmi)	2	2		nmi
Length (nmi)	224	283	**507**	nmi
Duration (just transects)	1.7	2.2	**3.9**	days
Effective duration (including trawling)	2.5	3.2	**5.7**	days

Figure 2.6. Planned survey areas used in the 2020 6aN surveys.

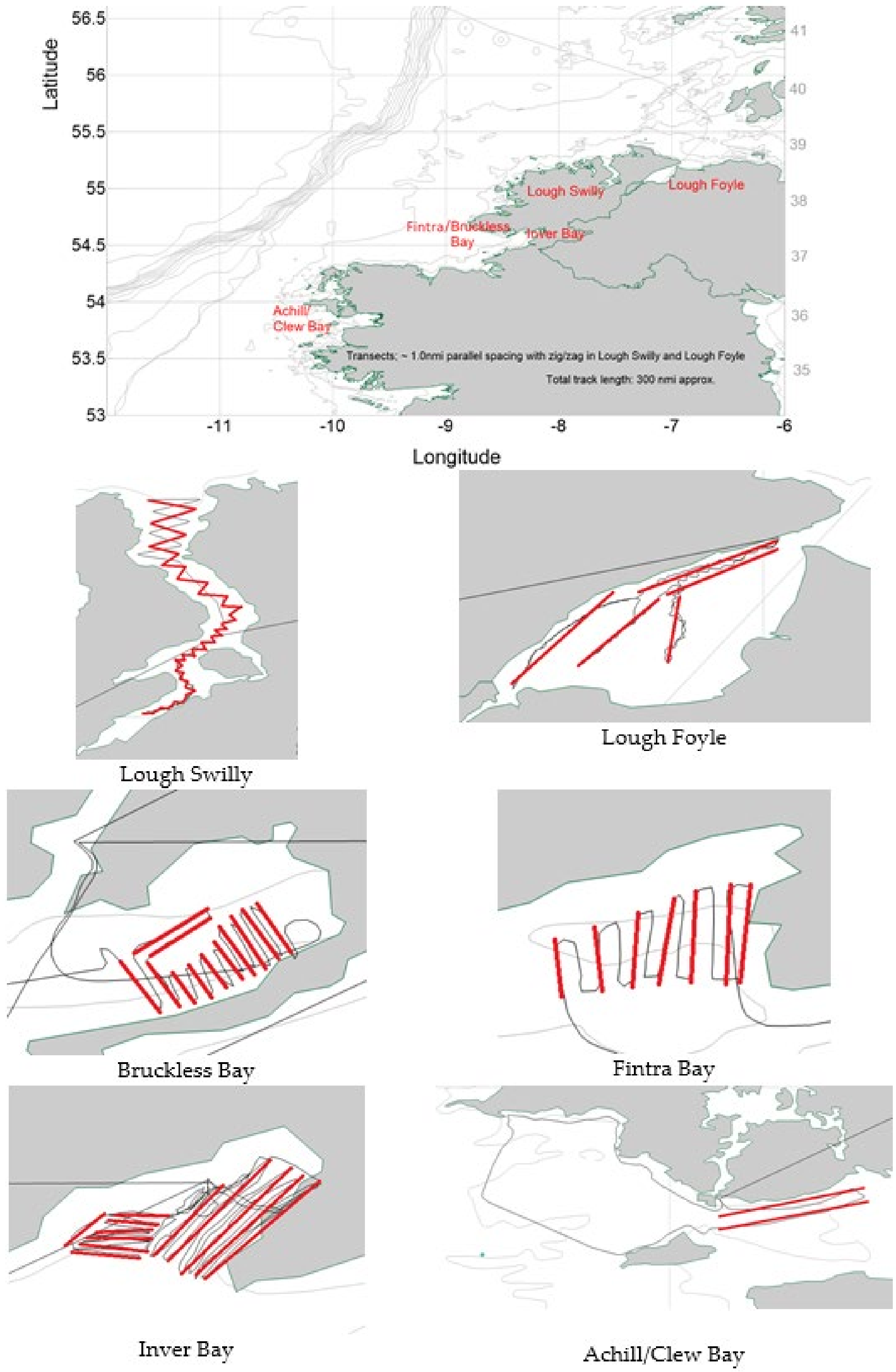


Figure 2.7. 6aS/7b industry acoustic survey in 2020: The 6 core areas were selected in 6aS/7b (top panel) based on information from the monitoring fishery and previous surveys (2016-2019). The 6 core areas in 2020 included: Lough Swilly, Lough Foyle, Bruckless Bay, Fintra Bay, Inver Bay and Achill/Clew Bay.

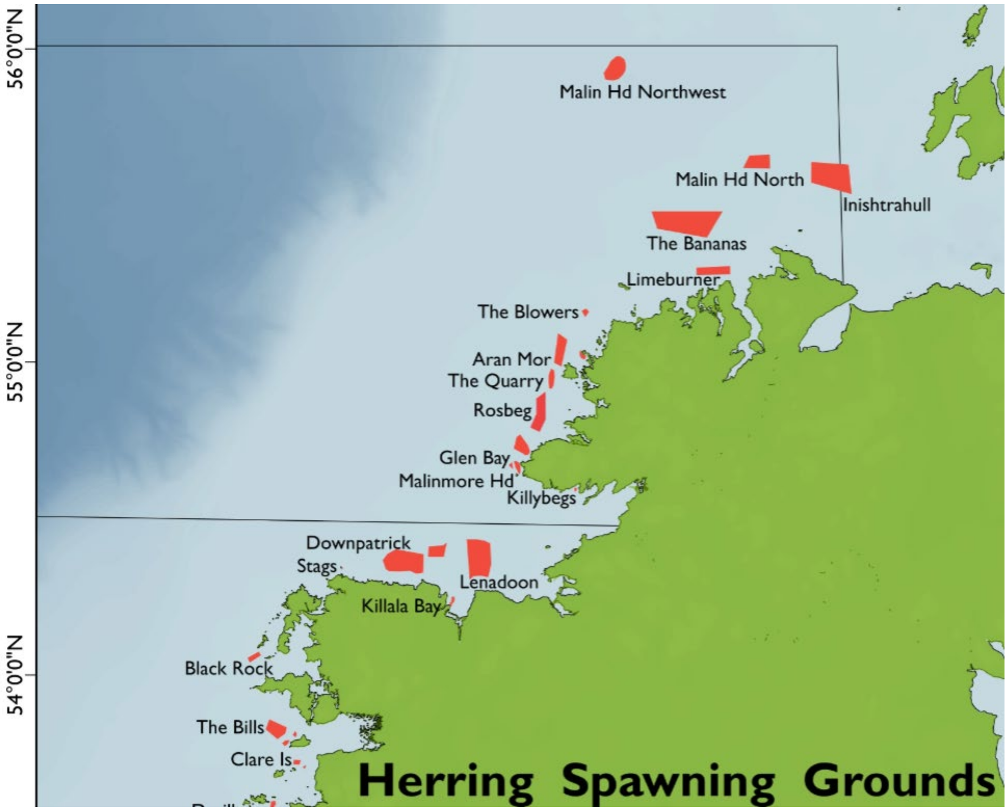


Figure 2.8. Herring Spawning grounds in 6aS/7b,c (extracted from O'Sullivan, 2013).

Table 2.1. Spawning areas, spawning grounds and spawning beds in 6aS/7bc. Area (km^2) and depth (m) refer to individual spawning beds (from O'Sullivan, 2013).

Spawning Area	Spawning Ground	Spawning Bed	Depth (m)	Area (Sq Km)	Activity
North Donegal	Malin Head	Inishtrahull	45	121.58	November
		Malin Head North	90	39.06	November
	Limeburner	Limeburner	30	33.28	November
		The Bananas	58	169.17	Nov and Feb
	Tory	Malin Head Northwest	70-90	47.42	Nov and Feb
West Donegal	The Blowers	The Blowers	30	3.96	Oct/Nov
		Stags	20	0.89	Nov/Dec
	Aran Mor	Aran Mor 1	43	32.35	Oct/Nov
		The Quarry	70-80	11.84	October
	Rosbeg 1	Rosbeg 1.1	32-36	0.13	Oct/Nov
	Rosbeg 2	Rosbeg 2.1	43	44.06	October
	Glen Head	Glen Bay	32-36	24.17	Nov/Dec
		Malinmore Head 1	18	6.31	November
		Malinmore Head 2	90	1.59	Jan/Feb
Donegal Bay	Killybegs	Killybegs 1	20	1.01	Dec/Jan
	Lennadoon	Lennadoon 1	32-42	101.92	Jan/Feb
		Killala Bay	25	3.05	January
	Downpatrick	Downpatrick West	32	23.66	November
		Downpatrick/Ceide Fields	34-45	97.05	Dec/Jan
Mayo	The Stags	The Stags 1	36	0.89	November
	Blackrock	Blackrock 1	36	7.74	Oct/Nov
	Clare Island	The Bills	36	29.83	November
		Clare Island 1	32	3.07	Oct/Nov
		Clare Island 2	36	1.58	Oct/Nov
		South Clare Island 1	45	3.71	December
		South Clare Island 2	~40-45	2.01	Nov/Dec
	Lecky Rock	Davillaun/Lecky Rock	20	3.63	Sept/Oct

Table 2.2. Timing of 2020 surveys in 6aN.

Vessel	Start	End	Duration	Timing and area coverage	Mon 24-Aug	Tue 25-Aug	Wed 26-Aug	Thu 27-Aug	Fri 28-Aug	Sat 29-Aug	Sun 30-Aug	Mon 31-Aug	Tue 01-Sep	Wed 02-Sep	Thu 03-Sep	Fri 04-Sep	Sat 05-Sep	Sun 06-Sep	Mon 07-Sep	Tue 08-Sep	Wed 09-Sep	Thu 10-Sep	Fri 11-Sep	Sat 12-Sep	Sun 13-Sep	Mon 14-Sep	Tue 15-Sep	Wed 16-Sep	Thu 17-Sep	Fri 18-Sep	Sat 19-Sep	Sun 20-Sep
Ocean Star	**30-Aug**	03-Sep	**5**	**Strata 1 & 2 (acoustic)**	C					P																						
Alida	**15-Sep**	19-Sep	**5**	**Strata 1 & 2 (acoustic)**																						P	C					
				C=Calibration																												
				P=Passage to/from grounds																												

Table 2.3. Timing of 2020 surveys in 6aS/7b.

Area	Survey date	Survey distance	Vessel and type	Flag	Homeport	Vessel#	Role	Skipper
Lough Foyle	07 Nov 2020	~50nmi	MFV *Crystal Dawn* Half-decker trawler under 12m	IRL	Greencastle	WD201	Acoustic and catch sampling	Liam O'Brien
Loch Swilly	10 Nov 2020	~50nmi	MFV *Ros Ard* Trawler under 19.81m	IRL	Burtonport	SO745	Acoustic and catch sampling	Edward Gallagher
Bruckless Bay and Fintra Bay	26 Nov 2020	~50nmi	MFV Johnny G Half-decker trawler under 12m	IRL	Killybegs	S653	Acoustic and catch sampling	Francis Gallagher
Inver Bay	27 Nov 2020	~50nmi	MFV Abigail S ring netter under 12m	IRL	Inver	SO354	Acoustic and catch sampling	Gary Kennedy
Achill	06 Jan 2021	~50nmi	MFV St. Catherine trawler under 19.81m	IRL	Achill	D299	Acoustics	James O'Gorman

2.2 Abundance estimation

2.2.1 Acoustic survey design

The purpose of the acoustic surveys was to estimate the minimum spawning biomass of adult herring and spawning ready herring within the boundaries of the survey areas.

Acoustic surveys were conducted in survey strata 1 and 2 in 6aN (Figure 2.5) designed on regularly spaced parallel transects (Figure 2.6) Transect direction was assigned perpendicular to the narrowest dimension of the survey area to maximise precision of the estimation by having many short transects rather than a few long ones. In 6aN each vessel surveyed acoustically the two strata at different timings: early September for the Ocean Star FV and mid to end of September for the Alida FV (Table 2.2). The survey dates aimed to give best chances to cover the peak time of spawning and were decided based on records of known spawning times and advice of fishermen familiar in working the areas.

In 6aS/7b, the planned survey with parallel and zig/zag transect design for 2020 is shown in Figure 2.7. Areas like Lough Swilly suited a zig/zag transect design approach, whereas Inver, Bruckless, Fintra and Achill were more suited to parallel transect design. The straight line transects were completed at constant speed. Deviations from the planned transects were documented on acoustic log sheets. When the vessel deviated from transect for any reason it returned to the same position to resume the survey.

Sufficient time was factored in to the planning to provide opportunity for the survey areas to be adapted according to the situation observed, such as changes to the survey boundary to ensure full coverage of fish aggregations, or undertaking finer scale observations in high density locations. Table 2.4 summarises the survey setup for each vessel that took part in the 6aN and 6aS/7b surveys. Also noted are any adaptations to the original planned survey transects.

2.2.2 Equipment specifications and calibration

See Table 2.4 for specification, e.g. frequency used and settings.

The standard calibration procedure described in Demer et al. (2015)[1] was used to calibrate each of the echosounders deployed on each of the vessels. Echomaster Marine

[1] http://courses.washington.edu/fish538/resources/CRR326_Calibration.pdf

successfully performed the calibration of Ocean Star and Charisma (see Annex 1), stern on to the breakwater in Peterhead at the slack of a high tide (22m under transducer) in calm conditions.

Each frequency of the hull mounted echosounder onboard the Alida FV were calibrated in open sea in the North Sea under very clement conditions. Results are shown in Figure 2.10 for the calibration gain and the S_a correction and are in line with what was measured in 2018, confirming the effective functioning of each echosounder frequency.

Calibration of the EK80 38kHz echosounder on the MFV *Ros Ard* was carried out in Lough Swilly (6aS) at the end of the survey on 18/12/2020. A chain clump was dropped off the stern of the vessel to assist in keeping the vessel in position. Water depth was approximately 25m at the calibration site. This calibration was carried out using standard methodology as described by Demer *et al*. 2015. Standard EK80 calibration was carried out and the successful calibration was made possible by good conditions in the deep water. There was minimal interference from biota in the water column.

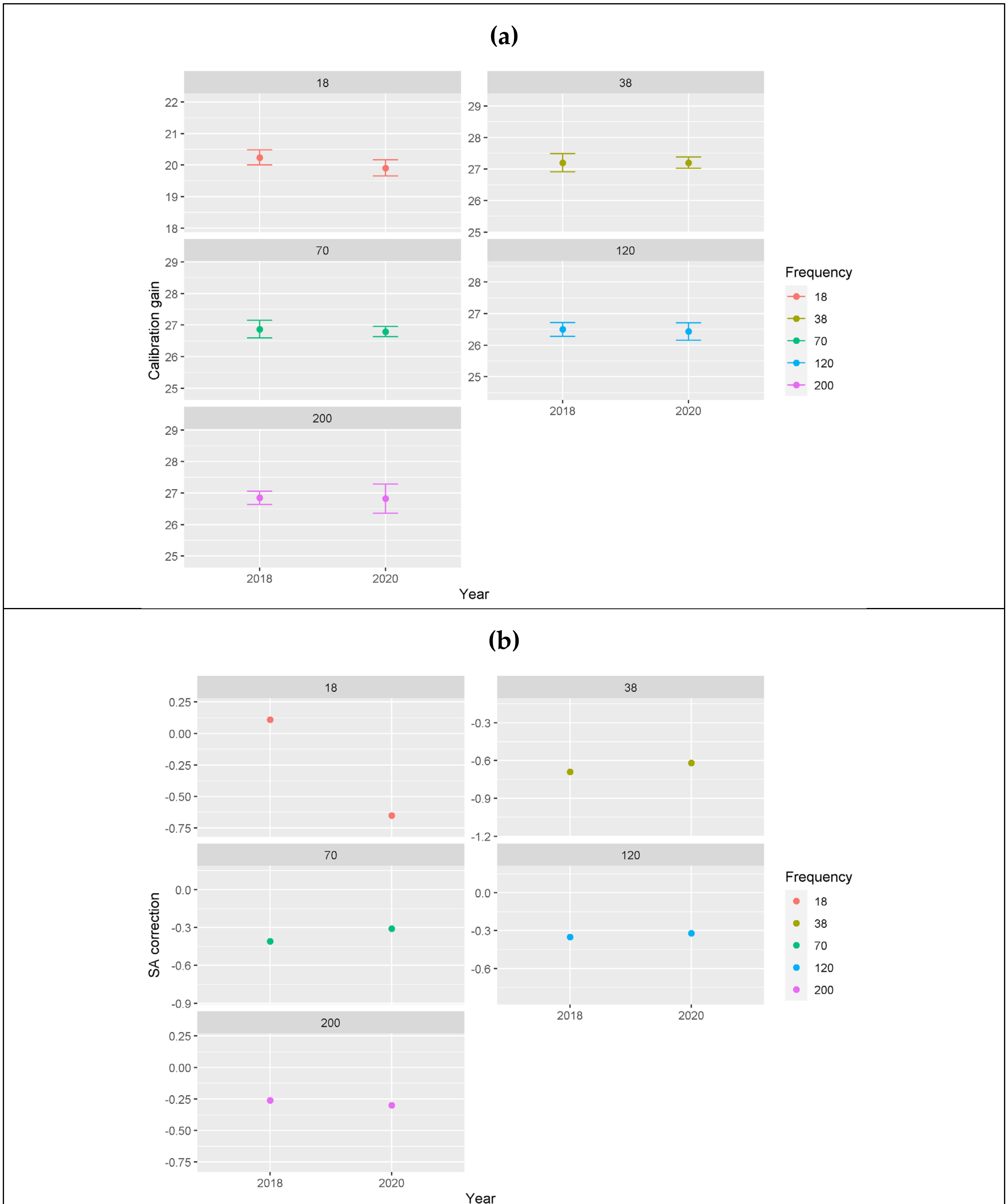


Figure 2.10. Calibration results from the Alida FV. Results of the 2020 survey are compared to those from the 2018 6aN survey. (a) Calibration gain with error bars reflecting RMS error for each measurement. (b) Sa correction.

2.2.3 Acoustic survey protocols

Surveys in 6aN were conducted in daylight hours only, 05:00 to 19:00 UTC/GMT. At the beginning of the next day, the survey restarted and continued from the position it ended on the day before. This maintained continuity in the coverage and avoided the possibility of double counting herring schools, which can occur if the survey does not continually progress in the same direction.

To maximise acoustic data quality, Refrigerated Sea Water (RSW) vessels took on board ballast water to aid stability of the vessel and minimise cavitation. The vessels proved to be very stable platforms in all the conditions experienced and at no time was the quality of acoustic data compromised. All other acoustic equipment was turned off to eliminate interference with the EK80. Only during fishing operations were other acoustic instruments used. A motion reference unit was installed to compensate for heave, pitch and roll.

Raw acoustic data were recorded and stored on the ships PC and backed up each day on a portable hard disk drive for later processing.

Survey log sheets were used to record haul position and other events relevant to aiding in the interpretation of the acoustic data.

Surveys in 6aS/7b were only conducted during daylight in good weather. Survey speed was ~7 knots throughout. Acoustic data were collected using a SIMRAD EK80 wide band combination scientific echosounder with transducers (38 kHz (split) and 200 kHz (single)) from a pole-mounted system attached to the gunwale of each vessel. A GPS feed was obtained from an independent receiver, and the whole topside system was powered by an un-interrupted power source (UPS) and located in the wheelhouse. The 38 kHz frequency only was used for survey estimates, the 200 kHz was used for reference and as an aid to scrutiny.

2.2.4 Fishing operations for scientific samples

During the acoustic surveys, selected fish marks were targeted with a fishing operation (Figure 2.11 to capture fish for the purposes of:

(i) Confirming the species identity of acoustic marks, particularly those suspected to be herring or to confirm that they were definitely not herring.

(ii) Collecting samples for biological analysis and to enable disaggregation acoustic densities into length/age groups.

The fishing operations of FVs were directed to take a catch of the smallest possible size sufficient for biological sampling. No commercial catch was undertaken during the 2020 surveys.

Scottish RSW vessels were granted a derogation to discard fish that were not required to be retained for biological sampling, subject to specific conditions.

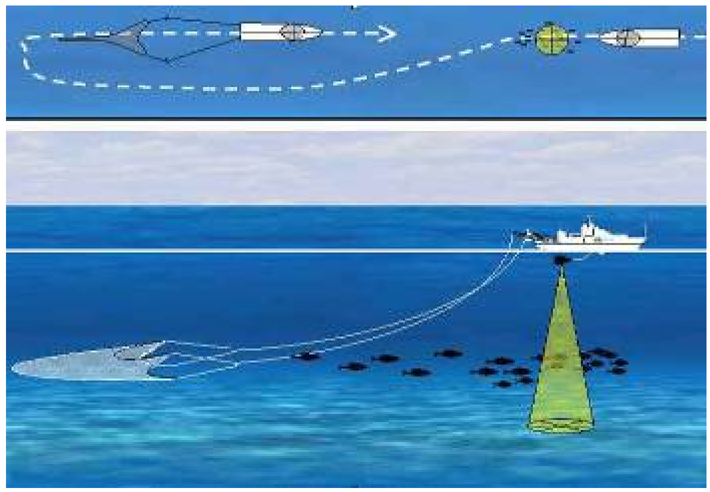


Figure 2.11. Schematic description of fishing operation to collect a biological catch sample during an acoustic survey.

Table 2.4. Summary of equipment used for the 2020 acoustic surveys.

Area surveyed	Vessel	Transducer and Frequency	Echo-sounder	Power Pulse duration Ping interval	Environment	Calibration Location/ date, supplier	Survey area changes
Strata 1 & 2	Ocean Star (FR77)	Hull mounted split beam ES38B (38kHz), draft ~5m With heave compensation. ES200-7C (200kHz) split beam [not used]	SIMRAD EK80	**@38kHz** Power: 2000W Pulse duration: 1.024ms Pulse form: Continuous wave Ping interval = 0.5 sec	Temp = 10C, Salinity =35ppt, Sound speed 1491.5 m/s	Peterhead breakwater 29 Aug, Echomaster Marine	
Strata 1 & and 2	Alida (SCH06)	Hull mounted EK60 at: 18 kHz, 38 kHz, 70 kHz, 120 kHz and 200 kHz	SIMRAD EK60	**@38kHz** Power: 2000W Pulse duration: 1.024ms Pulse form: Continuous wave Ping interval = 0.5 sec	Temp = 10C, Salinity =35ppt, Sound speed 1491.5 m/s	Scapa Flow Benoit Berges (WMR)	
6aS/7b,c	MFVs *Crystal Dawn WD201, Ros Ard SO745, Johnny G S653, Abigail S SO354, and St. Catherine D299*	Pole mounted EK80-18 C (38 kHz) attached to gunwale of each vessel	SIMRAD EK80 (38 kHz only used for estimates)	Power: 500W (38 kHz) Power: 100W (200 kHz) Pulse duration: 1.024ms Ping interval = 0.75 Hz	Temp = 10˚C, Salinity =35ppt, Sound speed 1493.89 m/s	Lough Swilly, Co. Donegal 18th December 2020	6 core areas covered – replicate survey conducted in Lough Swilly on 18/12/2020 (replicate survey not used in the survey estimation)

2.2.5 Biological sampling

The purpose of the biological sampling was to

i. provide data on the relative abundance of each length and age class of herring, which is needed to make age-disaggregated acoustic abundance estimates.
ii. determine the maturation state of herring and indicate the location and timing of spawning.
iii. perform genetic analysis to identify stock ID (which is not reported here).

2.2.5.1 *Haul information*

Haul data were recorded using the same template for all surveys, 1 sheet per haul. Information was recorded on the date, time, fishing position, depth, gear, catch composition, total weight of catch and weight of the sub sample taken for length frequency and biological sampling. To aid in processing the acoustic data, screen captures (Figure 2.12) were taken during the haul operation; identifying first the targeted mark and later the marks covered while trawling. Comments about the marks were written on the haul sheet, as well as whether or not the herring were spawning (based on “running” eggs and sperm upon capture) and whether any catch remaining after biological sampling was retained or discarded.

2.2.5.2 *Catch sampling*

The catch sampling procedure was as follows:

- Weight of the catch of all species, or where the catch was too large, 3-5 randomly mixed baskets were taken as a sample of the catch and weighed.
- The catch sample was sorted and the total weight of each species recorded.
- One full basket (or 2 half) of herring was weighed (approx. 30kg). This subsample was used to determine lengths, weight, age and for genetic samples. (see below). (Figure 2.13)

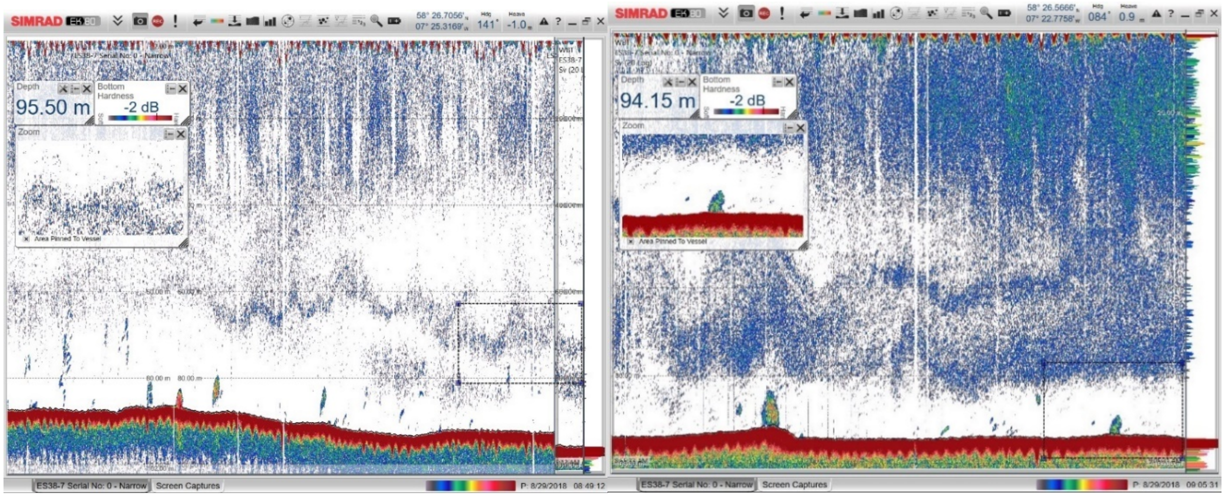


Figure 2.12. Example screen shots of targeted marks (first panel) and those trawled on.

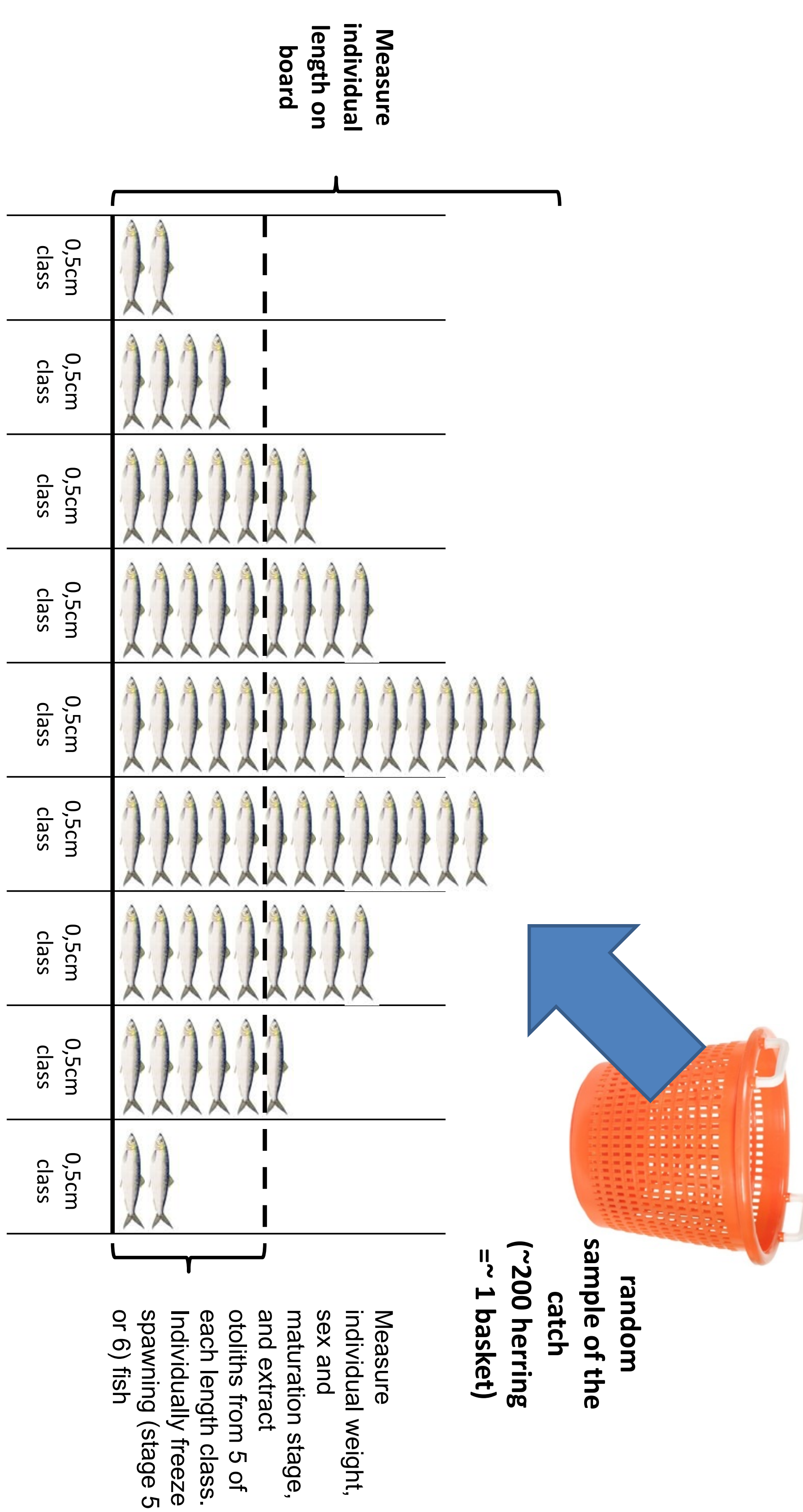


Figure 2.13. Illustration of the required catch sampling procedure.

2.2.5.3 *Length measurements*

The length of all the herring in the subsample was measured and recorded to the nearest half centimetre below (e.g. if the fish was 24.7cm then it was recorded as 24.5cm). This data is used to determine a length frequency distribution of the catch and subsequently to apply an age-disaggregated estimate of biomass. Additional biological measures (next section) were recorded from five fish within each half centimetre length class.

2.2.5.4 *Whole weight, Sex, Maturity stage, Otolith, Genetics*

Each fish from was assigned an ID number so that subsequent genetic samples can be cross-referenced to biological data.

In addition to the length, the following information was recorded for each fish.

- Weight in g
- Sex
- Maturity stage from 1-9 based on the classification in the Scottish and Irish sampling (MSS manual 2011) or on the ICES 6 point scale (ICES 2011) for the Dutch-collected samples. All maturity estimates were later converted to the ICES scale.
- Otoliths were extracted for age determination at the lab. Standard procedures for age determination from the growth rings on the otoliths (ear bones) of herring were used to determine the age of fish sampled (ICES 2005). This age data was used to create an age-length key (ALK).
- If the fish was from a spawning haul (see 2.2.5.1), it was bagged, labelled and frozen for later genetic analysis.

2.2.6 Acoustic Analysis methods

2.2.6.1 *Echogram scrutinisation – partitioning to species*

Scrutinising echograms involves identifying fish marks and assigning them to species, and ensuring that any non-fish acoustic signals are not included as fish (e.g. bottom signals).

Assigning fish marks to species is a heuristic process that relies upon (i) evidence from the targeted hauls made during the survey, (ii) prior experience of ‘experts’ (fishermen and acoustic scientists) based on their knowledge of what was caught when certain types of fish marks were fished upon in the area in previous surveys occurring around the same time, and (iii) knowledge of fish behavior.

While it's impossible to be 100% confident when assigning fish marks to species, following some agreed guidelines for classification of marks greatly improves the consistency in the way that acoustic data from different surveys are scrutinized. Hence, this ensures the quality and comparability of the biomass estimates between the different surveys and between years.

Acoustic fish marks were classified in to the following categories (See examples in Figure 2.16, 2.18, 2.19):

- **Herring** – confident that the marks were herring based on either evidence from a targeted haul or proximity and similarity to other schools known to be herring.
- **Maybe herring** – aggregations/ collections of marks within reasonable vicinity of definite herring marks (approx. 10nm radius) and shape and appearance similar to definite herring marks but often associated with hard ground where identity cannot be confirmed by trawling.
- **Possibly herring** – Marks that look like herring, but possibly isolated individual marks and found in areas beyond the immediate vicinity of confirmed herring marks.
- **Cap-hugging marks** – from 2016-2018, significant marks have been observed on rocky outcroppings that are not possible to trawl (see examples in 2019 report). Despite consulting acousticians and fishermen, the expert knowledge on these marks was inconclusive, hence they were classified separately. In July 2019, FV Grateful sought to identify these marks with a drop-down camera, the evidence from which suggests that they are not herring, but more likely Norway pout, juvenile gadoids and zooplankton concentrations. However, there is a need to verify this for the September surveys, and some uncertainty still remains regarding possible avoidance by herring, which we hope to address in future work. It is important to note that where marks on the sides of steep slopes of outcropping occurred, they were excluded from the analysis because of the possibility of being registration of acoustic side lobes.
- **Sprat** – confident that the marks were sprat based on either evidence from a targeted haul or proximity and similarity to other schools known to be sprat. A lot of very dense discrete schools close to the surface are believed to be sprat. Targeted hauls generally have low success rate due to fish going

through the net and difficulties in fishing close to the surface. Sprat schools tend to be sharp streak-like marks that are very dense. They can also occur in mixed

- **Unclassified –** confident that the marks were not herring or sprat based on either evidence from a targeted haul or proximity and similarity to other schools known to not be herring, or characteristics atypical of herring schools.
- **Horse mackerel –** a lot of horse mackerel marks were observed through 6aS/7b and are routinely found in 6aN. They can be difficult to identify and require trawl verification because they look a lot like herring marks, although they are generally more amorphous in shape and form more extended layer-like aggregations near the bottom.
- **Mackerel** – The difference in frequency response from 38 to 200 KHz (stronger) makes mackerel easier to identify. They tend to be found in layers (can be at different depths) and are ubiquitous in 6aN with some mackerel caught in most hauls.

How strongly the acoustic marks are displayed on the screen (backscatter threshold) can have a bearing on the interpreters classification of the acoustic marks and their selection using school detection algorithms. While it is desirable to be consistent in the setting of this parameter, in practice the setting is determined largely by the need to filter out fish schools from other acoustic signals that create noisy backscatter data. Other methods used to help distinguish herring marks from other fish and organisms causing backscatter included looking at the ‘frequency response’ (i.e. how the backscatter properties look at different acoustic frequencies), and the application of filters (Figure 2.14). Great attention was given to comparing and discussing the types of marks recorded and validated by trawls from all of the vessels involved in the surveys. In the end, every school was manually scrutinised thereafter to ensure that it was appropriately classified and delineated based on the available information.

One feature of the 2020 surveys on spawning grounds was an apparent ‘cleanness’ or separation of acoustic marks, compared to the mixed assemblages encountered in the previous two years.

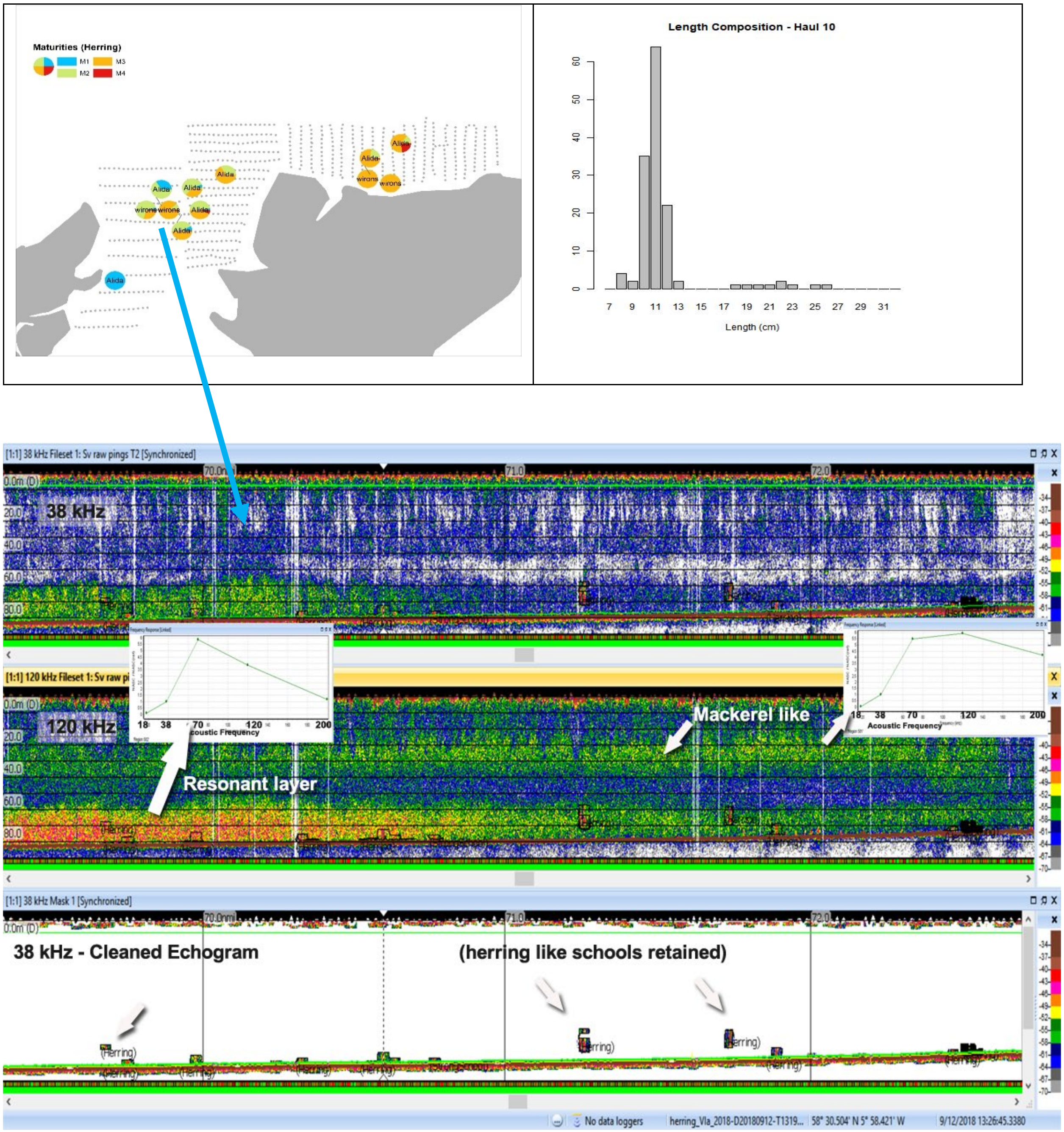
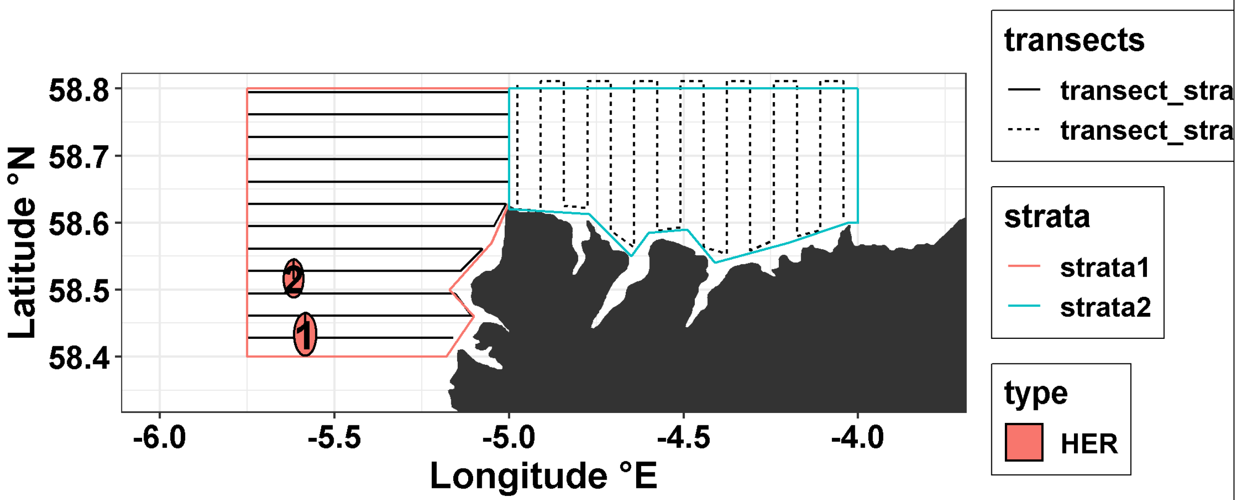


Figure 2.14. Example of analysis of acoustic properties to help classify schools in 6aN from Alida acoustic data in 2018.

6aN acoustic marks recorded by Ocean Star

(a)

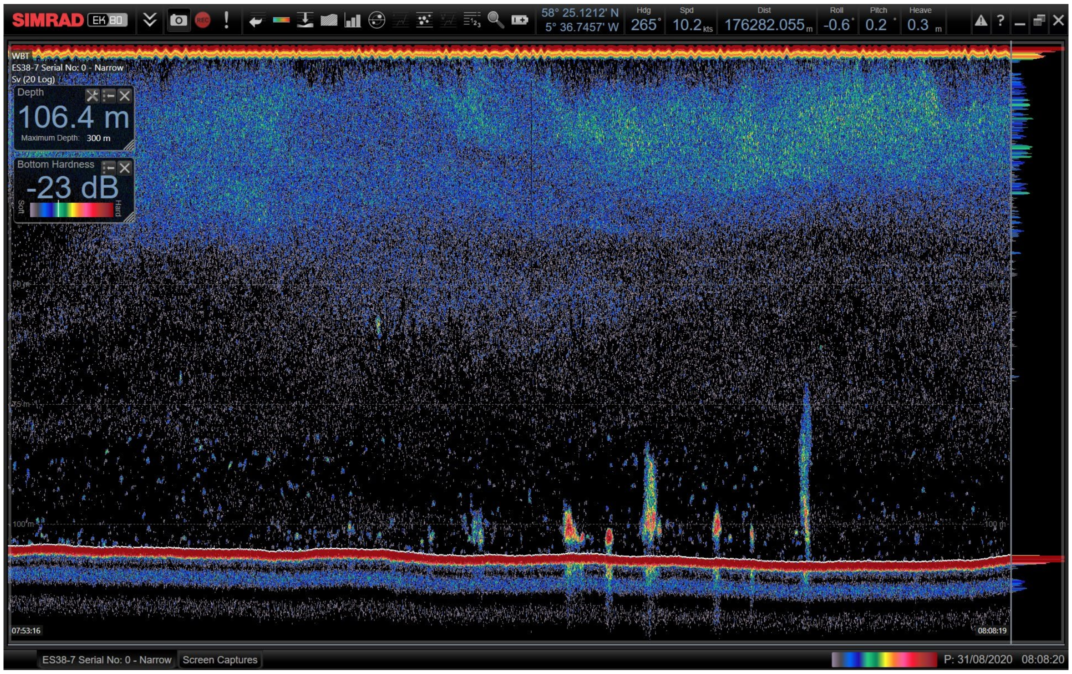


(b)

Catch proprtions (%)								
	HER	HOM	MAC	NOP	WHG	WHB	Jelly	Catch weight (t)
Haul 1	70%	0%	2%	0%	2%	0%	27%	0.129
Haul 2	83%	0%	3%	5%	0%	10%	0%	0.25
Haul 3	0%	6%	83%	0%	0%	0%	11%	0.18

Figure 2.15. biological sampling by Ocean Star. (a) location and species composition of catches. (b) length frequency of herring samples.

(a)



(b)

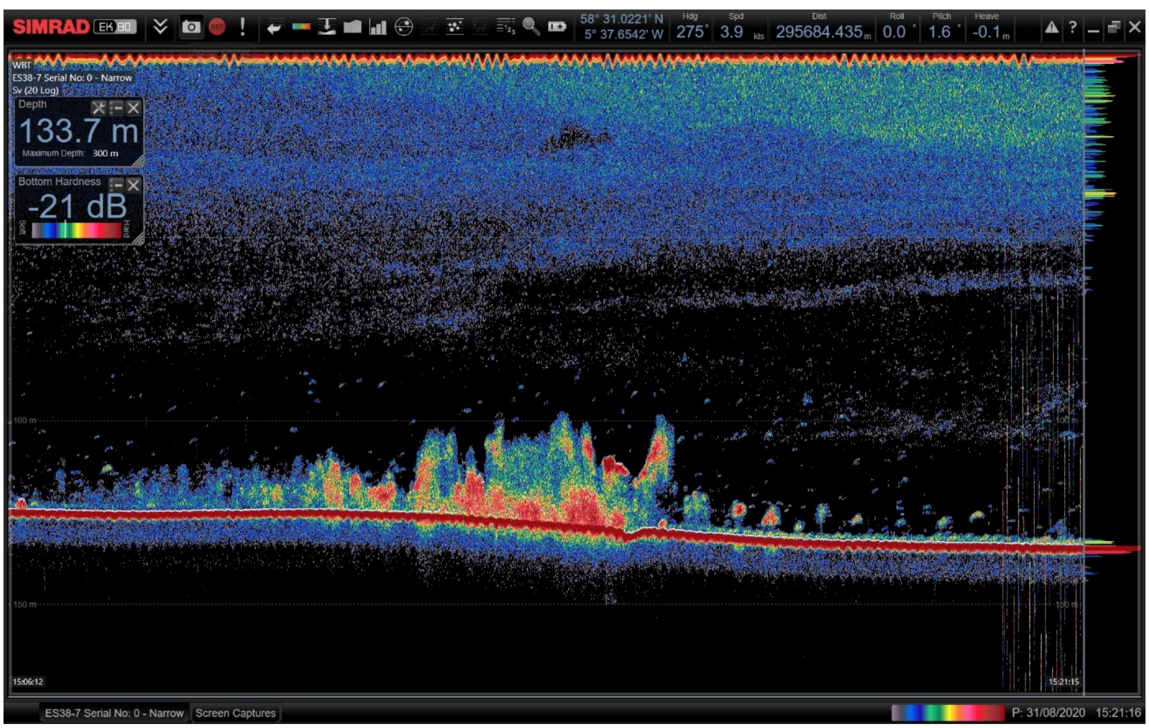
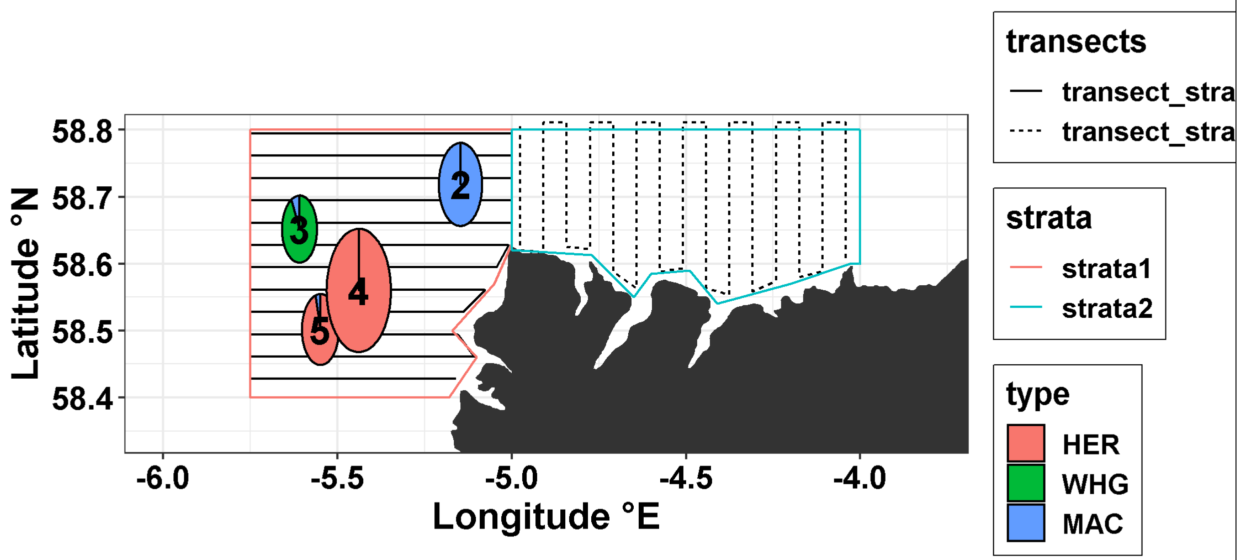


Figure 2.16. Echograms of sample hauls from Ocean Star. (a) haul 1 . (b) haul 2.

6aN acoustic marks of Juvenile herring recorded by Alida

(a)

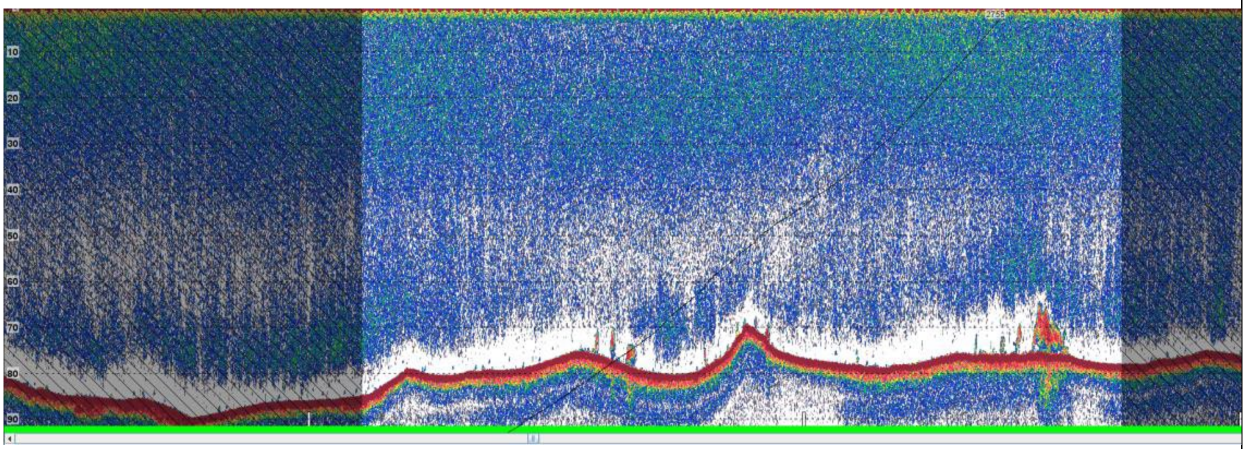


(b)

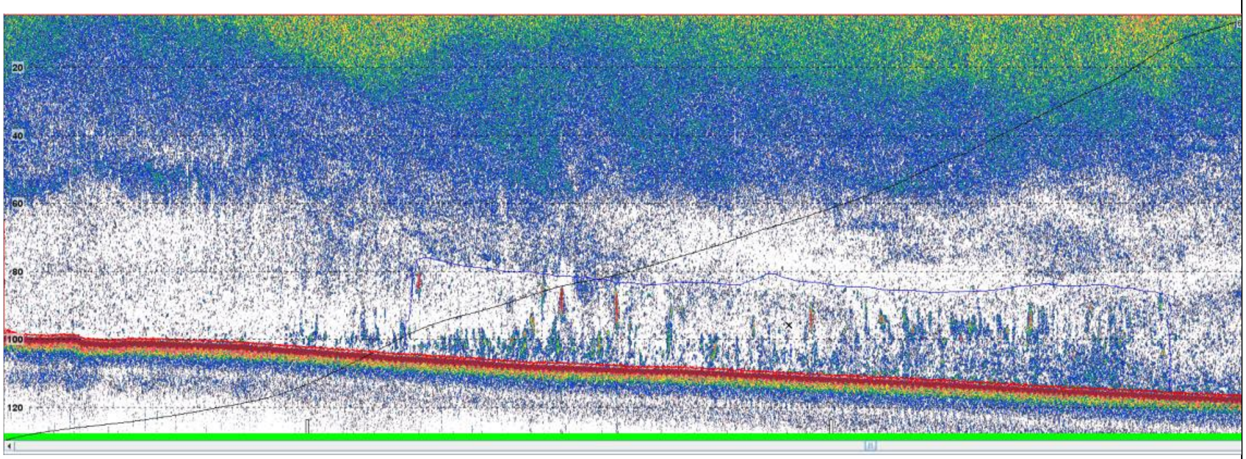
	HER	MAC	WHG	catch weight (t)
haul 2	0.0	100.0	0.0	0.5
haul 3	0.0	7.7	92.3	0.15
haul 4	100.0	0.0	0.0	10
haul 5	95.6	4.4	0.0	0.2

Figure 2.17. biological sampling by Alida. Location and species composition of catches.

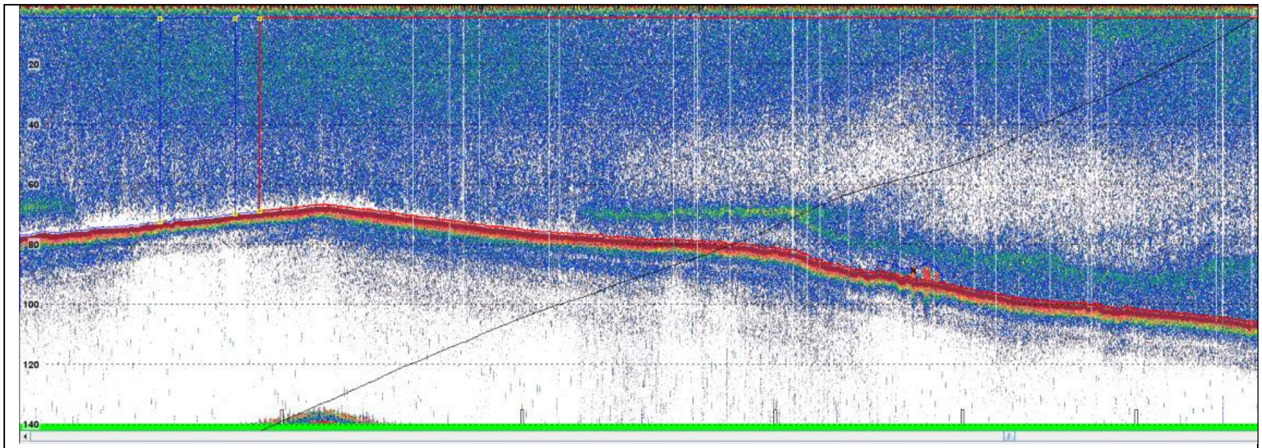
(a)



(b)



(c)



(d)

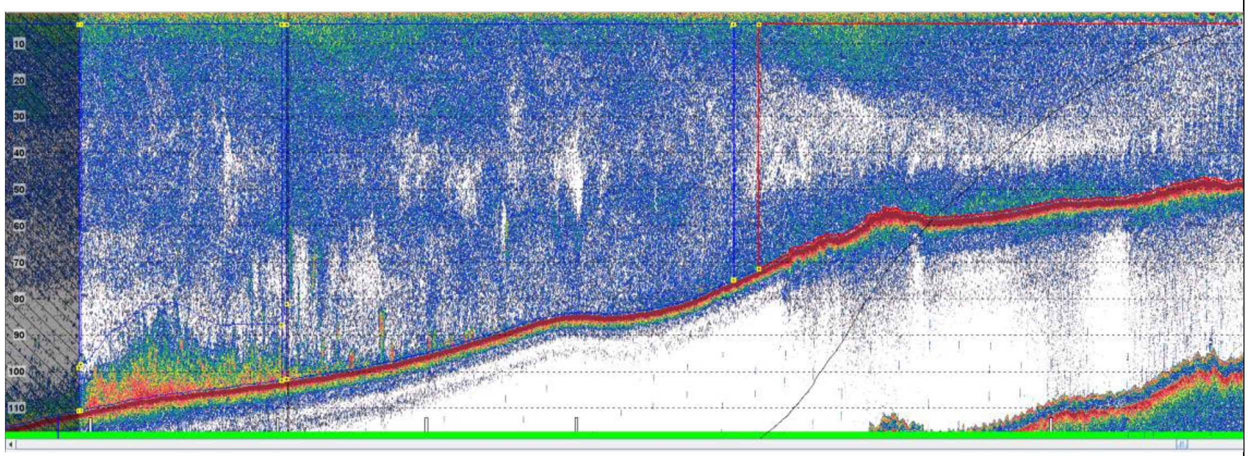
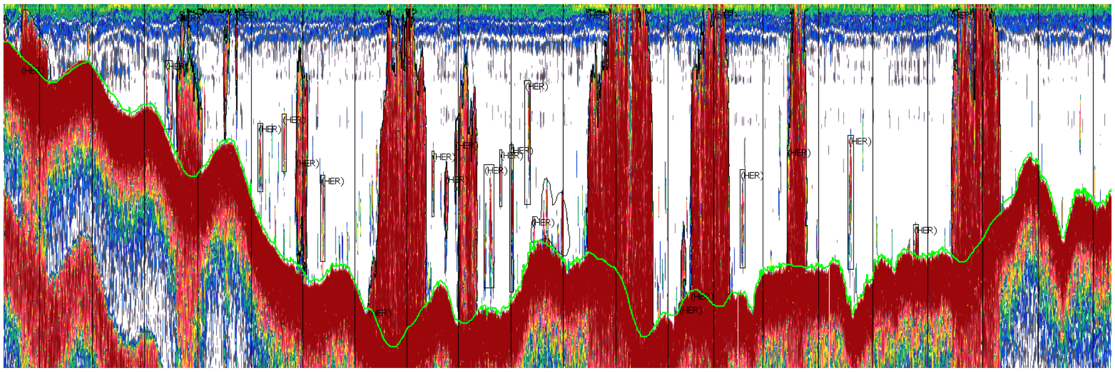


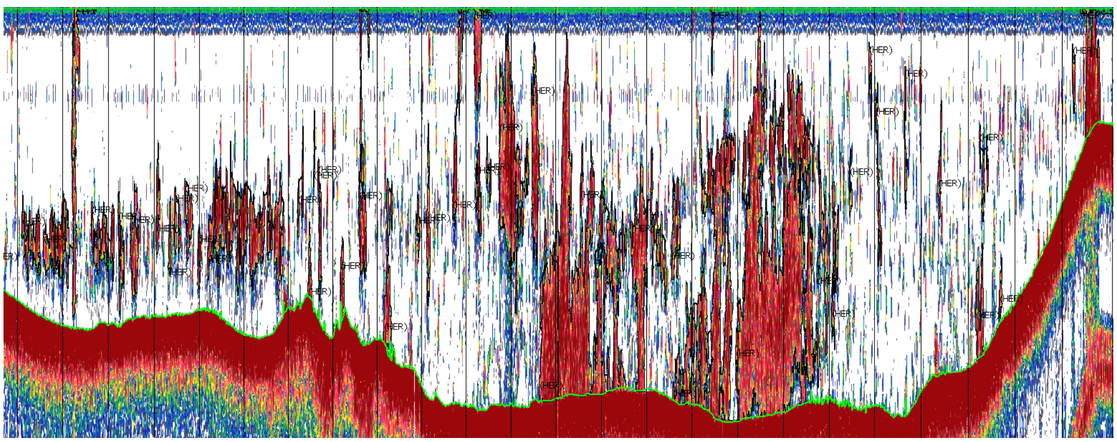
Figure 2.18. Echograms of sample hauls from Alida. (a) haul 2 . (b) haul 3. (c) haul 4. (d) haul 5.

6aS/7b acoustic marks

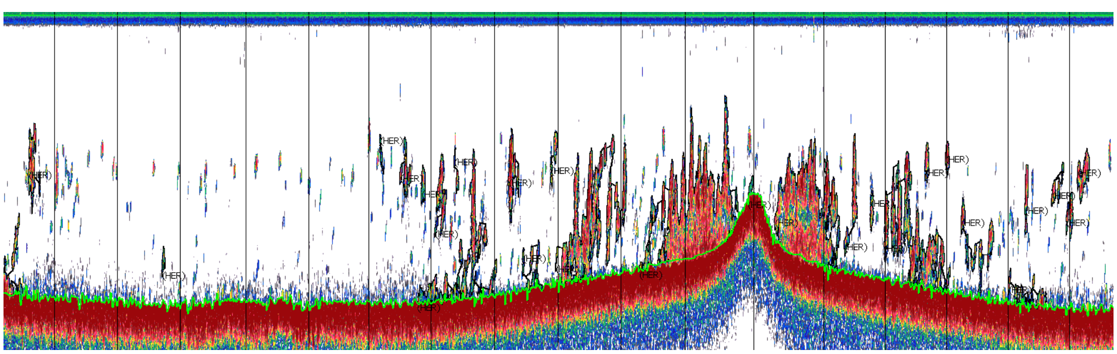
(a)



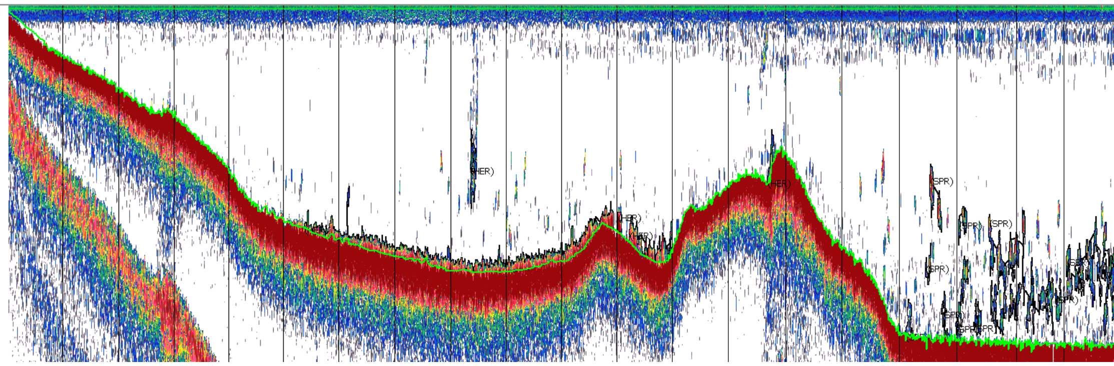
(b)



(c)



(d)



(e)

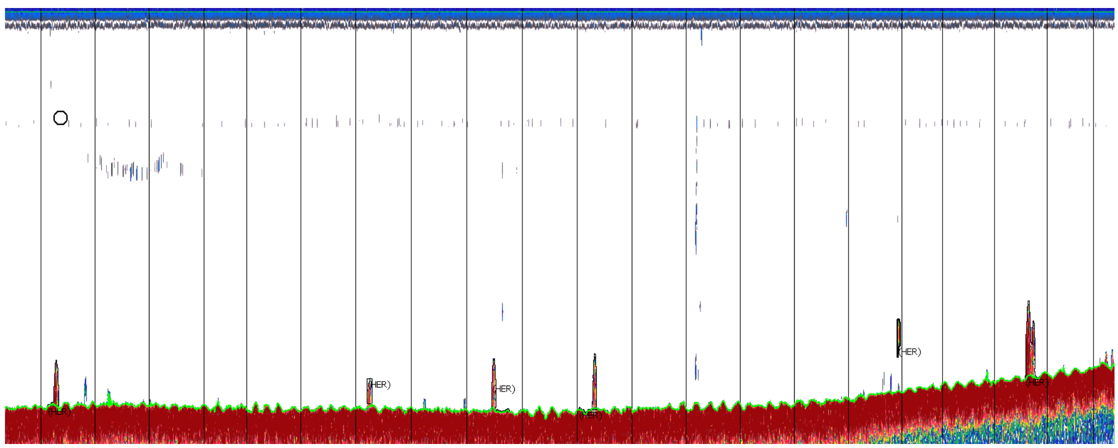


Figure 2.19. 6aS/7b industry acoustic survey in 2020. (a) A series of very strong herring marks (38 kHz) in Lough Foyle, Co. Donegal (ICES area 6aS). Water depth max ~ 15m approximately. (b) A series of strong herring marks (38 kHz) in Lough Swilly, Co. Donegal (ICES area 6aS). Water depth max ~ 18m approximately. (c) A series of strong herring marks (38 kHz) in Bruckless Bay, Co. Donegal (ICES area 6aS). Water depth max ~ 20m approximately. (d) Herring marks (38 kHz) tight to the bottom in Inver Bay, Co. Donegal (ICES area 6aS). Some less strong sprat marks are also visible on right hand side of echogram. Water depth max ~ 20m approximately. (e) A series of small herring marks (38 kHz) tight to the bottom in Achill (Clew Bay), Co. Mayo (ICES area 7b). Water depth max ~ 30m approximately.

2.2.6.2 *Age disaggregated abundance estimation*

The process for estimating abundance and biomass from the acoustic data is shown in Figure 2.20, with additional description given below.

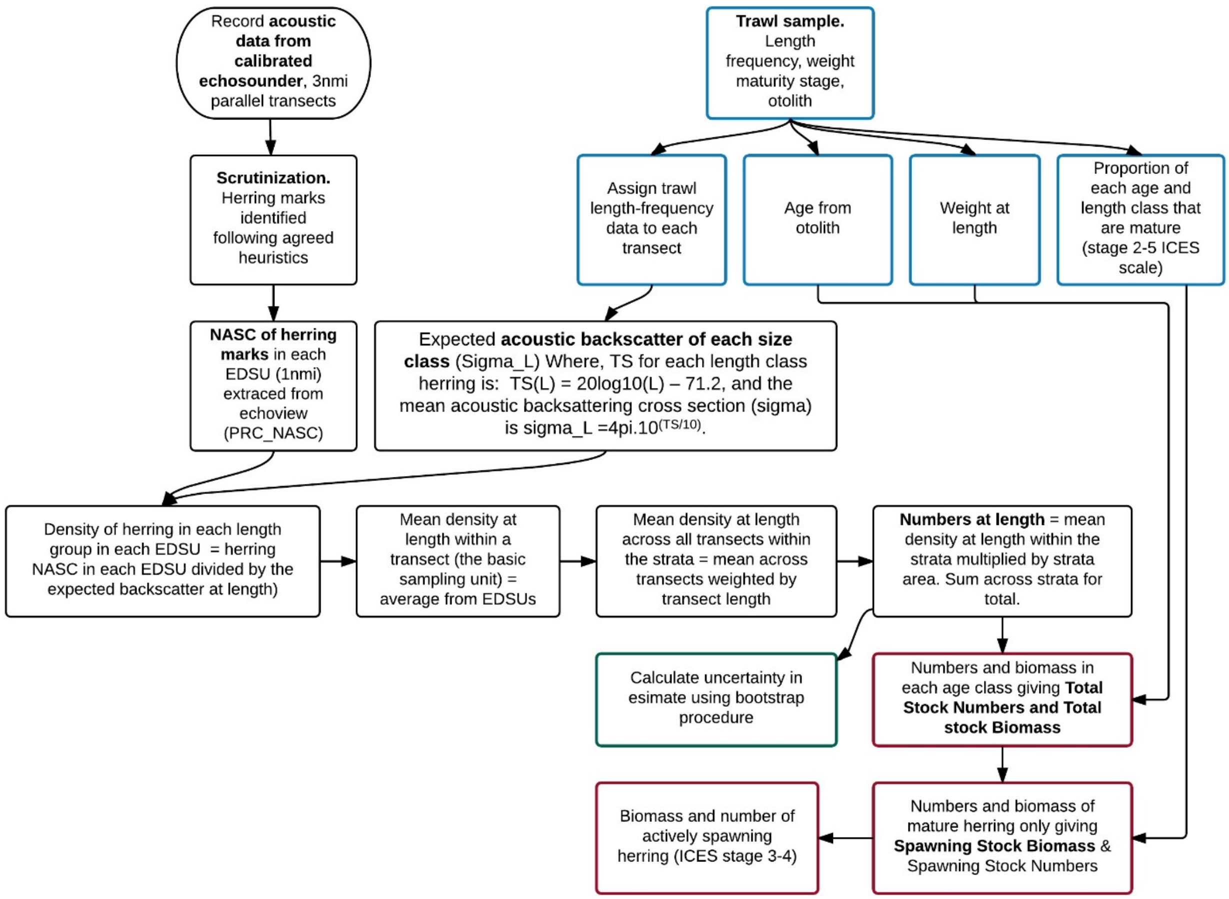


Figure 2.20. Flow diagram of the analysis methods to estimate abundance and biomass. Blue boxes – biological data; black boxes – treatment of acoustic data; red boxes- derived abundances indices; green box – uncertainty estimates

The StoX software (Johnsen et al, 2019)[2] was used to calculate the age disaggregated acoustic abundance estimates. StoX is an open source software developed at IMR, Norway to calculate survey estimates from acoustic and swept area surveys. The program is a stand-alone application built in Java for easy sharing and further development in cooperation with other institutes, and is now routinely used to derive abundance estimates from WGIPS coordinated surveys. Documentation and user guides are available from the website. Estimation of abundance from acoustic surveys with StoX is

[2] http://www.imr.no/forskning/prosjekter/stox/nb-no

carried out according to the stratified transect design model developed by Jolly and Hampton (1990).

The scrutinisation of the echograms was first performed using the LSSS or Echoview post-processing software and Nautical Area Scattering Coefficient values assigned to herring marks were exported for each 1nm cell. Then, the calculation of age disaggregated abundance was as follows:

1. **Define survey strata.** In 6aN, two strata were defined. In 6aS/7b, 6 core strata were defined in 2020, (i) Lough Foyle, using zig-zag transects, where the boundaries of the strata was delineated approximately 50m either side of the centre line of the deepest part of the 3 main Lough Foyle channels in approximately 10 – 20m water depth. (ii) Lough Swilly, using zig-zag transects, where the boundaries of the strata was delineated approximately 100m either side of the centre line of the deepest part of the Lough Swilly channel in approximately 10 – 20m water depth. (iii) Parallel transects with ~1.0 nmi spacing including shallow inshore areas of Bruckless Bay, Fintra Bay Inver Bay and Achill.
2. **Assigning herring length data from trawls to acoustic transects.** For each transect within each survey strata, the length distribution of herring associated with the transect was determined as the un-weighted mean of all trawls allocated to the respective transects. The allocation of trawls to each transect is shown in Figure 2.21 for the Ocean Star and Alida surveys respectively. Discussion over concerns regarding the impact of limited samples from each survey led to the decision to combine the biological samples from both vessels and apply them to acoustic data to estimate abundance and biomass from each survey separately.
3. **Expected backscattering cross section of fish in each length group.** The mean acoustic backscattering cross-section "sigma" (σ_{bs}) for each length group of herring was calculated from the length frequency data assigned to each transect using the target strength-length relationships for herring recommended by the ICES Working Group on International Pelagic Surveys. Where, the target strength (TS) relationship used to calculate the mean acoustic backscattering cross-sections for herring is:

TS = 20log10 (L) – 71.2 [at 38 kHz] *for herring*

TS = 20log10 (L) – 67.5 [at 38 kHz] *for horse mackerel*

TS = 20log10 (L) – 76 dB [at 120 kHz] *for herring* and the mean acoustic backscattering cross section is:

$$\sigma_{sp} = 4\pi . 10^{(TS/10)}$$

4. **The average density of herring in each length class on a single transect** was calculated by dividing the Nautical Area Scattering Coefficient (NASC - the area backscattering coefficient for a particular integration region in areal units (m^2/nmi^2), within each Elementary Distance Sampling Unit (EDSU, here =1nmi or 0.5nmi) on each transect by the length-specific σ_{bs} (acoustic fish backscatter) assigned to the transect, then averaging over the EDSUs.
5. **Numbers of herring in a single stratum & total numbers.** For each length group, a weighted average (weighted by transect length) of the mean density of herring in each transect is multiplied by the area of the stratum. Total numbers at length is the sum for each stratum.
6. **The numbers and biomass per age & maturity class.** Trawl data on the relationship between length, age and maturity stage were used to partition the numbers at length to estimates of numbers and biomass in each age class and maturity stage. The 9 point maturity stage classification used in the Scottish and Irish sampling (MSS manual 2011) was converted to the ICES 6 point scale prior to analysis (Table 2.5) (ICES 2011).
7. **Estimate of the relative sampling error.** Within StoX a bootstrap procedure was used to estimate the coefficient of variance (CV) of the estimate of numbers at length. The procedure randomly selects transects within a stratum in every n bootstrap iteration (n =1000 check). For each selected transect, biological information from trawl stations that were assigned to the transect are randomly sampled and used as input to estimate fish abundance in the stratum in that particular bootstrap iteration. Each bootstrap iteration follows the same estimation procedures as used in StoX and described above (using the combination of mean acoustic density per transect and associated biological information, to estimate fish numbers at length in each stratum). This procedure was not performed for the 6aN survey this year because of difficulties in getting the StoX software to work.
8. **Choosing the best estimate from replicates**. In the 6aN, where replicate acoustic surveys were conducted for each stratum, the maximum biomass estimate of these was chosen as the best estimate.

Acoustic data were recorded on hard-drives at sea and uploaded to network facilities back at the laboratory. The acoustic metadata and cleaned post-processed EV files are stored on the SPFA's secure cloud storage, WMR network drives and in Marine Scotland Science data base following established procedures. 6aS/7b raw and processed data are stored at the Marine Institute, Ireland. Estimates of NASC values and biological sample data from the surveys are stored in the ICES acoustic database, since surveys began in 2016.

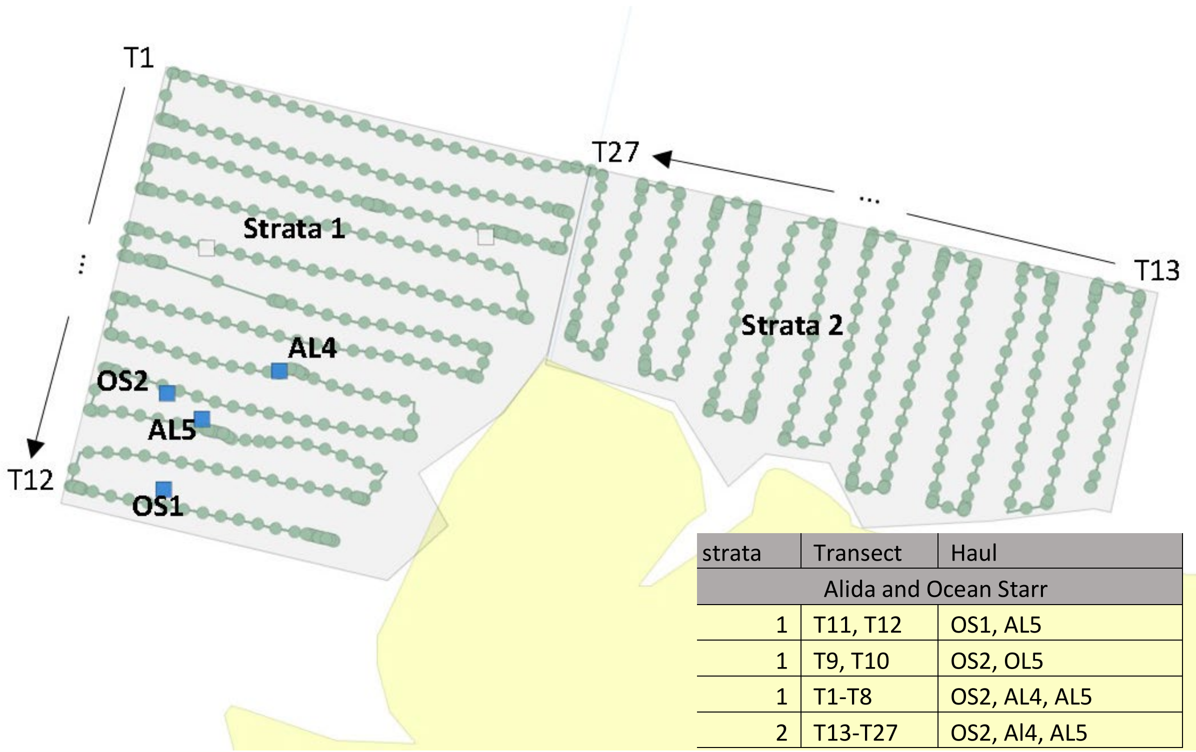


Figure 2.21. Acoustic transects and haul identifiers used in analyses and assignment of biostations.

Table 2.5. Translation of Marine Scotland 9 point maturity scale to ICES 6 point scale

NINE POINT MATURITY SCALE (MARINE SCOTLAND MANUAL)	EQUIVALENT ICES SCALE STAGE
1 Immature virgin	1 (Immature)
2 Immature	1 (Immature)
3 Early maturing	2 (Mature – but not included in spawning category))
4 Maturing	2 (Mature – but not included in spawning category)
5 Spawning prepared	3 (Mature – included in spawning category)
6 Spawning	3 (Mature – included in spawning category)
7 Spent	4 (Mature – Spent – included in spawning category)
8 Recovering/resting	5 (Mature – resting - not included in spawning category)
9 Abnormal	6 (Abnormal – not included in Mature or spawning categories)

3 Results

3.1 Sampling summary

3.1.1 Sampling statistics 6aN

In 6aN the survey vessels covered strata 1 and 2 between the between 2020-08-30 and the 2020-09-19 (Figure 3.1), making a total of 7 hauls for biological sampling resulting in biological information collected from a total of 855 herring. No samples were obtained from Strata 2.

Length distributions of herring from both vessels revealed and abundance of small immature fish (av. ~20cm), but the overall combination of samples from Ocean Star recorded a much higher proportion of these small fish (Figure 3.1, 3.2). Age reading confirmed that the small fish were predominantly age 1 (Figure 3.3).

All maturity data were converted into a common six point scale, in which stage 1 is immature, stage 2 is ripening, stage 3 is spawning and stage 4 is spent or resting. Only one spawning herring was found in the samples (Figure 3.4, 3.5).

Maps of the relative acoustic density, and locations of hauls whose biological data was used in for the estimation of the biomass of herring in 6aN are shown in Figure 3.6, Table 3.1.

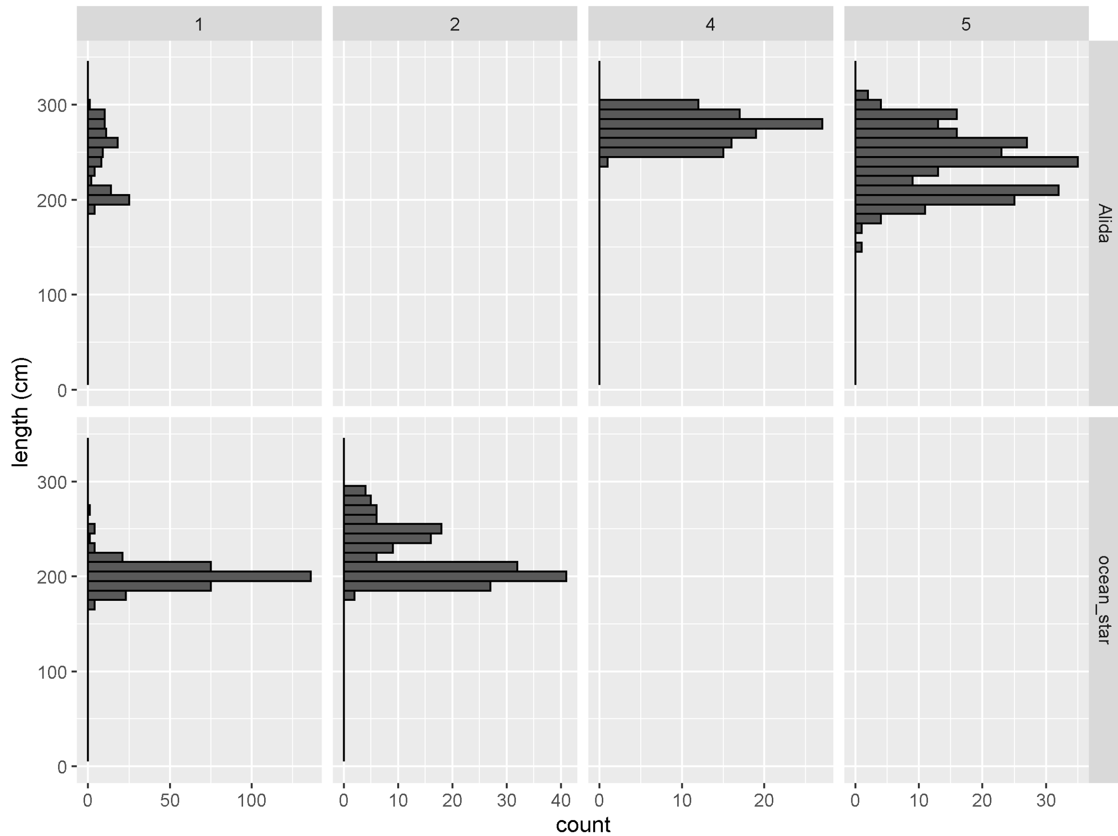


Figure 3.1. Herring length frequencies for the sample hauls taken by the Ocean Star and the Alida.

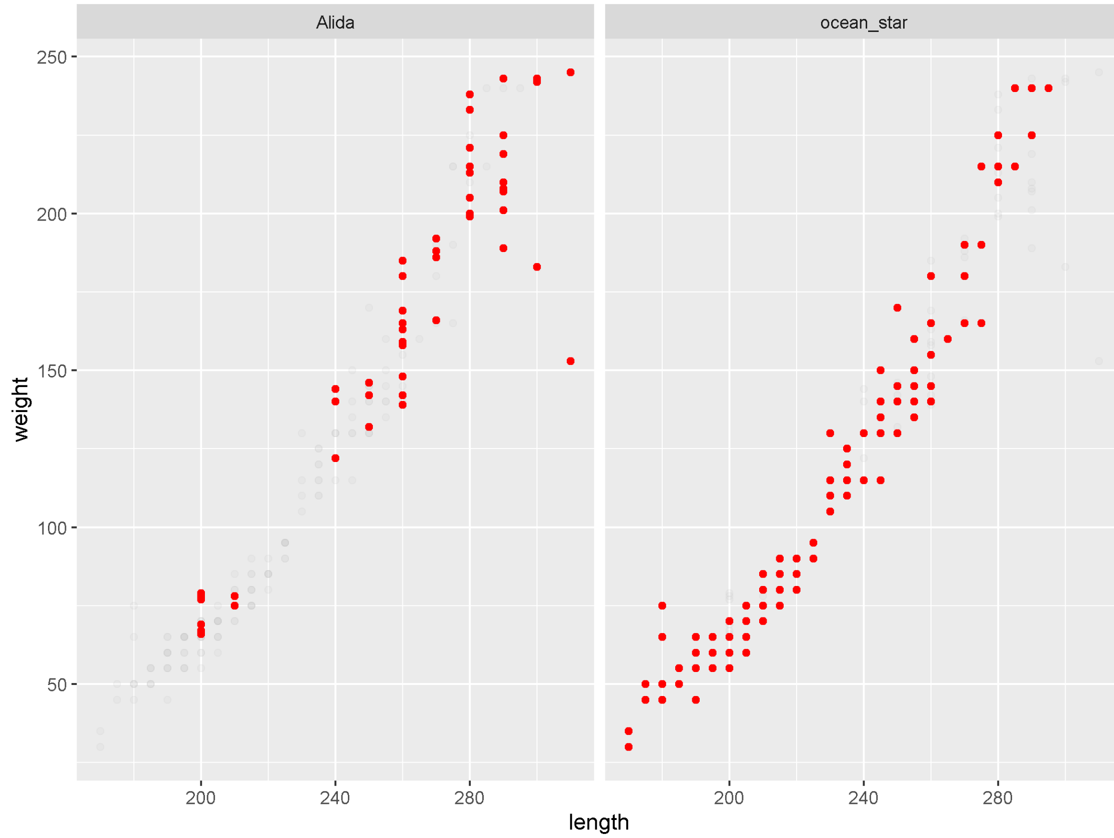


Figure 3.2. Herring weight length for the sample hauls taken by the Ocean Star and the Alida. Red circle markers are data from each individual surveys and grey circle markers are those combined for both surveys.

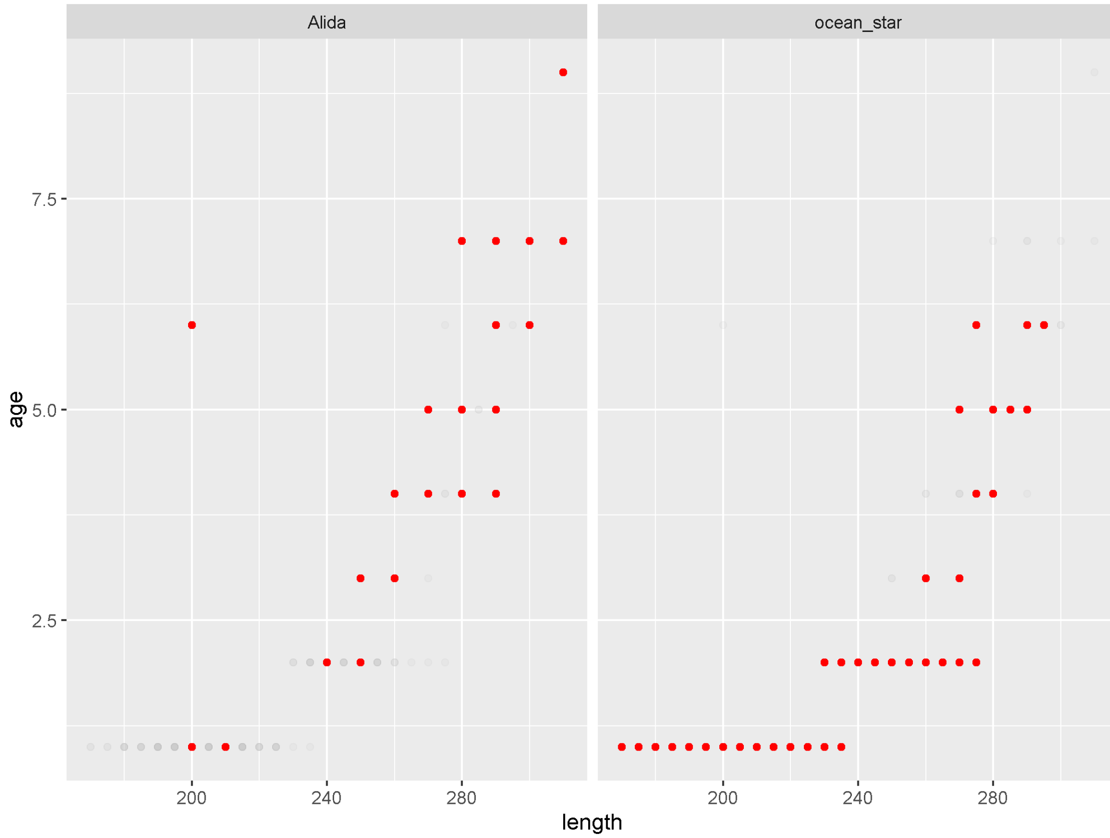


Figure 3.3. Herring age length keys for the sample hauls taken by the Ocean Star and the Alida. Red circle markers are data from each individual surveys and grey circle markers are those combined for both surveys

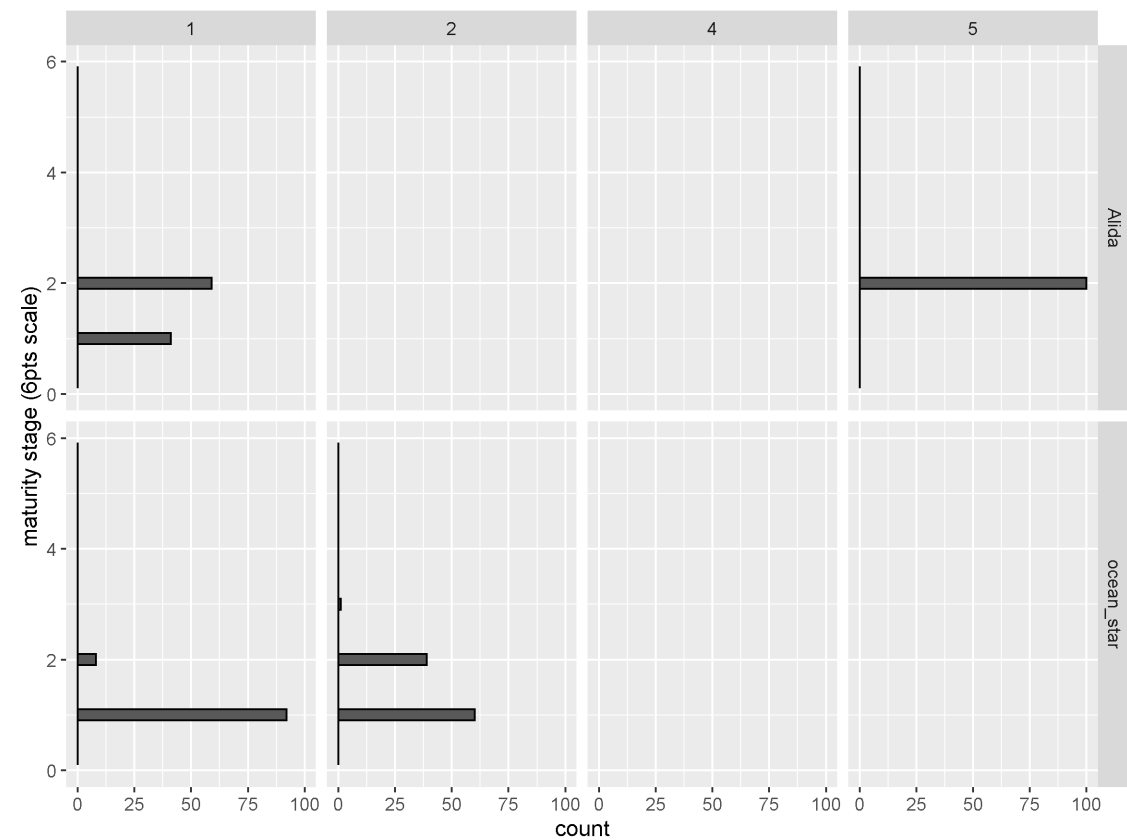


Figure 3.4. Herring maturity scales for the sample hauls taken by the Ocean Star and the Alida. Individuals with maturity stages 3 and 4 are considered spawners.

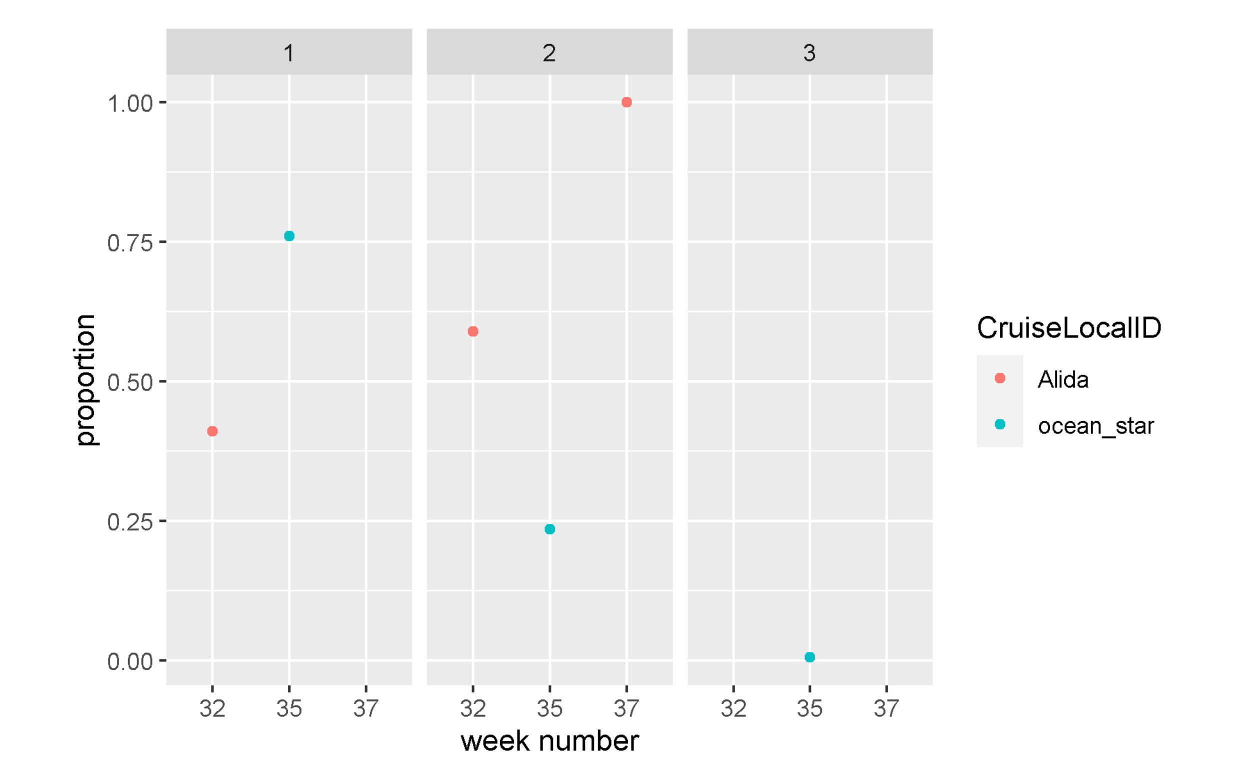


Figure 3.5. Proportion of maturity stage by date. Maturity stage 3 refers to spawning herring.

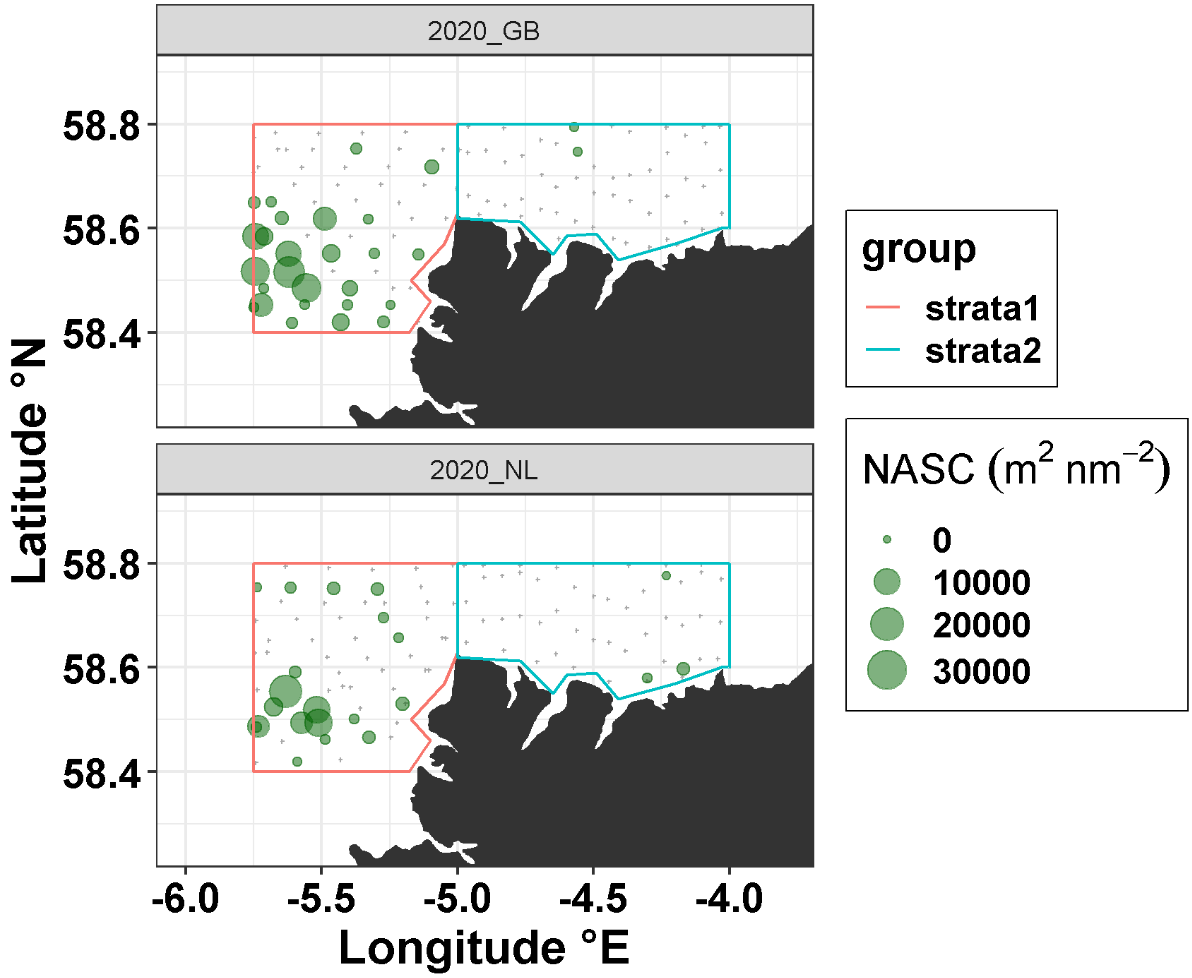


Figure 3.6. Maps of relative acoustic density in the two surveys (GB-Ocean Star, NL-Alida)

Table 3.1. Haul information and catch composition for hauls relevant to the analysis of the acoustic surveys in 6aN.

			Position			Catch (kg)						
Vessel	**Haul no.**	**Date-Time**	**North**	**West**	**Used in analysis area**	**HER**	**HOM**	**MAC**	**NOP**	**WHG**	**WHB**	**Jelly**
Alida	1	13/08/2020 08:30	58°98'	07°13'	Not used (commercial haul in Area 1)	55000	0	0	0	0	0	0
	2	03/09/2019 14:20	58°43'	05°07'	Not used (no herring)	0	0	500	0	0	0	0
	3	04/09/2019 08:39	58°38'	05°39'	Not used (no herring)	0	0	11.6	0	138	0	0
	4	04/09/2019 20:26	58°34'	05°26'	Applied to strata 2 and the 9 northern most transects in strata 1 (see Figure 2.21).	10000	0	0	0	0	0	0
	5	05/09/2019 09:14	58°30'	05°31'	Applied to strata 2 and the 6 southern most transects in strata 1 (see Figure 2.21).	191.2	0	8.8	0	0	0	0
Ocean Star	1	31/08/2020 08:35	58°26'	05°35'	Applied to strata 1, transect 12&13 alone and with haul 2 in strata 1 transects 1-11. Applied in combination with haul 2 to all strata 2 transects. (see Figure 2.21).	90.1	0	2.0	0	2.1	0	35
	2	31/08/2020 15:05	58°31'	05°37'	Applied with combination with haul 1 to strata 1, transects 1-11. Applied in combination with haul 2 to all strata 2 transects. (see Figure 2.21).	206.3	0	7.9	11.9	0	23.8	0
	3	01/09/2020 13:00	58°39'	05°28'	Not used (no herring)	0.0	10	150	0	0	0	20

3.1.2 Sampling statistics 6aS/7bc

Approximately 300nmi of survey track were completed successfully over six surveys in the core areas. 118 nmi of survey tracks encompassing 72 individual transects were used in the analysis. Transects from survey tracks were selected to achieve approximately equal spacing between parallel transects in each strata. Data collected on survey tracks during searching or inter-transects were eliminated during the scrutinisation process. There were 6 strata area selected for survey abundance estimation (Lough Foyle, Lough Swilly, Bruckless Bay, Fintra bay, Inver Bay, and Achill). This resulted in a total area coverage of approximately 66.26 nmi². A total of ten biological samples were obtained from commercial tows on herring during the fishery (Figure 3.7 and Table 3.2). The fishery in 6aS/7b began in mid-November and continued throughout the survey period. All of the fishing activity was inshore in shallow water and in the same areas where the survey took place.

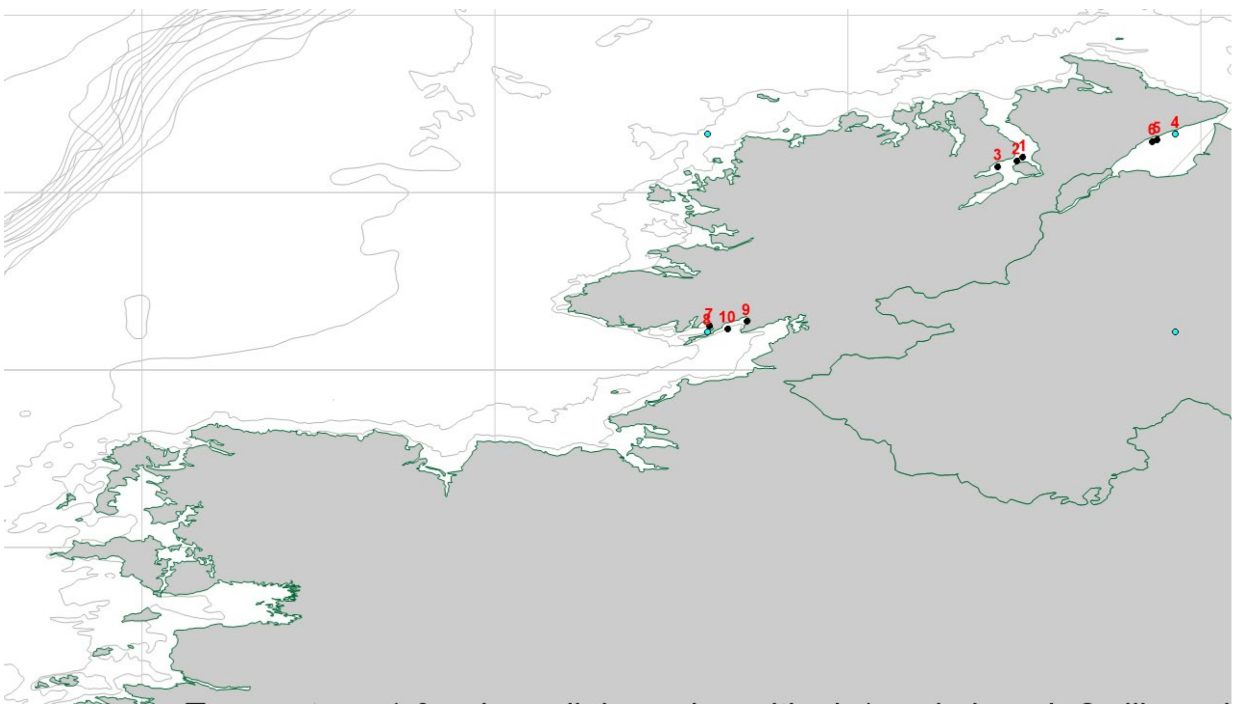


Figure 3.7. 6aS/7b industry acoustic survey in 2020: Distribution of biological samples obtained in 6aS/7b - all samples were inshore from the monitoring fishery taking place at the same time.

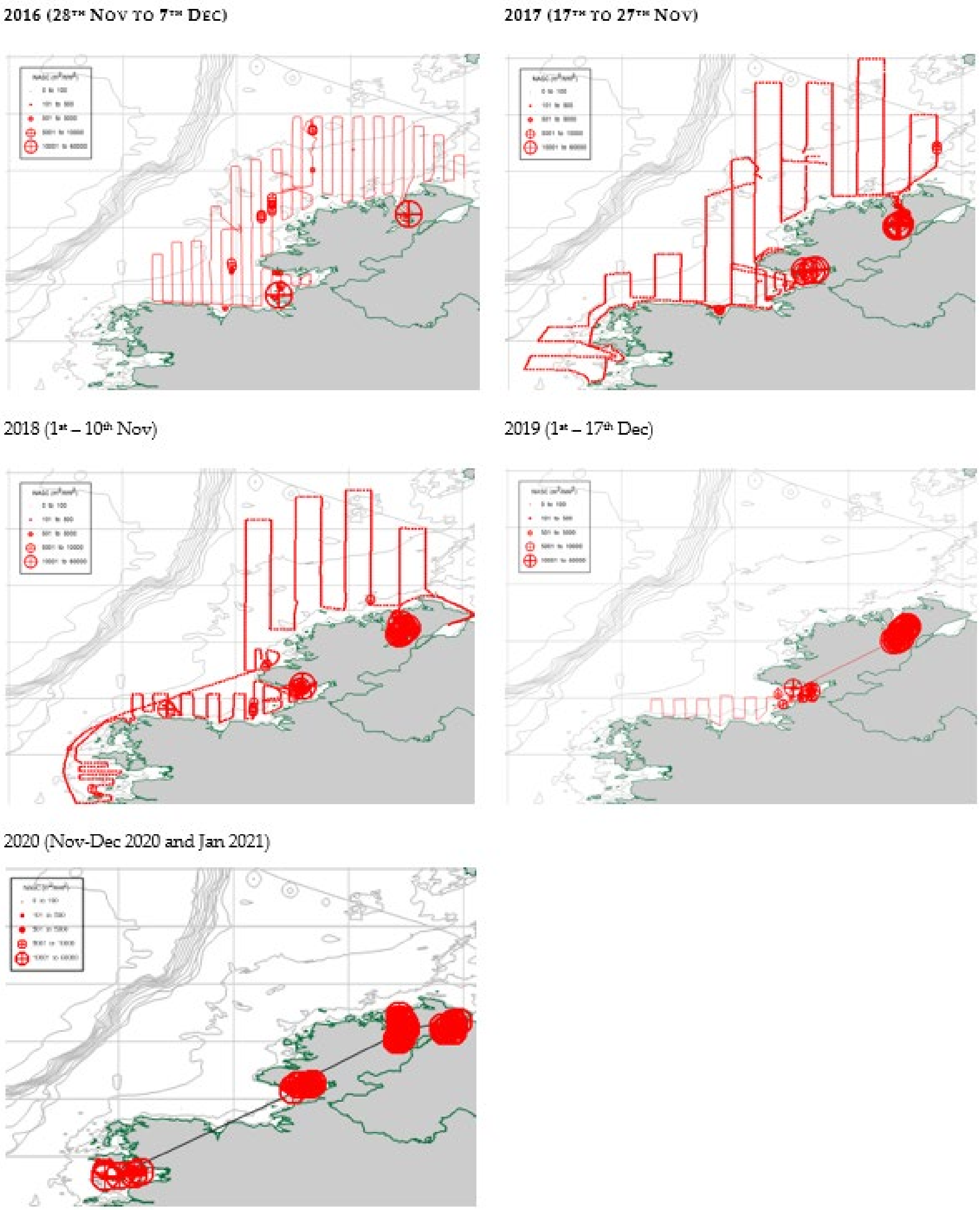


Figure 3.8. 6aS/7b industry acoustic survey 2016 - 2020: NASC distribution in the surveys 2016-2020. The survey design has been evolving since its inception in 2016. In 2020, area covered was much reduced compared to previous years. Only 6 core areas were surveyed where there was prior knowledge from the monitoring fishery that there were herring present.

Table 3.2. 6aS/7b industry acoustic survey in 2020: details of biological samples from the fishery hauls used in the survey estimates.

Haul no.	Date	ICES area	Ground	Measured	Otoliths	Gear
1	11/11/2020	6aS	Lough Swilly	298	73	Pair trawl
2	11/11/2020	6aS	Lough Swilly	382	75	Pair trawl
3	11/11/2020	6aS	Lough Swilly	121	54	Pair trawl
4	12/11/2020	6aS	Lough Foyle	372	91	Single trawl
5	15/11/2020	6aS	Lough Foyle	416	91	Single trawl
6	19/11/2020	6aS	Lough Foyle	392	86	Single trawl
7	23/11/2020	6aS	Bruckless Bay	425	63	Pair trawl
8	24/11/2020	6aS	Bruckless Bay	393	58	Pair trawl
9	07/12/2020	6aS	Inver Bay	224	58	Ringnet
10	15/12/2020	6aS	Inver Bay	291	54	Pair trawl

Very strong herring marks were evident in Lough Foyle and Lough Swilly (Figure 2.19) in the channel in marks that extended for many miles. This was also an area where smaller boats in the fishery were concentrating effort. There were a series of herring marks in Bruckless Bay and Inver Bay in discreet areas. There were some herring marks in the Achill strata (Clew Bay and around the Bills and Clare Island, and there was some evidence of small marks between the islands. Consequently, the distribution of herring NASC values is dominated by Lough Foyle and Lough Swilly in particular, and distribution was generally similar to previous years (Figure 3.8). Some sprat marks were evident in the Bruckless and Inver Bay areas.

The relative length frequency distributions of herring in the samples used by the survey from the fishery in 2020 is shown in Figure 3.9a. There was a good spread of length classes in all hauls, with most hauls dominated by larger (> 22 cm) mature fish. Larger fish were particularly evident in Lough Foyle (hauls 1, 2 and 3) and Lough Swilly (hauls 4, 5 and 6). Slightly smaller herring were found in hauls 7, 8, 9 and 10 (hauls from Bruckless and Inver Bay). The samples were dominated by mature fish (Table 3.3b), expected in fish captured close to areas and times where spawning is known to occur during this time (Table 2.1).

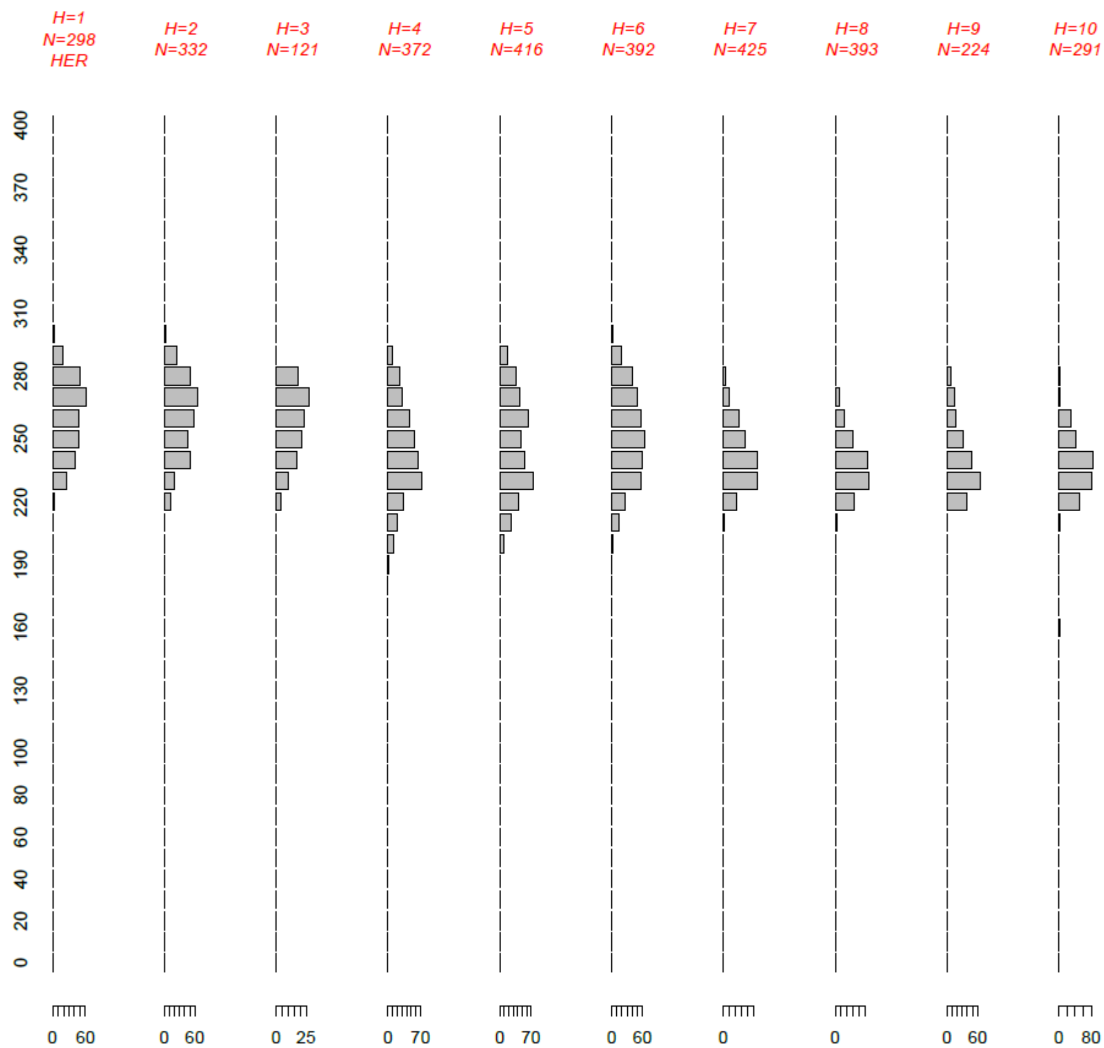


Figure 3.9a. 6aS/7b industry acoustic survey in 2020: relative length (cm) frequency distributions of herring in each haul that contained herring.

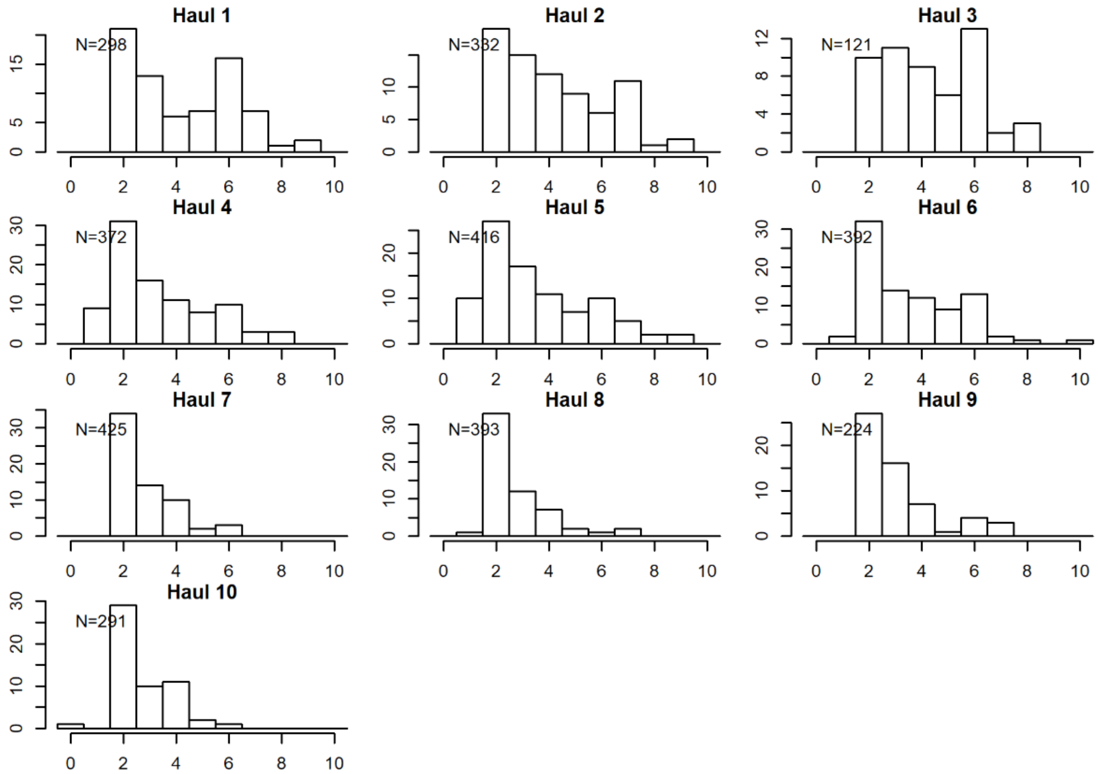


Figure 3.9b. 6aS/7b industry acoustic survey in 2020: relative age (-wr) frequency distributions of herring in each haul.

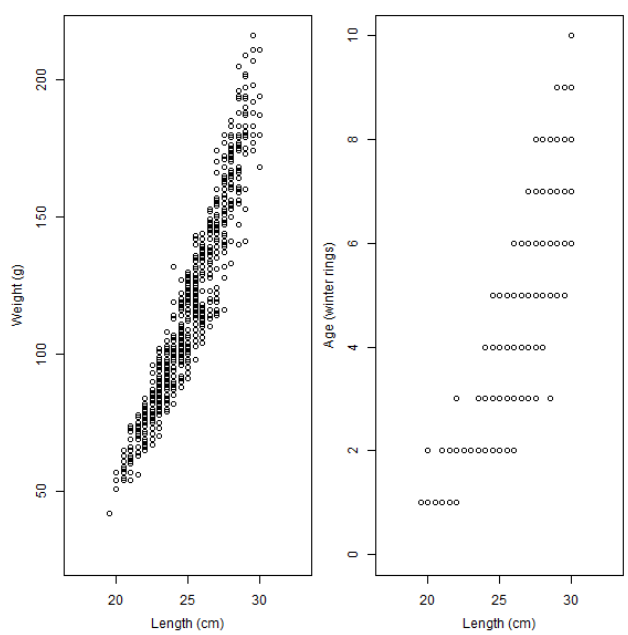


Figure 3.10. 6aS/7b industry acoustic survey in 2020: weight at length and age at length of herring.

The 2- and 3-wr age class of herring accounted for 54% of the overall numbers (2-wr ~ 32% and 3-wr ~22%) in 2020 (Table 3.3a). This follows on from 2019 when the 1- and 2-wr age class of herring constituted 52% of the overall numbers. The 4-wr in 2020 made up 15% of the numbers, similar to 2019 when 3-wr were also 15%. There is still a relatively strong 6-wr age class showing in 2020, at 12%, compared to 11% at 5-wr in 2019. Maturity at age for 6aS/7b herring is shown in Table 3.3b. Approximately 92% of 1-wr herring were immature, but 1-wr herring were found in low numbers in 2020 on the survey compared to 2019. 5.2% of 2-wr herring were immature, in line with other years. Maturity scales used for herring are shown in Table 2.4.

Table 3.3a. 6aS/7b industry acoustic survey in 2020: relative age (wr) distribution for 6aS/7b herring in 2020.

Age (winter rings)	*Relative age distribution (%) Herring*
0	**0.01**
1	**2.28**
2	**31.92**
3	**21.83**
4	**14.89**
5	**9.49**
6	**12.19**
7	**5.45**
8	**1.09**
9	**0.76**
10	**0.10**

Table 3.3b. 6aS/7b industry acoustic survey in 2020: maturity at age for 6aS/7b herring in 2020.

Age (winter rings)	*Immature (%)*	*Mature (%)*
0	100	0
1	91.6	8.4
2	5.2	94.8
3	0.1	99.9
4	0	100
5	0	100
6	1.2	98.8
7	0	100
8	0	100
9	0	100
10	0	100

3.2 Abundance estimation

Biological data were used to estimate the abundance and biomass of herring in each strata according to length, age and maturity stage.

3.2.1 6aN

3.2.1.1 2020 results

A summary table for each vessel's coverage of their entire surveyed area (Table 3.4) and breakdown for each area (Table 3.5) is followed by a summary of the maximum biomass recorded in each of the surveyed areas, including the CV of the biomass estimate (Table 3.6). CVs on biomass estimates are highest where the biomass estimates are derived from few concentrated marks occurring over a limited number of transects, and lower where marks are more evenly spread across the area. CVs on abundance at age are generally poor across all ages, reflecting relatively low sample sizes.

Total biomass estimates are similar between Ocean Star and Alida, but the age structure is different with Ocean Star reporting a higher abundance of age 1 immature fish and Alida a more even spread of ages (Table 3.4, 3.5 Figure 3.11, 3.12). Both vessels recorded very low abundance in Strata 2. (Table 3.5).

Table 3.4a. Combined results for all strata covered by Ocean Star in 2020. (Figures in bold are weighted averages based on the numbers in each age group).

	Numbers (mill)	Biomass (kt)	Maturity	Weight (g)	Length (cm)
0	1	0	0.00	27.49	15.00
1	170	12	0.01	69.87	20.39
2	82	11	0.81	133.03	24.51
3	38	6	1.00	156.10	25.82
4	25	5	0.97	202.94	27.71
5	19	4	1.00	207.36	27.88
6	17	4	1.00	221.19	29.27
7	10	2	1.00	212.21	29.06
8	0	0	0.00	0.00	0.00
9	1	0	1.00	245.00	31.00
Immature	185	14		**75.05**	**20.75**
Mature	178	30		**169.17**	**26.31**
Spawning	0	0			
Total	363	44	**0.49**	**121.09**	**23.47**

Table 3.4b. Combined results for all strata covered by Alida in 2020. (Figures in bold are weighted averages based on the numbers in each age group).

	Numbers (mill)	Biomass (kt)	Maturity	Weight (g)	Length (cm)
0	1	0	0.00	27.26	15.00
1	119	8	0.02	70.76	20.41
2	63	8	0.82	133.41	24.46
3	26	4	1.00	156.85	25.76
4	20	4	0.95	195.37	27.36
5	17	4	1.00	212.98	28.09
6	12	2	0.88	207.60	28.06
7	7	2	1.00	217.94	29.38
8	0	0	0.00	0.00	0.00
9	1	0	1.00	245.00	31.00
Immature	131	10		**76.02**	**20.88**
Mature	134	23		**169.33**	**26.11**
Spawning	0	0			
Total	266	33	**0.51**	**123.20**	**23.52**

Table 3.5a. Ocean Star strata summary

	Abundance (mill)	Biomass (kt)	Mean length (cm)	Mean weight (g)	% mature
Strata1	363	44	23.47	121.07	0.49
Strata2	0	0	24.53	139.24	0.62
total	363	44			

Table 3.5b. Alida strata summary

	Abundance (mill)	Biomass (kt)	Mean length (cm)	Mean weight (g)	% mature
Strata1	262	32	23.51	122.99	0.50
Strata2	3	0	24.53	139.49	0.61
total	266	33			

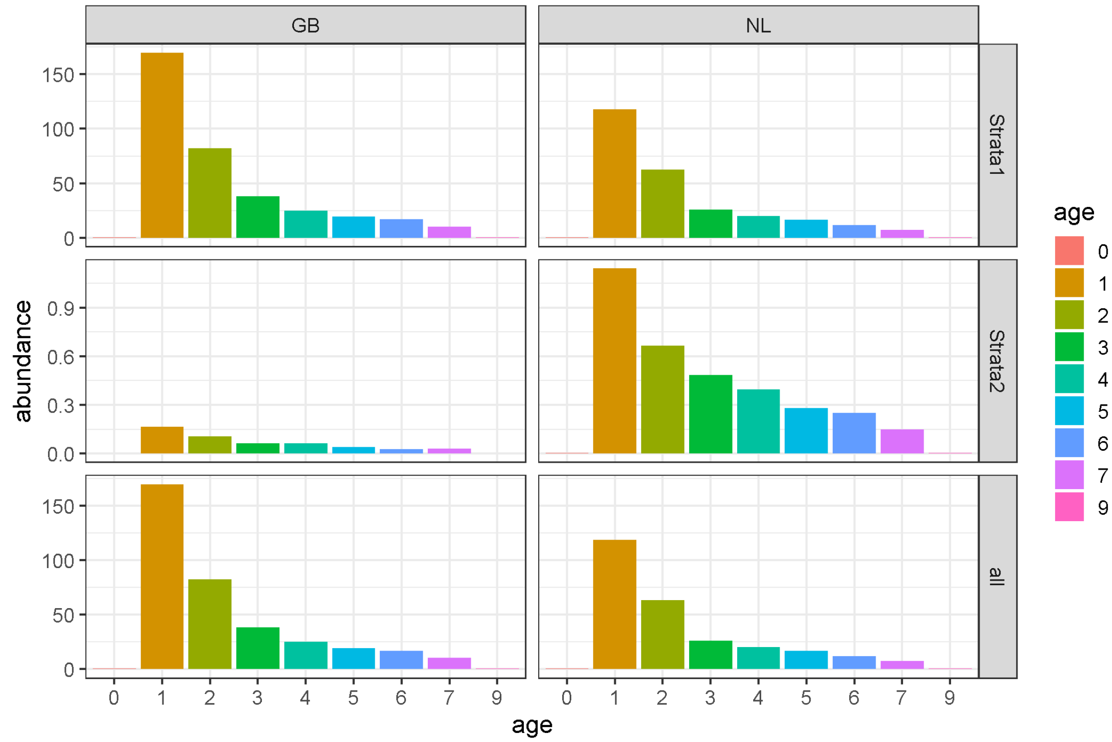


Figure 3.11. Combined abundance at age and per strata for the two 2020 surveys: GB is the survey from the Ocean Star and NL is the survey from the Alida.

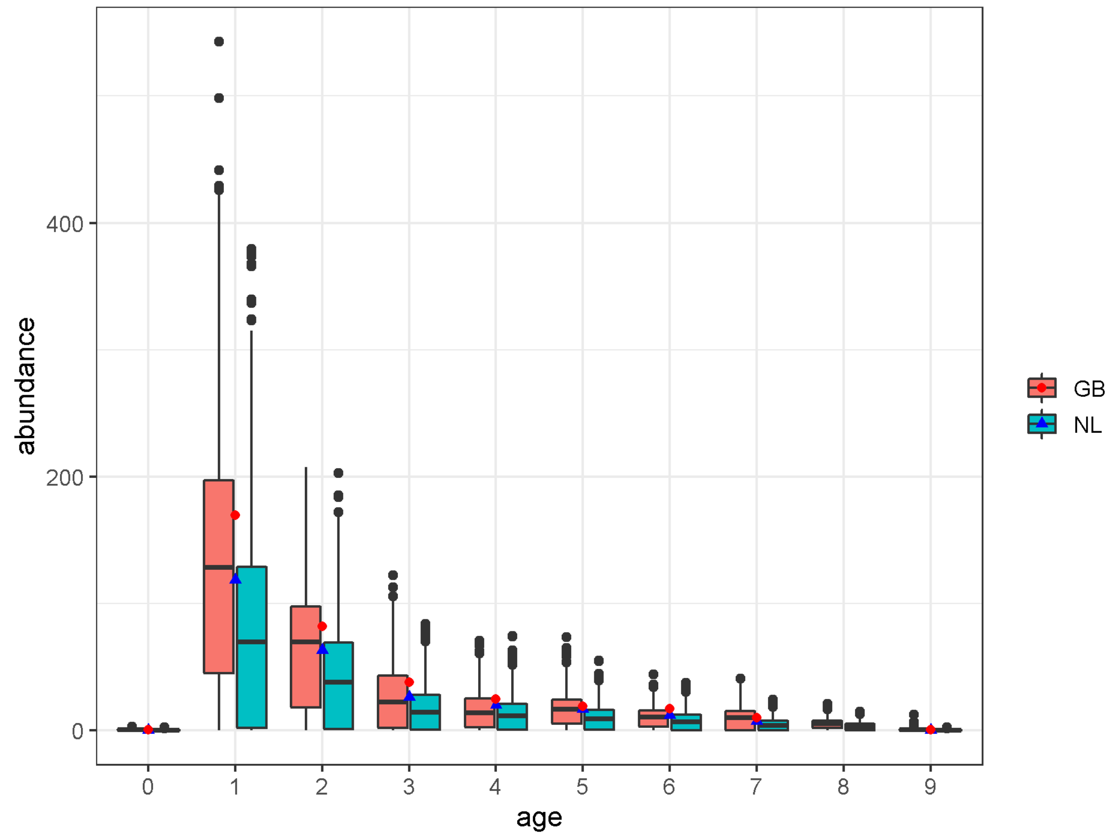


Figure 3.12. Abundance at age from the baseline and bootstrap runs. The red circle markers and red boxes are the results from the Ocean Star. The blue triangle markers and blue boxes are the results from the Alida.

Table 3.6. Summary CV estimates for survey areas in 2020.

	Ocean Star			Alida		
	Strata1	Strata2	total	Strata1	Strata2	total
5% abundance	152	0	152	74	0	75
50% abundance	337	1	338	234	3	239
95% abundance	545	2	545	498	9	504
mean abundance	340	1	340	252	4	255
sd abundance	124	0	124	132	3	132
CV abundance	0.37	0.52	0.37	0.53	0.73	0.52
5% biomass	18	0	18	9	0	10
50% biomass	40	0	41	29	0	29

95% biomass	67	0	67	60	1	60
mean biomass	41	0	41	31	0	31
sd biomass	15	0	15	16	0	16
CV biomass	0.36	0.50	0.36	0.52	0.68	0.51

3.2.1.2 *Historical perspective*

Pelagic industry and scientific institutions from Scotland, Ireland, Northern Ireland, The Netherlands, and England have worked closely together since 2016 to undertake scientific surveys on herring stocks in 6aN and 6aS,7bc. These surveys were conducted during pre-spawning and spawning time, with the aim of providing relevant data and information to ICES to assist in determining the identity of stocks and assessing their status.

The principal purpose of the acoustic survey is to provide an index of abundance and biomass for all mature stages and ages of herring, and a separate index for those in spawning condition (ICES maturity scale stage 3-4, Marine Scotland scale 5-7). The utility of the '6aSPAWN' acoustic indices for use in stock assessment will be evaluated during the benchmark process in the first quarter of 2022.

A summary of the surveys and how the design and implementation has adapted over time is provided in the report of the ICES Workshop on Herring Acoustic Spawning Surveys (WKHASS). The review by WKHASS reflected on how survey designs had evolved to explore appropriate timing and spatial containment, and investigated how the designs and sources of uncertainty affected CVs of the abundance estimates and sampling precision. This insight together with experience from the Irish Sea spawning surveys (7a) were particularly helpful in thinking about design refinements that would help to provide a useful index of herring abundance during spawning time.

For 6aN, it was concluded that an analysis focussing on areas 2 & 3 (labelled as such from 2016-2019), would provide the best candidates for such indices. The newly-defined focal strata (labelled 1 & 2) incorporate parts of the original survey areas 2,3 & 5 (Figure 2.5).

In preparation for the benchmark process, all acoustic data from 2016-2020 has been re-analysed to provide acoustic indices pertaining to the new Strata 1 & 2 (see Mackinson et al. 2020 working document for 6a7bc herring benchmark, in prep).

This section provides an overview of the results, showing the following:

- Distribution of acoustic density of herring (Figure 3.13)

- Abundance indices for all ages (Figure 3.14)
- Abundance estimate by length group and age (Figure 3.15)
- Abundance per year class (Figure 3.16)
- Abundance indices for mature and immature components (Figure 3.17)
- Biomass indices for maturity herring (SSB) and spawning ready herring (Spawner biomass (Figure 3.18)
- CV estimates for the abundance and biomass indices (Figure 3.19, 3.20)
- Biological indices – length, maturity and weight-at-age (Figure 3.21)
- Comparisons with WoS acoustic survey index (Figure 3.22 and Figure 3.23)

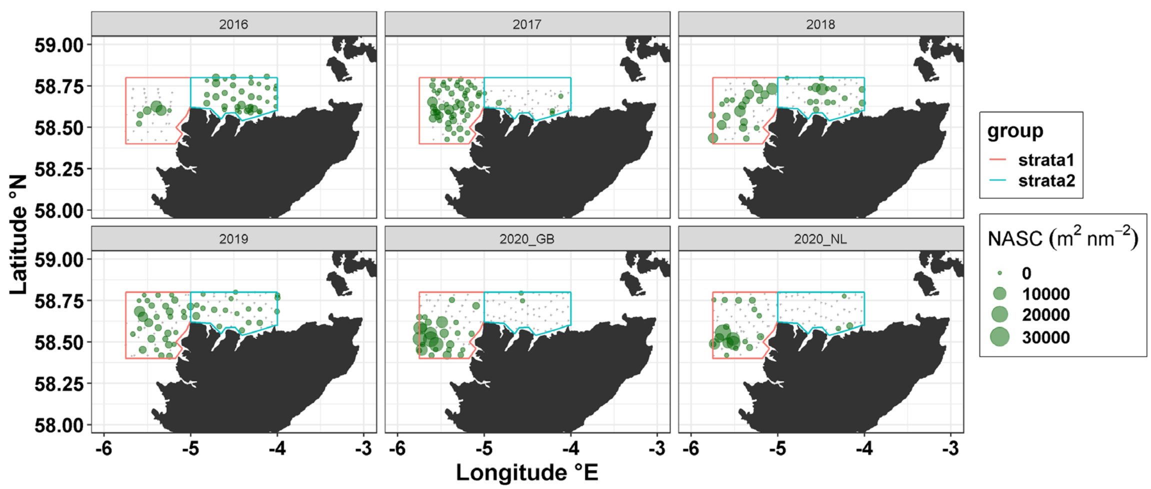


Figure 3.13. Herring acoustic density distribution (NASC) for the surveys in 6aN from 2016 to 2020. In 2020, the two surveys are plotted: 2020_GB = Ocean Star, and 2020_NL= Alida.

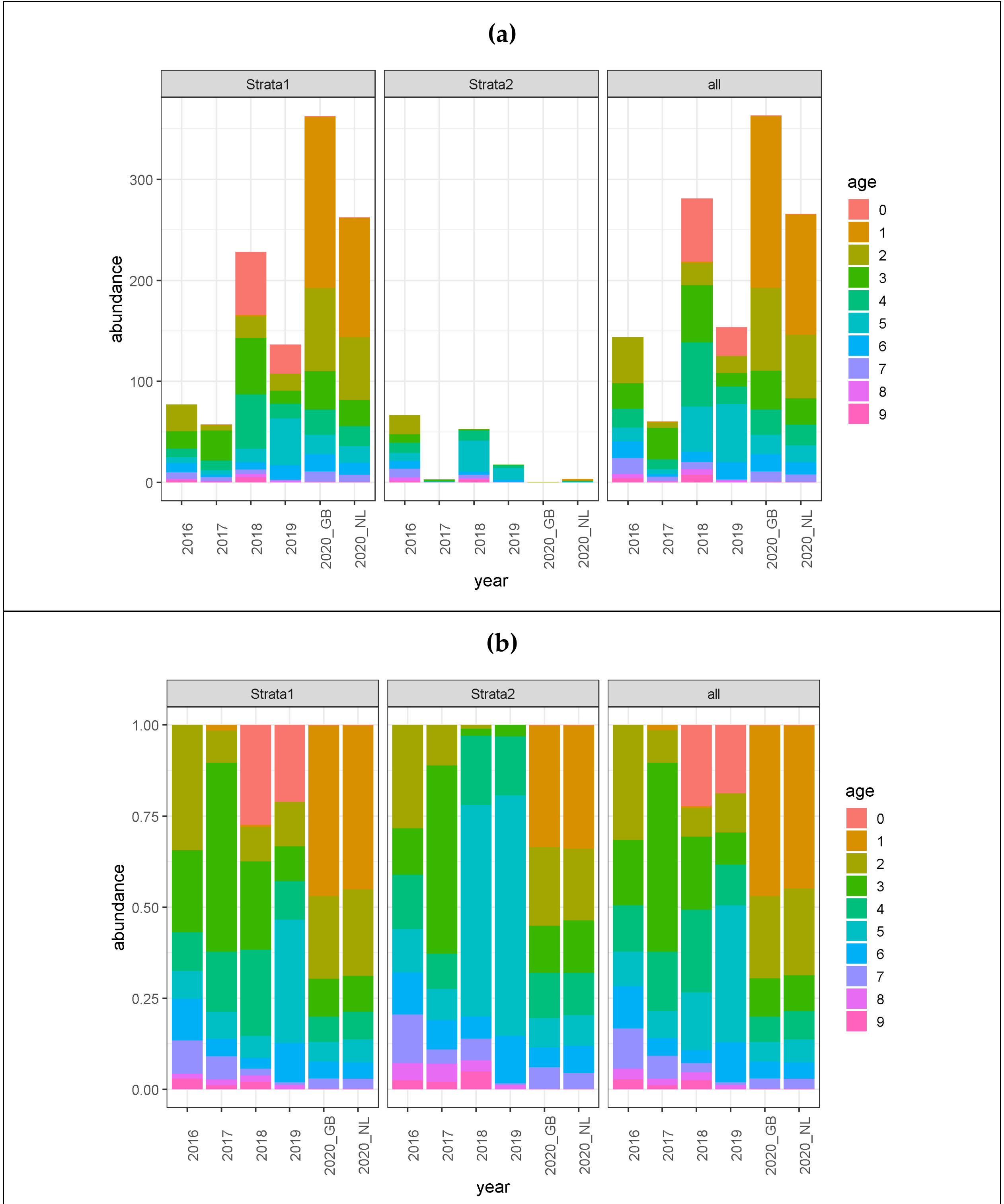


Figure 3.14. Historical abundance at age. For the 2016-2019 period, the final estimates are displayed. For 2020, both survey are shown. (a) absolute abundance levels. (b) abundance as proportion in each survey.

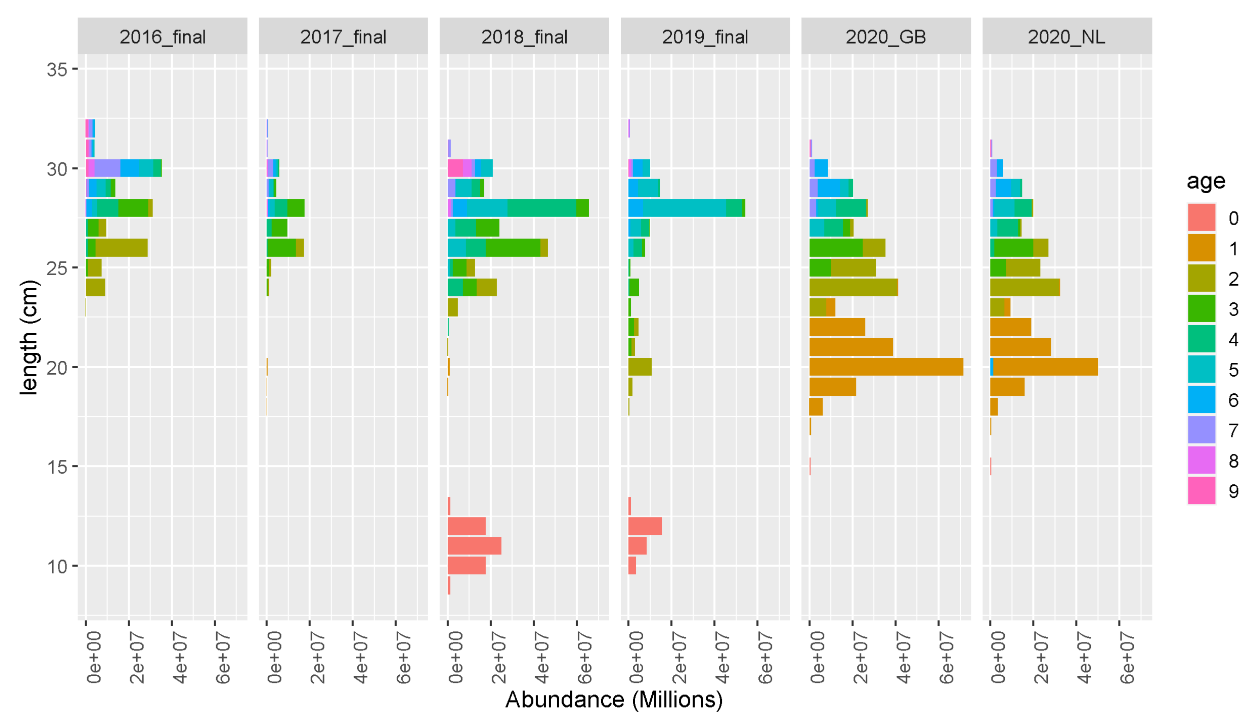


Figure 3.15. Abundance estimate by length group (1 cm bins) and age (winter rings) since 2016. For the 2016-2019 period, the final estimates are displayed. For 2020, both survey are shown.

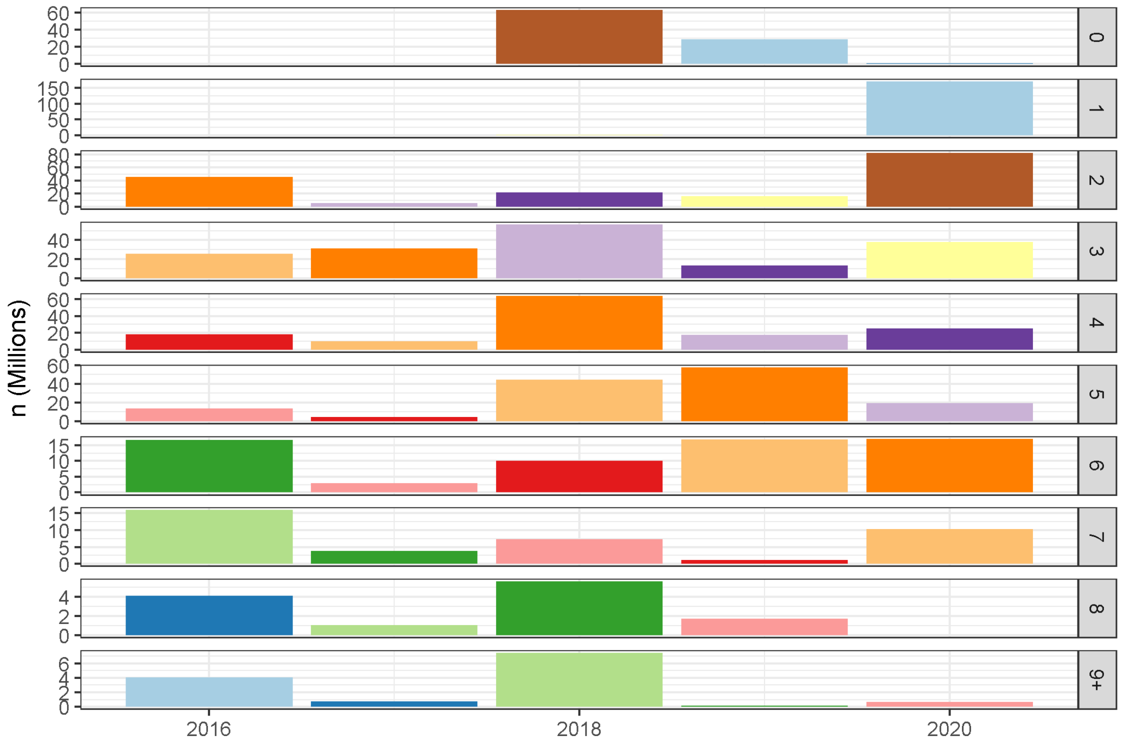


Figure 3.16. Indices at age (winter rings) and year from 2016 to 2020 (Ocean Star survey). Note diverging scales of abundance between ages.

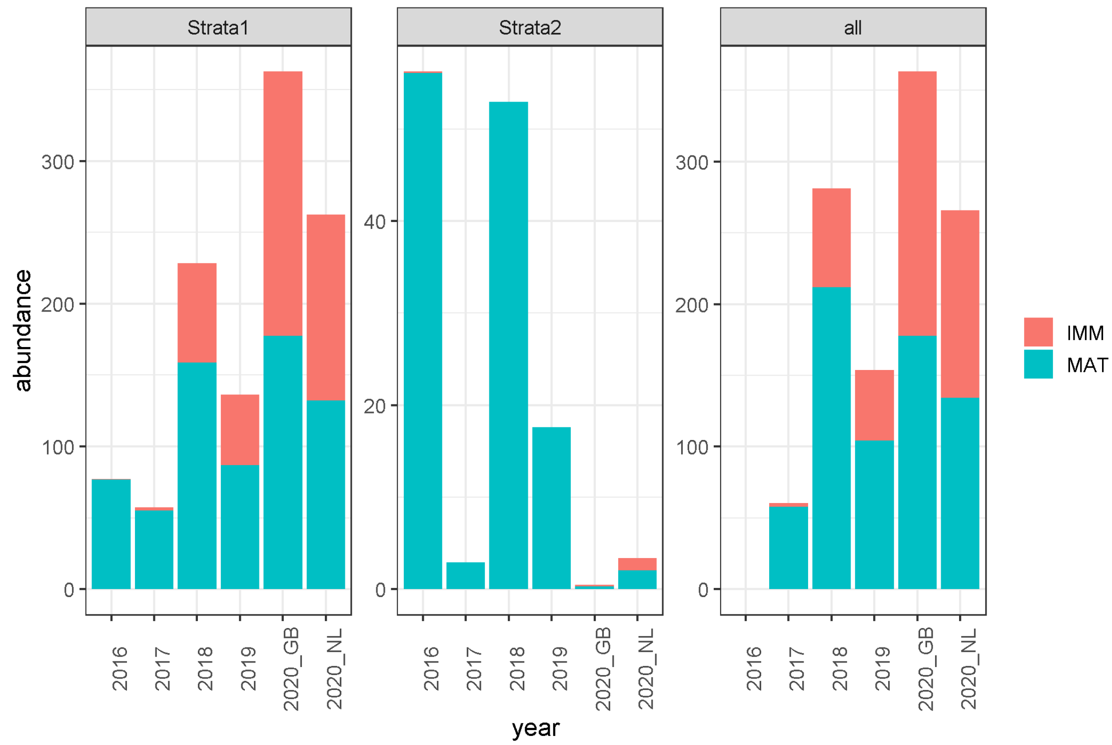


Figure 3.17. Historical abundance of mature and immature individuals.

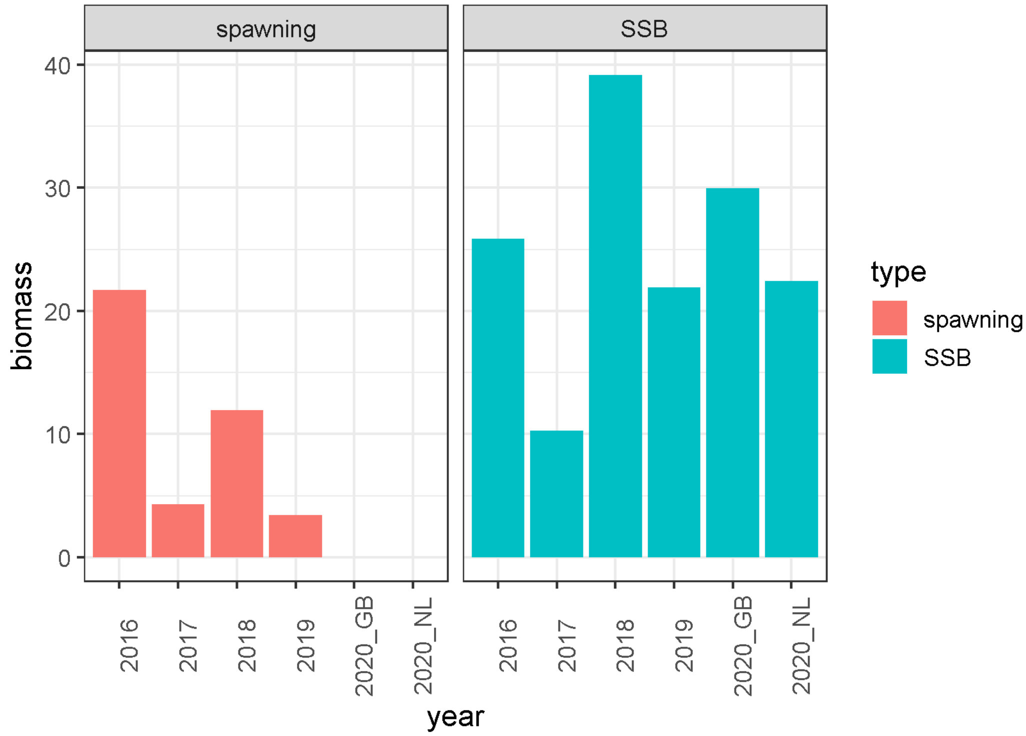


Figure 3.18. Historical SSB and biomass of spawners. Spawners are individuals at maturity stage 3 and 4.

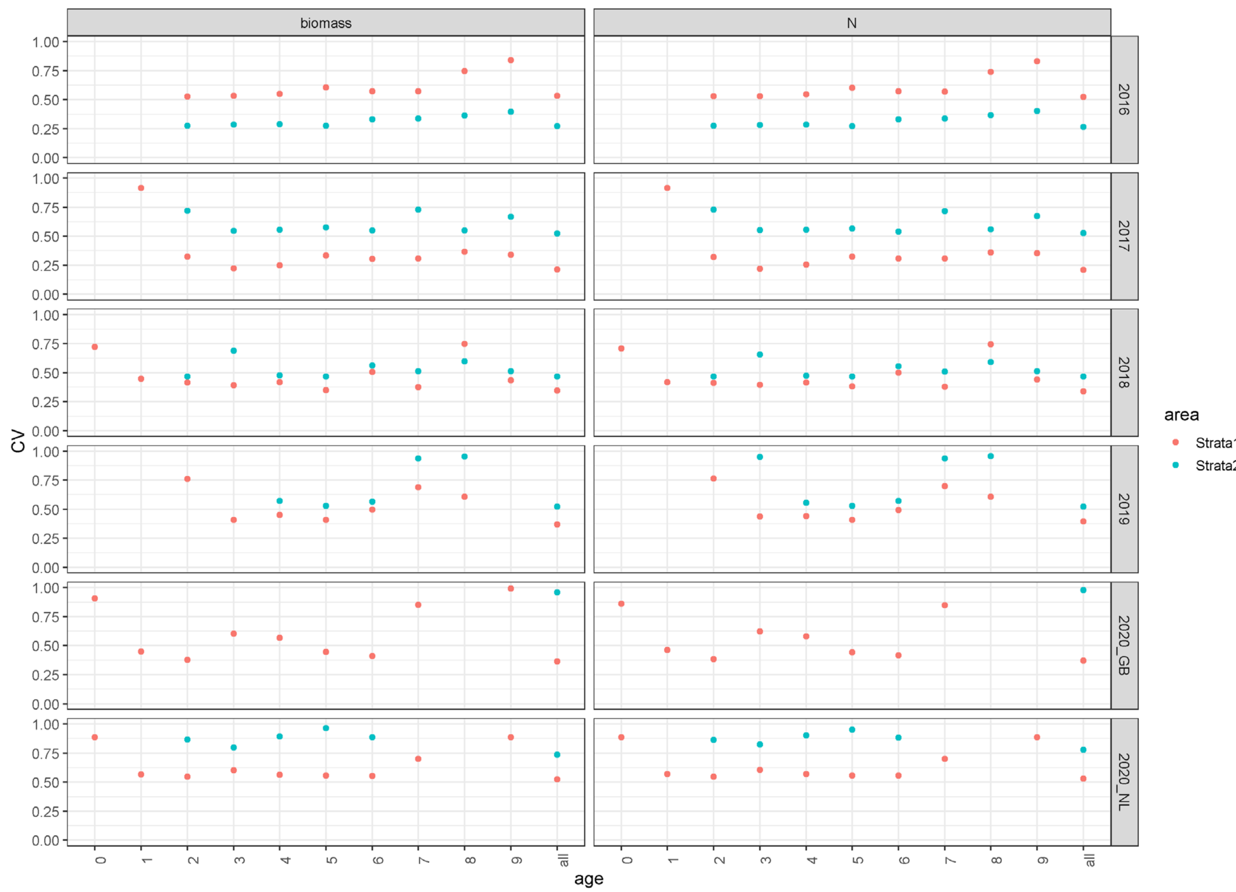


Figure 3.19. Historical CV per strata for abundance at age and biomass at age.

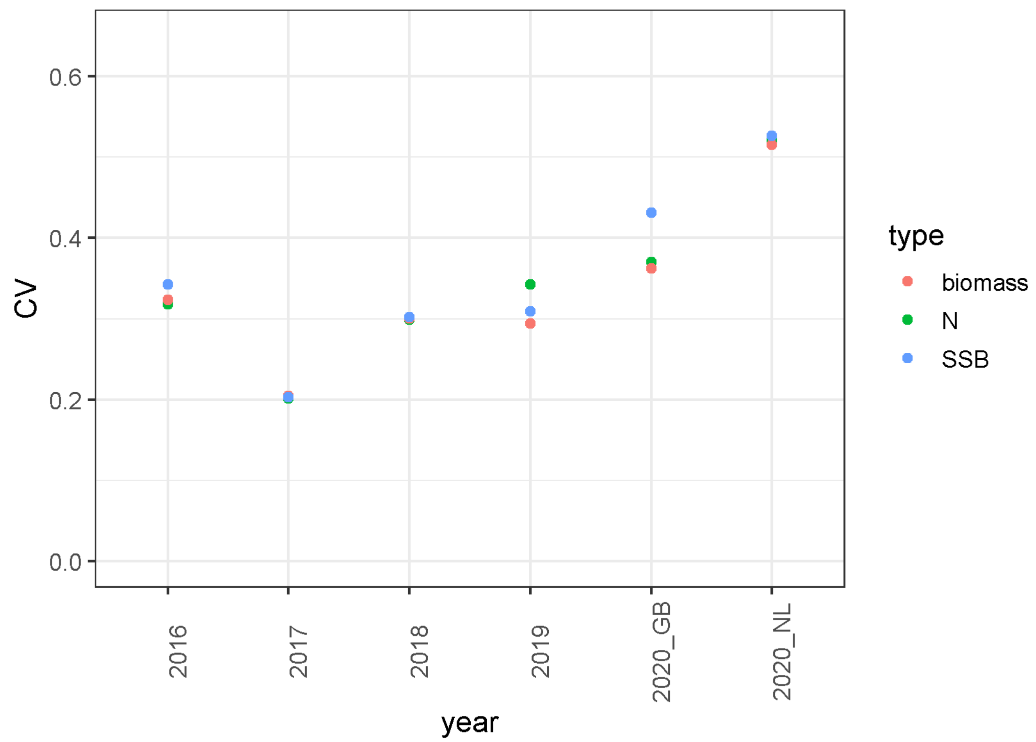


Figure 3.20. Historical CV in abundance at age, biomass and SSB. CV for the abundance at age and biomass is calculated as the mean across ages.

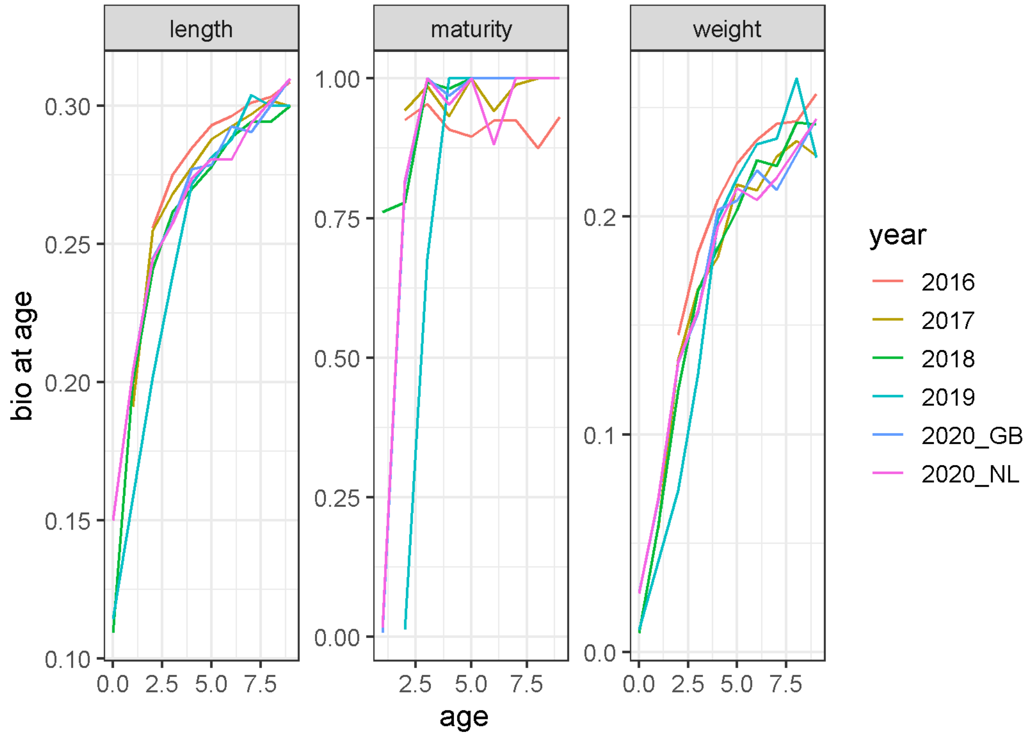


Figure 3.21. Historical biological parameters at age.

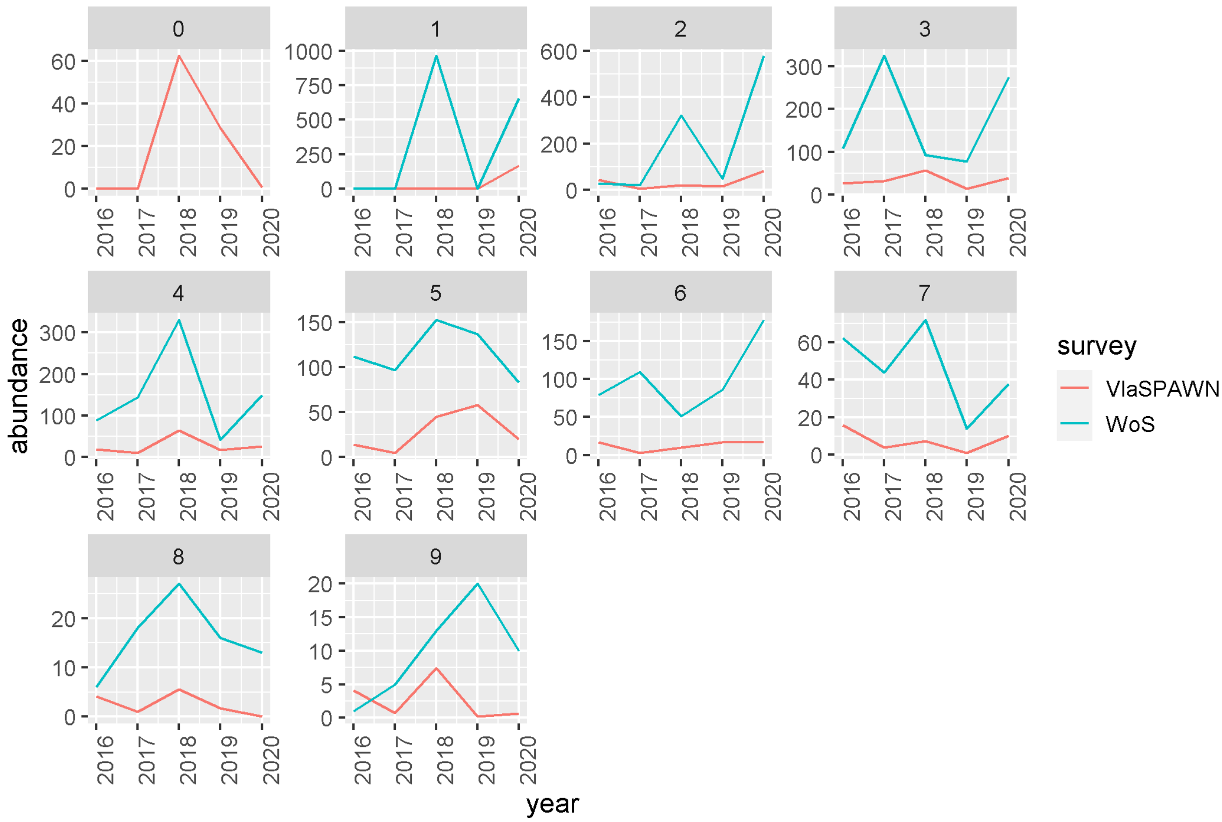


Figure 3.22. Comparison of abundance at age for the 6aSPAWN and West of Scotland (WoS) surveys.

3.2.2 6aS/7b herring

The estimated total stock biomass (TSB), number at age (TSN), numbers at length class and mean weight of herring found in each of the survey strata areas is shown in Tables 3.7 – 3.12. The 6 core area surveys were treated as separate strata within StoX (Lough Foyle, Lough Swilly, Bruckless Bay, Fintra Bay, Inver Bay and Achill. The combined estimated numbers at age and biomass at age over the entire survey area is also shown in Table 3.13. The TSB estimate of herring for the combined 6aS/7b area was 45,046 tonnes (Lough Foyle = 24,557 tonnes, Lough Swilly = 18,297 tonnes, Bruckless Bay = 356 tonnes, Fintra Bay = 84 tonnes, Inver Bay = 520 tonnes and Achill = 1,229 tonnes).

Table 3.7. 6aS/7b industry acoustic survey in 2020: age-disaggregated estimate of herring in the Lough Foyle area on 07/11/2020. The estimated TSB for the Lough Foyle strata = 24,557 t.

Variable: Abundance
EstLayer: 1
Stratum: 1.Lough Foyle
SpecCat: Clupea harengus
specialstage: TOTAL

LenGrp	age 1	2	3	4	5	6	7	8	9	10	Number (1E3)	Biomass (1E3kg)	Mean W (g)
16.0-16.5	-	-	-	-	-	-	-	-	-	-	-	-	-
16.5-17.0	-	-	-	-	-	-	-	-	-	-	-	-	-
17.0-17.5	-	-	-	-	-	-	-	-	-	-	-	-	-
17.5-18.0	-	-	-	-	-	-	-	-	-	-	-	-	-
18.0-18.5	-	-	-	-	-	-	-	-	-	-	-	-	-
18.5-19.0	-	-	-	-	-	-	-	-	-	-	-	-	-
19.0-19.5	-	-	-	-	-	-	-	-	-	-	-	-	-
19.5-20.0	369	-	-	-	-	-	-	-	-	-	369	15.5	42.00
20.0-20.5	738	369	-	-	-	-	-	-	-	-	1107	60.3	54.50
20.5-21.0	2777	-	-	-	-	-	-	-	-	-	2777	165.1	59.44
21.0-21.5	1909	2083	-	-	-	-	-	-	-	-	3992	258.6	64.78
21.5-22.0	1569	4882	-	-	-	-	-	-	-	-	6451	446.8	69.27
22.0-22.5	866	6584	-	-	-	-	-	-	-	-	7450	565.3	75.88
22.5-23.0	-	9957	-	-	-	-	-	-	-	-	9957	830.0	83.35
23.0-23.5	-	15377	-	-	-	-	-	-	-	-	15377	1427.8	92.85
23.5-24.0	-	18518	1572	-	-	-	-	-	-	-	20090	1910.3	95.09
24.0-24.5	-	9432	5764	1223	-	-	-	-	-	-	16419	1700.2	103.55
24.5-25.0	-	4928	9679	880	-	-	-	-	-	-	15487	1706.4	110.18
25.0-25.5	-	1227	12091	1752	-	-	-	-	-	-	15070	1816.1	120.51
25.5-26.0	-	1580	10360	1932	878	-	-	-	-	-	14750	1834.0	124.33
26.0-26.5	-	-	2605	10072	2605	-	-	-	-	-	15282	2088.1	136.64
26.5-27.0	-	-	1392	7135	3132	2088	-	-	-	-	13748	1917.7	139.49
27.0-27.5	-	-	1043	3652	4347	2608	1913	-	-	-	13564	1956.9	144.27
27.5-28.0	-	-	868	2431	1389	2431	1042	-	-	-	8162	1273.1	155.98
28.0-28.5	-	-	-	1556	3113	3805	519	519	-	-	9512	1599.3	168.15
28.5-29.0	-	-	-	-	1048	4892	1223	874	-	-	8037	1429.1	177.83
29.0-29.5	-	-	-	-	697	2264	2264	348	1045	-	6617	1202.0	181.66
29.5-30.0	-	-	-	-	340	510	-	510	-	-	1360	280.8	206.37
30.0-30.5	-	-	-	-	-	-	-	-	-	350	350	73.9	211.00
TSN(1000)	8229	74936	45376	30633	17550	18598	6960	2251	1045	350	205928	-	-
TSB(1000 kg)	492.9	6864.2	5404.8	4279.1	2706.0	3040.2	1107.2	403.9	185.1	73.9	-	24557.3	-
Mean length (cm)	20.87	23.11	25.03	26.24	27.12	27.92	28.06	28.69	29.00	30.00	-	-	-
Mean weight (g)	59.90	91.60	119.11	139.69	154.19	163.46	159.07	179.46	177.17	211.00	-	-	119.25

Table 3.8. 6aS/7b industry acoustic survey in 2020: age-disaggregated estimate of herring in the Lough Swilly area on 10/11/2020. The estimated TSB for the Lough Swilly strata = 18,297 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: 2.Lough Swilly
SpecCat: Clupea harengus
specialstage: TOTAL

LenGrp	age 2	3	4	5	6	7	8	9	Number (1E3)	Biomass (1E3kg)	Mean W (g)
16.0-16.5	-	-	-	-	-	-	-	-	-	-	-
16.5-17.0	-	-	-	-	-	-	-	-	-	-	-
17.0-17.5	-	-	-	-	-	-	-	-	-	-	-
17.5-18.0	-	-	-	-	-	-	-	-	-	-	-
18.0-18.5	-	-	-	-	-	-	-	-	-	-	-
18.5-19.0	-	-	-	-	-	-	-	-	-	-	-
19.0-19.5	-	-	-	-	-	-	-	-	-	-	-
19.5-20.0	-	-	-	-	-	-	-	-	-	-	-
20.0-20.5	-	-	-	-	-	-	-	-	-	-	-
20.5-21.0	-	-	-	-	-	-	-	-	-	-	-
21.0-21.5	-	-	-	-	-	-	-	-	-	-	-
21.5-22.0	-	-	-	-	-	-	-	-	-	-	-
22.0-22.5	570	-	-	-	-	-	-	-	570	43.9	77.00
22.5-23.0	3130	-	-	-	-	-	-	-	3130	268.8	85.87
23.0-23.5	3892	-	-	-	-	-	-	-	3892	346.7	89.08
23.5-24.0	5657	606	-	-	-	-	-	-	6263	600.4	95.87
24.0-24.5	6051	2733	586	-	-	-	-	-	9369	946.3	101.00
24.5-25.0	1638	6879	491	819	-	-	-	-	9827	1063.6	108.23
25.0-25.5	3475	4207	2012	549	-	-	-	-	10244	1175.6	114.77
25.5-26.0	-	9306	1117	372	-	-	-	-	10795	1377.1	127.57
26.0-26.5	932	3356	5220	2051	373	-	-	-	11931	1596.9	133.84
26.5-27.0	-	-	8566	1785	1249	-	-	-	11600	1613.1	139.06
27.0-27.5	-	1479	1294	4067	7210	-	-	-	14051	2090.5	148.78
27.5-28.0	-	-	1820	5278	5278	910	1092	-	14379	2306.4	160.41
28.0-28.5	-	-	355	1064	4964	5141	177	-	11700	1958.7	167.41
28.5-29.0	-	1059	-	-	5647	2647	-	-	9353	1589.0	169.89
29.0-29.5	-	-	-	561	-	2807	-	982	4350	796.4	183.06
29.5-30.0	-	-	-	-	290	871	290	290	1742	317.6	182.33
30.0-30.5	-	-	-	-	285	285	143	428	1141	206.9	181.38
TSN(1000)	25345	29624	21461	16546	25297	12661	1702	1700	134336	-	-
TSB(1000 kg)	2445.3	3599.9	2932.4	2489.1	4067.1	2162.8	289.9	311.4	-	18297.8	-
Mean length (cm)	23.75	25.26	26.21	26.89	27.66	28.44	28.10	29.34	-	-	-
Mean weight (g)	96.48	121.52	136.64	150.43	160.77	170.83	170.30	183.14	-	-	136.21

Table 3.9. 6aS/7b industry acoustic survey in 2020: age-disaggregated estimate of herring in the Bruckless Bay area on 26/11/2020. The estimated TSB for the Bruckless Bay strata = 356 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: 3.Bruckless Bay
SpecCat: Clupea harengus
specialstage: TOTAL

LenGrp	age 1	2	3	4	5	6	7	Number (1E3)	Biomass (1E3kg)	Mean W (g)
16.0-16.5	-	-	-	-	-	-	-	-	-	-
16.5-17.0	-	-	-	-	-	-	-	-	-	-
17.0-17.5	-	-	-	-	-	-	-	-	-	-
17.5-18.0	-	-	-	-	-	-	-	-	-	-
18.0-18.5	-	-	-	-	-	-	-	-	-	-
18.5-19.0	-	-	-	-	-	-	-	-	-	-
19.0-19.5	-	-	-	-	-	-	-	-	-	-
19.5-20.0	-	-	-	-	-	-	-	-	-	-
20.0-20.5	-	-	-	-	-	-	-	-	-	-
20.5-21.0	-	-	-	-	-	-	-	-	-	-
21.0-21.5	9	-	-	-	-	-	-	9	0.6	65.00
21.5-22.0	-	17	-	-	-	-	-	17	1.4	77.50
22.0-22.5	-	101	13	-	-	-	-	114	8.8	77.00
22.5-23.0	-	355	-	-	-	-	-	355	27.4	77.11
23.0-23.5	-	448	-	-	-	-	-	448	40.4	90.10
23.5-24.0	-	484	52	-	-	-	-	536	50.3	93.92
24.0-24.5	-	553	-	-	-	-	-	553	52.9	95.61
24.5-25.0	-	413	-	-	-	-	-	413	42.0	101.72
25.0-25.5	-	108	234	-	-	-	-	342	36.8	107.63
25.5-26.0	-	57	122	57	-	-	-	235	27.9	118.70
26.0-26.5	-	26	86	104	-	-	-	216	24.7	114.72
26.5-27.0	-	-	60	69	-	13	-	142	18.6	131.06
27.0-27.5	-	-	43	21	17	-	-	82	11.3	138.05
27.5-28.0	-	-	9	17	17	9	17	70	9.7	139.75
28.0-28.5	-	-	-	-	8	8	-	17	2.8	170.00
28.5-29.0	-	-	-	-	-	8	-	8	1.2	140.00
29.0-29.5	-	-	-	-	-	-	-	-	-	-
TSN(1000)	9	2562	619	268	43	38	17	3557	-	-
TSB(1000 kg)	0.6	238.2	70.8	32.4	6.6	5.7	2.6	-	356.8	-
Mean length (cm)	21.00	23.60	25.37	26.20	27.40	27.49	27.50	-	-	-
Mean weight (g)	65.00	92.95	114.41	120.81	152.64	147.94	151.00	-	-	100.31

Table 3.10. 6aS/7b industry acoustic survey in 2020: age-disaggregated estimate of herring in the Fintra Bay area on 26/11/2020. The total estimated TSB for the Fintra Bay area = 84 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: 4.Fintra Bay
SpecCat: Clupea harengus
specialstage: TOTAL

LenGrp	age 1	2	3	4	5	6	7	Number (1E3)	Biomass (1E3kg)	Mean W (g)
16.0-16.5	-	-	-	-	-	-	-	-	-	-
16.5-17.0	-	-	-	-	-	-	-	-	-	-
17.0-17.5	-	-	-	-	-	-	-	-	-	-
17.5-18.0	-	-	-	-	-	-	-	-	-	-
18.0-18.5	-	-	-	-	-	-	-	-	-	-
18.5-19.0	-	-	-	-	-	-	-	-	-	-
19.0-19.5	-	-	-	-	-	-	-	-	-	-
19.5-20.0	-	-	-	-	-	-	-	-	-	-
20.0-20.5	-	-	-	-	-	-	-	-	-	-
20.5-21.0	-	-	-	-	-	-	-	-	-	-
21.0-21.5	2	-	-	-	-	-	-	2	0.1	65.00
21.5-22.0	-	4	-	-	-	-	-	4	0.3	77.50
22.0-22.5	-	21	6	-	-	-	-	27	2.1	76.46
22.5-23.0	-	84	-	-	-	-	-	84	6.5	77.10
23.0-23.5	-	107	-	-	-	-	-	107	9.6	89.81
23.5-24.0	-	115	12	-	-	-	-	127	11.9	93.77
24.0-24.5	-	131	-	-	-	-	-	131	12.7	96.75
24.5-25.0	-	98	-	-	-	-	-	98	9.9	101.03
25.0-25.5	-	36	45	-	-	-	-	81	8.8	108.43
25.5-26.0	-	14	29	12	-	-	-	56	6.6	118.93
26.0-26.5	-	8	21	23	-	-	-	51	5.9	115.02
26.5-27.0	-	-	11	20	-	2	-	34	4.3	127.27
27.0-27.5	-	-	10	6	3	-	-	19	2.7	137.21
27.5-28.0	-	-	1	5	6	1	3	17	2.3	141.69
28.0-28.5	-	-	-	-	1	3	-	4	0.7	165.50
28.5-29.0	-	-	-	-	-	2	-	2	0.3	140.00
29.0-29.5	-	-	-	-	-	-	-	-	-	-
TSN(1000)	2	619	136	67	10	8	3	845	-	-
TSB(1000 kg)	0.1	57.8	15.5	8.0	1.6	1.2	0.5	-	84.8	-
Mean length (cm)	21.00	23.65	25.28	26.27	27.40	27.68	27.50	-	-	-
Mean weight (g)	65.00	93.41	114.37	120.10	152.93	150.44	148.67	-	-	100.28

Table 3.11. 6aS/7b industry acoustic survey in 2020: age-disaggregated estimate of herring in the Inver Bay area on 27/11/2020. The total estimated TSB for the Inver Bay strata area = 520 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: 5.Inver Bay
SpecCat: Clupea harengus
specialstage: TOTAL

LenGrp	age 0	2	3	4	5	6	7	Number (1E3)	Biomass (1E3kg)	Mean W (g)
16.0-16.5	19	-	-	-	-	-	-	19	0.5	27.00
16.5-17.0	-	-	-	-	-	-	-	-	-	-
17.0-17.5	-	-	-	-	-	-	-	-	-	-
17.5-18.0	-	-	-	-	-	-	-	-	-	-
18.0-18.5	-	-	-	-	-	-	-	-	-	-
18.5-19.0	-	-	-	-	-	-	-	-	-	-
19.0-19.5	-	-	-	-	-	-	-	-	-	-
19.5-20.0	-	-	-	-	-	-	-	-	-	-
20.0-20.5	-	-	-	-	-	-	-	-	-	-
20.5-21.0	-	-	-	-	-	-	-	-	-	-
21.0-21.5	-	19	-	-	-	-	-	19	1.3	69.00
21.5-22.0	-	-	-	-	-	-	-	-	-	-
22.0-22.5	-	323	-	-	-	-	-	323	23.2	71.77
22.5-23.0	-	658	-	-	-	-	-	658	50.2	76.30
23.0-23.5	-	836	-	-	-	-	-	836	66.0	79.04
23.5-24.0	-	614	164	-	-	-	-	778	67.3	86.49
24.0-24.5	-	766	43	-	-	-	-	809	75.1	92.80
24.5-25.0	-	300	289	-	-	-	-	589	55.4	93.96
25.0-25.5	-	76	259	86	-	-	-	421	43.0	102.15
25.5-26.0	-	55	132	143	44	-	-	373	41.7	111.68
26.0-26.5	-	-	109	185	-	-	-	294	33.5	113.78
26.5-27.0	-	-	41	103	41	-	-	185	22.7	123.06
27.0-27.5	-	-	37	25	-	50	12	125	15.1	120.50
27.5-28.0	-	-	-	36	-	24	-	60	8.5	143.40
28.0-28.5	-	-	-	-	24	36	-	60	8.5	142.80
28.5-29.0	-	-	-	-	-	-	50	50	8.0	161.00
29.0-29.5	-	-	-	-	-	-	-	-	-	-
TSN(1000)	19	3646	1075	578	109	110	62	5599	-	-
TSB(1000 kg)	0.5	307.0	107.5	66.7	14.0	14.9	9.5	-	520.1	-
Mean length (cm)	16.00	23.31	24.89	25.95	26.43	27.44	28.20	-	-	-
Mean weight (g)	27.00	84.20	100.01	115.48	128.62	135.84	151.80	-	-	92.89

Table 3.12. 6aS/7b industry acoustic survey in 2020: age-disaggregated estimate of herring in the Achill area on 06/01/2021. The total estimated TSB for the Achill strata area = 1,229 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: 6.Achill
SpecCat: Clupea harengus
specialstage: TOTAL

LenGrp	age 0	1	2	3	4	5	6	7	Number (1E3)	Biomass (1E3kg)	Mean W (g)
16.0-16.5	22	-	-	-	-	-	-	-	22	0.6	27.00
16.5-17.0	-	-	-	-	-	-	-	-	-	-	-
17.0-17.5	-	-	-	-	-	-	-	-	-	-	-
17.5-18.0	-	-	-	-	-	-	-	-	-	-	-
18.0-18.5	-	-	-	-	-	-	-	-	-	-	-
18.5-19.0	-	-	-	-	-	-	-	-	-	-	-
19.0-19.5	-	-	-	-	-	-	-	-	-	-	-
19.5-20.0	-	-	-	-	-	-	-	-	-	-	-
20.0-20.5	-	-	-	-	-	-	-	-	-	-	-
20.5-21.0	-	-	-	-	-	-	-	-	-	-	-
21.0-21.5	-	19	19	-	-	-	-	-	38	2.5	67.00
21.5-22.0	-	-	31	-	-	-	-	-	31	2.4	77.50
22.0-22.5	-	-	528	41	-	-	-	-	569	41.9	73.70
22.5-23.0	-	-	1376	-	-	-	-	-	1376	106.4	77.35
23.0-23.5	-	-	1743	-	-	-	-	-	1743	147.1	84.42
23.5-24.0	-	-	1559	274	-	-	-	-	1833	166.0	90.53
24.0-24.5	-	-	1881	19	-	-	-	-	1899	179.1	94.30
24.5-25.0	-	-	1149	252	-	-	-	-	1401	138.8	99.01
25.0-25.5	-	-	248	781	55	-	-	-	1085	116.0	106.94
25.5-26.0	-	-	124	439	200	76	-	-	840	97.4	115.92
26.0-26.5	-	-	65	279	372	-	-	-	717	82.2	114.77
26.5-27.0	-	-	-	172	235	36	18	-	462	58.3	126.20
27.0-27.5	-	-	-	148	69	10	49	10	286	37.8	131.79
27.5-28.0	-	-	-	9	100	36	18	27	191	27.0	141.14
28.0-28.5	-	-	-	-	-	32	65	-	97	14.9	152.89
28.5-29.0	-	-	-	-	-	-	24	48	71	11.0	154.00
29.0-29.5	-	-	-	-	-	-	-	-	-	-	-
TSN(1000)	22	19	8723	2415	1033	191	174	85	12661	-	-
TSB(1000 kg)	0.6	1.2	777.7	263.7	122.8	25.5	24.8	13.0	-	1229.3	-
Mean length (cm)	16.00	21.00	23.47	25.16	26.18	26.57	27.58	28.00	-	-	-
Mean weight (g)	27.00	65.00	89.16	109.22	118.89	133.27	142.06	153.17	-	-	97.09

Table 3.13. 6aS/7b industry acoustic survey in 2020: age-disaggregated estimate of herring in the total survey area. The total estimated TSB for the combined survey areas = 45,046 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: TOTAL
SpecCat: Clupea harengus
specialstage: TOTAL

LenGrp	age 0	1	2	3	4	5	6	7	8	9	10	Number (1E3)	Biomass (1E3kg)	Mean W (g)
16.0-16.5	41	-	-	-	-	-	-	-	-	-	-	41	1.1	27.00
16.5-17.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17.0-17.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17.5-18.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18.0-18.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18.5-19.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19.0-19.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19.5-20.0	-	369	-	-	-	-	-	-	-	-	-	369	15.5	42.00
20.0-20.5	-	738	369	-	-	-	-	-	-	-	-	1107	60.3	54.50
20.5-21.0	-	2777	-	-	-	-	-	-	-	-	-	2777	165.1	59.44
21.0-21.5	-	1939	2121	-	-	-	-	-	-	-	-	4060	263.2	64.82
21.5-22.0	-	1569	4934	-	-	-	-	-	-	-	-	6503	450.9	69.34
22.0-22.5	-	866	8127	60	-	-	-	-	-	-	-	9054	685.2	75.69
22.5-23.0	-	-	15560	-	-	-	-	-	-	-	-	15560	1289.2	82.85
23.0-23.5	-	-	22403	-	-	-	-	-	-	-	-	22403	2037.7	90.96
23.5-24.0	-	-	26946	2681	-	-	-	-	-	-	-	29627	2806.2	94.72
24.0-24.5	-	-	18814	8558	1808	-	-	-	-	-	-	29180	2966.2	101.65
24.5-25.0	-	-	8526	17100	1371	819	-	-	-	-	-	27816	3016.1	108.43
25.0-25.5	-	-	5170	17617	3906	549	-	-	-	-	-	27242	3196.3	117.33
25.5-26.0	-	-	1830	20388	3460	1370	-	-	-	-	-	27049	3384.6	125.13
26.0-26.5	-	-	1031	6456	15976	4656	373	-	-	-	-	28491	3831.4	134.48
26.5-27.0	-	-	-	1677	16129	4994	3371	-	-	-	-	26170	3634.8	138.89
27.0-27.5	-	-	-	2761	5068	8445	9918	1935	-	-	-	28127	4114.0	146.27
27.5-28.0	-	-	-	887	4410	6728	7761	2000	1092	-	-	22878	3627.2	158.54
28.0-28.5	-	-	-	-	1911	4242	8880	5660	696	-	-	21389	3584.9	167.60
28.5-29.0	-	-	-	1059	-	1048	10573	3968	874	-	-	17521	3038.6	173.42
29.0-29.5	-	-	-	-	-	1258	2264	5070	348	2027	-	10967	1998.4	182.22
29.5-30.0	-	-	-	-	-	340	800	871	800	290	-	3102	598.3	192.88
30.0-30.5	-	-	-	-	-	-	285	285	143	428	350	1491	280.8	188.33
TSN(1000)	41	8259	115831	79244	54039	34449	44226	19789	3953	2745	350	362926	-	-
TSB(1000 kg)	1.1	494.8	10690.3	9462.2	7441.4	5242.7	7153.8	3295.5	693.8	496.5	73.9	-	45046.0	-
Mean length (cm)	16.00	20.88	23.30	25.12	26.23	27.01	27.77	28.30	28.44	29.21	30.00	-	-	-
Mean weight (g)	27.00	59.91	92.29	119.41	137.70	152.19	161.76	166.53	175.51	180.86	211.00	-	-	124.12

The results of the uncertainty estimates (CV) for abundance and biomass of herring in 6aS/7b are shown in Table 3.14. The CV for the survey overall is 0.34, the second lowest in the time-series so far. The biomass is dominated by herring from Lough Foyle and Lough Swilly, and as a consequence the CV is influenced by the results from these areas. The survey design in Lough Swilly has improved in 2019 and 2020 compared to 2016-2018, with increased intensity of survey transects. The ICES workshop on herring acoustic surveys on spawning fish (WKHASS) held in 2019 (ICES 2020) investigated some of these issues and results from the workshop suggested that an increased transect intensity would improve the CV in such circumstances when herring are tightly aggregated. For herring in Lough Foyle, the high CV is mostly caused by the over-reliance on a few strong acoustic marks and some transects dominating in that strata in terms of herring abundance. There were relatively fewer transects in Lough Foyle compared to Lough Swilly. This may have caused the increased CV on the estimate from Lough Foyle and the overall estimate for the survey as the herring marks in Lough Foyle were very strong. The survey design in the bays (Inver, Bruckless, Fintra and Achill) strata were improved in 2020, however improvements still need to be made in survey design in some areas as evidenced from these results.

Table 3.14. 6aS/7b industry acoustic survey in 2020: uncertainty estimates of herring (with CV) by weight and number for all strata and the total survey area.

Ton by stratum

Stratum	Ton.5%	Ton.50%	Ton.95%	Ton.mean	Ton.sd	Ton.cv
1.Lough_Foyle	5486.62514	24524.67814	50349.1816	25774.68352	14023.44682	0.5440783
2.Lough_Swilly	9765.35629	18189.49348	27908.8434	18310.45493	5304.9544	0.2897227
3.Bruckless_Bay	150.94449	366.01172	610.8429	372.37433	142.99959	0.3840211
4.Fintra_Bay	20.23392	80.67741	165.658	85.14878	44.43513	0.5218528
5.Inver_Bay	274.63912	501.82657	802.2922	512.23385	158.72103	0.3098605
6.Achill	887.62973	1230.06534	1551.087	1217.99763	231.32269	0.1899205

Total number by stratum

Stratum	Ab.Sum.5%	Ab.Sum.50%	Ab.Sum.95%	Ab.Sum.mean	Ab.Sum.sd	Ab.Sum.cv
1.Lough_Foyle	45975018	205927666	421976712	215109999	116276769	0.5405456
2.Lough_Swilly	71561687	133299647	203472690	134067332	38788989	0.2893247
3.Bruckless_Bay	1505973	3643623	6063942	3711290	1430416	0.3854228
4.Fintra_Bay	203499	801430	1641616	848404	443513	0.5227616
5.Inver_Bay	2968753	5463086	8578891	5540923	1708660	0.308371
6.Achill	9186384	12661500	15872271	12533628	2367633	0.1889025

Ton by survey

Ton.5%	Ton.50%	Ton.95%	Ton.mean	Ton.sd	Ton.cv
23898.43	44698.48	73196	46272.89	15334.88	0.331401

Total number by survey

Ab.Sum.5%	Ab.Sum.50%	Ab.Sum.95%	Ab.Sum.mean	Ab.Sum.sd	Ab.Sum.cv
192573302	359668963	590395512	371811577	124941462	0.3360344

The survey in 2020 was not designed to contain the 6aS/7b stock in its entirety, however, the pre-determined core areas were covered as planned and containment most likely achieved within these discrete areas. Therefore the survey estimates from the 2020 survey are likely to be minimum estimates for the stock in this area at this time of the year. There was hyper-aggregating behaviour and shallow distribution (<15m) of herring in Lough

Foyle and Lough Swilly in particular, similar to previous years. These fish were primarily in the middle of the channel(s) in both Lough Foyle and Lough Swilly, with little or no marks of fish observed in the shallow edges of either area.

4 Achievements and Recommendations

4.1 Abundance estimation –acoustics

4.1.1 Recommendations for data users

4.1.1.1 *6aN*

The 2020 acoustic surveys in the two strata surveyed in 6aN are considered to

- Have contained a significant part of the area where herring spawn in 6aN during autumn. However, the extent of plans for surveys in 6aN 2020 was limited, with agreement on the details of the survey with Marine Scotland coming late in the planning. On consequence of this was the duration of the surveys was limited and it was not possible to maintain continuous observation over and extended period of time.
- Provide a reliable estimate of
  - the minimum biomass of age 1 (immature) and mature herring at age observed in survey areas during the survey period. The limited sampling in 2021 by each vessel, and the difference in age composition that was apparent led to the decision to combine biological samples from both vessels in the acoustic analysis. While this practice is not uncommon, the temporal lag of 14 days between the Ocean Star and Alida surveys is far from optimal.
- Does not provide a reliable estimate of
  - the minimum spawning biomass, because there were no fish sampled in 2020 were in stage 3 or 4 (spawning ready/ spawning), and because in strata 1 in particular the lack of any biological samples meant that biological data had to be inferred from Strata 1.

The acoustic survey in has particular value in relation to

- Monitoring the age structure and providing an index of abundance and biomass of herring in 6aN in known spawning areas (see ICES WKHASS 2020).
- Monitoring and changes in the timing of spawning and distribution at this time of year and mapping in detail the spawning locations in 6aN, which is useful in relation to marine spatial planning considerations.
- Promoting a positive example of industry-science and developing industry’s skills to assess pelagic stocks.

- Source of comparison of trends of abundance with the MALIN Shelf/ WoS herring acoustic survey.

4.1.1.2 *6aS/7bc*

- The 2020 TSB estimate of 45,046 tonnes is considered to be a minimum estimate of herring in the 6aS/7b survey area at the time of the survey; all areas were not covered in 2020, and therefore the stock was not overall contained in the survey area.
- The majority of herring marks were observed inshore in shallow areas, particularly in Lough Foyle and Lough Swilly. The stock appears to have been largely contained by the survey design in these discreet areas.
- COVID restrictions affected the survey planning, and some areas were only partially covered by the survey. It would have been preferable if surveys were completed in these areas later in December in 2020, particularly the Teelin, Bruckless, Inver Bay areas.
- The monitoring fishery is conducted on the same marks and at the same time as the survey, therefore the samples used from the monitoring fishery are considered representative of the surveyed biomass.
- The survey estimation of biomass and abundance was conducted by using a pole-mounted combi 38 kHz (split) and 200 kHz (single) echosounder. The pole-mounted system worked well, with the entire system independent of vessel electrics, making it suitable for surveys on any vessel with a dry wheelhouse.
- The herring surveyed were most likely/almost definitely 6aS/7b fish due to the inshore distribution, timing and proximity to the spawning grounds.
- The survey reflected what was experienced in the monitoring fishery occurring at the same time.
- There appears to be good cohort tracking in the survey over the 5-year time-series.
- There was a good spread of length classes in all hauls, with most hauls dominated by larger (> 22 cm) mature fish. The 2- and 3-wr age class of herring accounted for 54% of the overall numbers in 2020.
- The survey began after the fishery started in 2020. The fish were in Lough Foyle and Lough Swilly in large numbers before the beginning of the survey. The herring

appeared in Bruckless, Inver and Teelin Bays after the surveys in 2020, according to information coming from the monitoring fishery.

- There is a need to reduce uncertainty of estimate further through better survey design, particularly in the Lough Foyle strata. The CV would be reduced with more intense transects particularly when schools are hyper-aggregating in inshore areas.
- The improved design in Lough Swilly in 2019 was instigated following the workshop held in 2019 (WKHASS). A similar design that deals with the inshore behaviour in Lough Foyle during this time could overcome this issue. An improved survey design will be used in 2021 in this strata.
- The flexible spatial and temporal approach to organising surveys worked very well and will be a template for future designs going forward. The ability to avoid poor weather and use smaller vessels in shallow bays was a big improvement on previous years.

4.1.2 Recommendations for future surveys from WGIPS

4.1.2.1 *6aN*

- Continue to ensure that future surveys follow standard protocols whereby all fish recordings (even of non-commercial size) encountered on the echogram be sampled regularly. This is paramount to improve analysis of the acoustic data and accuracy of the estimated abundance and stock composition for different species in the survey area.
- Maintain the strategy of previous years to try and provide continuous coverage in key areas, Strata 1 and 2 covered in 2020. 2021, survey vessels should undertake repeat coverage of the strata, allowing for longer observation, and critically, improving opportunity to get sufficient samples to monitor the age structure and changes maturity, and provide some degree of flexibility to search more widely in 6aN for pre/ spawning in the area.
- Continue to ensure that industry vessels are equipped with nets and fishing is directed as appropriate for taking small samples for biological analysis.
- Notify creel fishermen of survey transects in advance.

4.1.2.2 *6aS/7bc*

- Survey in 2021 and beyond – funding of the survey is assured for 2021. The industry/science partnership survey involving smaller vessels and concentrating on core inshore areas only was successful in 2020 and will be continued in 2021. Although the total stock was not contained by the survey in 2020, results from 2016-2019 have shown that the vast majority of herring is distributed inshore in discreet areas during Nov/Dec in recent years.
- The design in Lough Swilly resulted in a lower measure of uncertainty (CV) for the Swilly strata in 2019 and 2020. It is important that the uncertainty for other inshore areas is also improved with future survey designs, following recommendations from WKHASS (ICES, 2020).

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Annex 1. FV Charisma – HERAS strata 1 and 3 survey – July 2020.

Coinciding with the 2020 International Herring Acoustic Survey, a 10-day acoustic survey was carried out by FV Charisma in July.

1. Objectives

1. **Increase the chance of obtaining sufficient biological samples of herring in Strata 1 and 3 of the International Herring Acoustic Survey (HERAS).**

   HERAS surveys covering the west and north-west of Scotland routinely have difficulty in obtaining sufficient biological samples required to determine the acoustic survey abundance-at-age. This makes the calculation of herring stock biomass and tracking of age structure particularly difficult in this area, which is source of uncertainty and weakness in the stock assessment. FV Charisma supported the HERAS survey in these areas to help increase the chances of getting successful biological and genetic samples required for stock assessment. The ships Simrad EK80 echosounder (38kHz) was calibrated and used to record acoustic data.

2. **Test the effect of transect spacing on estimation of herring abundance in HERAS Strata 1 and 3.**

   The HERAS survey in the Malin shelf and 6a areas currently operates with a 15nmi transect spacing, which is based on previous statistical analysis of survey designs conducted when herring were more abundant in the area. During the current lower stock size, a test of the implications of transect spacing on the acoustic estimate of herring abundance would be a useful exercise to understand survey performance and future design requirements.

2. Methods

2.1 Calibration settings

Calibration performed by Echomaster at Peterhead breakwater tanker jetty the day before sailing. Water depth 25m, sphere 15-16m from transducer face. (Table A2.1.)

Table A2.1. Charisma calibration settings

Setting	Value	Unit
AbsorptionDepth	100	(meters)
Acidity	8	(pH)
EffectivePulseLength	0.831	(milliseconds)
EK60SaCorrection	-0.01	(decibels)
Frequency	38	(kilohertz)
MajorAxis3dbBeamAngle	6.38	(degrees)
MajorAxisAngleOffset	-0.03	(degrees)
MajorAxisAngleSensitivity	18	[0.100000..100.000000]

MinorAxis3dbBeamAngle	6.3	(degrees)
MinorAxisAngleOffset	-0.05	(degrees)
MinorAxisAngleSensitivity	18	[0.100000..100.000000]
NumberOfTransducerSegments	4	[1..4]
Salinity	35	(parts per thousand)
SamplingFrequency	20.83333	(kilohertz)
SoundSpeed	1500	(meters per second)
Temperature	10	(degrees celsius)
TransceiverImpedance	5400	(ohms)
TransceiverSamplingFrequency	1500	(kilohertz)
TransducerGain	26.71	(decibels)
TransmittedPower	2000	(watts)
TransmittedPulseLength	1.024	(milliseconds)
TvgRangeCorrection	SimradEK80	[None, Simrad EK80]
TwoWayBeamAngle	-20.7	(decibels re 1 steradian)

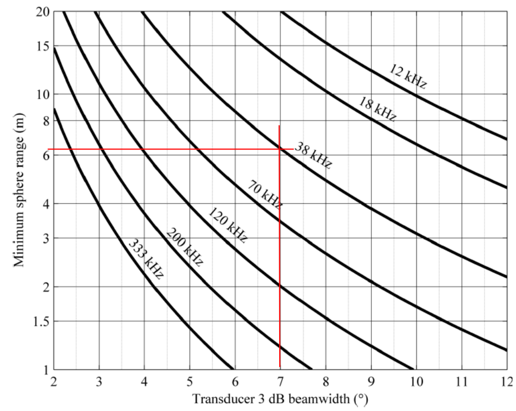
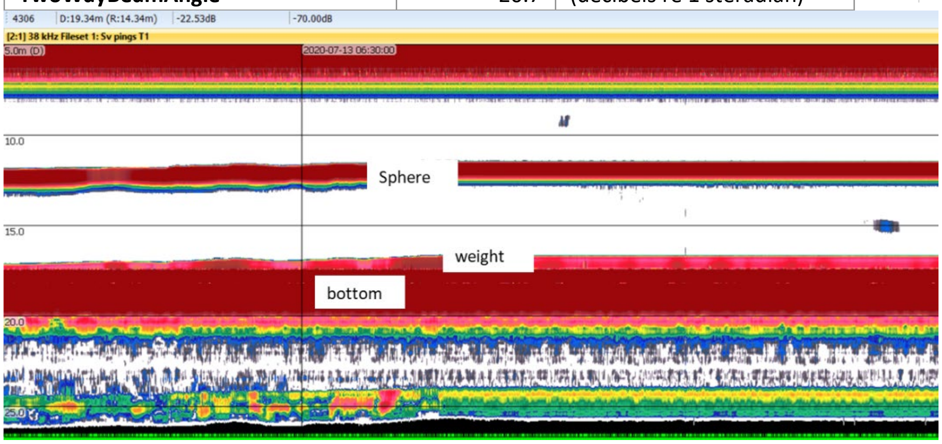


Figure 2.5. Minimum recommended range for the calibration sphere [$= 3r_{nf}$, as calculated in Equation (2.1b)] vs. transducer –3 dB beamwidth, $\theta_{-3\ dB}$, and acoustic frequency, f, for a circular-piston transducer and water sound speed, $c_w = 1470\ m\,s^{-1}$.



Target range = 7.5 m

Surveys conducted in daylight hours only, 03:00 to 23:00 UTC/GMT.

Table A2.2. Summary of equipment used for the 2020 acoustic surveys.

Area surveyed	Vessel	Transducer and Frequency	Echo-sounder	Power Pulse duration Ping interval	Environment	Calibration Location/ date, supplier	Survey area changes

HERAS (July 2020)	Charisma (LK362)	Hull mounted split beam ES38B (38kHhz), draft ~5.5m With heave compensation. ES200-7C (200kHz) split beam [not used]	SIMRAD EK80	**@38kHhz** Power: 2000W Pulse duration: 1.024ms Pulse form: Continuous wave Ping interval = 0.5 sec	Temp = 10C, Salinity =35ppt, Sound speed 1491.5 m/s	Peterhead breakwater 13 Jul, Echomaster Marine	

2.2 Survey design

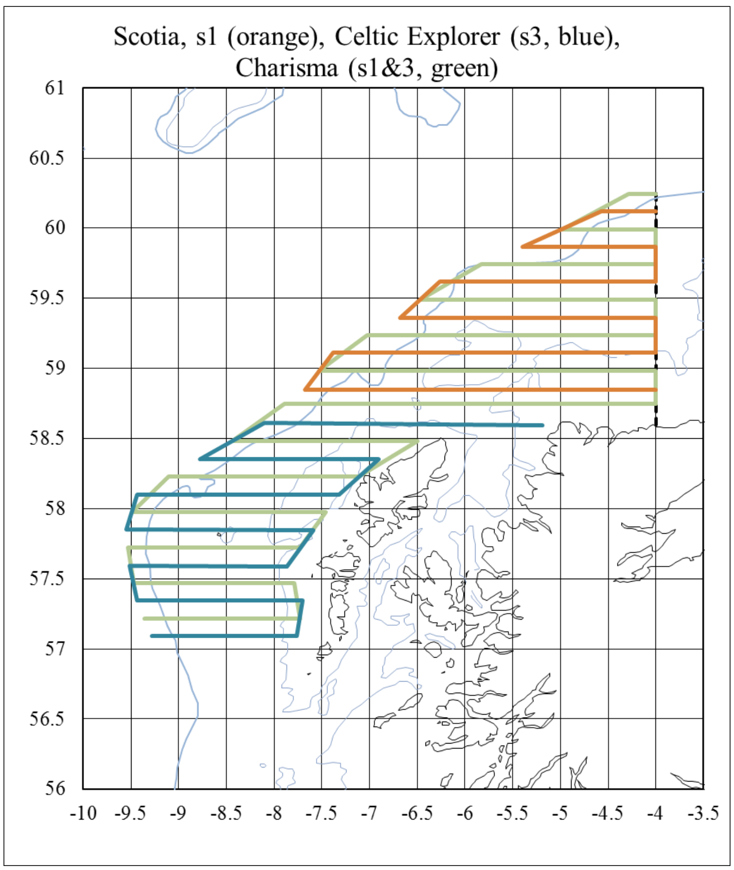


Figure A2.2. Charisma Survey plan. 15nmi spacing (green lines) covering HERAS strata 3 in the south and strata 1, North of the Butt of Lewis.

Haul locations are given in Figure 2. Two samples with herring [haul 1 & 7, and low number). Two damaged (unrepairable) at sea – unable to sample two lowest transects of strata 1 (t11&12). Therefore, analysis includes biological samples taken from Celtic Explorer (h31,32,34) and Scotia (h169).

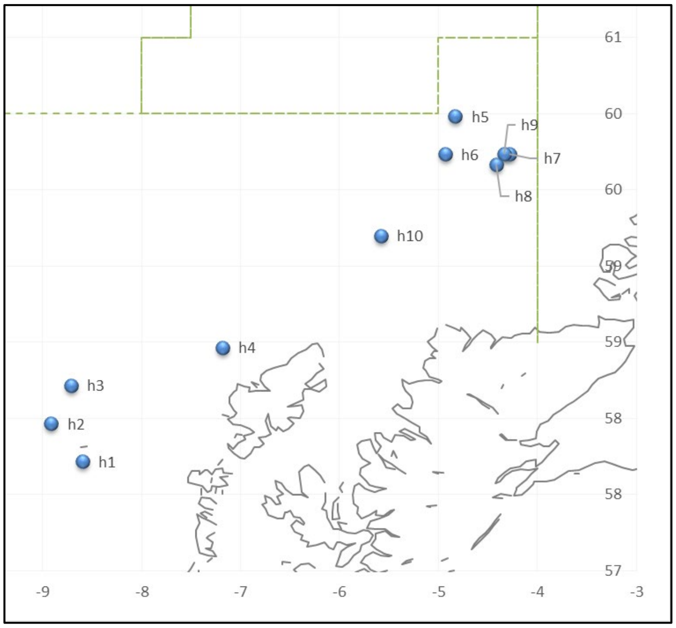


Figure A2.3. Haul locations

Schools detected with the lowest min detection threshold possible for the situation of the marks. This was -59 to -62 dB. Summary of acoustic marks shown in Table A2.3 and Figure A2.4.

Table A2.3. Overview metrics of acoustic marks classified in analysis

Row Labels	mean Sv_mean	mean NASC	No. of Schools
Cap-hugging marks	-43	9382	22
Probably herring	-54	972	494
Unclassified regions	-51	2114	1875

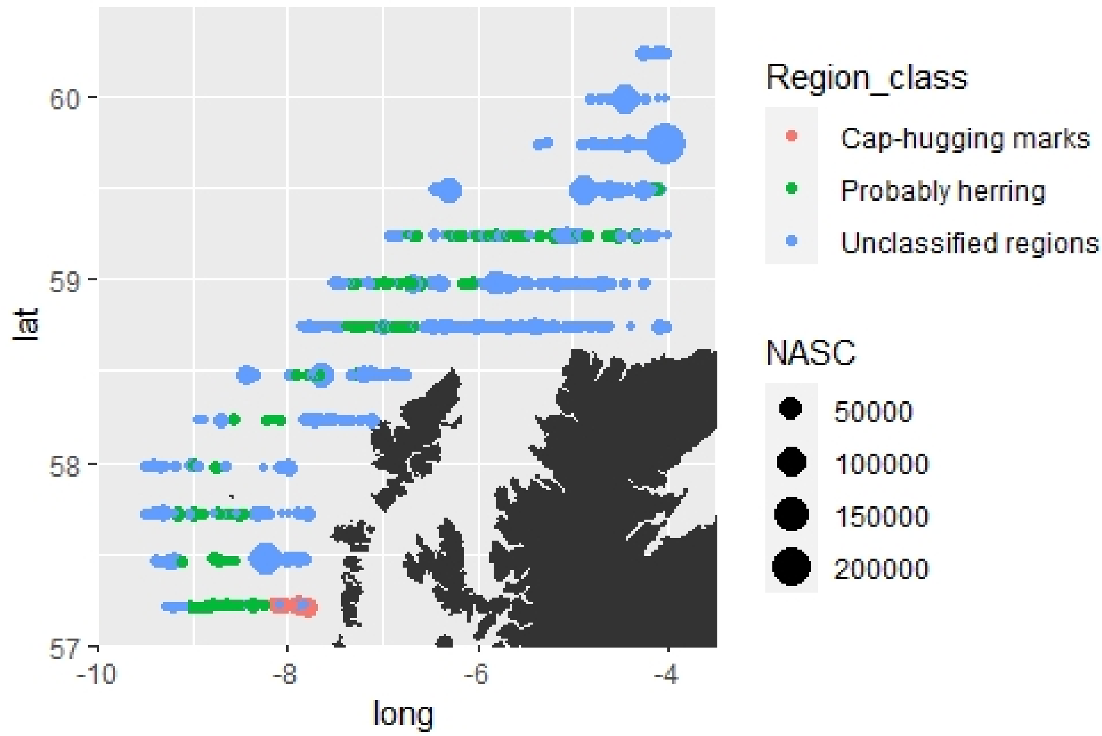


Figure A2.4. Acoustic survey recordings of herring and other marks.

2.2 StoX processing

Table A2.4. Overview of files used in StoX projects for focal strata

Year	Strata	Acoustic input	Biotic input
2020	Strata 1 and 3	Acoustic_CH0120_StoX.xml	Biotic_CH0120_StoX.xml Biotic_0920S_StoX.xml Biotic_45CE2020WESPAS_L2_StoX.xml

Biostation Assignment

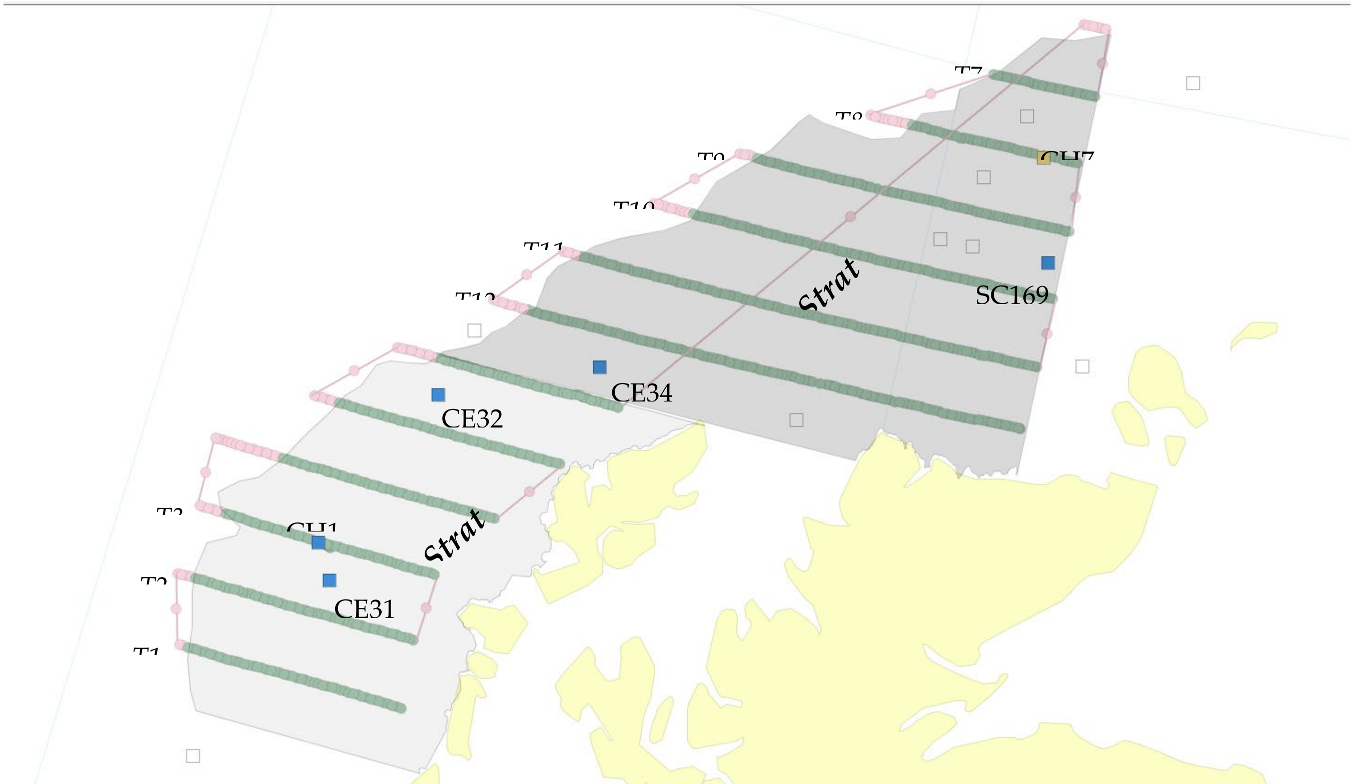
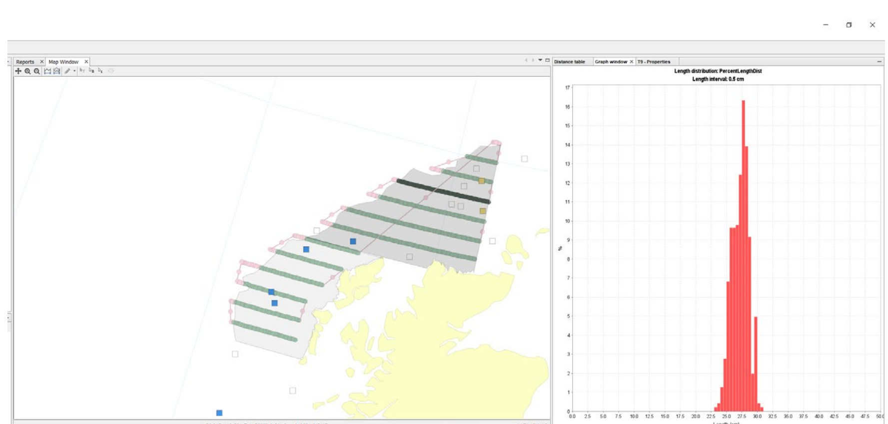
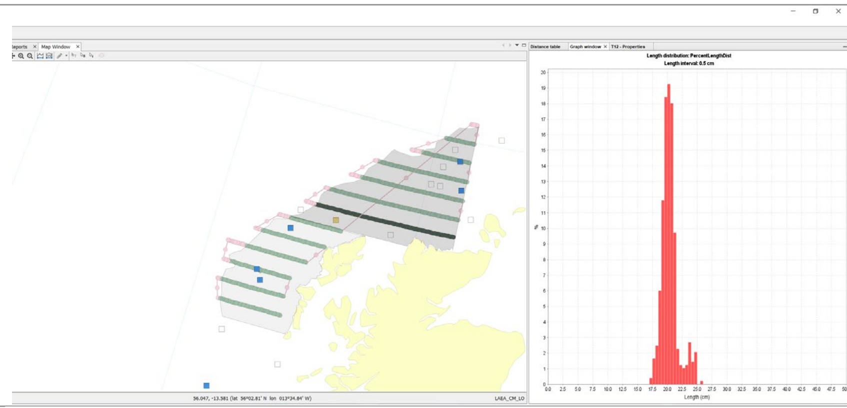
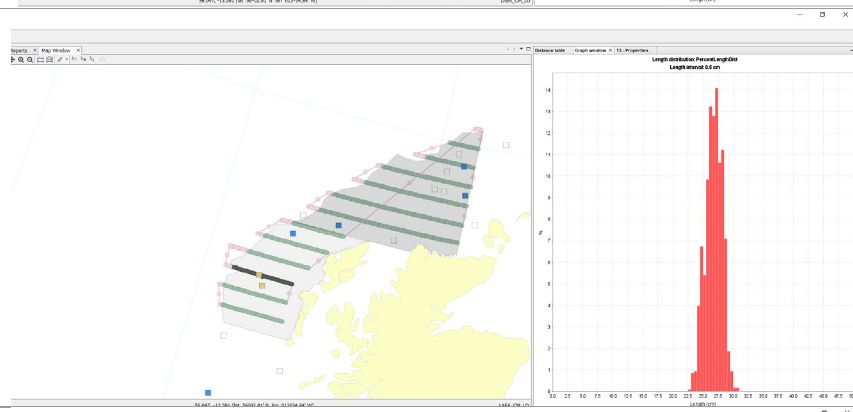
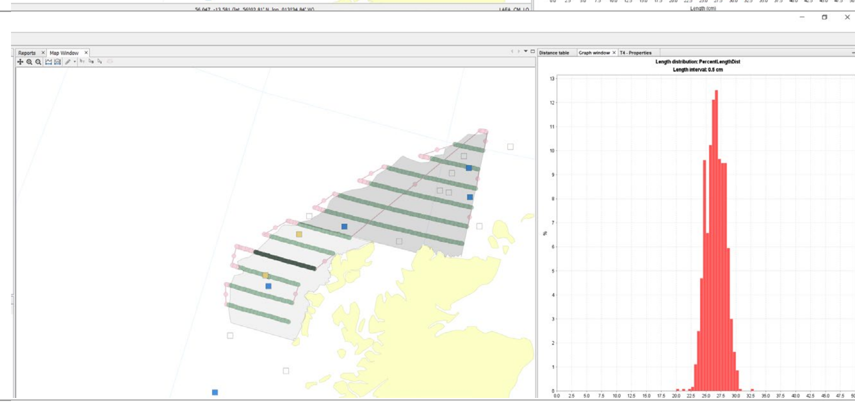
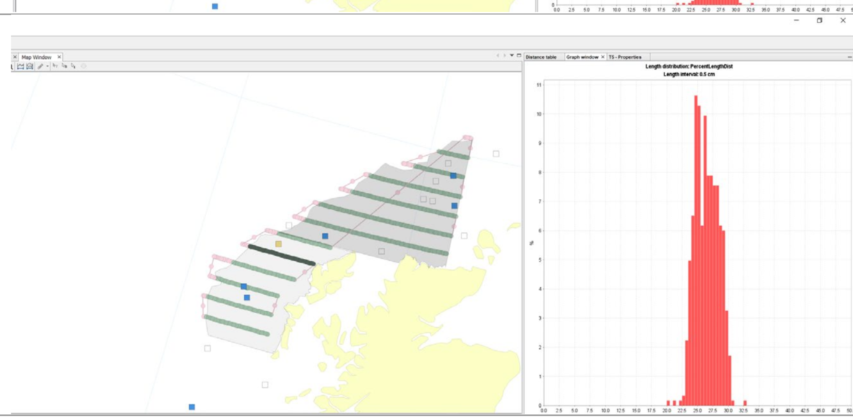
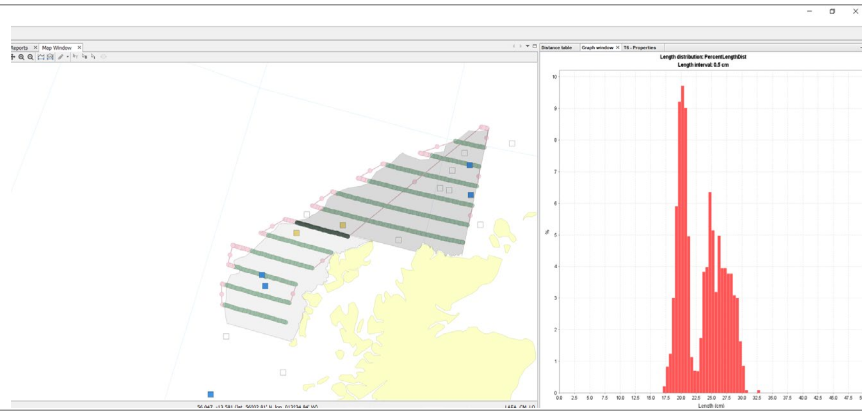


Figure A2.5. Acoustic transects and haul identifiers used in analyses and assignment of biostations.

Table A. 2.5 Details of biostation assignments

Strata	Haul - Transect biostation assignment	StoX view
1 (T7-12)	T7-10:CH7 & SC169	

	T11-12: CE34	
3 (T1-6)	T1-3: CH1 & CE31	
	T4: CH1 & CE32	
	T5: CE32	

	T6: CE32&34	

3. Results

Only two out of ten survey hauls contained herring, and sample sizes were low. Two nets were damaged beyond repair at sea, curtailing any further chances to obtain samples. Analysis of acoustic data was supported using biological sample information from Scotia and Celtic explorer, noting that these were taken a different times. Estimates of acoustic abundance were lower than those found by the survey vessels (Scotia 56kt Strata 1 compared to Charisma 13kt, and Celtic Explorer 72kt Strata 3 compared to Charisma 27kt), but considered well within the range of variability that could be expected when the surveys did not perfectly coincide.

Adundance and biomass estimates from StoX results are given in Table A2.7, with survey CV estimates in Table A2.8, Figure A2.6).

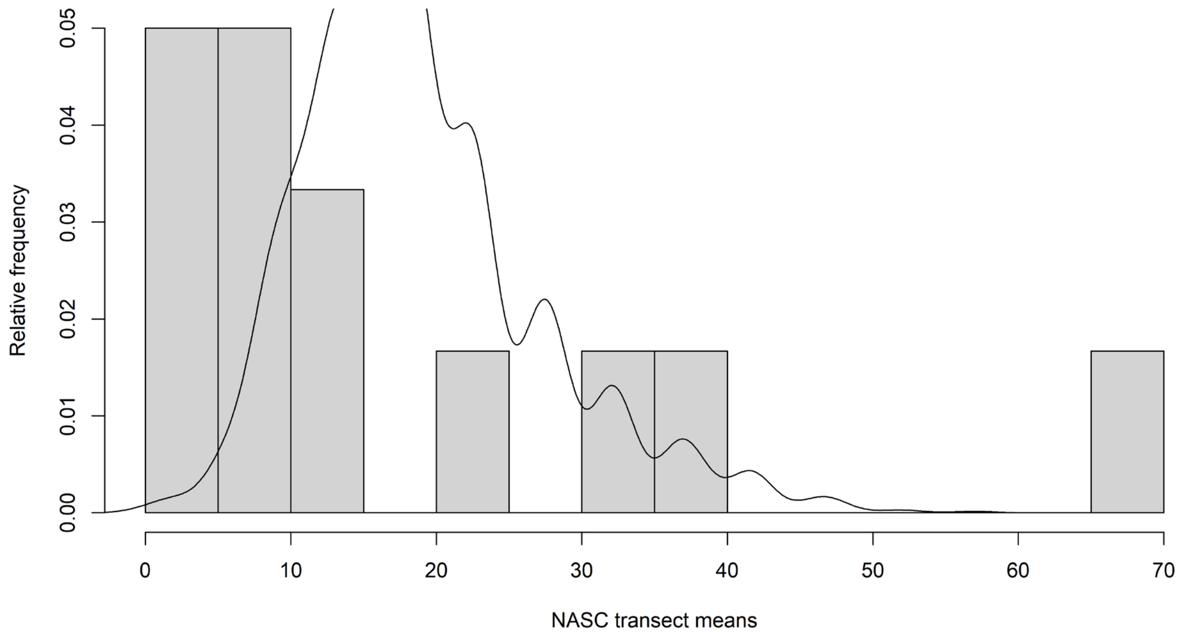


Figure A2.6. Distribution of herring NASC across transects

Table A2.7. Acoustic abundance results for each age for (a) strata 1, (b) strata 3, (c) combined strata 1&3. (Figures in bold are weighted averages based on the numbers in each age group.)

(a)

Results for all **Strata 1**					
Age (ring)	Numbers (mill)	Biomass (kt)	Maturity	Mean Weight (g)	Mean Length (cm)
0	0	0.0			
1	144	10.1	0.00	70.6	19.8
2	47	6.8	0.86	144.8	25.4
3	3	0.4	1.00	165.7	26.7
4	6	0.9	1.00	165.6	27.3
5	9	1.7	1.00	181.7	27.5
6	14	2.7	1.00	189.6	28.1
7	3	0.6	1.00	194.2	28.1
8	2	0.4	1.00	220.6	29.1
9+	0.6	0.1	1.00	233.0	29.5
Immature	150	10.937		73.0	20.0
Mature	78	13		165.5	26.7
Spawning	0	0			

unknown	0	0			
Total	228	**23.86**	0.34	**104.7**	22.3

(b)

Results for all **Strata 3**					
Age (ring)	Numbers (mill)	Biomass (kt)	Maturity	Mean Weight (g)	Mean Length (cm)
0	0	0.0			
1	4	0.3	0.00	71.0	19.9
2	37	5.0	0.53	137.1	24.6
3	33	5.5	0.78	164.1	25.9
4	33	5.7	1.00	174.1	26.6
5	19	3.6	1.00	188.2	27.2
6	44	8.7	1.00	196.7	27.7
7	8	1.6	1.00	203.1	27.9
8	2	0.4	1.00	213.2	28.8
9+	1.2	0.3	1.00	219.0	28.9
Immature	29	3.801		132.7	24.3
Mature	152	27		178.8	26.7
Spawning	0	0			
unknown	0	0			
Total	181	**30.99**	0.84	**171.4**	26.4

(c)

Results for all strata combined 2020					
Age (ring)	Numbers (mill)	Biomass (kt)	Maturity	Mean Weight (g)	Mean Length (cm)
0	0	0.0			
1	147	10.4	0.00	70.6	19.8
2	84	11.8	0.72	141.4	25.1
3	36	5.9	0.79	164.2	26.0
4	38	6.6	1.00	172.8	26.7
5	29	5.3	1.00	186.1	27.3
6	58	11.4	1.00	194.9	27.8
7	11	2.3	1.00	200.6	28.0
8	3	0.7	1.00	216.7	28.9
9+	1.8	0.4	1.00	223.7	29.1
Immature	179	14.738		82.5	20.7
Mature	230	40		174.3	26.7
Spawning	0	0			
unknown	0	0			
Total	409	**54.86**	0.56	**134.2**	24.1

	Strata summary 2020				
Strata	Abundance (mill)	Biomass (kt)	Mean length (cm)	Mean weight (g)	% Mature
Strata 1	228	23.9	22.3	104.7	0.34
Strata 2	180.8	31.0	26.4	171.4	0.84
TOTAL	409	54.86			

Table A2.7. CV estimates on abundance of each age in 6aN

age	Ab.Sum.5%	Ab.Sum.50%	Ab.Sum.95%	Ab.Sum.mean	Ab.Sum.sd	Ab.Sum.cv
1	3.86	109.25	200.87	97.04	69.29	0.71
2	18.19	62.38	129.80	66.41	34.46	0.52
3	5.73	34.19	63.27	34.70	16.49	0.48
4	9.65	34.08	66.49	35.64	17.33	0.49
5	10.08	25.98	45.29	26.65	10.64	0.40
6	19.51	52.87	95.41	54.64	22.66	0.41
7	4.01	11.56	28.43	13.32	8.81	0.66
8	1.19	3.91	10.36	4.55	3.03	0.67
9	0.00	0.87	2.50	1.02	0.78	0.77
10	0.00	0.53	1.70	0.61	0.56	0.92

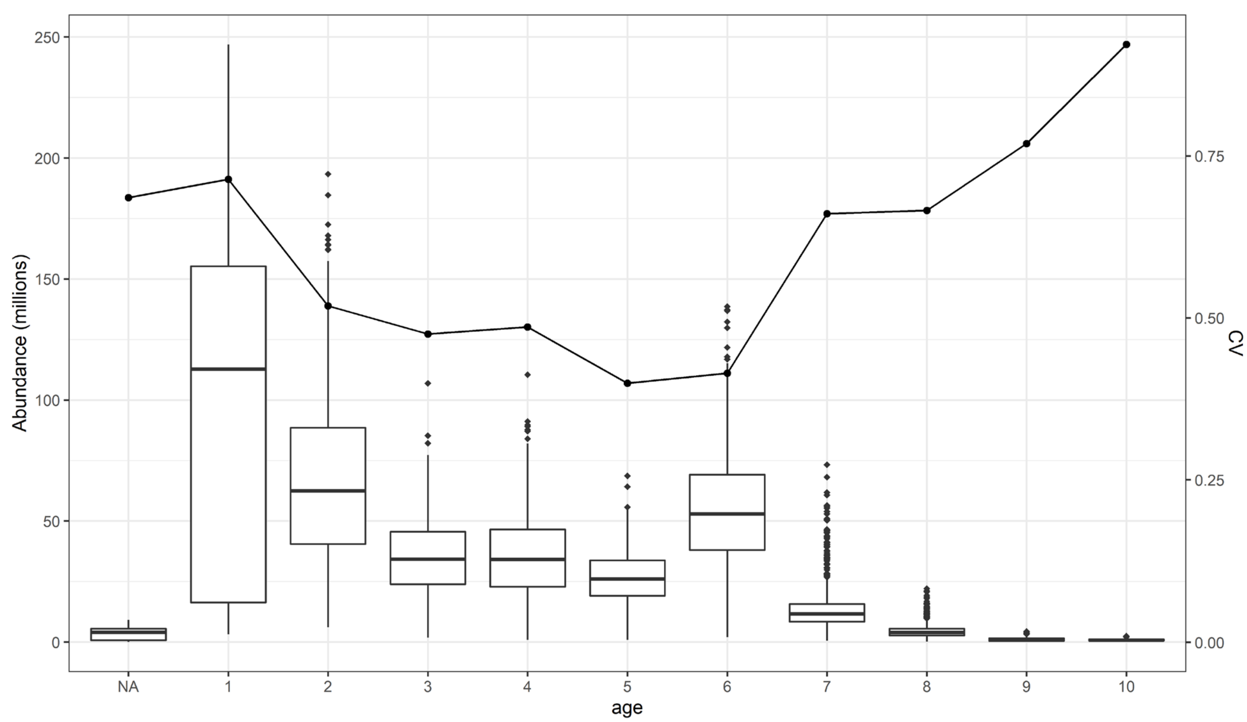


Figure A2.6. CV estimates on abundance of each age in 6aN

Ton by stratum						
Stratum	*Ton.5%*	*Ton.50%*	*Ton.95%*	*Ton.mean*	*Ton.sd*	*Ton.cv*
Strata1	7738	17694	33418	19187	8168	0.43
Strata3	6030	28133	50954	28781	12731	0.44
Total number by stratum (mill)						
Stratum	Ab.Sum.5%	Ab.Sum.50%	Ab.Sum.95%	Ab.Sum.mean	Ab.Sum.sd	Ab.Sum.cv
Strata1	49456045	166495106	322719972	169950068	89823123	0.53
Strata3	39391622	169949453	294831961	168526976	74213922	0.44
Ton by survey	Ton.5%	Ton.50%	Ton.95%	Ton.mean	Ton.sd	Ton.cv
.	21318.02	47371.9	77240.5	47928.97	17485.65	0.36
Total number by survey (mill)	Ab.Sum.5%	Ab.Sum.50%	Ab.Sum.95%	Ab.Sum.mean	Ab.Sum.sd	Ab.Sum.cv
.	161054860	325692846	572128667	338137144	128414673	0.38

Table A2.8 CV estimates on abundance estimates by strata

Biomass (t)	**CV**
Strata 1	0.43
Strata 3	0.44
Survey	0.36
Number (mill)	**CV**
Strata 1	0.53
Strata 3	0.44
Survey	0.38

Annex 14: 2020 PELACUS Survey Summary Table and Summary Report

The PELACUS (annex 14) surveys did not take place in 2020 due to the global COVID pandemic, therefore there is no annex 14 in this report.

Annex 15: Ecosystem Index Overview Table

	IBWSS					IESNS					HERAS						IESSNS			GERAS	CSHAS	WESPAS	ISAS	PELTIC
Participating countries	Norway	Faroe Islands	Ireland	Netherlands	Spain	Norway	Faroe Islands	Iceland	Denmark	Russia	Norway	Ireland	Netherlands	Denmark	Scotland	Germany	Norway	Faroe Islands	Iceland	Germany	Ireland	Ireland	UK	England
✓																								
Data type																								
fish																								
Organism collection	✓	✓				✓	✓				✓					✓	✓	✓		✓				
Stomach sampling	✓	✓				✓	✓				(✓)						✓	✓						✓
Additional biological data (of non-target species)	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓		✓		✓	✓	✓		✓	✓	✓	✓	✓
Disease/parasite registration											✓				✓									
Genetic information												✓										✓		
Lipid content											(✓)													
Omnidirectional sonar observations of pelagic fish	✓		✓			✓					✓	✓					✓				✓	✓		
Tagging																								
Bioactive material																								

Scientific multibeam echosounder for 3D fish school shapes/schools observations in surface 'dead zone'																	✓							
Multifrequency echosounder data for species identification, abundance and biomass estimation (number of frequencies)	5	2	4	2	5	6	2				4	4	2		3/5	4	5	2		4	4	4	2	4
Physical/chemical oceanography																								
Continuous underway measurements	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Station measurements	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Water movement						✓					✓													
Nutrients						✓					✓											(✓)		✓
Biological oceanography																								
Microbiological sampling																						(✓)		
Phytoplankton sampling						✓			✓					✓	✓									✓
Zooplankton samples	✓	✓	✓			✓	✓		✓					✓	✓		✓	✓				✓		✓
Multifrequency echosounder data for zooplankton identification & abundance estimation (number of high frequencies >=38 kHz)	4		1	1	3	5					2	3	1		2/3	1	4			1	3	3	1	3

	IBWSS					IESNS					HERAS						IESSNS			Western Baltic	CSHAS	WESPAS	Irish Sea	Peltic
Participating countries	Norway	Faroe Islands	Ireland	Netherlands	Spain	Norway	Faroe Islands	Iceland	Denmark	Russia	Norway	Ireland	Netherlands	Denmark	Scotland	Germany	Norway	Faroe Islands	Iceland	Germany	Ireland	Ireland	UK	England
Charismatic megafauna																								
Visual observations			✓	(✓)	✓*	✓					(✓)	✓				(✓)	✓				✓	✓	✓	✓
Towed hydrophones																						✓	✓	
Seabird observations					✓*																			
Species counts			✓		✓*							✓									✓	✓		✓
Abundance survey (ESAS)			✓									✓									✓	✓		✓
Habitat description																								
Camera observations			✓									✓					✓	(✓)			✓	✓		
Sidescan sonar						✓																		
Bathymetric multibeam echo-sounder			✓			✓						✓									✓	✓		
Physical ground samples																								
Pollution																								
Litter			✓	✓		✓			✓			✓		✓	✓	✓				✓	✓	✓		✓

Pollution in water column																								
Pollution in sediments																								
Pollution in organisms																								
Environmental conditions																								
Weather condition/sea state	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓

Annex 16: WGIPS Survey Plans 2021

IBWSS

Five vessels representing the Faroe Islands, the Netherlands (EU), Ireland (EU) and Norway are scheduled to participate in the 2021 blue whiting spawning stock survey. In addition, Spain will participate with 5 days of survey time, at the start time of the core survey, investigating the Porcupine Sea bight.

Survey timing and design were discussed during the 2019 IBWSS post-cruise and 2021 WGIPS meetings. The group decided that in 2021, the survey design should follow the principle of the one used during the last surveys. The zig-zag design in stratum 2 will also be continued and the focus will still be on a good coverage of the shelf slope in survey areas 2 and 3 (Figure A6.1.)

The design is based on variable transect spacing, ranging from 30 nm in areas containing less dense aggregation (areas 1 and 5), to 15-20 nm in the core survey area (area 2, 3 and 4) (Figure A6.1.). The western borders of the transects in area 3 are set to 12°W in order to cover potential blue whiting aggregations extending further from the continental slope into the Rockall Trough. Transects are drawn systematically with a random start location.

The aim is to have three vessels surveying on their transects in area 3 at the same time. That way, the core survey area 3 can be covered synoptically by several vessels with similar temporal progression.

The Irish and the Dutch vessels will start the survey in the southern areas. More or less at the same time the Norwegian vessel will start in stratum 2 (the zig-zag stratum). This will then ensure the progression of all three vessels northwards at the same time in stratum 3 (the core area). The Faroese vessel will start their coverage a few days later and join the other vessels in stratum 3. The Rockall area will also be covered by all vessels when they progress northwards. Survey extension in terms of coverage (51–61ºN) will be in line with the previous year to ensure containment of the stock and survey timing will also remain fixed as in previous years.

Key will be to achieve coverage of area 3 in a consistent temporal progression between vessels. It is therefore very important that all vessels covering the core Hebrides area are present on station in the north of area 2 (just north of Porcupine Bank) around 27th of March 2021. Nonetheless, if some vessels are found to lag behind others, the 20 n.m. transect spacing will allow for adaptation of the survey design without great loss of coverage. For instance, this may mean either skipping or extending some of the horizontal transects to catch up or keep pace with the other vessels. Biological sampling should be carried out following methods normally applied to sampling acoustic registrations.

If registrations of blue whiting marks are continuing at the end of any planned transects, the length of these transects should be extended until no more marks are registered for a distance of 5 n.m. (or 30 minutes at normal survey speed). The transect at the outer western border can be cut off, if no registration of blue whiting for 5 n.m.

Preliminary cruise tracks for the 2021 survey are presented. Detailed cruise lines for each ship are uploaded on the WGIPS sharepoint (/2021 Meeting docs/Working documents/IBWSS 2021 Post Cruise).

As the survey is planned with inter-vessel cooperation in mind it is vitally important that participants stick to the planned transect positioning.

Participants are also required to use the logbook system for recording course changes, CTD stations and fishing operations. The survey will be carried out according to survey procedures described in the ICES WGIPS Manual for Acoustic Surveys.

Table A16.1. Individual vessel dates for the active surveying period in the 2021 International Blue Whiting Spawning stock Survey (IBWSS).

Ship	Nation	Active surveying time (days)	Definitive surveying dates
Celtic Explorer	Ireland (EU)	15	22.3.2021 – 9.4.2021
Vendla	Norway	13	22.3.2021 – 8.4.2021
Tridens	Netherlands (EU)	13	22.3.2021 – 5.4.2021
Jakup Sverri	Faroes	11	25.3.2021 – 7.4.2021
Vizconde	Spain	5	18.3.2021 – 23.3.2021

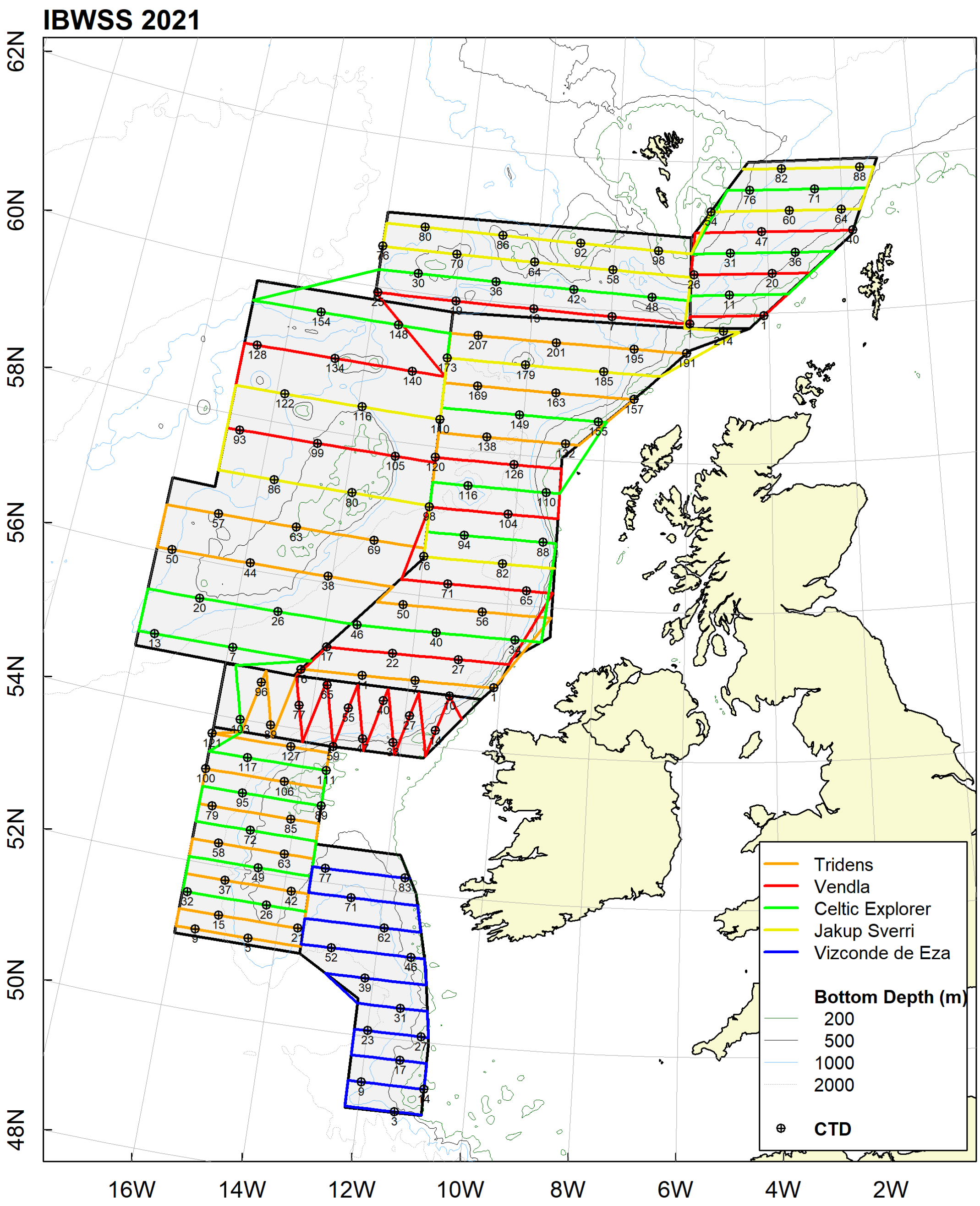


Figure A16.1. Planned survey tracks for the combined 2021 International Blue Whiting Spawning stock Survey (IBWSS).

IESNS

Denmark (EU-coordinator), Faroe Islands, Iceland and Norway will participate in the IESNS survey in April-May 2021. The Russian participation is uncertain and at this stage regarded as unlikely. Ships and preliminary dates are given in Table A16.2. Survey days exclude time for: hydrographic cross sections, coverage outside the IESNS area and crew change. As in the six previous years, the plan is to use a stratified systematic transect design with random starting points. The suggested transects in each stratum are shown in Figure A16.2. The survey planner function in Rstox was used to generate the transects.

A post-cruise meeting is suggested to be held 15-17 June 2021 as WebEx (Teams).

Table A16.2. Individual vessel dates for the active surveying period in the 2021 IESNS.

Ship	Nation	Dates (harbour to harbour)	Effective survey days	Crew change
Dana	Denmark (EU)	2 May – 24 May	19	11-12 May in Bodø
Jakup Sverri	Faroe Islands	29 Apr – 9 May	10	
Árni Friðriksson	Iceland	6 May – 25 May	15	
Dr. Fridtjof Nansen	Norway	30 Apr – 28 May	24	5-6 May in Kristiansund, 11 May in Bodø
	Russia	no participation		

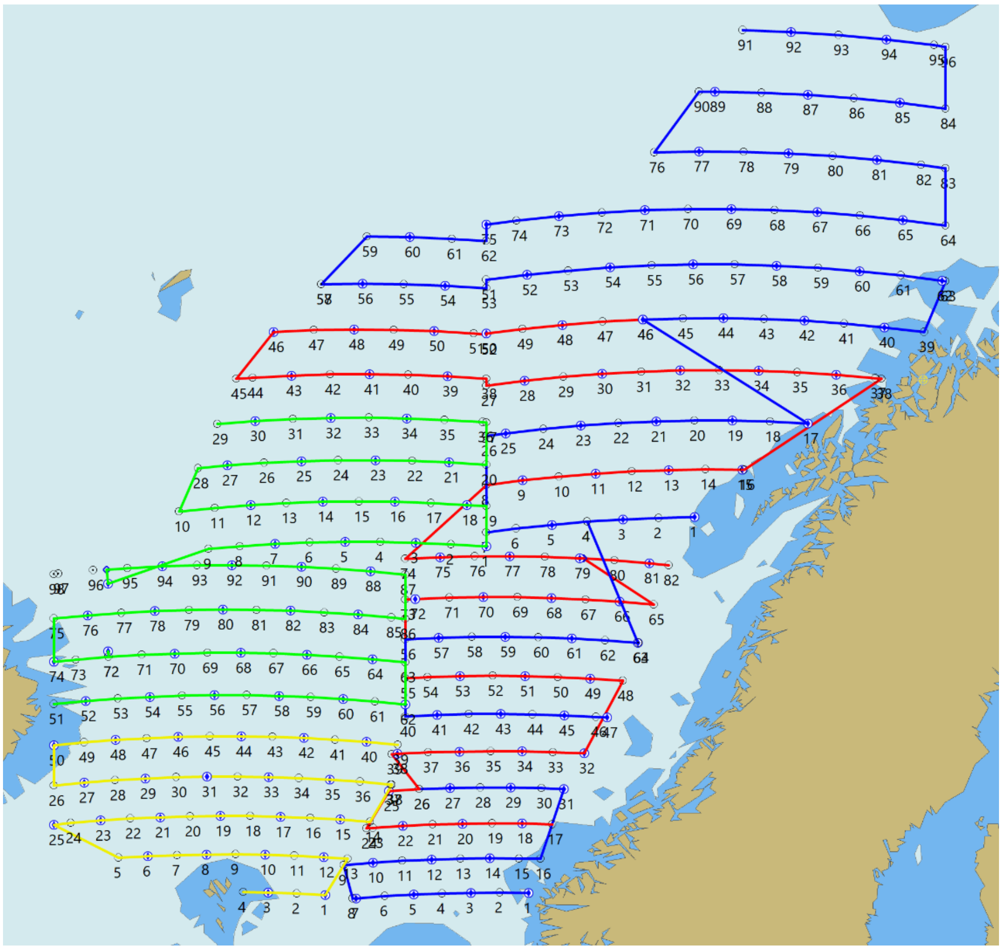


Figure A16.2. Planned cruise tracks and transects for the IESNS survey in 2021. Colors represent the different vessels/nations (yellow: FO, green: IS, dark blue: NO, red: EU,). Suggested CTD stations are shown as blue circles with a diamond inside (the numbered positions are transect points for each 30 nautical mile).

IESSNS

Preliminary planning for the International Ecosystem Summer Survey in Nordic Seas (IESSNS) 2021 was presented in plenary. As in previous years six vessels from five nations will survey approximately 2.5 million km2 in Nordic Seas and the North Sea during the period from June 29th to August 6 2021. The survey area is divided into thirteen strata, within each stratum there is equal distance between predetermined surface trawl stations, used to measure mackerel density. Distance between predetermined stations ranges from 35 nmi to 60 nmi. Strata with higher recorded density of mackerel in the past have shorter distance between stations (Figure A16.3). Post cruise meeting for IESSNS 2021 will be hosted online during the period August 16th – 20th 2021.

Four changes in operation of IESSNS 2021 compared to previous years are planned and they were presented at WGIPS 2021. The changes are:

1. Stratum 11 (southern Irminger Sea, no yellow lines between predetermined surface stations in Figure A16.3 and 12 (Iceland basin) will not be surveyed 2021 since no mackerel nor herring was measured there during IESSNS 2018-2020. During that same period, blue whiting has only been measured as juveniles in surface layers in a small area eastward in the Iceland basin (stratum 12). If mackerel is present on the southern boundaries of the three strata adjacent to strata 11 and 12, these strata will be expanded southwards until the mackerel zero boundary is located.
2. Stratum 4 (north of Iceland), will be expanded northward into Greenland EEZ and one station added to most transect located within Greenland EEZ. Also a west-to-east transect with on trawl station will be added in Greenland EEZ north of stratum Iceland east (stratum 3).
3. One of two Norwegian vessels will install a DeepVision camera inside the multpelt832 trawl in front of the cod-end for duration of the survey. The aim of experiment is to measure mackerel abundance using the camera system and compare to catch in the trawl. It is unknown if or how installing DeepVision inside the multpelt832 will impact catchability of the trawl.
4. Additional sampling of herring otoliths and herring scales for a Norwegian research project to investigate ageing discrepancies between nations (Erling and Florina to send sampling protocol to all IESSNS participants).

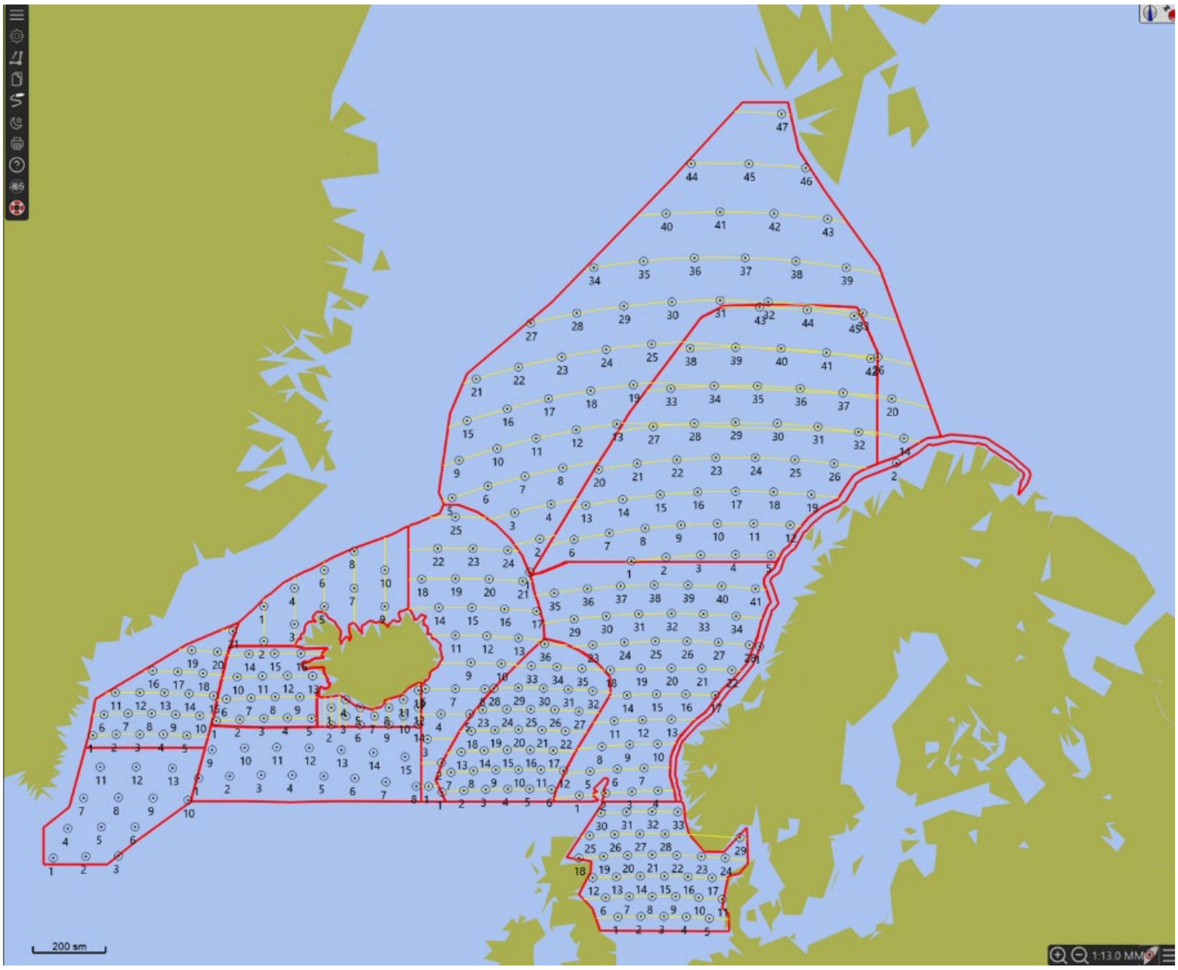


Figure A16.3. Preliminary survey plan for IESSNS 2021, including predetermined location of surface trawl stations (open circle with dot inside), survey track (yellow line), stratum boundary (red line), as presented at the WGIPS 2021 meeting.

HERAS

Norway, Denmark, Germany, Netherlands, Scotland and Ireland will participate in the 2021 HERAS and MSHAS surveys. Ships, preliminary dates and preliminary strata allocations are given in Table A16.3 below. Inshore extension is to be maintained at the 20-m contour for shallow waters regions of the Baltic and south eastern North Sea, and the 30-m contour for all other areas where applicable. The Norwegian survey is bounded a set distance from shore (5 n.mi) due to operational reasons as the 30-m contour is not practical due to the steep coastal topography. The 200-m contour marks the lower depth limit of the survey at the shelf edge and in the north-western boundary. The strata for 2021 are displayed in Figure A16.4 below.

The survey design has been standardised across participants and will follow best practice in terms of transect planning. The main body of the survey will utilise systematic parallel transect lines with randomised starting points and with transects running perpendicular to lines of bathymetry. Zig-zag transects are used in instances where parallel lines are not practical due to operational reasons, such as bays and inlets, or to better utilise survey time, and are stratified accordingly (Strata 2 and 81).

The survey effort, i.e. transect spacing, will be maintained at a similar level to that planned for 2020. Survey effort should also ensure adequate coverage of the North Sea sprat stock, which requires the southern boundary of the survey area to be kept at 52°N.

The survey design and the allocation of survey area and transects to vessels/nations must consider the specialist skills required to adequately cover the areas where stock splitting is carried out based on biological samples.

In all strata to the west of 4°W there is a requirement to collect tissue samples for genetic analysis, and to carry out analysis to prepare for splitting the acoustic index into 6.aN and 6.aS stock components. This sampling has been carried out by Scotland and Ireland since 2010 and it was recommended in the February 2015 benchmark of the Malin Shelf herring stocks that these efforts be continued (ICES, 2015).

To the east of 2°E and north of 56°N, in the areas traditionally covered by Denmark and Norway, there is a requirement to be able to split the survey abundance into North Sea Autumn spawning herring and Western Baltic spring spawning herring. Up to the 2020 survey, Denmark did this based on otolith shape analysis and provided stock discrimination on the individual fish level, whereas Norway used a vertebral count method that provided information only at the strata level. In 2021 it is planned to use genetic sampling for stock discrimination on individual fish level in both survey areas. Norwegian and Danish institutes will discuss and agree on compatible methodology prior to the survey start. Given the increased awareness of stock mixing issues throughout the survey area (6aN, 6aS, NSAS, WBSSH, NSSH) and recent developments in genetic methods it is recommended that genetic sampling of herring be carried out throughout the whole survey area including the areas were currently no stock splitting is carried out. Sampling protocols will be provided to all survey participants.

Transect allocation (excluding the MSHAS strata west of 4°W) has been accomplished (Figure A16.5). The final design will be amended with the MSHAS transects and confirmed over the coming weeks in discussion with participants.

Analysis and reporting

A post-cruise meeting will be held in ICES, Copenhagen, Denmark, in November 2021 (to be confirmed). The post-cruise meeting will allow the group to evaluate survey data, discuss issues arising from the surveys and produce the combined survey estimate. Data uploaded to the ICES acoustic database for the 2016-2018 survey is not complete in all cases. This should be rectified in time for the 2021 post cruise meeting. Survey data for the 2021 survey is to be uploaded to the ICES Acoustic database in the agreed format no later than **31 October 2021.**

Table A16.3. Time periods, areas and rectangles to be covered in the 2021 acoustic survey.

Vessel	Available days for survey	Period available	Strata to cover
Celtic Explorer (IRE)	20	30 June – 20 July	2, 3, 4, 5, 6
Scotia (GB-SCT)	18	22 June – 13 July	1, 91 (north of 58°30’N), 111, 121
Johan Hjort (NOR)	17	25 June – 13 July	11, 141
Dana (DEN)	13	21 June – 06 July	21, 31, 41, 42, 151, 152
Tridens (NED)	12	28 June – 23 July	81, 91 (south of 58°30’N), 101
Solea (GER)	19	29 June – 19 July	51, 61, 71, 131

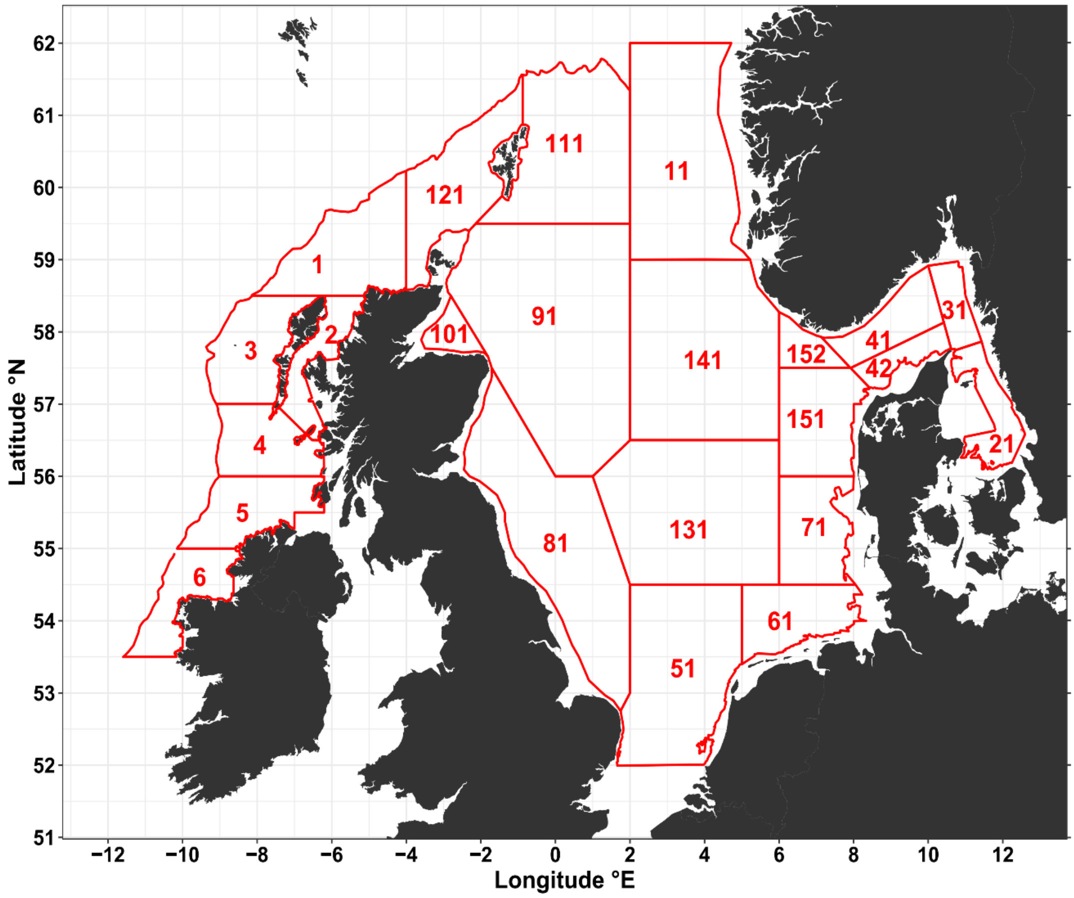


Figure A16.4. The 2021 ICES Coordinated Acoustic Survey in the Skagerrak and Kattegat, the North Sea, West of Scotland and the Malin Shelf area (HERAS): Strata.

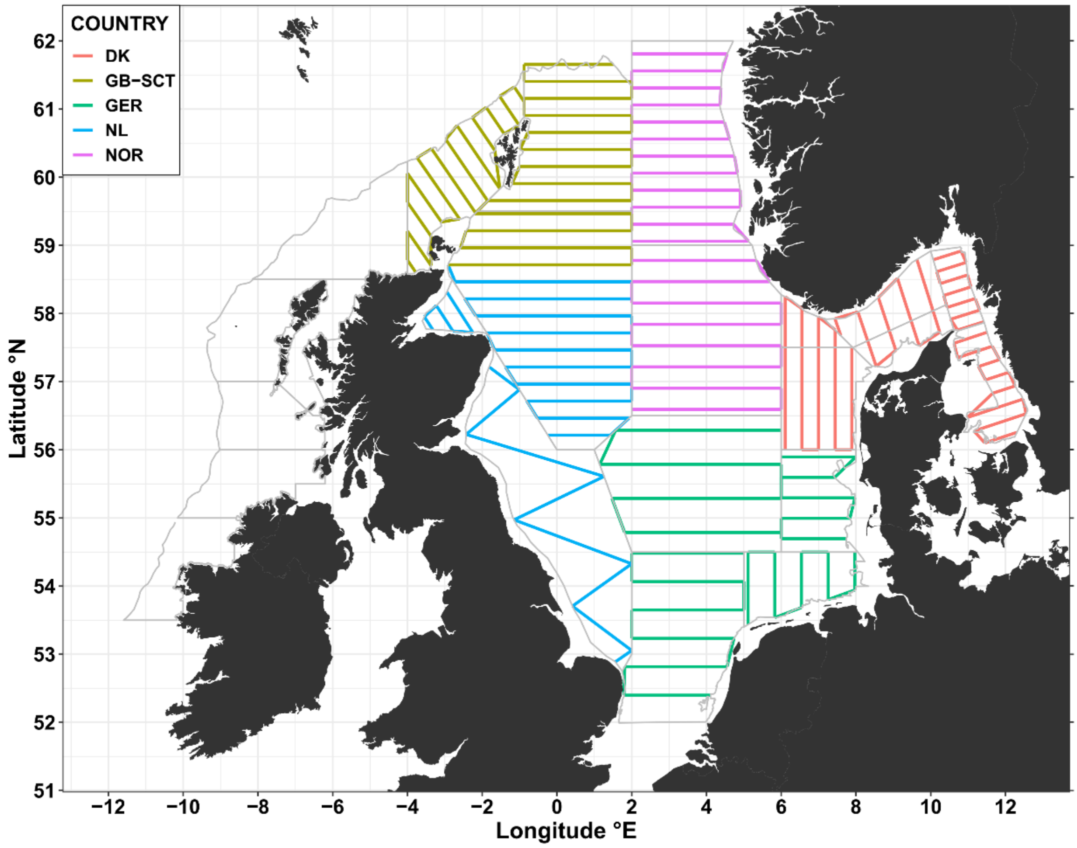


Figure A16.5. The 2021 ICES Coordinated Acoustic Survey in the Skagerrak and Kattegat, the North Sea, West of Scotland and the Malin Shelf area (HERAS): Strata and transects allocated to participants (excluding MSHAS transects West of 4°W)

WESPAS

The 2021 WESPAS (Western European Shelf Pelagic Acoustic Survey) will be carried out on board the RV *Celtic Explorer*. The survey will begin in Northern Biscay on the 09 June and work progressively northwards over 42 days ending on the 20 July to the north of Scotland (Figure A16.6). The survey will be broken into two 3-week legs, with a 1-day break to facilitate a crew change.

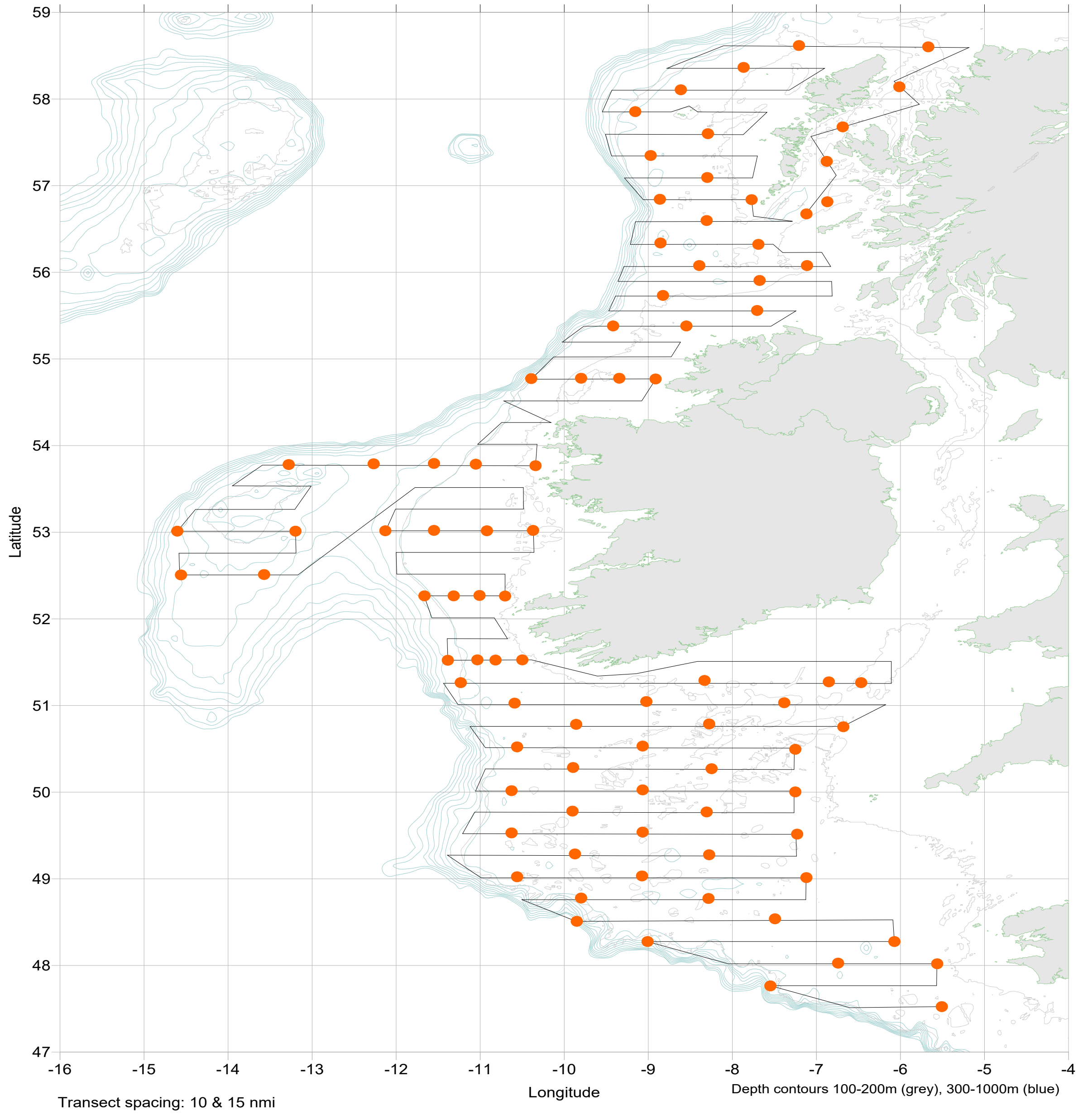


Figure A16.6. Proposed survey design and hydrographic station layout, WESPAS 2021.

CSHAS

The 2021 Celtic Sea acoustic survey will be carried out on board the RV *Celtic Explorer* from the 08 – 28 October (21 days). Survey design utilises a laddered broad scale survey and focused adaptive high resolution site surveys (Figure 16.7).

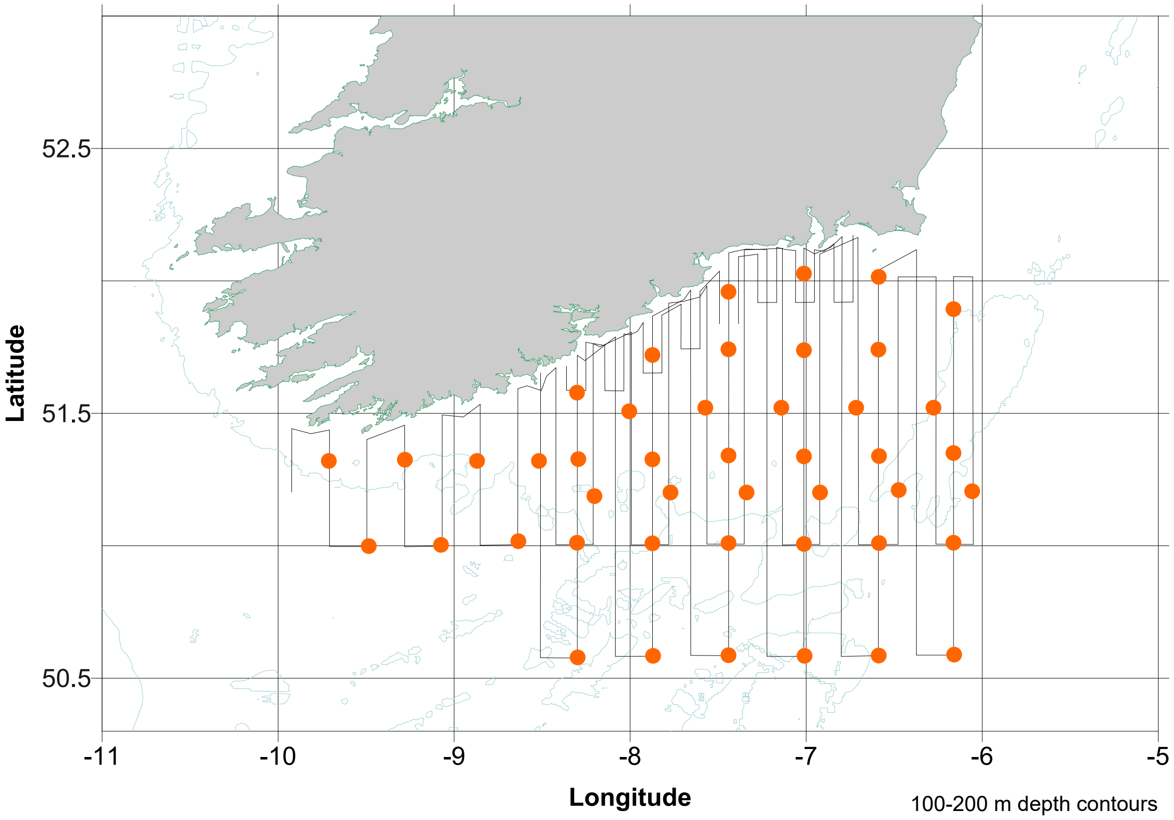


Figure A16.7. Proposed laddered survey design and hydrographic station layout, CSHAS 2021.

ISAS

The 2021 Irish Sea acoustic survey (ISAS) will be carried out onboard the RV *Corystes* between August 26th and September 14th. Figure A16.8 shows the plan and acoustic tracks for cruise C03521. The survey design of systematic, parallel transects covers approximately 620 nm and will be divided into two parts, transects around the periphery of the Irish Sea is randomized within +/- 4 nm of a baseline position each year with spacing set between 8-10 nm. Transect spacing is reduced to 2 nm in strata around the Isle of Man to improve precision of estimates of adult herring biomass.

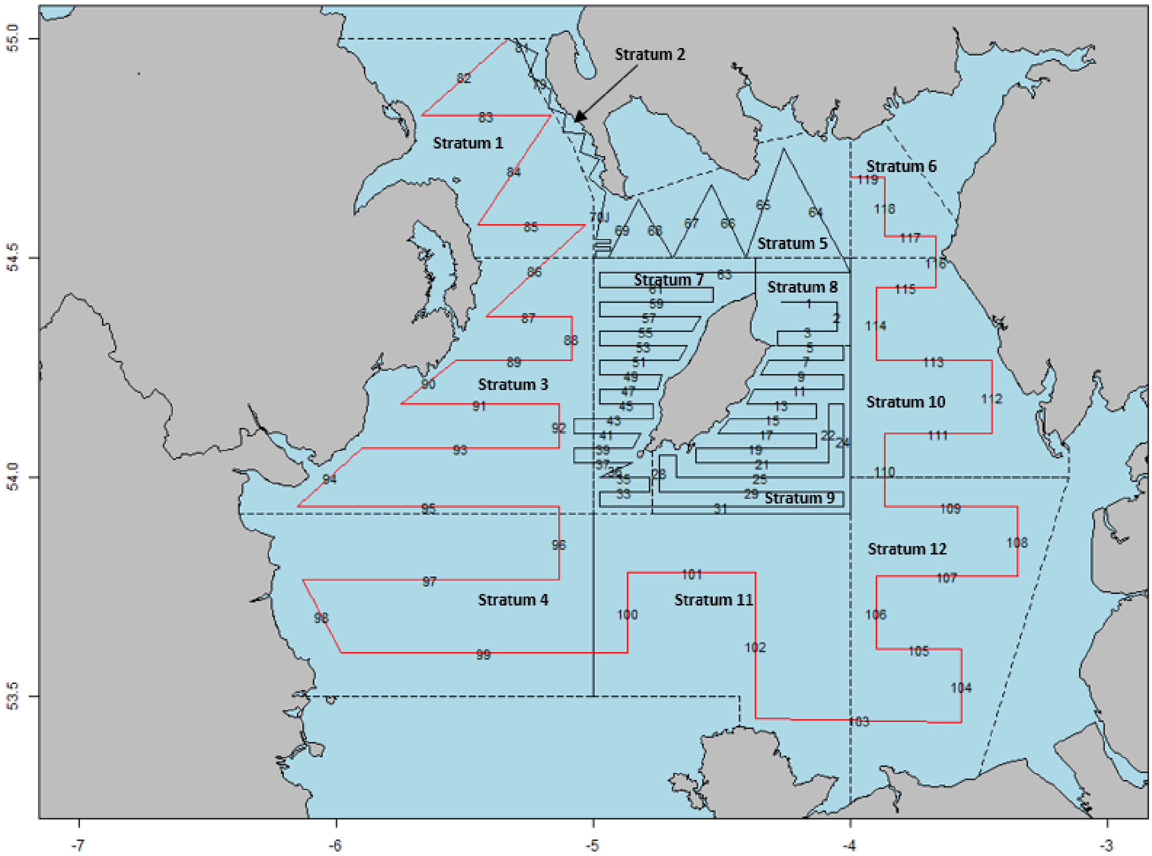


Figure A16.8. Map of Irish Sea and North Channel showing proposed coverage for the 2021 herring acoustic survey C03521.

ISSS

The 2021 Irish Sea Acoustic Spawning Survey (ISSS) will be carried out on-board a commercial pelagic fishing vessel to be named upon the successful completion of an AFBI initiated tender exercise. The survey will be conducted between September 24th and October 01st 2021. Figure A16.9 shows the plan and acoustic tracks for cruise HA3921. The survey design of systematic, parallel transects covers approximately 620 nm. The position of the set of transect with spacing is reduced to 2 nm in strata around the Isle of Man to improve precision of estimates of adult herring biomass.

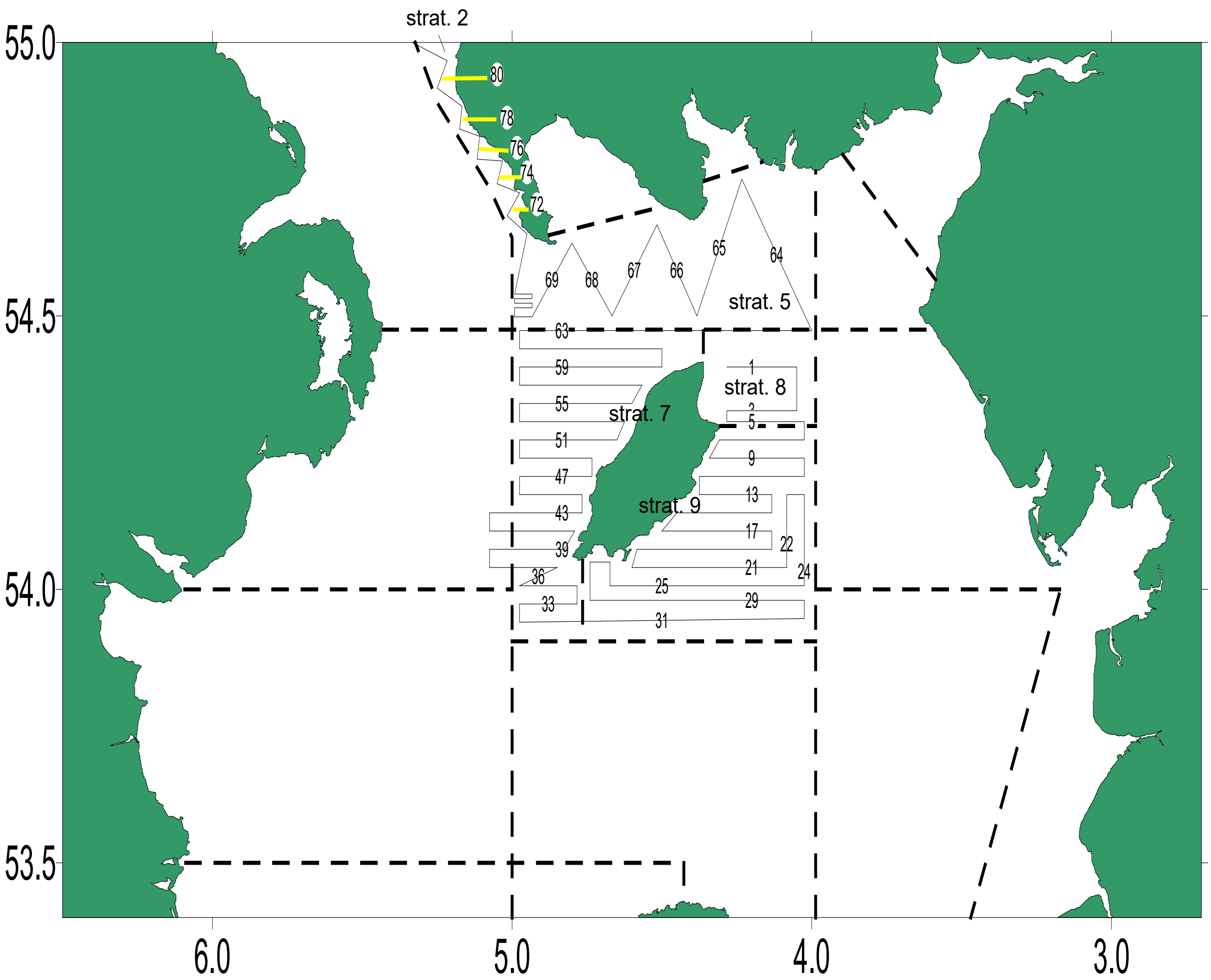


Figure A16.9. Map of Irish Sea and North Channel showing proposed coverage for the 2021 Irish Sea Acoustic Spawning Survey (ISSS) HA3921.

GERAS

The GERAS acoustic survey 2021 will be carried out on board FRV "*Solea*" from October 8th until October 28th. The plan for cruise SB798 and acoustic transects to be followed follow the design adopted for the previous years (figure A16.10) but may be subject to change regarding recent difficulties in attaining all required permits from Swedish authorities and short-term notices of specific area closures in the Swedish survey area in preceding years.

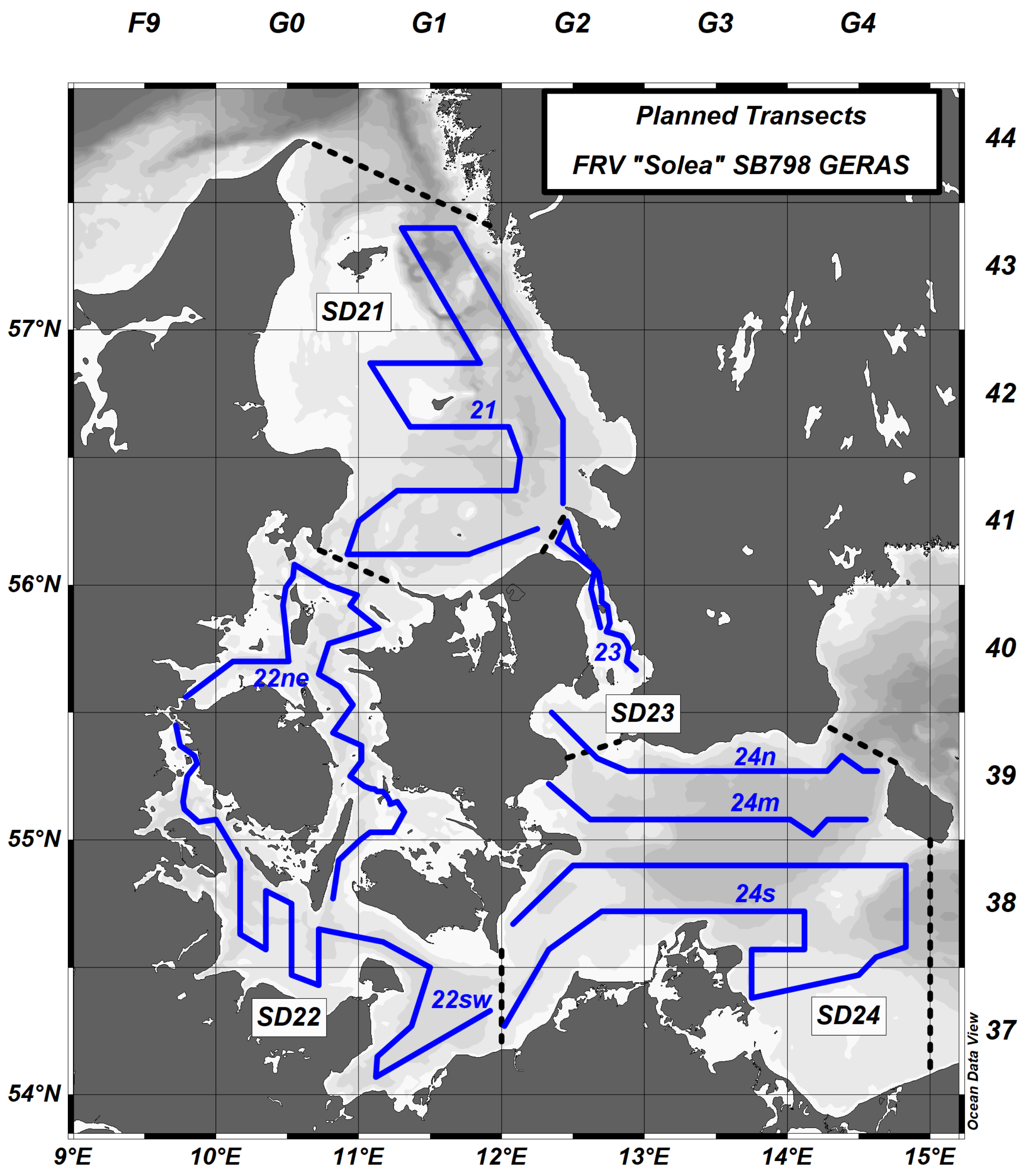


Figure A16.10. Map of the planned coverage in ICES Subdivisions (SD) 21-24 and acoustic transects (blue, transect ID indicated) for the German Acoustic Autumn Survey (GERAS) in 2021 (cruise SB798).

PELTIC

The 2021 PELTIC survey (Pelagic ecosystem survey in the Western Channel and eastern Celtic Sea) is scheduled to be carried out onboard the RV *Cefas Endeavour* from the 1st to the 29th October (TBC). The depicted extension north into Cardigan Bay is not confirmed and would extend the survey by several days (Figure 16.11).

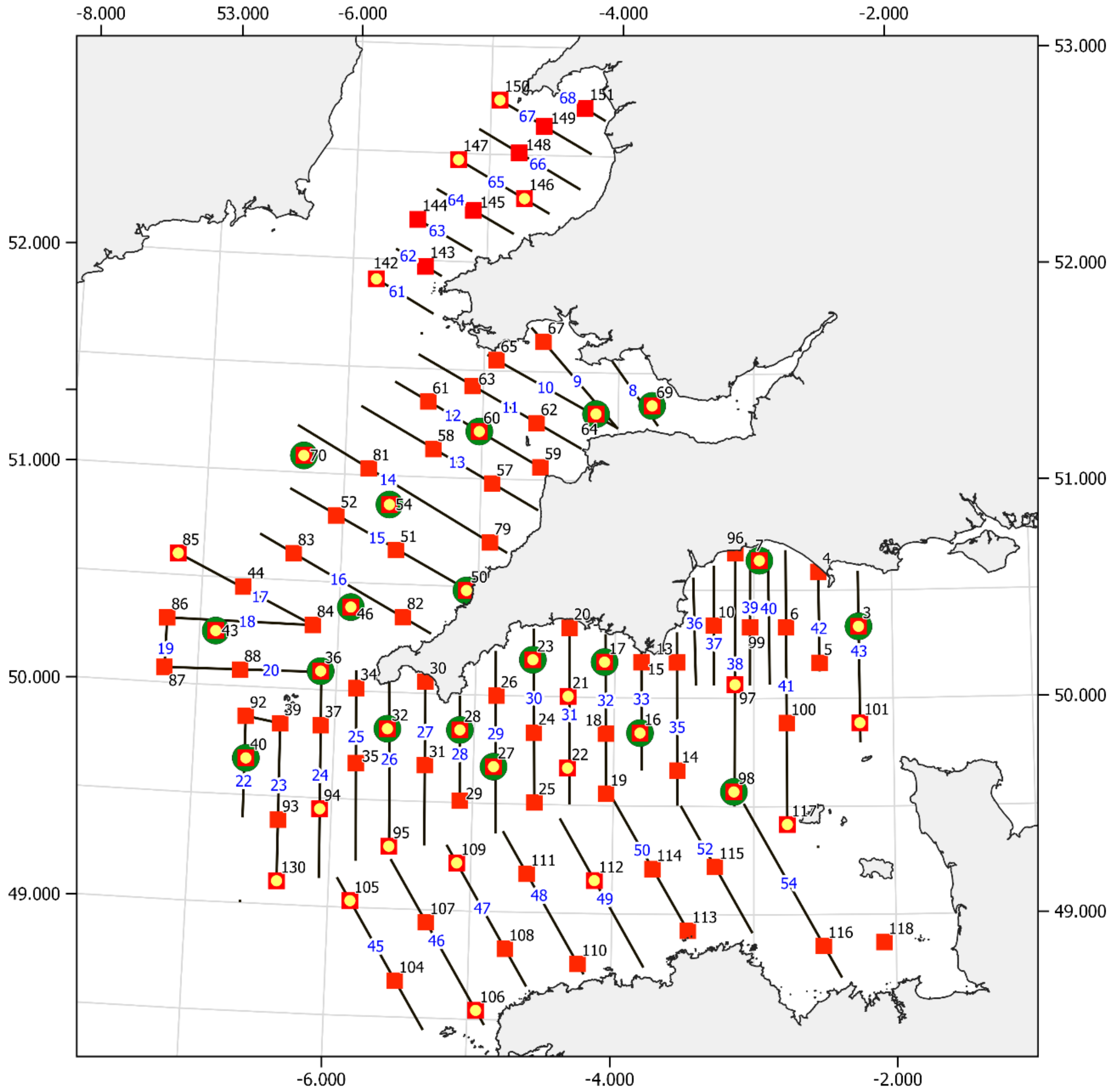


Figure A16.11 Overview of the planned survey area, with the acoustic transect (black lines), plankton stations (red squares) and hydrographic stations (yellow circles), PELTIC 2021.

6aSPAWN (Industry Survey in 6.a.N)

Following the same approach established in 2020, the SPFA and PFA propose to continue industry's participation in scientific monitoring of the state and development of 6aN herring stock. One survey would be coordinated with the HERAS survey in July, and a second focussing on spawning grounds in September.

Objectives and rationale

Objective	Rationale
(1) Increase the chance of obtaining sufficient biological samples of herring in Strata 1 and 3 of the International Herring Acoustic Survey (HERAS).	HERAS surveys covering the west and north-west of Scotland routinely have difficulty in obtaining sufficient biological samples required to determine the acoustic survey abundance-at-age. This makes the calculation of herring stock biomass and tracking of age structure particularly difficult in this area, which is source of uncertainty and weakness in the stock assessment. Having an industry vessel participate in the survey in these areas can help increase the chances of getting successful biological and genetic samples required for stock assessment.
(2) Test the effect of transect spacing on estimation of herring abundance in HERAS Strata 1 and 3.	The HERAS survey in the Malin shelf and 6a areas currently operates with a 15nmi transect spacing, which is based on previous statistical analysis of survey designs conducted when herring were more abundant in the area. During the current lower stock size, a test of the implications of transect spacing on the acoustic estimate of herring abundance would be a useful exercise to understand survey performance and future design requirements.
(3) Monitor the abundance-at-age of herring on the main spawning grounds in 6aN.	In 2020, both the HERAS and 6aSPAWN survey reported a decent recruitment of age 1 fish, which have not yet had chance to spawn. These fish could be very important in determining the state of the stock in coming years if it turns out to be a good year class. The question is 'will the immature fish seen in abundance in 6aN in 2020, spawn in 6aN in 2021?, or simply, 'are they 6aN fish'? Building on the 5 year time series, an acoustic-trawl survey would be used to determine the age structure of the herring on the main spawning grounds.
(4) Undertake maturity staging experiments to help resolve uncertainty in genetic discrimination of 6aN herring.	Results from the EASME project indicate a high degree of confidence in the genetic discrimination between 6aN and 6aS fish, but there were several samples that were an unexpected 'fly in the ointment' because they indicate mixing of 6aN and 6aS fish on the spawning grounds. During the benchmark process, these results will raise questions over the reliability of wider genetic results and the method's utility for stock splitting in assessments.

Survey Plans Outline

SURVEY 1: JULY (IN TANDEM WITH HERAS SURVEY)

Objectives 1 & 2. *Increase the chance of obtaining sufficient biological samples, and test the effect of transect spacing on estimation of herring abundance in HERAS Strata 1 and 3.*
In coordination with the RV Scotia and Celtic Explorer, one Scottish industry vessel would undertake ~10 days acoustic-trawl survey work (approx. 8-16th July) in HERAS Strata 1 &/or 3, following the same procedures regarding the collection of herring samples and analysis of acoustic data.

The plan would require surveying all transects of one or more complete strata (in terms of StoX analysis strata), at the same time as a scientific survey vessel. During such a test it would be necessary to conduct a vessel inter-calibration, where vessels attempt to record the same fish marks to ensure they see the same thing. As well as verifying the comparability of the data, the inter-calibration exercise would be beneficial to the industry by providing information to quantify the performance and quality of the acoustic data recorded by a commercial vessel side-by-side a scientific research vessel.

Deployment
Vessel: TBC
Dates: ~8-10 days between ~ 7/8 to 16 July
Staff: Steven Mackinson + Shaun Fraser (NAFC) + 1 x SFF (or other)
Survey design: 15nm spacing acoustic lines (Figure A16.12 left), in-between existing survey lines (Figure A16.12 right).

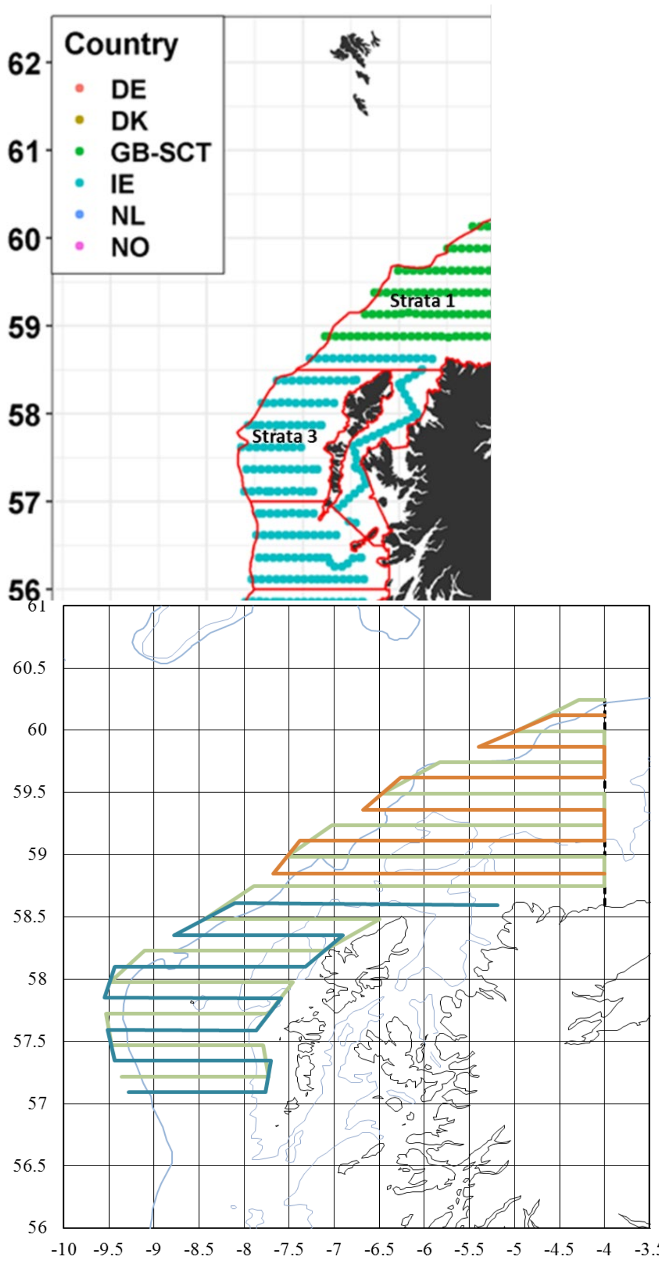


Figure A16.12. (a) left panel – HERAS survey strata, (b) right panel- Survey plan. 15nmi spacing (green lines) covering HERAS strata 3 in the south and strata 1, North of the Butt of Lewis. Blue lines are covered by Ireland (Celtic Explorer) and orange lines by Scotland (Scotia)

SURVEY 2: SEPTEMBER (6aSPAWN SURVEY)

Objectives 3 & 4. *Monitor the abundance-at-age of herring on the spawning grounds through and help resolve uncertainty in genetic discrimination of 6aN herring.*

As in 2020, acoustic-trawl surveys will be used to monitor the spawning population following the protocol established on the advice from ICES WKHASS (Oct 19) and WGIPS (Jan 2020). Two vessels (probably one Scottish and one Dutch) would undertake surveys covering the main spawning period in September. In addition, they would undertake specific experiments to help resolve unexpected results in genetic data that will be submitted to the assessment benchmark in 2022. Time and cost permitting, underwater camera work will be undertaken to confirm the identity of acoustic marks, helping to improve quality of the survey.

There is a suspicion that unexpected genetic results may be due to erroneous classification of maturity stage, with differences between different laboratories and/or between fish that are fresh vs those that are frozen. The discrepancies in staging have an important implication, both when the 9 point scale or 6 point maturity scale (Table A16.4). This is because there is a breakpoint at the same place in both scales, which would lead to fish being classified as spawning, and hence being included in the genetic baseline for stock separation, or not. Two experiments are proposed to help resolve this issue so that genetic analyses can be interpreted with confidence.

The first is genetic analysis of existing seven samples (4 of which are essential) that were not previously analysed [*NOTE: agreement to undertake this analysis is being dealt with under a new contract with Ed Farrel*]. The second is to undertake an experiment in 2021 to test and cross-validate methods and results of maturity staging. This would involve samples being maturity staged fresh at sea by different operators and fresh and frozen, in laboratories. Genetic tissue samples would be taken as routine during sampling and stored for subsequent analysis if needed.

As in 2020, the industry propose that catches in 6aN in 2021 are again restricted to only those necessary to obtain the data during the scientific surveys.

Table A16.4. Translation of Marine Scotland 9 point maturity scale to ICES 6 point scale

Nine point scale (MSS)	Equivalent 6 point scale (ICES)
1 Immature virgin	1 (Immature)
2 Immature	1 (Immature)
3 Early maturing	2 (Mature – but not included in spawning category))
4 Maturing	2 (Mature – but not included in spawning category)
Breakpoint between stage categories, spawning baseline or not	
5 Spawning prepared	3 (Mature – included in spawning category)
6 Spawning	3 (Mature – included in spawning category)
7 Spent	4 (Mature – Spent – included in spawning category)
8 Recovering/resting	5 (Mature – resting - not included in spawning category)
9 Abnormal	6 (Abnormal – not included in Mature or spawning categories)

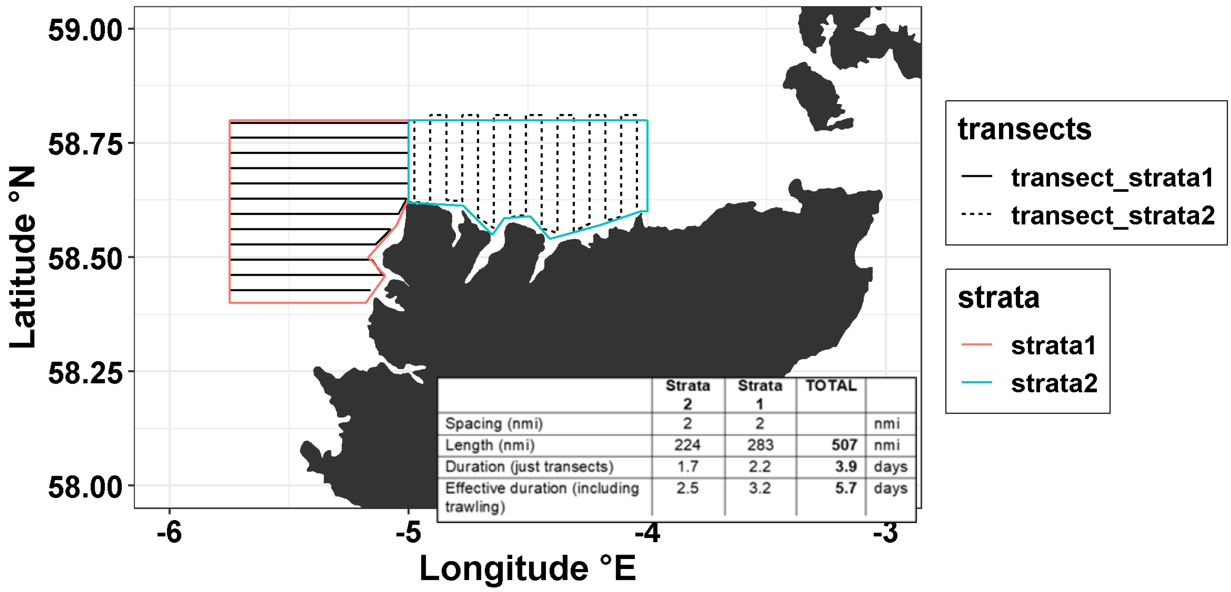
Deployment

Vessels: TBC (1 x Scottish vessel, 1x Dutch vessel)

Dates: 10 days between late Aug and end of Sept

Staff: Steven Mackinson + 1

Survey design: 2nm spacing acoustic lines (Figure A16.13). Each vessel covers the survey area twice to provide extended temporal coverage



	Strata 2	Strata 1	TOTAL	
Spacing (nmi)	2	2		nmi
Length (nmi)	224	283	507	nmi
Duration (just transects)	1.7	2.2	3.9	days
Effective duration (including trawling)	2.5	3.2	5.7	days

Figure A16.13. Survey areas for 2021 6aN surveys.

6aSPAWN (Industry Survey in 6.a.S)

An acoustic survey of Atlantic herring will be conducted in ICES areas 6aS/7b between November 2021 and February 2022. The survey design changed in 2020 compared with previous years (2016-19) in that only core areas with prior knowledge of herring distribution from the monitoring fishery were targeted for surveying. This was largely based on the results from ICES WKHASS (ICES 2020) and from lessons learned in the previous surveys in this area from 2016-2019. This survey design will continue in 2021/22 with the continued objective to capture the distribution of winter spawning herring in the core inshore areas within the greater in the 6aS/7b area (Figure A16.14). Parallel transects will be used in most areas where possible, and zigzags used in areas where narrow estuarine channels (Lough Foyle and Lough Swilly) makes parallel transects unworkable (Figure A16.15). The timing of surveys in the core areas will be flexible from the outset by design. The greater flexibility allows for a targeted spatial and temporal approach which can avoid the inevitable poor weather that can happen in this area during this time of the year. Using multiple smaller vessels will again allow surveys to be conducted in shallow inshore areas where herring are known to inhabit during this time of the year. The entire survey area will be divided up into 5 – 6 smaller strata, concentrating on areas where herring are known to occur in pre-spawning aggregations. Estimates will be generated from each strata area and replicates of some areas may be completed also if resources allow. This will require a more mobile echosounder (e.g. SIMRAD WBAT 38 kHz) that can be deployed easily from smaller vessels (10 -15m length) with minimal mob and de-mob time. It is hoped that many vessels can be involved in the survey with this approach, each surveying for 1-2 days covering all areas. The advantage will be that the survey design can be reactive to information coming from the fleet, poor weather can largely be avoided, and thereby improving the consistency of results and reducing bias. All the most important core inshore areas in 6aS/7b can be completed by using this approach. Information and expertise from inshore vessels will be considered in the survey. It is hoped that increased participation in the survey by the fleet that is actively fishing for herring in these areas will result in a more robust survey and therefore more accurate estimate of the stock at this time of the year. If the stock expands in areas or time in the future, the flexible approach can react to it, by adapting the survey design to include this information.

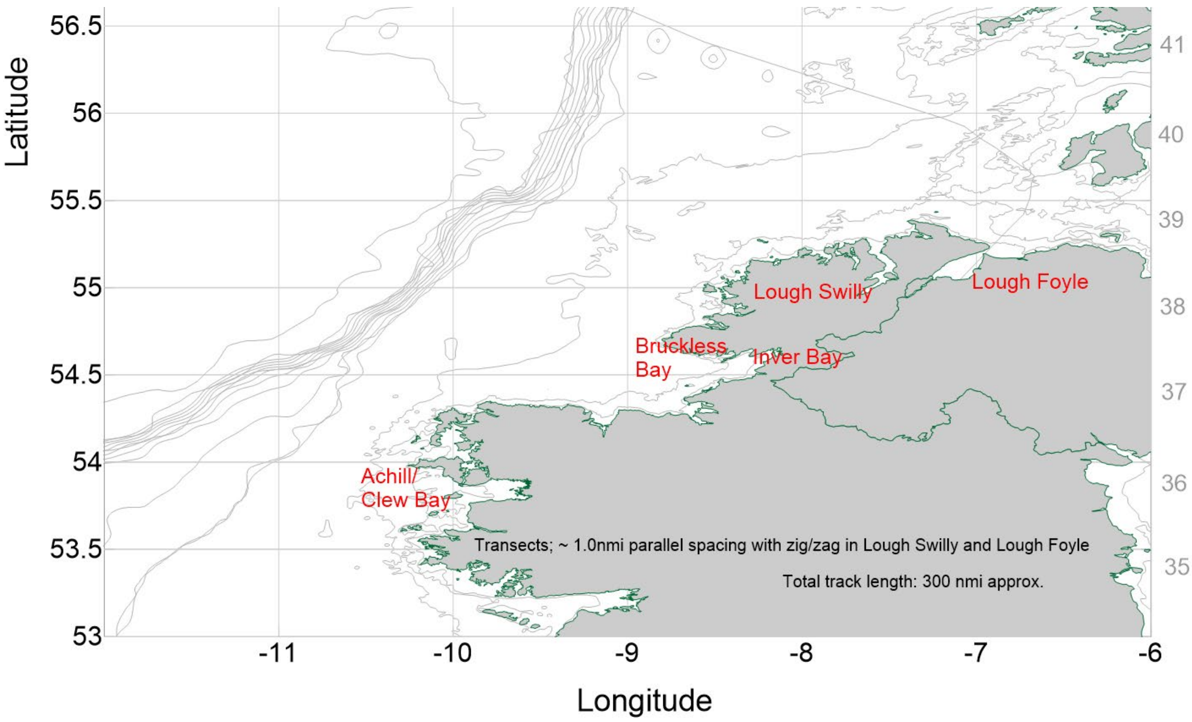
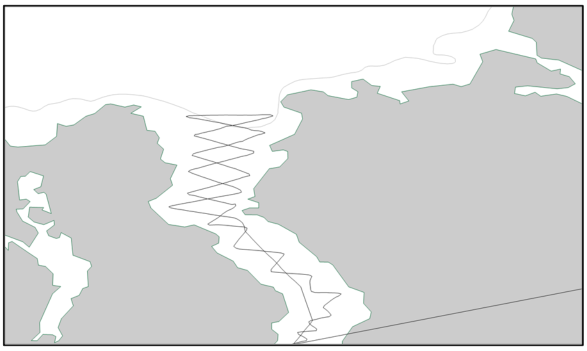


Figure A16.14. 6aS/7b industry acoustic survey in 2021: Core areas (5 – 6) will be selected for intense surveys based on information from the monitoring fishery and from previous surveys in 2016-2020. Estimates will be generated from these core areas and surveys will be replicated if possible.



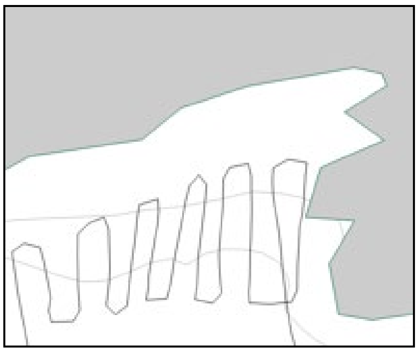


Figure A16.15. 6aS/7b industry acoustic survey in 2021: The total planned transect length is approximately 300 nmi in 5 core areas. The survey design allows for intense surveys in areas where fish are observed and also in areas known to contain herring from information from the fleet (e.g. Lough Swilly (left) and Fintra Bay (right)).

Annex 17: WGFAST response to WGIPS

Effects of Survey Speed on Herring Biomass Estimates

Laurent Berger, Benoit Berges, Dezhang Chu, David Demer, Mike Jech and Naig Le Bouffant (alphabetical)

Background:

For six weeks each summer, ships from Iceland, Denmark, the Faroe Islands, Greenland, and Norway conduct the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) to measure the abundances and distributions of Atlantic mackerel, Norwegian spring-spawning herring, blue whiting, lumpfish, and Atlantic salmon (Nøttestad et al., 2016). During these surveys, acoustic backscatter data are collected at vessel speeds of 10-13 kts along parallel, 30-60 nmi-long transects between pre-determined trawl stations. Data are collected to 500-m range using narrow-bandwidth 38-kHz echosounders with 7º-beam width hull-mounted transducers, transmitting 1.024 ms pulses every ~1 s (**Table 1**). The herring schools are typically shallower than 50-m depth. Biomass estimates from the acoustic-trawl-method (ATM) survey require classification of the echoes, information on fish species, size and age from the catches, and ultimately enumeration of each target species (e.g., Zwolinski et al., 2016).

In 2020, the ICES Workshop on Scrutinizing of Acoustic Data from the IESSNS Survey (WGSCRUT2) asked the ICES Working Group on Fisheries Acoustics, Science and Technology (WGFAST) to investigate whether survey speeds above 10 kts will affect measures of integrated volume backscattering coefficients (s_A) and thereby bias ATM estimates of herring biomass. Through the following analysis, WGFAST endeavours to provide a focussed and actionable recommendation.

Table 1. Acoustic instruments and settings for the primary frequency (38 kHz) during the IESSNS in July 2019 (WGIPS 2020 Annex 6, Table 4, ICES 2020).

	M/V Kings Bay	R/V Árni Friðriksson	M/V Vendla	M/V Finnur Fríði	Eros
Echo sounder	Simrad EK80	Simrad EK 60	Simrad EK 60	Simrad EK 60	Simrad EK80
Frequency (kHz)	18, 38, 70, 120, 200	18, 38, 120, 200	18, 38, 70, 120, 200	38,120, 200	18, 38, 70, 120, 200
Primary transducer	ES38B	ES38B	ES38B	ES38B	ES38B
Transducer installation	Drop keel	Drop keel	Drop keel	Hull	Hull
Transducer depth (m)	9	8	9	8	8
Upper integration limit (m)	15	15	15	Not used	15
Absorption coeff. (dB/km)	9.6	10.0	9.1	9.8	9.3
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.43	2.43	2.43	2.43	2.43
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.90	21.9	21.90	21.9	21.9
2-way beam angle (dB)	-20.7	-20.81	-20.6	-20.3	-20.7
TS Transducer gain (dB)	24.33	24.36	24.56	26.67	25.63
s_A correction (dB)	-0.58	-0.58	-0.69	-0.58	-0.6
alongship:	7.01	7.28	7.03	7.16	6.86
athw. ship:	7.00	7.23	7.09	7.22	7.05
Maximum range (m)	500	500	500	500	750 for 18 and 38 kHz, 500 for 70, 120 and 200 kHz
Post processing software	LSSS v.2.5.1	LSSS v.2.3.0	LSSS v.2.5.1	Echoview 10.x	LSSS v.2.5.1

Analysis Scope:

There are many potential sources of uncertainty in ATM-estimates of fish biomass (Rose et al., 2000; Demer, 2004; Løland et al., 2007), but the principal factors typically relate to target strength (*TS*) estimation, echo classification, and fish behaviour. In the IESSNS surveys, herring *TS* is estimated using a model (Ona, 2003) parameterized with the lengths of fish in trawl catches, which are not affected by the transect speed. Although ship speed may affect the apparent dimensions of fish-school echoes (see Diner, 2001), and therefore classifications resulting from visual scrutinization of echograms, these potential effects cannot be quantified theoretically. Also, because fish schools may dive or swim laterally, disperse or coalesce, or react in a combination of these and other ways in response to an approaching survey ship (e.g., De Robertis and Handegard, 2013), and these may also affect the acoustic properties and shape of herring schools (Olsen, 1983), the variable effects of fish behaviour on herring biomass estimates are specific to the survey ship and environment, among other factors such as ontogeny. Furthermore, because any increases in bubble attenuation and acoustic and electrical noise resulting from increased ship speed (Ryan et al., 2015) are also specific to the survey ship and environment, their effects on measured s_A must be quantified empirically. Therefore, towards an actionable recommendation, this analysis is focused on estimating the effects of increased transect speed on herring biomass estimates resulting from reduced horizontal sampling.

Biomass Estimation:

The ATM is based on the theory of echo-integration (Moose et al., 1971; Ehrenberg et al., 1972), which involves the sum of the volume backscattering coefficients (s_V) measured over a sample depth, and the average of the resulting integrated volume backscattering coefficients (s_A) over a sample distance. In this context, Coetzee (2000) defined *school detection* as the accurate measurement of the school's acoustic properties (s_V and s_A), and vertical and horizontal dimensions from periodic acoustic samples (**Fig. 1**).

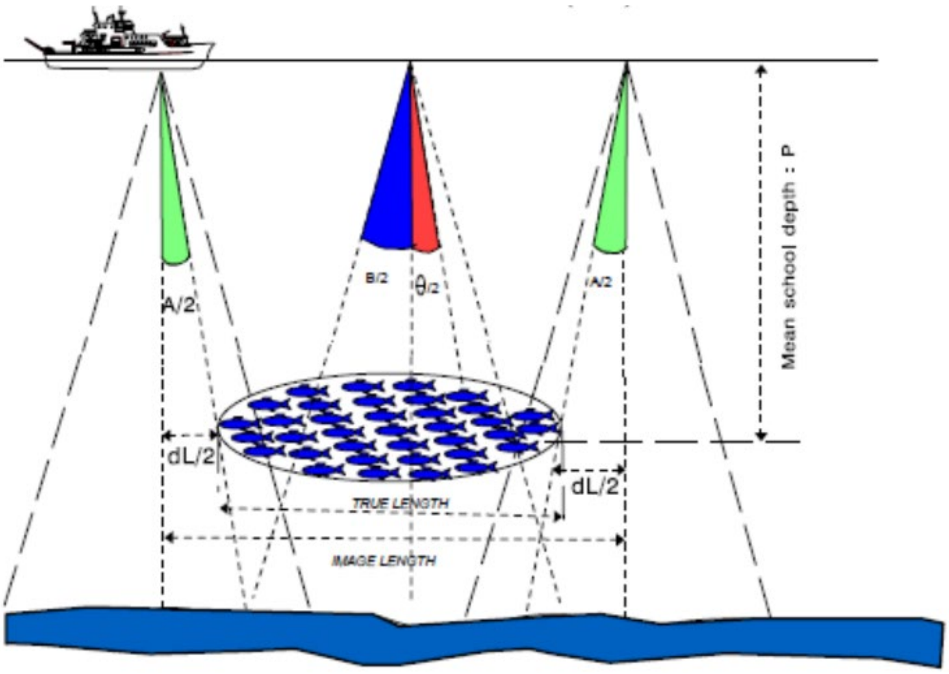


Figure 1. Schematic of a conical acoustic beam periodically sampling a relatively stationary fish school located between a hull-mounted transducer and the seabed as a ship moves from left to right (from Diner, 2001). The nominal beamwidth (θ) is the angle between half-power points (one-way) relative to the beam axis.

Signal Quality:

The power received by an echosounder depends on the acoustic frequency, transmit power and pulse duration, bubble attenuation, sea-water absorption, and spreading loss, fish *TS*, school range and packing density, and transducer gain. The variance in received power increases with acoustic frequency and s_V, and decreases with the number of averaged samples. Noise in the received power may be acoustic or electrical, both of which increase with ship speed (Ryan et al., 2015). The signal-to-noise ratio may be estimated from ensembles of received-power recordings (De Robertis and Higginbottom, 2007) from which the effects of speed may be evaluated.

Vertical Sampling:

Vertical-sampling uncertainty depends on the transducer depth and near-field range (Scalabrin et al., 2009; Totland et al., 2009), duration of the narrowband-echosounder pulse, and the s_V, depth, and height of the fish schools (Diner, 2001). Disregarding any effects of fish behaviour that may result from increased ship speed (e.g., diving that may affect fish *TS* and school depth and packing density; De Robertis and Handegard, 2013), vertical sampling is unaffected. On the other hand, ship speed varies the horizontal inter-sample distance and the signal quality, which may affect the bias and precision of herring biomass estimates.

Horizontal Sampling:

The horizontal inter-sample distance is dependent on the range-dependent distance between successive ensonifications, which depends on the ship speed (c_s; m s^{-1}), the transmit interval (i_t; s), and the transducer beam width (*B*). The maximum inter-sample distance, which is equal to the distance that the transducer moves along the transect between successive transmissions (*d*; m) is:

$$d = c_s i_t \ . \tag{1}$$

Disregarding beam spreading with range, the number of times the school is ensonified on the beam axis (n_d) is:

$$n_d = l/d \ , \tag{2}$$

where *l* is the along-transect length of the school echo. This provides a conservative estimate for the number of samples from the school (Diner, 2001).

An objective of stock assessment surveys is to provide an estimate of mean fish areal density, $\overline{D}$ (number of fish per unit area), over a given survey area. Acoustic measurements provide observations of s_A along survey lines, from which areal fish densities (*D*) are generated. Areal density is intrinsically highly variable and minimizing variance in our estimates will provide greater confidence in our estimates of fish density. The variance of the estimate of the mean density will depend on the variability of the "true" fish density and on the number of uncorrelated measurements (*N*) used for the average:

$$\sigma_{\overline{D}}{}^2 \sim \sigma_D{}^2/N \ , \tag{3}$$

The number of uncorrelated averaged measurements over a given elementary sampling unit (ESU; m) is based on the correlation distance (*Cd*) and *d*:

$$N = ESU/\max(d, Cd) \ , \tag{4}$$

where *Cd* is the minimal distance between acoustic measurements that ensures that they are not correlated, and "max" is the maximum of *Cd* and *d*. *Cd* is similar to school image length (**Fig. 1**) and directly related to l and *B* (horizontal along-track sample length, which increases with depth for conical beams projecting downward from hull-mounted transducers). It also potentially depends on the inter-school distance, but we consider here the case where inter-school distance is larger than l (i.e., the fish schools are separated by distances greater than their along-transect length), and that it is not an impacting parameter. For *B* small compared to *l* (i.e., large or shallow schools):

$$Cd \sim l \quad \text{(5a)},$$

and for *B* large compared to *l* (i.e., small or deep schools):

$$Cd \sim B \quad \text{(5b)}.$$

The exact expression of *Cd* when *l* and *B* converge is not direct, but a conservative approximation can be taken as :

$$Cd < l + B \quad \text{(5c)}.$$

This relationship results from equations (3) and (4) where increasing *d* will not impact estimate accuracy until *d~Cd*, and as *d* increases greater than the *Cd*, the variance of the estimate will increase as *d* increases.

Although many aspects of the IESSNS protocol are unchangeable (e.g., the survey ships, acoustic frequency and beamwidth), the transmit interval should be optimized, considering the seabed depth and avoidance of aliased seabed echoes (Trenkel et al., 2009; and Renfree and Demer, 2016), to reduce the inter-sample distance. This approach could reduce uncertainty in estimates of biomass for relatively small schools of herring derived from ATM surveys conducted at speeds greater than 10 kts, if the signal quality is not degraded.

Simulated effects of horizontal inter-sample distance Methods

Although the combined effects of increased ship speed should be estimated empirically, the isolated effect of increased *d* on measurements of s_A may be quantified through simulation. Simulation software (OASIS, IFREMER) was used to calculate theoretical, single-frequency echosounder measurements of volume backscattering strength (S_V) received from individual fish aggregated in schools above a flat seabed, each having prescribed characteristics. The simulation's sonar equation accounts for the transducer location and orientation, source level, fish target strength (*TS*), transmit and receive beam directivity patterns, and propagation loss along the beam.

Simulation measurements were calculated for multiple transmit intervals and school dimensions and locations while holding the other parameters constant (**Table 1**). The maximum school length, 30 m, corresponds to the median length of herring schools observed during the 2017, 2018 and 2020 IESSNS surveys.

Table 1. Simulation variables and parameters for OASIS software.

Category	Parameters	Values
Echosounder		
	Frequency	38 kHz
	Beam directivity	For circular piston with 7° beamwidth
	Source Level	230 dB
	Transmit interval	0.2, 1, 2 s

	Number of transmissions	Transect length/Distance between transmissions
Environment		
	Temperature	12.6 °C
	Salinity	35.4 PSU
	Sound velocity	1495 m/s
Ship		
	Speed	10 kts
	Attitude	Heave, roll, and pitch = 0°
Schools		
	Fish *TS*	-45 dB
	School S_v	-35 dB
	Inter-fish spacing, mean	(10^((Sv-TS)/10))^(-1/3) = 0.46 m
	Inter-fish spacing, standard deviation	(1/5) mean inter-fish spacing = 0.09 m
	Length	30, 15, or 5 m
	Width	30, 15, or 5 m
	Height	10, 5, or 5 m
	Alongships school location	Regular interval, 50 m Random uniform, ±30, ±15 or ±5 m
	Vertical school location	Random uniform (5-55 m)
	Number of schools	800
Transmit signals		
	Pulse duration	1 ms
	Pulse shape	Hamming shape
	Sampling rate	10 kHz
Output		
	File format	HAC
	Sampling rate	10 kHz

The resulting data were further processed (MOVIES3D; Trenkel et al., 2009), using $S_{V\ threshold}$ = -80 dB, to calculate s_A for eleven 50-m horizontal by 5-m vertical cells between 5 and 55-m depth. These 800 x 11 simulated s_A values, each independent observations of the same school randomly positioned relative to the beam axis, were averaged over larger ESUs.

To estimate measurement error, theoretical values of s_A were computed by:

$$s_A^{theory} = \frac{Nb_{fish}}{V} * \sigma_{bs} * 1852^2 \;, \qquad (6)$$

where Nb_{fish} is the total number of fish randomly positioned in the sampling volume V, and σ_{bs} is the backscattering cross section of each fish $\sigma_{bs} = 4\pi 10^{TS/10}$ (MacLennan et al., 2002), and the ratios of simulated and theoretical ESU-averaged s_A values were compared. To estimate measurement precision as a function of integration distance, we used a bootstrap technique with 100 random selections of 50-m ESUs among the 800 simulated values and further averaging over larger ESUs (~0 to 10 nmi).

To elucidate the effect of changing d (modulated by transmit interval, ship speed, or both) as a function of depth, the ratio of simulated and theoretical ESU-averaged s_A values was evaluated for 2 and 0.2 s transmit intervals for 11 layers from 5 to 55 m depth (**Fig. 2**).

d 0.2 s transmit intervals for 11 layers from 5 to 55 m depth (**Fig. 2**).

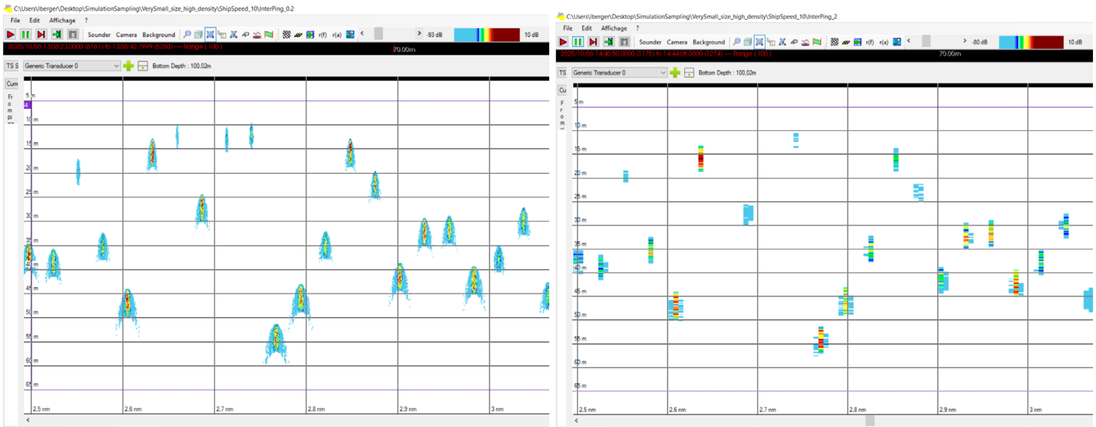
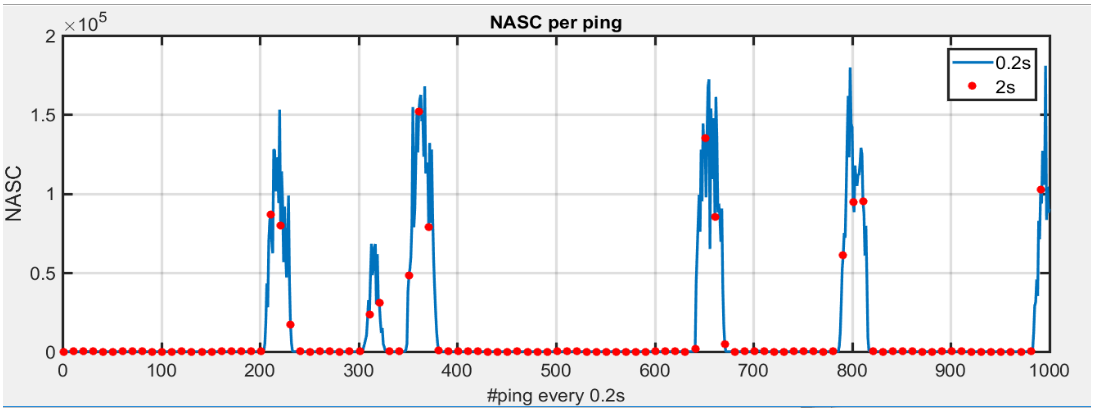


Figure 2. Simulated echograms of 5-m long, 5-m wide, and 5-m tall schools sampled with 0.2 s (left) and 2 s (right) transmit intervals.

The uncertainty in s_A as a function of integration distance was simulated for two school sizes and two transmit intervals (**Fig. 3**).



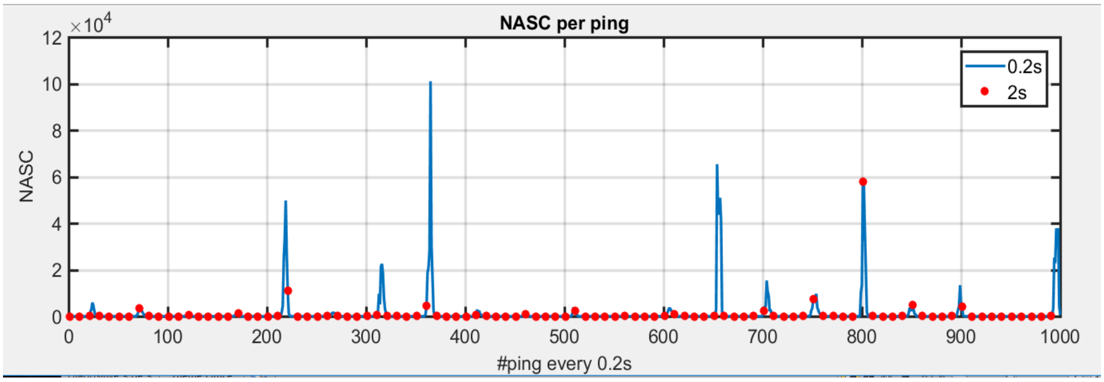


Figure 3. NASC (s_A in units of m^2 nmi^{-2}) per transmit/receive cycle (aka "ping") for *l*=30 m (top panel) and 5 m (lower panel). Blue symbols indicate samples at 0.2-s transmit interval and red symbols indicate samples at 2-s transmit intervals. *d*~1 m and 10 m at transmit intervals of 0.2 and 2 s, respectively (at 10 kts). Note that every 30-m school has at least one sample, whereas some 5-m schools were not sampled at the 2-s transmit interval.

Results:

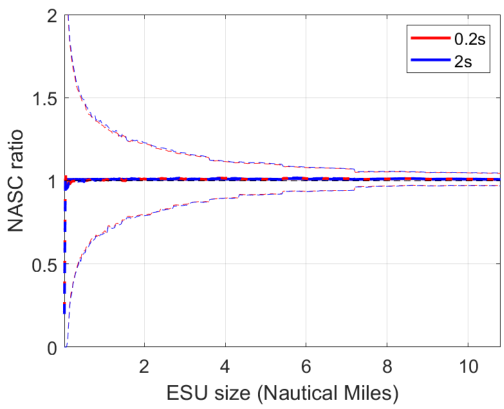
Accuracy (SA mean error)

For 30x30x10 m (length x width x height) schools and 5x5x5 m schools, the s_A ratio = 1 for all ESU lengths (**Fig. 4**), i.e., the accuracy is unaffected by vessel speed, transmit interval, and number of samples averaged per ESU (for those simulated).

Precision (SA variability)

For both sizes of schools and both transmit intervals, precision increases (variance decreases) with ESU length (i.e., the number of s_A samples averaged per ESU increases as ESU length increases (Equations 3 & 4)) (**Fig. 4**)

For the 30x30x10 m schools, the precision is the same for both transmit intervals simulated. Indeed, 30-m schools are well sampled even at 2-s ping rate, and increased sampling rate does not bring additional information nor precision. However, for school size of 5x5x5 m, ship speed = 10 kts, and transmit interval = 2 s (i.e., the school length is small compared to the 10-m inter-sample distance), the sampling is sparse (not every school is sampled) and the s_A precision is nearly doubled compared to transmit interval = 0.2s (dashed lines in **Fig. 4**).



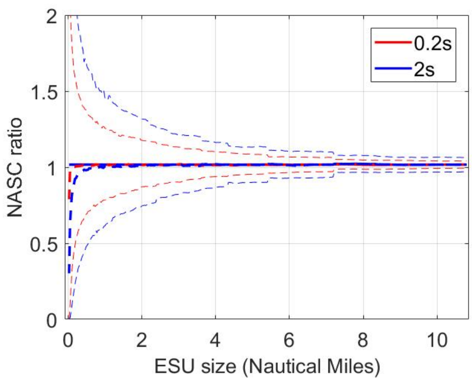


Figure 4. The mean (solid line) and median and 5th and 95th quantiles (dashed lines) of the s_A ratio for school size 30x30x10 m (left panel) and 5x5x5 m (right panel), for transmit interval = 0.2 s (red lines) and 2 s (blue lines).

Depth Dependence

The ratios of school s_A for school sizes of 30x30x10 m and 5x5x5 m, and transmit interval = 0.2 and 2 s, were computed as a function of depth from 5 to 55 m (**Fig. 5**). The variability in the s_A ratios is related to the ratio of the number of s_V samples integrated for each school, *Ni*.

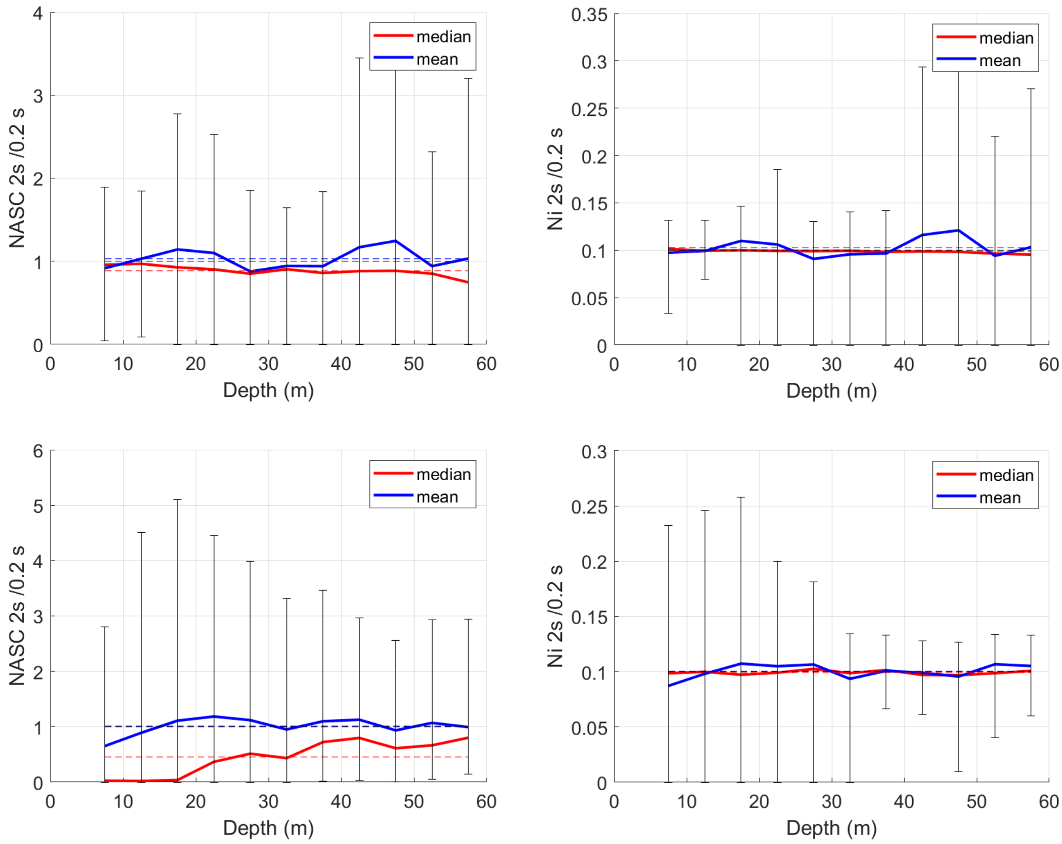


Figure 5. Mean (blue lines) and median (red lines) s_A (NASC) ratios at 0.2 and 2 s transmit intervals for school sizes 30x30x10 m (top left panel) and 5x5x5 m (bottom left panel). Corresponding mean and median ratios of the number of s_V samples in the ESU (*Ni*) (right panels). Error bars represent the 5th and 95th quantiles. The solid lines represent ratios at 5 m intervals, and the dashed lines are for the entire depth range of 5-55 m.

For school size = 5x5x5 m, the ratios of s_A for transmit intervals 2 and 0.2 s differ for shallow depths, where *B* is smaller than *l* (**Fig. 5**). For the small school, the median differs substantially from the mean s_A ratio at shallow depths. In cases with insufficient school detections, e.g., when *B* is small relative to *l* (at shorter ranges), the ping interval is too large or the ESU is too small, s_A is not normally distributed (not shown), and the mean s_A is more variable but less biased than the median.

Discussion:

Survey speed modulates the underwater sound and vibration from a ship, which varies due to a variety of factors such as fish species, depth, feeding or spawning season, and weather, and may affect fish behaviour, echo classification, and biomass estimates. Survey speed also affects the number of samples from each along-transect fish school, and the signal attenuation due to bubbles and noise, all of which can affect both the accuracy and precision of measured s_A and therefore the herring biomass estimate.

Based on the simulations presented here, precision of density estimates is maximal if each school located along the acoustic transect is sampled at least once. Considering only the horizontal inter-sample distance, schools with length ≥ 7 m and located along the survey track will be sampled at least once when surveyed with a ship speed ≤ 13 kts and 1-s transmit interval, and the precision in estimates of fish abundance will be minimally effected by vessel speed. In other words, if the IESSNS surveys are conducted at 13 versus 10 kts, the abundance estimates will not be impacted for schools with 30-m length. Note, however, that this statement ignores any effects of fish behaviour or signal quality resulting from increased ship speed.

The precision (inverse of variance) of the density estimates is a function of the initial school spatial distribution and the number of uncorrelated samples in the ESU. In general, as the number of samples increases, either by more schools in an ESU or increasing ESU length, the precision increases (variance decreases). As vessel speed increases, the number of samples in an ESU decreases. If distance between transmissions is still smaller than apparent school length, precision is not impacted. Otherwise variance increases as the inverse of the number of pings in an ESU, which for constant transmit interval, is inverse of speed. For example, the increase in variance is 1.3 (13/10) (standard deviation of 1.14 ($\sqrt{13/10}$)) for the smaller schools (l < 7 m) we simulated at speeds of 10 and 13 kts.

Simulations provide a basis for evaluating optimal data acquisition parameters (e.g., ship speed, transmit interval), but simulating all potential scenarios is nearly impossible. We simulated two school sizes, two transmit intervals, and two vessel speeds. Because the transmit interval and vessel speed combine to define the inter-transmit distance (i.e., distance between successive pings), simulations are based on school size and distance travelled between pings. These simulations were useful to provide recommendations for whether fish density could be estimated at vessel speeds of 10 kts or 13 kts, but the bias and precision of s_A versus the number of s_V samples per school could be developed into a predictive model from simulation data of more school sizes and transmit intervals. In addition, data collected using different acquisition parameter settings under survey conditions can be used to evaluate simulation results, provide recommendations for new simulations, and provide an empirical basis for selecting parameter settings.

For simulated schools with identical size and along-transect density, differences between the mean and median s_A appeared to be sensitive to the number of uncorrelated samples per ESU, where “insufficient” (i.e., not all schools sampled at least once) sampling had greater differences. This potential indicator of measurement accuracy degradation should be confirmed for real s_A measurements made over ranges of school size and density.

The simulations do not incorporate other factors, such as behaviour. Behavioural changes could be observed during survey conditions using a variety of instruments such as multi-frequency, Doppler, and multibeam echosounders mounted on landers, buoys, boats, USVs, or AUVs. The data could be used to characterize fish-school behaviour in an undisturbed state for comparison to beneath a ship surveying at various speeds. Investigations could include biases due to vertical migration, the near-surface "dead zone", i.e., schools shallower than the transducer and its near-field exclusion range.

Recommendations:

Increased ship speed affects fish behaviour, echo classification, horizontal sampling resolution, and signal quality.

The WGFAST recommends that the IESSNS:

1. Analyse existing/historical survey data collected at different speeds to explore effects of vessel speed on estimates of herring biomass.
2. Conduct field experiments to quantify any effects on estimates of herring biomass resulting from changes in behaviour and signal quality when surveying at different speeds. In the simplest design, each ship would randomly run transects at 10 or 13 kts, and the data would be evaluated for any statistically significant differences. During this experiment, some protocols, such as the acoustic frequency (38 kHz) and the transducer beam width (7º) and depth (ship dependent) may be unchanged. However, other factors, such as recording range and transmit interval, could be optimized to mitigate the effects of ship speed.
3. Explore modification to its protocol to optimize the transmit interval (e.g., Renfree and Demer, 2016) to improve school detection probability.

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Annex 18: Response to Recommendation 28 (HAWG to WGIPS)

Recommendation 28 (HAWG to WGIPS)

HAWG recommends that stock splitting is taken into account in future analysis and planning of the HERAS summer survey in 6aN and 6aS. This should follow the recommendations from the EASME project which is examining stock separation of herring west of Scotland and Ireland and will allow for separate indices to be delivered for these stocks. The results of this project will be available at the end of 2020.

Response:

WGIPS members discussed this recommendation at their meeting in January 2021. The group acknowledges the importance of establishing an appropriate method to split the Malin Shelf survey index estimates in order to separate the herring stock components that are found in this area during the survey. The group sees the development of the splitting methods on the Malin Shelf survey as something that ideally the members of the EASME project should be involved in, as they are best placed to interpret the results from the project appropriately. WGIPS feels that having a workshop at this stage dealing with just the Malin Shelf survey would not be appropriate as the issue is broader than this survey and will ultimately need to be addressed by many surveys and stocks within WGIPS in the future. A wider workshop that incorporates other surveys and stocks in WGIPS would be supported in the future by the members and will be required eventually as knowledge on genetics and stock identification of fish species expands throughout the areas covered by this group. Instead, we suggest that a Working Document (WD) is produced that gives worked examples of ways that the EASME results can be interpreted and used to split the Malin Shelf index from 2014-2020. This WD should be delivered by 8th November 2021, ahead of the HERAS post-cruise meeting. Splitting the Malin Shelf survey index is identified on the issue list of the 6a herring benchmark, therefore WGIPS advises that a work-plan and time schedule is developed and agreed at HAWG 2021 for the delivery of the WD. The production of the WD should also ideally involve contributions from members of WGIPS, HAWG and ICES that have stock splitting expertise. The primary contributors of the WD should be the Marine Institute and Marine Scotland Science as they can also draw from multidisciplinary experience within their institutes. WGIPS suggests that particular attention needs to be paid to sampling precision, sampling size and its effect on the split index. It has been noted at WGIPS in recent years that biological sampling of herring on the Malin Shelf has been relatively low, and there is concern that this has been causing increased uncertainty in the index in some years. The WD should also be presented at WGIPS in 2022.

Annex 19: Response to Recommendation 29 (HAWG to WGIPS and WGBIOP)

Recommendation 29 (HAWG to WGIPS)

HAWG recommends that WGIPS investigates possible causes for the deterioration of the internal consistency in the HERAS index and suggest that both the analysis method and the biological sampling methods are scrutinised for issues that could cause the deterioration of the ability of the survey to accurately track cohorts past the age of 6 wr.

In addition to investigating the analysis method it is recommended that a thorough review of differences and changes in biological sampling strategy and intensity amongst participating laboratories and over the time series are documented and their potential effect investigated as far back as possible.

Finally, it is recommended that consideration is given to how otoliths have been aged by all participating labs over the time series (mounted/unmounted/different mediums etc) and if / when changes have occurred how such changes might have affected aging results.

WGIPS Reply:

WGIPS agrees that the detected deterioration of internal consistency in the HERAS survey at older ages warrants a thorough investigation.

The HERAS survey has undergone a level of standardisation in recent years as part of the move to a new survey design and analysis tool in 2016 (ICES 2015, WGIPS 2016; Annex 6 and 9). However, when it comes to biological sampling, different sampling strategies are still in use by each institute taking part. Although all sampling can be classed as random, some strategies have numeric targets for each length class of herring in the catch rather than an overall target for each catch and some are further stratified by length with higher targets for larger fish (to resolve an age structure where larger fish covers increasing number of age classes). Furthermore, changes have also been made by individual institutes over the course of the survey time series as resources and other survey needs have changed in the institutes. In recent times, this has typically been in the direction of reducing the number of age readings per length group or overall catch, or limiting the number of trawls carried out (survey time reductions). Finally, stock separation is carried out on the herring abundance with different methods used in DK and NOR with some changes having been made along the way in method and also in numbers included in this analysis.

The HERAS survey group agrees to review and document the different sampling strategies used within the coordinated survey over the time series and when these may have changed in different institutes. The survey group also agrees to document detailed overviews of numbers of trawl samples and numbers of age readings carried out each year in the survey by each participating institute as far back as possible to investigate if there is a simple explanation such as an overall decrease in biological sampling effort with time. The results of this exercise can be ready in time for consideration by WGIPS and HAWG in 2022.

However, to evaluate the effect of changes made to the sampling strategies over the time series a more detailed investigation will have to be carried out on the effect the different biological sampling strategies has on the survey results, with particular emphasis on the accuracy of the age structure.

If the scope of such an exercise was broadened to also look at how the different sampling strategies performs in terms of accuracy of age structure results at different levels of sampling effort and under different requirements for splitting the surveyed abundance into different stocks, ages and maturity levels, the results would have a much wider relevance both within the WGIPS survey community and beyond. Such an exercise will be useful to investigate the performance of surveys coordinated in WGIPS and the resulting indices and could be used in the future to inform decisions about the optimal sampling levels and sampling strategies to be used on the surveys to fulfil future requirements.

WGIPS has already this year an additional request from HAWG to take into account stock splitting in future planning and analysis of the HERAS survey component in 6aN and 6aS. As our understanding of the levels of stock mixing in all WGIPS surveys increases through the development of more and better tools for stock identification especially for herring there is an increasing demand for being able to split survey results by stock. This puts an increased demand on biological sampling and necessitates an investigation along the same lines as mentioned above.

The scope of this work is beyond the intersessional work of WGIPS and we suggest that a study like this is much better handled in a dedicated workshop. This would allow us not only to answer the two requests from HAWG, but also facilitate the development of common methods and procedures to answer similar requests for other surveys and to investigate the adequacy of the sampling carried out on the surveys. The effects of sampling strategy and how these data are presented also has implications for how data are reported within the ICES data repository.

This could also be used to make recommendations for optimal sampling strategy for the different surveys. Furthermore it could help establish levels of sampling needed and indicate the impact on results in cases where sampling levels cannot be met if resources have to be reduced.

Special emphasis should be put on the biological sampling strategies used and their ability to resolve the age structure of the stock with minimal bias also for the ages that are less common in the stock (typically the older ages). Such effects may only be observed at low sampling effort (for example at low number of total trawl samples and/or through a low number of age readings per haul). An analysis of how each sampling strategy performs at different levels of sampling effort is essential (both in terms of numbers of hauls and number of age readings per haul/length group).

The second part of the recommendation requests that consideration is given to how otoliths have been aged by all participating institutes in the HERAS survey over the time series with particular emphasis on the preparation of the otoliths for age reading (mounted/unmounted/submersed in different mediums (alcohol, distilled water, oil) and if / when changes have occurred. The HERAS survey group in WGIPS will provide this review along with the biological sampling strategy review. However, how the preparation of otoliths for aging might affect the age reading results especially at older ages is beyond the expertise of WGIPS and therefore we cannot comment on how these changes might have affected aging results without drawing on expertise from other experts. We suggest that WGIPS/HAWG approach WGBIOP for advice on this part of the issue as this will not only be an issue in the survey indices, but also for herring age data from catches delivered from the same institutes to the assessment process.

References

ICES. 2015. Report of the Workshop on evaluating current national acoustic abundance estimation methods for HERAS surveys (WKEVAL), 24-28 August 2015, ICES Headquarters, Copenhagen, Denmark. ICES CM 2015/SSGIEOM:16. 48 pp.

ICES. 2016. Report of the Working Group of International Pelagic Surveys (WGIPS), 18-22 January 2016, Dublin, Ireland. ICES CM 2016/SSGIEOM:05. 433pp.

Annex 20: Response to Recommendation 120 (WGWIDE to WGIPS and WGBIOP)

Recommendation 120 (WGWIDE to WGIPS and WGBIOP)

It is recommended that an age reading exchange and a following workshop are held for Norwegian spring spawning herring. The work should also deal with issues related to the mixing of NSSH with adjacent herring stocks in the fringes of the distribution area. The workshop participants should be both age readers and participants with statistical, stock identification and stock assessment expertise.

WGIPS Reply:

The request to WGIPS is assumed to relate to the sampling of material (otoliths and scales) from the IESNS and IESSNS surveys to be used in an exchange. Additionally, material for genetic analysis will be sampled. The exchange and the workshop are assumed to be organized by WGBIOP.

The background for the request was presented and a possible sampling strategy was proposed and discussed. The nations involved in the two surveys agreed on an extensive sampling from the 2021 surveys. The importance of obtaining both scales and otoliths from the same individual was emphasized. A detailed protocol for sampling both ageing structures and samples for genetic analysis has been developed and was circulated to survey participants (Annex 25).

Annex 21: Recommendations from WGIPS to other groups in 2021

Recommendation from WGIPS to WGBIOP, HAWG

WGIPS recommend that WGBIOP investigate how differences in preparation of herring otoliths (mounted/unmounted/different mediums such as water, oil, ethanol, etc.) affect age reading results, particularly for older ages.

Background:

HAWG has recommended that WGIPS give consideration to how herring otoliths have been aged by institutes contributing ages to the HERAS survey index on North Sea herring over the time series and if / when changes have occurred how such changes might have affected aging results especially at older ages (recommendation 29 in 2020 from HAWG to WGIPS).

WGIPS can provide a review of methods used in each institute involved and the timing of changes where they have occurred. However, how the preparation of herring otoliths for aging might affect the age reading results is beyond the expertise of WGIPS, and therefore we cannot comment on how these changes might have affected aging results without drawing on expertise from WGBIOP.

WGIPS recommend that WGBIOP look into this, and ask that if this is indeed an issue of concern for the integrity of the survey index, that studies are reviewed or carried out to investigate the magnitude of the issue. WGIPS notes that if this is considered an issue for concern that it has wider implications than the North Sea herring survey index as the same institutes provide ages to the catch data and survey indices used in the assessment of most herring stocks assessed in HAWG.

Recommendation from WGIPS to WGFAST

WGIPS acknowledges that acoustic backscatter values collected during surveys coordinated by the group and used to calculate biomass estimates for stock assessments, may be affected by acoustic shadowing when very dense schools are encountered, thereby potentially adversely impacting the quality of the stock assessment. While a handful of papers report on shadowing, to the best of our knowledge, there are currently no standardised guidelines in the peer review literature on how to robustly test for the occurrence of shadowing, to quantify it, or to correct for these biases. The group seeks advice from WGFAST on standardised methods to identify, measure and correct for acoustic shadowing.

Recommendation from WGIPS to ICES Data Centre

WGIPS held a TAF session at their meeting in 2021 to assist surveys that were interested in moving their processes onto the TAF system. While some surveys made good progress during the session, others will need more help to move to TAF. WGIPS recommends that a work flow and/or other documentation is produced by the ICES Data Centre to assist surveys that want to begin the process of moving to TAF.

Recommendation from WGIPS to HAWG

WGIPS recommends that a Working Document (WD) is produced that gives worked examples of ways that the EASME results can be interpreted and used to split the Malin Shelf index from 2014-2020. This WD should be delivered by 8th November 2021, ahead of the HERAS post-cruise meeting. Splitting the Malin Shelf survey index is identified on the issue list of the 6a herring benchmark, therefore WGIPS advises that a work-plan and time schedule is developed and agreed at HAWG 2021 for the delivery of the WD. The production of the WD should also ideally involve contributions from members of WGIPS, HAWG and ICES that have stock splitting expertise. The primary contributors of the WD should be the Marine Institute and Marine Scotland Science as they can also draw from multidisciplinary experience within their institutes. WGIPS suggests that particular attention needs to be paid to sampling precision, sampling size and its effect on the split index. It has been noted at WGIPS in recent years that biological sampling of herring on the Malin Shelf has been relatively low, and there is concern that this has been causing increased uncertainty in the index in some years.

Recommendation from WGIPS to WGISDAA and others (ACOM, SCICOM, national institutes and WGWIDE)

WGIPS recommend to investigate the problem of how to deal with occasionally very large catches (or NASC values) leading to over-estimates of abundance in surveys.

Background:
Catch curves of mackerel abundance estimates from the IESSNS survey indicate that the stock has been gradually over-estimated in the survey. Compared with other data sources, the IESSNS estimates indicates a very low total mortality, in particular for the most recent cohorts. A possible explanation for the over-estimates is the occurrence of very high catches in the most recent surveys. It is recommended to organize work to address the problem of occasionally very high catches that lead to over-estimates of abundance in surveys. A related problem is also apparent in some acoustic surveys where a few EDSUs have a very large effect on the abundance estimate.

Annex 22: Mesoplankton scrutinization protocols for IBWSS

Scrutinization guidelines for reporting mesopelagic fish (IBWSS)

During WGIPS 2021, a sub group made up of IBWSS participants met to develop acoustic scrutinization guidelines to harmonise the reporting of mesopelagic fish from survey data. This work followed on from discussions at previous meetings and recommendations from other groups (WGMESO & WKMESOMeth).

The limitations associated with the routine reporting of the abundance of mesopelagic fish during the IBWSS survey previously considered include:

-Limitations associated with the use of hull mounted acoustic systems including, frequency dependent depth limitations and target resolution.

-Opportunistic sampling within an existing survey program. Time allowances for trawl sampling and experimental work.

-Directed trawl sampling and the ability to representatively sample target animals. A common trawl design for sampling does not currently exist, so interim sampling tools are being employed e.g. macrozooplankton trawls. Dedicated trawl designs are being developed as part of larger Horizon2020 projects (MEESO & SUMMER) and will be considered for future use.

Scrutinization guidelines:

Operating within the described limitations, it was agreed that meaningful reporting could be achieved if the following guidelines are adhered to:

- Depth restricted from 50 to 400 m, below the surface plankton layer and above the DSL (deep scattering layer). It is advised that when reporting to the ICES database that acoustic data are reported in 50m vertical depth channels in line with previous reporting structure (PGNAPES database).

-Daylight only reporting and avoiding crepuscular periods where active migration is underway to avoid the complexities of species mixing.

-Reporting of candidate aggregations below 400 m and within the DSL is not advised due to the complexity of species mixing and taxa identification.

-Reporting of clear and readily definable aggregations/schools shallower than 400 m.

-Species specific reporting should only be carried out when species composition has been verified by directed trawl sampling.

-Reporting of species specific acoustic categories should only occur when species composition has been verified by directed trawl sampling and should follow the existing three letter SACategory vocabulary as outlined in the acoustic database (http://vocab.ices.dk/?ref=1458) and outlined in Table 2. More codes can be added to the database as required based on user requirements.

Table 1. Reporting categories within the PGNAPES database.

PGNAPES reporting codes	
Species	**Code**
Greater argentine	ARU
Lanternfish	MYX
Pearlside	PLS
Meganyctiphanes norvegica	KRZ

Table 2. Reporting categories within the ICES database. Three letter Acoustic code (ASFIS) and numeric Biotic (Aphia) codes.

ICES database reporting codes		
Species	**Acoustic**	**Biotic**
Maurolicus muelleri	MAV	127312
Argentina silus	ARU	126715
Meganyctiphanes norvegica	NKR	110690
Benthosema glaciale	BTG	126580
Myctophids	LXX	125498
Stomiidae	RQX	125604

-Reporting of biological samples should follow the format within the Acoustic data reporting vocabulary (http://ices.dk/data/data-portals/Pages/acoustic.aspx) and use numeric Aphia codes (http://www.marinespecies.org/aphia.php?p=search) to identify to species level.

-In circumstances where trawl sampling has not been carried and the processor is confident of the echotype composition then the higher taxonomic level codes 'LXX' and 'RQX' codes can be applied where appropriate.

-For mixed species aggregations, with species composition determined by directed trawling, then splitting into constituent acoustic density (TS splitting) should be carried out where possible. This can be done using a SplitNASC project within StoX (split acoustic mix categories from one or more acoustic XML files using biological species categories).

These guidelines will be used during the IBWSS survey in 2021 and reviewed at the next WGIPS meeting in 2022.

Annex 23: HERAS WD on NSAS/WBSS sensitivity analysis

Please see the report on the next page.

HERAS survey indices: automation, TAF and testing

Benoit Berges[1*], Serdar Sakinan[1], Florian Berg[2], Susan Mærsk Lusseau[3], Matthias Schaber[4], Steven O'Connell[5]

[1] Wageningen Marine Research, The Netherlands
[2] Institute of Marine Research (IMR), Bergen, Norway
[3] DTU-Aqua, Hirtshals, Denmark
[4] Thünen Institute of Sea Fisheries, Bremerhaven, Germany
[5] Marine Scotland Science, Marine Laboratory, Aberdeen, Scotland, UK

[*] benoit.berges@wur.nl

ABSTRACT

Fisheries acoustic surveys are routinely conducted around the world, and particularly within the ICES community. Following pre-defined transects, these surveys make use of downward active acoustic systems (i.e. so called scientific echosounders) a coupled with biological sampling through fishing operations to estimate abundance and distribution of marine species. Of interest here is the HERAS survey that takes place yearly for ~1 month and is a dedicated international survey effort. It is performed across the North Sea, West of Scotland and the Malin Shelf, more specifically in the context of the Western Baltic Spring Spawning (WBSS) and North Sea Autumn Spawning (NSAS) herring stocks. Recently, the calculation of the WBSS and NSAS indices underwent a major update with the introduction of the ICES acoustic trawl database and the use of the StoX software. In the context of these recent changes, the aim of the current study is three-fold:

1. Develop R code for the automatic calculation of the NSAS and WBSS indices with the aim of minimizing manual user input.
2. Run sensitivity tests against various assumption on NSAS and WBSS indices.
3. Generate NSAS and WBSS indices under the ICES TAF framework.

Overall, good agreement was found between previously derived indices and indices calculated using automatic routines. The only large discrepancies found was for 2017 in strata 11 and 141 which and is accountable to discrepancies in WBSS/NSAS stock separation in these strata. This should be investigated further but the automatic routines as derived through this project will be used in the future for the derivation of the index alongside rigorous checking of outputs. Yearly, this process will also be running on the ICES TAF framework, providing improved transparency and robustness.

A secondary aim for this study was to run sensitivity tests programmatically. This was done for a range of assumptions around: calibration of acoustic instruments, stock splitting in strata 11 and 141, alternative strata definition and alternative haul allocation strategy. Firstly, it was found that calibration error was very influential on the index. In light of this, it is recommended to run thorough checks of calibration results prior to every survey (e.g. yearly comparing results historically). Secondly, the stock splitting in strata 11 and 141 mostly influences WBSS and the introduction of novel identification methods will be beneficial, rotating out the currently used method based on vertebrae count. Thirdly, the change in strata tested here did not exemplify large differences, suggesting that the current stratification is appropriate. Lastly, the use of automatic haul allocation to transect was tested and was found influential, highlighting the importance of expert input during for the haul allocation process.

Contents

1 INTRODUCTION

Fisheries acoustic surveys are routinely conducted around the world, and particularly within the ICES community. Following pre-defined transects, these surveys make use of downward active acoustic systems (i.e. so called scientific echosounders) to estimate abundance and distribution of marine species (Mehl et al. 2018; Dalen and Nakken 1983; Simmonds and MacLennan 2005). This type of survey is often used to derive abundance indices for a specific stock which are subsequently used in stock assessments. Of interest here is the HERAS survey that takes place yearly across the North Sea, West of Scotland and the Malin Shelf. This survey consists of an ~1 month international survey effort in the June/July period. In recent years, the following countries have been participating Scotland (GB-SCT), Germany (DE), Denmark (DK), Ireland (IE), Norway (NO) and The Netherlands (NL). A map of the coverage by country for the 2020 survey is shown in Figure 1-1.

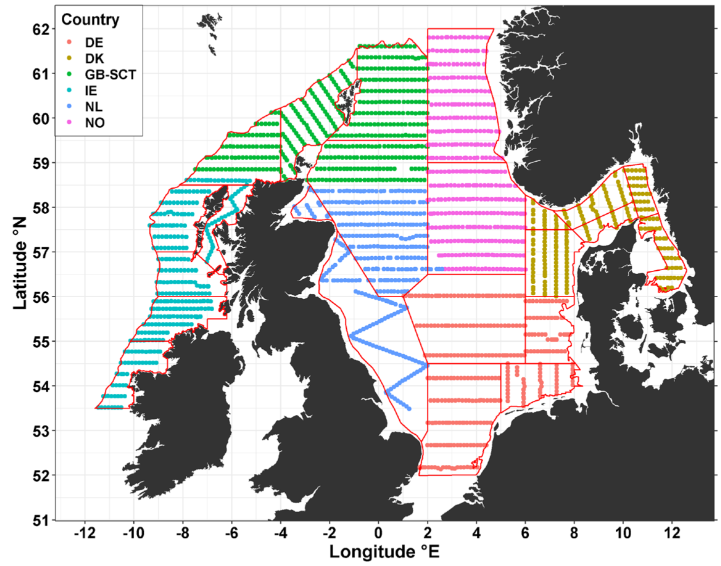


Figure 1-1: *2020 Survey area of HERAS with transects covered by country.*

The collation and analysis of the combined survey results is carried out collaboratively annually in November in a post cruise meeting with all survey participants. The HERAS survey delivers indices of abundance as well as key biological parameters (abundance at age, proportion mature at age and weight at age) for use in the assessments of the status of sprat and herring stocks across the North Sea and to the West of Scotland and Ireland (Figure 1-2). More specifically, these indices are delivered for the following stocks for which assessments are carried out in the ICES Herring assessment working group (ICES 2020d):

- North Sea Autumn Spawning herring (NSAS): Autumn spawning herring in Subarea 4 and divisions 3.a and 7.d)
- Western Baltic Spring Spawning herring (WBSS): Spring spawning herring in subdivisions 20–24 (where subdivision 20-21 is the same as division 3.a))
- West of Scotland herring (Herring in division 6.a(North)
- Malin shelf herring (Herring in Divisions 6.a and 7.b–c**)**
- North Sea Sprat (Sprat in division 3.a and subarea 4)

The geographical extent of the distribution of the different herring and sprat stocks is shown in Figures 1-2(c) and (d) respectively. For NSAS and WBSS, it is essential to note that both stocks are found in division 3.a as well as in the north-eastern part of the North Sea at the time of the

HERAS survey. To provide abundance indices and biological parameters specific to each of these two stocks, the biological sampling in these survey areas includes sampling to provide stock ID information for the herring caught during the survey. This permits a splitting of the acoustic herring abundances into the component stocks. This document focuses on the automation of these computations and on sensitivity tests of the resulting indices against a range of assumptions. Only WBSS and NSAS herring stocks are dealt with in this study.

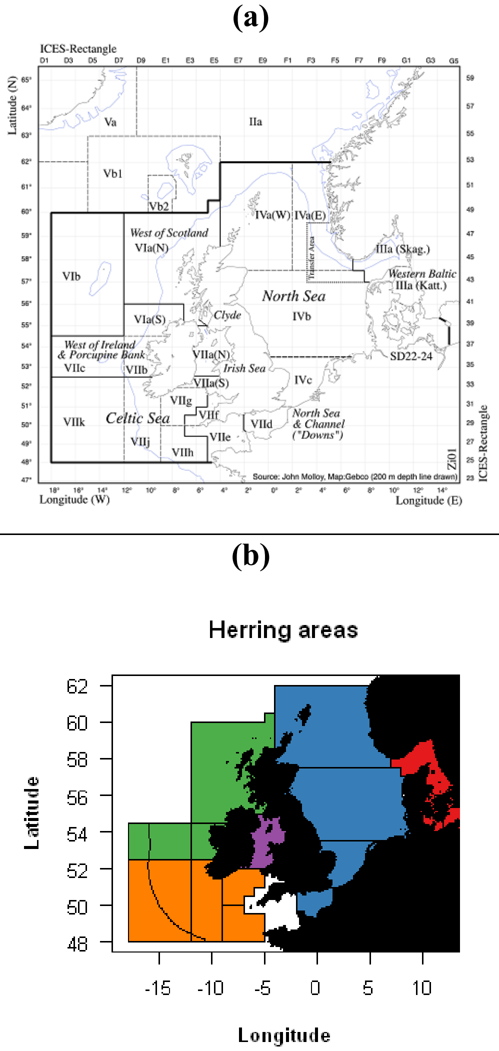


Figure 1-2: *geographical definition of herring and sprat stocks in the North Sea. (a) ICES divisions and subdivisions. (b) ICES areas for the different herring stocks. The HERAS survey provides abundance indices for West of Scotland and Malin shelf herring (green), North Sea Autumn spawning herring (blue) and Western Baltic Spring spawning herring (red). The North Sea Sprat stock is located in in division 3.a and subarea 4.*

Survey indices for NSAS and WBSS derived from the HERAS survey are directly used in their respective stock assessments, ages 1 to 9 for NSAS and ages 3 to 6 for WBSS. Both assessments use the SAM model, a probabilistic, state-space model (Nielsen and Berg 2014). The assessments are the basis for fisheries advice for these two stocks provided by ICES (ICES 2020b, 2020c).

For NSAS, the HERAS index spans the 1989-2020 period and follows closely the trajectory of the stock (Figure 1-3(a)), mostly within the assessment uncertainty, and is an important source of information for the stock assessment model. This is shown by the observation variance per data source as estimated by the model (Figure 1-3(b)). Within the SAM model, the lower the observation variance the more weight the data source has in the model. Here, the HERAS index for ages 2-6 is close to catch at age data in terms of observation variance. Moreover, the survey has a very good correlation between ages (internal consistency), suggesting a good tracking of cohorts. However this cohort tracking is not as close as it has been in recent years (ICES 2020a).

For WBSS, the HERAS index spans the period between 1991-2020. has a long term trend that follows the trajectory of the stock (Figures 1-3(c)) though with yearly variation exceeding assessment uncertainty. Similarly, to NSAS, the HERAS index is a key source of information for the core ages (ages 3-6) of the stock. This is illustrated by low observation variance (Figures 1-3(d)). For WBSS, the level of observation variance for the HERAS survey is close to levels from the GERAS (German Autumn Acoustic Survey, part of BIAS) survey and catch data.

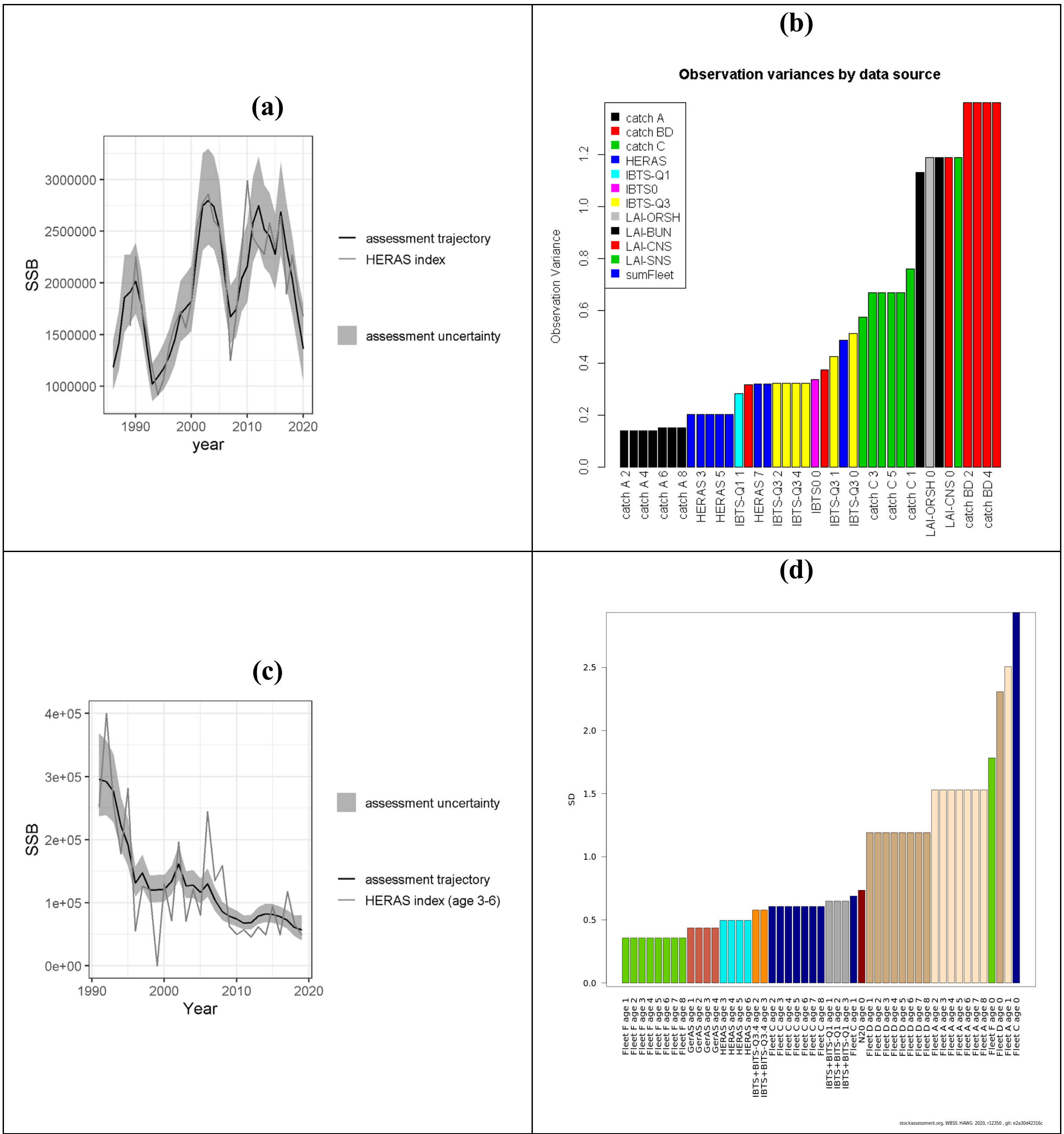


Figure 1-3: *NSAS and WBSS assessments and in the context of the use of the indices derived from the HERAS survey. (a) NSAS SSB trajectory for the assessment and HERAS survey. (b) NSAS observation error of input sources as estimated by the assessment model. (c) WBSS SSB trajectory for the assessment and HERAS survey. (d) WBSS observation error of input sources as estimated by the assessment model.*

Since the start of the time series for NSAS and WBSS in 1989 and 1991 respectively, the method of calculation has changed, especially in recent years (Figure 1-4(a)). Prior to 2015, the calculation of survey indices was performed at a national level per ICES rectangle and collated to provide final overall estimates. This involved processing through national programs and collation using a specific database (FishFrame). This processing involved several manual inputs which was an error-prone process. Since 2015, a transition was undertaken with 1) using the newly developed ICES acoustic trawl database[1] for data storage and 2) using a new calculation workflow for the derivation of abundance at age using the StoX software[2] (Johnsen

[1] http://ices.dk/data/data-portals/Pages/acoustic.aspx

[2] https://www.hi.no/en/hi/forskning/projects/stox

et al. 2019). The use of the ICES acoustic trawl database alongside the StoX software provide several advantages such as: data disaggregation (e.g. to better handle stock mixing), uncertainty estimation, more robust estimation, traceable process. Moreover, the use of the ICES acoustic trawl database also drove harmonization of the HERAS survey (e.g. biological sampling, acoustic data analysis) across participating countries. A drawback induced using StoX is the loss in spatial heterogeneity of the calculated outputs. With the use of StoX, each stratum used encompasses several ICES rectangles whilst previously, calculations were undertaken on each ICES rectangle, providing a finer spatial scale. Previously, the survey area was stratified in post-processing based on biological composition in the trawls. Since 2016, the survey design is determined based on strata used in post-processing in StoX (e.g. when allocating survey coverage by country). Generally, this provides a more robust and sounder framework for the survey. A comparison of the 2015 indices between previously applied analysis method and calculations using StoX did not detect significant differences overall (Lusseau et al. 2016; ICES 2015). In 2015, the survey was carried out according to the old design and indices calculations were performed at ICES rectangle levels and using StoX. For the StoX calculations on that year, the stratifications were defined during post-processing (Figure 1-4(b)). Starting from 2016 the newly defined strata definition were used for the survey design (Figure 1-4(c)) in order to ensure consistency between survey and index calculations. In addition, since the first use of the StoX software, the NSAS/WBSS calculation procedure has been optimised between 2015 and 2017 with increased familiarity with the new ICES acoustic trawl database and analysis method. Since 2017, the calculations undertaken follow the same streamlined workflow.

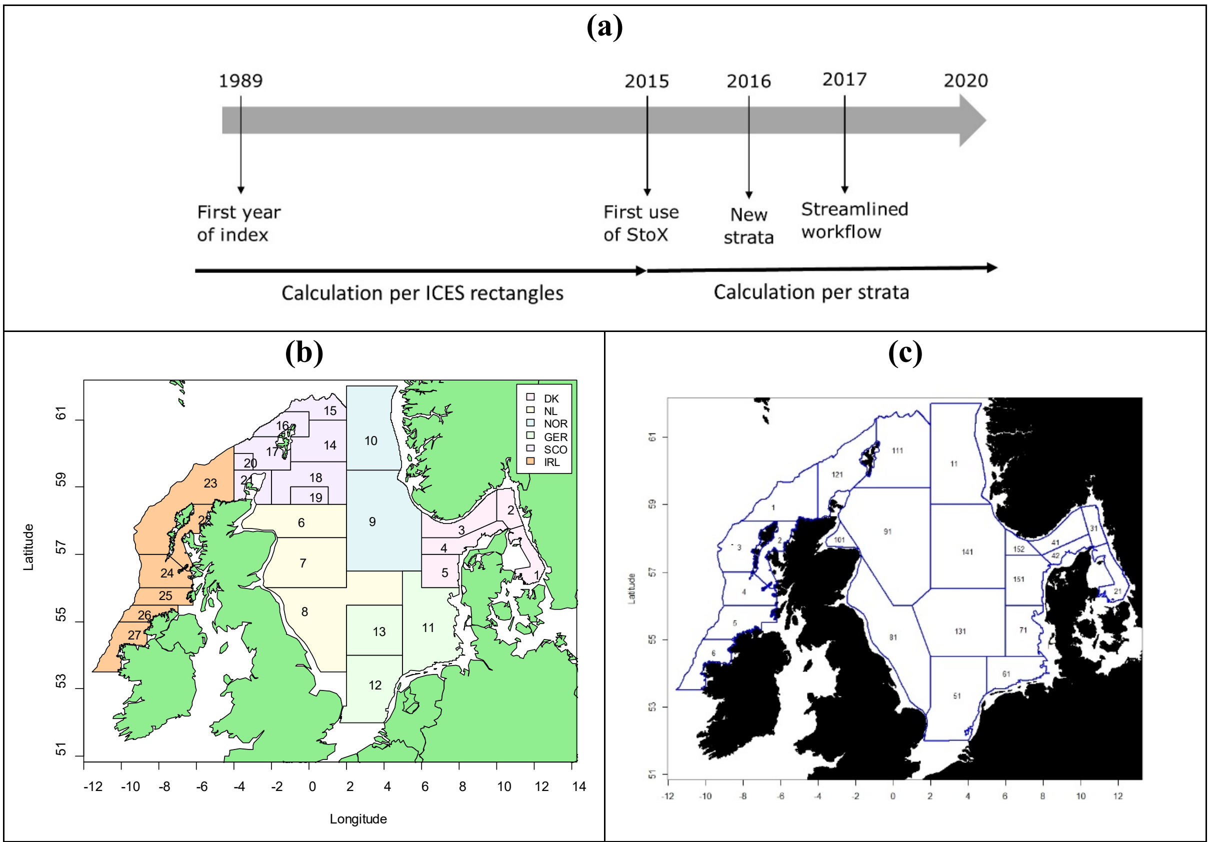


Figure 1-4: *(a) methodological changes in index calculation for the HERAS survey. (b) strata definition used in the analysis of the 2015 survey. (c) strata definition of the HERAS survey since 2016.*

In an effort to increase transparency, ICES is engaged in building and maintaining a range of databases[3] and has recently developed the Transparent Assessment Framework (TAF)[4] (Figure 1-5). TAF is an online resource used to publish and run R code for annual stock assessments but also for inputting data computations such as survey indices. This framework is open and works toward a transparent and fully traceable stock assessment process, from data all the way to fisheries advice. To date, a range of stock assessments and survey index calculations have been developed on TAF but currently the code used in the calculation of indices from acoustic surveys is not documented.

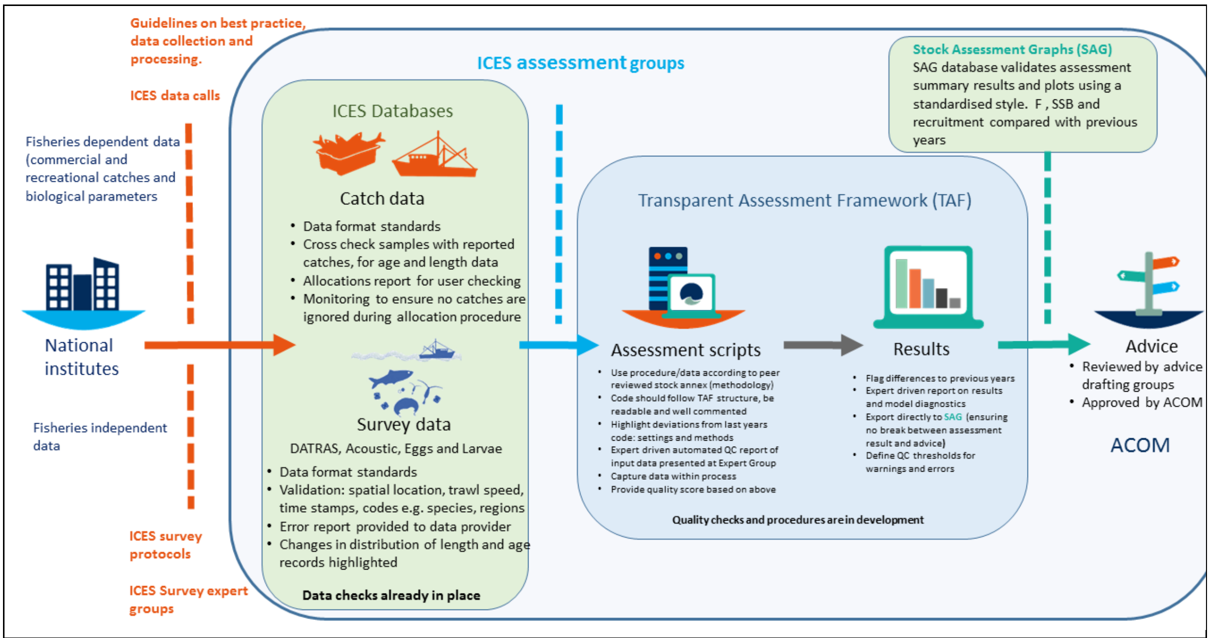


Figure 1-5: *fisheries advice process from national institutes to advice, including the role of TAF. Extracted from (Millar and Magnusson 2018).*

Using the TAF tool and the StoX software, the aim of this study is three-fold:

1. Develop R code for the automatic calculation of the NSAS and WBSS indices with the aim of minimizing manual user input.
2. Run sensitivity tests against various assumption on NSAS and WBSS indices.
3. Generate NSAS and WBSS indices under the TAF framework.

The code developed through this study has been stored and versioned on git repositories:

- git@git.wur.nl:berge057/heras_index_kbwot.git for ongoing development related to aim 1 and 2.
- git@github.com:ices-taf/2020_her.27.3a47d_acousticIndex.git and git@github.com:ices-taf/2021_her.27.3a47d_acousticIndex.git for the 2019 and 2020 survey indices calculated through the TAF framework (aim 3). These repositories are private, but access can be easily granted by contacting the first author.

Because the currently used workflow with StoX has been in place since 2017 (Figure 1-4(a)), for consistency, only years from 2017 to 2020 are considered in this study.

In the future, the streamlined workflow should tentatively be applied to years prior to 2017 as far back in time as possible. However, an important caveat in the use of StoX for survey years

[3] https://www.ices.dk/data/data-portals/Pages/default.aspx

[4] https://www.ices.dk/data/assessment-tools/Pages/transparent-assessment-framework.aspx

prior to 2016 (prior to survey design based on StoX strata) is the fact that previous index calculation methods relied on a different survey design. The previous design may be largely compatible with the new analysis method in the area covered by the Scottish and Dutch components, but this might be challenging for the German and Danish components.

2 METHOD

The aim of this study is three-fold: 1) automate the calculation of the NSAS/WBSS indices, 2) run sensitivity tests, 3) run the calculation of the NSAS/WBSS on the TAF framework. Separate runs of index calculation are performed for 1) and 2) with a total of 10 runs with various assumptions/model settings. Aim 3) is an implementation of the base run baseline under TAF. A description of methods for each run are given in the subsequent sections but for clarity, the organization and listing of runs is given beforehand:

1. Automation of NSAS/WBSS index calculation
    - i. Base run baseline
    - ii. Base run bootstrap
2. Sensitivity test runs
    - a. Calibration error
        - i. Calibration gain offset
        - ii. SA error
    - b. Stock splitting
        - i. Split ratio offset
        - ii. Otolith split
        - iii. Genetics split baseline
        - iv. Genetics split bootstrap
    - c. Strata definition
        - i. New strata definition
    - d. Alternative haul allocation
        - i. Alternative haul allocation

2.1 Underlying principles

A typical acoustic survey from a vessel follows predefined transects, collecting acoustic data continuously and performing directed fishing operations. The latter is essential to 1) ground truth echo traces from the acoustic records and 2) provide information on length and age structure as well as other biological parameters such as maturity level, weights at age and level of mixing of stocks. Outputs from Surveys then consist of both acoustic data and biotic data.

2.1.1 Acoustic data

The standard agreed acoustic equipment of choice when performing an acoustic survey for fish stock assessment are split-beam active acoustic systems (so called echosounders) operated in narrowband mode. Examples of echosounders that are routinely used are the SIMRAD EK60 and EK80 systems used in the HERAS survey. The definition of quantities associated with acoustic data are summarized in (Maclennan, Fernandes, and Dalen 2002). Acoustic data collected by these systems represents the volumetric level of backscattering in the water column and is expressed as the volume backscattering coefficient. This quantity S_{v} is calculated as:

$$S_{\mathrm{v}} = 10\log(p) + 20log(r) + 2\alpha r - 2G - 10\log(U), \quad (1)$$

with p the digital power amplitude, r the range from the transducer, α the acoustic absorption through the water at the transmit frequency (Francois and Garrison 1982; Ainslie and McColm 1998) and G the calibration gain. For simplicity, effects from beam angle, pulse duration and transducer characteristics have been encapsulated in U. In depth explanation of the calculation of S_{v} is given in (Demer et al. 2015) or (Lunde et al. 2013; Lunde and Korneliussen 2016). The quantity S_{v} is expressed in dB re 1 m^{-1} with $S_{\mathrm{v}} = 10\log(s_{\mathrm{v}})$ and s_{v} is expressed in m^{-1}. An important component of Equation (1) is the calibration gain G which accounts for transducer specificities relative to idealized lossless omnidirectional transducer (G_0) and filter attenuation ($s_{\mathrm{a}\,corr}$): $G = G_0 + s_{\mathrm{a}\,corr}$. Amid an accurate estimation of G, the echosounder provides absolute level of S_{v}.

In order to determine G, a dedicated calibration trial is necessary. This is most commonly done using the calibration sphere method (Demer et al. 2015; Foote et al. 1987). During the HERAS survey, calibration trials are performed prior to the survey onboard each participating vessel. The built-in calibration tool of the EK80 or EK60 systems are used for that purpose and provide calibration gain G_0 and filter attenuation $s_{\mathrm{a}\,corr}$.

Following calibration, data collected through the survey can be corrected and yield absolute level of S_{v}. The echograms are then interpreted by allocating fish species to different echotraces. The final output is given in an integrated form across a range (i.e. depth):

$$s_{\mathrm{a}} = \int s_{\mathrm{v}}\, dr. \qquad (2)$$

The quantity s_{a} is the area backscattering coefficient and is expressed in $\mathrm{m}^2/\mathrm{m}^2$. It is most often used relative to nautical miles with $s_{\mathrm{A}} = 4\pi(1852)^2 s_{\mathrm{a}}$ in $\mathrm{m}^2/\mathrm{nmi}^2$ (synonym: NASC – Nautical Area Scattering Coefficient). Values of s_{A} can be broken down in different depth bins but are further summarized per distance interval by taking the average over the distance interval for each depth bin. This constitutes the final output from a survey, i.e. s_{A} per depth bin for each distance interval covered. For the HERAS survey, each participating vessel produces a single acoustic output that is stored on the ICES acoustic trawl database.

2.1.2 Biotic data

An important component of fisheries acoustic surveys is fishing operations. These are performed when large echo traces are observed on the echosounder. Trawling is attempted on these echo traces as much as possible (similar depth and geographical location) in order to collect fish samples. In terms of catches, there is no absolute requirement for large sample sizes or standardized tows, but rather for a representative sample of the fish schools targeted (enough specimens per species for representative length-frequency and other biological measurements).

The fish samples that are collected through fishing operations are essential for the analysis of the survey. Firstly, they allow ”ground truthing” of the echo traces during scrutinization and post-processing of the acoustic data. Depending on the schools that are targeted, catches do not always consist of “clean” samples of the target species, but often consist of a mix of different species, either mixing in the schools observed and targeted or caught in conjunction with the targeted tow. The level of mixing between species varies between different surveys. During HERAS, a high level of mixing with other species (whiting, haddock, Norway pout) can be observed in several regions, as well as a high level of mixing of different clupeid species. In this context, fishing information is essential in the decision making for species allocation of echo traces. Secondly, linking acoustic data to specific categories provides density to specific fish species categories (herring and sprat for HERAS) but these need to be further disaggregated by length, age, stock id and maturity stage. To that end, biotic data are used to allocate biological data to different transects with the purpose to characterize the biological composition of acoustic abundances detected along the transect. Biological samples typically consist of length, weight, maturity and age readings. For the HERAS survey, these data are stored in the ICES acoustic trawl database.

2.1.3 Abundance calculation

Abundance estimation relies on the principle that there is a linear relationship between the number of individuals in the observed portion of the water column and the echosounder output, s_A (Simmonds and MacLennan 2005; Maclennan, Fernandes, and Dalen 2002). Therefore, once the expected energy level from individual targets are established, s_A can be converted to an abundance estimate. Factors such as species and size composition, behaviour and spatial variability in the distribution of fish have an impact on this estimation. Each of these factors are handled at different levels of processing by the StoX software.

Allocation of acoustic backscatter to species:

The s_a recorded during the HERAS survey is generally representative of multiple fish species in the area (including clupeids such as herring, sprat and occasionally sardine in the southern areas as well as gadoids such as Norway pout, haddock or blue whiting). As described in the earlier section, these data go through an initial interpretation for identification of the echo traces and allocation of s_A to species based on expert judgement and trawl information. Factors considered mainly consist of the catch composition from the targeted trawl hauls, the echo characteristics of the detected fish aggregations and other environmental parameters such as depth, vertical position in the water column and geographical location among others. In certain cases, nearby representative trawl hauls are directly used to calculate the s_A that can be attributed to the target species through a separate process. The final s_A used in the abundance estimation is assumed to be 100% composed of the targeted species (e.g. herring).

Target Strength of fish:

In linear form, the expected energy level from individual fish is termed as backscattering cross-section, σ_{bs}, and in logarithmic (dB) form Target Strength (*TS*) such that $\sigma_{\text{bs}} = 10^{\text{TS}/10}$. Target strength is a stochastic value, affected by tilting behaviour and morphological variability between individuals. The size dependency is accounted for by known species specific TS/ Length relationship. This requires a reliable length frequency data to be acquired by trawl samples and allocated to the s_A values in order to convert s_A to an abundance estimate. For HERAS the TS/Length relationship used is:

$$TS = 20log(L) - m, \quad (3)$$

with L the fish length and m a variable that is species dependent. For the HERAS survey, $\text{m} = 71.2$ dB is used which is standard for North Atlantic clupeid fish. Equation (3) does not account for depth but this effect can potentially be included (Ona 2003).

The sampling units:

Echosounder measurements during HERAS are performed continuously typically 1 ping per seconds while the vessel is underway of 10 knots. These samples are aggregated at different levels in StoX for different purposes. The sampling units are:

- *Pings:* Typically, every 2-5 meters depending on speed and ping rate

- *Elementary Distance Sampling Units (EDSU):* Every 0.1 or 1 nautical mile. EDSUs consists of the aggregation of pings within a standard distance.
- *Primary Sample Unit (PSU):* Transects.
- *Stratum (part of a strata system):* Strata are represented as spatial polygons in the StoX analysis software. Strata are predefined based on known homogeneity in variability within the area with respect to distribution of aggregations and size compositions.

StoX procedures for abundance estimation:

StoX uses the biotic and acoustic inputs that are previously submitted in the ICES acoustic trawl database and converted to a specific *.xml StoX input format. StoX is composed of different modules performing specific tasks and provides different template modules for a range of surveys. For HERAS, the template "Acoustic abundance by transect and r-model with uncertainty" is used. The template is constructed in 24 steps in a predefined order. For detailed description of each step, please refer to the StoX user manual[5]. The steps can be visualized, parametrized and executed through the GUI but are here automated in R using the RStoX package[6].

2.2 HERAS index calculation: base run

For the HERAS survey, the level of mixing between the main species (herring and sprat) and other species (e.g. whiting, sardines, haddock) varies throughout. In the Dutch, Irish, Norwegian and Scottish survey (Figure 1-1), scrutiny of the acoustic data is taken to species level. Based on scattering characteristics of echo traces as well as catch composition of corresponding targeted trawl catches, a robust allocation of herring and sprat to echoes originating from detected fish schools and aggregations is feasible. The acoustic categories, herring and sprat, are then allocated to these echo traces and corresponding NASC values are exported from integration results. However, in the German and Danish survey area, this is not possible due to the very high level of mixing and the impossibility to discern mixed clupeid schools from echo traces. For these survey components, there is no direct herring/ sprat categorization. Instead, the species composition of each trawl is used to disaggregate NASC values into species categories by transect. This is achieved using the StoX software with dedicated projects to split NASC values for Danish and German surveys.

Furthermore, in the Norwegian and Danish survey components, strong mixing of herring stocks occurs between NSAS, WBSS and Norwegian Spring Spawning (NSS) herring. Historically the mixing with the NSS stock is not considered and only separation between WBSS and NSAS is performed. This is accounted for in two different ways:

- Danish survey (in strata 21, 31, 41, 42, 151, 152 in Figure 1-4c): use of otolith microstructure and shape (Clausen et al. 2007; ICES 2018b) to determine stock ID for the sampled fish. Stock information is embedded in the biotic data for each sampled fish and submitted to the ICES acoustic trawl database.
- Norwegian survey (strata 11, 141 in Figure 1-4c): use of vertebrae counts to determine fraction of WBSS at age for each year of survey. The proportion of each stock is determined using ordered statistics on vertebrae counts from the biological data. This split proportion cannot be used to allocated stock id to individual fish biological

[5] ftp://ftp.imr.no/StoX/

[6] https://github.com/Sea2Data/Rstox/

samples. Biological information as submitted to the ICES acoustic trawl database therefore does not contain direct information on stock id. Instead, stock splitting is applied after the abundance at age estimation process.

Because of the multi-country survey components, species mixing and herring stock mixing, the procedure for the derivation of NSAS and WBSS indices involve the use of several inputs and StoX projects. Figure 2-1 gives a workflow summary of this process.

The processing of the biotic and acoustic data using StoX is first divided into two separate components: the main project with data from all strata except 11 and 141 and a side project that include data from strata 11 and 141 only (mostly consisting of data from the Norwegian survey but not exclusively). For the main project, a further two specific StoX projects are needed for the splitting of acoustic densities into fish species categories (herring and sprat). This is done through separate projects for the Danish and German survey components. The resulting split acoustic data alongside biotic data is further fed into the main project with data from other surveys (The Netherlands and Scotland). This specific process is depicted in Figure 2-2(a). The main and side StoX projects are then run, yielding abundance of herring for each stratum disaggregated by:

- Age
- Length per 0.5 cm bins
- Maturity stage (mature/immature)
- Stock id (NSAS.WBSS)

As a consequence of the survey biological sampling strategy, combinations of length, age, stock and maturity are missing sporadically. These are propagated through by StoX and the resulting final estimates will also include cases with missing allocation. In order to account for these missing fields in the final abundance estimates, these are filled using the following protocol:

1. Maturity of age 0 allocated to immature.
2. Maturity of length < 8.5 cm allocated to immature
3. Missing lengths: filled in using inverse of weight/length growth relationship inferred from data.
4. Missing weights: filled in using the weight/length growth relationship inferred from data.
5. Missing ages: iterative process comparing abundance proportions in associated length group.
6. Missing maturities: iterative process comparing abundance proportions in associated age group and/or length group.
7. Missing stock id: iterative process comparing abundance proportions in associated age group and/or length group.

In the filling in process, steps 6 and 7 are the most complex. Historically, this has been done manually in spreadsheets but is now automated, and more traceable and reproduceable. It is important to note that the filling in of stock id is only performed for the main project but not the side project. For the side project, the abundance in each category is broken down into NSAS/WBSS using split proportions calculated directly from the raw biotic data. NSAS/WBSS estimates from the side and main projects are then combined to produce final abundance at age. The procedure is visualised in Figure 2-1(b). With the newly developed automatic routines, the outputs from the processing are stored and managed in multiple dimensions (maturity, age, area, year) using the FLR R package (Kell et al. 2007)[7].

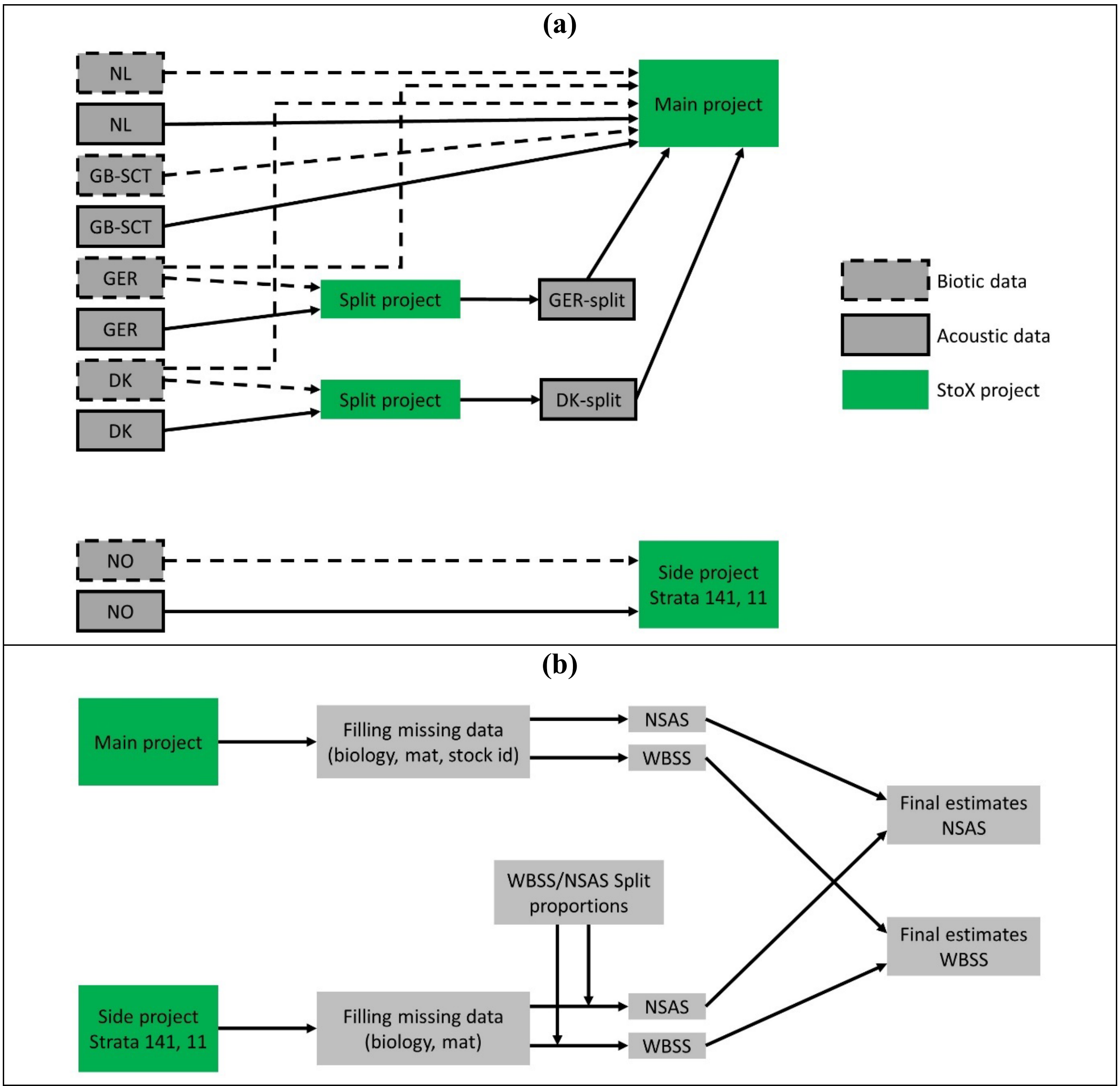


Figure 2-1: *workflow of NSAS and WBSS index calculations. (a) flow diagrams of input data and StoX projects. (b) Use of StoX projects to derive abundance at age.*

In strata 11 and 141, the abundance derived from the side project is divided into NSAS/WBSS using split proportions. This quantity is computed every year using vertebrae count measured through biological sampling. The fraction of WBSS in those strata is given by:

$$F_{\text{WBSS}} = \left(56.5 - \overline{v_c}(a, y, s)\right)/(56.5 - 55.8). \quad (4)$$

With $\overline{v_c}(a, y, s)$ the mean vertebrae count in strata s, for year y at age a. It is important to note that this is only calculated for ages 1 to 4. For ages 4+, values for age 4 are used. In the rarer case of the presence of age 0, the value for age 1 is used. Equation (4) transforms the vertebrae

[7] https://flr-project.org/

count $\bar{v}_c$ into a [0,1] interval. This is exemplified in Figure 2-2(a). Categories with $\bar{v}_c$ greater than 56.5 corresponds to $F_{\text{WBSS}} = 0$ (only NSAS), categories with $\bar{v}_c$ smaller than 55.8 are allocated $F_{\text{WBSS}} = 1$ (only WBSS) and any category with $\bar{v}_c$ comprised between 56.5 and 55.8 is allocated F_{WBSS} with a linear decrease with increasing vertebrae count. The resulting WBSS split proportion for each age, strata and year is shown in Figure 2-2(b).

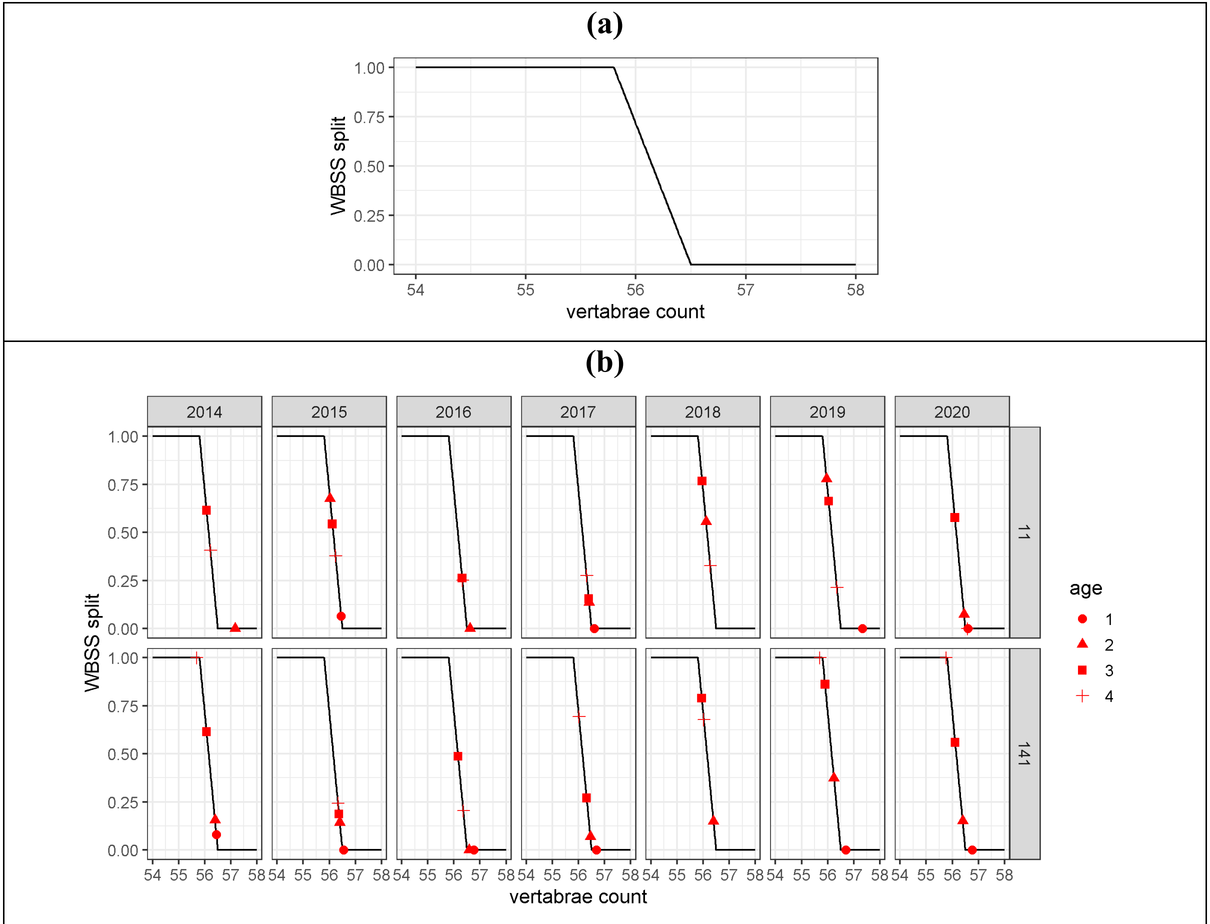


Figure 2-2: *split proportion of WBSS as applied in strata 11 and 141. (a) function to determine the split proportion of WBSS given mean vertebrae counts at a given age, strata and year. (b) WBSS split proportion function and associated values per age, strata and year.*

Moreover, the StoX software can compute the uncertainty for the abundance at age using a bootstrapping method on transects. Because of the filling in process and the use of external split proportions (in strata 11 and 141), manual inputs were required in the past. As these two steps are now automated, it is now possible to compute a bootstrap for both the side and main projects and combine projects for each iteration of the bootstrapping, in turn yielding uncertainties for the final abundance estimates. Two separate runs are then computed for the base run, one using baseline (all transects included) and another one using the Acoustic Trawl bootstrap option from StoX using 500 iterations.

2.3 Transparent Assessment Framework (TAF)

TAF is a framework developed by ICES to organize data, methods, and results used in fish stock assessments, so they are easy to reference and re-run with new data or methods. The framework uses the R language and is computed on an ICES server and dedicated website to display results. The link between the R code developed and the app is performed through individual repositories on GitHub[8]. Through this platform, all data input and output are fully traceable and versioned.

TAF is used to run various stock assessment models and compute survey indices (e.g. from trawl surveys) but there is currently no example of the computation of indices from acoustic surveys. With tools such as the ICES acoustic trawl database and the StoX software, it is now possible to automate the calculation of abundance estimates for complex cases such as NSAS/WBSS and run this on TAF. With this addition, the NSAS assessment now consists of the following TAF repositories:

- Acoustic index: calculation of the HERAS indices for NSAS and WBSS (the focus of the current study).
- Single fleet stock assessment
- Multi-fleet stock assessment
- Forecast as used to provide catch advice

The working principle of a TAF repository is shown in Figure 2-3. To produce the NSAS and WBSS indices the processing is divided into four main parts:

1. Data: fetching acoustic and biotic data from the acoustic trawl database and data stored locally on the repository. The latter includes:
   - Individual *.xml StoX project files.
   - DK and GER split acoustic data
   - Strata files
   - File with split proportion for strata 11 and 141
2. Input: organize folder tree on the repository for swift running of StoX projects.
3. Model: run side and main StoX projects (Figure 2-1)
4. Output: create outputs and plots from final estimates.

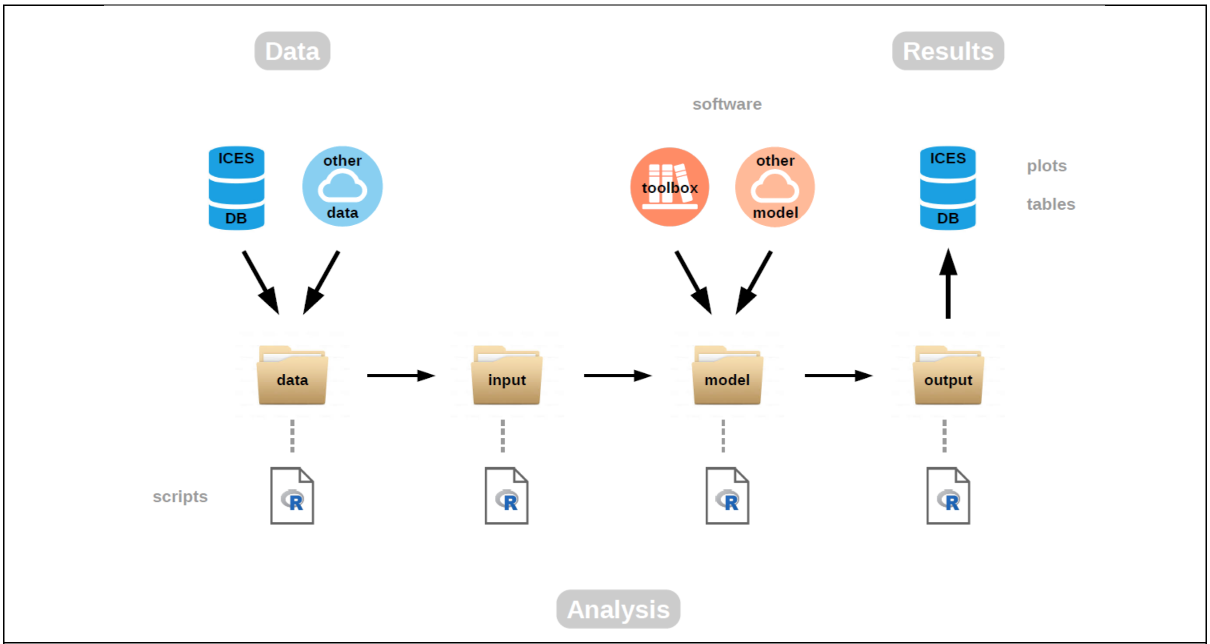


Figure 2 3: *TAF working principles from data to results. Extracted from (Millar and Magnusson 2018).*

[8] https://github.com/ices-taf/doc

2.4 Sensitivity test runs

2.4.1 Calibration error

During an acoustic survey such as HERAS, the calibration of the echosounder from each participating vessel is paramount to provide absolute estimates of S_v and in turn yields consistent measurements between platforms. Any offset from genuine calibration gain G directly influences abundance estimates as it impacts the level of acoustic density that is measured. Small variability in calibration gain can occur because of factors such as variation in sphere parameters, weather conditions during calibration trials or inherent variability in calibration measurement. Moreover, larger discrepancies can sometime arise from echosounder malfunctioning, miss handling during calibration trials or bugs in software. In that context, it is important to investigate the impact of various levels and types of calibration offsets can have on final abundance estimates. In this study, two scenarios are considered:

- Constant offset of calibration gain.
- Nonlinear offset of S_A values based on ping to ping evaluation of malfunctioning echosounder from Tridens II (NL component of the HERAS survey).

Calibration gain offset:

Here, the sensitivity of NSAS/WBSS abundance estimates are tested by adding an error to the calibration gain as:

$$G_{\text{erroneous}} = G + e, \quad (5)$$

with e the calibration error in dB. Here, a range of errors between 0.2 and 2 dB in 0.2 dB increments are tested. Each calibration error is introduced in raw acoustic files (input to StoX) and tested for each survey component (NL, GB-SCT, DK, NO, GER) and survey year separately (2017 to 2020).

S_A error from Tridens II echosounder malfunctioning:

In 2020, (Sakinan and Berges 2020) used data from the Dutch component of the HERAS survey to test the comparability of the EK60 and EK80. This was done by running a multiplexer, producing ping to ping data between EK60 and EK80 for effective comparison. Similar to findings in other studies (Macaulay et al. 2018; Sakinan et al. 2018), both systems yielded similar results. However, this study revealed a malfunctioning EK80 38 kHz echosounder onboard RFV Tridens II (vessel participates in the HERAS survey). Onboard Tridens II, the EK60 was used for survey purposes until 2018. Therefore, the malfunctioning of the EK80 in 2017 had no implications for the HERAS survey. The ping to ping data of opportunity produced with the malfunctioning EK80 provides insight on a type of malfunctioning that can easily be overlooked but has implications for the survey results.

The origin of the EK80 issue was tracked down to 13th July 2017 and is due to malfunctioning of the EK80 transceiver (not the transducer). The transition in the echogram is shown in Figure 2-3(a) and is very subtle and hard to identify in survey conditions. An analysis of the impedance level of each echosounder quadrant shows the malfunctioning more clearly Figure 2-3(b). The inspection of calibration results in perspective to older results also revealed the malfunctioning with a drop of ~2 dB in calibration gain whilst expected variations usually do not exceed 0.1-

0.2 dB Figure 2-3(c). The ping to ping data set was further used to build the relationship between the EK60 data and the erroneous EK80 CW data Figure 2-3(d).

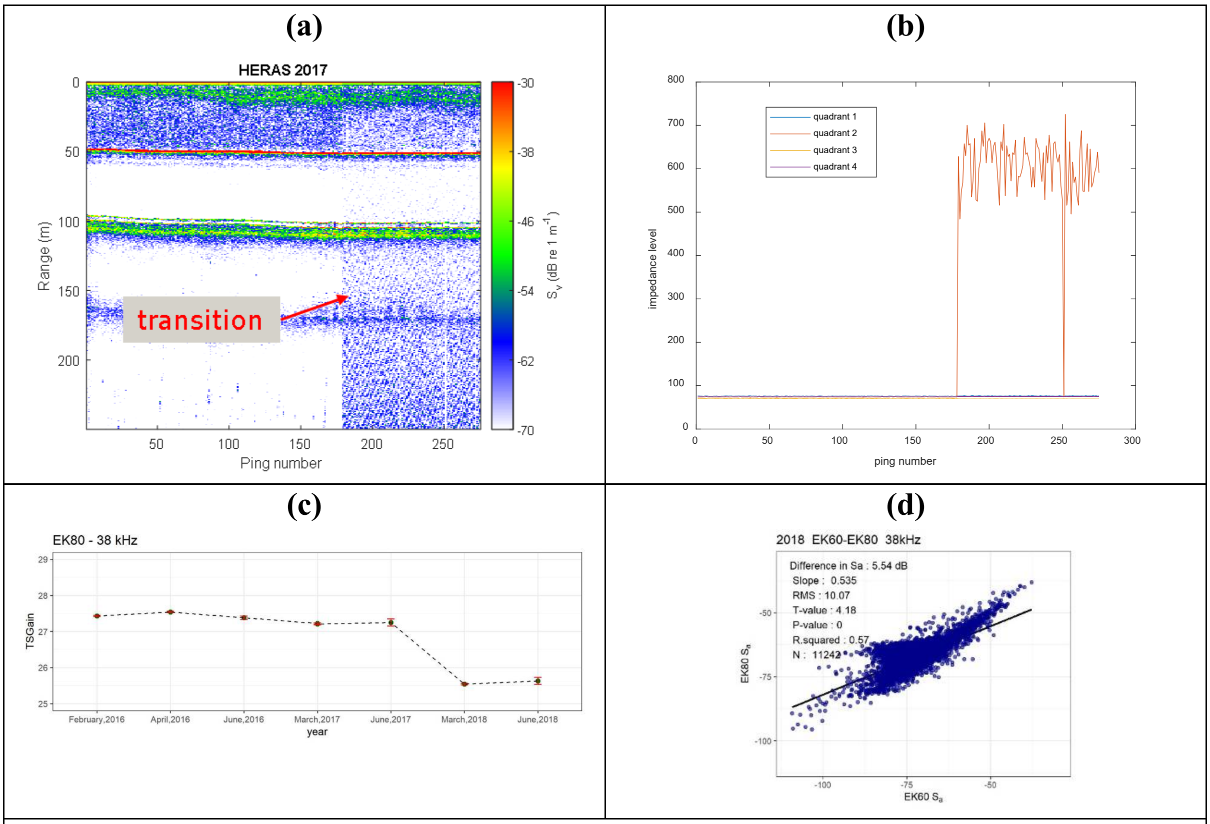


Figure 2-3: *ping to ping analysis of EK80 CW malfunctioning onboard Tridens II RFV during HERAS 2017 and 2018. (a) transition to erroneous data in echogram. (b) time series of impedance levels around the occurrence of echosounder malfunctioning. (c) comparison of results from EK80 CW calibration trials onboard Tridens II. Erroneous calibration starts on March 2018. (d) EK60 vs EK80 CW ping to ping with malfunctioning EK80 CW echosounder.*

For the current study, the relationship shown in Figure 2-3(d) is modelled using a GAM model with a smoothing function, with EK80 SA as the response variable and EK60 SA as the sole explanatory variable. Here, EK80 SA is the erroneous SA measurement whilst EK60 SA are the calibrated measurements. The model can be used to generate erroneous SA values given a random draw of initial SA values. An example distribution is shown in Figure 2-4. This process was applied to acoustic input files from the Dutch component of the survey for each of the survey years 2017-2020. For each specific year, error is introduced to each input file prior to running StoX projects. Results for abundance at age can then be compared with the results from the base run.

(a)	(b)

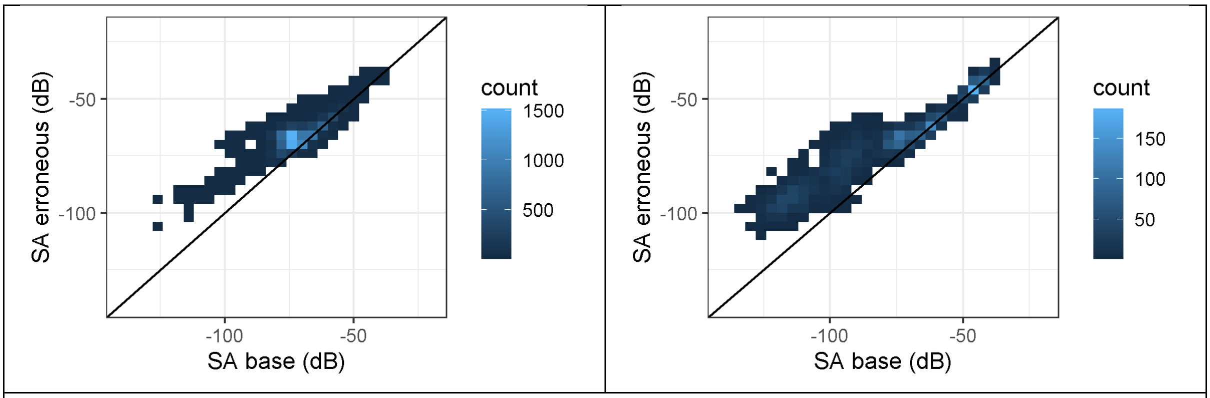


Figure 2-4: *Simulation or erroneous SA values using the study by (Sakinan and Berges 2020). (a) distribution of ping to ping data. (b) modelled distribution with randomly drawn SA values between -130 dB and 25 dB.*

2.4.2 Stock splitting

An important aspect of the calculation of NSAS/WBSS indices is the mixing between herring stocks at the border between the Baltic Sea and the North Sea. The area of interest correspond to the following strata (Figure 1-4(c)): 11, 141, 152, 151, 42, 41, 31, 21. In these regions, mixing is taking place between NSAS and WBSS but also NSS along the Norwegian coast. Historically mixing with NSS has been assumed small and not considered for calculations of NSAS/WBSS indices. Currently, the way mixing is handled is different between strata 11/141 and other strata with mixing. In strata 11 and 141, the ratio of WBSS and NSAS is computed using Equation (4) which relies on biological measurements of vertebrae counts. The data set used for that purpose is shown in Figure 2-5 and resulting WBSS split ratios are shown in Figure 2-2(b) and Figure 2-6. Overall, it is observed that it can vary significantly between years. Of importance when calculating WBSS split ratios using Equation (4) are the 56.5 and 55.8 threshold values first introduced by (ICES 1994). Beside that these values might be somewhat outdated, (Gröger and Gröhsler 2001) notes that no stochastic assumption or theoretical background is available for Equation (4). Overall, the use of Equation (4) combined with potentially outdated vertebrae count thresholds and uncertainty associated with the use of vertebrae count for stock splitting could introduce bias to the final NSAS/WBSS estimates. Moreover, new developments in research and of stock identification methods (Berg et al. 2017) should enable a more accurate splitting of the stock in future years. It is therefore of interest to test the following:

- Sensitivity of final WBSS/NSAS estimates against variation in vertebrae count
- Use of new methods for stock splitting, namely otolith shape recognition (Berg et al. 2019) and genetics (Berg et al. 2021).

It is important to note that the testing undertaken here is only for strata 11 and 141. For other strata (152, 151, 42, 41, 31, 21), stock splitting is performed on individual herring samples using otolith microstructure and shape (Berg et al. 2021; ICES 2018b). It would be of interest to also perform sensitivity tests on stock mixing in these strata but due to the complication in implementation of such scenarios (which would require artificially altering biotic data), this not considered in this study.

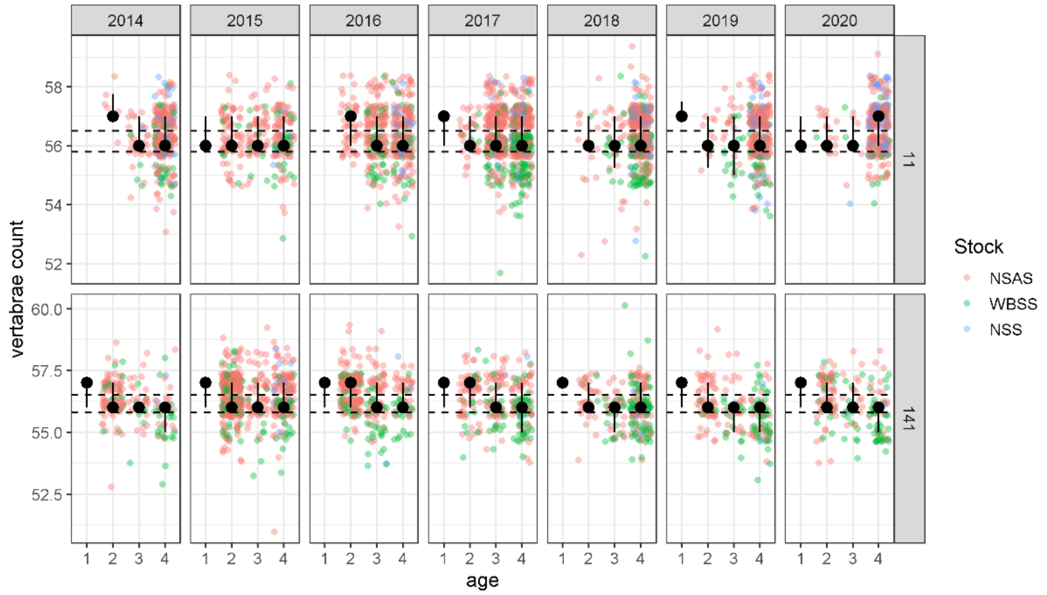


Figure 2-5: *statistics of vertebrae count in each year strata and age groups. Black circle markers are the median of vertebrae count in each category and the extend of vertical black lines are the 25th and 75th quantiles. Coloured circle markers are the vertebrae counts for each fish sample with stock identification determined using otolith shape (Berg et al. 2019): NSAS (red), WBSS (green), NSS (blue). The dashed horizontal lines are the 55.8 and 56.5 thresholds as used in Equation (4).*

Split ratio with offset in vertebrae count:

Here, the sensitivity of index calculation is tested against changes in vertebrae count that in turn changes split proportions used in strata 11 and 141. The metric used in Equation (4) is the mean vertebrae count in each category (age, year, strata) $\overline{v}_c$. For testing, this is altered using the standard deviation in vertebrae count in each category and computing a new split ratio using the following for $\overline{v}_c$:

$$\overline{v_{c\,\text{error}}}(a, y, s) = \overline{v}_c(a, y, s) + \beta \times \sigma(a, y, s). \qquad (6)$$

The term β is a scalor that is used to introduce a deviation in $\overline{v}_c$. The range of values tested for β are -0.2 to 0.2 in 0.1 increments. The change in split ratio is shown in Figure 2-6 for a limited range of β values.

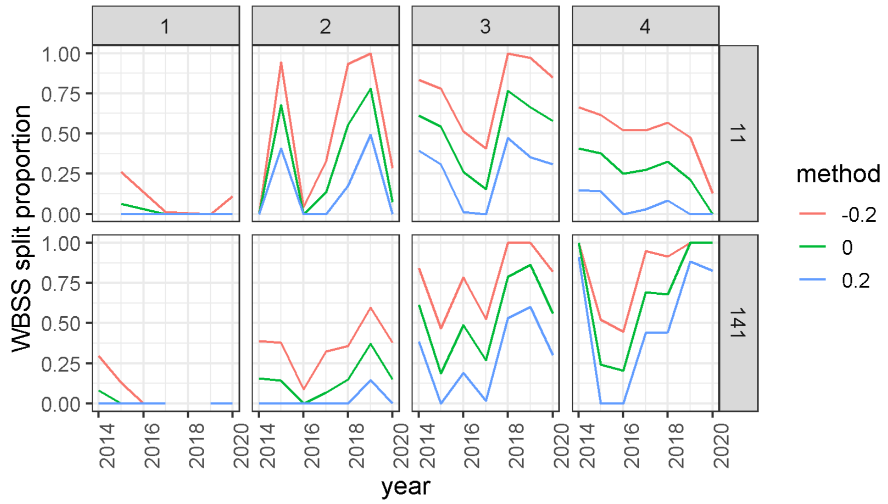


Figure 2-6: *WBSS split proportions in each age group, strata and year. Also shown is the effect of deviation from mean vertebrae count by -0.2/+0.2 sd.*

<u>Split based on otolith shape:</u>

The method by (Berg et al. 2019) uses otolith shape recognition using machine learning to identify the stock id of a given otolith. The discrimination is made between NSAS, WBSS and NSS. This method has been applied to the Norwegian biological samples for the period 2014-2020, yielding alternative split proportion estimates to those calculated using vertebrae count (Equation (4)). Using otolith photographs, probabilistic estimates are derived for each individual otolith. Here, a threshold of 0.75 on the probability is used to filter out individual samples that are not discriminated with a high enough confidence. The proportion of individuals in each category (age, year and strata) is then calculated. The comparison between split proportions inferred from vertebrae counts and otolith shape recognition (with a probability threshold of 0.75) is shown in Figure 2-7. There are significant differences between the results from the vertebrae count and otolith shape recognition methods. Notably, the otolith shape recognition exemplifies fewer variable results (e.g. age 2 in strata 11). Using these new split proportions, alternative NSAS/WBSS abundance estimates can be generated and compared to base run.

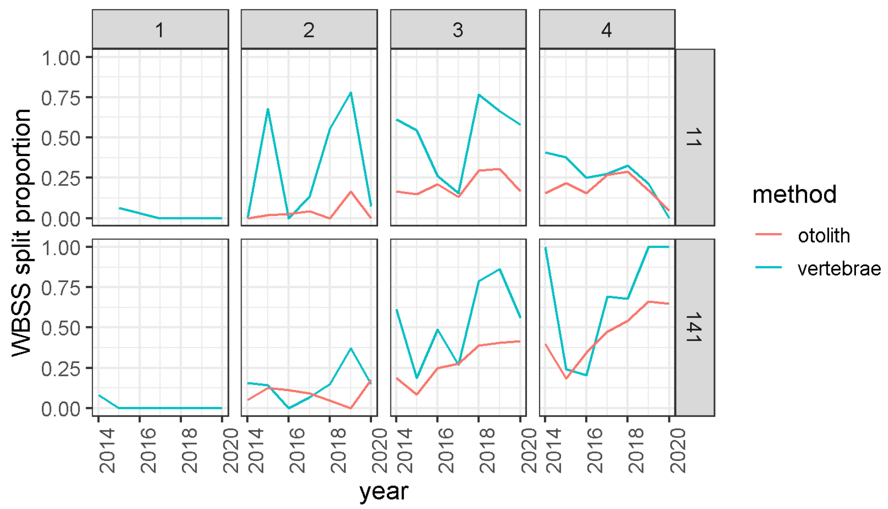


Figure 2-7: *time series of split proportion at age as derived using vertebrae count and otolith shape (Berg et al. 2019) from 2014 to 2020 in strata 11 and 141. The split proportion from the otolith method is computed using a probability threshold of 0.75.*

Split based on Genetic data:

In 2020, genetic data was available for biological samples taken in strata 11 and 141. Biological samples could thus be allocated a stock id at an individual level in the biotic files from the Norwegian survey. This allows for combining all data from individual surveys and run a single StoX project as opposed to having to break down the processing into a main project and a side project (Figure 2-1). This new project can be running as a baseline but also using transect bootstrapping for uncertainty estimation. These results can then be compared with results from base run.

2.4.3 Strata definition

The HERAS survey extends over a wide geographical area covering the habitat of herring and sprat at their different life stages. Their distribution is heterogenous due the impact of different biological and physical drivers, such as age, reproductive state, temperature, depth, food availability etc. This heterogeneity reflects on their aggregation densities and size distribution and results in geographical patchiness and gradients. One of the objectives of the survey design is to allocate the survey effort in an optimal way with the aim to keep the survey precision as high as possible. This is achieved by stratification (Figure 1-4(c)). Normally, the main goal of the stratification is to minimize the variability within each stratum. Ideally the sampling variability between the strata should be independent from each other. Although the stratification has a direct effect on the variability in the results, the data of an individual survey cannot be used to determine the strata since the survey design is one of the factors that determines the results. For example, as a survey design strategy, in a stratum where the variability is known to be higher than the others, the effort would be increased to improve the precision.

Prior to 2016, the HERAS survey strata were either based on ICES statistical rectangles or based on historic catch data. Beginning from the year 2016 this was changed based on an internal work carried out in 2015, and the new survey strata was formulated which is independent from the ICES rectangles. This new design had two main goal:

- Standardization of survey design and effort within co-surveyed strata
- Improvement in precision in the abundance estimate

This new stratum design has been in use for the surveys from 2016 to 2020. While this design was effective in maintaining homogeneity (e.g. variability in the aggregation patterns, maturity level and size distributions), some minor concerns arose during post cruise meetings for certain exceptional cases with a potential change of strata to take into account historically known north-south gradients and coastal-offshore gradients,.

A clear example is from the 2018 HERAS survey, where aggregations of both small-immature and large-mature herring were observed along the same transect in strata 91. Despite being found along the same transect, there was a large distance between these aggregations in the inshore-offshore direction. Normally, the stratum 91 is historically characterized by large – mature herring with distinct aggregations in high densities. The inshore strata 81 and 101 are more characterized by the earlier life stages and small sizes of herring. Although not as clear as in the 2018 example, this issue also occurred in strata 81 and 101 repeatedly. Having two distinct age/size groups with different aggregation behaviour and spatial structure in the same strata have the potential to violate the survey design principles.

Here an alternative strata design was created and compared against the current design (Figure 1-4(c)). For this purpose, the spatial variability in the mean length distributions, mean age and maturity levels, the biological data from individual survey hauls from 2016 to 2019 were combined for the entire survey area and distribution maps were created using geostatistics. Although all parameters show specific patterns, it was decided to use maturity proportions as it was found the most informative parameter. Figure 2-8 shows the underlying spatial structure in maturity levels. Figure 2-8(a) shows the original strata design overlaid and Figure 2-8(b) shows a slightly modified version of the current stratification with modifications to the following strata: 111, 101, 91 and 81. In this design, the inshore strata 81 and 101 are extended to follow the maturity pattern.

Based on these new polygons, the survey indices are recalculated. For the sake of this exercise, the transects are also modified such that; when a section exceeds the limit of one stratum, it is split into another section and either added to an existing transect or identified as a new transect. This trial allowed for separation of young and adult herring aggregations that were initially observed on the same transect within the same stratum. Note that, this is only a hypothetical test, and in principle, the transect design should not be changed after the survey has been conducted.

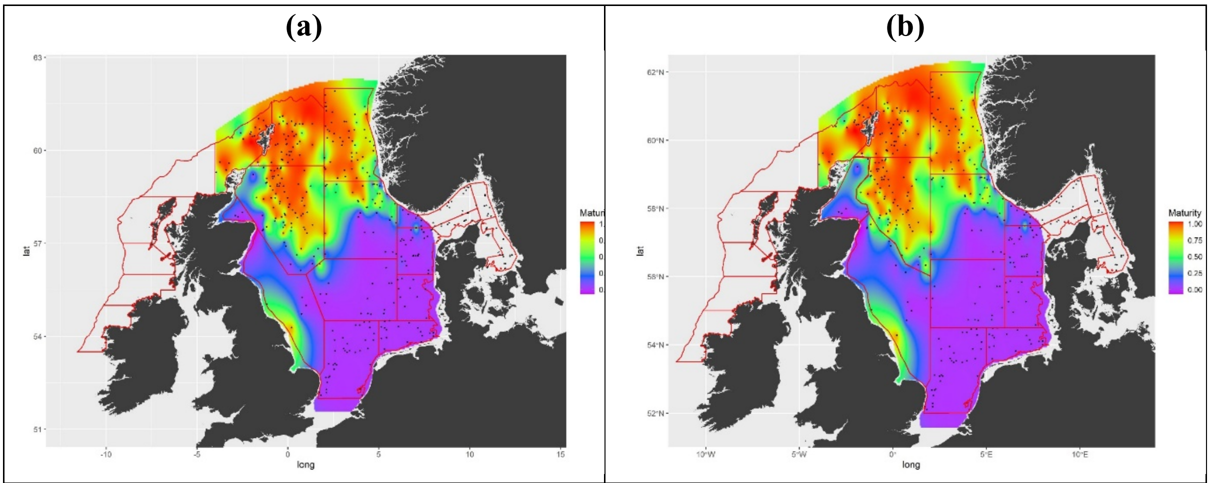


Figure 2-8: *Defining new strata based on spatial distribution of maturity levels. (a) base strata definition. (b) newly developed strata definition. The underlying colormap is the spatially interpolated distribution of maturity levels using biotic data from 2016 to 2019*

2.4.4 Haul allocation

In StoX, it is necessary to assign at least one set of biological measurement to each acoustic transect. This allows for the calculation of length dependent acoustic target strength (TS) and estimation of disaggregated abundance (age, length, maturity) for each transect taking the most representative length distribution into account. In theory, all the hauls within a stratum should be representative for all transects. However, this is not considered to be true in practice as there are local variabilities in addition to global variability and anisotropy within each stratum. Especially in strata 91 and 111 there is well known gradient of size with larger herring typically being further north. Therefore, the standard way of performing this allocation in HERAS survey is to use neighbouring hauls and survey knowledge with a manual assignment based on distance and expert judgment. The downside of this approach that it introduces subjectivity and operator dependence to the analysis.

In this exercise, the difference between the manual assignment and the stratum assignment was tested in StoX. The stratum assignment basically aggregates all the samples from all the hauls within a stratum by equal weighting and assign them to all transects in that stratum in the same way. Ideally it is expected that during the survey there are representative numbers of hauls within each stratum. However, in practice, there is limited time that can be dedicated to trawling during the survey. The location selection is generally a trade-off between resolving local variability in high density areas and effective coverage of all strata. During the HERAS surveys, on few occasions, there were no hauls corresponding to a stratum. To be able to perform this exercise, in such cases, most representative hauls from the neighbouring strata were used. Furthermore, in all strata, the samples with too few measurements (<30 herring samples in haul) to produce a clear statistical distribution were identified as outliers and removed.

3 RESULTS AND DISCUSSION

3.1 Base run and TAF

3.1.1 Automatic calculation of NSAS/WBSS index

The method for the calculation of the WBSS and NSAS abundance indices described in Section 2.2 is applied to the period 2017-2020. This is the period where a well-defined workflow for processing is in place (Figure 1-4(a)). Prior to adoption of the newly automated procedure implemented in R, it is important to check the routines against potential bugs and investigate discrepancies with existing indices as used in the assessment. This is shown in Figure 3-1 for the abundance at age and SSB (in % relative to values used in assessments). For both NSAS and WBSS, whilst the discrepancy is marginal for 2018 and 2019, it is significant for 2017. In order to investigate those more in depth, a thorough check of the results for each year was performed, comparing manually derived numbers from spreadsheets and results from automatic routines. As in Figure 3-1 very good agreement was found for the years 2018-2019 (and 2020). The remaining minor discrepancies are due to small differences in filling of missing fields (Figure 2-1(b)), which are arguably correctly attributed by the automated routine, and rounding. Closer investigation of the higher differences seen in 2017 comparison, the discrepancies are mainly due to differences in WBSS split ratio for that year used in the automated process and those used in the original analysis in 2017. This needs to be followed up and an update of the index for the assessment should be performed in the future for both NSAS and WBSS.

In addition to abundance at age, the results from the HERAS survey also provide biological parameters for NSAS: weight at age in the stock and maturity at age in the stock. These are used in the calculation of SSB. The effect of the new calculation routines on these parameters is shown in Figure 3-2. Only small differences were observed, most notably in 2017. For WBSS, weight at age and maturity at age calculated from the data of the HERAS survey is not directly used in the assessment because of the timing of the survey. Therefore, no sensible comparison can be made.

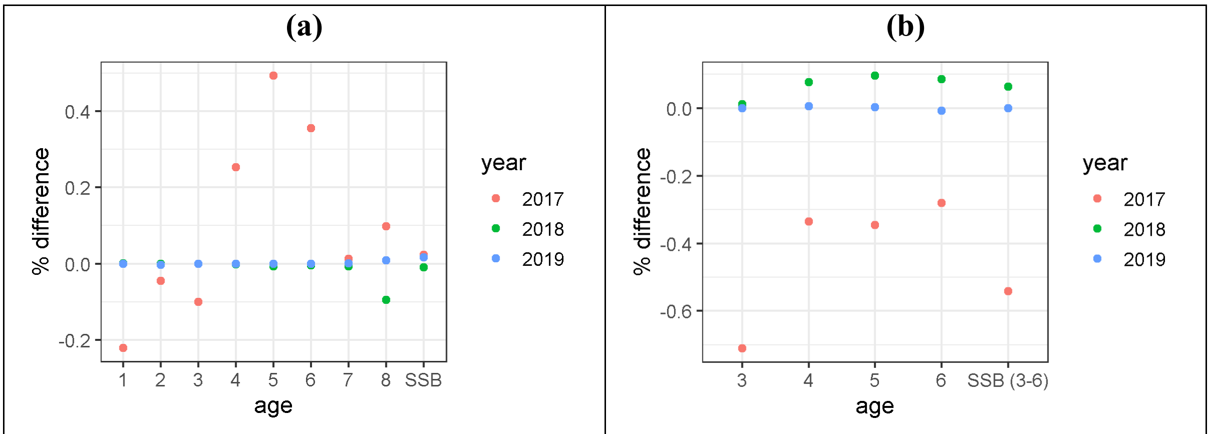


Figure 3-1: *comparison of abundance at age and SSB as computed using the automated routines against those used in the assessment. (a) NSAS. (b) WBSS. For WBSS, only ages 3-6 are used in the assessment.*

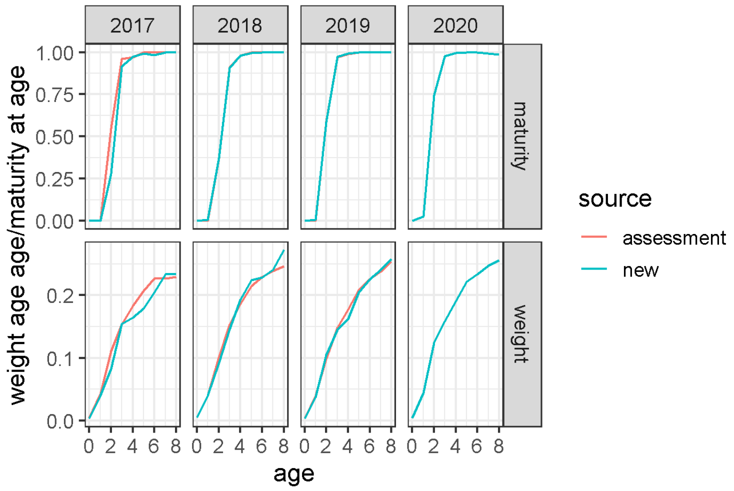


Figure 3-2: *comparison of maturity at age and weight at age computed using the automated routines against those used in the assessment for NSAS. For WBSS, these quantities can be derived from the HERAS survey but are not used in the assessment due to survey timing and are therefore not shown.*

3.1.2 NSAS and WBSS results (2017-2020)

With the newly developed framework for the automated calculation of the NSAS/WBSS indices and the use of FLR, results can be plotted efficiently in a generic way. This is exemplified in Figure 3-3 and Figure 3-4 for the years 2017-2020 with abundance at age and abundance for mature/immature categories in each strata (Figure 1-4(b)).

Results for NSAS abundance at age are shown in Figure 3-3(a) per strata and for all strata combined. It shows the bulk of the stock for ages above 2 is concentrated in the Northern strata (91, 111, 101, 121, 11). Since 2017, there is a decreasing trend in stock trajectory for NSAS (Figure 1-3(a)). This is notable from the abundance at age for all strata combined in Figure 3-3(a) with a decrease since 2018 which is driven by decrease in stock abundance in strata such as 111, 91 or 11. Strata with predominantly younger ages show large variations in abundance in recent years (e.g. strata 81, 131 or 141). The age composition of the stock is similar since 2017. The abundance for mature and immature fish as shown is overall consistent between years for the different strata (Figure 3-3(b)).

WBSS herring stock has followed a downward trajectory for the last ~15 years (Figure 1-3(c)). The abundance estimates from the HERAS survey is also an important source of information for the assessment of WBSS. The survey has with some inter-annual variations given an overall downward trend for the last 15 years, and this is reflected in the stock assessment. Though, since 2017, there is a slight increase in abundance. This is shown in Figure 3-4(a). Only strata 11 (the northern most one) shows a strong consistent decrease in abundance which is partly caused by a decrease in stock proportions in that strata (Figure 2-6). Strata 141 with the highest WBSS abundance shows steady abundance levels and even an increase in 2020. Also, to note is the large proportion of age 1 individuals observed in 2020. The proportions of mature/immature abundances remain at similar levels Figure 3-4(b).

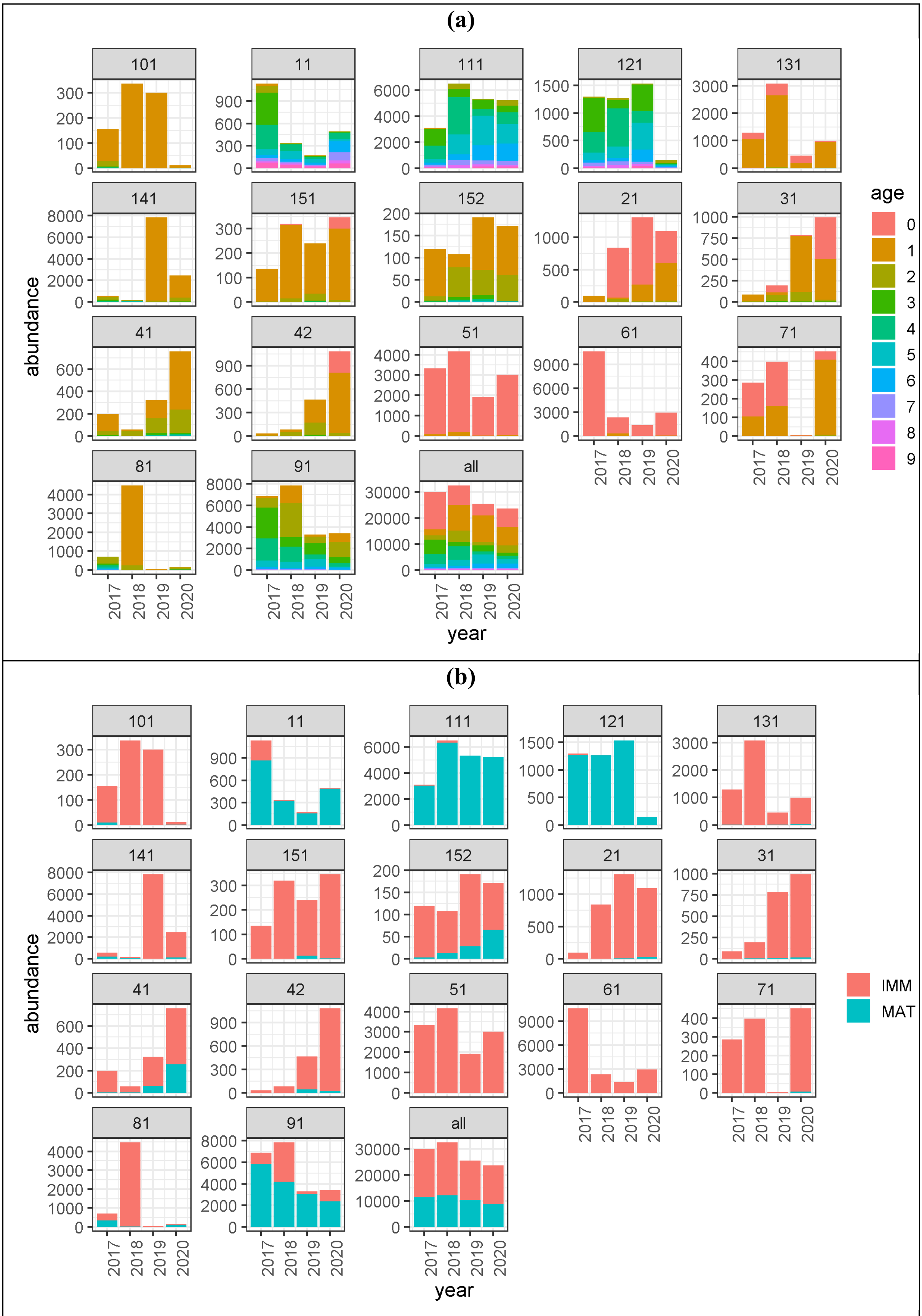


Figure 3-3: *NSAS base run abundance per strata between 2017 and 2020. (a) abundance by age group. (b) abundance for mature/immature stages*

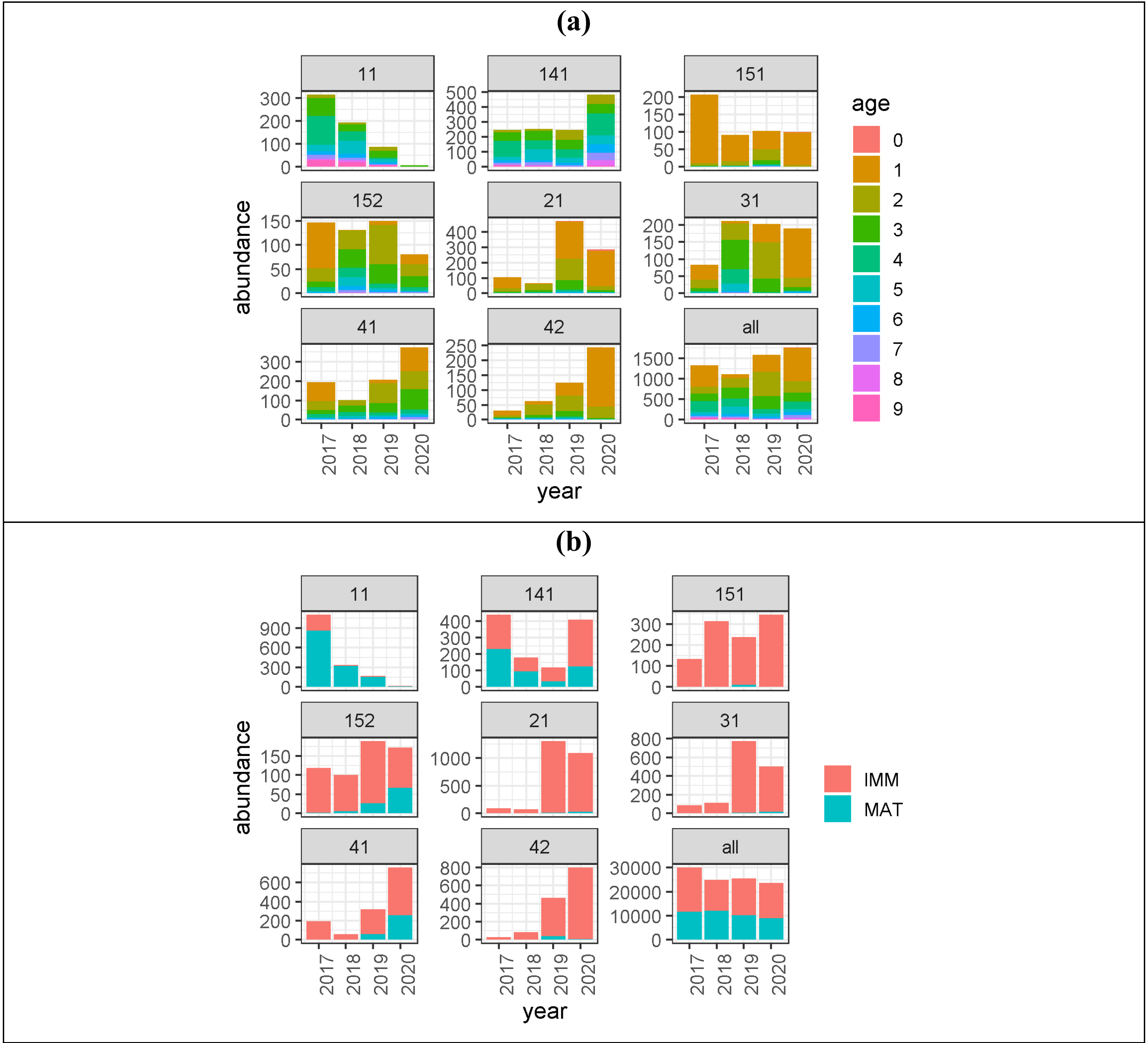


Figure 3-4: *WBSS base run abundance per strata between 2017 and 2020. (a) abundance by age group. (b) abundance for mature/immature stages.*

3.1.3 Index uncertainty through Bootstrapping

Because WBSS and NSAS indices are currently derived using two separate StoX projects (Figure 2-1), it has not been possible to use the acoustic trawl bootstrap feature in StoX which enables uncertainty estimation. However, in order to derive uncertainty from bootstrapping for final NSAS/WBSS abundance estimates, one needs to combine projects for each iteration with filling of missing fields (stock id, maturity, age, length) and applying split proportion ratio for strata 11 and 141. With 500 iterations, this was not possible with manual processing but is now enabled with automatic routines. For both NSAS and WBSS, uncertainties associated with the index calculation process can therefore now be estimated with ease and delivered with the annual survey results.

Uncertainties for SSB is shown in Figure 3-5. For NSAS (Figure 3-5(a)), both the 25^{th} and 75^{th} quantiles are within the assessment uncertainty. For WBSS, assessment uncertainty is larger than the $25^{th}/75^{th}$ quantiles interval. Moreover, a large difference exist for 2017 between the new index and the index currently used in the assessment which is attributable to data discrepancies (e.g. in split proportions) for that year (Figure 3-1). Of importance is the difference (in SSB and abundance at age) for both NSAS and WBSS between baseline estimates and median values of bootstrap. The use of median values from bootstrap is possibly a more robust estimation.

The comparison between baseline and bootstrap runs for both NSAS and WBSS is presented in Figure 3-6(a) for NSAS and Figure 3-6 (b) for WBSS. Whilst there is consistency between the results, baseline results can be somewhat higher (e.g. NSAS age 1 in 2019).

(a)	(b)

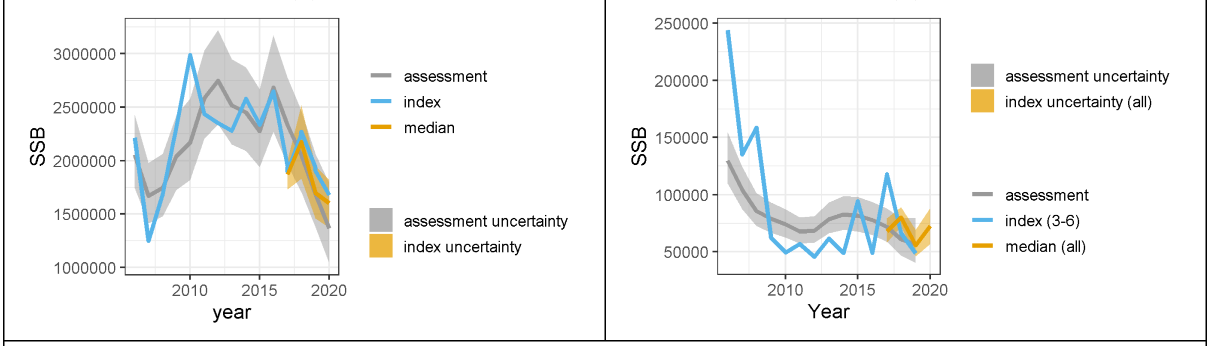


Figure 3-5: *comparison of SSB from the assessment with index sampling uncertainty derived from bootstrap computation. (a) NSAS. (b) WBSS. The index uncertainty bounds are the $25^{th}/75^{th}$ quantiles from each year's pool of independently derived SSB for each iteration.*

(a)	(b)

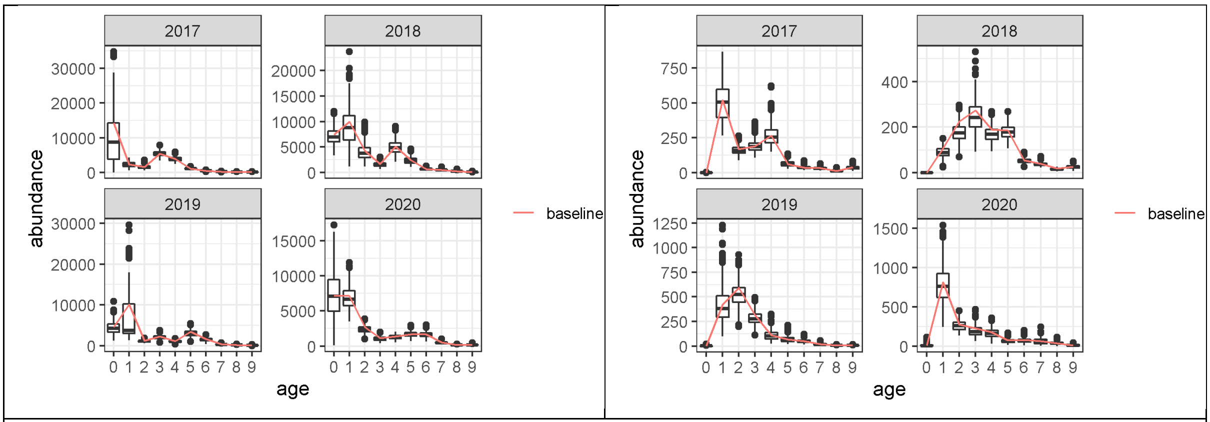


Figure 3-6: *base run abundance at age comparison between baseline and bootstrap computations. (a) NSAS. (b) WBSS.*

3.2 Sensitivity tests

3.2.1 Sensitivity to calibration error

Error in calibration gain can be introduced by either echosounder malfunctioning or measurement variability. The latter is caused by factors such as weather conditions (i.e. sea state), accuracy of sphere parameters or quality of calibration trial (e.g. number of target hits acquired). Unpredictable and hardly identifiable errors can notably come from slight malfunctioning of equipment or software/firmware bugs. Calibration errors from bugs can be difficult to spot and are often present at the release of new equipment. This has been a point of attention with the introduction of the EK80 system from SIMRAD which superseded the EK60 system, equipment of choice for the last nearly 2 decades in fisheries acoustics. Even though it has been shown that the two systems yield comparable results (Macaulay et al. 2018; Demer et al. 2017; ICES 2018a, 2017; Sakinan and Berges 2020), an underlying bug in the EK80 calibration tool was identified by (Sakinan et al. 2018)[9]. As a result of this bug, (Sakinan et al. 2018) observed discrepancies of up to 1.76 dB in $s_{\mathrm{a}\,corr}$. Considering the potential of such discrepancies or echosounder malfunctioning, it is important to screen for any calibration error prior to the start of survey, ideally during calibration trials. This can be achieved by:

- Keep track of abnormal rms error in calibration results.
- Keeping records of calibration gain and $\boldsymbol{s_{\mathrm{a}\,corr}}$ for the specific vessel, putting any new calibration results considering previous ones, tracking any suspicious changes.
- Monitoring impedance level of each transducer quadrant regularly using the BITE tool from the EK80 software.

Here, the sensitivity of WBSS/NSAS index calculations are tested against two scenarios: an offset in gain, like an error in calibration and an echosounder malfunctioning as observed in 2018 during the Dutch component of the HERAS survey.

<u>Calibration gain offset:</u>

In order to test the effect of bugs or calibration error, a fixed offset in calibration was introduced in each acoustic input files separately. Results are shown in Figure 3-7 (NSAS) and Figure 3-8 (WBSS) for each participating country from 2017 to 2020.

For NSAS, the effect of calibration error on SSB is greatest for the Scottish and Dutch surveys as they cover the bulk of the adult stock. For 2020, the effect is limited for the Dutch survey as the distribution of herring was observed to have shifted further north. Depending on the extend of calibration error, a change in SSB of up to 50% can be observed (2dB calibration error, 2020 Scottish survey). In that context, it is interesting to note that the large spike in 2010 (Figure 1-3(a)) is apparently attributed to the handling of calibration results in the postprocessing software and would need to be corrected when running the calculation method back in time. Errors in calibration on other participants would have a smaller impact on absolute SSB levels. However, the impact can be substantial for specific ages, e.g. 2019 NO survey having a 50% decrease with a 2 dB error. Beside a bias in absolute level, such errors in abundance at age can also lead to inconsistencies in the age structure because of the relative bias of the erroneous survey with the other surveys. Such an inconsistency in age structure can lead to issues when running the stock assessment model, especially if the calibration error is both variable in scale and persistent in time.

[9] https://www.echoview.com/products-services/news/important-information-for-simrad-ek80-software-users

For WBSS, error in both the Norwegian and Danish surveys are very influential in term of age structure and SSB level as both surveys observe a large part of the stock. Because WBSS relies on two individual surveys (as opposed to five for NSAS), error in calibration is potentially more influential.

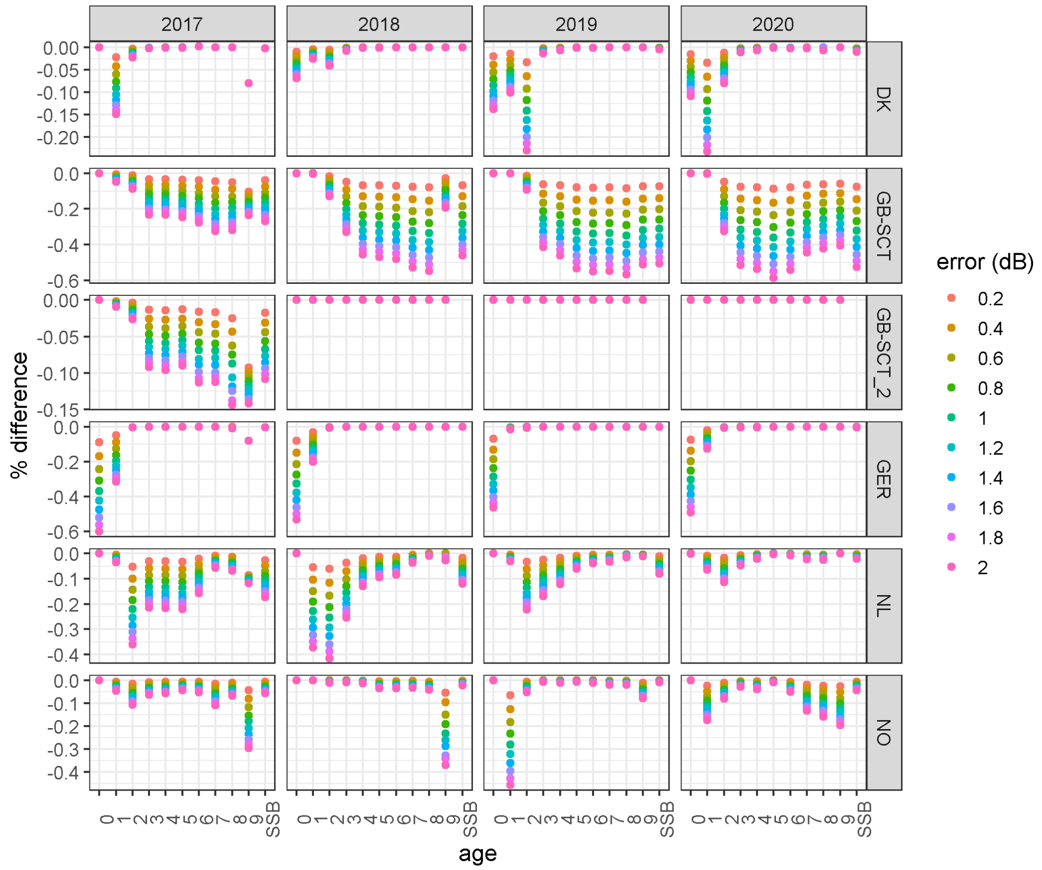


Figure 3-7: *NSAS % difference relative to base run abundance at age and SSB for a range of calibration errors by country and year of survey. For 2017, the Scottish part of the survey was covered through two distinct surveys, here identified as GB-SCT and GB-SCT_2. The % difference is relative to the baseline of the base run.*

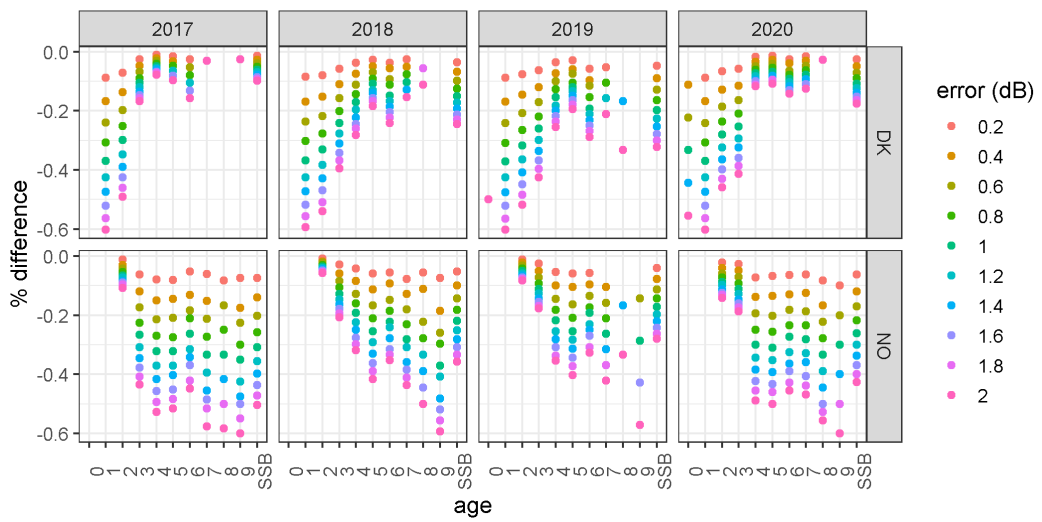


Figure 3-8: *WBSS % difference relative to base run abundance at age and SSB for a range of calibration errors by country and year of survey.*

SA error from Tridens II opportunistic echosounder malfunctioning:

Further to calibration gain offset, the echosounder malfunctioning revealed by the ping to ping analysis by (Sakinan and Berges 2020) can provide realistic insights on the impact of such an issue. Because the ping to ping data used here were collected onboard Tridens II, the vessel conducting the Dutch component of the HERAS survey, the test carried out here only considers alteration of NL data. Using the mapping of genuine SA values to erroneous SA values as presented in Figure 2-4, the SA values in the NL acoustic input files are altered. The NSAS/WBSS automatic routines are then applied, yielding alternative NSAS index (the Dutch component of the survey does not cover a stratum with WBSS/NSAS mixing). The comparison of the results with the base run is presented in Figure 3-9 for the strata of interest (101, 81 and 91) and for the overall NSAS index from 2017 to 2020. Whilst the effect for 2020 and 2019 are limited in term of SSB deviation (~1%), it is higher for 2018 (5%) and 2017 (6%). For 2018, the discrepancy is driven by differences in strata 91 whilst for 2017, it originates from strata 81. The direct effect of these discrepancies on the assessment is shown in Figure 3-10(a) for the model estimates of SSB and in Figure 3-10(b) for the catchability of the survey. Results are given in % deviation relative to the 2020 assessment (mostly using data up to 2019) for the cases of erroneous SA in 2017, 2018, 2019 and over the 2017-2019 period. From these plots, the most influential year is 2017 but erroneous SA over the 2017-2019 period yield the largest differences in both SSB and catchability. It is also important to note that to be able to run the assessment with erroneous SA over the 2017-2019 period, it was necessary to provide initial values to assessment model for convergence, suggesting greater instability with the introduction of these erroneous data.

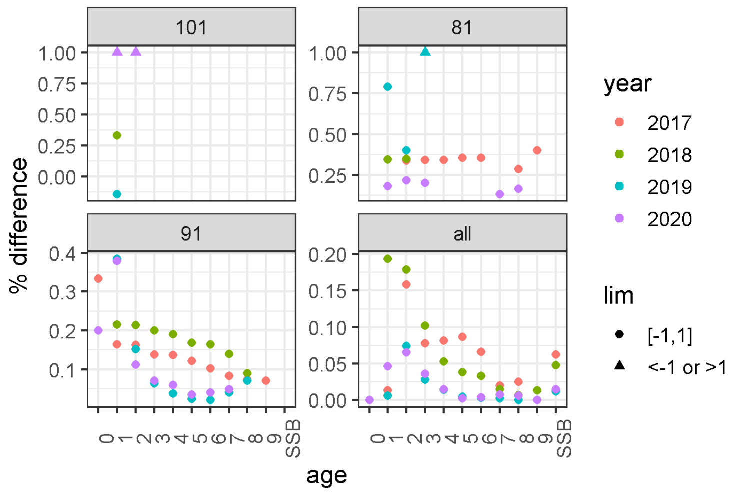


Figure 3-9: *error in NSAS abundance at age and SSB induced by malfunctioning of echosounder (SA error). Results are given as % difference relative to base run for each affected strata and combined strata. Triangle markers show values that are higher than 1 for display purposes.*

(a)	(b)

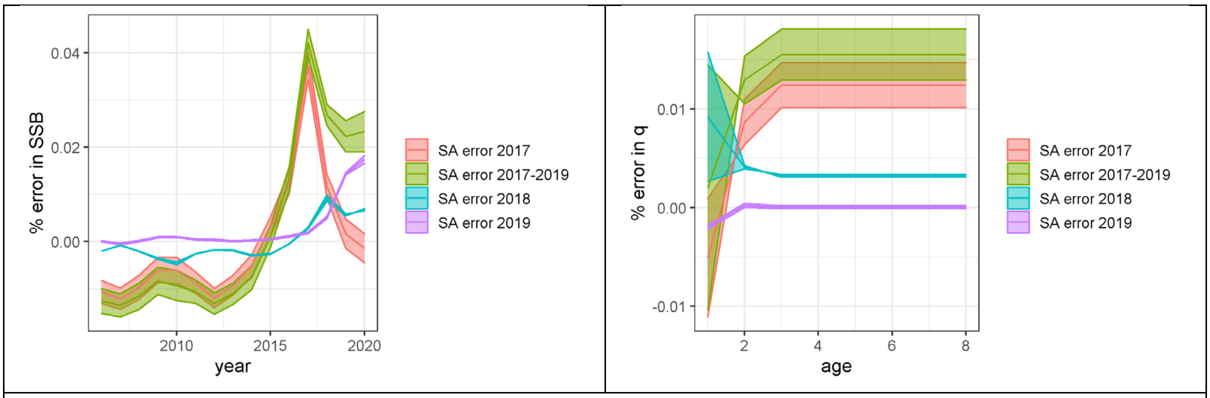


Figure 3-10: *error in NSAS assessment by malfunctioning of echosounder (SA error). (a) difference in SSB trajectory. (b) difference in catchability for the HERAS survey.*

3.2.2 Stock splitting

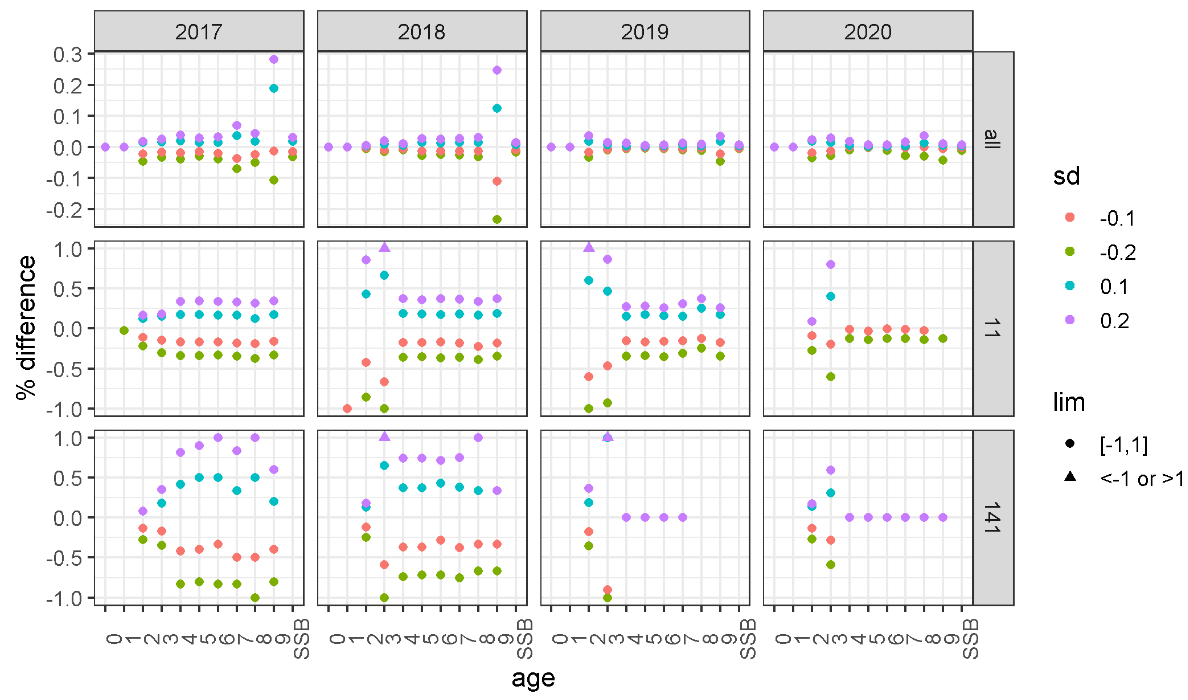
Stock splitting is an important aspect of the WBSS/NSAS calculation. As described in Section 2, this is handled differently between the Norwegian survey and the Danish survey. Using otolith microstructure and shape, the data issued by the Danish survey provide stock identification at individual fish level. However, this is currently not possible for the Norwegian survey and a split of the abundance is applied instead. This split is currently undertaken using a simple formulae (Equation (4)) based on vertebrae count (ICES 1994; Gröger and Gröhsler 2001). The use of such method is surrounded with uncertainties as the split proportion is highly variable in time (Figure 2-6). Moreover, newer more accurate methods are now available. In this section, three scenarios are tested:

- WBSS/NSAS split ratio with deviation in vertebrae counts.
- WBSS/NSAS split ratio inferred from otolith shape.
- Stock identification using genetics.

<u>Split ratio with offset in vertebrae count:</u>

The mean vertebrae count in each category (age, year, strata) is altered using a scalar β on the standard deviation, as described in Section 2.4.2. The range of values used is -0.2 to 0.2 in 0.1 increments. This introduces an error in split ratio between WBSS and NSAS (Figure 2-6). Results are shown in Figure 3-11(a) for NSAS and Figure 3-11(b) for WBSS. Expectedly, the impact is larger for WBSS with a change of ~20% with $\beta = \pm 0.2$. For WBSS, any change in split ratio has the potential to impact the age structure of the index significantly whilst discrepancies induced for NSAS are more marginal relative to the total abundance for this stock.

(a)



(b)

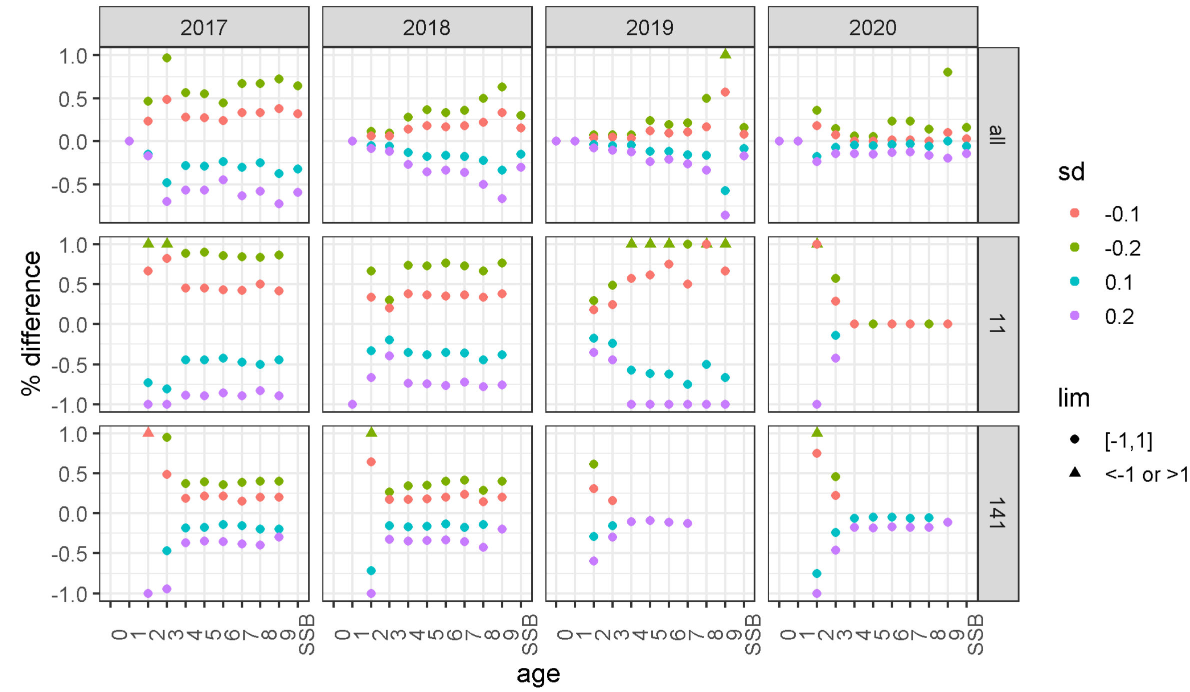
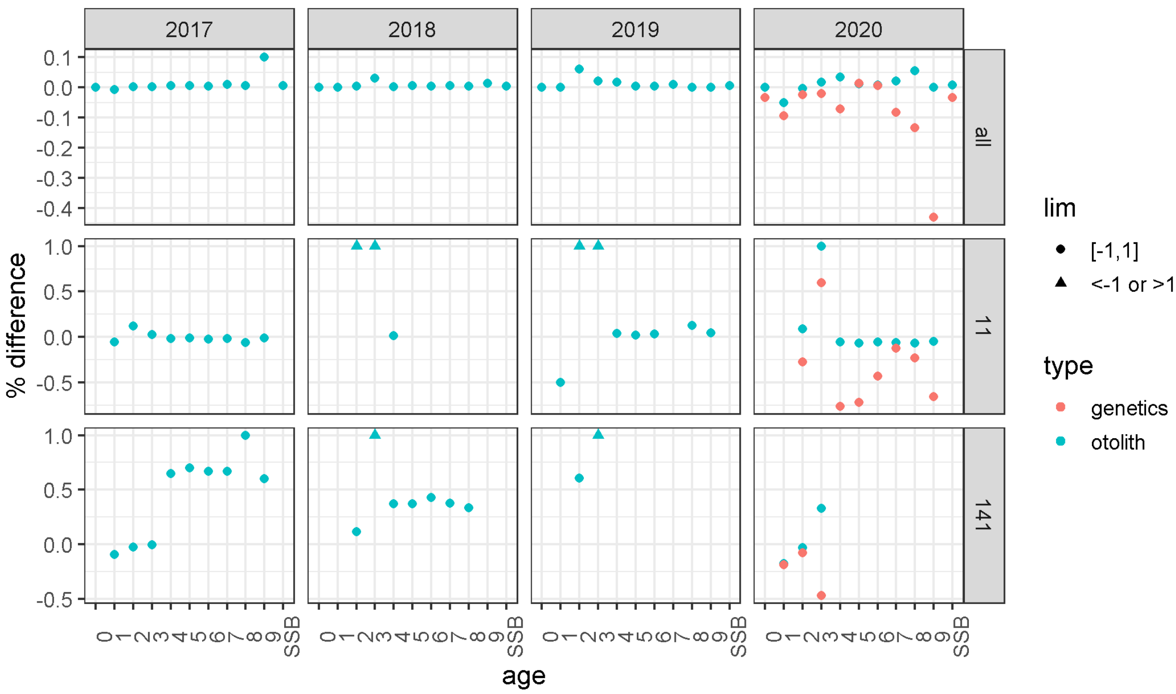


Figure 3-11: *% difference relative to base run for abundance at age and SSB with varying alternative ratios (offset in vertebrae count). (a) NSAS. (b) WBSS. Triangle markers show values that are higher than 1 for display purposes.*

Split based on otolith shape and genetics:

The use of vertebrae counts and derived split proportions has two main flaws: 1) it forces the use of two separate StoX projects (Figure 2-1), therefore complicating the calculations, 2) it is highly variable and sensitive. Whilst strata 11 and 141 only account for a small proportion of NSAS, a large proportion of the WBSS stock is observed in these strata each year. As shown in Figure 3-11(b), a small deviation in vertebrae counts can lead to discrepancies of ~20%. In that context it will be advantageous to change the NSAS/WBSS mixing calculation procedure in strata 11 and 141 using newer methods. In recent years, there have been the introduction of methods such as otolith shape recognition (Berg et al. 2019) or genetics (Berg et al. 2021). For the HERAS survey in strata 11 and 141, data from otolith shape recognition is available for the period 2014-2020 but genetics were only applied in 2020. Using these stock splitting methods, alternative computation of NSAS/WBSS indices are computed and compared to the base run. This is shown in Figure 3-12 for both stocks. It can be observed that the change induced by the use of otolith recognition for NSAS (Figure 3-12(a)) is marginal (<1% in SSB for all years,) whilst the use of genetics is more influential though limited (~5%). For WBSS (Figure 3-12(b)), the use of genetics data leads to large discrepancies in abundance at age (e.g. age 0, 7, 8 and 9+) but the overall change in SSB is limited (~10%). Using data from otolith shape recognition gives larger discrepancies with a decrease of SSB of ~25% in 2020.

(a)



(b)

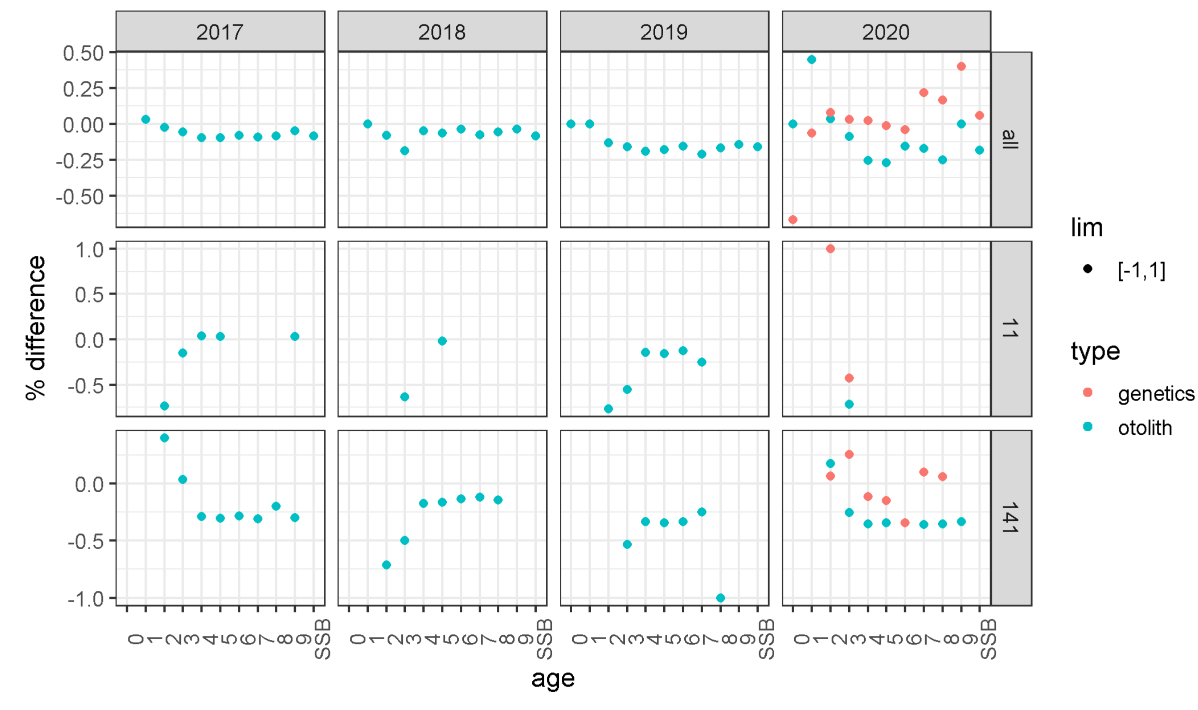


Figure 3-12: *% differences from baseline with genetics and otolith structure.*

One advantage in the use of genetics data is the allocation of stock ID in the biotic files. This lift the constraint of having two separate StoX projects (Figure 2-1) and allow one to compute the WBSS/NSAS indices using the same procedure in all strata. It also simplifies the use of the bootstrapping in StoX (used to compute uncertainty), alleviating the need to combine iterations from two separate bootstrapped projects. The comparison between baseline and bootstrap runs for both the base run and the run using genetic data is presented in Figure 3-13. Though trends are similar, some differences can be observed, e.g. at age 1 for both stocks.

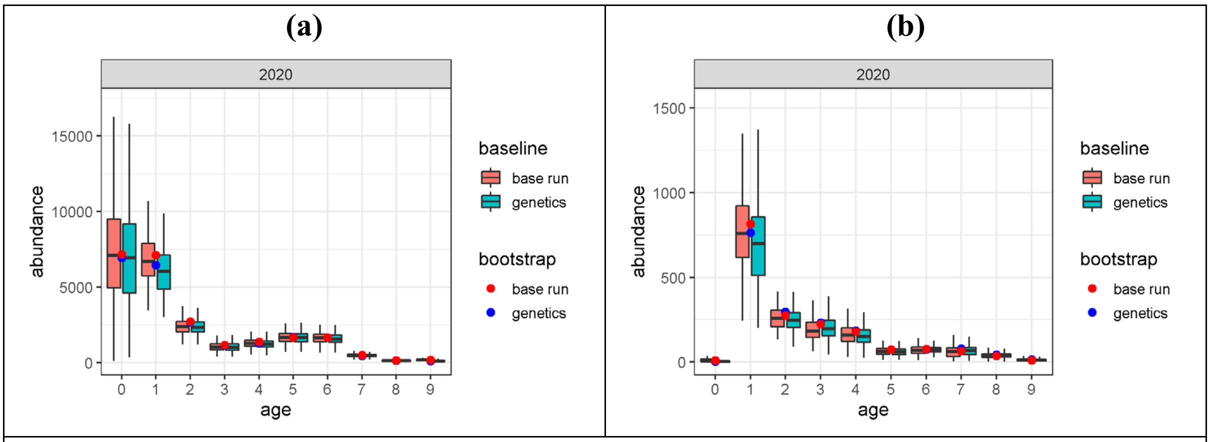


Figure 3-13: *comparison of baseline and bootstrap for the baseline run and the run using genetic data in strata 11 and 141. (a) NSAS. (b) WBSS.*

3.2.3 Change in strata definition

A set of tests were performed to compare the effect of the design of the original strata and the modified strata. Figure 3-14 shows both the original and modified strata together with their ID numbers. In terms of areal coverage, the largest change was in stratum 101, corresponding to the Moray Firth region. Originally this is the smallest stratum in the survey area and considered as an important nursery spot for herring, therefore characterized mainly by small sized early stages herring as well as sprat and other small fish. On the other hand, the neighbouring stratum in the east, stratum 91 captures the main adult herring aggregation areas in the survey region, generally containing nearly 50% of the total adult abundance. Together with stratum 111, they make up more than 90% of adult herring.

The extrapolation based on aggregated data set of maturities showed that the characteristics of stratum 101 extent a bit further to the East and North (Figure 2-8). As a result, in the hypothetical design, this stratum increased in size by 3-fold. Similarly, the inshore stratum 81, also increased in size by 32 percent while stratum 91 shrunk by 27 percent (Table 1).

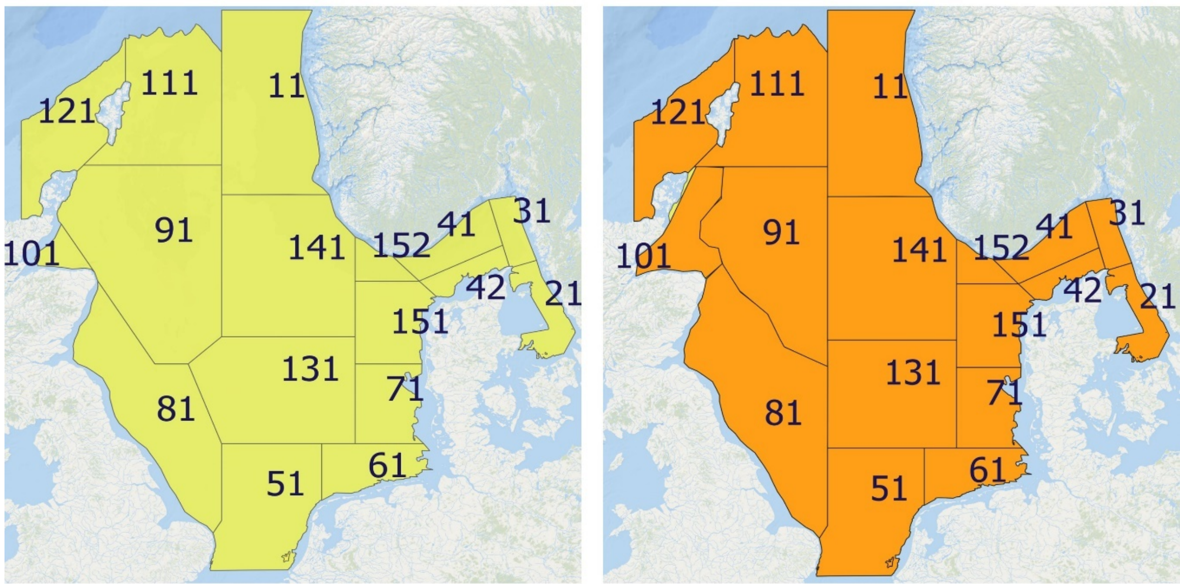


Figure 3-14: *Map showing the HERAS Strata Id numbers. The left panel shows the original strata and the right panel shows a hypothetical stratum where stratum 81,91,101 and 111 are modified based on the maturity percentages in the samples from 2016 to 2019.*

Table 1: *strata area in nautical square miles for both original and modified strata.*

Stratum ID	Original Area	Modified Area	Percentage changed
11	14174	14174	0.00%
21	2981	2950	0.00%
31	1809	1809	0.00%
41	3377	3377	0.00%
42	1742	1742	0.00%
51	14919	14835	0.00%
61	5321	5307	0.00%

71	5521	5521	0.00%
81	17593	23213	31.94%
91	24558	17872	-27.23%
101	1272	4829	279.55%
111	11550	11550	0.00%
121	6968	6968	0.00%
131	18375	16328	-11.14%
141	18569	18569	0.00%
151	6103	6103	0.00%
152	1596	1596	0.00%

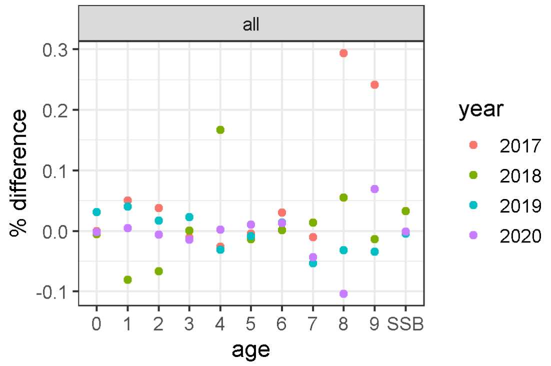
The effect of the strata modification is twofold: 1) it changes the total area of strata and 2) it changes allocation of acoustic transects and trawl samples. As an example, the results are shown in Table 2 for the most important adult herring strata, the 91 and 111 for the year 2018. A more complete table showing the rate of changes based on test scenarios are given on Table 3. In the test scenario where the haul allocation remained nearly the same while transects were split and reallocated, the total abundance of mature herring decreased only by 6 % in stratum 91 in 2018 despite a 27% reduction in the total area of this stratum. While the change in adult abundance being minor for this stratum, the total contribution of immature herring is largely decreased (by 38 %). This result indicates that overall, the new design achieves a better separation in the geographical distribution between mature and immature herring. For the stratum 111, the strata definition had not changed therefore no difference in the outputs were observed based on the stratum definition. Figure 3-15(a) shows the changes in abundance at age and SSB for the entire survey area for different years based on the changed strata definition. One can observe that the overall impact is marginal. As for the proportion of mature/immature individuals, this is shown in Figure 3-15(b). A small change is observable in 2018 but proportions overall remain like those from the base run.

Table 2: *Results of the tests of 4 different assumptions for the two most important strata (91 and 111) for the HERAS 2018 survey (the most affected by change in stratification).*

Results for Stratum 91				
Design	**Haul Allocation**	**IMM**	**MAT**	**TOTAL**
Original	Original	3666263	4165122	7849550
Modified	Original	2294023	3909307	6216679
	Change:	**-37%**	**-6%**	**-21%**
Modified	By Strata	2588629	3746531	6344355
	Change:	**-29%**	**-10%**	**-19%**
original	By Strata	3107573	4376850	7499487
	Change:	**15%**	**-5%**	**-4%**
Results for Stratum 111				
Design	**Haul Allocation**	**IMM**	**MAT**	**TOTAL**
Original	Original	178606	6311074	6546024

Modified	Original	176347	6313109	6546024
	Change:	**-0.1%**	**0%**	**0%**
Modified	By Strata	76917	6602956	6738959
	Change:	**-57%**	**5%**	**3%**
Original	By Strata	88172	6491553	6657163
	Change:	**-51%**	**-3%**	**-2%**

(a)



(b)

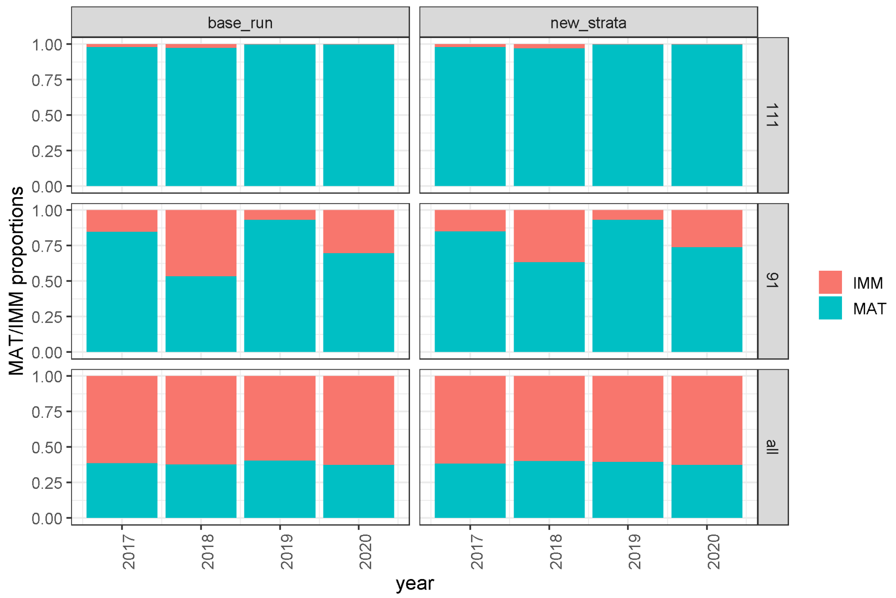


Figure 3-15: *Impact of change in strata definition with a stratum following maturity contour. (a) NSAS differences in abundance. (b) NSAS differences in mature/immature abundance at age proportions for strata 91 and 111 and overall results.*

3.2.4 Haul allocation

The changed method in haul allocation from manual assignment to stratum assignment did not have a large effect in the estimated mature herring numbers for stratum 91 and 111 where the changes were 5% and 3 % respectively for 2018 (Table 3). However, the effect was large for the estimated immature numbers. In stratum 91, the immature numbers increased by 15% and decreased by 51% in stratum 111. In 2018, immature numbers increased by 28.9% for this scenario. In 2019, this method of haul allocation resulted strikingly 316% and 140% increase in the immature numbers for the stratum 91 and 111. This discrepancy shows the importance of the expert interpretation of the assignments during the post-cruise meetings. Although it can be considered as subjectivity, this is mainly incorporation of the observations during the survey in terms of aggregation characteristics and their most likely demographic characteristics. Currently there is no straightforward method to systematically incorporate this knowledge into an automated procedure. The Figure 3-16 show the changes based on each age group and SSB for the entire survey area for different years based on the changed strata definition. The differences are very significant with for example a change in age 1 abundance in 2017 for NSAS of ~30% (Figure 3-16(a)). For WBSS (Figure 3-16(b)), the change is substantial, especially for 2019. Overall, these results illustrate the sensitivity of index calculation to haul allocation and the need for expert knowledge and human input.

Table 3: *Percent changes based on the original project in the results from strata 91 and 111.*

Year	Stratum	Design	Allocation	IMM	MAT	TOTAL
2017	91	Modified	Manual	-12%	-8%	-8%
2017	91	Modified	Stratum based	-28%	-8%	-11%
2017	91	Original	Stratum based	8%	-2%	-1%
2017	111	Modified	Manual	-1%	0%	0%
2017	111	Modified	Stratum based	-57%	5%	3%
2017	111	Original	Stratum based	-51%	3%	2%
2018	91	Modified	Manual	-37%	-6%	-21%
2018	91	Modified	Stratum based	-29%	-10%	-19%
2018	91	Original	Stratum based	-15%	5%	-4%
2018	111	Modified	Manual	-1%	0%	0%
2018	111	Modified	Stratum based	-57%	5%	3%
2018	111	Original	Stratum based	-51%	3%	2%
2019	91	Modified	Manual	-12%	-10%	-11%
2019	91	Modified	Stratum based	29%	-12%	-9%
2019	91	Original	Stratum based	316%	-11%	11%
2019	111	Modified	Manual	-7%	0%	0%
2019	111	Modified	Stratum based	140%	3%	3%
2019	111	Original	Stratum based	122%	3%	3%
2020	91	Modified	Manual	-20%	-1%	-7%
2020	91	Modified	Stratum based	53%	-12%	7%
2020	91	Original	Stratum based	9%	-33%	-21%

(a)	(b)

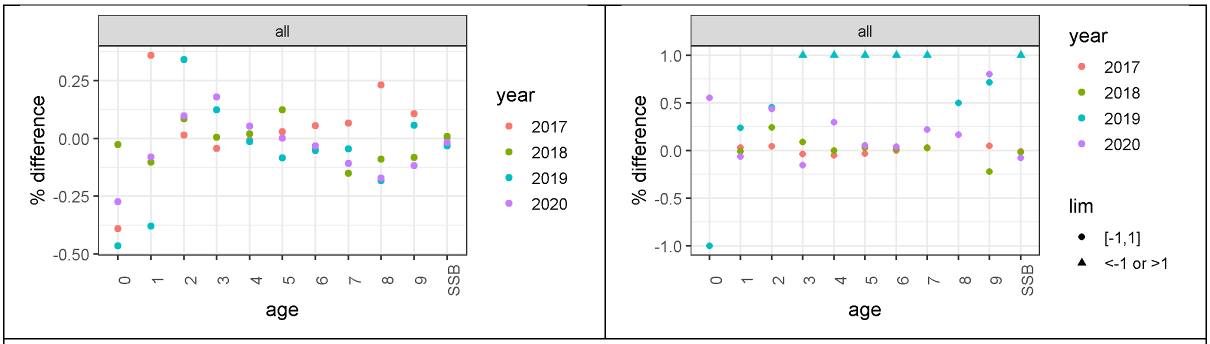


Figure 3-16: *difference in abundance with alternative haul allocation per strata. (a) NSAS. (b) WBSS.*

4 CONCLUSION AND IMPLICATIONS FOR THE INDICES

Automatic routines for the calculation of WBSS and NSAS indices were developed through this project. In the future, this will allow the process to be more traceable and will expand possibilities of index calculation (e.g. deriving uncertainties). Prior to the adoption of the automatic processing, it was important to perform thorough checks of results to ensure no discrepancies with the process currently in place. For the period 2018-2020, very good agreement was found between manually and automatically derived results with small discrepancies only accountable to bugs in the manual procedure or to difficult decision making. Large discrepancies were found for 2017, mostly due to differences in split proportions that was used to split the WBSS/NSAS stocks in strata 11 and 141. This should be investigated further. Overall, it is recommended to use the automatic procedure described here to compute the WBSS/NSAS indices as it offers advantages in terms of processing time, traceability and consistency. However, in the forthcoming years, the manual procedure should still be run alongside the automated routines to cross check results to prevent potential overlooked bugs and inconsistencies. Besides, it should be investigated if the processing of survey data prior to 2017 can be performed according to the latest processing workflow, alongside the processing of forthcoming HERAS survey data. With the automated procedures it will also likely be possible to implement better decision-making tools for the allocation of unallocated "super individuals" to category. The automated procedure will be able to handle more complicated decision making than the manual procedure could, for example performing a split out on proportions rather than the present procedure where all are assigned to where the majority lies for example. Once a large portion of the time series has been handled using the newly developed automatic routines, and agreements to the most correct allocation algorithms have been made, a revision of the HERAS index should be performed for both NSAS and WBSS.

The code developed through this project was stored on git repositories and is fully accessible. This includes a repository used for development[10] and repositories for the calculation of the 2019[11] and 2020[12] indices under the ICES TAF framework. The integration of calculation of acoustic survey indices for the HERAS index brings more transparency to the fisheries advice process of both NSAS and WBSS herring stocks. In addition, the R code developed for TAF can now easily be applied to other acoustic surveys.

A secondary aim for the current study was to run sensitivity tests programmatically. This was done for the following range of assumptions:

- Introduction of calibration errors
- Introduction of error in split in strata 11 and 141
- Testing of alternative WBSS/NSAS split in strata 11 and 141
- Testing of alternative strata definition
- Testing of haul allocation using objective assignment by stratum

Expectedly, error in calibration of echosounder was found to be influential for both NSAS and WBSS, though of varying importance depending on which survey component is affected. In that context, consistency in calibration gain for each participating vessel should undergo

[10] git@git.wur.nl:berge057/heras_index_kbwot.git

[11] git@github.com:ices-taf/2020_her.27.3a47d_acousticIndex.git

[12] git@github.com:ices-taf/2021_her.27.3a47d_acousticIndex.git

specific attention to identify and troubleshoot echosounder malfunctioning prior to surveying. Experience from an echosounder malfunctioning onboard Tridens II (Sakinan and Berges 2020) showed that effective ways to identify issues can consists in keeping an historical record of calibration gain and $s_{\mathrm{a}\ corr}$ and regularly monitoring the impedance levels of each transducer quadrants.

Currently, the stock splitting in strata 11 and 141 is handled externally to StoX using derived split proportions between NSAS and WBSS based on vertebrae counts. A sensitivity analysis showed the final WBSS indices to be sensitive to this quantity which has significant fluctuations since 2014. The introduction of genetics and otolith shape recognition data was tested and found to be influential, especially for WBSS though this influence is fluctuating the year of survey. Overall, the introduction of genetic data in forthcoming HERAS surveys in strata 11 and 141 will enable one to improve the accuracy and consistency of stock splitting.

The use of the new strata was effective in separating the immature and mature aggregations and thereby improving the homogeneity in the strata for improved precision. However, the results did not demonstrate significant differences in term of abundances and proportion mature for NSAS. This suggests that the stratification as currently used is suitable with a manual haul assignment based on expert judgment.

The use of allocation of all haul in each stratum is clearly influential, emphasizing the need for accurate haul allocation to transects. Manual assignment enables incorporation of the observations during the survey in terms of aggregation characteristics and their most likely demographic characteristics and therefore preferable to stratum-based assignment.

With automatic routines as developed in this project, there is potential for further testing of the WBSS/NSAS indices. Such work includes

- Testing the use of depth dependent TS
- Testing the use of error in biological samples
- Testing the effect of changes to biological sampling strategies
- Investigate impact on NSAS/WBSS assessments and advice

AKNOWLEDGEMENTS

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Annex 24: HERAS WD on stock splitting

Stock splitting to estimate individual survey estimates for herring stocks occurring during the HERAS survey – Genetics as new method

Florian Berg[1*], Gaute Seljestad[2], Dorte Bekkevold[3], Cecilie Kvamme[1], Geir Dahle[1], Kevin Glover[1,2]

[1]Institute of Marine Research (IMR), Bergen, Norway

[2]University of Bergen, Department of Biological Sciences, Bergen, Norway

[3]National Institute of Aquatic Resources, Technical University of Denmark, Silkeborg, Denmark

* Corresponding author: Mailing address: Post box 1870 Nordnes, 5817 Bergen, Norway; telephone: +47 94209887; e-mail: florian.berg@hi.no

Abstract

The North Sea Herring Acoustic Survey (HERAS) is the most important fisheries independent data input to the stock assessment of Atlantic herring (*Clupea harengus*) in the North Sea. However, during the survey time (summer), multiple herring stocks occur in the area and it is therefore necessary to obtain individual survey estimates for each stock. Currently, these stocks are identified using phenotypic characteristic, and only two stocks (NSAS = North Sea autumn spawning herring; WBSS = Western Baltic spring spawning herring) are considered. Our objective here was to apply a new diagnostic panel of SNPs to identify individual herring captured in HERAS to their original stock(s) of origin. We focused on the Norwegian part of the survey and genotyped 950 individuals. In total, 809 (85%) individuals were successfully assigned to their original stock of origin. Furthermore, our results demonstrated that the spatial distribution and phenotypic characteristics of stocks agreed with expectations. However, we also assigned some individuals as Norwegian spring spawning herring (NSS) in the survey area. This will have a bias on the survey estimates because NSS are usually bigger than other herring. This work demonstrates the benefit of using genetic methods to identify the different stock components in the region of study, in comparison with traditionally implemented phenotyping methods

Keywords: stock identification, genetics, stock discrimination, SNP, stock assessment

Introduction

Identification of stock(s) is crucial when conducting abundance estimates in regions where multiple populations and or stocks are known to overlap in time and space (Begg et al., 1999). An important input source for the stock assessment are scientific survey estimates. Many fish stocks were historically, and are still, identified using a priori assumptions that fish stocks rigidly follow artificial geographical boundaries instead of using biological and ecological characteristics. An example is Atlantic herring in the greater North Sea ecoregion which is annually surveyed in June-July through the "North Sea Herring Acoustic Survey" (HERAS). Currently, stocks are identified in this survey using differences in vertebral counts for the north-eastern part of the North Sea (covered by Norway), whereas otolith microstructure is used for south-eastern North Sea, Skagerrak and Kattegat (covered by Denmark and Germany; ICES, 2020). The disadvantage of both methods is that they can only account for two components (Gröger and Gröhsler, 2001; Clausen et al., 2007).

Recent genetic studies document strong genetic differences among the herring populations (biological units) occurring in the management areas surveyed by HERAS (Pettersson et al., 2019; Han et al., 2020). In general, HERAS provide estimates for two stocks (management units), namely North Sea autumn spawners (NSAS) and western Baltic spring spawners (WBSS) which are comprised by several populations. A potential advantage of genetic methods is that they have the ability to identify more than two stocks simultaneously, compared to the currently used methods to identify herring, and identify individuals with a high degree of precision. Our main objective was to apply genetic methods to discriminate and assign herring collected during the Norwegian part (north-eastern North Sea) of the HERAS to their stock of origin.

Materials and Methods

Fin clips of 950 Atlantic herring were collected during the Norwegian part of the HERAS in June-July 2020 for DNA extraction. After DNA extraction, the samples were genotyped for 99 diagnostic SNPs to identify population specific allele frequencies. After genotyping, outputs were quality controlled, resulting in the removal of 18 SNPs and 141 individuals. The remaining 81 SNPs were used to assign individuals to their origin using inference about allele frequencies from Han et al. (2020). As a genetic baseline for assignment of the herring captured in HERAS, we used herring from NSAS (including populations of both Downs herring, and typical autumn spawners collected near Shetland), WBSS (including several populations from Skagerrak, Kattegat and Rugen), and Norwegian spring spawners (NSS) as reference samples. For simplification we only assigned herring to stock complex (NSAS, WBSS or NSS) and not to their specific population. Genetic assignment using data from the 81 diagnostic SNPs was computed using GeneClass2 (Piry et al., 2004). We used a direct assignment following the Bayesian method of Rannala and Mountain (1997) using a threshold of 0.05. Further, we applied Monte-Carlo simulation studies (N = 1000, Type I error = 0.01) following the algorithm of Paetkau et al. (2004) to compute assignment probabilities. The simulation studies were used to verify the results of the direct assignments. In addition, we compared if the phenotypic characteristics of assigned individuals correspond with those expected from previous studies (Berg et al., 2017).

Results

A total of 809 out of 950 individuals (85%) were successfully assigned to stocks (Fig. 1). Only 5 individuals had a ranking score <90%, but the stock assignment based on the simulation studies corresponded with the direct comparison, therefore we accounted these as successfully assigned. As expected, both NSAS and WBSS herring occurred in the survey area. WBSS were present in the south-eastern part of the survey area and mainly as older fish. Additionally, NSS were present, mainly as 1-year old herring or 4+ group. 1-year olds were distributed throughout the entire survey area, while older herring were mainly present in the most northern region. Phenotypic characteristics, mainly number of vertebrae, corresponded with expected values (Fig. 2).

Discussion

Our study clearly demonstrates that the use of genetic tools to discriminate and assign individual herring to their original stock is successful. There are two beneficial outcomes when using genetic stock identification: (1) an individual genetic assignment of herring to their original stock will provide a more accurate and less uncertain survey estimate than currently used methods identifying two stocks only; (2) the possibility to identify more than two stocks will further reduce bias of the survey estimates. We highly recommend a change from discrimination methods currently used to genetic analysis considering all present stocks for splitting the survey estimates.

For the Norwegian part of the survey, stocks are currently split based on mean vertebral counts (VS) which only considers two stocks, NSAS and WBSS, whereas additional stocks are neglected (assumed non-existing in the area). However, we demonstrate the occurrence of at least one additional stock, NSS, in the survey are. When using VS to split stock, only proportions of two stocks are estimated, and no individual biological information can be used. NSS have a much higher average VS (57.2) than NSAS (56.5) and WBSS (55.8), thus the proportion of NSAS will be overestimated when NSS are present because the mean VS of the catch will be higher. The effects of overestimation will be more important when stock sizes differ markedly (in this case stock size of NSAS is more than 10 times larger than WBSS). Consequently, preliminary results from this work indicate that the survey estimate of NSAS may be changed by approximately 1%, whereas changes may be up to 35% for WBSS. The historical overestimation might not be critical if the proportion of NSS is constant over time. However, our data show that in the 2020 survey, most 4+ NSS belong to the 2016 year-class, which had high recruitment. Similarly, the 1-year-olds might also be an indication of a strong year class of NSS, or that significant abundance of spawning NSS occurred along the southern coast of Norway in spring 2019 resulting in juvenile herring utilizing this area as nursery ground.

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Fig. 1 Genetic assignment of individual herring to their original stock. Norwegian part of HERAS 2020 separated by age 1-3 and 4+. Numbers indicate the numbers of analysed herring.

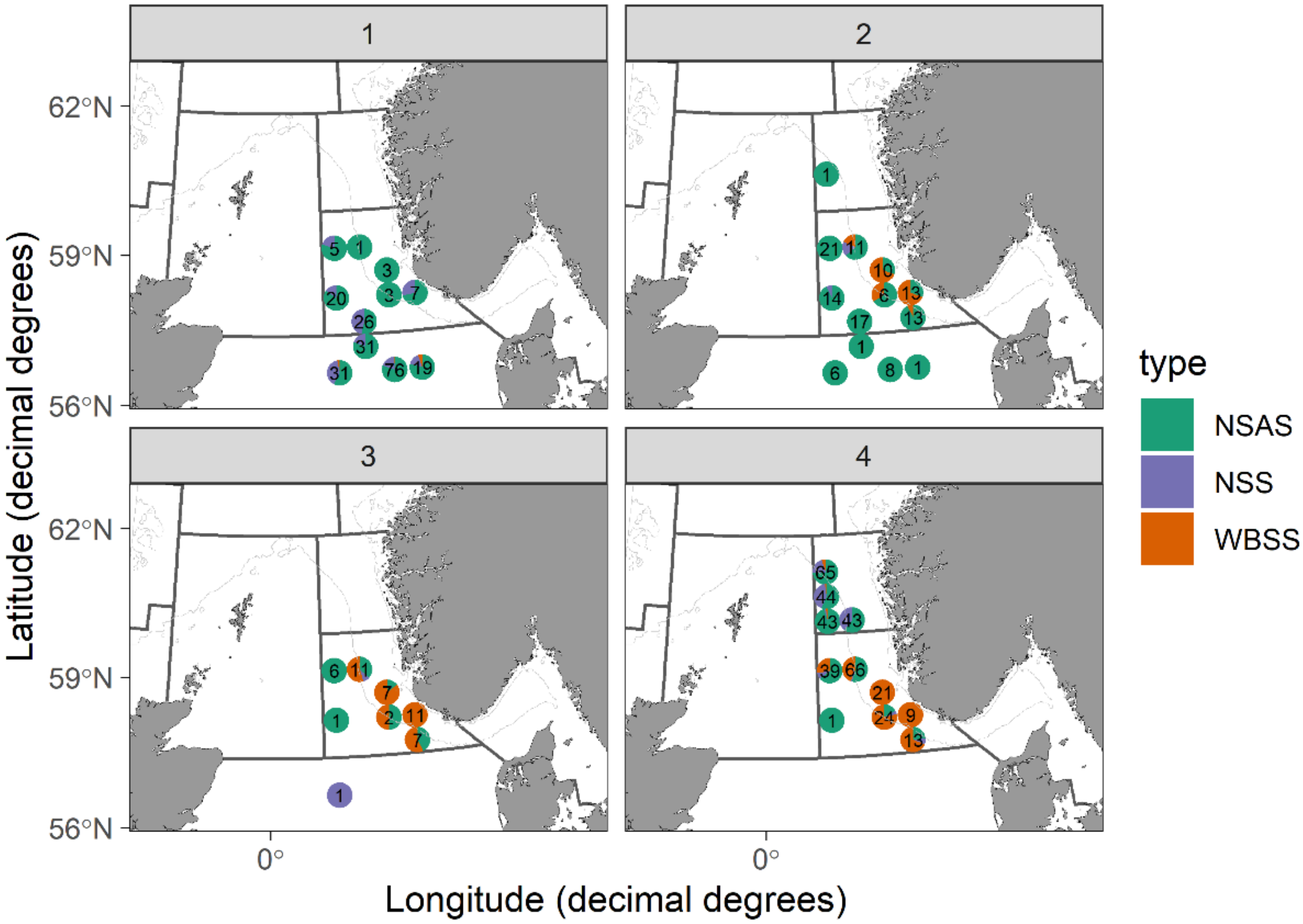
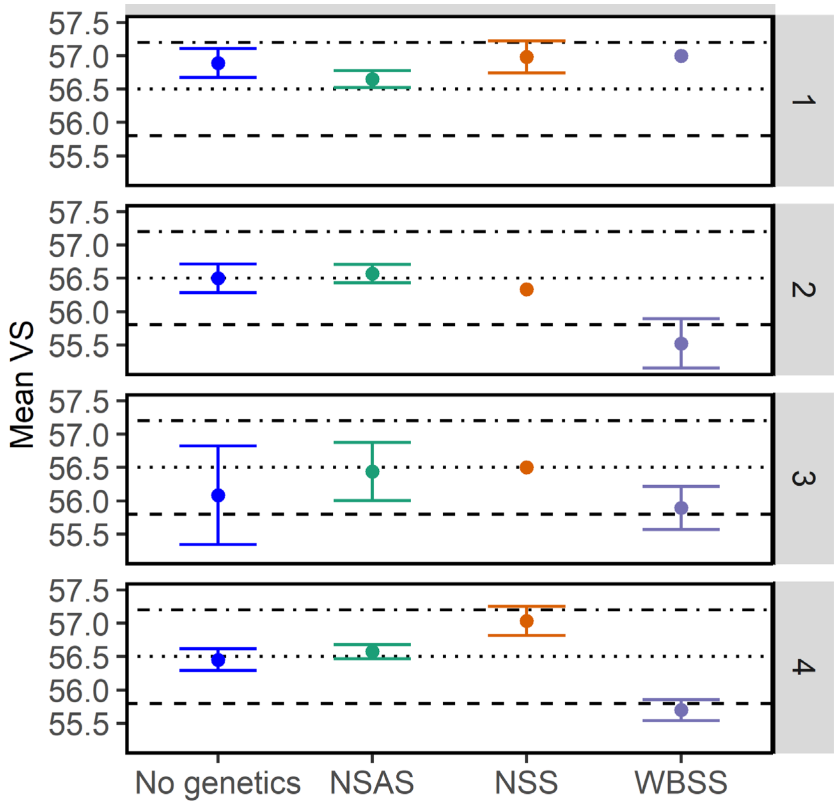


Fig. 2 Mean number of vertebrae (VS) for genetically assigned herring to their original stock for ages 1-3 and 4+. Lines represent expected mean VS for the three stocks: WBSS (dashed; 55.8), NSAS (dotted; 56.5), and NSS (dashed-dotted; 57.2).



Annex 25: Plan for sampling of ageing structures and genetics to be used in exchange and workshop on age reading of Norwegian spring spawning herring

It is important to collect both scales and otoliths from the same individual for comparison of age reading between structures. Individuals from which only one structure can be sampled will not be included in the exchange. It is also important to have samples from the entire age range and throughout the year. In addition, genetic samples should be collected to verify that pure Norwegian spring spawning herring are used, and to exclude potential stock mixing with e.g. Icelandic summer spawners, North Sea or Faroes autumn spawners.

Surveys

Norwegian acoustic survey on the spawning grounds

Use: Tuning index in the assessment (ages 3-12+)

Area: Spawning grounds along the Norwegian coast

Time: February

Country: Norway

Sampling: Collect otoliths and scales from the same 25 individuals from each trawl samples of NSSH. Otoliths should be stored dry while scales should be mounted.

International Ecosystem Survey in the Nordic Seas (IESNS)

Use: Tuning index in the assessment (3-12+)

Area: Feeding area in the Nordic Seas

Time: May-June

Countries: Denmark (EU), Faroe Islands, Iceland, Norway

Sampling:

Denmark: Coverage is overlapping with the Norwegian vessel. No need for samples for the exchange.

Faroe Islands: Collect otoliths, scales and genetics from the same 25 individuals from each trawl samples of NSSH. One otolith should be stored dry while the other otolith can be used for routine age reading. Scales should be mounted.

Iceland: Collect otoliths, scales and genetics from the same 25 individuals from each trawl samples of NSSH. One otolith should be stored dry while the other otolith can be used for routine age reading. Scales should be mounted.

Norway: Collect otoliths, scales and genetics from the same 25 individuals from each trawl samples of NSSH. One otolith should be stored dry while the other otolith can be used for routine age reading. Scales should be mounted.

International Ecosystem Summer Survey in the Nordic Seas (IESSNS)

Use: Not used in NSSH assessment, but potential candidate as tuning index (3-12+)

Area: Feeding area in the Nordic Seas, wider area for mackerel

Time: July-August

Countries: Denmark (EU), Faroe Islands, Greenland, Iceland, Norway

Sampling:

Denmark: Coverage is limited to the North Sea. No need for samples for the exchange.

Faroe Islands: Collect otoliths, scales and genetics from the same 25 individuals from each trawl samples of NSSH. One otolith should be stored dry while the other otolith can be used for routine age reading. Scales should be mounted.

Greenland: Coverage is limited to Irminger Sea. No need for samples for the exchange.

Iceland: Collect otoliths, scales and genetics from the same 25 individuals from each trawl samples of NSSH. One otolith should be stored dry while the other otolith can be used for routine age reading. Scales should be mounted.

Norway: Collect otoliths, scales and genetics from the same 25 individuals from each trawl samples of NSSH. One otolith should be stored dry while the other otolith can be used for routine age reading. Scales should be mounted.

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