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Working Group on International Pelagic Surveys (WGIPS)

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ICES CIEM International Council for the Exploration of the Sea Conseil International pour l'Exploration de la Mer

Contents

i Executive summary

The core objectives of the Working Group on International Pelagic Surveys (WGIPS) are to combine and review the 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 the upcoming 2022 surveys. To support this work, the group is drafting an update to the Series of ICES Survey Protocols 9 - Manual for International Pelagic Surveys (SISP9-IPS).

This past year, WGIPS held a number of focal sessions including: (1) a session for presenting auxiliary monitoring of ecosystem components beyond the standard fishery survey results for the target species. This session has been held annually since 2019, with presentations this year on tests with an in-trawl stereo camera system during part of the 2021 International Ecosystem Summer Survey in the Nordic Seas (IESSNS), (2) a session on the future and development of databases used to store data from surveys in WGIPS (ICES Acoustic Database and the “PGNAPES” database), developments and use of the acoustic survey analysis software “StoX” and progress on adopting the ICES Transparent Assessment Framework (TAF) for archiving and documenting acoustic index calculations, and (3) a session on biological sampling strategies in WGIPS surveys. The group is documenting the sampling strategies used in all WGIPS surveys (on request from ICES Working group on Acoustic Trawl Data Portal Governance (WGAcousticGov) and is planning a workshop on sampling strategies in the ICES Coordinated Acoustic Survey in the Skagerrak and Kattegat, the North Sea, West of Scotland and the Malin Shelf area (HERAS).

The group also reviewed progress on mesopelagic sampling with an update from the European Union Horizon 2020-programme on Ecologically and Economically Sustainable Mesopelagic Fisheries (MEESO), presentations on new net developments for the International Blue Whiting Spawning Survey (IBWSS) and experiences with using a Methot Isaac Kidd (MIK) net to target scattering layers at 150m. Lastly, WGIPS reviewed progress in using genetic stock separation methods for splitting survey results to component herring stocks and discussed ways forward to continue to develop these methods whilst maintaining the integrity of the survey indices. WGIPS encourages continued close collaboration of the survey group, assessment groups and institutes carrying out the genetic analysis work.

ii Expert group information

Expert group name	**Working group on International Pelagic Surveys (WGIPS)**
Expert group cycle	**Multiannual fixed term**
Year cycle started	**2022**
Reporting year in cycle	**1/3**
Chair(s)	**Susan Mærsk Lusseau, Denmark**

Meeting venue(s) and dates	**WGIPS meeting. 24 – 28 January 2022, Remote meeting via WebEx. 33 participants.**

1 Terms of Reference

ToR	Description	Background	Science plan codes	Duration	Expected Deliverables
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.	a) Advisory Requirements b) Requirements from other EGs	3.2	years 1–3	Survey reports containing indices of stock biomass and abundance at age, spatial distributions of stocks and hydrographic conditions. Survey summary tables delivered to: HAWG, WGWIDE
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)	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs d) follow-up of WKPilot NS-FIRMOG	3.1	years 1–3	Cruise plans for international and individual surveys.
c	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	Periodically review and update the WGIPS acoustic survey manual to address and maintain monitoring requirements for	a) Science requirements b) Advisory requirements	3.1	years 1–3	Updated WGIPS survey manual in TIMES format.

	pelagic ecosystem surveys				
e	Review the work, and report of workshops organised by WGIPS and develop formal ICES recommendations. This should include TIMES manual updates and adopting changes to survey coordination where deemed appropriate.	a) Science requirements b) Advisory requirements	3.1	years 1–3	Integrate results from WGIPS workshops into survey protocols where possible. Develop formal recommendations to other groups and agree answers to recommendations from other groups.
f	Review and evaluate survey designs across all WGIPS coordinated surveys to ensure the integrity of survey deliverables.	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.
g	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	year 1-3	Documented standardised scrutinisation recommendations; Update of survey manual to address and maintain monitoring requirements for pelagic ecosystem surveys.
h	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. Make time-series data available for MEESO.
i	Assess developing pelagic ecosystem surveying technology (e.g. optical technology, multibeam 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	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.

	support the development of tools to improve the accuracy and precision of survey estimates.				
j	Continuted development of trawl sampling and hull mounted acoustic data collection during IBWSS surveys to support the routine reporting of mesopelagic fish abundance and distribution within established limitations. Leverage latest research from ongoing research projects (MEESO & SUMMMER) to improve data quality and reporting capacity	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs	3.1, 3.4,	years 1–3	Ultimate goal is the routine reporting of mesopelagic fish abundance and distribution as part of the IBWSS survey and uptake by other candidate surveys within WGIPS. Upload of bioloigcal and acoustic data to the ICES trawl acoustic database. Provision of data to interested WGs and research projects.

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 and coordinate planning and discuss designs for surveys taking place in Year 1. Review the WGIPS acoustic manual in the TIMES format. Session 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 DB and the PGNAPES database), use of StoX and progress on TAF. Session on mesopelagic sampling: Review and feedback of sampling carried out in 2021. Update on reports from MEESO and SUMMER projects and workshops. Session on stock discrimination projects and the consequences for biological sampling on WGIPS surveys. Delivery of a WD on biological sampling strategies on HERAS surveys over time. Session on biological sampling strategies in WGIPS surveys Conduct a workshop on biological sampling strategies in WGIPS surveys.
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 and coordinate planning and discuss designs for surveys taking place in Year 2. Review the WGIPS acoustic manual in the TIMES format, prepare for submitting for external review. Session 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), use of StoX and progress on TAF. Session on mesopelagic sampling: Review and feedback progress of trawl sampling and acoustic sampling methods used. Session on stock discrimination and the consequences for biological sampling on WGIPS surveys. Session on biological sampling strategies in WGIPS surveys
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 and coordinate planning and discuss designs for surveys taking place in Year 3. Review the WGIPS acoustic manual in the TIMES format, submit for publishing. Session 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), use of StoX and progress on TAF. Session on mesopelagic sampling. Update the group on progress of sampling and reporting of mesopelagic fish resources. Session on stock discrimination and the consequences for biological sampling on WGIPS surveys.

Session on biological sampling strategies in WGIPS surveys

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 and DSTSG, especially relevant links to WGAcousticGov, WGACEGG, WGALES, WGBIFS, WGFAST, WGFTFB, WGISDAA, WGISUR, WGMEGS, WGTC, WGINOR, WGINOSE, WGIAB, WKEVAL, WKMSMAC2, WKSCRUT, WKSUREQ, WGS2D, WKPilot NS-FIRMOG
Linkages to other organizations	

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:

1. 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)
2. Western Baltic spring-spawning herring numbers, biomass, mean weight, and length-at-age, from the HERAS
3. West of Scotland autumn spawning herring numbers, biomass, maturity proportion, mean weight, and length-at-age, from the HERAS
4. Malin Shelf herring (areas 6.a/7b,c) numbers, biomass, maturity proportion, mean weight, and length-at-age, from the HERAS
5. Sprat in the North Sea (Subarea 4) numbers, biomass, mean weight, and length-at-age, from the HERAS
6. Sprat in Division 3.a numbers, biomass, mean weight, and length-at-age, from the HERAS
7. Norwegian spring-spawning herring numbers, biomass, mean weight, and length-at-age, from the International Ecosystem Survey in the Nordic Sea (IESNS)
8. Blue whiting numbers, biomass, mean weight, and length-at-age, from the IESNS
9. Mackerel numbers, biomass, mean weight, and length-at-age, from the International Ecosystem Summer Survey in the Nordic Sea (IESSNS)
10. Norwegian spring-spawning herring numbers, biomass, mean weight, and length-at-age, from the IESSNS
11. Blue Whiting numbers, biomass, maturity proportion, mean weight, and length-at-age, from the ICES International Blue Whiting Spawning stock Survey (IBWSS)
12. 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).
13. Irish Sea (area 7.a N), Industry spawning survey of herring biomass and distribution (ISSS)
14. 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)
15. Boarfish numbers, biomass, maturity proportion, mean weight, and length-at-age, from the Western European Shelf Pelagic Acoustic Survey (WESPAS)
16. Celtic Sea herring numbers, biomass, maturity proportion, mean weight, and length-at-age, from the Celtic Sea herring Acoustic Survey (CSHAS)
17. 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
18. Blue whiting numbers, biomass, maturity proportion, mean weight, and length-at-age, from PELACUS

Other ecosystem survey-derived operational products:

19. Horse Mackerel numbers, biomass, maturity proportion, mean weight, and length-at-age, from WESPAS
20. Zooplankton distribution based on dry weight samples from the IESNS, IESSNS and WESPAS surveys.
21. Recorded observations of marine mammals during the IESSNS, CSHAS and WESPAS.
22. Recorded observations of seabird abundance and distribution during CSHAS, IBWSS and WESPAS surveys

Other outcomes and achievements:

23. Comments and input to development of the ICES Acoustic database;
24. Overview of new and currently applied auxiliary pelagic ecosystem sampling technologies.
25. Collection of genetic samples on board HERAS/WESPAS surveys for splitting of herring stocks
26. 2022 survey plans (see Annex 16 for 2022 survey plans);
27. Contributions to ICES Annual Science Conference
28. 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
29. 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

Coordinated collection of scale and otolith material for Norwegian Spring spawning herring age reading workshop

5 Progress Report on ToRs and work plan

ToR a:

Results from the coordinated multinational ecosystem surveys conducted in 2021 were examined and combined during four post cruise meetings prior to the WGIPS meeting. Survey execution and final results from all surveys were presented at the WGIPS meeting for review. The combined results provided indices of abundance and distribution for stocks of herring, sprat, mackerel, boarfish, and blue whiting in Northeast Atlantic waters. Survey reports with full details of each survey and resulting indices are in Annex 3 to 13.

ToR b:

Timing, planning, and methods applied for coordinated multinational surveys (IBWSS, IESNS, IESSNS, HERAS) and individual surveys (CSHAS, BFAS, ISAS, ISSS, PELTIC, GERAS and 6a Industry surveys) were presented, discussed and agreed for the 2022 survey year.

This year new participation of a MSS (UK) chartered vessel to IBWSS and a CEFAS (UK) chartered vessel to IESNS was discussed in terms of how to best add these contributions to existing coverage. Survey plans for 2022 are in Annex 16.

ToR c:

Nearly all WGIPS coordinated and individual acoustic surveys used the ICES Acoustic Trawl survey database (ICES DB) e.g. HERAS, CSHAS, WESPAS, PELTIC, IBWSS, IESNS, IESSNS and 6.aN Industry survey (6.aSPAWN) for 2021 survey data (Table 1). Under this ToR, the group will keep following the progress for the rest of the surveys coordinated by WGIPS (GERAS, ISAS and ISSS).

Some surveys have also started to upload data collected prior to adopting the ICES Database. This will be a longer process that WGIPS will continue to encourage progress on where possible.

The group actively engage with the ICES datacentre on issues relating to the ICES DB through the governance group, WGAcousticGOV, and the developers of the analysis software StoX to ensure compatibility between the data collection at sea and storage in national institutes, the ICES database, the analysis software and the end users of indices (HAWG and WGWIDE) resulting from the surveys.

In 2022 WGAcousticGOV initiated a survey on biological sampling strategies in the surveys to ensure the ICES DB design is compatible with the various sampling strategies employed across all surveys in ICES survey coordination groups (Annex 17). WGIPS will collate and provide this information to WGAcousticGOV.

Although it has now been demonstrated that all surveys can use ICES DB as repository for data, the PGNAPES database still needs to be maintained. Firstly, because it is still being used for producing hydrography and mesozooplakton figures for the survey reports during the post-cruise meetings, which take place within a couple of weeks after the surveys; this time limitation prohibits calibrating hydrography data, which is needed prior to upload to the ICES hydrography database. Secondly, it is not realistic that the full time-series of biology and acoustic data will be uploaded to the ICES acoustic database in the near future, and therefore there is a wish to keep the full time series in PGNAPES. To avoid two separate data upload streams for the surveys using PGNAPES, it was agreed that an export from ICES db to PGNAPES format would be accomodated and this will be discussed in the governance group (WGAcousticGov).

The group is also by now predominantly using StoX to generate results from the surveys (Table 1). A new generation of StoX (version 3.0.0 onwards) was launced in summer 2021 containing many improvements and new functionalities, including more flexibility in input data formats.

There is a wish to get some common automated output tables and figures from StoX, which are used during the post-cruise meetings; some for preparatory work – other in the survey reports. WGAcousticGOV suggested to coordinate this effort across survey coordination groups (Annex 18). The survey groups are encouraged to identify inspirational scripts and figures before the 2023 meetings.

Finally, the group discussed the need for data version control (in cases where cruise data are re-submitted after index calculation for example). The ICES TAF-framework is suitable for this purpose as the TAF-repositories can store large files (>1 Gb), and therefore this framework should be suitable to store the large WGIPS-StoX-projects. Some surveys have started to move index calculation onto the TAF-framework and WGIPS will continue to monitor and encourage progress on this.

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

Survey	Database (ICES or other)	Abundance estimation software (StoX or other)
Herring Acoustic Survey (HERAS)	ICES DB	StoX
6.a/7.b/c Industry herring acoustic survey(6.aSPAWN)	ICES DB	StoX
GERAS	National Access database/Preparation underway for uploading files to ICES DB	GERIBAS II
ISSS	National SQL database//Preparation underway for uploading files to ICES DB	National R-scripts
ISAS	National SQL database/ /Preparation underway for uploading files to ICES DB	National R-scripts
WESPAS	ICES DB	StoX
PELTIC	ICES DB	EchoR, StoX
IBWSS	PGNAPES & ICES DB	StoX
IESSNS	PGNAPES & ICES DB	StoX
IESNS	PGNAPES & ICES DB	StoX
CSHAS	ICES DB	StoX

ToR d:

Progress was made on updating the WGIPS survey manual (SISP 9) to the TIMES format. Agreement was reached on a format for the new manual and tasks assigned for the next step of updating the old manual to the new format. The group prepared a resolution to update the manual to be submitted this year and agreed to work inter-sessionally to progress this work.

ToR e

The group responded to recommendations from WGBIFS and WGMEGS (Responses have been uploaded to the recommendations database.)

Contact was facilitated between WGMEGS and survey coordinators to further investigate possibilities for and coordinate the requested sampling of ovaries from mackerel from the IESNS, and IBWSS and horse mackerel from the WESPAS during the 2022 surveys.

WGIPS received a very detailed and useful response from WGFAST on the question of acoustic shadowing (Annex 19). The response will help identify when acoustic shadowing is potentially affecting the survey results and suggests means of correcting any bias. This should be very helpful particularly for those WGIPS surveys carried out on, at times, very dense spawning aggregations (e.g. ISSS, 6aSPAWN).

ToR f:

WGIPS 2022 held a session on biological sampling strategies in WGIPS surveys with focus on the HERAS survey. The group has committed in 2021 to delivering a working document to HAWG which has been delayed due to COVID-19. This should be delivered in 2023. The group also discussed the need for a workshop on biological sampling strategies in WGIPS surveys. It was decided to limit the scope initially to one survey and as the HERAS survey is the least harmonised of the coordinated surveys it was decided to plan a workshop specifically focussing on biological sampling strategies on the HERAS survey and consequences for results.

Issues of mixing of herring stocks is a feature in all the surveys of herring under the WGIPS umbrella and the group continues to monitor and discuss progress in the development of the genetic methods and their use to separate herring stocks in the surveys. This year presentations were given on the progress made in the HERAS/MSHAS survey on using genetics for splitting herring stocks as well as preliminary genetic results from studies of herring around The Shetland Isles. In several areas of the HERAS survey the genetics methods have now been advanced enough to be used for splitting the survey estimates into component genetic stocks. This year the splitting of Malin Shelf herring stock components (6aS from 6aN) in western areas and the North Sea autumn spawners (NSAS) from Western Baltic Spring Spawners (WBSS) in the eastern areas were carried out using the genetic method, where these stocks traditionally have been discriminated using other methods. The splitting method of herring in the Malin Shelf area was evaluated in a benchmark process in February 2022 (WKNSCS 2022) and is described in detail in Annex 20. WGIPS is collaborating closely with the assessment working groups to ensure the integrity of assessment indices be maintained in these processes. WGIPS will continue to focus on this topic and work to advance the use of stock discrimination methods across its surveys where possible.

ToR g:

The group continues to encourage that scrutinisation is compared and discussed within and between surveys. This year no formal workshops have been held, but several of the post cruise meetings dedicated time to compare and align scrutiny of the 2021 survey between participating nations. In the agreed format for the new survey manual there will be a dedicated chapter for describing the scrutiny protocol for each survey.

ToR h:

As WGS2D has been dissolved this collaboration has now been terminated. WGIPS is looking at maintaining the blue whiting forecast models developed in this collaboration within WGIPS.

Acoustic data for MEESO is being uploaded to the ICES database under an independent survey tag (MEESO).

In 2022 WGIPS agreed to collaborate with WGSPF to utilize HERAS time-series data to look at distribution of small pelagic fish in the North Sea in relation to hydrographic parameters.

ToR i:

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 (dry weight), in-trawl optics and broadband acoustic and sonar data. Annually, the group report these additional data sources within the Ecosystem index overview table (Annex 15). 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 these 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.

Under this ToR the group also holds a session at each meeting dedicated to presenting new methods and tools being developed to survey wider ecosystem components or that aims to improve existing methods.

During the 2022 session tests with an in-trawl stereo camera system during part of the 2021 IESSNS were presented to the group (Annex 21). IMR (Norway) tested the Deep Vision in-trawl stereo camera system during part of the 2021 IESSNS. The system was tested both in five surface trawl hauls, with comparative hauls without Deep Vision at the same survey stations, and in five deep hauls without comparative hauls. Results indicated the camera system did not affect the trawl's geometry and there are indications that catch rates were in fact higher with the Deep Vision system in the trawl (result just statistically significant). A RetinaNet neural network did a good job of differentiating between Atlantic mackerel; Atlantic herring and blue whiting, with good correspondence to species percentages measured from the catches. Absolute counts are less accurate due to double-counting the same individual in consecutive images and difficulty detecting all individuals when the density of fish passing the camera was extremely high. Counts can likely be improved by training the network with more high-density images. Work to automate measurements of length from images is in very early stages. The Deep Vision system will not be used during the 2022 IESSNS, but will be implemented during the Norwegian portion of the 2022 IESNS.

ToR j:

During the IBWSS 2021 first deployment of macro-zooplankton net by IE aboard RV *Celtic Explorer* returned mixed catches of small Mueller's pearlsides (*Maurolicus muelleri*) and zooplankton when targeting upper backscattering layer. During the WESPAS summer shelf sea survey, samples of larger pearlsides were observed. There is an on-going debate of the trade-offs between graded and non-graded trawls among the mesopelagic community reflecting the trade-off in fishing speed and getting a representative sample, respectively. For IBWSS 2022, IE partners will deploy a customised fine meshed graded mid-water trawl designed to target mesopelagic fish. This net will include pocket nets to monitor escapement in the larger forward meshes of the trawl.

NL have deployed a MIK net aboard the *RV Tridens* during IBWSS 2021 which returned catches of mostly Chaetognaths, Euphasiids, Hydroids, small pearlsides and pteropods. Using a 500 μm mesh while towing at 1.5 knots has likely caused a "ballooning effect" and it was recommended to switch to 1.6 cm for future surveys.

When scrutinising IE IBWSS acoustic data for mesopelagic species it was found that dB differencing of 18 kHz and 38 kHz frequencies can resolve deeper layers thought to largely be comprised of non-swimbladdered fish and crustaceans. Resolving the upper scattering layers thought to be largely comprised of swimbladdered fish and zooplankton remains more of a challenge and NL and IE partners agreed to work together to use images and samples collected during IBWSS 2021 to come up with backscatter models of zooplankton groups and pearlsides to help resolve these layers.

Initial results of eDNA sampling carried out by IE showed contamination issues as well as issues with matching reads with publicly available sequences. The focus for any future work will be to minimize contamination and expand collections of mesopelagic library specimens. At present eDNA sampling can at best support insights into biodiversity and presence/absence of key species.

6 Recommendations issued to WGIPS from other Working Groups

Recommendations issued to WGIPS from other working groups in 2021. Answers have been uploaded to the ICES recommendations database.

Recommendation ID 60 From WGBIFS
WGBIFS recommends WGIPS to discuss whether there would be interest within the group to have a standardized trawl gear for surveys targeting herring and sprat.
ID 60 Reply: Survey sampling trawls are a key component of acoustic trawl reporting, providing biological samples used to determine age stratified abundance. Discussions within the group in response to this request included; consistency in the existing time series using the existing survey gear, gear design tailored to target species (multiple spp in some ecosystem surveys), geographical area as well as scrutiny and species partition methods used. In summary, development of new survey trawl is welcomed. However, due to the issues described above the adoption of a standard trawl design across all WGIPS survey may not be possible.
Recommendation ID 79 From WGMEGS
WGMEGS recommends during the IESNS survey to collect mackerel biological data and ovary samples. This is to confirm the presence of non-spawning but developing females in northern waters. These data could be used to confirm the mackerel DEPM periods during the MEGS survey
ID 79 Reply: To ensure the highest quality of samples are provided, those requesting samples are asked to provide a detailed methodology to include point of contact, collection procedure, sampling level, sample handling and stored procedures, equipment requirements, transport and delivery details and time lines. This information should be provided to the WG chair and survey coordinator well in advance of the survey date to facilitate adequate planning. Survey coordinator contact details can be provided on request through the WG Chair. Sampling requests received without this accompanying information provided may not be facilitated.
Recommendation ID 80 From WGMEGS
WGMEGS recommends during the Blue whiting survey to look for possibilities to collect pre-spawning ovary samples of mackerel in order to provide additional samples to estimate AEPM fecundity parameters.
ID 80 Reply: To ensure the highest quality of samples are provided, those requesting samples are asked to provide a detailed methodology to include point of contact, collection procedure, sampling level, sample handling and stored procedures, equipment requirements, transport and delivery details and time lines. This information should be provided to the WG chair and survey coordinator well in advance of the survey date to facilitate adequate planning. Survey coordinator contact details can be provided on request through the WG Chair. Sampling requests received without this accompanying information provided may not be facilitated.
Recommendation ID 81 From WGMEGS
WGMEGS recommends during the WESPAS Survey (Western European Shelf Pelagic Acoustic) to collect ovary samples of horse mackerel during regular sampling. This will help to ensure additional samples are available in order to estimate batch fecundity and spawning fraction in adult females.
ID 81 Reply: To ensure the highest quality of samples are provided, those requesting samples are asked to provide a detailed methodology to include point of contact, collection procedure, location(s), sampling level, sample handling and stored procedures, equipment requirements, transport and delivery details and time lines.

This information should be provided to the WG chair and survey coordinator well in advance of the survey date to facilitate adequate planning. Survey coordinator contact details can be provided on request through the WG Chair. Sampling requests received without this accompanying information provided may not be facilitated.

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 reports 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. The communication between the two groups benefit from overlap between members of both groups and facilitates the delivery of indices to the assessment process in-year.

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). Additional input continues to be provided from the yearly WGIPS and survey post-cruise meetings as well as through the large overlap in members of WGIPS and the database-governing group, WGAcousticGOV.

The Acoustic Trawl Survey Data Portal is now in production being maintained and several WGIPS coordinated surveys are now actively using the database i.e. HERAS, CSHAS, WESPAS, 6aSPAWN now exclusively use the database. IBWSS and IESNS have also fully adopted the database and IESSNS is trialling it. The remaining surveys are all taking preparatory steps.

8 Revisions to the Work Plan

Two items planned for Year 1 was not completed. The WD on biological sampling strategies on HERAS surveys over time has not been completed in Year 1 as planned, but the HERAS survey group has committed to completing this task before next meeting. There were also plans for conducting a workshop on biological sampling strategies in WGIPS surveys. This has also been postponed and it has been agreed to focus the workshop on just the HERAS survey for now. The group still anticipates to conduct this workshop during this reporting cycle.

9 References

*No references

Annex 1: List of participants

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Annex 2: Resolutions

WGIPS-Working Group on International Pelagic Surveys

2021/FT/EOSG02 The **Working Group on International Pelagic Surveys (WGIPS)**, chaired by Susan Maersk Lusseau, Denmark, will meet to work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2022	24–28 January	Online Meeting	Interim report by 7 March 2022 to EOSG, SCICOM & ACOM	Incoming chair Susan Maersk Lusseau. Outgoing: Bram Couperus and Michael O´Malley
Year 2023	23–27 January	Belfast, Ireland	Interim report by 6 March 2023 to EOSG, SCICOM & ACOM	
Year 2024	22–26 January	Faroe Islands	Final report by 11 March 2024 to EOSG, SCICOM & ACOM	

ToR descriptors

ToR	Description	Background	Science plan codes	Duration	Expected Deliverables
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.	a) Advisory Requirements b) Requirements from other EGs	3.2	years 1–3	Survey reports containing indices of stock biomass and abundance at age, spatial distributions of stocks and hydrographic conditions. Survey summary tables delivered to: HAWG, WGWIDE
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)	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs d) follow-up of WKPilot NS-FIRMOG	3.1	years 1–3	Cruise plans for international and individual surveys.
c	Adopt standardized analysis methodology and data storage format utilizing the ICES acoustic database repository for all acoustically derived	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

	abundance estimates of WGIPS coordinated surveys				repository for WGIPS coordinated surveys.
d	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 in TIMES format.
e	Review the work, and report of workshops organised by WGIPS and develop formal ICES recommendations. This should include TIMES manual updates and adopting changes to survey coordination where deemed appropriate.	a) Science requirements b) Advisory requirements	3.1	years 1–3	Integrate results from WGIPS workshops into survey protocols where possible. Develop formal recommendations to other groups and agree answers to recommendations from other groups.
f	Review and evaluate survey designs across all WGIPS coordinated surveys to ensure the integrity of survey deliverables.	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.
g	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	year 1-3	Documented standardised scrutinisation recommendations; Update of survey manual to address and maintain monitoring requirements for pelagic ecosystem surveys.
h	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. Make time-series data available for MEESO.
i	Assess developing pelagic ecosystem surveying technology (e.g. optical technology, multibeam 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.
j	Continted development of trawl sampling and hull mounted acoustic data collection during IBWSS surveys to support the routine reporting of mesopelagic fish abundance and distribution within established limitations. Leverage latest research from ongoing research projects (MEESO &	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs	3.1, 3.4,	years 1–3	Ultimate goal is the routine reporting of mesopelagic fish abundance and distribution as part of the IBWSS survey and uptake by other candidate surveys within WGIPS. Upload of bioloigcal and acoustic data to the ICES trawl acoustic database.

SUMMMER) to improve data quality and reporting capacity		Provision of data to interested WGs and research projects.

Summary of the 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 and coordinate planning and discuss designs for surveys taking place in Year 1. Review the WGIPS acoustic manual in the TIMES format. Session 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 DB and the PGNAPES database), use of StoX and progress on TAF. Session on mesopelagic sampling: Review and feedback of sampling carried out in 2021. Update on reports from MEESO and SUMMER projects and workshops. Session on stock discrimination projects and the consequences for biological sampling on WGIPS surveys. Delivery of a WD on biological sampling strategies on HERAS surveys over time. Session on biological sampling strategies in WGIPS surveys Conduct a workshop on biological sampling strategies in WGIPS surveys.
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 and coordinate planning and discuss designs for surveys taking place in Year 2. Review the WGIPS acoustic manual in the TIMES format, prepare for submitting for external review. Session 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), use of StoX and progress on TAF. Session on mesopelagic sampling: Review and feedback progress of trawl sampling and acoustic sampling methods used.

	Session on stock discrimination and the consequences for biological sampling on WGIPS surveys. Session on biological sampling strategies in WGIPS surveys
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 and coordinate planning and discuss designs for surveys taking place in Year 3. Review the WGIPS acoustic manual in the TIMES format, submit for publishing. Session 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), use of StoX and progress on TAF. Session on mesopelagic sampling. Update the group on progress of sampling and reporting of mesopelagic fish resources. Session on stock discrimination and the consequences for biological sampling on WGIPS surveys. Session on biological sampling strategies in WGIPS surveys

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	There is a very close working relationship with other groups in EOSG and DSTSG, especially relevant links to WGAcousticGov, WGACEGG, WGALES, WGBIFS, WGFAST,

committees or groups	WGFTFB, WGISDAA, WGISUR, WGMEGS, WGTC, WGINOR, WGINOSE, WGIAB, WKEVAL, WKMSMAC2, WKSCRUT, WKSUREQ, WGS2D, WKPilot NS-FIRMOG
Linkages to other organizations	

* The group has submitted for approval a resolution to update the Survey Manual (SISP 9) to the TIMES format.

Annex 3: 2021 IBWSS Survey Summary Table and Survey Report

Document 3a: IBWSS 2021 survey summary table

Survey Summary table WGIPS 2022	
Name of the survey (abbreviation):	International blue whiting spawning stock survey (IBWSS)
Target Species:	Blue whiting
Survey dates:	18 March – 5 April 2021
Summary:	
The International Blue Whiting Spawning stock survey was carried out over 19 days and thus within the recommended 21 day time window agreed by the group. Weather conditions were regarded as exceptionally poor and all vessels experienced multiple days of downtime, except for the Spanish vessel working in the Porcupine Seabight. This considered, the stock was regarded as suitably contained within the survey area. Effort in the Porcupine Seabight area was extended in 2021 and included as a new stratum area however, the total survey effort was comparable to survey effort in 2019. The survey in 2021 shows a 44% decrease in total stock biomass and a corresponding 46% decrease in total abundance when compared to the 2019 estimate. The estimated uncertainty around the total stock biomass was lower than in 2019, CV=0.14 compared to 0.17. The stock biomass within the survey area was dominated by 5, 6 and 7-year-old fish contributing 61% of total stock biomass. The proportion of immature fish (1 year old) in the 2021 estimate was higher compared to 2019 and is as usually most notable in the northern strata around the Faroes. No immature fish were observed from samples taken in the Rockall Bank and north Porcupine strata. Survey effort, timing and area coverage were comparable to previous years and sampling equipment (transducers and trawl) were used.	

	Description
Survey design	Stratified systematic parallel design (15 - 35 nmi spacing) with randomised start point. Adaptive surveying was used in border areas to the west where blue whiting spawning concentrations disappear. Zigzag design in stratum 2 (the northern slope of Porcupine)
Index Calculation method	StoX (via the ICES 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	Yes, in poor weather conditions three of the four vessels use a drop keel and minimum integration is at 12 m
Extinction (shadowing)	Some issues on the shelf break but considered minor
Blind zone	NA, blue whiting distributed in deeper layers
Dead zone	Some issues on the shelf break but considered minor
Allocation of backscatter to species	Directed trawling for verification and species composition purposes and age structure.
Target strength	TS = 20 log10 (L) - 65.2 Pedersen et al. 2011
Calibration	All survey frequencies were calibrated and results were 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	The 2021 estimate of abundance is considered as robust. Good stock containment was achieved for both core and peripheral strata.
Stock ID and mixing issues	*No issues*
Measures of uncertainty (CV)	Estimated uncertainty around the total stock biomass remains low, CV=0.14 which is lower than 2019 (around 0.17).
Biological sampling	Sampling levels was considered representative and well distributed across strata, in line with previous years.
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	No concerns were raised regarding the fitness of the survey for use in the assessment.

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	Yes

Document 3b: IBWSS 2021 survey report

*Please find report on the next page.

Working Document

Working Group on International Pelagic Surveys
January 2022

Working Group on Widely Distributed Stocks
August 2021

INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY (IBWSS) SPRING 2021

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R/V Tridens

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R/V Celtic Explorer

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Material and methods

Survey planning and Coordination

Coordination of the survey was initiated at the meeting of the Working Group on International Pelagic Surveys (WGIPS) in January 2021 and continued by correspondence until the start of the survey. During the survey effort was refined and adjusted by the survey coordinator (Norway) using real time observations. Participating vessels together with their effective survey periods are listed below:

Vessel	Institute	Survey period
Celtic Explorer	Marine Institute, Ireland	21/3 – 04/4
Jákup Sverri	Faroe Marine Research Institute, Faroe Islands	29/3 – 05/4
Tridens	Wageningen Marine Research, the Netherlands	18/3 – 03/4
Vendla	Institute of Marine Research, Norway	25/3 – 05/4
Vizconde de Eza	Spanish Institute of Oceanography, Spain	18/3 – 23/3

The survey design was based on methods described in ICES Manual for International Pelagic Surveys (ICES, 2015). Weather conditions were regarded as exceptionally poor and all vessels experienced multiple days of downtime, with the exception of the Spanish vessel working in the Porcupine Seabight. This considered, the stock was covered comprehensively and contained within the survey area. The entire survey was completed in 19 days, below 21-day target threshold (Figure 4).

Vessel cruise tracks and survey strata are shown in Figure 1. Trawl stations for each participant vessel are shown in Figure 2 and CTD stations in Figure 3. Communication between vessels occurred daily via email to the coordinator (Norway) exchanging up to date information on blue whiting distribution, echograms, fleet activity and biological information. Tridens keeps a weblog during the survey with echograms, catches and additional information.

Sampling equipment

All vessels employed a single midwater trawl for biological sampling, the properties of which are given in Table 1. Acoustic equipment for data collection and processing are presented in Table 2. Survey abundance estimates are based on acoustic data collected from calibrated scientific echo sounders using an operating frequency of 38 kHz. All transducers were calibrated using a standardised sphere calibration (Demer et al. 2015) prior, during or directly after the survey. Acoustic settings by vessel are summarised in Table 2.

Biological sampling

All components of the trawl haul catch were sorted and weighed; fish and other taxa were identified to species level. A summary of biological sampling by vessel is provided in Table 3.

Hydrographic sampling

Hydrographic sampling (vertical CTD casts) was carried out by each vessel at predetermined locations (Figure 3 and Table 3). Depth was capped at a maximum depth of 1000 m in open water, with the exception of the Spanish vessel where the maximum depth was 520 m. Not all pre-planned CTD stations were undertaken due to weather restrictions.

Plankton sampling

Plankton sampling by way of vertical WP2 casts were carried out by the RV *Jákup Sverri* (FO) to a depth of 200 m (Table 3). WP2 casts were also carried out by FV *Vendla*, with a focus on sampling blue whiting eggs to a depth of 400 m.

Acoustic data processing

Echogram scrutinisation for blue whiting was carried out by experienced personnel, with the aid of trawl composition information. Post-processing software and procedures differed among the vessels;

On RV *Celtic Explorer*, acoustic data were backed up every 24 hrs and scrutinised using EchoView (V 11.0) post-processing software for the previous day's work. Data was partitioned into the following categories: blue whiting and mesopelagic fish species. For mesopelagic fish, categorisation was based on criteria agreed at WGIPS 2021 (ICES 2021, Annex 22).

On RV *Jákup Sverri*, acoustic data were scrutinised every 24 hrs on board using LSSS post processing software. Data were partitioned into the following categories: plankton (<200 m depth layer), pearlside (surface down to 250 m), mesopelagics/krill and blue whiting. Partitioning of data into the above categories was based on trawl samples and acoustic characteristics on the echograms. The pearlside layer typically migrated above the transducer depth during night and reappeared on the echogram early in the morning.

On RV *Tridens*, acoustic data were backed up continuously and scrutinised every 24 hrs using the Large Scale Survey System LSSS (2.10.1) post-processing software. Blue whiting were identified and separated from other recordings based on trawl catch information and characteristics of the recordings.

On FV *Vendla*, the acoustic recordings were scrutinized using LSSS (V. 2.10.1) once or twice per day. Data was partitioned into the following categories: plankton (<120 m depth layer), mesopelagic species and blue whiting.

On RV *Vizconde de Eza*, acoustic data were backed up every 12 hrs and scrutinised after the survey using EchoView (V 9.0) post processing software. Data were partitioned into the following categories: Blue whiting and Müeller's pearlside which were identified and separated from other recordings based on trawl catch information and characteristics of the recordings.

Echogram scrutinisation for mesopelagic fish species was conducted by participants using guidelines developed at WGIPS 2021 (ICES 2021, Annex 22). This process is ongoing and requires further development in terms of categorisation and trawl sampling equipment. Progress updates will be reported through WGIPS.

Due to the bad weather conditions acoustic recording of all vessels suffered from transmission loss and spikes caused by wave impact on the ship's hull (Figure 8e). Scientists onboard RV *Tridens* analysed data collected during the survey to investigate the effects of bias. A case study showed that there was no significant bias and therefore no need to apply filtering or a correction factor. Further details are provided in Annex 1.

Acoustic data analysis

Acoustic data were analysed using the StoX software package (V3.0.5) and R-StoX packages software package (RStoX Framework 3.0.12, RStoX Base 1.3.8 and RStoX Data 1.1.3). A description of StoX software package is provided by Johnsen et. al. (2019). Estimation of abundance from acoustic surveys with StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990). Baseline survey strata, established in

2017, were adjusted based on survey effort and observations in 2021 (Figure 1). Area stratification and transect design are shown in Figure 1 and 5. Length and weight data from trawl samples were equally weighted and applied across all transects within a given stratum (Figure 5).

Following the decisions made at the Workshop on implementing a new TS relationship for blue whiting abundance estimates (WKTSBLUES, ICES 2012), the following target strength (TS)-to-fish length (L) relationship (Pedersen et al. 2011) is used:

$$TS = 20 \log10 (L) - 65.2$$

In StoX an impute super-individual table is produced where abundance is linked to population parameters including age, length, weight, sex, maturity etc. This table is used to split the total abundance estimate by any combination of population parameters. The StoX project folder for 2021 is available on request.

Estimate of relative sampling error

For the baseline run, StoX estimates the number of individuals by length group which are further grouped into population characteristics such as numbers at age and sex.

A total length distribution is calculated, by transect, using all the trawl stations assigned to the individual transects. Conversion from NASC (by transect) to mean density by length group by stratum uses the calculated length distribution and a standard target strength equation with user defined parameters. Thereafter, the mean density by stratum is estimated by using a standard weighted mean function, where each transect density is weighted by transect distance. The number of individuals by stratum is given as the product of stratum area and area density.

The bootstrap procedure to estimate the coefficient of variance randomly replaces transects and trawl stations within a stratum on each successive run. The output of all runs are stored in a RData-file, which is used to calculate the relative sampling error.

Results

Distribution of blue whiting

In total 7,794 nmi (nautical miles) of survey transects were completed across seven strata, relating to an overall geographical coverage of 118,169 nmi² and is comparable to survey effort in 2019 (Figure 1, Tables 3 & 7). Effort in the Porcupine Seabight area was extended in 2021 and included as a new stratum area. The stock was considered well contained within core and peripheral abundance areas (Rockall Bank and south Porcupine Bank). The distribution of blue whiting as observed during the survey is shown in Figures 6 and 7.

The bulk of the stock in 2021 was located within the three strata that cover the shelf edge area (Strata 1-3 inclusive) accounting for 84% of total biomass observed (Table 4). The Rockall Trough, strata 3, contained less biomass than observed in 2019 (41% and 61 % of TSB respectively). Distribution in the Porcupine Bank (stratum 1) decreased by 69% compared to 2019. However, it should be noted that this stratum was subdivided into what is now stratum 7 (Porcupine Seabight). The three strata outside the core shelf edge area (stratum 4, 5, and 6) collectively increased from around 5% in 2019 to 10% in 2021 (Table 4). The new Porcupine Seabight area (stratum 7) contributed around 6% of the overall biomass of blue whiting in 2021.

The two northernmost strata South Faroes (stratum 4) and Shetland Channel (stratum 6) accounted for 3.2% of the biomass (Table 4).

Overall, the distribution of blue whiting was found to be highly compressed against the shelf edge from south to north, with the main body of the stock located in the mid-latitudes to the north of the Porcupine Bank (strata 2-3).

The highest s_A value (73,312 m²/nmi² - per 1 nmi EDSU) observed in the survey in 2021 was recorded by *Celtic Explorer* on the slope in the southern part of stratum 3 (Figure 8c). The second highest density value for the combined survey was also found in the same area in the eastern part of the northern slope of Porcupine Bank (stratum 2). Example echograms are provided in Figures 8a, 8b, 8g, showing high density layers of blue whiting extending onto the shelf area on the Porcupine Bank. Juvenile blue whiting, observed as weak scattering layers were found in the northern stratum of South Faroes and Faroe – Shetland Channel (Figure 8d).

The vertical distribution of blue whiting observed in 2021 did not extend deeper than 750 m as observed in 2018 and so were considered vertically contained in the insonified layer.

Stock size

The estimated total stock biomass of blue whiting for the 2021 international survey was 2.4 million tonnes, representing an abundance of 36.9×10^9 individuals (Table 4). Spawning stock was estimated at 2.3 million tonnes and 18.1×10^9 individuals (Table 5).

Stock composition

Survey samples show the age range of 1 to 13 years were observed during the survey.

The main contribution to the spawning stock biomass was composed of the age groups 5, 7 and 6 years representing 63% of the total. Five year olds (2016 year-class) being most abundant (20%), followed by the 7-year-olds (17%) and lastly the 6-year-olds (16%) (Table 5).

The highest mean lengths of blue whiting were caught in Stratum 1 and 7 (Figure 9). High mean weights were also found in this area but two samples in the northern part (Stratum 3 and 4) also had large blue whiting in relation to weight (Figure 10). Highest mean weight in 2021 was in Stratum 7 (Porcupine Seabight) representing 136g.

This year different age groups dominated in different strata (Figure 12). The oldest and largest fish were found in the southern part of the survey area. In the western and southern part of the Porcupine area (Strata 1 and 7) six-year olds (2015 year-class) dominated. On the northern slope of Porcupine (Stratum 2) two-year olds were the second most important age group, but still five-year olds were dominant. In the northern part of the survey area (Strata 4 and 6) the youngest fish were present, and the 2020 year-class dominated. In the core area (Stratum 3) three, five and seven-year olds were approx. at the same level with 15-16% of the estimate each. (Figure 12). The proportion of the different age groups in the total estimate in 2021 were considered evenly distributed and well represented from 1-7 years (Figure 13).

An uncertainty estimate at age based on a comparison of the abundance estimates was calculated for IBWSS for years 2018, 2019 and 2021 using StoX (Figure 11). By comparing the estimates from 2018 to 2021 it appears that good cohort tracking is achieved in the survey for some year classes. For example, the relative abundance of four year olds in 2018 (2014-year class) was high; the strong abundance of this cohort is also seen in 2019 as five year olds, and to some extent in 2021 as seven year olds. Similarly, the 2015 year-class were picked up as three-year olds in 2018, and subsequently the four and six year olds in 2019 and 2021 respectively are relatively strong. The CV of the abundant age groups 3 to 7 was below 0.25 in 2019 (Figure 11).

The CV of the total estimate of both biomass and abundance were 0.14, which is lower than the years before (0.16 - 0.17)

The survey time series (2004-2021) of TSN and TSB are presented in Figures 14 and 15 respectively and Table 6.

Hydrography

A total of 102 CTD casts were undertaken over the course of the survey (Table 1). Horizontal plots of temperature and salinity at depths of 50 m, 100 m, 200 m and 500 m as derived from vertical CTD casts are displayed in Figures 16-19 respectively. A decrease in salinity observed in 2017 persisted through 2018 and 2019, but seems to have reversed again in 2020 with an increasing trend (K.M. Larsen, pers. comm., Faroe Marine Research Institute). This is thought to have limited the western extent of the blue whiting spawning distribution on the Rockall and Hatton Bank areas in recent years.

Mesopelagic fish

Echogram scrutinisation for mesopelagic fish species was conducted by participants during the survey and included in uploads to the ICES database. However, due to the complexities involved and issues regarding representative trawl catches these data are considered as experimental and outputs reported to the ICES database should be treated as such.

Concluding remarks

Main results

- Weather conditions were regarded as exceptionally poor and all vessels experienced multiple days of downtime, except for the Spanish vessel working in the Porcupine Seabight. This considered, the stock was regarded as suitably contained within the survey area.
- The total area surveyed and acoustic sampling effort (miles) was the same as 2019.
- Overall, biological sampling saw an increased number of both measured and aged individuals compared to 2019.
- The International Blue Whiting Spawning Stock Survey 2021 shows a 44% decrease in total stock biomass and a corresponding 46% decrease in total abundance when compared to the 2019 estimate.
- The survey was carried out over 19 days, below the 21-day time window target. With core areas covered well by multiple vessels.
- Estimated uncertainty around the total stock biomass was lower than in 2019, CV=0.14 compared to 0.17.
- The stock biomass within the survey area was dominated by 5, 6 and 7-year-old fish contributing 61% of total stock biomass.
- There was no evidence of blue whiting below 750 m
- Immature fish (mainly 1-year-old) represent 3.6% of the TSB and 10% of TSN.
- The harmonisation of reporting of mesopelagic fish began in earnest and will be developed within the IBWSS survey over the coming years to report abundance and biomass of identified target groups.

Interpretation of the results

- The group considers the 2021 estimate of abundance as robust. Good stock containment was achieved for both core and peripheral strata. Sampling effort (biological and acoustic) was comparable to previous years.
- The bulk of SSB was distributed from the northern edge of the Porcupine Bank and continued northwards through the Rockall Trough and the Hebrides.
- The Northern migratory stock and the Porcupine Seabight; Spatio-temporal survey data and biological data from trawl hauls (RV *Vizconde de Eza*) were comparable in terms of length cohorts. The eastward extension of the survey area is necessary to contain the northern stock. Comparative analysis of age readings is required.

Recommendations

- The group recommends that coverage in the western Rockall/Hatton Bank (stratum 5) should be carried out based on real time observations. That is, effort should not be expended where no aggregations are evident and transects are terminated when no blue whiting is observed for 15 nmi consistent ‘clear water’ miles. This applies to peripheral regions to the west of the Rockall and Hatton Bank areas.

- To facilitate the process of calculating global biomass the group requires that all data be made available at least 72 hours in advance of the meeting start date and made available through the ICES database.
- Hydrographic and Plankton data along with Log book files formats should still be submitted in the PGNAPES format.
- The group recommends that the process of producing output reporting tables, figures and maps from StoX outputs files (StoX 3.2) are standardised and developed by WGIPS for wider use.
- Through WGIPS, agreement needs to be reached on the synchronisation of reporting blue whiting maturity by participants and how this is handled within the ICES database.
- It is recommended that the effective timing of the survey point is maintained to begin around the 20th March in 2022.

Achievements

- Acoustic sampling effort (track miles), trawling effort and biological metrics of blue whiting were comparable to 2019.
- All survey data were uploaded to the ICES trawl-acoustic database in advance of the post cruise meeting.
- Mesopelagic fish scrutinisation was carried out by all participants using the guidelines developed during WGIPS.
- Directed trawling on mesopelagic layers was carried out using a range of sampling nets (MiK and Macrozooplankton). Although still experimental, this is a further step towards reporting.

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Table 1. Country and vessel specific details, IBWSS March-April 2021.

	Celtic Explorer	Jákup Sverri	Tridens	Vendla	Vizconde de Eza
Trawl dimensions					
Circumference (m)	768	852	860	832	752
Vertical opening (m)	50	45	30-70	45	30
Mesh size in codend (mm)	20	45	40	40	20
Typical towing speed (kts)	3.5-4.0	3.0-4.0	3.5-4.0	3.5-4.0	4.0-4.5
Plankton sampling					
Sampling net	-	WP2 plankton net	-	WP2 plankton net	
Standard sampling depth (m)	-	200	-	400	
Hydrographic sampling					
CTD Unit	SBE911	SBE911	SBE911	SBE25	SBE25
Standard sampling depth (m)	1000	1000	1000	1000	520

Table 2. Acoustic instruments and settings for the primary acoustic sampling frequency, IBWSS March-April 2021.

	Celtic Explorer	Jákup Sverri	Tridens	Vendla	Vizconde de Eza
Echo sounder	Simrad EK 60	Simrad EK80	Simrad EK 60	Simrad EK 80	Simrad EK 80
Frequency (kHz)	**38**, 18, 120, 200	18, **38**, 70, 120, 200, 333	18, **38**, 70, 120, 200, 333	18, **38**, 70	**38**, 18, 70, 120, 200
Primary transducer	ES 38B	38-7	ES 38B	ES 38B	ES 38B
Transducer installation	Drop keel	Drop keel	Drop keel	Drop keel	Drop keel
Transducer depth (m)	8.7	6	8	8.5	7.5
Upper integration limit (m)	20	15	15	15	15
Absorption coeff. (dB/km)	9.8	10.7	9.5	9.5	9.2
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.43	3.06	2.43	2.43	2.43
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	21.9	21.9	21.9
2-way beam angle (dB)	-20.6	-20.4	-20.6	-20.7	-20.6
Sv Transducer gain (dB)			27.28		
Ts Transducer gain (dB)	25.65	26.96	27.27	25.18	24.68
s_A correction (dB)	-0.64	-0.16	-0.01	-0.66	-0.54
3 dB beam width (dg)					
alongship:	6.97	6.55	6.86	7.01	6.90
athw. ship:	7.06	6.45	6.89	6.90	7.10
Maximum range (m)	1000	750	750	750	1000
Post processing software	Echoview	LSSS	LSSS	LSSS	Echoview

Table 3. Survey effort by vessel, IBWSS March-April 2021. Directed mesopelagic sampling 150-350 m depth layer) was carried out by the RV *Celtic Explorer* and RV *Tridens* using macrozooplankton and Mik net trawls respectively.

Vessel	Effective survey period	Length of cruise track (nmi)	Trawl stations	CTD stations	Mesopelagic sampling	Aged fish	Length-measured fish
Celtic Explorer	21/3-04/4	2123	15	19	3	550	6571
Jákup Sverri	25/3-5/4	1100	3	19	-	300	668
Vendla	25/3- 5/4	2100	9	19	-	239	800
Tridens	18/3-3/4	1574	13	31	5	1000	2836
Vizconde de Eza	18/3-23/3	897	5	14	-	-	1144
Total	28/3-11/4	7794	45	102	8	2089	12019

Table 4. Abundance and biomass estimates of blue whiting by strata in 2019 and 2018. IBWSS March-April 2021.

		2021				2019				Difference 2021-2019	
Strata	Name	TSB (10^3 t)	TSN (10^9)	% TSB	% TSN	TSB (10^3 t)	TSN (10^9)	% TSB	% TSN	TSB	TSN
1	Porcupine Bank	270	2 232	11.4	11.1	870	8 350	20.7	22.6	-69 %	-73 %
2	N Porcupine Bank	746	6 500	31.6	32.3	572	5 692	13.6	15.4	30 %	14 %
3	Rockall Trough	977	8 094	41.4	40.2	2 555	21 116	60.9	57.2	-62 %	-62 %
4	South Faroes	154	1 413	6.5	7.0	125	1 039	3.0	2.8	24 %	36 %
5	Rockall Bank	41	300	1.7	1.5	29	272	0.7	0.7	43 %	10 %
6	Faroe/Shetland Ch.	34	595	1.5	3.0	47	448	1.1	1.2	-27 %	33 %
7	Porcupine Seabight	139	984	5.9	4.9	0	0				
	Total	2 361	20 119	100	100	4 198	36 918	100	100	-44 %	-46 %

Table 5. Survey stock estimate of blue whiting, IBWSS March-April 2021.

	Age in years (year class)										Number	Biomass	Mean	Prop
Length	1	2	3	4	5	6	7	8	9	10+			weight	Mature
(cm)	2020	2019	2018	2017	2016	2015	2014	2013	2012		(10^6)	(10^6 kg)	(g)	
14-15										0	0	0	0.0	0
15-16	24										24	1	21.7	84
16-17	386										386	9	24.0	12
17-18	476										476	13	27.7	6
18-19	403	9									412	13	32.2	2
19-20	228										228	9	39.0	0
20-21	177										177	8	45.1	3
21-22	155										155	8	52.4	0
22-23	67	1	17								85	5	62.0	21
23-24	34	167	41								242	17	68.1	86
24-25		498	327	22	18						865	66	76.5	97
25-26		746	585	154	83	6					1 574	134	85.0	95
26-27		468	685	545	713	9	1	0			2 421	225	92.8	97
27-28		139	483	568	686	160	52	4			2 092	223	106.5	99
28-29		62	255	539	808	573	223	19	1		2 479	294	119.0	100
29-30			38	187	454	681	799	5	1		2 165	287	132.4	100
30-31		6	86	82	586	621	806	40	76		2 302	326	142.1	100
31-32			28	127	286	581	606	25	35	22	1 712	267	155.5	100
32-33				41	225	245	514	21			1 047	176	168.3	100
33-34				4	16	158	238	105			521	98	188.8	100
34-35				2	28	82	69	136	5	21	343	71	206.9	100
35-36				2	9	27	38	55	10	40	181	41	227.4	100
36-37				2		49	12	19	13	1	94	25	254.4	100
37-38						5	7	12	32		57	17	280.3	100
38-39						1		21		8	31	9	296.5	100
39-40							4			8	12	4	345.3	100
40-41									15		15	6	386.3	100
41-42							4				4	1	329.0	100
42-43										6	6	3	432.0	100
43-44										6	6	0	556.0	100
44-45							6				6	3	448.7	100
TSN(mill)	1 948	2 095	2 545	2 275	3 914	3 197	3 379	463	189	114	20 119			
TSB(1000 t)	68.8	179.3	243.9	265.0	470.0	469.0	504.1	98.5	35.2	20.9	2 357.3			
Mean length(cm)	18.1	25.0	26.1	27.5	28.3	30.0	30.5	33.3	33.0					
Mean weight(g)	35	84	98	111	122	144	152	199	206					
% Mature	6	96	95	100	100	100	100	100	100	100				
SSB (1000kg)	3.9	172.0	232.3	264.8	469.5	469.0	504.1	98.5	35.2	20.9	2 270.1			
SSN (mill)	109.1	2010.0	2423.6	2273.4	3910.1	3197.2	3379.0	462.6	189.1	113.7	18 067.7			

Table 6. Time series of StoX abundance estimates of blue whiting (millions) by age in the IBWSS. Total biomass in last column (1000 t).

	Age										
Year	1	2	3	4	5	6	7	8	9	10+	TSB(1000 t)
2004	1 097	5 538	13 062	15 134	5 119	1 086	994	593	164		3 505
2005	2 129	1 413	5 601	7 780	8 500	2 925	632	280	129	23	2 513
2006	2 512	2 222	10 858	11 677	4 713	2 717	923	352	198	31	3 512
2007	468	706	5 241	11 244	8 437	3 155	1 110	456	123	58	3 274
2008	337	523	1 451	6 642	6 722	3 869	1 715	1 028	269	284	2 639
2009	275	329	360	1 292	3 739	3 457	1 636	587	250	162	1 599
2010*											
2011	312	1 361	1 135	930	1 043	1 712	2 170	2 422	1 298	250	1 826
2012	1 141	1 818	6 464	1 022	596	1 420	2 231	1 785	1 256	1 022	2 355
2013	586	1 346	6 183	7 197	2 933	1 280	1 306	1 396	927	1 670	3 107
2014	4 183	1 491	5 239	8 420	10 202	2 754	772	577	899	1 585	3 337
2015	3 255	4 565	1 888	3 630	1 792	465	173	108	206	247	1 403
2016	2 745	7 893	10 164	6 274	4 687	1 539	413	133	235	256	2 873
2017	275	2 180	15 939	10 196	3 621	1 711	900	75	66	144	3 135
2018	836	628	6 615	21 490	7 692	2 187	755	188	72	144	4 035
2019	1 129	1 169	3 468	9 590	16 979	3 434	484	513	99	144	4 198
2020*											
2021	1 948	2 095	2 545	2 275	3 914	3 197	3 379	463	189	114	2 357

*Survey discarded.

Table 7. IBWSS survey effort time series.

Survey effort	Survey area (nmi^2)	Transect n. miles (nmi)	Trawls	CTDs	Plankton	Bio sampling (WHB) Measured	Aged
2004	149 000		76	196			
2005	172 000	12 385	111	248	-	29 935	4 623
2006	170 000	10 393	95	201	-	7 211	2 731
2007	135 000	6 455	52	92		5 367	2 037
2008	127 000	9 173	68	161	-	10 045	3 636
2009	133 900	9 798	78	160	-	11 460	3 265
2010	109 320	9 015	62	174	-	8 057	2 617
2011	68 851	6 470	52	140	16	3 810	1 794
2012	88 746	8 629	69	150	47	8 597	3 194
2013	87 895	7 456	44	130	21	7 044	3 004
2014	125 319	8 231	52	167	59	7 728	3 292
2015	123 840	7 436	48	139	39	8 037	2 423
2016*	134 429	6 257	45	110	47	5 390	2 441
2017	135 085	6 105	46	100	33	5 269	2 477
2018	128 030	7 296	49	101	45	5 315	2 619
2019	121 397	7 610	38	118	17	6 228	1 938
2021	118 169	7 794	45	102	8	12 019	2 089

* End of Russian participation.

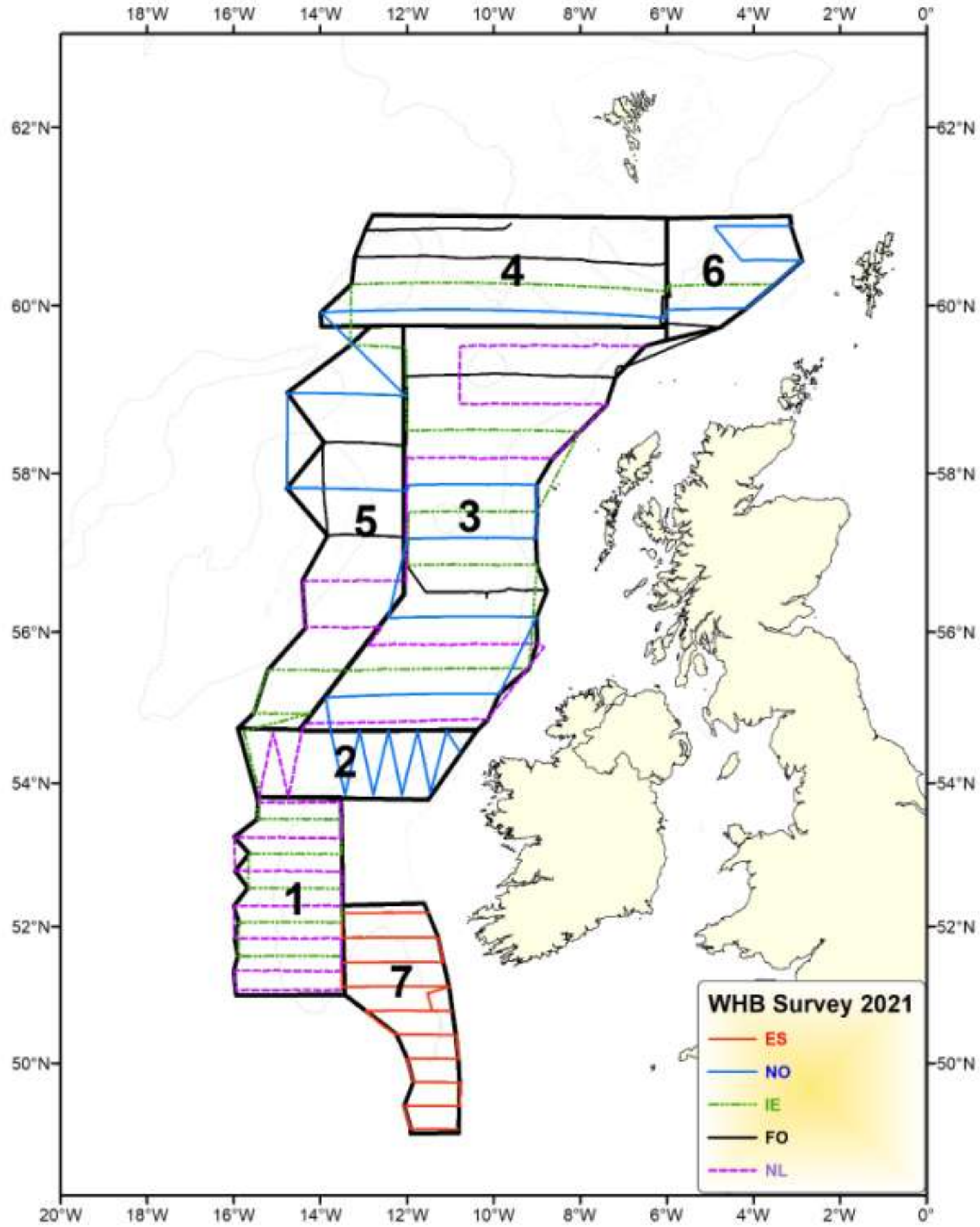


Figure 1. Strata and cruise tracks for the individual vessels (country) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2021.

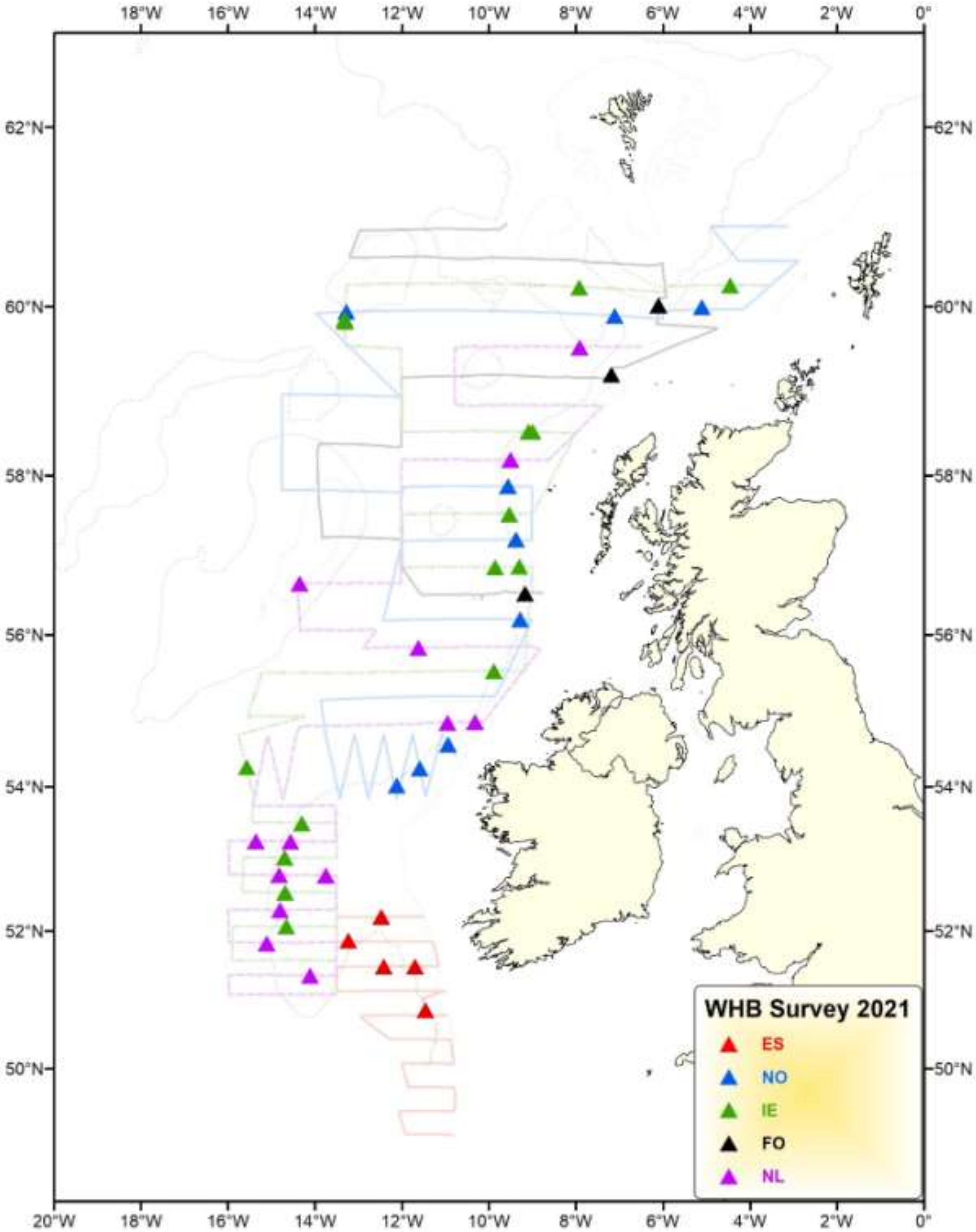


Figure 2. Vessel cruise tracks and trawl stations of the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2021. ES: Spain (RV *Vizconde de Eza*); FO: Faroe Islands (RV *Jakúp Sverrí*); IE: Ireland (RV *Celtic Explorer*); NL: Netherlands (RV *Tridens)*; NO: Norway (FV *Vendla*).

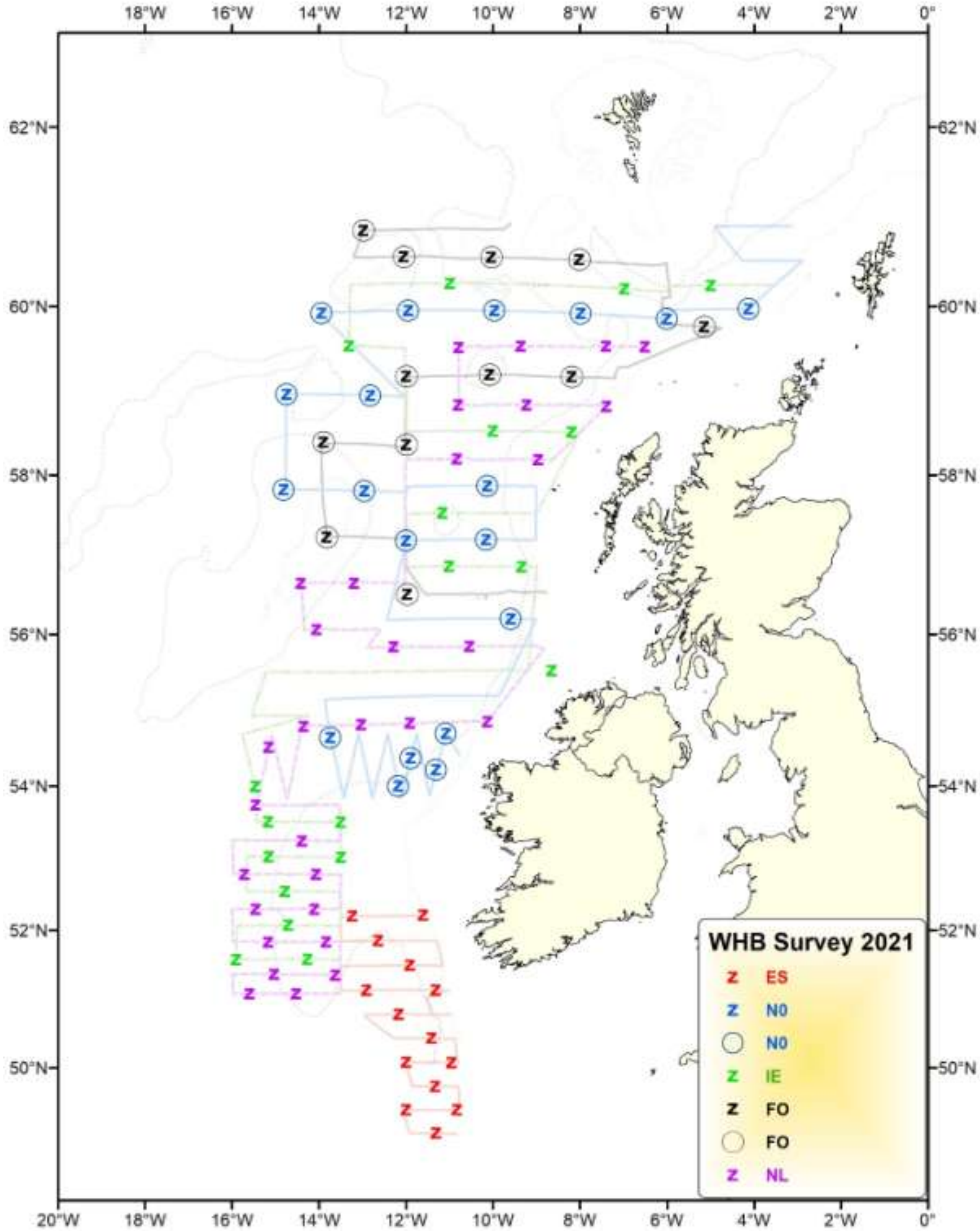


Figure 3. Vessel cruise tracks with hydrographic CTD stations (z) and WP2 plankton net samples (circles) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2021. Colour coded by vessel.

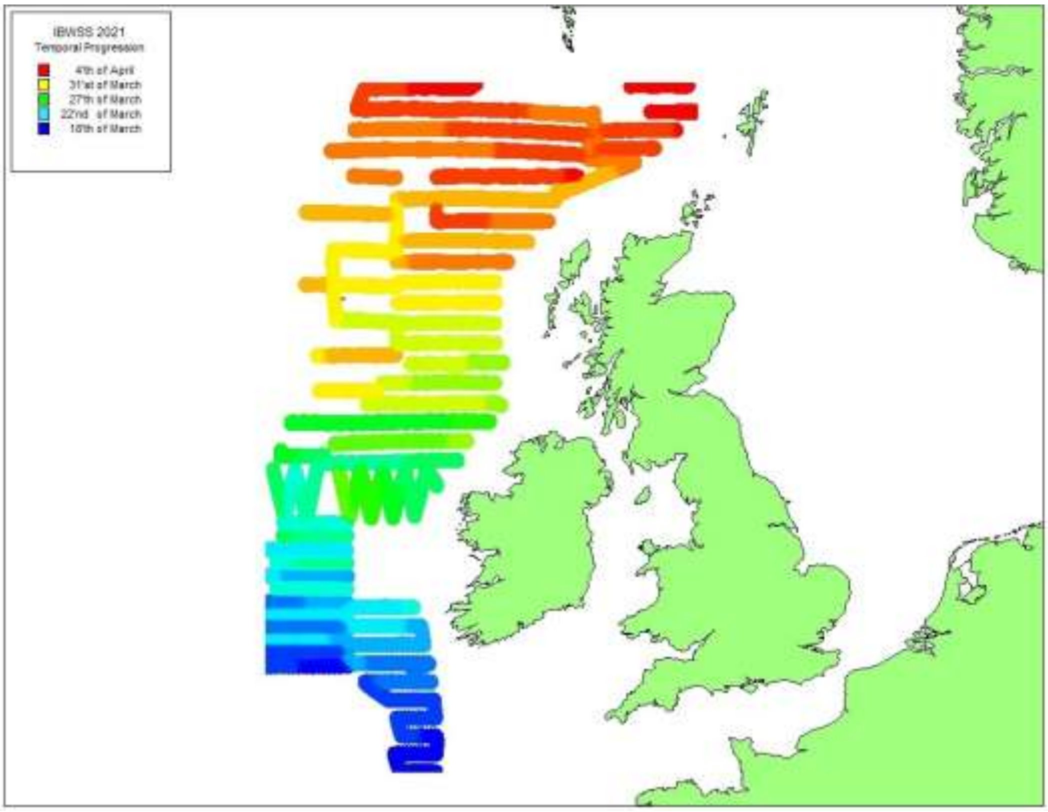


Figure 4. Temporal progression for the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2021.

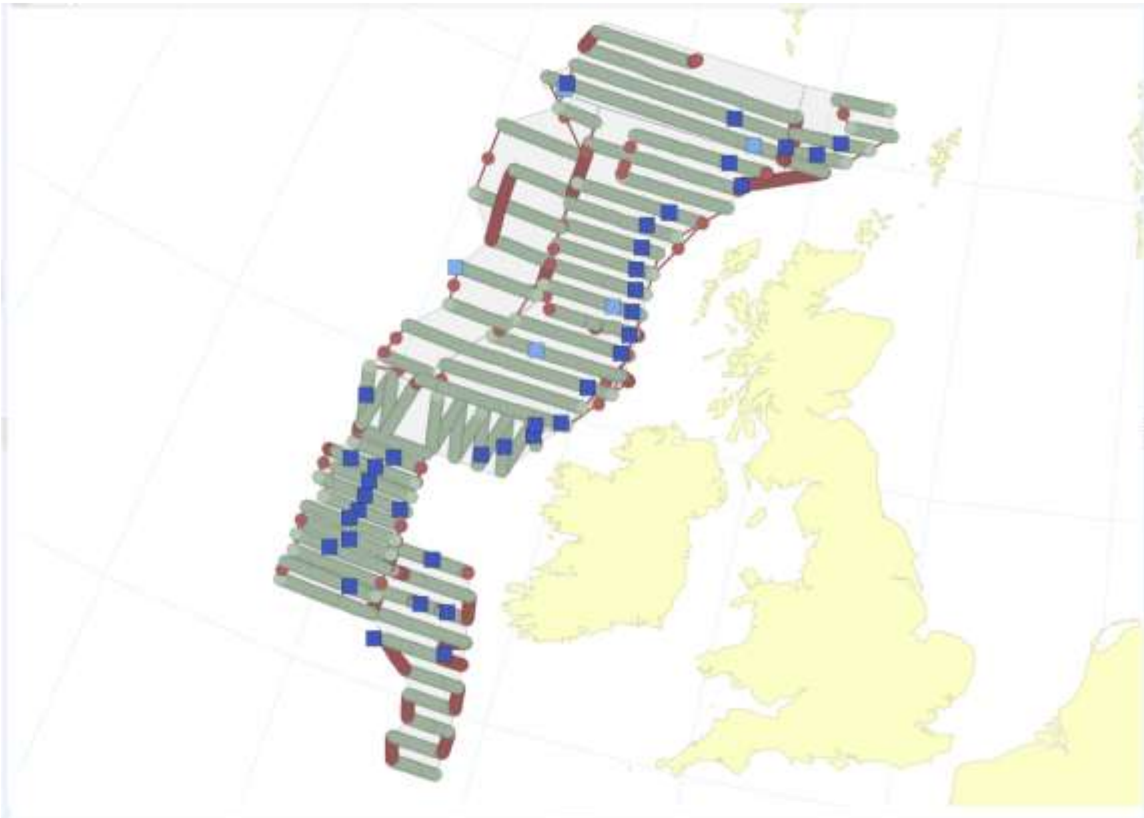


Figure 5. Tagged acoustic transects (green circles) with associated trawl stations containing blue whiting (dark blue squares) used in the StoX abundance estimation. IBWSS March-April 2021.

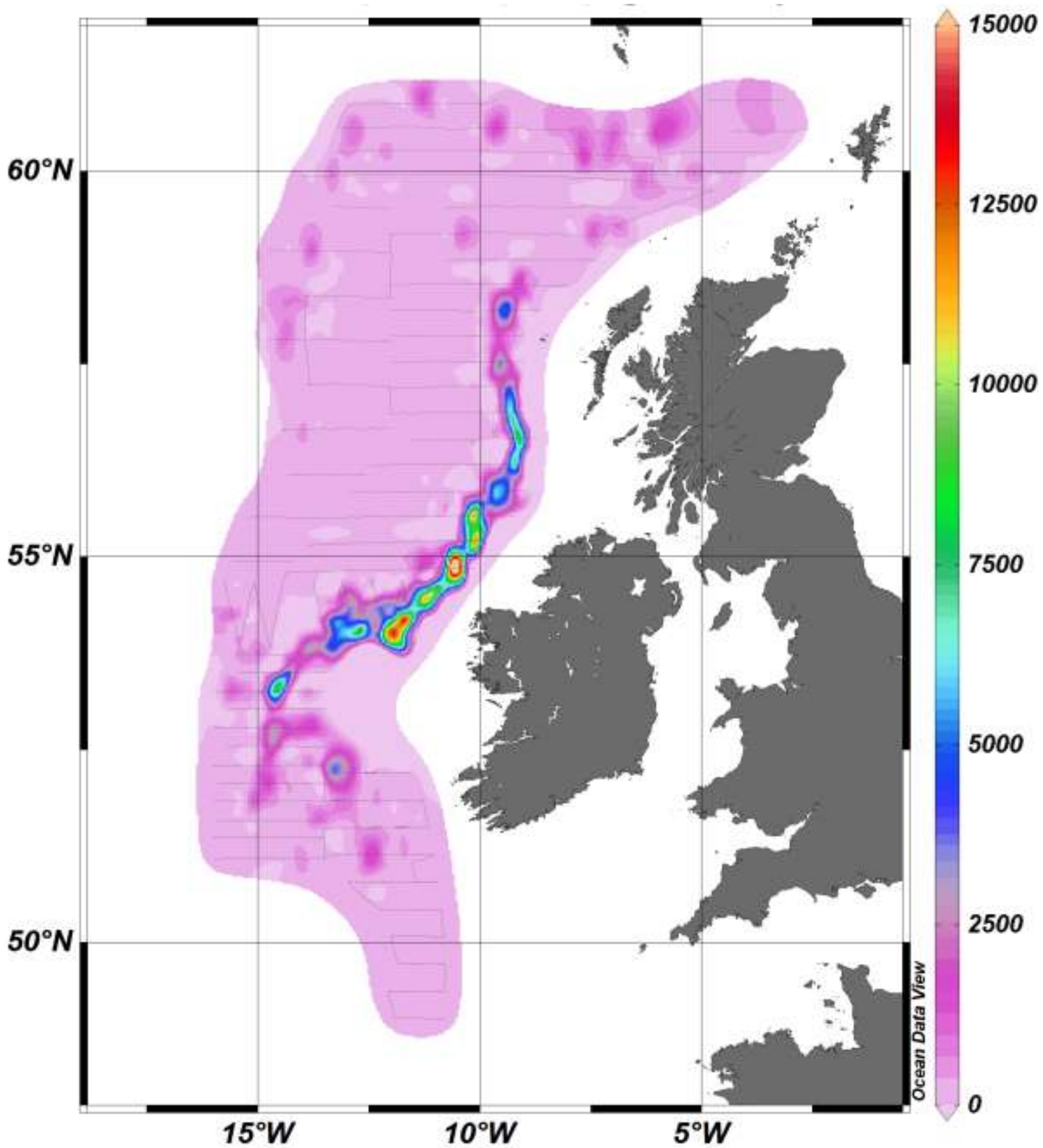


Figure 6. Acoustic density heat map (s_A m^2/nmi^2) of blue whiting during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2021.

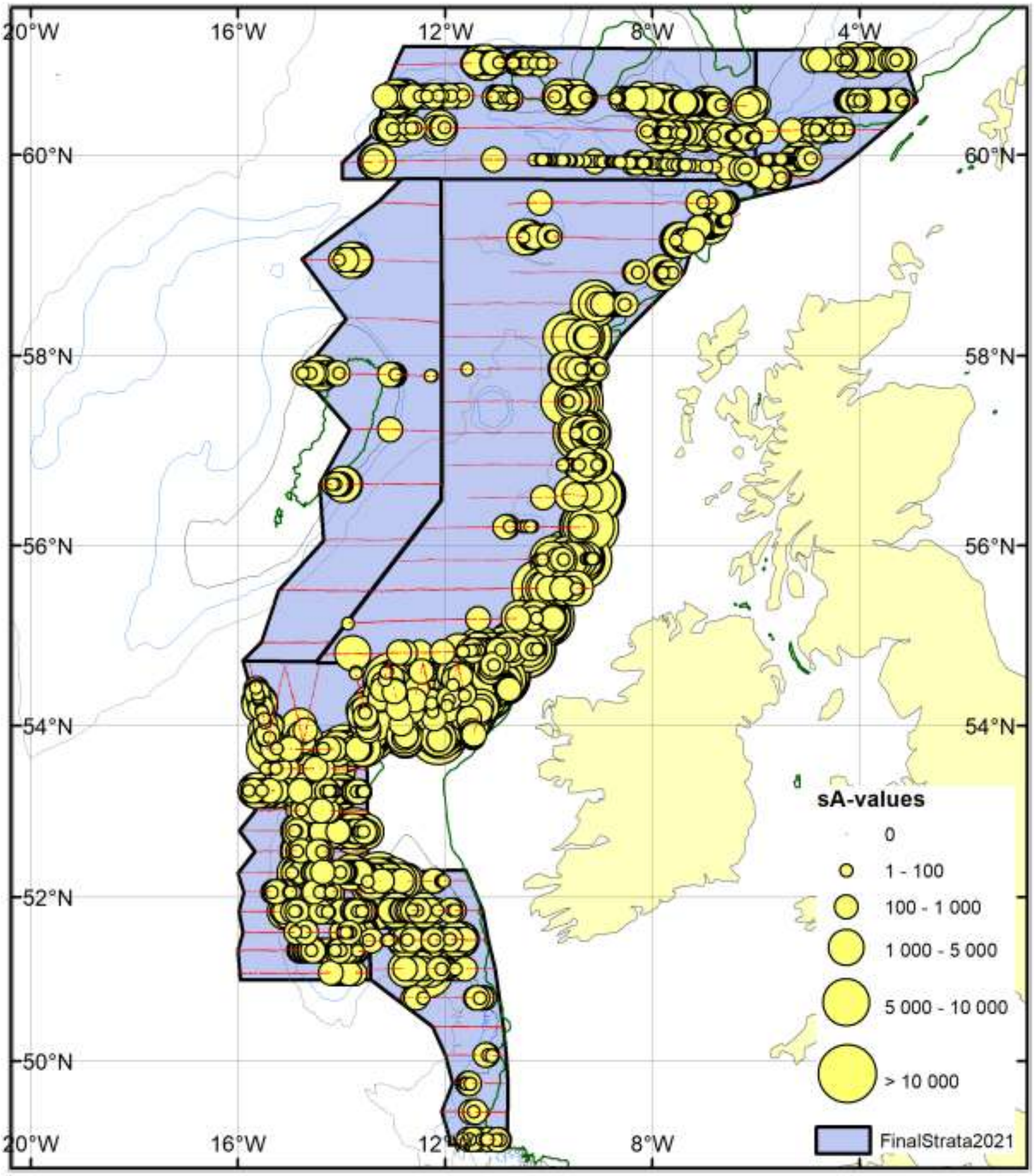
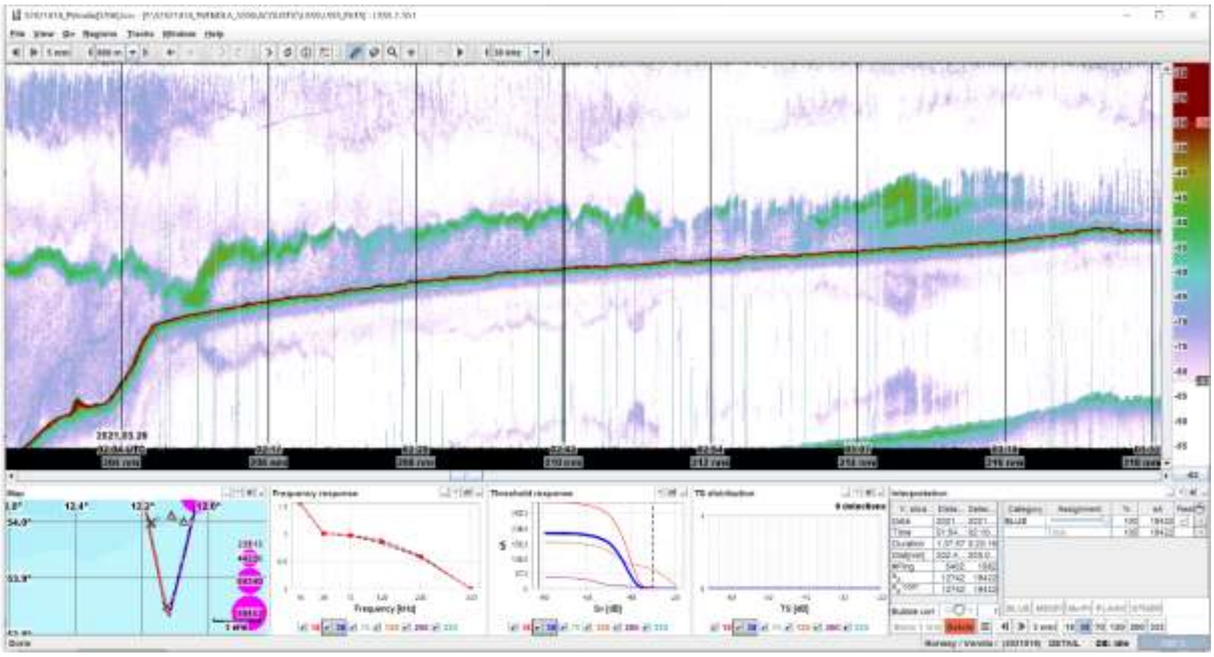
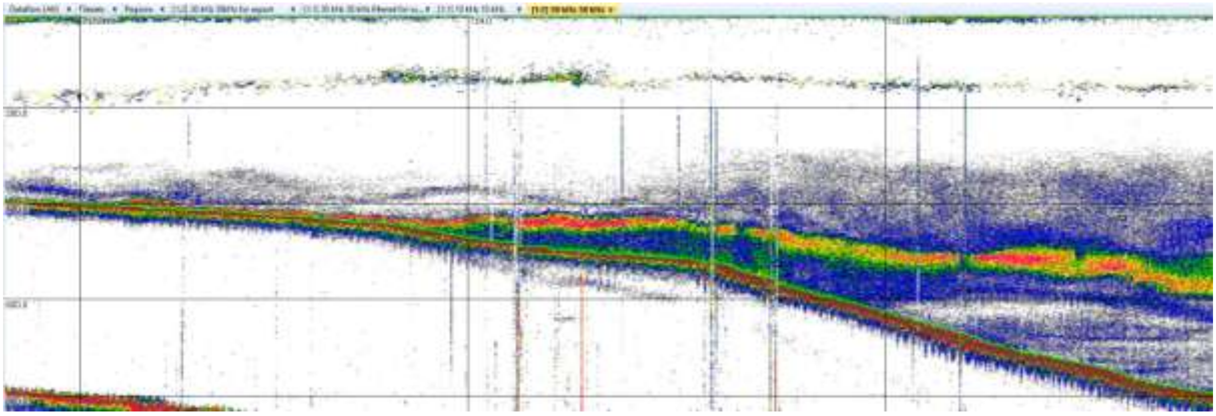


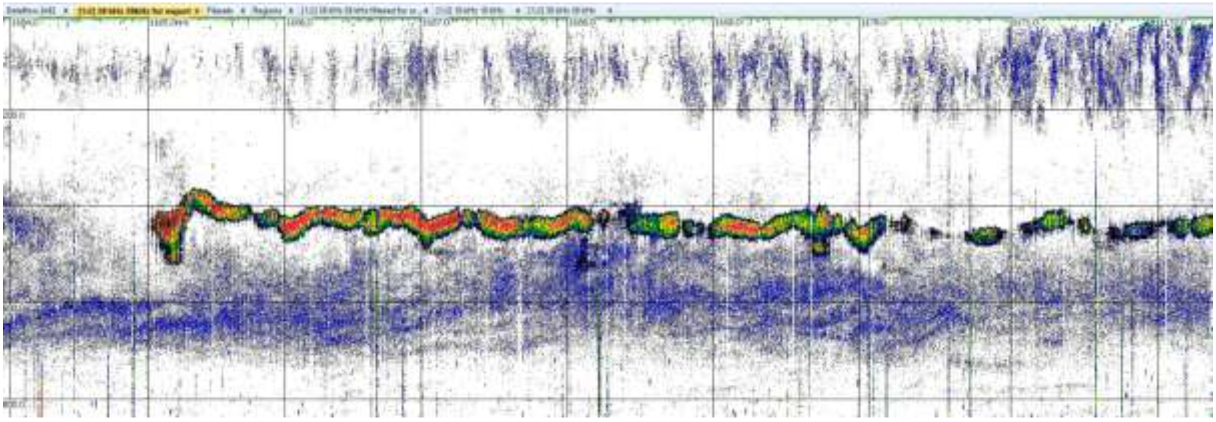
Figure 7. Map of proportional acoustic density (s_A m^2/nmi^2) of blue whiting by 1 nmi sampling unit. IBWSS March-April 2021.



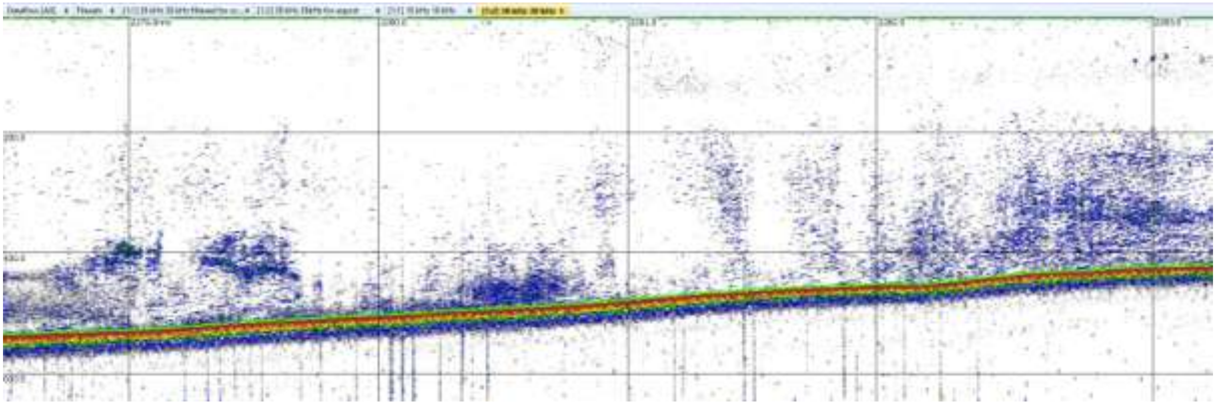
a) High density blue whiting per 1nmi log interval recorded on the northern slope of the Porcupine Bank area (Stratum 2) FV *Vendla*, Norway.



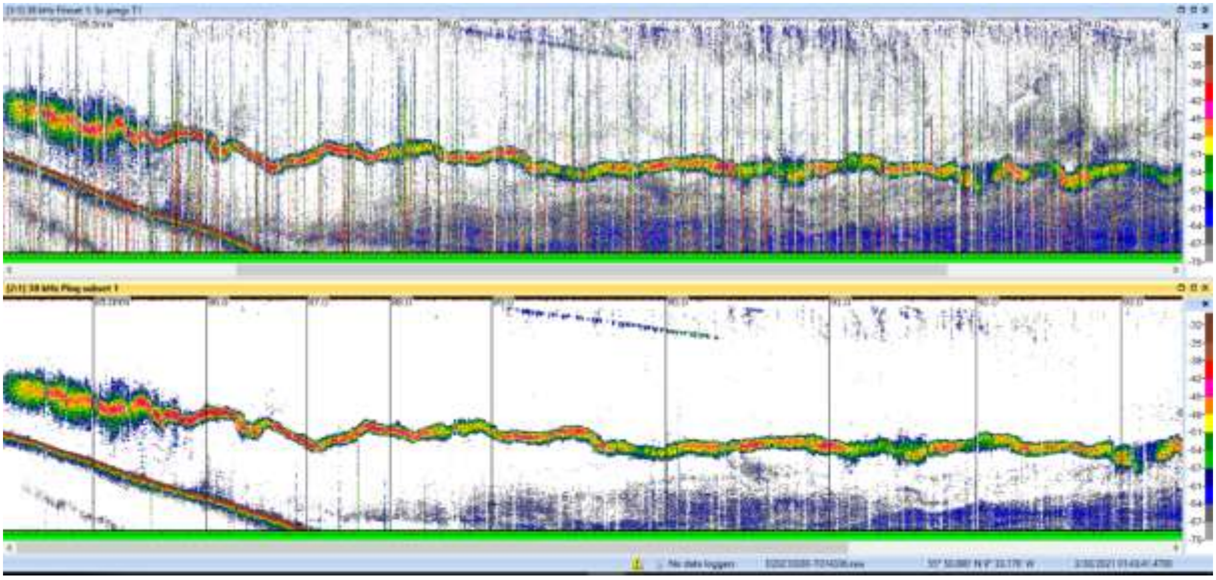
b) High density blue whiting layer per 1nmi log interval at 400- 600m recorded by the RV *Celtic Explorer* in the western Porcupine Bank area (strata 1).



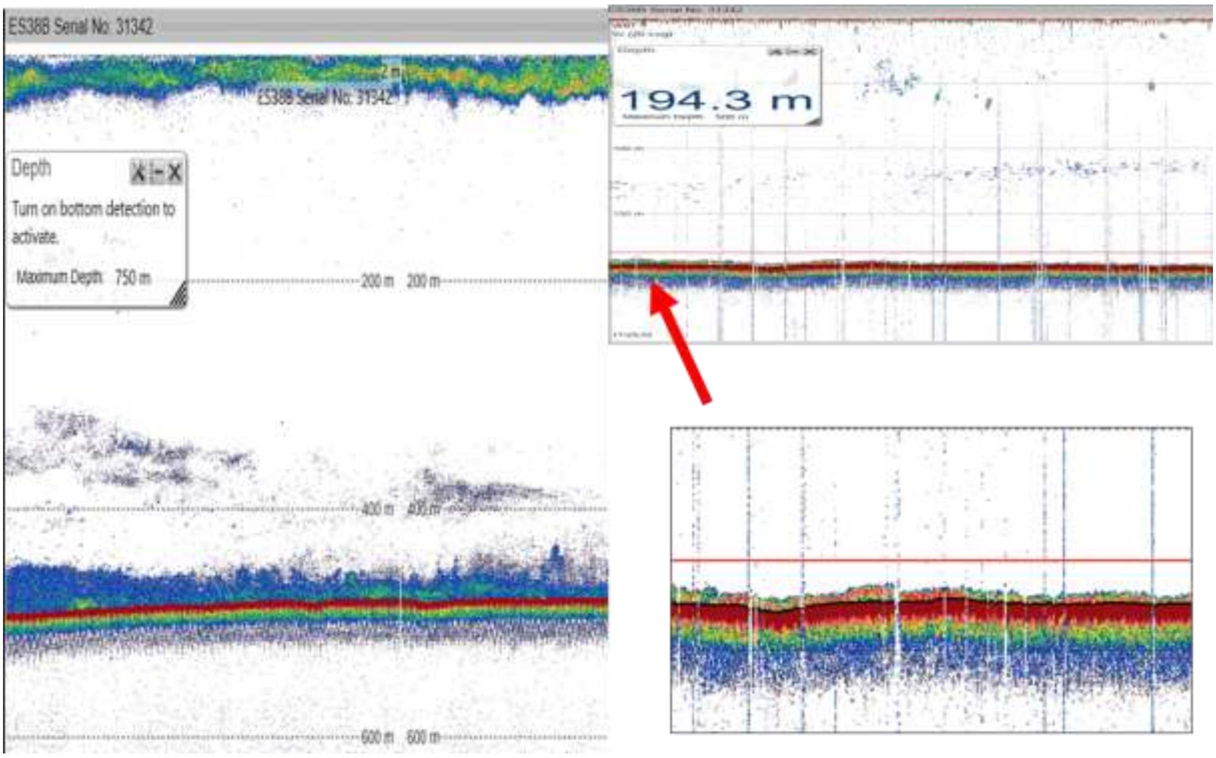
c) Single highest density blue whiting layer per 1nmi log interval (s_A value (73,312 m²/nmi²) observed during the survey recorded by the Celtic Explorer in the Rockall Trough area (Stratum 3) in 400 – 500 m.



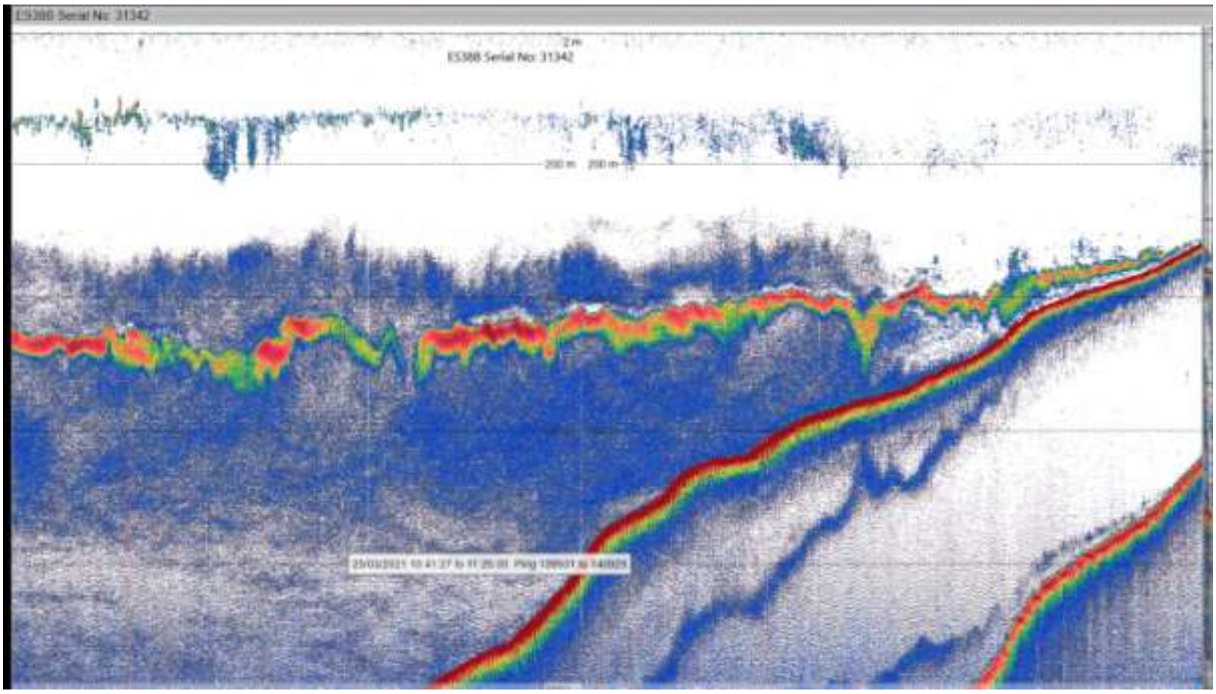
d) Weak scattering of predominantly juvenile blue whiting per 1 nmi log interval along the 400-500 m contour depth. This was an area that some of the fleet were fishing during the survey. Recorded by the RV *Celtic Explorer* in the Faroe – Shetland channel area (Stratum 6).



e) Blue whiting aggregations as observed by Tridens at the shelf edge (55.51N-9.00W). Above: without spike filtering. Below: after spike filtering. Test with spike filtering and removal of transmission loss, showed that there was no significant difference in NASC assigned to blue whiting before and after filtering (See annex 1). The weather conditions did not allow fishing.



f) Left: layer of blue whiting on Rockall Bank (*Tridens* – 19 March, haul1). Right: layer of grey gurnard on Rockall Bank (*Tridens* – 31 March, haul 11).



g) Blue whiting aggregations observed by *Tridens* at the edge of the continental shelf at 54.51N – 10.19W (25 March, haul 9).

Figure 8. Echograms of interest encountered during the IBWSS, March-April 2021. Vertical banding represents 1 nmi acoustic sampling intervals (EDSU). All echograms presented at 38 kHz.

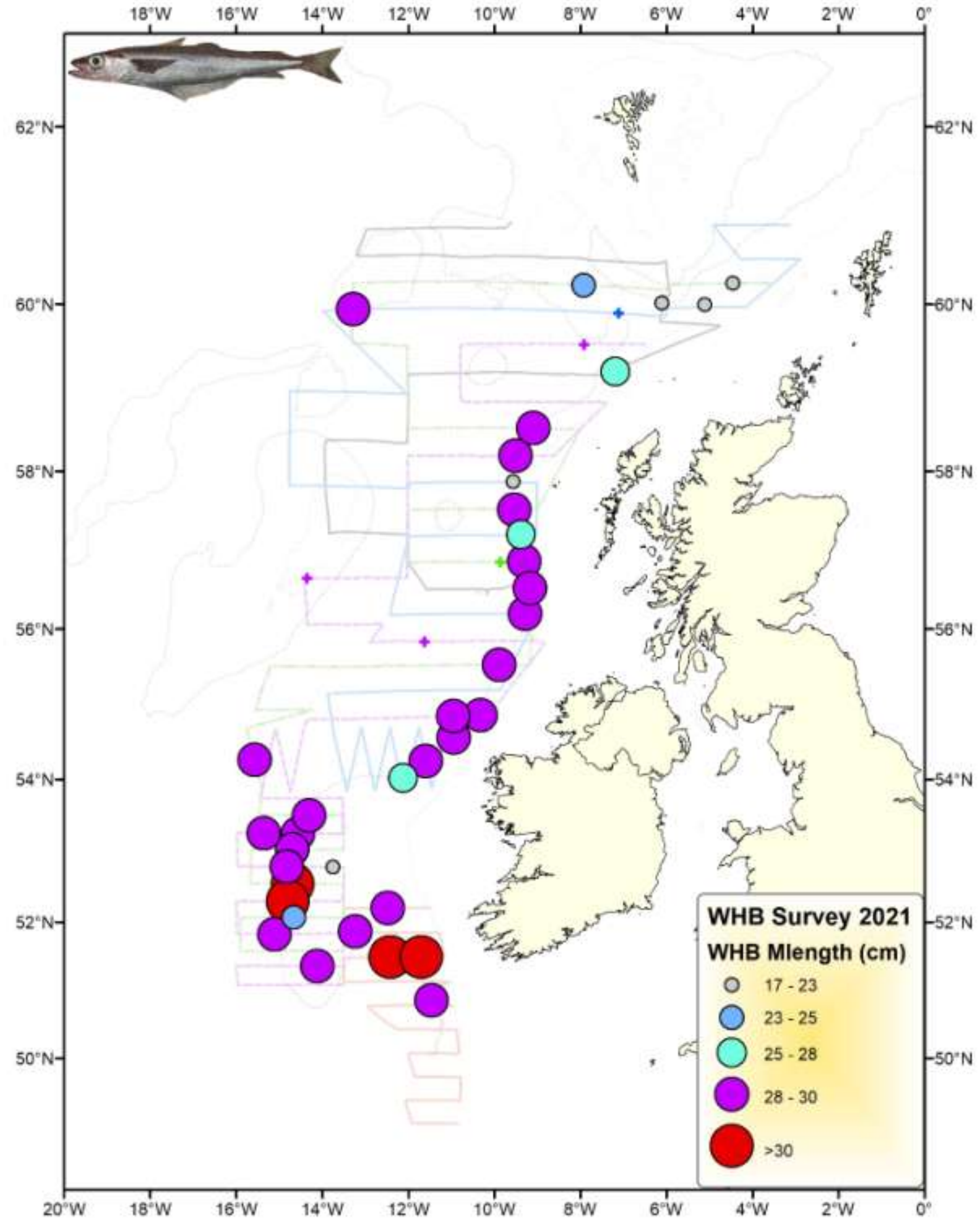


Figure 9. Combined mean length of blue whiting from trawl catches by vessel, IBWSS in March- April 2021. Crosses indicate hauls with zero blue whiting catches.

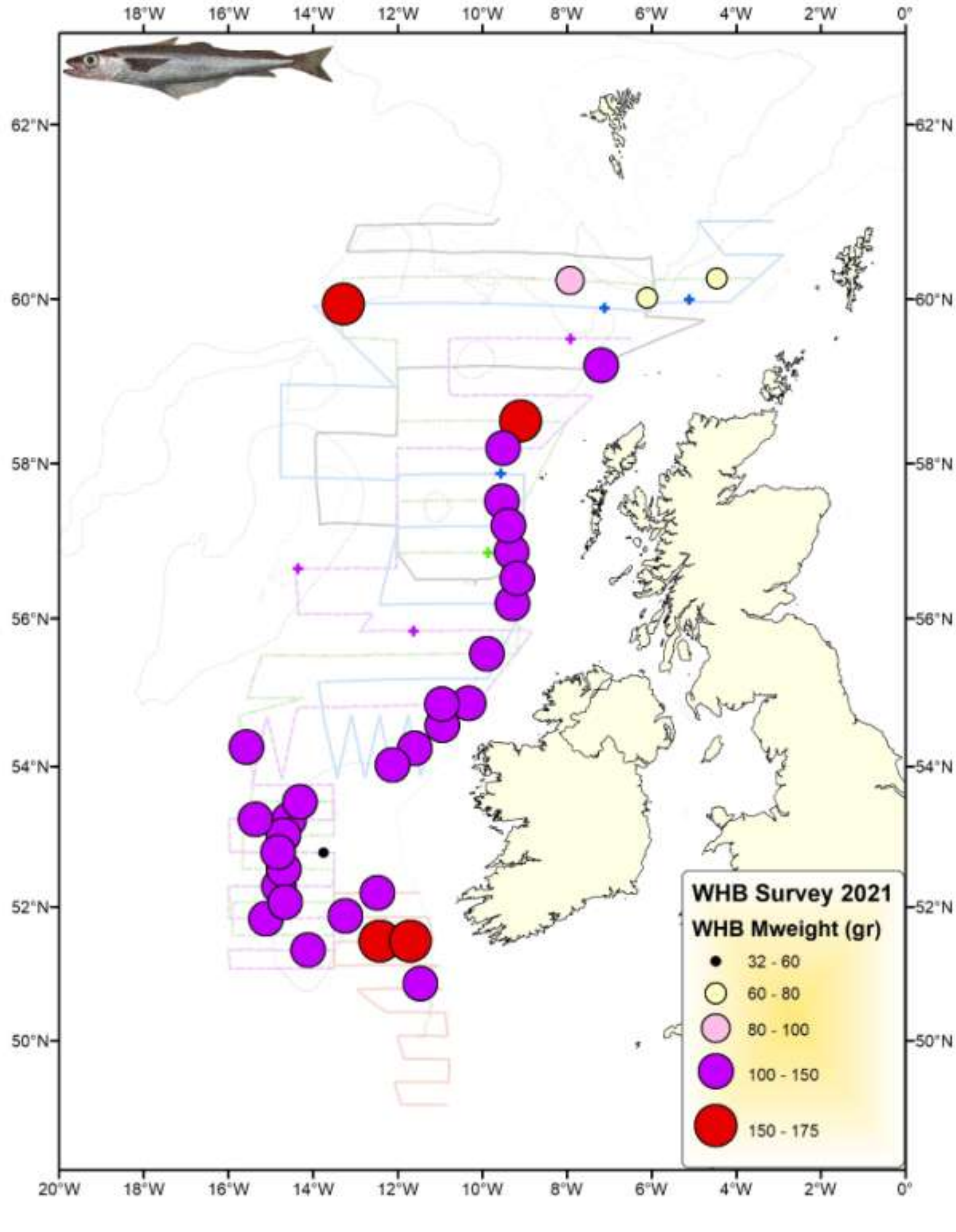


Figure 10. Combined mean weight of blue whiting from trawl catches, IBWSS March- April 2021. Crosses indicate hauls with zero blue whiting catches.

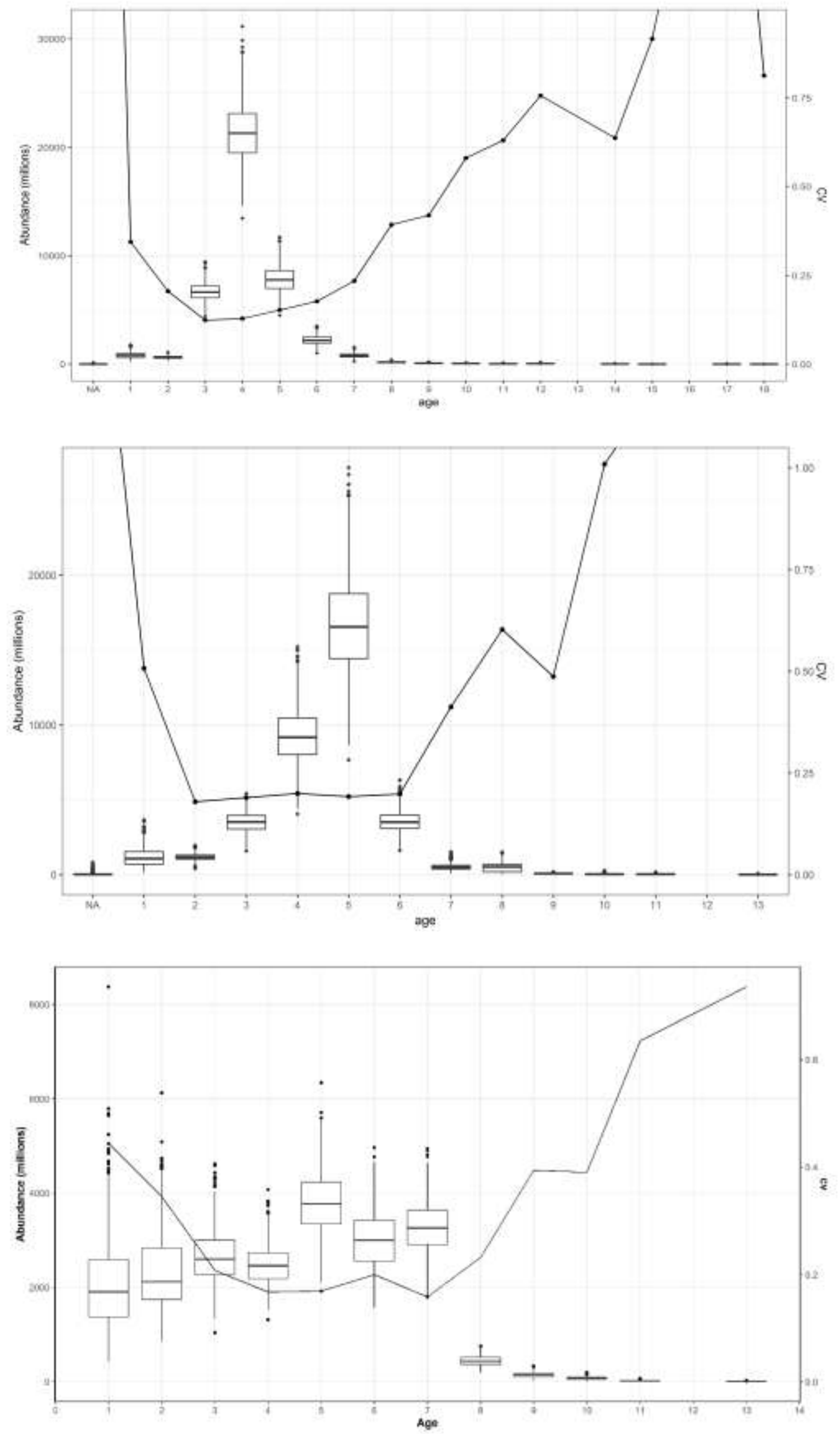


Figure 11. Blue whiting bootstrap abundance (millions) by age (left axis) and associated CVs (right axis) in 2018 (top panel), 2019 (middle panel) and 2021 (lower panel). From StoX.

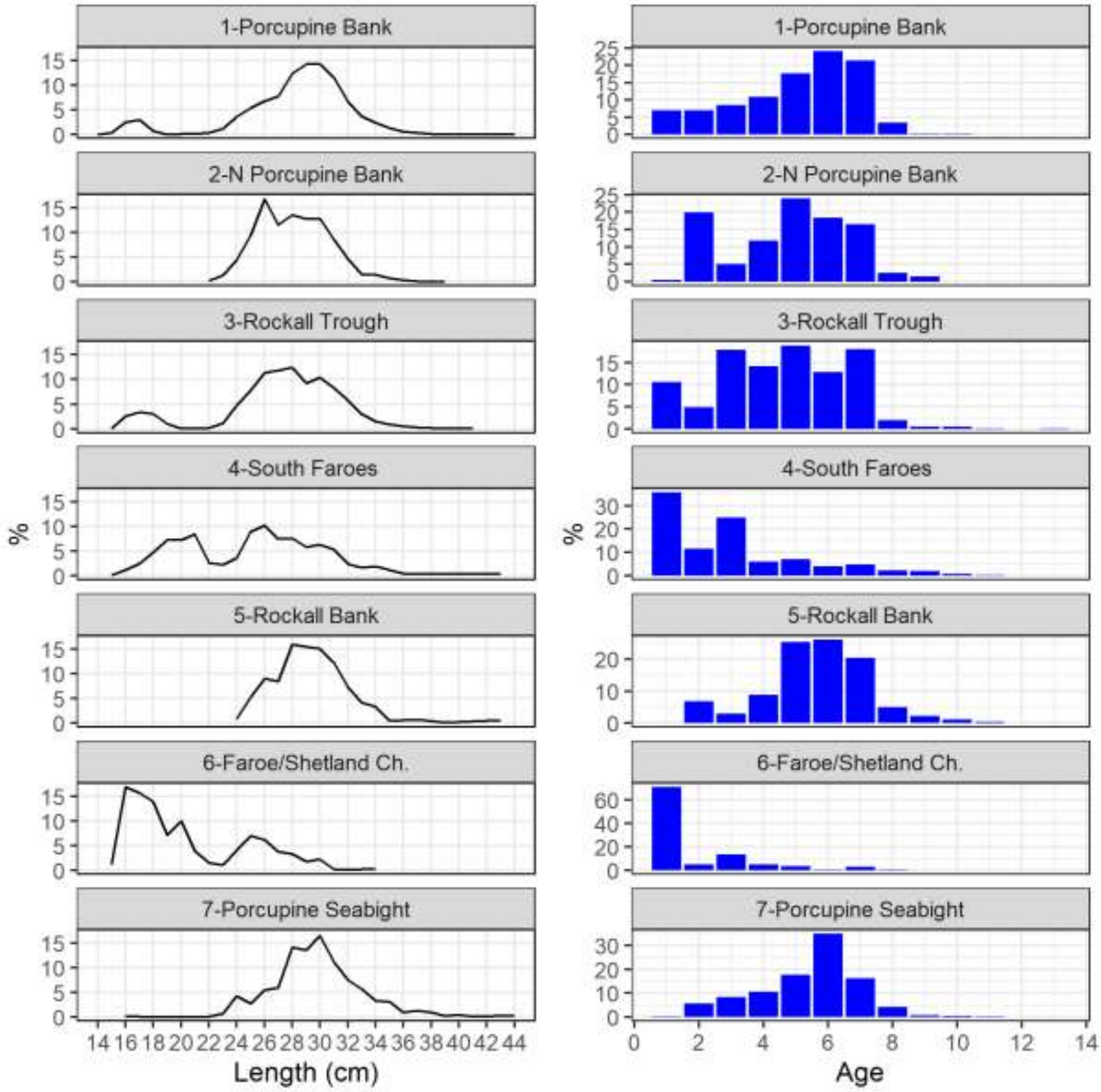


Figure 12. Length and age distribution (numbers) of blue whiting by survey strata. March-April 2021.

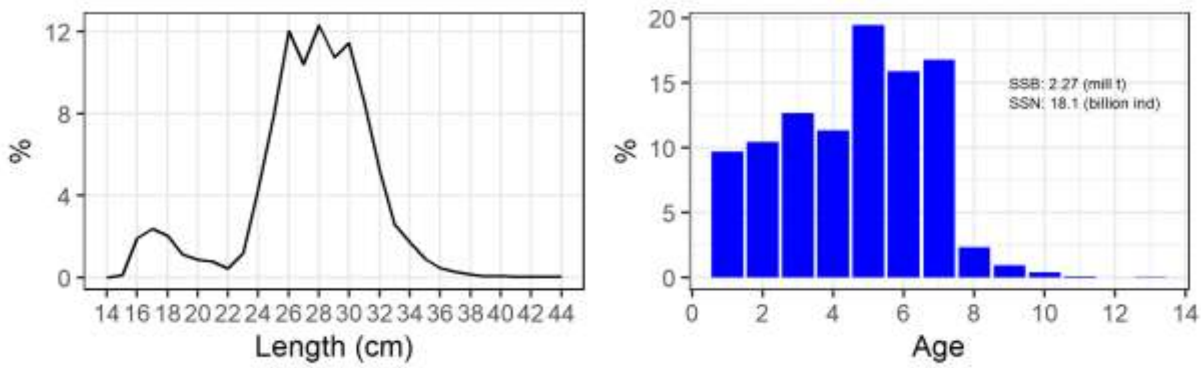


Figure 13. Length and age distribution (numbers) of total stock of blue whiting. March-April 2021.

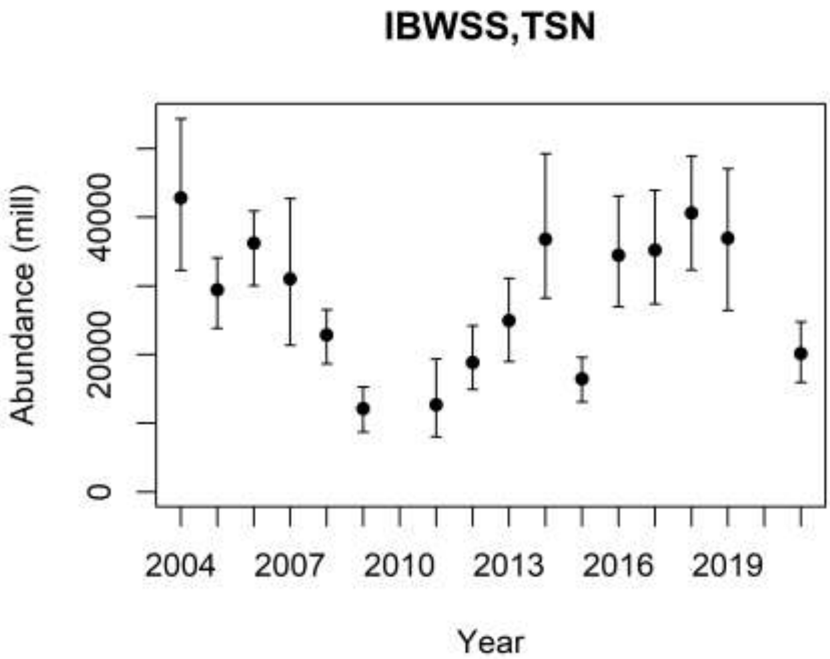


Figure 14. Time series of StoX survey indices of blue whiting abundance, 2004-2021, excluding 2010.

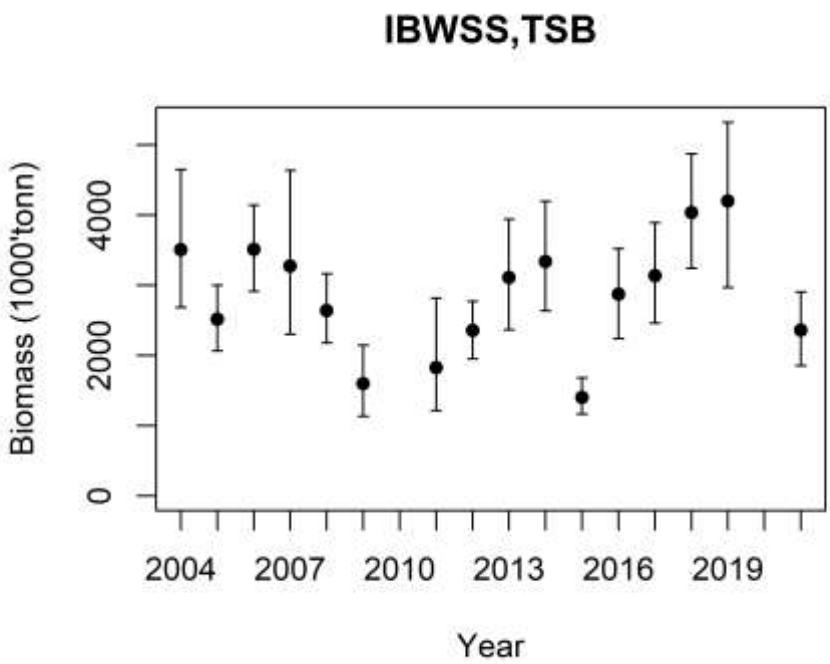


Figure 15. Time series of StoX survey indices of blue whiting biomass, 2004-2021, excluding 2010.

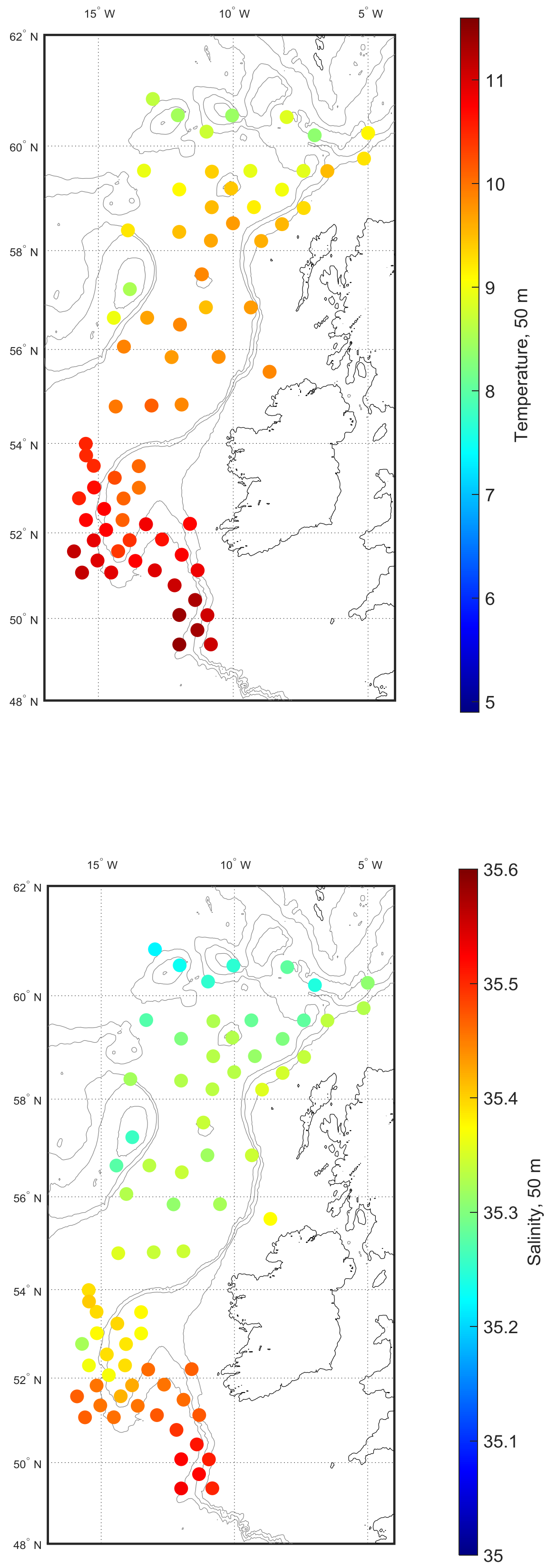


Figure 16. Horizontal temperature (top panel) and salinity (bottom panel) at 50 m subsurface as derived from vertical CTD casts. IBWSS March-April 2021.

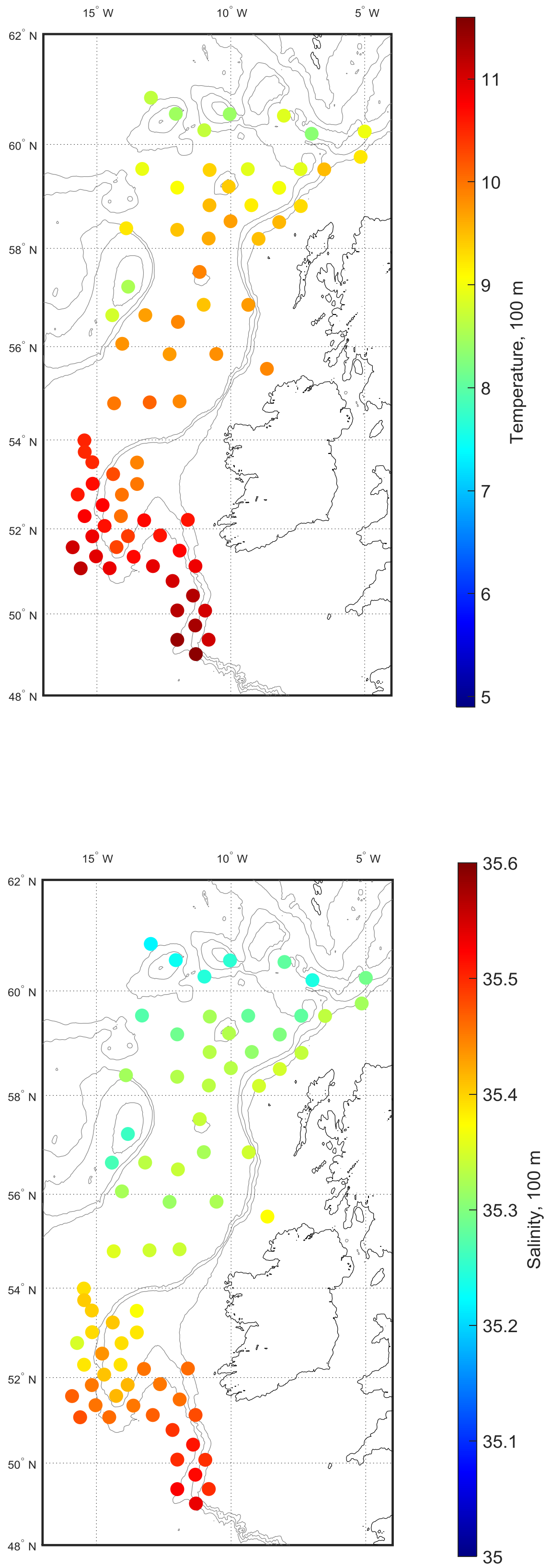


Figure 17. Horizontal temperature (top panel) and salinity (bottom panel) at 100 m subsurface as derived from vertical CTD casts. IBWSS March-April 2021.

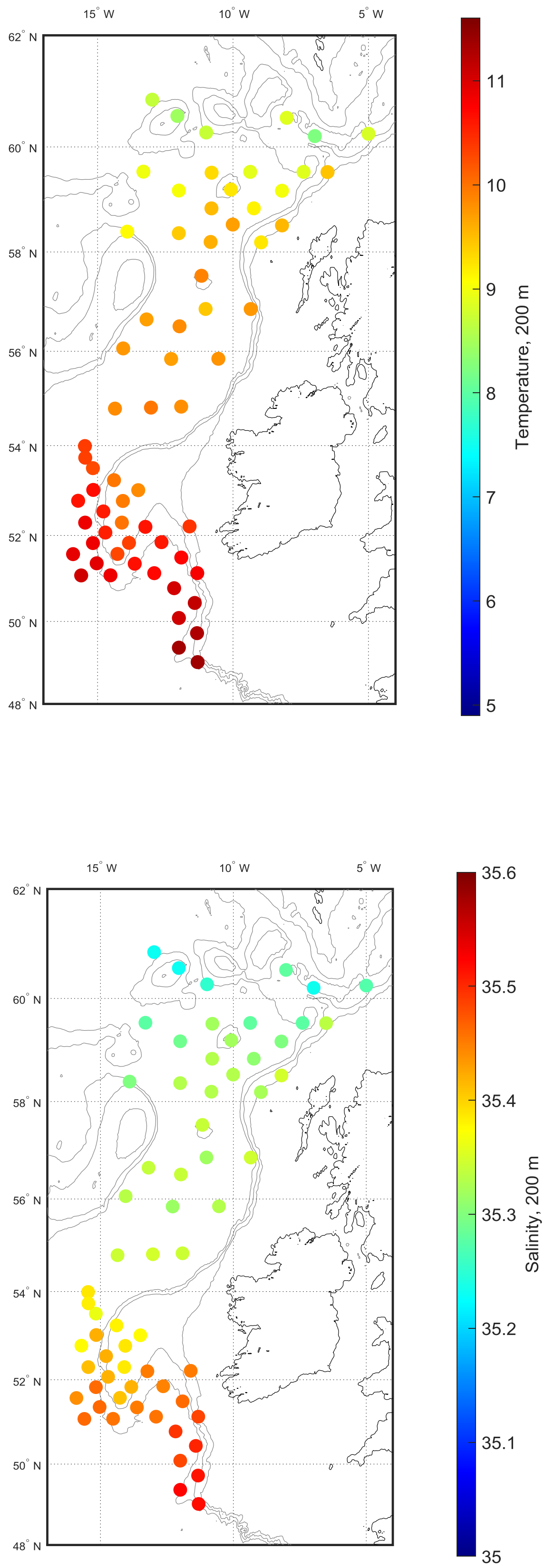
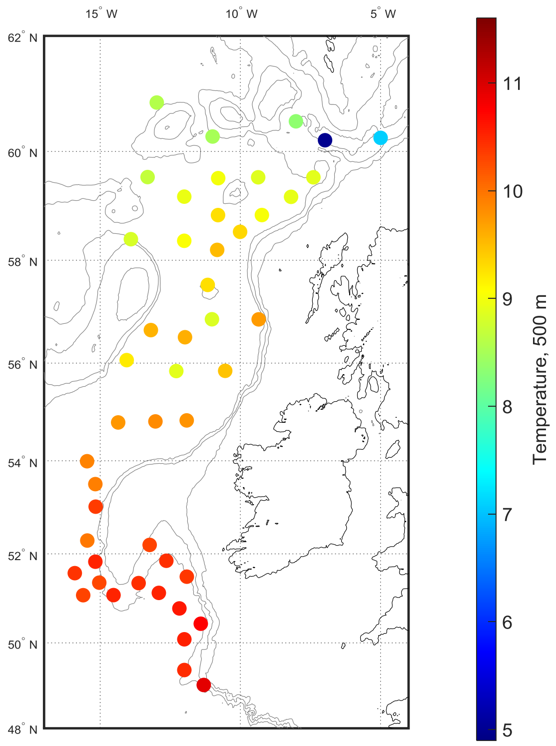


Figure 18. Horizontal temperature (top panel) and salinity (bottom panel) at 200 m subsurface as derived from vertical CTD casts. IBWSS March-April 2021.



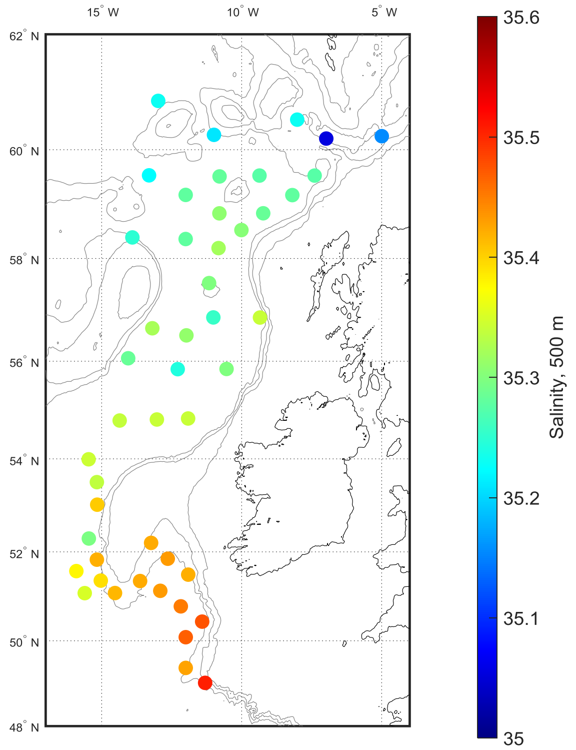


Figure 19. Horizontal temperature (top panel) and salinity (bottom panel) at 500 m subsurface as derived from vertical CTD casts. IBWSS March-April 2021.

Annex 1 – Bad data treatment on board RV Tridens

Part of this year's survey had to be conducted during adverse weather conditions where data quality deteriorated due to vessel motion, increased bubble entrainment and increased noise levels. These factors caused the signal degradation in the form of attenuations, spikes or dropouts. Concerns were especially raised in areas where dense and large aggregations of blue whiting were observed when the weather condition was adverse. Typically, Echoview and LSSS software have generic tools to address these issues, such as noise removal tools (Dunford correction, transient or impulse noise filter) or spike filters. However, such manipulations can come with a cost of data loss or possible additional bias. To understand the effects of this adverse weather condition, a data processing exercise was carried out on board Tridens during the Survey.

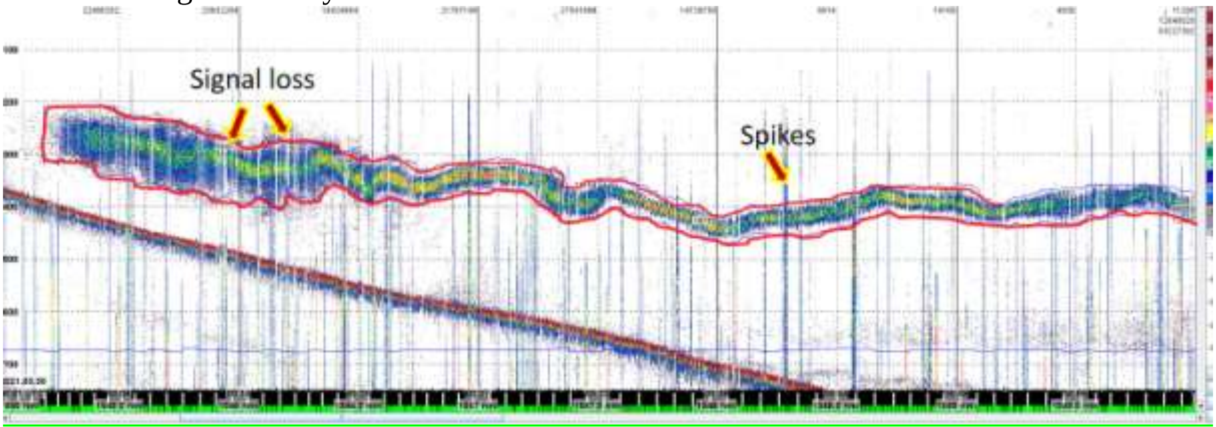


Figure 1 Dense-large aggregation of blue whiting encountered during a period of bad weather (2021 -03-30 early morning). Data contains both spike noise and transmission loss due to abrupt motion of the ship as well as bubble entrainment as a result of bad weather.

The exercise focused on a particular data set where the wind force was 7-8 Beaufort and swell height was greater than 2 m (March 30, 2021). During this time a large and dense aggregation was encountered along the transect where the acoustic recordings were subjected to signal degradation.

The effect of such signal degradation was investigated by using various methods including custom-written R-codes and postprocessing software: LSSS and Echoview. The main objective was to classify the recorded signals as "good pings" and "bad pings".

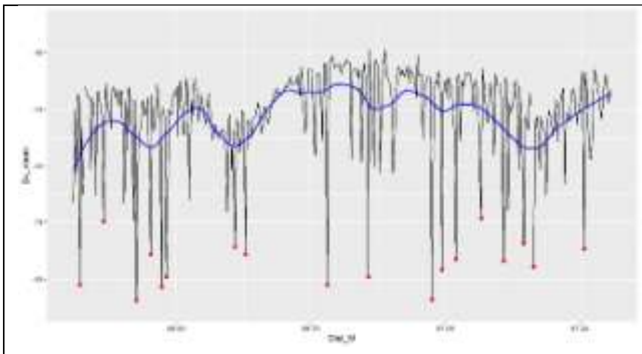
The stepwise processing procedure was as follows;

1- The aggregation was isolated by drawing a line around it.
2- Center of mass (CofMass) of the aggregation was determined per each ping (a function of Echoview that averages the sample depths weighted by sample Sv).
3- A horizontal line connecting the CofMass of each ping was created and a median smoothing filter (moving window of 21 pings) was applied.
4- A region from 5 meter above and below (10 meters in total) of this smoothed CofMass line was integrated per ping.
5- The integrated output values were grouped by 1000 consecutive pings.
6- For each of these 1000 pings a LOESS (local regression smoothing) curve was fitted based on mean Sv values. Using this fitted curve, expected values per each ping were calculated.
7- Standard deviation (SD) per each 1000 ping group was calculated.

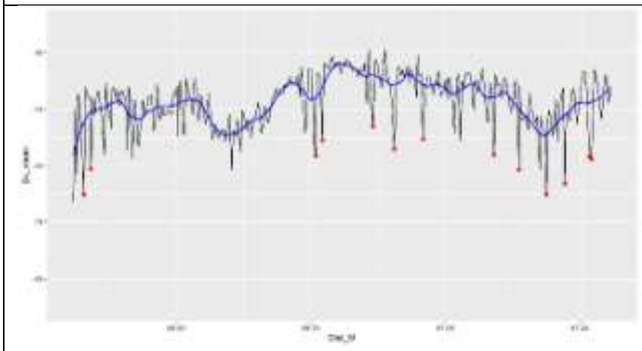
8- The predicted values were subtracted from the observed Sv values per each 1000 ping group and compared against the SD for detection of the outliers (“bad pings”).

9- For outlier-detection a stepwise approach was applied such that,

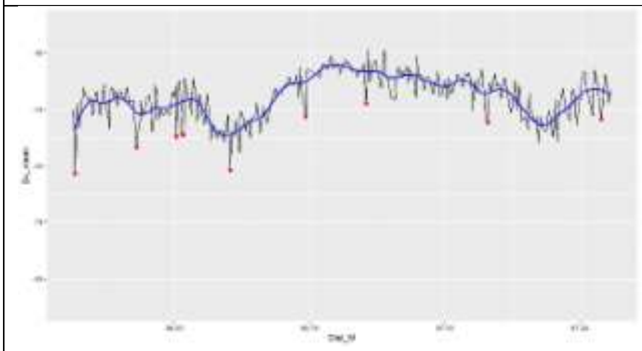
   a. 2*SD was used as a threshold. Values below -2*SD and above +2*SD standard deviations were identified as bad pings and removed from the data.
   b. After removal of bad pings, a new LOESS curve was fitted over the retained values. Again, a new standard deviation was calculated from these retained values and used as threshold for bad pings again.
   c. Same procedure repeated over the same 1000 ping group until no more bad pings were detectable. Then the same procedure was applied to the next ping group.



Step 1



Step 3



Step 5

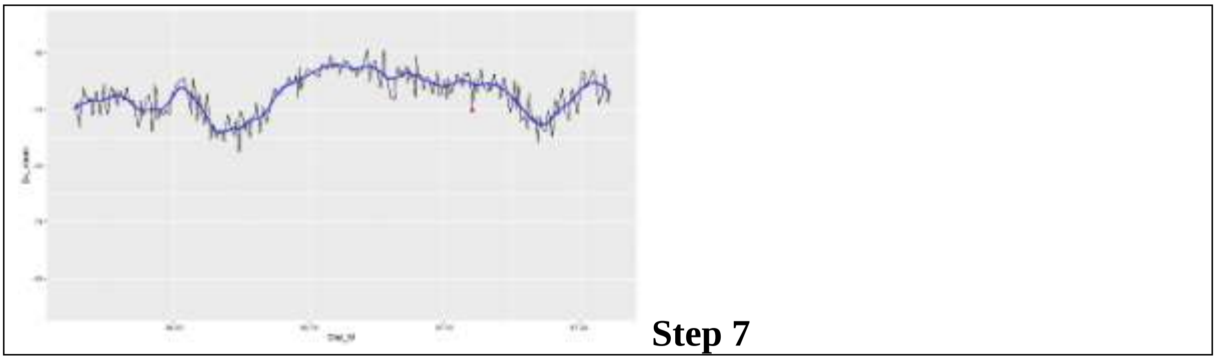


Figure 2 An example of bad ping detection for a group of 1000 pings. For this group, the procedure was finalized in 7 repetitive steps. The red dots indicate the bad pings (beyond SD threshold), the blue line is the fitted LOESS curve. The x axis is the time and the y axis is the mean Sv.

The identified bad-pings were handled in different ways by:

1- Removing all the bad pings
2- Assign bad pings with 0 values
3- Use of the mean value of the surrounding pings

In addition to this custom processing, both Echoview and LSSS has built-in spike filtering algorithms. These algorithms were also used to process separately as well. Results from these different methods were compared with non-cleaned values. The solution where all bad pings were removed resulted in a slightly higher mean Sv. And those where bad pings were assigned to “0” resulted in slightly lower values. However overall variation was less than 5% relative to the uncleaned echograms. Consequently, non-cleaned data was used for the survey calculations.

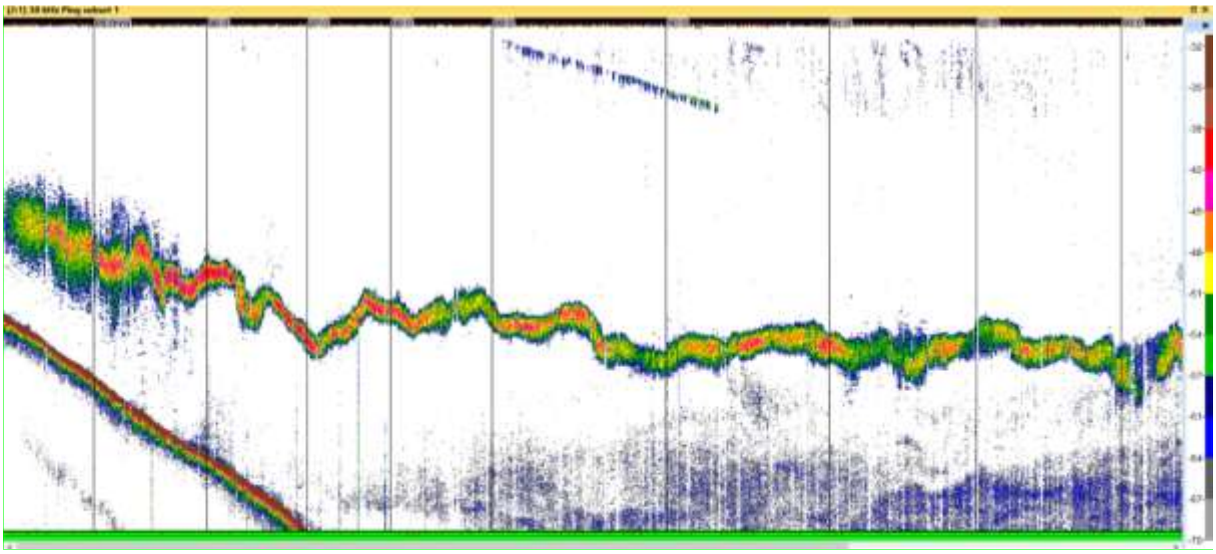


Figure 3 One of the processing solutions where all the identified bad pings were removed using the ping-subset function of Echoview. The resulting echogram looks similar to recordings in good weather.

Annex 4: 2021 IESNS Survey Summary Table and Survey Report

Document 4a: IESNS 2021 survey summary table

Survey Summary table WGIPS	
Name of the survey (abbreviation):	International Ecosystem Survey in the Nordic Seas (IESNS)
Target Species:	Norwegian spring-spawning herring
Survey dates:	29 April – 28 May
Summary:	
Survey effort, timing and area coverage in 2021 were comparable to previous years in the Nordic Seas and the Barents Sea was covered again after the lack of coverage in 2020. The zero-line of the distribution of herring was considered to be fully reached in the Nordic Seas and in the Barents Sea. It is recommended that the results from IESNS 2021 can be used for assessment purpose. 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 western areas, while relatively high concentrations of herring of the 2016 year-class were obseverd in the easternmost and central part of the survey area. The total estimate of herring in the Norwegian Sea from the 2021 survey was 22.9 billion in numbers and the biomass 5.10 million tonnes. This estimate is a 21 % increase from the 2020 survey estimate in biomass and a 1% 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. Five year old herring (year class 2016) dominated both in terms of number and biomass. Its number at age 5 is at the same level as the 2004 year class at same age. The estimate from the Barents Sea was 125 million individuals and 4321 t.	

	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 ICES 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 2021 survey: the entire stock during its migration on the feeding grounds, the adults in the Nordic Seas and the juveniles in the Barents Sea.
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 samples were collected in 2021 to further address this.
Measures of uncertainty (CV)	The estimated survey uncertainty (CV) for the main age groups in the sestimate was around 0.2-0.25.
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. Samples for such a workshop were collected.
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 2021 survey report

*Please find report on the next page.

IESNS post-cruise meeting, webex 15-18/6 2021

Working Document to

Working Group on International Pelagic Surveys (WGIPS)
January 2022
and
Working Group on Widely Distributed Stocks (WGWIDE)
25 - 31 August 2021

INTERNATIONAL ECOSYSTEM SURVEY IN NORDIC SEA (IESNS) in April - May 2021

Post-cruise meeting on Teams, 15-18 June 2021

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 Dr. Fridtjof Nansen

Susan Mærsk Lusseau[2], Matthias Kloppmann[3]
RV Dana

Sigurvin Bjarnason[4]
RV Árni Friðriksson

Eydna í Homrum[5], Jan Arge Jacobsen[5], Leon Smith[5]
RV Jákup Sverri

Maxim Rybakov[6]
RV Vilnyus

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[6] Polar branch of VNIRO («PINRO»), Murmansk, Russia

Introduction

In April-May 2021, five 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 Jakup Sverri, Faroe Islands, R/V Árni Friðriksson, Iceland, R/V Dr. Fridtjof Nansen, Norway and R/V Vilnyus, Russia 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 abundance 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 2021 that are stored in the PGNAPES database and the ICES database and supported by national survey reports from each survey (Dana: Cruise Report R/V Dana Cruise 03/2021. International Ecosystem survey in the Nordic Seas (IESNS) in 2021, Árni Friðriksson: Report on Survey A9-2021, Bjarnason ,2021, Vilnyus: Rybakov PINRO 2021).

Material and methods

Coordination of the survey was done during the WGIPS meeting in January 2021 and by correspondence. Planning of the acoustic transects and hydrographic stations and plankton stations were carried out by using the survey planner function in the r-package Rstox version 1.11 (see https://www.hi.no/en/hi/forskning/projects/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, because the transects follow great circles 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	01/5-27/5
Dr. Fridtjof Nansen	Institute of Marine Research, Bergen, Norway	29/4-28/5
Jákup Sverri	Faroe Marine Research Institute, Faroe Islands	29/4- 9/5
Árni Friðriksson	Marine and Freshwater Research Institute, Iceland	06/5-25/5
Vilnyus	Polar branch of VNIRO («PINRO»), Murmansk, Russia	28/4-25/5

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 conditions did not affect the survey even if there were some days that were not favourable and prevented trawling, 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	Dr. Fridtjof Nansen	Arni Friðriksson	Jákup Sverri	Vilnyus
Echo sounder	Simrad EK60	Simrad EK80	Simrad EK80	Simrad EK80	Simrad EK60
Frequency (kHz)	**38**	**38**, 18, 70, 120, 200, 333	**38**, 18, 70, 120, 200	18,**38**, 70, 120, 200, 333	**38**
Primary transducer	ES38BP	ES 38-7	ES38-7	ES38B	ES 38B
Transducer installation	Towed body	Drop keel	Drop keel	Drop keel	Hull
Transducer depth (m)	5 - 7	5.35	8	6-9	4.5
Upper integration limit (m)	10	15	15	15	10
Absorption coeff. (dB/km)	10.3	10.1	10.5	10.7	10.0
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.43	2.425	3.06	2.425
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	18	21.9	21.9
2-way beam angle (dB)	-20.5	-20.7	-20.3	-20.4	-20.6
Sv Transducer gain (dB)					
Ts Transducer gain (dB)	25.45	27.02	27.05	26.96	26.02
s_A correction (dB)	-0.55	0.02	-0.02	-0.16	-0.67
3 dB beam width (dg)					
alongship:	6.89	6.29	6.42	6.55	6.97
athw. ship:	6.87	6.31	6.47	6.45	7.00
Maximum range (m)	500	500	500	500	500
Post processing software	LSSS	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. Immediately after the 2021 survey an online meeting was held to standardise the scrutiny and to agree on particularly difficult scrutiny situations encountered. 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	Dr. Fridtjof Nansen	Arni Friðriksson	Jákup Sverri	Vilnyus
Circumference (m)		**624**	**832**	**832**	**500**
Vertical opening (m)	**20-35**	**25-35**	**20–35**	**45–55**	**50**
Mesh size in codend (mm)	**20/40**	**22**	**20/40**	**45**	**16**
Typical towing speed (kn)	**3.5-4.0**	**3.0–4.5**	**3.1–5.0**	**3.8–.4.9**	**2.9-4.6**

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	Dr. Fridtjof Nansen	Arni Friðriksson	Jákup Sverri	Vilnyus
Length measurements	Herring	200-300	100	300	200-300	300
	Blue whiting	200-300	100	50	100-200	0
	Mackerel	100-200	100	50	100-200	0
	Other fish sp.	50	30	30	100-150	100-300
Weighed, sexed and maturity determination	Herring	50	25-100	100	50-100*	50-100
	Blue whiting	50	25-100	50	50*	0
	Mackerel	50	25-100	50	50	0
	Other fish sp.	0	0	0	0*	25-50
Otoliths/scales collected	Herring	50	25-30	100	50-100	50-100
	Blue whiting	50	25-30	50	50	0
	Mackerel	0	25-30	50	50	0
	Other fish sp.	0	0	0	0	25-50
Stomach sampling	Herring	0	10	10	5	25
	Blue whiting	0	10	10	5	0
	Mackerel	0	10	10	5	0
	Other fish sp.	0	0	0	0	25

* Number of weighed individuals significantly higher.

Acoustic data were analysed using the StoX software package (version 3.1.0) 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: https://www.hi.no/en/hi/forskning/projects/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 5 strata with pre-defined acoustic transects. 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 2. Generally, and in accordance with most WGIPS coordinated surveys, 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. However, due to uneven distribution of younger and older herring in Strata 1 and 3 (see Fig 12) adaptations were made as follows: In Stratum 1, all transects were split in two at 7°W and trawl stations east and west of 7°W were assigned to the respective transects east and west of 7°W; in Stratum 3 the first three transects were split at 5°W – west of 5°W the 5 closest trawl stations were assigned and east of 5°W the four closest trawl stations were assigned.

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 (Foote et al. 1987)

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 except the Russian vessel which used a Djedi net, 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. It has been noted that the Djedy net applied by the Russian vessel in the Barents Sea seems to be less effective in catching zooplankton in comparison to WP2

WPII net applied by other vessels in an overlapping area. Thus, the biomass estimates for the Barents Sea are not directly comparable to the other areas but are comparable among years within the Barents Sea. The Russian data from the Barents Sea are not included in the 2021 report.

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 9-10°C in the southern part of the Norwegian Sea (Figure 5). The Arctic front was encountered below south of 65°N east of Iceland extending eastwards towards about 2° W where it turned north-eastwards 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° W 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 5-6 °C to the Bear Island at 74.5° N in the surface layer.

Relative to the 25 year long-term mean, from 1995 to 2019, the temperatures at 0-50 m were below mean in the southern and eastern parts of the Norwegian Sea and in the Lofoten Basin (Figure 5). Below 50 m depth, the patterns were more fragmented but at 200-500 m depth the Norwegian Basin was in general colder than the long-term mean, probably due to increased influence of Arctic water at this depth (Figure 7). Largest negative temperature anomalies were between Iceland and Faroe Islands due to a more southern located Iceland-Faroe front compared to the long-term mean. This was found for all depths and the temperatures in this region were in some locations 2-3 °C lower than the mean (Figures 5-7). Warmest region relative to the long-term mean was in the eastern Greenland Sea and particular in the upper 200 m with temperatures 2 °C higher than the mean.

The temperature, salinity and potential density in the upper 800 m at the Svinøy section in 6-8 May 2021 are shown in Figure 8. Atlantic water is lying over the colder and fresher intermediate/deep 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 30 years long-term mean, from 1978 to 2007, the temperatures in 2021 near the shelf edge were higher than the mean at 50-400 m depth and lower the mean below this depth. Further westward, the temperatures were both lower and higher than the mean due to meandering or eddies. The pattern of salinity anomaly follows in general the pattern of temperature anomaly. The increased influence of Arctic water observed at 200-500 m (Figures 6-7) can also be observed in the western part of the section at 200-400 m depth with temperature and salinity anomalies lower than the long-term mean (Figure 8).

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 in the last four decades a similar layer has been observed all over the Norwegian Sea. Also, in periods this layer has been less well-defined.

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 sampling area. High biomasses were found east/northeast of Jan Mayen (i.e. in northwestern parts of the Norwegian Sea), north of Faeroe Islands, in the Lofoten/Vesterålen area at the Norwegian coast, and in the northernmost sampled area towards the Bear Island at the entrance to the Barents Sea. Lower biomasses were found in the most central parts of the Norwegian Sea.

Figure 10 shows the zooplankton indices for the sampling area (delimited to east of 14°W and west of 20°E). To examine regional biomass difference, the area was divided into 4 sub-areas 1) the Norwegian Sea Basin (covering the southern Norwegian Sea), 2) the Lofoten Basin (covering the northern Norwegian Sea, 3) the Jan Mayen Arctic front, and 4) East of Iceland. The mean index of sub-area 1 and 2 is also given, called the Norwegian Sea index, and this index cover large parts of the Norwegian Sea. The zooplankton biomass index for the Norwegian Sea was in 2021 8.0 g dry weight m^{-2}, which is at similar level as in previous years, but with a small decrease. The same situation was observed in all sub-areas. Highest biomass (12.3 g dry weight m^{-2}) was observed in the sub-area "Northeast of Iceland".

The zooplankton biomass indices for the Norwegian Sea in May have been estimated since 1995. For the period 1995-2002 the plankton biomass was relatively high (mean 11.5 g), with fluctuations 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 2003-2021. There has been an increasing trend during 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 reasons for the changes in zooplankton biomass are not obvious. It is worth noting that the period with lower zooplankton biomass coincides with higher-than-average heat content in the Norwegian Sea (ICES, 2020) and reduced inflow of Arctic water into the southwestern Norwegian Sea (Kristiansen et al., 2019). Timing effects, such as match/mismatch with the phytoplankton bloom, can also affect the zooplankton abundance. The 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 may be 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.

Norwegian spring-spawning herring

Survey coverage in the Norwegian Sea was considered adequate in 2021. The zero-line was believed to be reached for adult NSS herring in most of the areas. It is recommended that the results from IESNS 2021 can be used for assessment purpose. The herring was primarily distributed in the south-western area (Figure 11). In the westernmost area old herring dominated, but in general, the 2016-year-class was the most abundant year class throughout the survey area. 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).

Five year old herring (year class 2016) dominated both in terms of number (53%) and biomass (46 %) on basis of the StoX bootstrap estimates for the Norwegian Sea (Table 2). This year class as 5 year old is as large as the 2004 year class was at same age (Figure 13), and this puts the magnitude of the 2016 year class into perspective as a large year class. There was a slight decrease in abundance of the 2016 year class from last year, which is not expected for young herring. However, the decrease was small and within the uncertainty estimates of abundance of 4 year old herring last year and 5 year old herring this year. The 2004 year class, which has dominated the stock together with the 2002 year class, still contributes significantly to the biomass of older age-groups (see paragraph on issues with age determination below). Herring aged 12-18 years old thus comprised 13% of the numbers and 21% of the biomass. Uncertainty estimates for number at age based on bootstrapping within StoX are shown in Figure 14 and Table 2. The relative standard error (CV) of the total biomass estimate is 15 % and 16 % for the total numbers estimate, and the relative standard error for the dominating age groups is around 20 % (Figure 14 and Table 5).

The total estimate of herring in the Norwegian Sea from the 2021 survey was 23 billion in number and the biomass was 5.1 million tonnes. The biomass estimate is 0.90 million tonnes (21 %) higher than the 2020 survey estimate while the estimated number is 2% higher in 2021. 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 16), with the lowest abundance occurring in 2017. The 2016 year class now appears to be fully recruited, distributed widely in the feeding area and more dominant than the older year classes.

The Barents Sea was also covered adequately in 2021. The results based on bootstrap are shown in Table 4 and Figure 15. The estimated total abundance (125 million) and biomass (4.3 thousand tonnes) of herring in the Barents Sea was the lowest observed in the time series that started in 1991. The 3 year olds (2018 year class) was the most abundant year class in the Barents Sea.

In the last 6 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. As a follow-up on that work, a new exchange and following workshop are currently being planned and sampling of exchange material has started. 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 the cruise tracks of the Norwegian vessel did not cover strata 1 and 3. However, in strata 2 and 4 there was overlap between the Norwegian vessel and the Danish vessel and the age distributions from those strata seem to be relatively similar between the two vessels (Figure 17). In stratum 1 there was overlap between the Icelandic and Faroese vessel and the difference in age distributions mainly reflected differences in the length distribution.

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. 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).

In the IESNS 2021 survey, all herring in Stratum 1 was allocated to NSSH. This year there were only minor issues with mixing, because only limited amounts of herring of autumn spawning type were caught.

Blue whiting

The spatial distribution of blue whiting in 2021 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 off Norway and along the Scotland – Iceland ridge (Figure 18). Blue whiting was distributed similar as last year. The largest fish were found in the western and northern part of the survey area (Figure 19). 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 2021 was 0.85 million tonnes, which is a 118 % increase from the biomass estimate in 2020 (0.39). The abundance index for 2021 was 13.9 billion, which is 184 % higher than in 2020 (4.9). Age 1 is totally dominating the acoustic estimate (50 % of the biomass and 74% by number). Uncertainty estimates for numbers at age based on bootstrapping with StoX are shown in Figure 20 and Table 3. The relative standard error (CV) of total biomass estimate is 14 % and 14 % also for total numbers (Table

3). The 2021 estimate of one-year old blue whiting was the highest in the IESNS time series (from 2008). The survey group compared age and length distributions by vessel and strata (Figure 21 and 22) and no clear differences were found compared to earlier years.

Mackerel

Trawl catches of mackerel are shown in Figure 23. Mackerel was present in the southern and eastern part of the Norwegian Sea (as far north as 68°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.

Pink Salmon

Pink salmon is a relatively new species in the Nordic Seas and was caught in the IESNS surveys since 2017 – and only every other year, when the odd-year spawning component conducts oceanic migrations. This is in accordance with observations of spawning pink salmon in particularly northern Norwegian rivers in later years. In 2021 a total of 91 pink salmon were caught during the survey. The distribution area was mainly on and off the Norwegian shelf and north off the Faroe Plateau.

General recommendations and comments

Recommendation	Addressed 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

Next year's post-cruise meeting

We will aim for next meeting in 14-16 June 2022. The final decision will be made at the next WGIPS meeting.

Concluding remarks

- The sea temperature in 2021 was generally below the long-term mean (1995-2019) in the Norwegian Sea, but the pattern was more fragmented 50-200 m.
- The 2021 index of meso-zooplankton biomass in the Norwegian Sea and adjoining waters decreased marginally from last year.

- The total biomass estimate of NSSH in herring in the Norwegian Sea was 5.1 million tonnes, which is a 21 % increase from the 2020 survey estimate. The estimate of total number of NSSH was 23 billion, which is 2 % higher than in the 2020 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 (53%) and biomass (46%), and it is on the same level as the strong 2004 year class at the same age (in the 2009 survey). In numbers, the estimate of the 2016 year class decreased from age four to age five. This is not the usual pattern for NSS herring, but the decrease was small and within the uncertainty estimates of abundance of four year old herring in 2020 and five year old herring in 2021.
- The estimated total abundance and biomass of herring in the Barents Sea was the lowest observed in the time series that started in 1991.
- The biomass of blue whiting measured in the 2021 survey increased by 118 % from last year's survey and 184 % in terms of numbers. Age 1 (2020 year class) is the dominating year class (50 % of the biomass and 74% by number), and this year's estimate of one year olds is the highest in the time series.

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Tables

Table 1. Survey effort by vessel for the International ecosystem survey in the Nordic Seas in May - June 2021.

Vessel	Effective survey period	Effective acoustic cruise track (nm)	Trawl stations	Ctd stations	Aged fish (HER)	Length fish (HER)	Plankton stations
Dana	01/05-27/05	2056	20	35	476	1537	35
Jákup Sverri	29/4-9/5	1334	16	22	361	1547	21
Árni Fridriksson	8/5-23/5	2980	22	38	1531	5537	34
Dr. Fridtjof Nansen	29/4-28/5	4518	37	47	362	1149	45
Vilnyus	29/4-21/5	3540	58	50	151	362	50
Total		**14428**	**153**	**192**	**2881**	**10132**	**185**

Table 2. IESNS 2021 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring. The estimates are mean of 1000 bootstrap replicates in Stox.

Length	Age in years (year class)																			Number	Biomass	Mean
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Unknown			weight
(cm)	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003		(10^6)	(10^6 kg)	(g)
15-16																						
16-17																						
17-18																			8.4	8.4	0.3	31.5
18-19																			4.2	4.2	0.2	40.0
19-20																			66.8	66.8	2.9	43.6
20-21			270.1	16.4																286.5	15.3	53.4
21-22			318.4																0.2	318.6	19.5	61.4
22-23			236.4	2.3															0.1	238.8	16.6	73.4
23-24			147.5	49.5															0.7	197.7	16.1	90.6
24-25			9.5	155.8																165.4	16.8	110.6
25-26		23.1	5.6	156.9	12.0														0.2	197.8	24.2	123.4
26-27	14.9	10.5	34.8	91.6	158.6															310.3	41.8	136.6
27-28			42.1	171.9	389.2	6.0	5.9													615.1	92.0	152.0
28-29			31.6	232.3	1138.6	5.3	14.2													1 422.0	231.6	163.9
29-30			12.8	258.4	2834.1	13.6	59.8	13.5	12.8			2.9								3 207.8	570.5	178.3
30-31				91.2	3052.8	93.4	116.3	87.0	40.8	32.1	3.6									3 517.2	685.8	195.7
31-32				40.6	2619.6	126.1	108.4	168.9	22.6		31.4	21.3								3 138.9	688.2	218.5
32-33				10.3	1431.7	264.5	199.8	181.6	38.7	29.8	45.9									2 202.4	517.3	235.2
33-34				12.6	221.4	107.0	311.6	616.5	19.7	32.0	4.2	5.3								1 330.4	343.7	259.9
34-35					47.9	55.0	175.0	622.0	104.6	54.6	4.4	1.1								1 064.7	298.0	281.7
35-36						27.3	44.3	300.6	150.7	103.5	51.3	66.5	45.8	52.0	34.8	2.3	12.2			891.2	269.5	304.6
36-37							15.9	41.6	88.1	163.3	226.6	189.5	178.3	201.8	160.9	95.8	6.5			1 368.3	450.6	332.1
37-38								7.1	20.0	120.2	97.1	159.8	141.7	269.5	324.2	248.3	38.9	5.8		1 432.6	496.3	349.0
38-39									2.8	15.3	11.9	15.3	65.0	72.8	189.4	182.2	76.7	2.8		634.2	235.1	373.7
39-40													11.5	19.2	42.8	37.6	42.1	5.6		158.8	61.6	388.9
40-41																	6.1		2.7	8.8	2.3	387.8
TSN(mill)	14.9	33.6	1108.8	1289.9	11906.0	698.2	1051.1	2038.8	500.8	550.8	476.4	461.7	442.3	615.3	752.1	566.1	182.4	14.2		22 983.8		
cv (TSN)	1.20	1.22	0.50	0.19	0.20	0.22	0.21	0.19	0.20	0.25	0.25	0.26	0.30	0.30	0.31	0.31	0.35	0.64		0.16		
TSB(1000 t)	2.0	3.7	82.2	196.7	2 329.5	163.8	259.5	546.2	140.9	166.2	148.2	150.7	149.9	212.0	267.7	201.8	66.2	5.5		5 096.3		
cv (TSB)	1.20	1.22	0.45	0.18	0.20	0.21	0.20	0.19	0.20	0.25	0.26	0.27	0.31	0.30	0.31	0.31	0.35	0.64		0.15		
Mean length(cm)	26.0	25.3	23.5	27.3	29.9	32.0	32.7	33.7	34.7	35.6	35.9	36.2	36.6	36.7	37.1	37.2	37.9	37.7				
Mean weight(g)	137.0	110.3	98.3	157.7	195.2	237.1	256.5	276.4	295.3	312.7	325.6	334.6	342.7	347.9	359.0	359.1	363.9	382.0				

Table 3. IESNS 2021 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of blue whiting. The estimates are mean of 1000 bootstrap replicates in Stox.

Length	Age in years (year class)											Number	Biomass	Mean
	1	2	3	4	5	6	7	8	9	10	Unknown			weight
(cm)	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011		(10^6)	(10^6 kg)	(g)
15-16														
16-17	67.8	6.7									0.3	74.8	1.8	24.1
17-18	888.9	13.9										902.9	26.3	29.7
18-19	2344.4	65.7										2 410.1	81.6	34.5
19-20	3056.6	65.1										3 121.7	124.7	40.3
20-21	2457.7	32.4	10.0									2 500.2	117.2	47.0
21-22	1048.4	143.0	3.7									1 195.2	63.8	53.6
22-23	331.6	191.2	61.6									584.4	36.0	62.0
23-24	55.4	348.1	43.6									447.1	32.2	73.5
24-25	5.6	319.8	91.0	3.0								419.3	33.9	82.6
25-26	4.4	139.4	201.4	9.6	2.5							357.4	34.3	96.9
26-27		145.4	150.9	46.3		35.1		10.4				388.1	42.0	109.7
27-28		27.9	147.3	36.4	4.8	1.6	18.3					236.4	27.6	118.6
28-29	2.8	2.0	64.8	45.4	11.4	43.0	16.4	10.1				195.7	26.3	135.9
29-30			43.7	83.8	77.8	5.3	14.4					225.0	35.3	159.2
30-31			2.8	23.2	66.9	126.6	44.4	6.7		12.3		282.9	48.4	173.0
31-32				35.6	45.5	134.7	34.3	29.5	8.3			287.9	55.6	195.2
32-33			11.5	18.9	19.5	49.1	24.1	11.5				134.5	28.2	210.9
33-34					18.2	13.9	9.6	8.3	7.0		0.1	57.1	13.1	233.4
34-35					2.2	12.7	27.5				0.2	42.5	10.0	242.0
35-36					10.1						0.3	10.3	2.4	235.1
36-37						11.9						11.9	3.4	283.0
37-38														
38-39						7.8					1.3	9.1	2.9	316.4
39-40											5.3	5.3	1.4	462.0
> 40											3.8	3.8	2.8	732.0
TSN(mill)	10264	1500	832	302	259	442	189	77	15	12		13 903.3		
cv (TSN)	0.17	0.23	0.25	0.32	0.38	0.46	0.40	0.66	0.77	1.21		0.14		
TSB(1000 t)	424.9	110.1	86.8	45.3	47.2	79.1	34.1	13.6	3.4	2.1		851.2		
cv (TSB)	0.16	0.22	0.26	0.33	0.39	0.46	0.41	0.66	0.76	1.21		0.14		
Mean length(cm)	19.3	23.1	25.7	28.2	30.0	30.6	30.4	30.3	31.8	30.0				
Mean weight(g)	43	77	106	147	179	184	178	179	223	175				

Table 4. IESNS 2021 in the Barents Sea. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring. The estimates are mean of 1000 bootstrap replicates in Stox.

Length (cm)	Age in years (year class) 1 2020	2 2019	3 2018	4 2017	5 2016	Number (10^6)	Biomass (10^3 kg)	Mean weight (g)
9-10	7.1					7.1	32	4.6
10-11	8.5					8.5	49	5.8
11-12	2.8					2.8	25	9.0
12-13	2.8					2.8	31	11.0
13-14								
14-15								
15-16								
16-17		1.7				1.7	50	29.0
17-18			5.7			5.7	187	32.9
18-19			18.8			18.8	733	39.0
19-20			29.2			29.2	1291	44.3
20-21			23.1			23.1	1165	50.4
21-22			5.2	1.4		6.6	378	57.4
22-23			2.6	0.7		3.3	208	62.9
23-24			1.9			1.9	131	68.0
24-25				0.2		0.2	20	92.0
25-26								
26-27					0.2	0.2	20	92.0
27-28								
28-29								
29-30								
TSN(mill)	21.2	1.7	86.5	2.3	0.2	125.1		
cv (TSN)	0.81	0.84	0.37	0.58	0.78	0.36		
TSB(t)	138.3	50.5	3 974.7	137.8	20.1	4 321.4		
cv (TSB)	0.81	0.84	0.37	0.53	0.78	0.37		
Mean length(cm)	10.1	16.0	19.3	22.2	26.0			
Mean weight(g)	7	29	47	68	92			

Figures

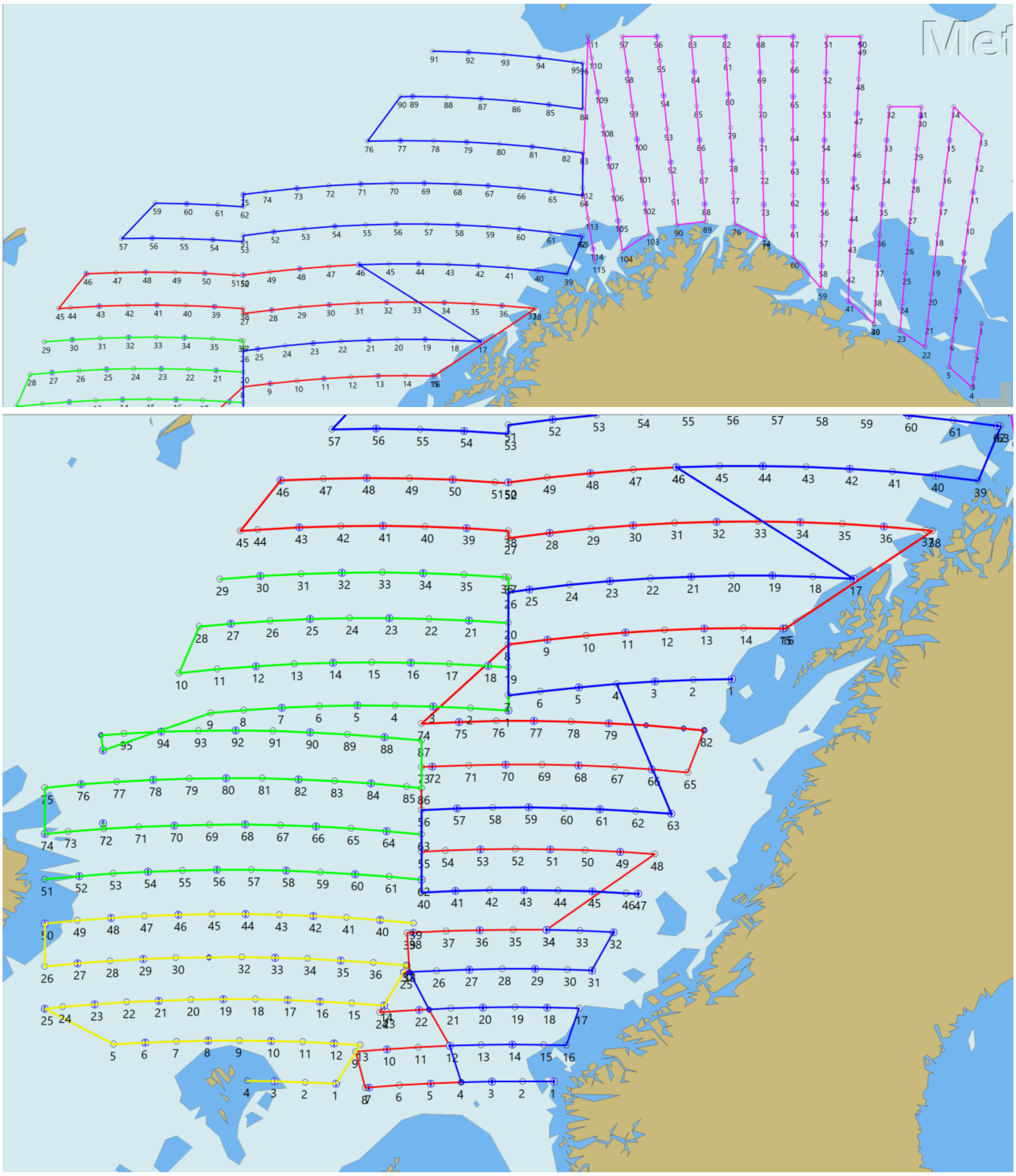


Figure 1. The pre-planned strata and transects for the IESNS survey in 2021 (red: EU, dark blue: Norway, yellow: Faroes Islands, violet: Russia, green: Iceland). Hydrographic stations and plankton stations are shown as blue circles with diamonds. All the transects have numbered waypoints for each 30 nautical mile and at the ends.

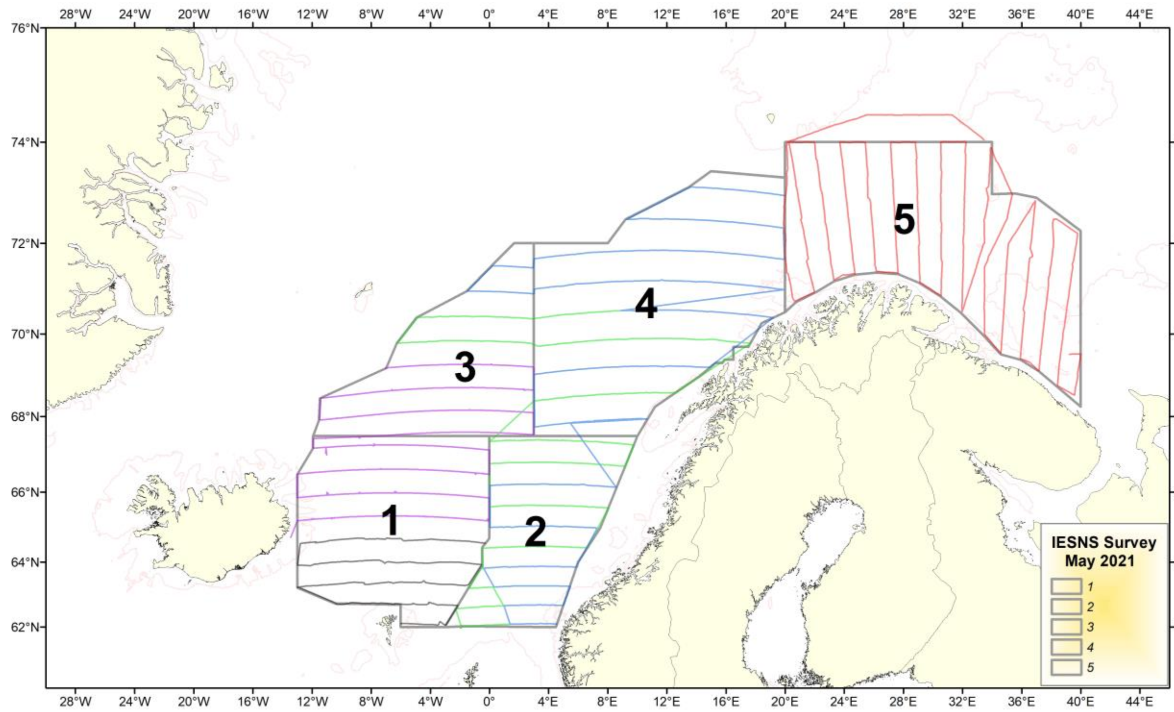


Figure 2. Cruise tracks and strata (with numbers) for the IESNS survey in May 2021.

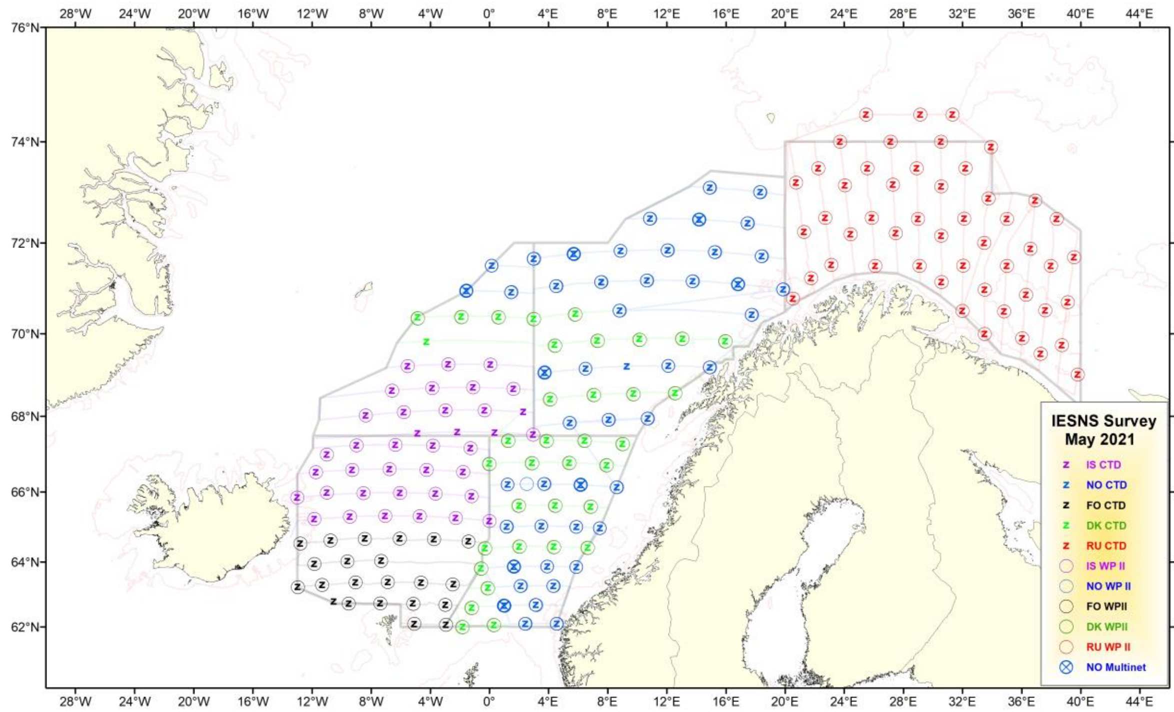


Figure 3a. IESNS survey in May 2021: location of hydrographic and plankton stations. The strata are shown.

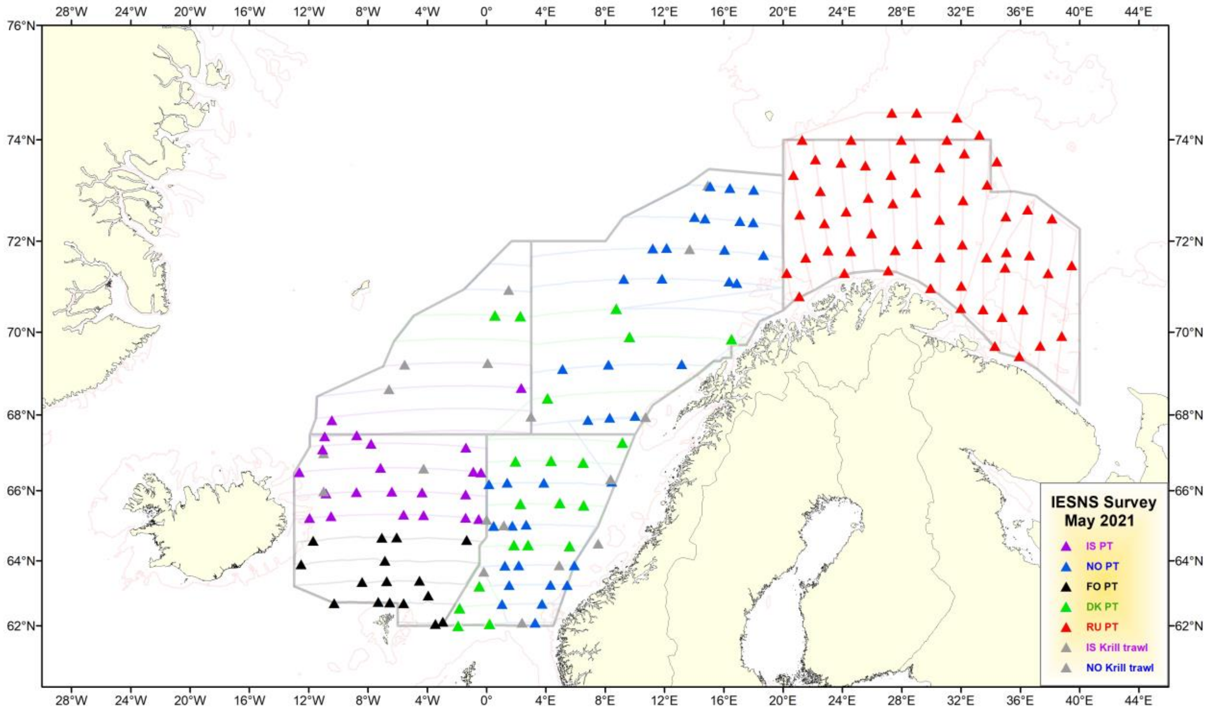


Figure 3b. IESNS survey in May 2021: location of pelagic trawl stations. The strata are shown.

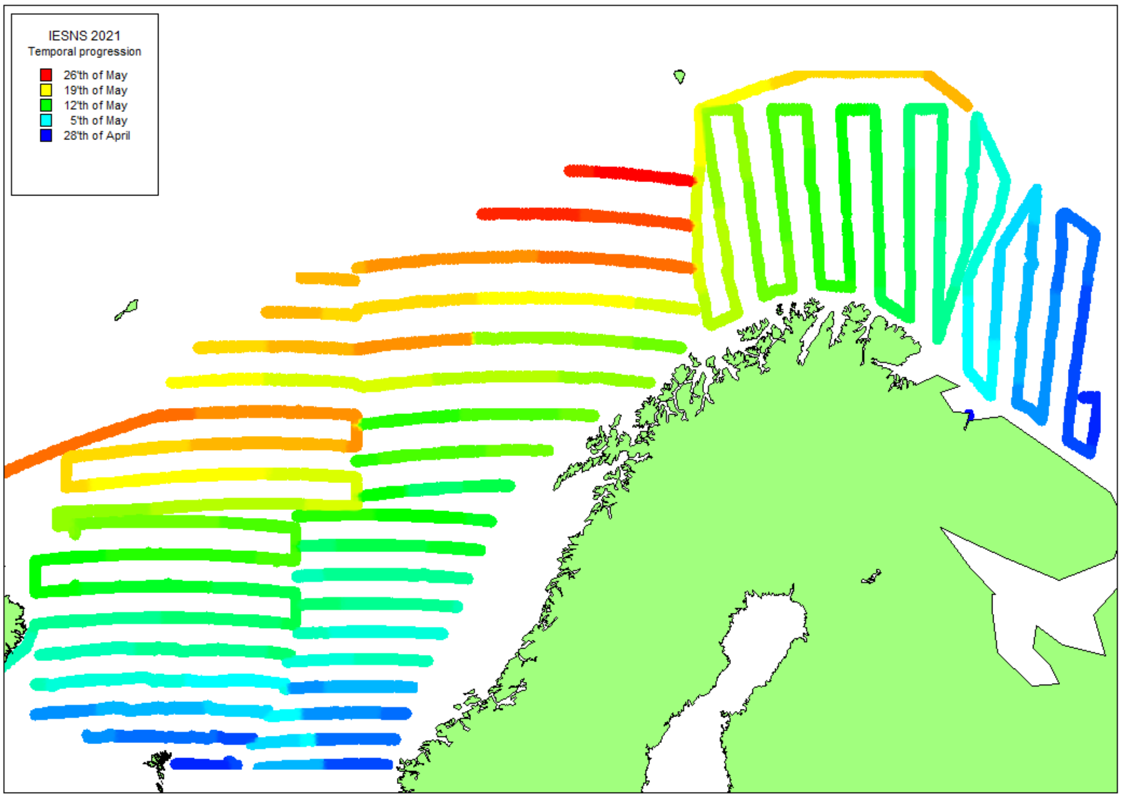


Figure 4. Temporal progression IESNS in May 2021.

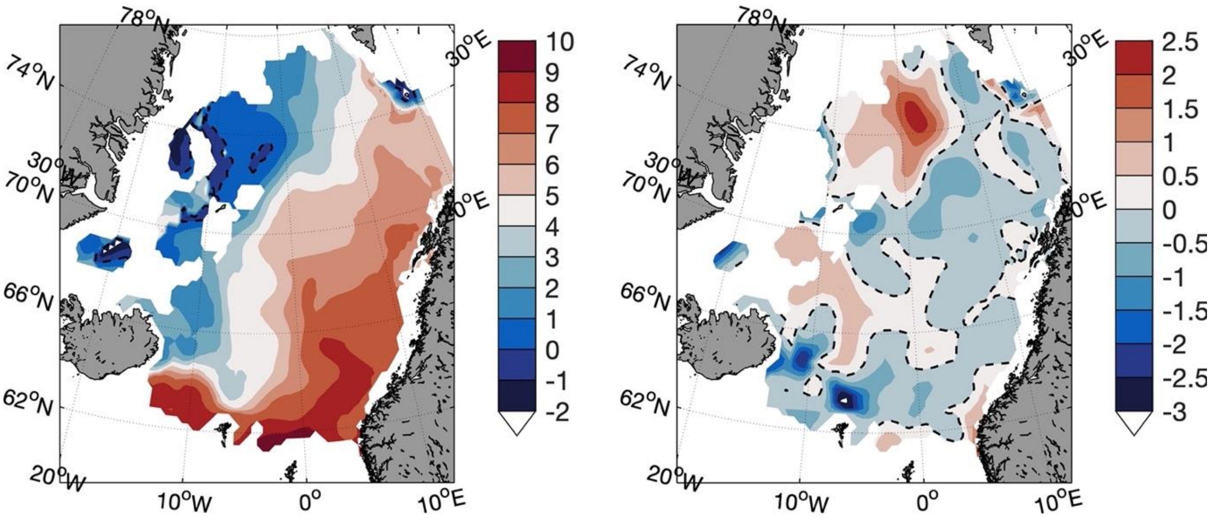


Figure 5. Temperature (left) and temperature anomaly (right) averaged over 0-50 m depth in May 2021. Anomaly is relative to the 1995-2019 mean.

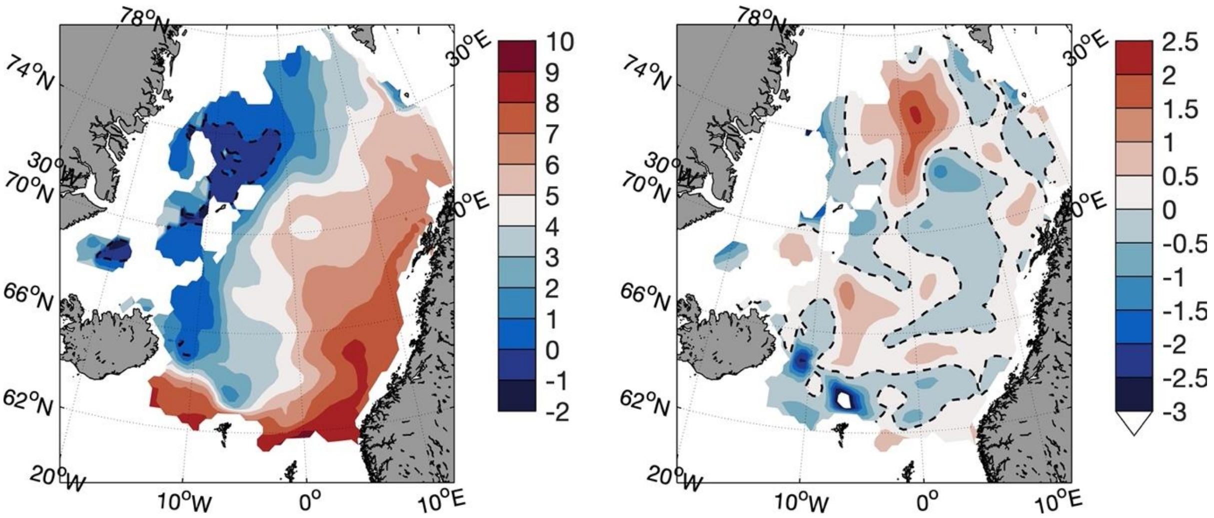


Figure 6. Same as above but averaged over 50-200 m depth.

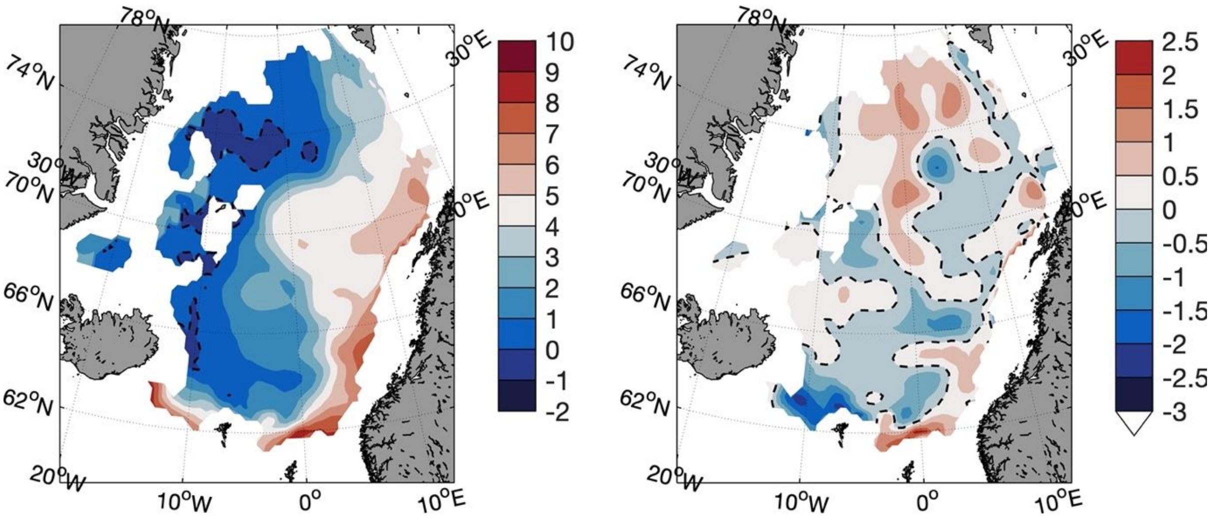


Figure 7. Same as above but averaged over 200-500 m depth.

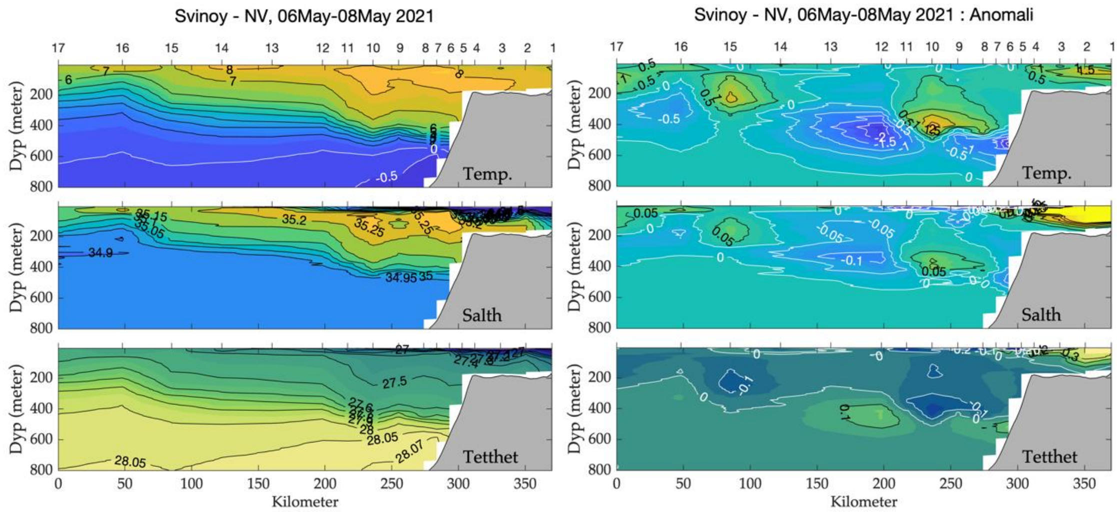


Figure 8. Temperature, salinity and potential density (sigma-t) (left figures) and anomalies (right figures) in the Svinøy section, 6-8 May 2021. Anomalies are relative to 30 years long-term mean (1978-2007).

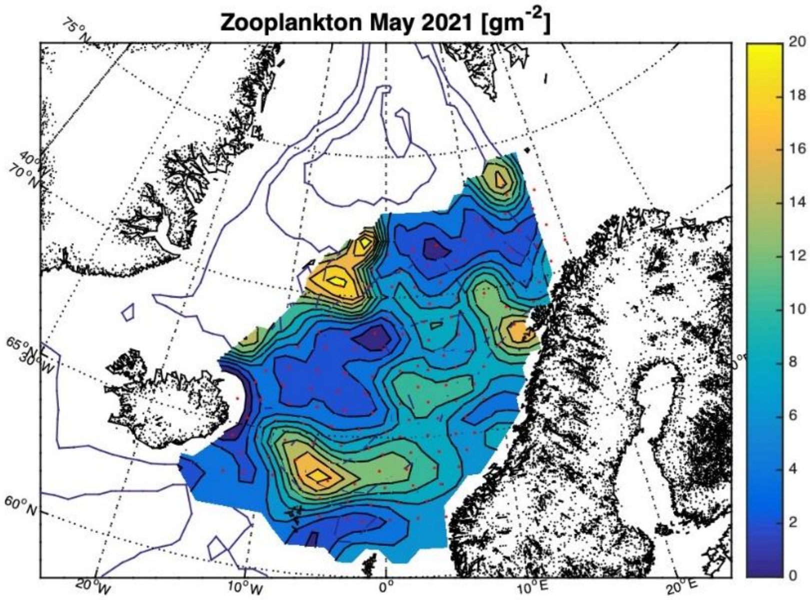


Figure 9. Representation of zooplankton biomass (g dry weight m^{-2}; at 0-200 m depth) in May 2021.

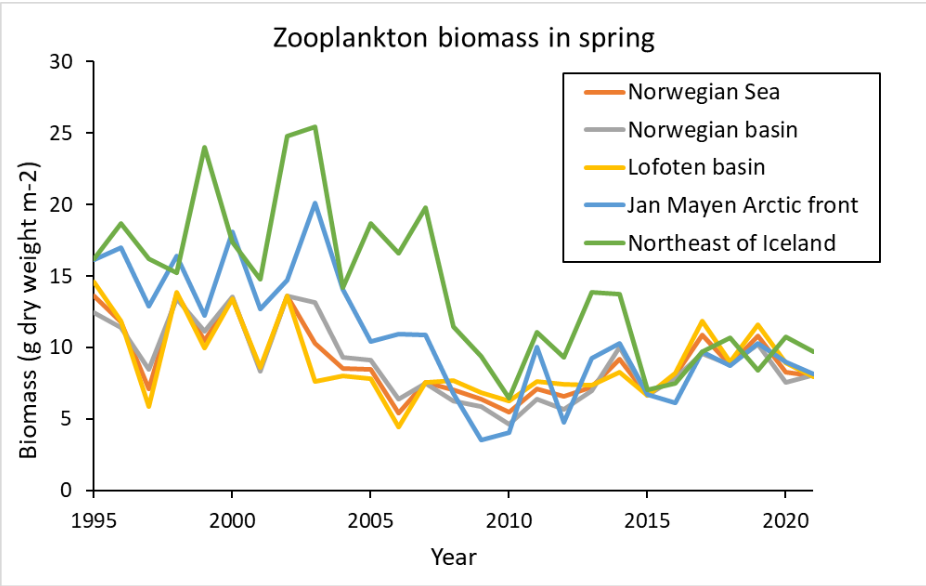
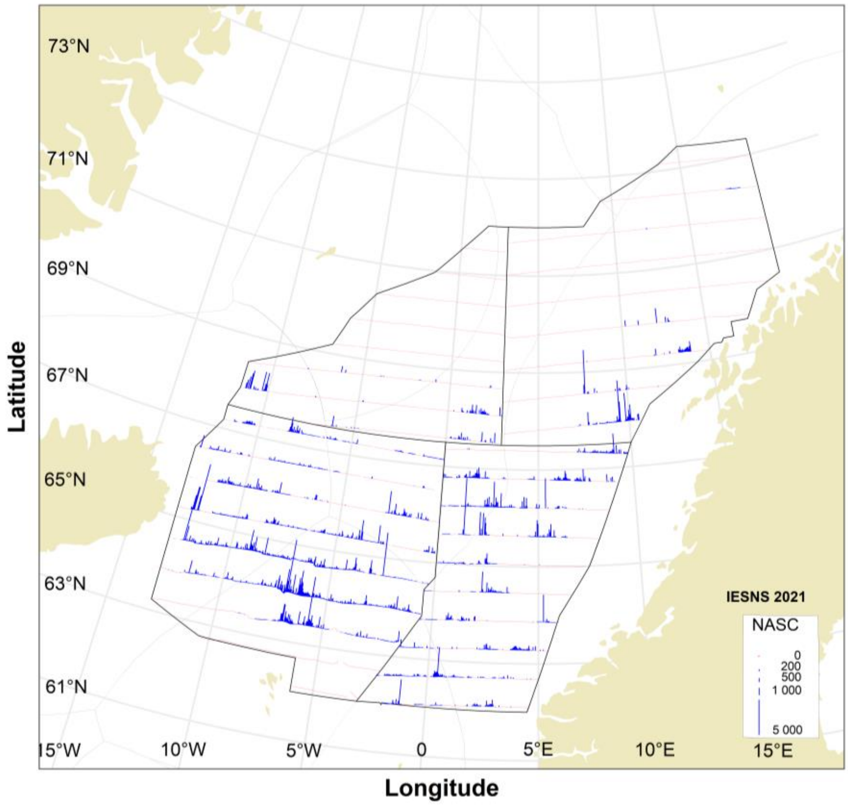


Figure 10. Indices of zooplankton biomass (g dry weight m^{-2}) sampled by WP2 in May in the Norwegian Sea and adjacent waters from 1995-2021.

(a)



(b)

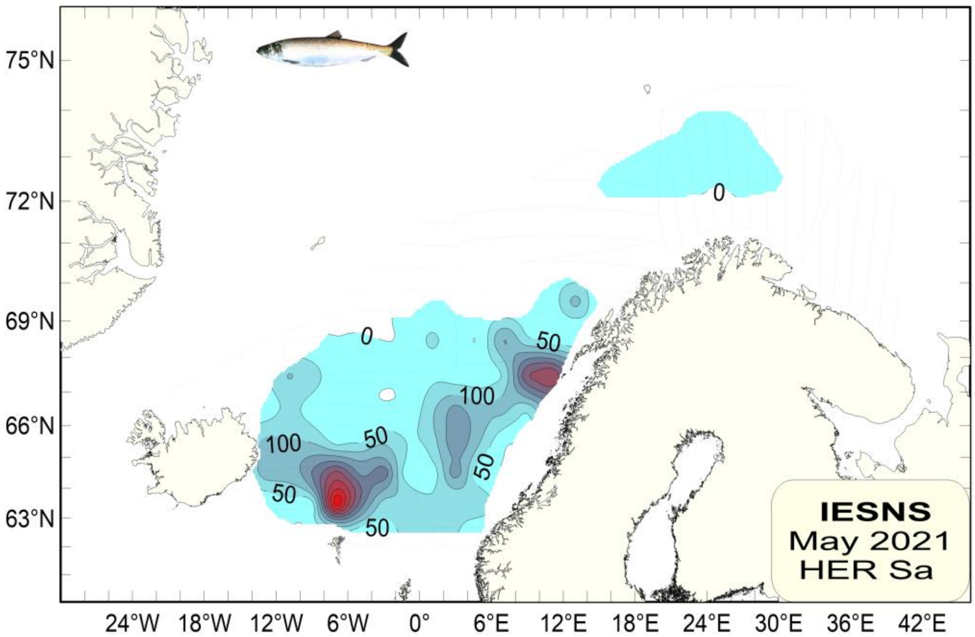


Figure 11. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in May 2021 in terms of NASC values (m²/nm²) averaged for every 1 nautical mile and (b) represented by a contour plot. Note that

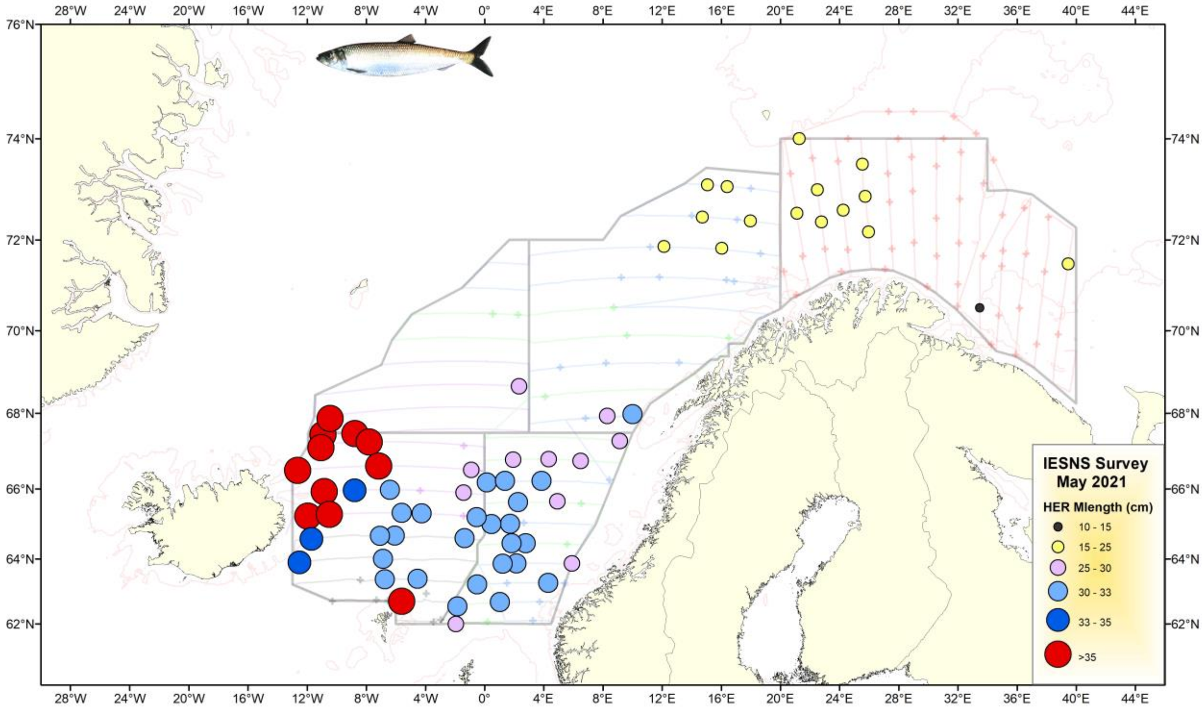


Figure 12. Mean length of Norwegian spring-spawning herring in all hauls in May 2021. The strata are shown.

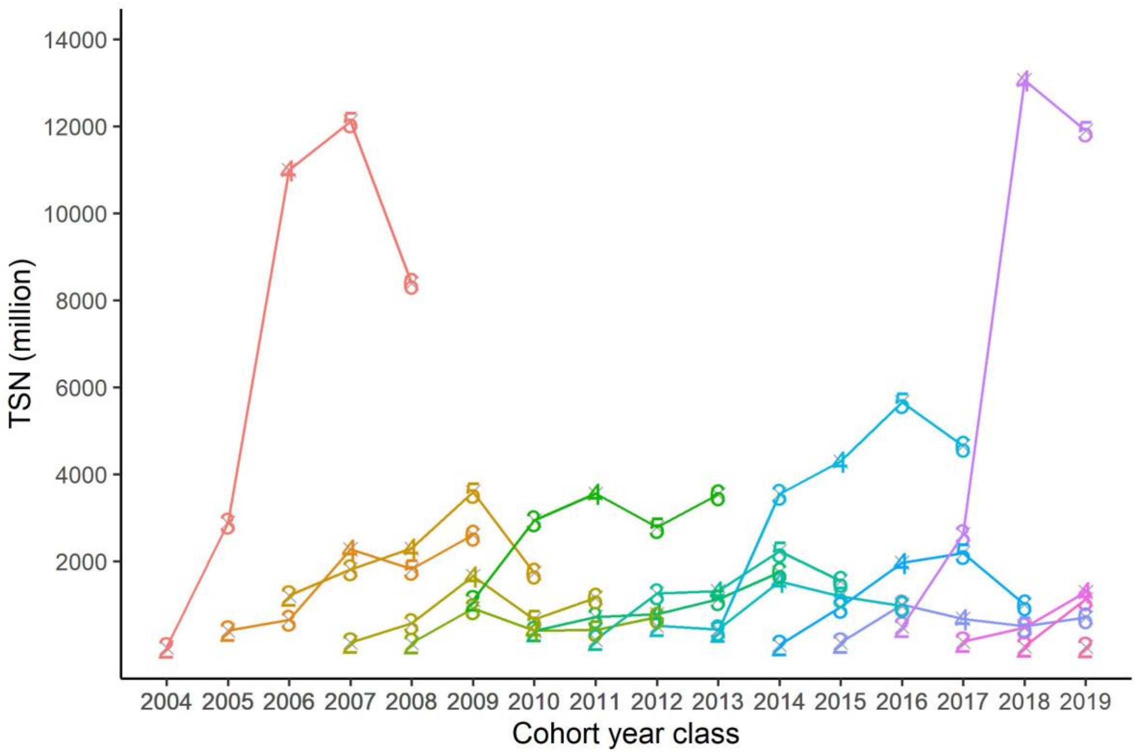


Figure 13. Tracking of the Total Stock Number at age (TSN, in millions) of Norwegian spring-spawning herring for each cohort since 2004 from age 2 to age 6. From 2008, stock is estimated using the StoX software. Prior to 2008, stock was estimated using BEAM.

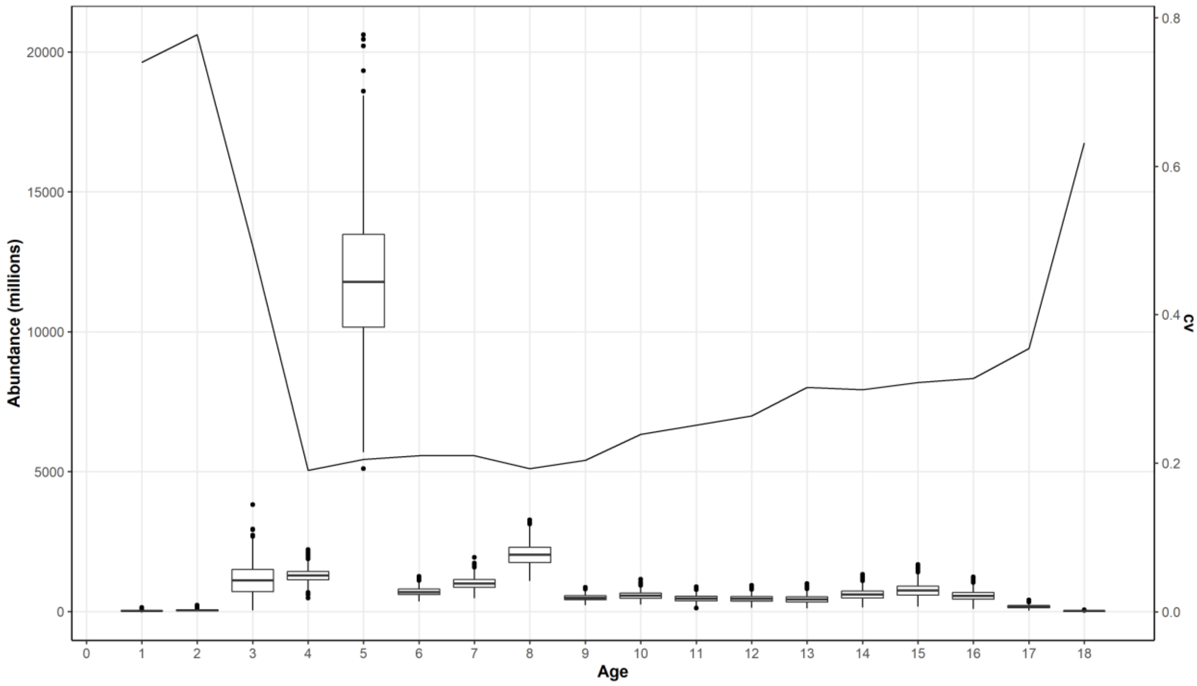


Figure 14. Norwegian spring-spawning herring in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

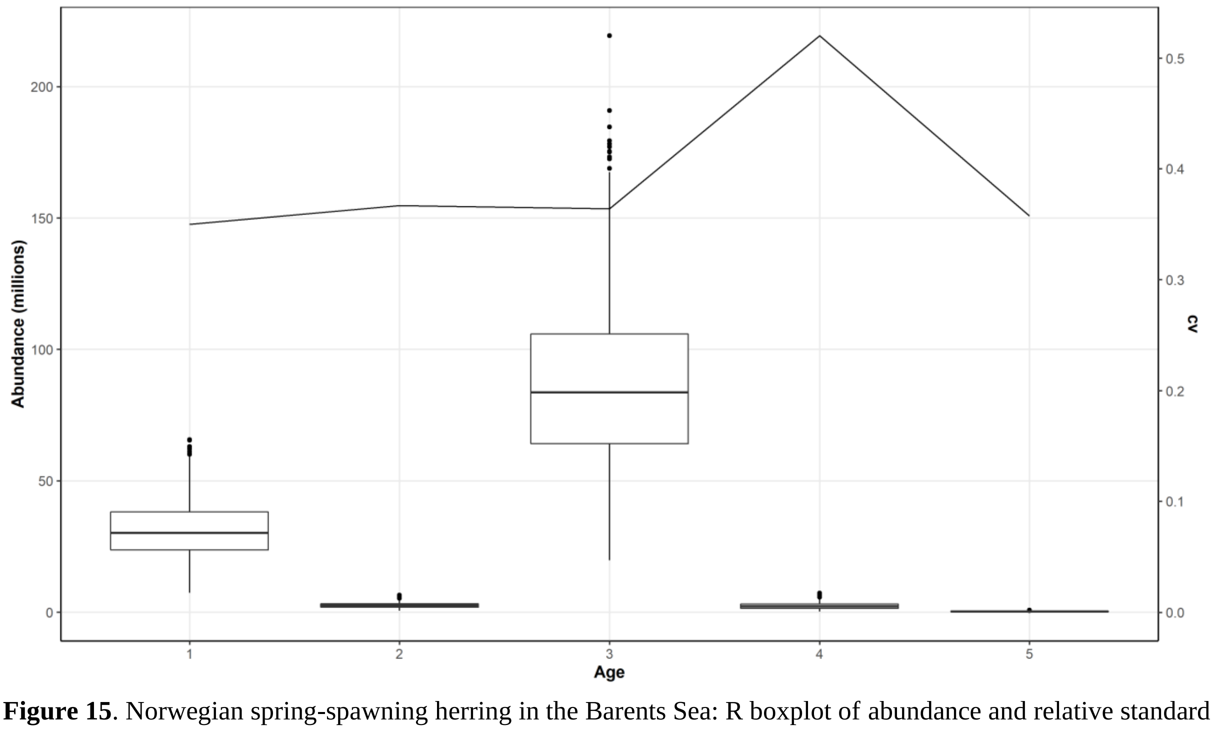


Figure 15. Norwegian spring-spawning herring in the Barents Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

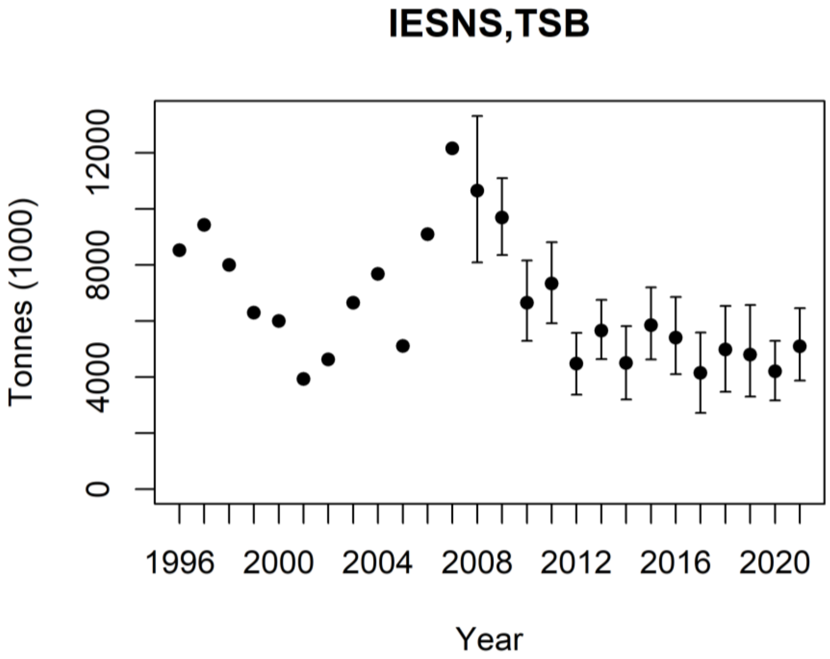


Figure 16. Biomass estimates of Norwegian-spring spawning herring in the IESNS survey (Barents Sea, east of 20°E, is excluded) from 1996 to 2021 as estimated using BEAM (1996-2007; calculated on basis of rectangles) and as estimated with the software StoX (2008-2021; bootstrap means with 90% confidence interval; calculated on basis of standard stratified transect design).

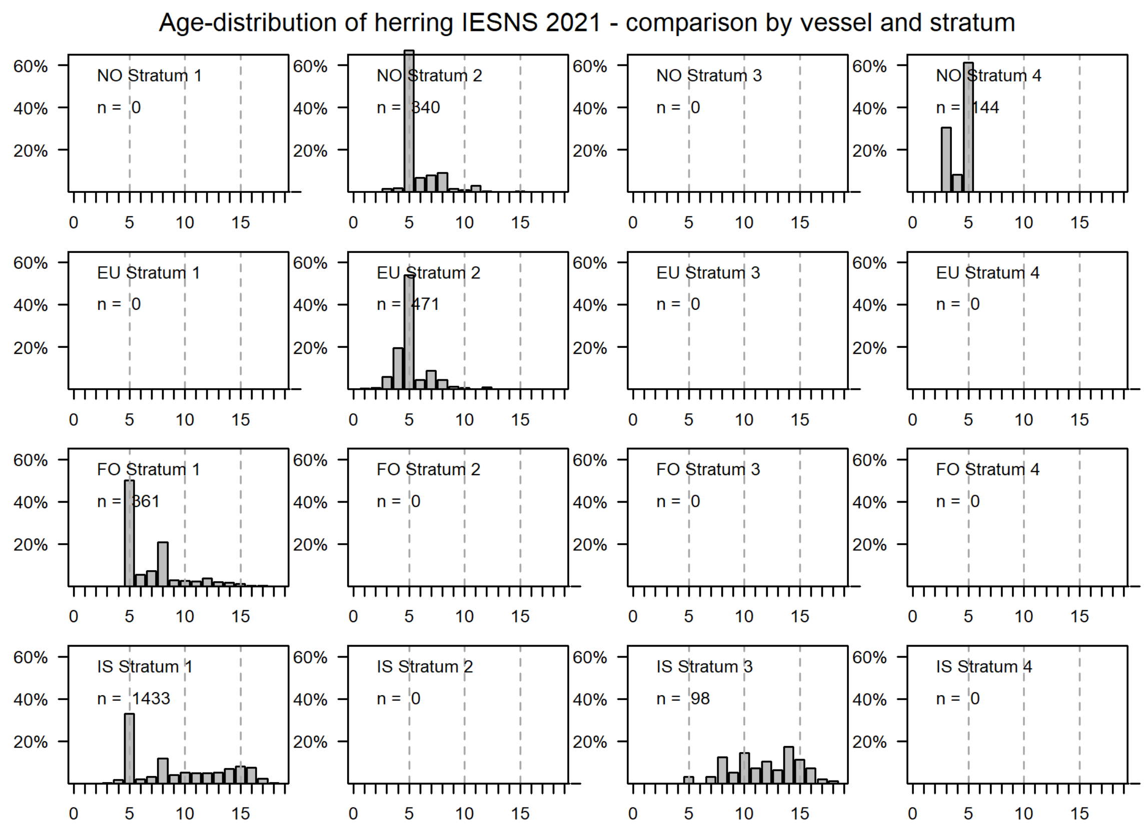
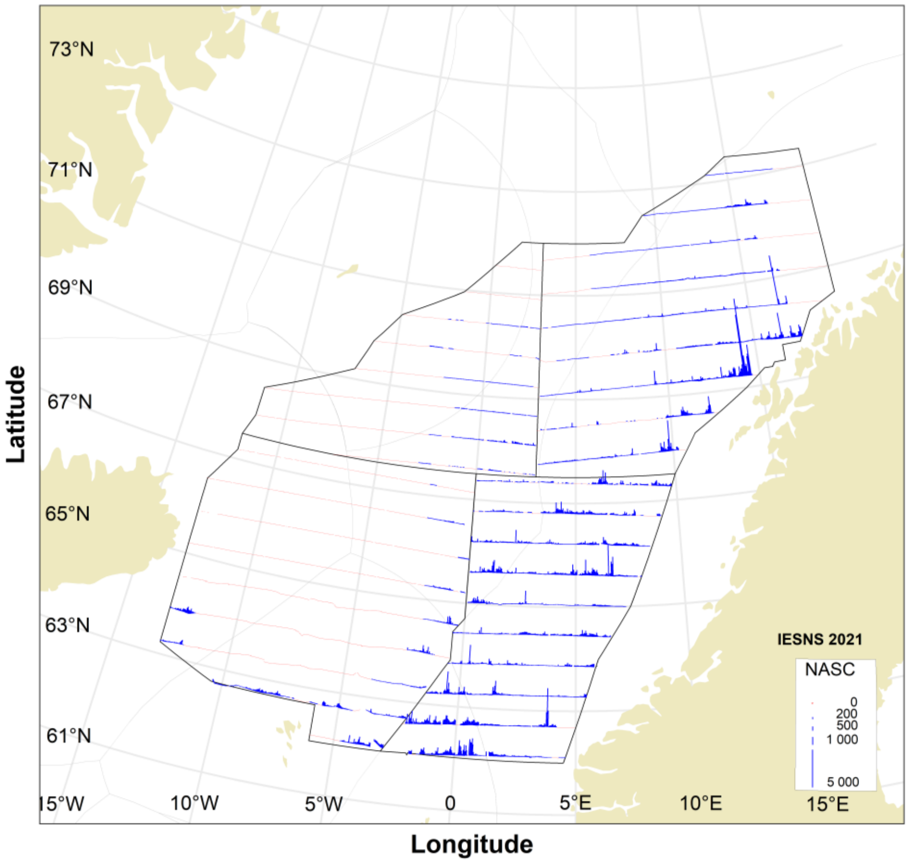


Figure 17. Comparison of the age distributions of NSS-herring by stratum and country in IESNS 2021 (Barents Sea not included). The strata are shown in Figure 3.

(a)



(b)

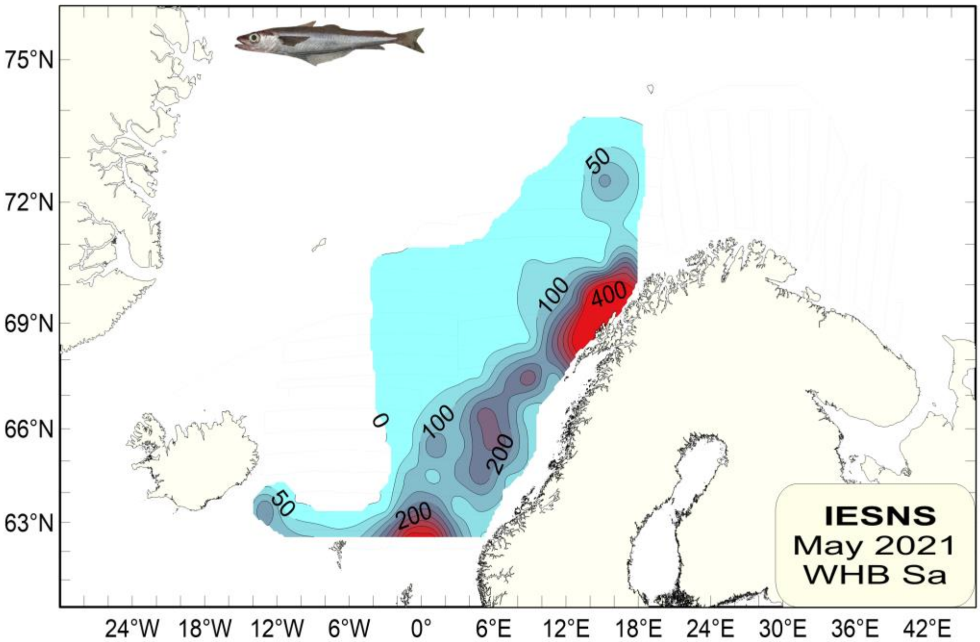


Figure 18. Distribution of blue whiting as measured during the IESNS survey in May 2021 in terms of NASC values (m²/nm²) (a) averaged for every 1 nautical mile and (b) represented by a contour plot.

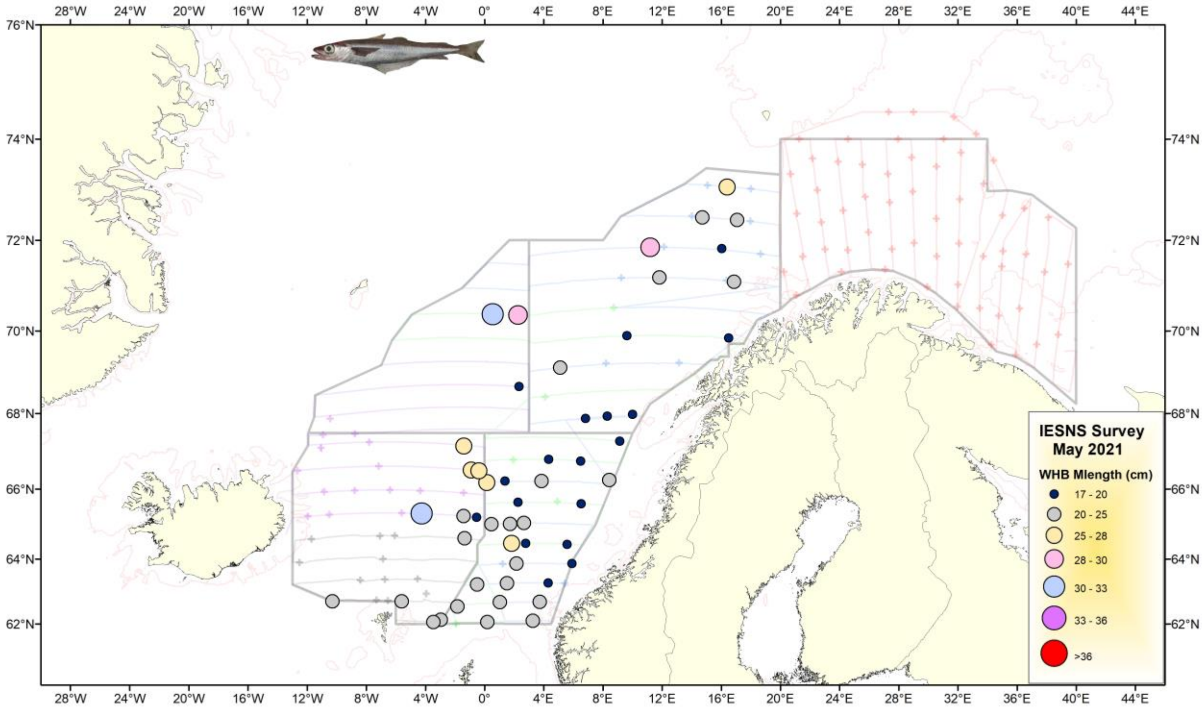


Figure 19. Mean length of blue whiting in all hauls in IESNS 2021. The strata are shown.

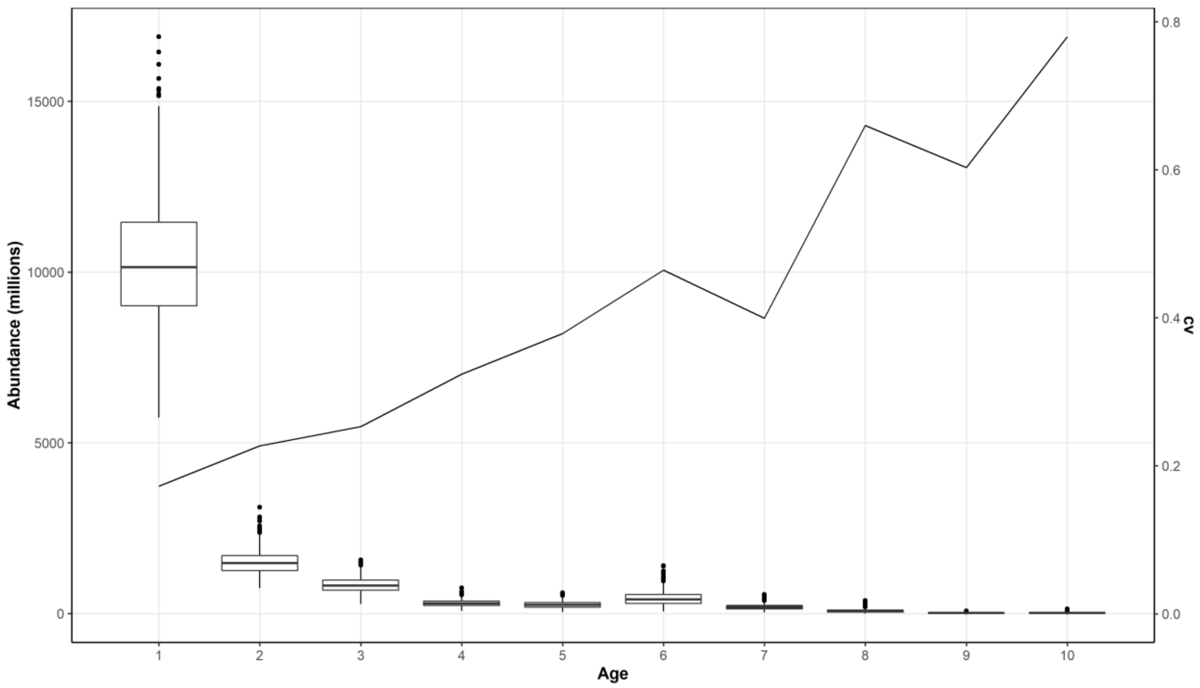


Figure 20. Blue whiting in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

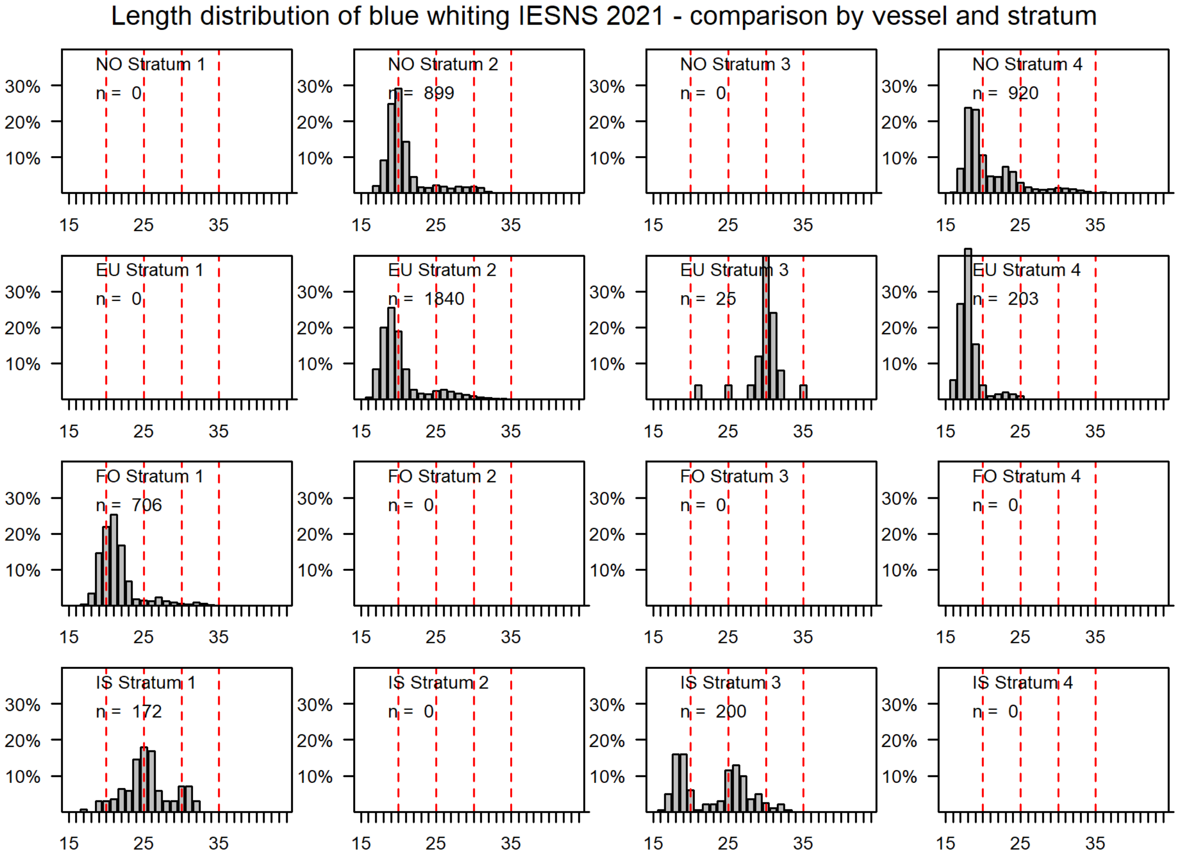


Figure 21. Comparison of the length distributions of blue whiting by stratum and country in IESNS 2021 (Barents Sea not included). The strata are shown in Figure 3.

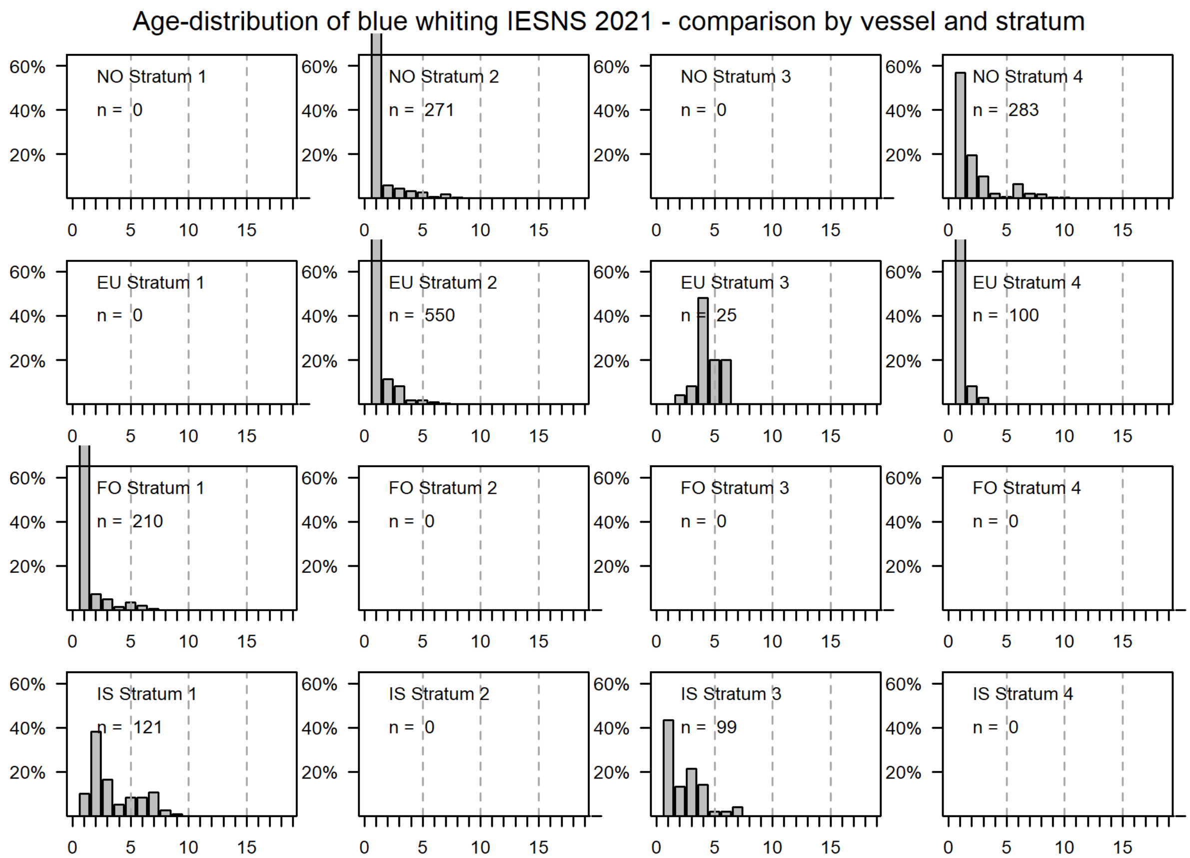


Figure 22. Comparison of the age distributions of blue whiting by stratum and country in IESNS 2021 (Barents Sea not included). The strata are shown in Figure 3.

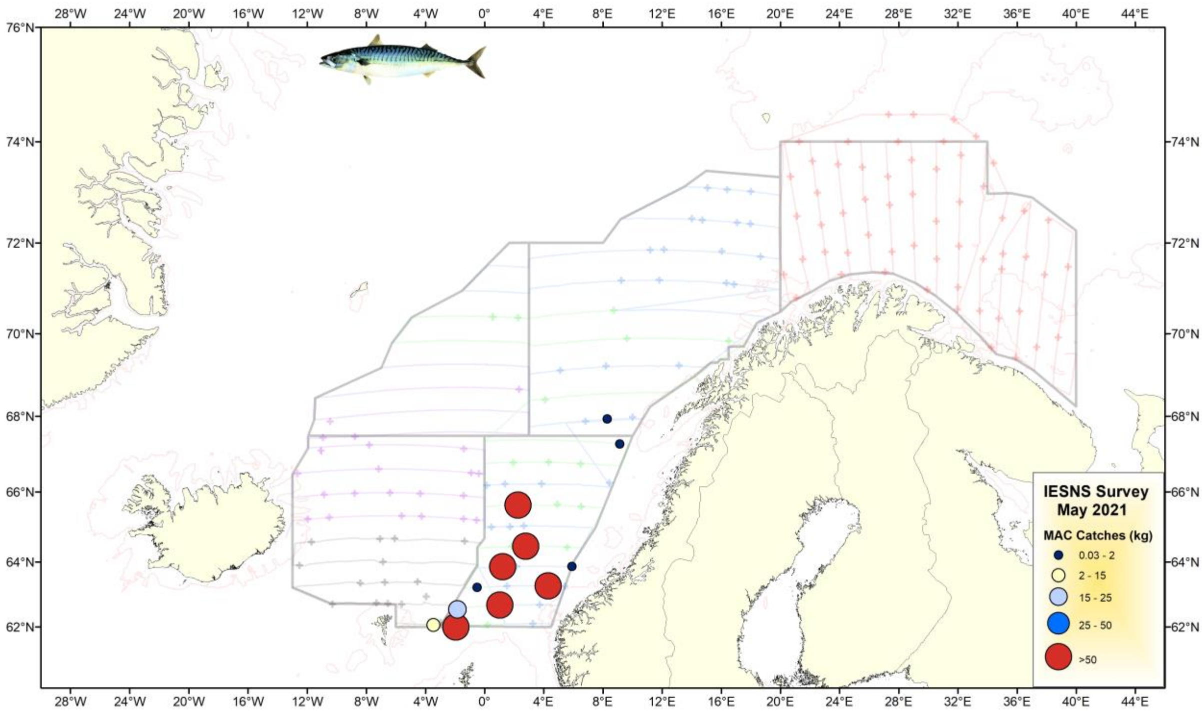


Figure 23. Pelagic trawl catches of mackerel in IESNS 2021. The strata are shown.

Annex 5: 2021 HERAS Survey Summary Table and Survey Report

Document 5a: HERAS 2021 survey summary table

Survey Summary table WGIPS 2022	
Name of the survey (abbreviation):	HERAS
Target Species:	Herring and sprat
Survey dates:	21 June – 26 July 2021
Summary:	

The 2021 survey covered planned strata and survey effort. Timing and coverage were comparable to previous years, and all main aggregations of herring and sprat are considered to have been sampled sufficiently. Stratum 131 (German survey area) and stratum 81 (Netherlands) were not covered in full, due to losses in survey time from bad weather (131) and due to navigational constraints in parts of the stratum (81). The transect distance was increased/modified in these strata to ensure uniform coverage. The survey group does not consider this to have affected the overall abundance estimation significantly.

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.

A new version of the analysis software StoX including substantial updates was released prior to the 2021 HERAS analyses. The version change and the changes in some modules/processes are not expected to bias the calculations of survey estimates and are not expected to compromise or bias the time series of survey results.

The distribution of NSAS herring was similar to that observed in the previous years, with the largest concentrations of herring registered west and southwest of the Shetland isles. Few herring were encountered to the north and west of the Shetland isles. Juvenile herring were seen primarily in the usual distribution in the south eastern parts of the North Sea and in the Skagerrak and Kattegat as well as in the central North Sea. Abundance estimates of NSAS herring were lower than those in 2020 indicating a 12% decrease in spawning stock biomass. At 74%, the proportion mature at 2 winter rings in 2021 is again at the high end of the time series

The 2021 abundance estimate of WBSS herring showed a 4% decrease from 2020, equalling a decrease of 20% in biomass. This is again among the lowest estimates of the time series.

Malin Shelf herring were distributed throughout the western survey area in 2021, but with increased occurrence in the southern part of the survey area, similar to 2020. With the low stock size in the western area it has been difficult to secure catches there in recent years, potentially affecting the accuracy of the stock composition estimates for West of Scotland and Malin Shelf herring. However, increased overall trawling in 2021 provided good confidence in school recognition and supported biological data for age stratified abundance estimates of herring in most strata. Herring was found in all strata and successful sampling was achieved in all strata apart from the Minch. Genetic samples were collected throughout for use in the stock splitting process. The abundance in 2021 was increased 27% compared to 2020 and the highest recorded since the all-time low in 2016.

The CV on the estimate for the Malin Shelf survey in 2021 was 0.26, an improvement on the 2019 estimate of 0.41 and in line with 2020. The increase in juvenile/immature herring estimated in this area in 2021 continued to increase compared to previous years, however these are not considered reliably estimated in this survey. Good containment of the adult stock was achieved in the Malin Shelf area in 2021; biomass that is sometimes observed straddling the 4°W line was not a significant issue in 2021.

Sprat was also encountered within the expected areas. Abundance estimates in the North Sea were lower than in 2020 but ranged around the long-term average of the time series in terms of both abundance and biomass. In Div. 3.a, sprat abundance was estimated at the second lowest level of the time series and well below the long-term average level in both abundance and biomass.

The estimates derived from the 2021 survey are considered to be valid for all 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 3.1.12 (via ICES database) is used to provide indices of abundance.
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	2021: OK Not generally an issue. During severe weather survey effort was paused in most strata until conditions improved.
Extinction (shadowing)	2021: OK Target species not thought to aggregate in dense enough schools to produce extinction effects.
Blind zone	2021: 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	2021: OK Target species (herring and sprat) typically not distributed tight to seabed, and thus not a problem.

Allocation of backscatter to species	2021: OK Species composition verified by directed trawling. Allocation of backscatter to species mainly using multifrequency algorithms in LSSS and Echoview. In strata covered by Denmark and Germany, clupeids often aggregate in mixed schools, and a species specific allocation is not feasible. In these cases, mixed acoustic categories are allocated and disaggregated to species-specific backscatter based on trawl catch composition in split-NASC- modules in the combined StoX-project.
Target strength	2021: 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	2021: The northward extension of herring appeared to be largely contained within the survey strata 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	2021: Common genetic analysis method for stock splitting applied in strata where mixing occurs and where stock splitting based on olotith microstructure/shape methods and vertebrae count methods had been applied previously.

	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 – 0.26 HERAS – n.a.
Biological sampling	2021: 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 older north sea autumn spawning herring. Discussions are ongoing and work to address this is being 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)	*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 5b: HERAS 2021 survey report

*Please find report on the next page.

The 2021 ICES Coordinated Acoustic Survey in the Skagerrak and Kattegat, the North Sea, West of Scotland and the Malin Shelf area

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[2] Wageningen Marine Research, IJmuiden, The Netherlands
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[4] Thünen Institute of Sea Fisheries, Bremerhaven, Germany
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[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 on 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 in the previous year at 1.5 million tonnes (2020: 1.7 million tonnes) with a further decrease in the number of mature fish (2020: 8 915 million fish, 2021: 8 170 million fish).

The 2021 estimate of Western Baltic Spring Spawning herring 3+ group is 82 000 tonnes and 639 million. Compared to the 2020 estimates of 103 000 tonnes and 667 million fish, this equals a decrease of 20% in biomass.

The West of Scotland herring estimate (6.a.N) of SSB in 2021 is 147 000 tonnes and 871 million individuals, which is a ~7% decrease in both biomass and abundance compared to the 158 000 tonnes and 943 million herring estimate in 2020.

The 2021 SSB estimate for the Malin Shelf area (6.a and 7.b, c combined) is 278 000 tonnes and 1 827 million individuals. This is higher than the 2020 estimates (226 000 tonnes and 1 435 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 2021, which is similar to 2020. There were significant numbers of herring distributed south of 56°N again in 2021, including large numbers of immature herring.

For consistency, the survey results continue to be presented separately for sprat in 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 2021 was estimated at 56 200 million individuals and the biomass at 420 000 tonnes (Table 5.10). This is a decrease from last year, and around the long-term average of the time series, in terms of both abundance and biomass. The stock is dominated by 1-year-old sprat (75% in biomass). The estimate includes 0-group sprat (2% in numbers, and 1% in biomass), which only occasionally is observed in the HERAS survey.

In Div. 3.a, the sprat abundance in 2021 is estimated at 623 million individuals and the biomass at 6 200 tonnes. This is the second lowest estimate of the time series in terms of biomass, and well below the long-term average both in terms of abundance (70% below) and biomass (76% below). The stock is dominated by 1- and 2-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 2021 herring acoustic surveys.

VESSEL	PERIOD	CONTRIBUTING TO STOCKS	STRATA
Celtic Explorer (IRL) EIGB	30 June - 20 July	MSHAS, WoS	2, 3, 4, 5, 6
Scotia (SCO) MXHR6	7 July – 26 July	MSHAS, WoS, NSAS, Sprat NS	1, 91 (north of 58°30’N), 111, 121
Johan Hjort (NOR) LDGJ	25 June – 12 July	NSAS, WBSS, Sprat NS	11, 141
Tridens (NED) PBVO	26 June - 12 July	NSAS, Sprat NS	81, 91 (south of 58°30’N), 101
Solea (GER) DBFH	30 June – 20 July	NSAS, Sprat NS	51, 61, 71, 131
Dana (DEN) OXBH	21 June – 06 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 38 kHz 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) or Echoview (Echoview Software Pty Ltd, Hobart, Australia).

The survey is designed to be analysed using StoX 3.1.12 (Johnsen et al., 2019) with a set of strata surveyed through a grid of evenly spaced parallel transects. The survey area is divided into 23 strata with a randomized starting point for the grid of transects in each stratum and with transects running perpendicular to lines of bathymetry where possible (Figures 5.1 and 5.2). The planned transect spacing in the (parallel transect) strata ranges from 10 to 30 nautical miles (n.mi.) (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 overall survey design being implemented (2005 – 2015), and the strata had been classed as high, medium and low effort (ICES, 2016).

A total of 9842.5 n.mi of acoustic transects covered during the survey were used in the acoustic analysis, achieving good coverage of the entire survey area. Due to a loss of survey time through several instances of inclement weather, the overall transect length had to be reduced in stratum 131 covered by Germany. One transect was dropped, and the reduced number of transects were spaced evenly in that stratum, leading to an increased transect spacing of 40 instead of the planned 30 nautical miles. The coverage of stratum 81 by the Netherlands was adapted due to time constraints and navigational restrictions due to wind farms. In the far south of the stratum the bathymetry did not allow sailing and fishing. The modifications and adaptions allowed full and even coverage in each of the affected strata, but partly with increased transect spacing and altered transects.

Scrutiny of acoustic data

In the Dutch, Irish, Norwegian and Scottish survey, scrutiny of hydroacoustic data during post-processing is conducted 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.

From the 2021 survey the scrutiny of acoustic data in the areas covered by Denmark has been brought into line with those used by the other participants. Aggregations are classified by directed trawling and where appropriate the categories of HER and SPR are used where single species catches allowed this. Mixed aggregations of clupeid species are prevalent in this area and the acoustic category CLU assigned to these with the composition of associated trawl hauls used to split the NASC from this category into NASC for each component species. A combined acoustic category of MIX has been assigned to aggregations containing additional species, typically young gadoids, and the split to species specific NASC again based on composition of associated hauls.

The composition of both the CLU and MIX categories in the Danish and German surveys 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 process in the StoX software, where all categories employed are clearly defined (Table 5.20). The resulting disaggregated and species-specific NASC values attributed to herring and sprat etc. are used in subsequent processes in the overall analysis.

For 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

Stock splitting

Stock splitting was conducted using genetic analysis in several parts of the survey area (See section 5 for details). For the genetic analysis, Single Nucleotide Polymorphism (SNP) panels were used including diagnostic markers to discriminate known populations (Farrell et al., 2021; Han et al., 2020). Each laboratory have developed their individual SNP panel consisting of diagnostic markers to specifically indentify populations of interest in that specific region, e.g., is there no need to include markers discriminating central Baltic herring in the Malin Shelf area. However, the development of individual panels was conducted in close collaboration between laboratories. This also accounts for the establishment of reference baselines. Several reference samples that would be of interest for multiple laboratories have been exchanged. This ensures that all laboratories use the identical baseline to identify known populations.

Data analysis

The 2021 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 (v. 3.1.12; 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./7. b, c) as well as sprat in the North Sea and 3.a.

1 https://www.ices.dk/ 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, 21, 31, 41, 42, 141, 151 and 152, , herring is split into North Sea Autumn Spawning herring and Western Baltic Spring Spawning herring (Figure 5.1) based on genetic analysis (See more details in section 5).

Western Baltic Spring Spawning herring (WBSS)

The allocation to the Western Baltic Spring Spawning herring stock is limited by the geographical boundaries of strata 11, 21, 31, 41, 42, 141, 151, and 152. Stock splitting is only applied within these strata (Figure 5.1). Individual biological assignments of WBSS herring are based on genetic analysis (See details in section 5).

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 and 6.a.S/7.b, c) using genetic techniques (Farrell et al. 2021). The split results for the 2014 – 2021 MSHAS surveys are presented in Annex 20, and were generated using the method described in (O'Malley et al., 2021) These results were also delivered to the 6a herring benchmark WKNSCS in February 2022. 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 and biomass estimate based 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, including the northern part (strata 11, 91, 111 and 121), where low but recurring registrations of sprat have been observed in the preceding years (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 2021

The survey strata used for the analysis are shown in Figure 5.1. The area and transects covered during the national acoustic surveys are 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 sprat in Div. 3.a) and the time series of these are given in Figures 5.5-5.10. The time series of biomass/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 biomass and abundance for sprat in the North Sea and in Div. 3.a are given in Tables 5.11 and 5.13 and Figures 5.15 and 5.16 respectively. In each of the figures, 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. As in previous years, the largest aggregations of adult herring in the North Sea were concentrated in the areas to the east of the Shetland Isles, between 2°W and 2°E and app. 57.5°N - 61.5°N (Figures 5.3 & 5.17). Adult herring was also encountered in concentrations in the deeper parts of Skagerrak. The distribution was similar to that observed in the previous years, with the largest concentrations of herring registered west and southwest of the Shetland isles. Few herring were encountered to the north and west of the Shetland isles. Juvenile herring were seen primarily in the usual distribution in the south eastern parts of the North Sea and in the Skagerrak and Kattegat as well as in the central North Sea (Figure 5.18).

The estimate of **North Sea** Autumn Spawning herring spawning stock biomass has decreased again by 12% from 1.7 million tonnes in 2020 to 1.5 million tonnes this year (Table 5.6, Figure 5.11). The abundance of mature fish has also decreased from 8 915 million in 2020 to 8 170 in 2021 (Table 5.2). The mean weight of mature fish is lower than last year at 183.7 g, contributing stronger than the concurrent decrease in numbers to the decrease in biomass. The 2012- and 2013- year classes (age 7 and 8 winter ring now) continue to be stronger than the long-term average (especially the 2013 year class). The 2014-year class which has been estimated to be well below average so far, is now, at age 6 wr in 2021, at average size for its age group. All yearclasses since 2015 are well below the 10 year average with the 2016-yearclass (4-wr in 2021) being very weak with abundance at only 33% of the average level since 2010.

The abundance of immature fish in the stock has increased by 57% from 14 851 million in 2020 to 23 311 million this year. While prior to 2020 2 winter ring fish contributed substantially to the abundance of immature fish, the maturity level in this age group was as in the previous year comparatively high (59% mature in 2019, 75% mature in 2020, 74% mature in 2021). The abundance in this group was at the same level as in the previous year. The high maturity level of 2 winter ringers meant this age group mainly contributed to the mature fish abundance in 2021. (Table 5.2, Figure 5.5).

At 74%, the proportion mature at 2 winter rings in 2021 is again at the high end in the time series – compared to e.g. the all-time low of 37% in 2018. Maturities for ages 3 and above were again comparable to the long-term average with 99% of 3 winter ringers and 100% maturity for all ages 4 and above (Table 5.2). Since 2015, observed maturities are reported for all age groups. Previously maturity had been fixed at 100% for ages above 4 wr.

The 2021 estimate of **Western Baltic** Spring Spawning herring 3+ group is 82 000 tonnes and 639 million herring (Table 5.3). This is a 20% decrease in biomass (4% decrease in abundance) compared to 2020, and continues to be below from 2009 to the present (2009 – 2020; 712 million herring). The 2020 estimate was 667 million. The 2017 estimate had been the highest level observed since 2008 (1 353 million) and was comparable to the stock size prior to the low levels observed after 2008 (Table 5.8). The stock is dominated by 2 and 3 winter ring fish (Table 5.3, Figure 5.6) with a notable decrease of almost 100% in the 1 winter ring group (2021: 26 millions; 2020: 815 millions). The numbers of older herring (3+ group) accounted for 70% of the total stock in 2021. This is a much higher contribution than was observed in the period 2009 to 2020 where the 3+ group on average accounted for 37% of the stock. Compared with 2020, mean weights were about 20 % higher or similar for 1 and 2 year old fish respectively, but distinctly lower in the older ages 3-5 (20%, 30% and 6% respectively).

The **Malin Shelf** (6.a and 7.b, c) herring estimate of SSB is 278 000 tonnes and 1 827 million individuals (Table 5.5), an increase compared to the 226 000 tonnes and 1 435 million individual herring found in 2020. The estimate is the largest since 2015 when it was 430 000 tonnes (Table 5.9, Figure 5.14). In 2021, 43% of the total biomass (TSB) and 53% of the SSB was observed north of 56°N (the geographic area that forms the **West of Scotland** (6.a.N) index). Herring were distributed throughout the survey area in 2021, but with increased distribution in the southern part of the survey area, similar to 2020. The **West of Scotland** (6.a.N) herring estimate of SSB is 147 000 tonnes and 871 million individuals (Table 5.4) is a slight decrease compared to the 158 000 tonnes and 943 million herring estimate in 2020. 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. The estimates since 2016 are still the lowest in the time series. The distribution of herring schools was similar to 2020 with more herring distributed south of 56°N line of latitude (Figure 5.3). There were some herring marks found to the south of St. Kilda in 2021, but generally less than found historically in this area.

Immature herring were found north of Malin Head, Stanton Bank and in the north Minch (Figure 5.18). Adult herring schools were mainly found in deeper water west of Malin Head to the north of Tory Island, west of Stanton Bank and west of the Outer Hebrides (Figure 5.17). Most of the herring in Stratum 1 to the north of Scotland were found in the North East of the stratum near the 4°W line. 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 low levels in 2021 (Figure 5.3). However, it appears that in general the increase in estimates since 2016 were a result of a greater spread in the distribution of herring throughout the area and particularly in the south of the survey area, rather than distributions occurring around the 4°W line. A similar pattern to 2020 seems to have occurred in 2021.

The Malin Shelf survey estimate was dominated by 2- and 3- winter ringers (2018 and 2017 year classes), making up 79% of the total abundance and 75% of the total biomass. Immature herring made up 48% of the total biomass. Age disaggregated survey abundance indices for Malin Shelf herring since 2008 are given in Table 5.9.

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 distribution extends further south into 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 2021 was estimated at 56 200 million individuals and the biomass at 420 000 tonnes (Table 5.10). This is around the long-term average of the time series in terms of both abundance and biomass. Compared to the 2020 estimate, abundance and biomass are 16% and 21%

lower, respectively (Table 5.11, Figure 5.9). The estimate was dominated by 1-year-old sprat (75% of biomass), and 57% of the sprat were found to be mature (Table 5.10).

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 (85% of the abundance, and 87% of the biomass), but sprat were also found in strata 31 and 42 in the Skagerrak area (comprising strata 31, 41, 42). In 2018 and 2013, sprat were only found in the Kattegat. The abundance is estimated at 623 million individuals, 85% lower than the 4 282 million individuals in 2020 (Table 5.12). The biomass was 84% lower than in 2020, at 6 200 tonnes. 1- and 2-year-old sprat dominate the stock (93% in numbers and 89% 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.

5 Quality considerations

The 2021 HERAS global survey estimates of abundance were calculated using StoX (Johnsen et al., 2019) version 3.1.12 with Rstox Framework 3.1.17, with input files (XML) 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 2021 survey covered planned strata, and survey effort, timing and coverage were mainly comparable to previous years. All main aggregations of sprat and herring are considered to have been sampled sufficiently.

In stratum 131, covered by Germany, one planned transect had to be dropped due to survey time constraints caused by several days of inclement weather. However, in increasing the transect spacing accordingly (from 30 to 40 nautical miles), a full and consistent coverage of the stratum was achieved. Since the distribution patterns of clupeids in this stratum (based on spatial echo intensity measured) were 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 and no adjustments were made. Accordingly, increasing transect distance is not expected to have affected the StoX analysis and subsequent abundance estimates.

Parts of stratum 81 covered by the Netherlands are not accessible anymore due to the building of wind farms requiring a slight modification in transect orientation. Additionally, the southern part of stratum 81 does not allow sailing and pelagic fishing due to topographical constraints. As these restrictions are permanent it may be necessary to consider a permanent modification to this stratum in the future. The modifications carried out this year are typical for this stratum and are not thought to have a significant effect to the overall result.

Good biological sampling was achieved in the Malin Shelf survey area in 2021, an improvement on recent years. There were samples obtained in all the relevant strata, including genetic sampling which was used for stock splitting in preparation for the 6.a benchmark (WKNSCS 2022). The CV on the estimate for the Malin Shelf survey in 2021 was 0.26, slightly higher than the 2020 estimate of 0.23. There has been an increase in the juvenile/immature herring occurring in the Malin Shelf area in recent years, particularly in the southern area, however these are not considered reliably estimated in this survey.

Stock containment

In previous years, herring had 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. The amount was considered not currently significant, and in the 2021 HERAS survey, the northward extension of herring appeared to be largely contained within the survey strata. Other surveys covering the area north of the HERAS area have also detected small amounts of herring in recent years, and genetic 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

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

thereof) of North Sea herring. In 2021, NORACU had ten bottom tows north of the HERAS survey area, whereof seven had very small herring catches (less than one kg).

Good containment of the adult stock was achieved in the Malin Shelf area in 2021, biomass that is sometimes observed straddling the 4°W line was not a significant issue in 2021.

Stock splitting methods

Previously, two different methods were used within the survey to assign herring in the splitting area to the North Sea Autumn Spawning (NSAS) herring stock or the Western Baltic Spring Spawning (WBSS) herring stock. Otolith microstructure and shape were used in strata 21, 31, 41, 42, 151, 152, and vertebrae count was used in strata 11 and 141). The vertebrae count method was used by Norway and did not provide stock information at the individual fish level. This method was only able to estimate proportions of two groups and was very sensitive to small changes in the mean vertebral counts (Bergès et al. 2021). The vertebrae count methods used the mean vertebral counts of NSAS and WBSS herring (56.5 and 55.8, respectively), for their calculations. If other stocks would be present this could have led to an over- or underestimation of the proportion, e.g. Norwegian Spring Spawning (NSS) herring having a mean vertebral count of 57.2 would led to an overestimation of NSAS herring, whereas the occurrence of Central Baltic herring (mean vertebral count 55.3) to an underestimation.

The otolith microstructure method that was used by Denmark utilises that it is possible to identify the hatching season, i.e., spring, autumn or winter, of an individual (Clausen et al., 2007). All herring identified as either autumn or winter spawners was assumed to be NSAS herring, whereas all spring spawners were assumed to be WBSS herring. In terms of NSS herring, they would have been included in the NSAS proportion using vertebral counts, but in WBSS when using otolith microstructure.

This year, these two methods were replaced by a common genetic analysis method in those strata where stock splitting is applied. The advantage of genetic data is a more fine-scale discrimination down to the population level compared to the previously used methods. The results of the genetic analysis revealed that several populations that were previously not considered occur in the survey area. In total, 7 different herring populations have been identified (Figure 5.21). Aside from the 3 identified with previous methods (NSAS, Downs (included in NSAS indices) and WBSS), the genetic method also identified herring from several adjacent populations in the survey area: Norwegian Spring Spawning (NSS) herring, Central Baltic herring (CBH), Baltic Autumn Spawning (BAS) herring, and Icelandic Summer Spawning herring (ISSH, only 1 individual). This increased resolution of stock discrimination at individual level provides challenges to the index calculation and warrants a larger discussion with the assessment working group (HAWG) for the way forward. In terms of consistency in the calculation of the indices for NSAS and WBSS, individuals were only assigned to either the NSAS or WBSS herring stock as was done previously. Their assignments to either stock was based on the genetic result and where this indicated an different stock than NSAS or WBSS, the assignment was mapped to how the previously used splitting methods would have assigned them (Table 5.21). So, in strata where the vertebrae counts were previously used, NSS herring would be mapped to NSAS, whereas in strata where the otolith microstructure methods were used, they would be mapped to WBSS and so forth following linkages in table 5.21. This allows us to provide estimates abundance of NSAS and WBSS herring that are comparable to previous years and therefore compatible with the time series. We do however now have firm evidence that these indices contain several more herring stocks than previously considered in the splitting process and need to discuss a way forward. The indices used for NSAS and WBSS are "contaminated" by other stocks, however we cannot estimate by how much each year going back in time, or how variable this has been between years. There is likely a high inter-annual variability in mixing proportion both due to the migratory behavior of herring in these areas and also to differences in year class strength between the different stocks in the mix.

In addition, herring outside the stock splitting area for NSAS and WBSS are assumed to be 100% NSAS herring. Small scale investigations over recent years have indicated that other stocks may be encountered in these areas, albeit in relatively small numbers. We therefore recommend that genetic analysis also be applied in other survey areas to identify potential mixing with other stocks. Norwegian Spring Spawning herring is for example occasionally encountered in the most northern part of the survey area in strata 11, 111 and 141 and should be considered in a future splitting scenario.

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). These are suspected to be from local spring spawning populations in the adjacent Ringkøbing Fjord, but this has not been genetically verified. Historically 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.

Malin Shelf (6.a./7. B, c): 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 morphometries, so both stocks of herring are reported as one combined 6.a stock from this survey. Genetic techniques are currently being put forward to facilitate this split and the results are being considered at the 6.a benchmark (WKNSCS 2022) for the herring stocks contained in 6a, 7b, c. A working document containing splitting methods for the MSHAS and a split index (2014 – 2020) for the survey back in time using results from the EASME project (Farrell et al., 2021) was put forward to this benchmark for consideration (O'Malley et al., 2021).

StoX version change/update

A substantial update was implemented in StoX software prior to the analyses conducted for the HERAS 2021 estimates. The current version 3.1.12 contained changes in the workflow as well as in a range of modules used and required for processing both acoustic and biological data. To retain consistency with the processes developed for the calculations of preceding survey estimates in the previous version, the 2020 StoX project was "translated" into the most recent version and spot checks were conducted to assure comparable results between both versions. The updated processes were utilized for the 2021 survey estimates. The version change and the changes in some modules/processes are not expected to bias the calculations of survey estimates and are not expected to compromise or bias the time series of survey results.

A notable change from the previous StoX version was the implementation of the disaggregation of mixed category acoustic data in the main project. Previously, separate Split-NASC projects had to be created for the participating countries that worked with combined and mixed acoustic categories (i.e. Germany and Denmark). In the current version, this process is a part of the workflow of the main project, i.e. the combined acoustic categories are disaggregated and further processed within the same project as the main survey estimates. This is not considered to lead to diverging survey results compared to the previous version, since the dis-aggregation steps are achieved using the same assumptions and settings as before, but are merely included in a continuous workflow rather than a separate StoX project.

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. With the development of automatic routines, CVs have been estimated for abundance at age in each stratum. Results are shown for the period 2017-2020 for the NSAS and WBSS herring estimates in Figure 5.19 and 5.20, respectively. Overall, there is consistency in CV estimates since 2017 for both NSAS and WBSS herring. For

2021 the procedure has not yet been realised in the new version of StoX. The survey group anticipates CVs to be estimated again in 2022 and forward.

Biological sampling

Overall increased trawling in 2021 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 continued 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.

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 procedure for 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. This has been discussed during the 2022 WGIPS meeting and is currently being planned.

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 post-processing, 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 project. Finally, a category of echo-traces that are not thought to contain clupeids (UNK) has also been used in 2021. This approach is considered to give a robust estimate of the disaggregated, species-specific clupeid NASC distribution in the German survey area.

Since 2021, the post-processing and scrutinization of hydroacoustic data in the Danish survey has been brought in line with this approach. Where possible, species-specific echo allocation (HER, SPR) was conducted when single-species catches allowed this. In other cases, a MIX category is allocated to echo data and split according to the catch composition of trawl hauls considered representative of the registrations. Due to the partly high species diversity in catch samples with notable contributions of other than the target species and the expectable contribution of those fishes to the echo registrations recorded, the MIX category in the Danish survey is split into a broader species range than in the German survey. This is also partly expected to result from different trawl gear employed and areas visited. In general, the current approach followed that is in line with the scrutiny protocol and assumptions followed regularly in adjacent survey areas with a high degree of mixed aggregations is considered distinctly more robust than the scrutiny procedure followed previously. Disaggregated, species-specific NASC values used for the further estimate are considered spatially more explicit representative of the actual distribution of both target and non-target species.

The change in scrutiny approach in the Danish area necessitated a change to trawling being directed more directly to observed fish aggregations. This was achieved by an increase in staff on the vessel to allow for trawling around the clock when needed rather than when working time dictated opportunities. This ultimately has led to a better match between observed aggregations and trawl compositions and allowed for the species specific allocation of acoustic categories in many cases compared to the previously followed approach.

The group recommend mixed-species acoustic categories 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. In general, it is recommended to scrutinize to the highest resolution where possible and to improve species allocation to mixed aggregations through more directed trawling on aggregations.

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): FRV “Solea” from Germany, RV “Johan Hjort” from Norway and FRV “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, 2017; 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 is 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 where 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). The performance of each system used during the HERAS survey was evaluated in 2019 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.

6 Further improvements to survey

1) Efforts to further standardise the HERAS survey should continue.
   a. Assess the various biological sampling strategies used in the survey by different laboratories and develop a 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 incl. check of compliance with the ICES acoustic trawl database format requirements to be performed prior to the post-cruise meetings. This includes also thorough checks of the reporting format for e.g. age: All ages for herring must be provided in winter rings to be used by the assessment working group.
5) Further 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 2021. Mean weights, mean length and fraction mature by age winter ring.

Age (ring)	Numbers	Biomass	Maturity	Weight(g)	Length (cm)
0	17500	78	0.00	4.4	8.5
1	5196	248	0.02	47.7	17.9
2	2803	340	0.74	121.3	23.9
3	1800	299	0.99	165.8	26.4
4	773	148	1.00	191.0	27.4
5	877	178	1.00	203.4	27.9
6	915	202	1.00	220.8	28.7
7	1021	238	1.00	233.1	29.0
8	388	93	1.00	240.0	29.2
9+	208	57	1.00	272.1	30.4
Immature	23311	379		16.2	10.9
Mature	8170	1501		183.7	27.0
Total	31481	1880	0.26	59.7	15.1

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 2021. Numbers, biomass, mean weights and mean length and by winter ring.

Age (ring)	Numbers	Biomass	Weight (g)	Length (cm)
0	0	0	-	-
1	26	1	54.4	19.0
2	245	21	86.9	21.8
3	275	30	107.4	23.6
4	203	23	112.5	23.8
5	52	9	168.8	27.0
6	49	8	169.1	27.0
7	22	5	212.0	29.0
8+	39	8	209.0	29.2
3+	639	82	128.5	24.7
Total	911	105	115.2	23.8

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 June-July 2021. Mean weights, mean lengths and fraction mature by winter ring.

Age (ring)	Numbers	Biomass	Maturity	Weight (g)	Length (cm)
0	0	0.0	0.0	-	-
1	61	3.9	0.0	62.9	19.4
2	511	61.6	0.5	120.6	23.7
3	282	45.5	1.0	161.3	25.8
4	97	17.4	1.0	180.0	27.0
5	54	10.2	1.0	189.1	27.5
6	41	9.3	1.0	228.1	29.1
7	80	17.8	1.0	222.8	28.9
8	26	6.1	1.0	233.1	29.9
9+	23	5.1	1.0	223.3	29.4
Immature	304	30.3		99.6	22.3
Mature	871	146.6		168.4	26.3
Total	1175	176.9	0.7	150.6	25.2

Table 5.5. Total numbers (millions) and biomass (thousands of tonnes) of Malin Shelf herring (6.a./7. b, c) June-July 2021. Mean weights, mean lengths and fraction mature by winter ring.

Age (ring)	Numbers	Biomass	Maturity	Weight (g)	Length (cm)
0	0	0.0	0.0	-	-
1	227	15.7	0.0	68.9	20.0
2	1808	201.0	0.4	111.2	23.0
3	711	109.3	0.9	153.8	25.3
4	177	30.2	1.0	170.5	26.4
5	81	15.1	1.0	185.4	27.3
6	48	10.7	1.0	221.2	28.8
7	83	18.4	1.0	221.9	28.9
8	27	6.3	1.0	233.1	29.9
9+	23	5.1	1.0	223.5	29.5
Immature	1359	133.7		98.4	22.2
Mature	1827	278.1		152.2	25.3
Total	3186	411.8	0.6	129.3	24.0

Table 5.6. Estimates of North Sea Autumn Spawning herring (millions) at age and SSB from acoustic surveys, 1986–2021. 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 2021 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
2021	5,196	2,803	1,800	773	877	915	1,021	388	208	31,481	1,501

Table 5.7. Numbers at age (millions) of Western Baltic Spring Spawning herring at age (winter rings) from acoustic surveys 1992 to 2021. 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
2021	26	245	275	203	52	49	22	39	911	639

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 2021. 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
2021	61	511	282	97	54	41	80	26	23	147

Table 5.9. Numbers at age (winter rings, millions) and SSB (thousands of tonnes) of the Malin Shelf acoustic survey (6.a./7. b, c) time series from 2008 to 2021. This table has 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
2021	227	1808	711	177	81	48	83	27	23	278

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 2021 North Sea acoustic survey (HERAS).

Age	Abundance (million)	Biomass (1000 t)	Mean weight (g)	Mean length (cm)
0i	1 345	3.7	2.8	7.2
1i	22 675	116.1	5.1	8.7
1m	23 921	199.1	8.3	10.1
2i	6	0.0	7.1	10.0
2m	6 786	81.5	12.0	11.5
3i	4	0.1	16.0	13.0
3m	1 461	19.7	13.5	12.0
4m	2	0.0	18.1	13.7
Immature	**24 030**	**119.9**	**5.0**	**8.6**
Mature	**32 170**	**300.3**	**9.3**	**10.5**
Total	**56 200**	**420.2**	**7.5**	**9.7**

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 2000-2021. 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
2021	1 345	46 595	6 793	1 467	**56 200**	4	315	82	20	420
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 2021 North Sea acoustic survey (HERAS).

Age	Abundance (million)	Biomass (tonnes)	Mean weight (g)	Mean length (cm)
0i	0	0	-	-
0m	0	0	-	-
1i	53.1	379	7.1	9.5
1m	270.1	2 175	8.1	9.9
2i	1.9	18	9.5	10.9
2m	256.1	2 847	11.1	11.1
3m+	42.0	769	18.3	13.5
Immature	55.0	397	7.2	9.5
Mature	568.2	5 790	10.2	10.7
Total	623.2	6 187	9.9	10.6

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 2006-2021.

	Abundance (million)					Biomass (1000 t)				
Year/Age	0	1	2	3+	Sum	0	1	2	3+	Sum
2021	0.0	323.2	258.0	42.0	623.2	0.0	2.6	2.9	0.8	6.2
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.

	2020				2021			
Strat.	Abundance (mill)	Biomass (kt)	Mean weight (g)	Proportion mature	Abundance (mill)	Biomass (kt)	Mean weight (g)	Proportion mature
11	492	115	233.7	0.98	567	123.1	217.2	1.00
21	1096	25	22.9	0.03	11605	67.2	5.8	0.00
31	991	22	22.7	0.02	439	16.3	37.1	0.00
41	758	61	80.8	0.34	208	12.9	62.0	0.06
42	1081	37	34.4	0.02	922	37.0	40.2	0.01
51	3021	12	4.0	0.00	250	1.8	7.4	0.00
61	2931	12	4.1	0.00	2995	6.4	2.1	0.00
71	452	14	30.0	0.02	2910	15.3	5.3	0.00
81	156	21	133.6	0.80	189	7.8	41.2	0.01
91	3421	430	125.8	0.70	5251	623.8	118.8	0.62
101	12	1	43.6	0.02	0	0	-	-
111	5234	1135	216.9	1.00	3724	781.0	209.7	0.99
121	144	26	181.8	1.00	349	65.4	187.6	1.00
131	981	32	32.7	0.02	94	1.4	14.3	0.00
141	2479	135	54.4	0.05	1223	85.7	70.1	0.16
151	345	11	32.2	0.01	651	24.8	38.1	0.05
152	172	14	81.2	0.39	102	9.8	96.0	0.37

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.

	2020			2021		
Stratum	Abundance (mill)	Biomass (kt)	Mean weight (g)	Abundance (mill)	Biomass (kt)	Mean weight (g)
11	8	2	194.4	128	24.9	194.5
21	286	12	41.2	12	0.5	46.0
31	189	9	47.9	25	1.3	52.2
41	373	39	103.5	204	18.8	92.3
42	243	11	47.2	6	0.6	105.3
141	484	78	160.5	442	48.2	108.9
151	100	3	33.8	21	2.5	118.3
152	81	8	102.6	74	8.2	109.7

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 *.

	2020				2021			
Stratum	Abun-dance (mill)	Bio-mass (kt)	Mean weight (g)	Proportion mature	Abun-dance (mill)	Bio-mass (kt)	Mean weig ht (g)	Proportion mature
1*	639	84.3	131.8	0.52	126.5	25.6	202.6	0.95
2*	156	11.5	73.3	0.03	15.5	0.8	54.1	0.00
3*	584	90.7	155.3	0.69	593.9	93.8	158.0	0.82
4*	603	60.0	99.5	0.34	438.7	56.6	128.9	0.60
5	1549	153.3	99.0	0.30	1875.8	219.4	117.0	0.48
6	103	10.1	98.1	0.24	135.6	15.5	114.3	0.42

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.

		2020				2021			
ICES area	Stratum	Abundance (mill)	Biomass (t)	Mean Weight (g)	% Mature	Abundance (mill)	Biomass (t)	Mean Weight (g)	% Mature
Div. 3.a	21	2 643	23 937	9.1	90	530	5 381	10.1	99
	31	912	7 321	8.0	74	15	134	8.7	54
	41	0	0	-	-	0	0	-	-
	42*	722	8 597	11.8	92	77	672	8.7	47
North Sea	11	0	0	-	-	0	0	-	-
	51	37 268	268 133	7.2	57	27 630	209 846	7.6	54
	61	19 714	151 297	7.7	46	13 509	75 126	5.6	17
	71	732	7 964	10.9	89	5 805	44 863	7.7	98
	81	2 699	21 967	8.1	99	709	7 074	10.0	100
	91	3 051	34 442	11.3	100	2 274	23 915	10.5	100
	101	128	1 026	8.0	100	233	1 833	7.9	100
	111	0	0	-	-	0	0	-	-
	121	0	0	-	-	0	0	-	-
	131	2 100	26 782	12.8	98	5 113	47 408	9.3	99
	141	1 109	15 905	14.3	100	168	2 347	14.0	100
	151	253	3 180	12.6	90	759	7 822	10.3	100
	152*	0	0	-	-	0	0	-	-

* New strata from 2017, 42 and 152 were part of stratum 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 2020 and 2021 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.

	2020				2021			
Stratum	Total transect length (nmi.)	Herring ages	Sprat ages	Transect spacing (nmi.)	Total transect length (nmi.)	Herring ages	Sprat ages	Transect spacing (nmi.)
1	486	285	-	15	481.4	234	-	15
2	145	201	-	*	154.9	47	-	*
3	299	341	-	15	303	232	-	15
4	241	462	-	15	223.3	286	-	15
5	400	581	-	10	393.5	516	-	10
6	216	461	-	15	224	191	-	15
11	964	462	-	15	942	316	-	15
51	492	186	164	30	594	304	269	25
61	236	222	112	23	240	147	265	23
71	232	274	283	23	293	306	233	17.5
81	526	262	59	*	475	57	34	*
91	1622	734	95	15	1692	1104	21	15
101	51	100	29	15	61	57	24	15
111	821	1427	-	15	711.6	1398	-	15
121	477	386	-	15	484.9	166	-	15
131	466	305	240	40	462	277	359	40
141	964	567	49	18.75	999.4	450	24	18.75
21	199	1059	885	13	209.2	274	203	13
31	159	898	490	10	153.3	363	107	10
41	172	396	133	17.5	156.8	268	-	17.5
42	93	663	214	17.5	85.8	383	79	17.5
151	363	561	337	15	384.2	717	326	15
152	99	303	13	15	118.2	368	-	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 1/2 cm class below 22 cm, 5 per 1/2 cm class from 22 1/2-27 1/2 cm and ten per 1/2 cm class for 28 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	100 random fish aged, length, weight, sex, maturity and genetic sample. Additional 100 random fish for length and weight only. Length frequency only continued until 60 individuals is reached in one length class.	200 (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

Table 5.20. Defining acoustic categories uploaded to ICES database by Denmark and Germany in 2021. The table shows the category name used in the ICES Database, which acoustic (split) categories and associated species are contained in these mixed categories, and the TS relationship used to split the NASC where a and m refer to the values in the standard formula: TS = m* log L – a, where L is length in cm.

Acoustic category in database	Country	Name in StoX project	AcousticSplit category	Species name	Aphia code	(a) dB	(m)
CLU	GER, DEN	CLU	HER	*Clupea harengus*	126417	-71.2	20
			SPR	*Sprattus sprattus*	126425	-71.2	20
			PIL	*Sardina Pilchardus*	126421	-71.2	20
			ANE	*Engraulis encrasicolus*	126426	-71.2	20
MIX	GER	MIX_GER	HER	*Clupea harengus*	126417	-71.2	20
			SPR	*Sprattus sprattus*	126425	-71.2	20
			PIL	*Sardina Pilchardus*	126421	-71.2	20
			ANE	*Engraulis encrasicolus*	126426	-71.2	20
			WHB	*Micromesistius poutassou*	126439	-65.2	20
MIX	DEN	MIX_DEN	HER	*Clupea harengus*	126417	-71.2	20
			SPR	*Sprattus sprattus*	126425	-71.2	20
			PIL	*Sardina Pilchardus*	126421	-71.2	20
			ANE	*Engraulis encrasicolus*	126426	-71.2	20
			WHB	*Micromesistius poutassou*	126439	-65.2	20
			GUG	*Eutrigla gurnardus*	150637	-67.5	20
			HAD	*Melanogrammus aeglefinus*	126437	-67.5	20
			COD	*Gadus morhua*	126436	-67.5	20
			GSE	*Hyperoplus lanceolatus*	126756	-81.5	21.7
			HKB	*Merluccius merluccius*	126484	-67.5	20
			NOP	*Trisopterus esmarkii*	126444	-67.5	20
			POL	*Pollachius pollachius*	126440	-67.5	20
			POK	*Pollachius virens*	126441	-67.5	20
			MSE	*Ammodytes marinus*	126751	-81.5	21.7
			WHG	*Merlangius merlangus*	126438	-67.5	20

Table 5.21. Assignment of herring populations to either North Sea Autumn Spawning herring or Western Baltic Spring Spawning (WBSS) herring based on genetic analysis, mean vertebral counts, or otolith microstructure.

Genetics	*Vertebral counts*	*Otolith microstructure*
North Sea autumn spawners (NSAS)	NSAS	NSAS (autumn)
Downs	NSAS	NSAS (winter)
Western Baltic spring spawners (WBSS)	WBSS	WBSS (spring)
Norwegian spring spawners (NSS)	NSAS	WBSS (spring)
Baltic Autumn spawners (BAS)	WBSS	NSAS (autumn)
Central Baltic spring spawners	WBSS	WBSS (spring)

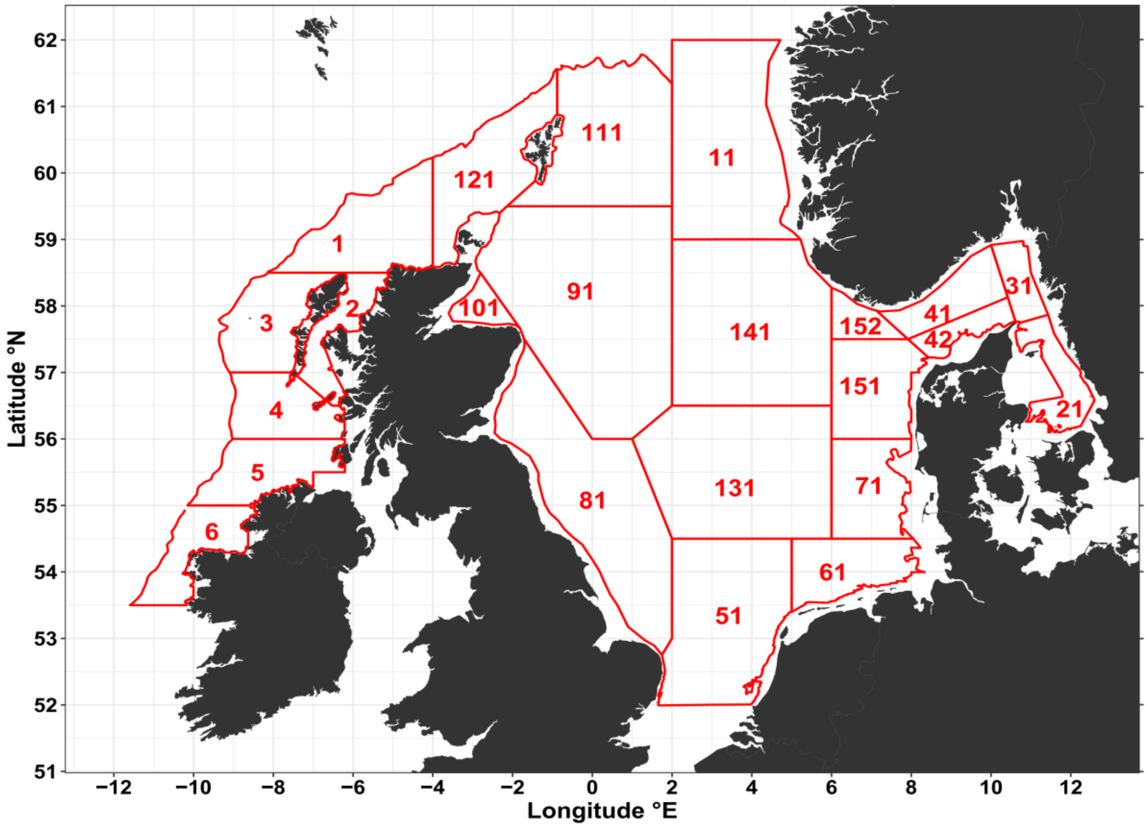


Figure 5.1. Strata used in the HERAS survey 2021.

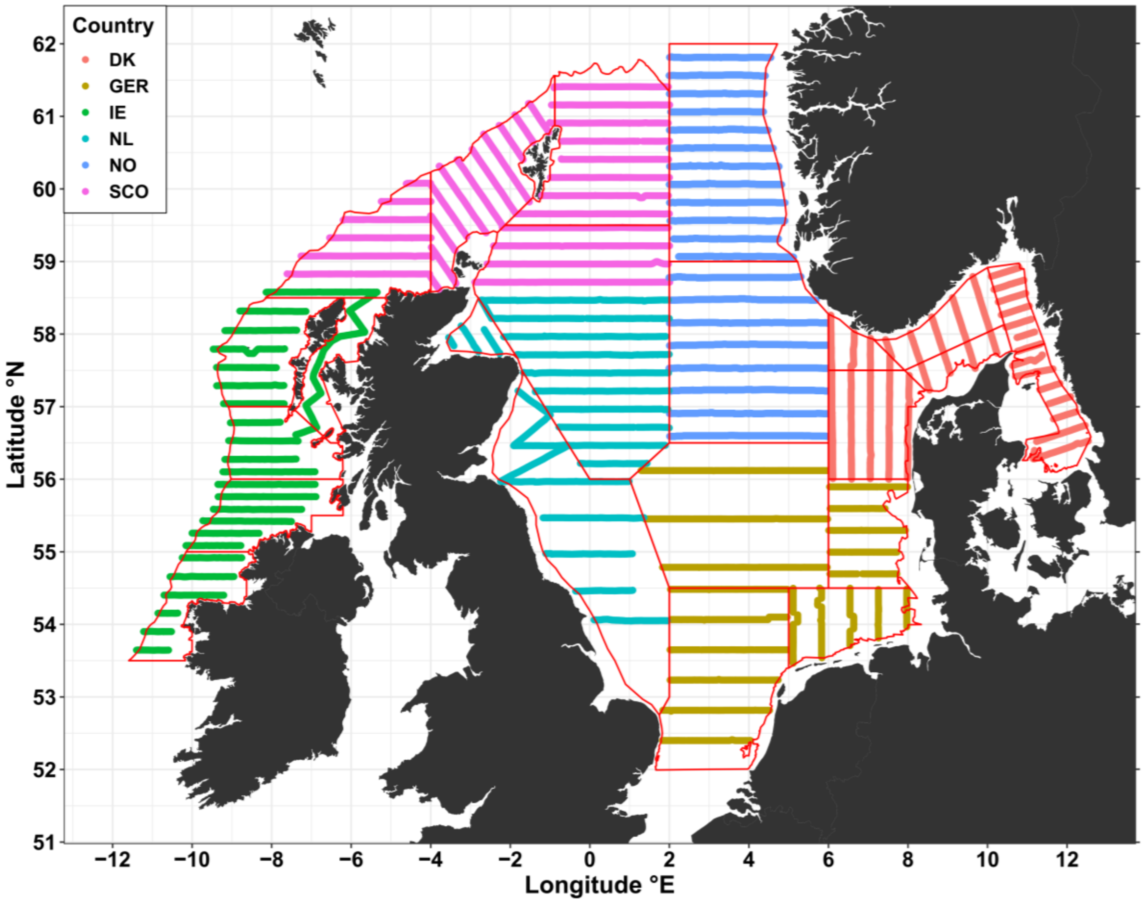


Figure 5.2. Survey area coverage in the HERAS survey in 2021 and individual vessel tracks by nation.

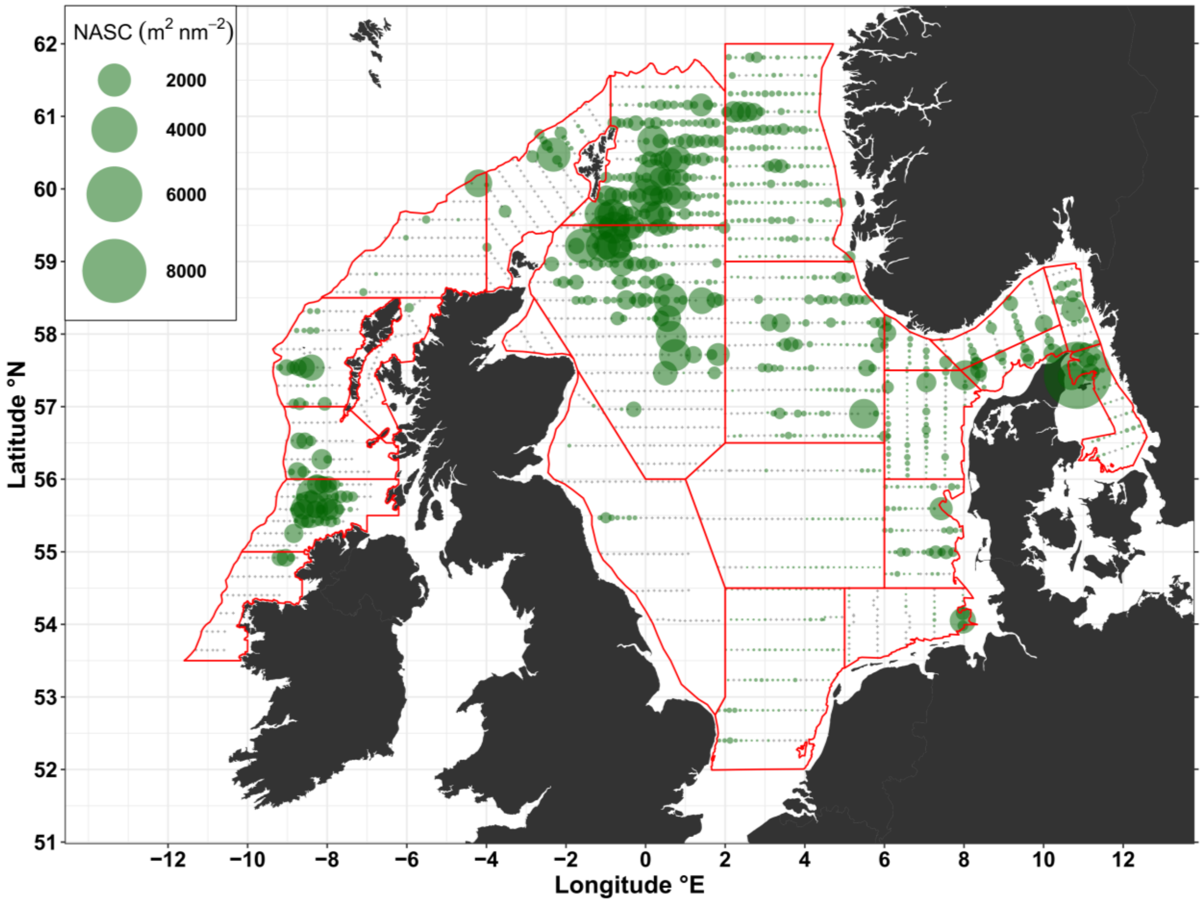


Figure 5.3. Distribution of NASC attributed to herring in HERAS in 2021. Acoustic intervals represented by light grey dot with green circles representing size and location of herring aggregations. NASC values are resampled at 5 n.mi. intervals along the cruise track. The red lines show the strata system.

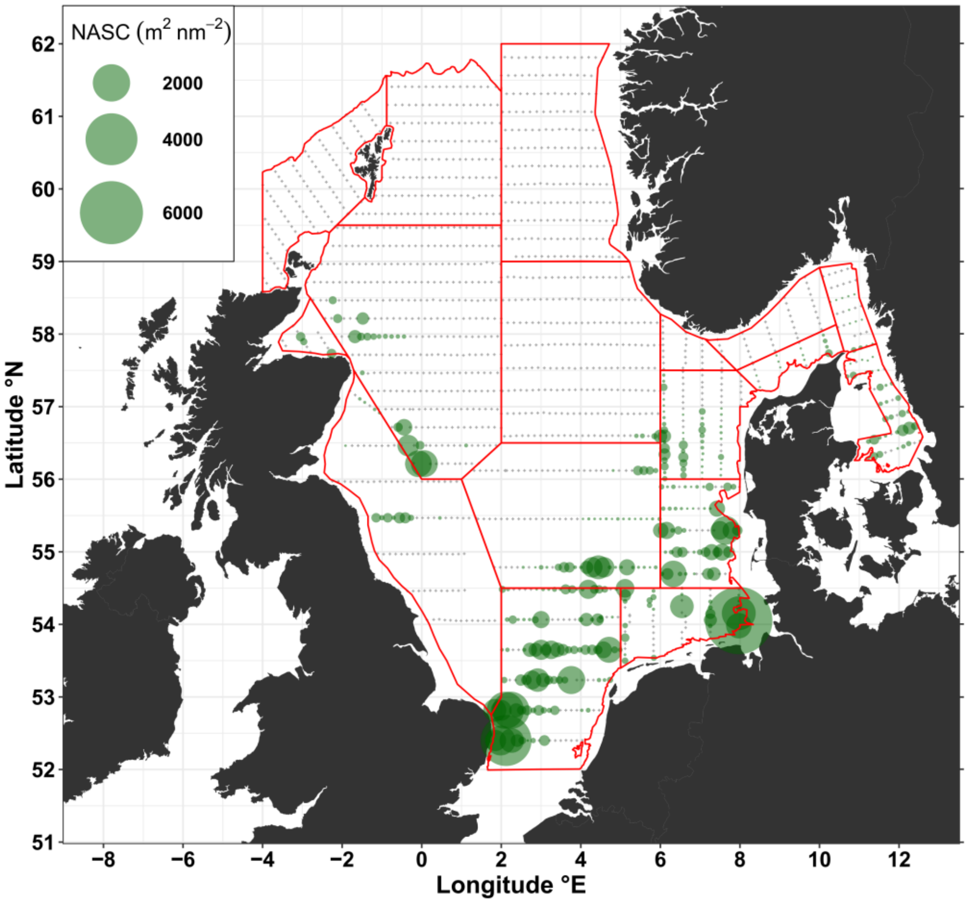


Figure 5.4. Distribution of NASC attributed to sprat in HERAS in 2021. Acoustic intervals represented by light grey dot with green circles representing size and location of sprat aggregations. NASC values are resampled at 5 n.mi. intervals along the cruise track. The red lines show the strata system.

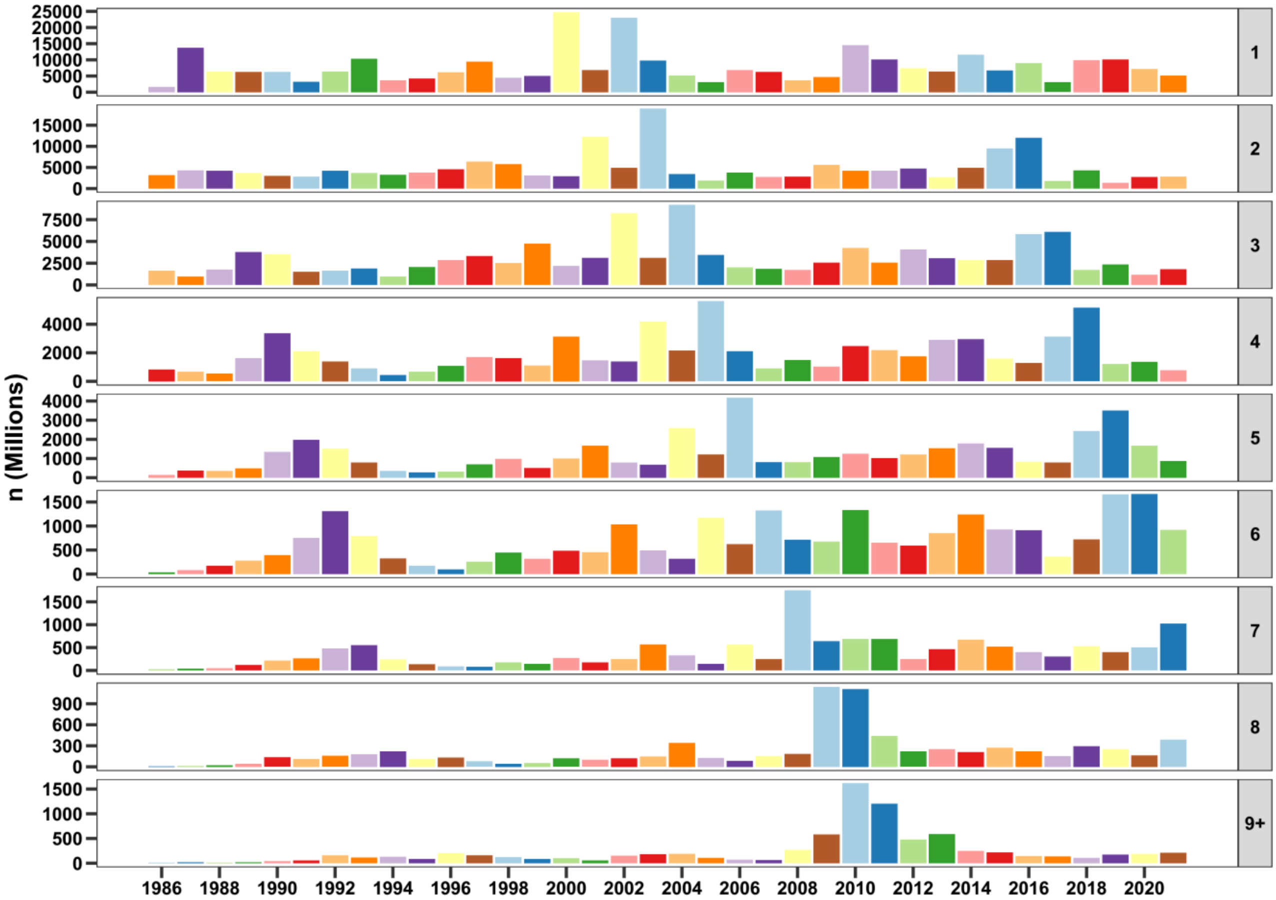


Figure 5.5. North Sea Autumn Spawning herring: HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 1986-2021. Note diverging scales of abundance between ages.

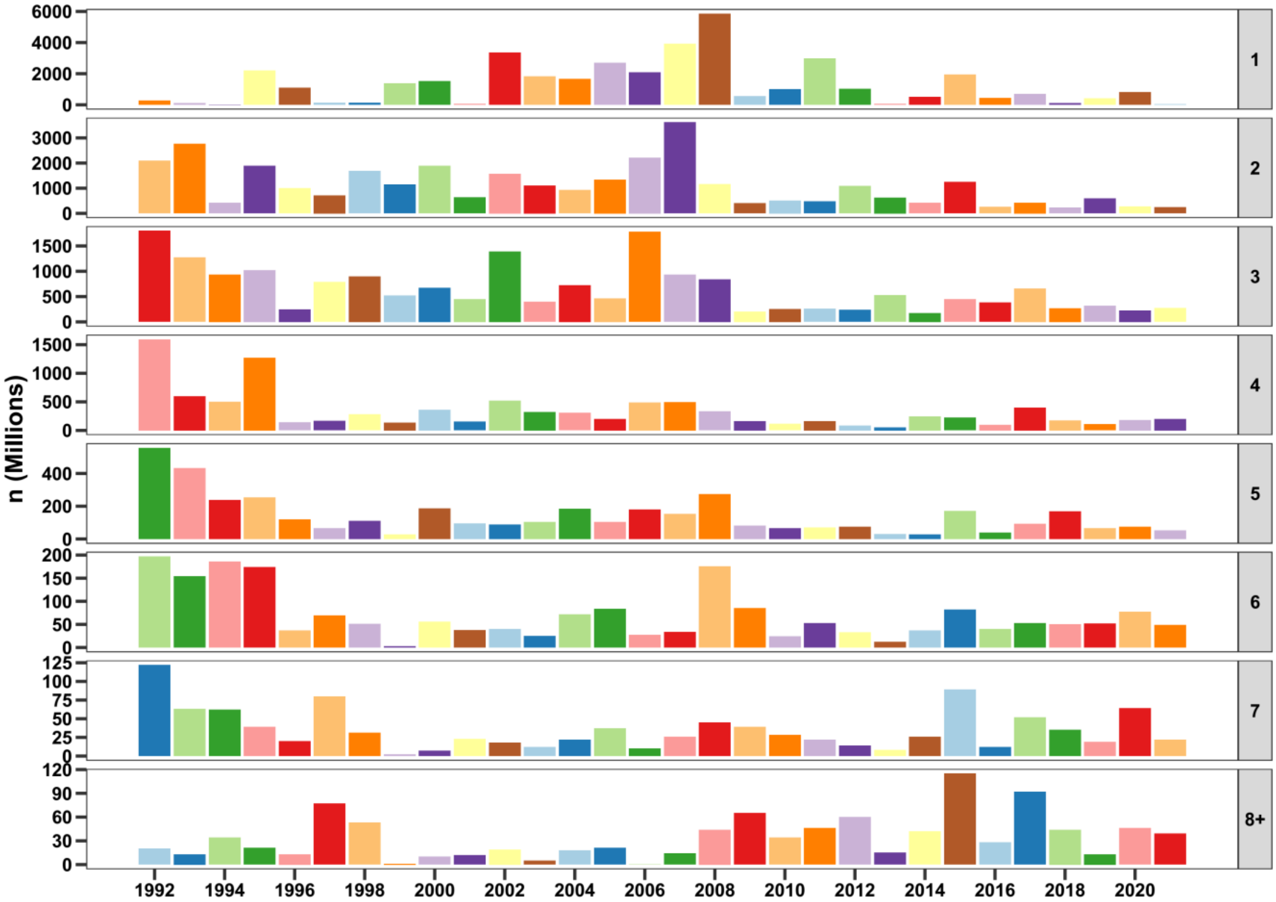


Figure 5.6. Western Baltic Spring Spawning herring: HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 1992-2021. Note diverging scales of abundance between ages.

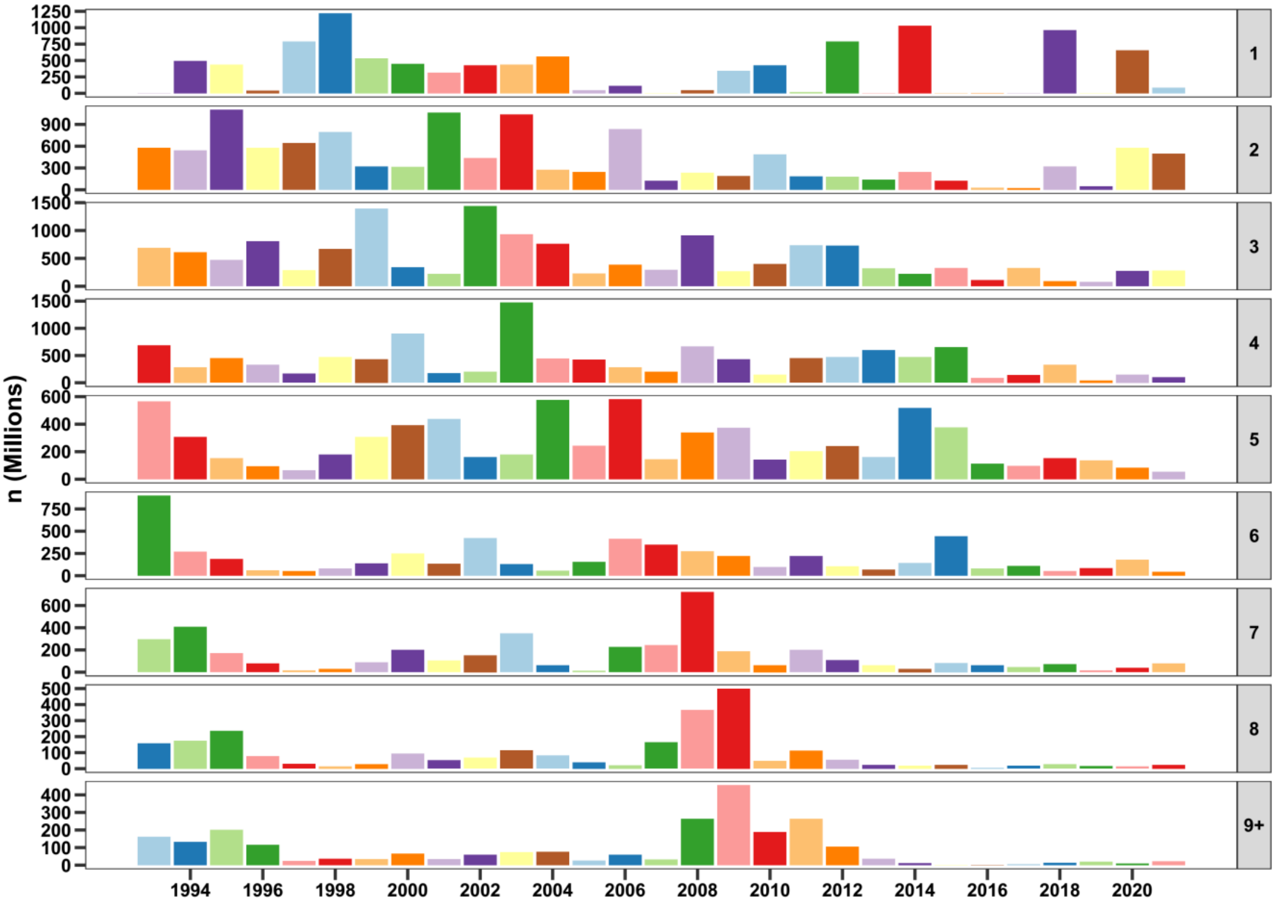


Figure 5.7. West of Scotland (6.a.N) herring: HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 1993-2021.

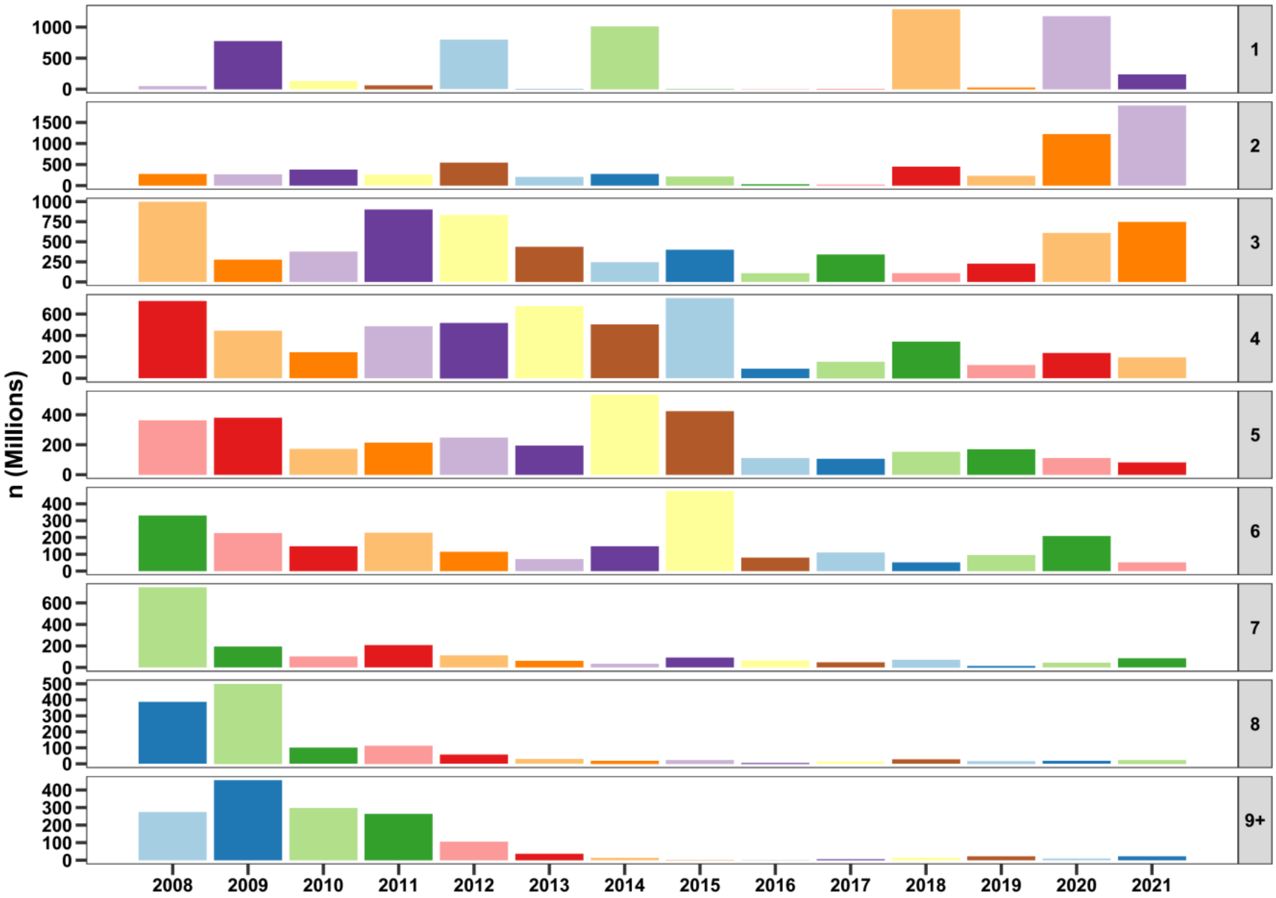


Figure 5.8. Malin Shelf Herring (6.a./7. b, c): HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 2008-2021.

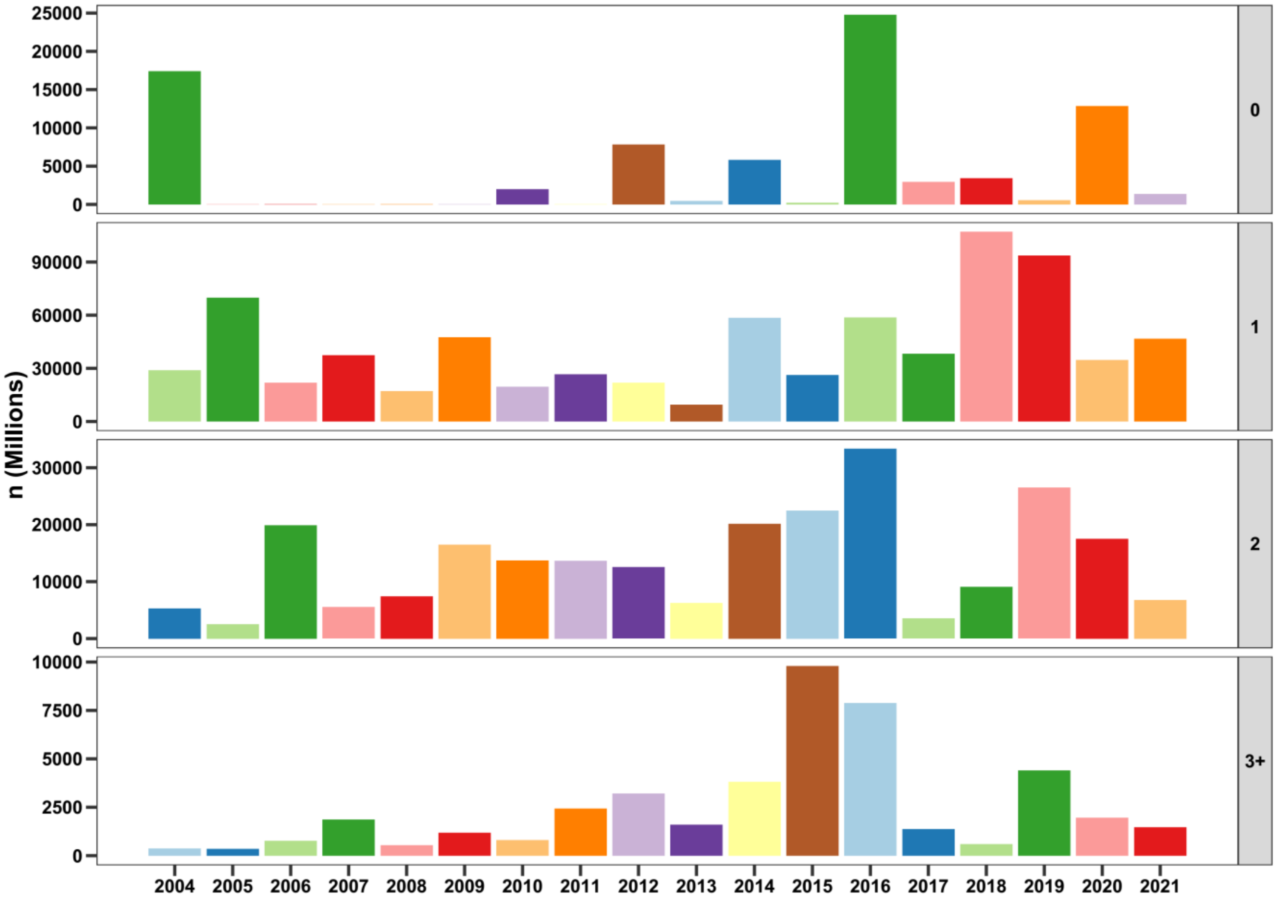


Figure 5.9. North Sea Sprat (ICES Subarea 4): HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 2004-2021. Note diverging scales of abundance between ages.

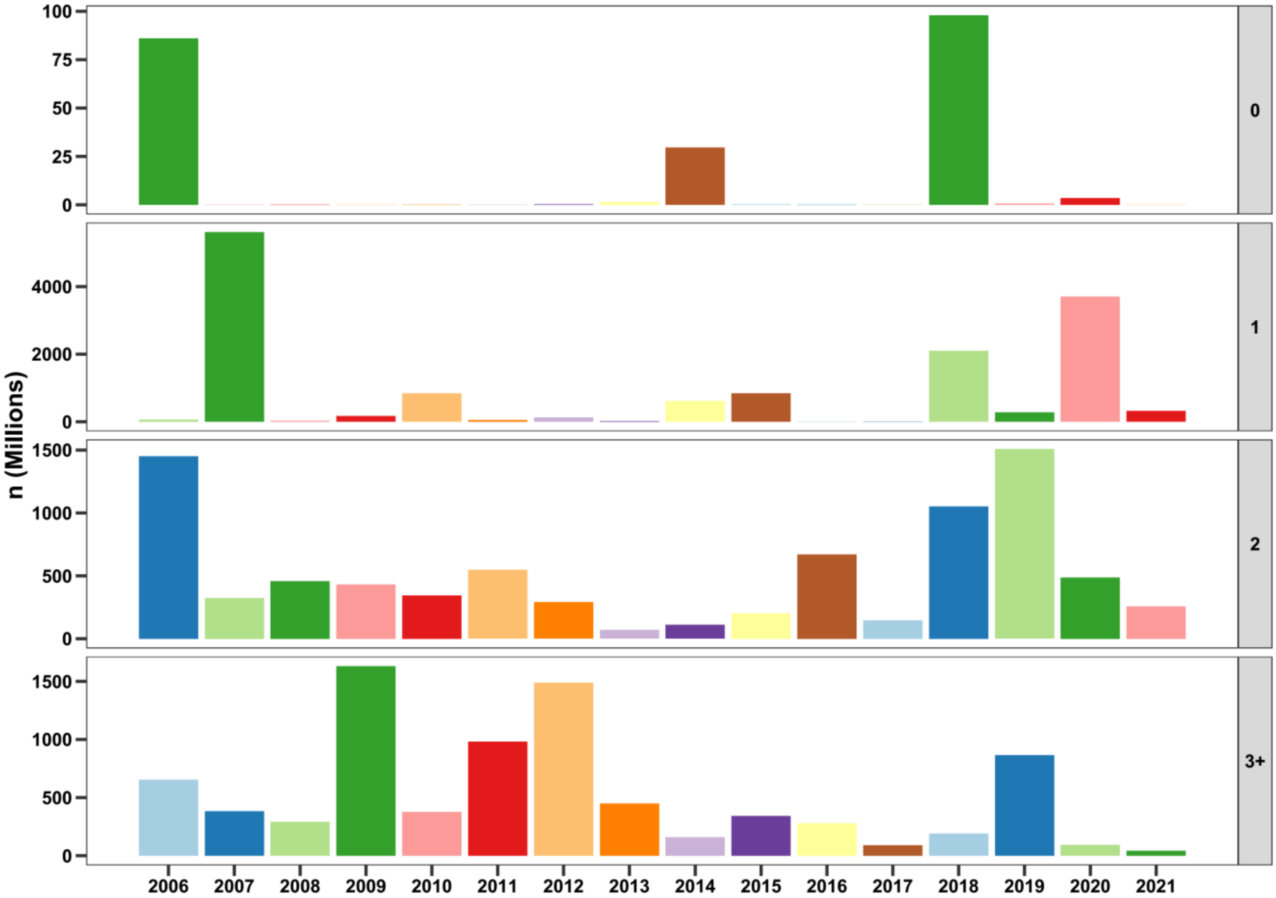
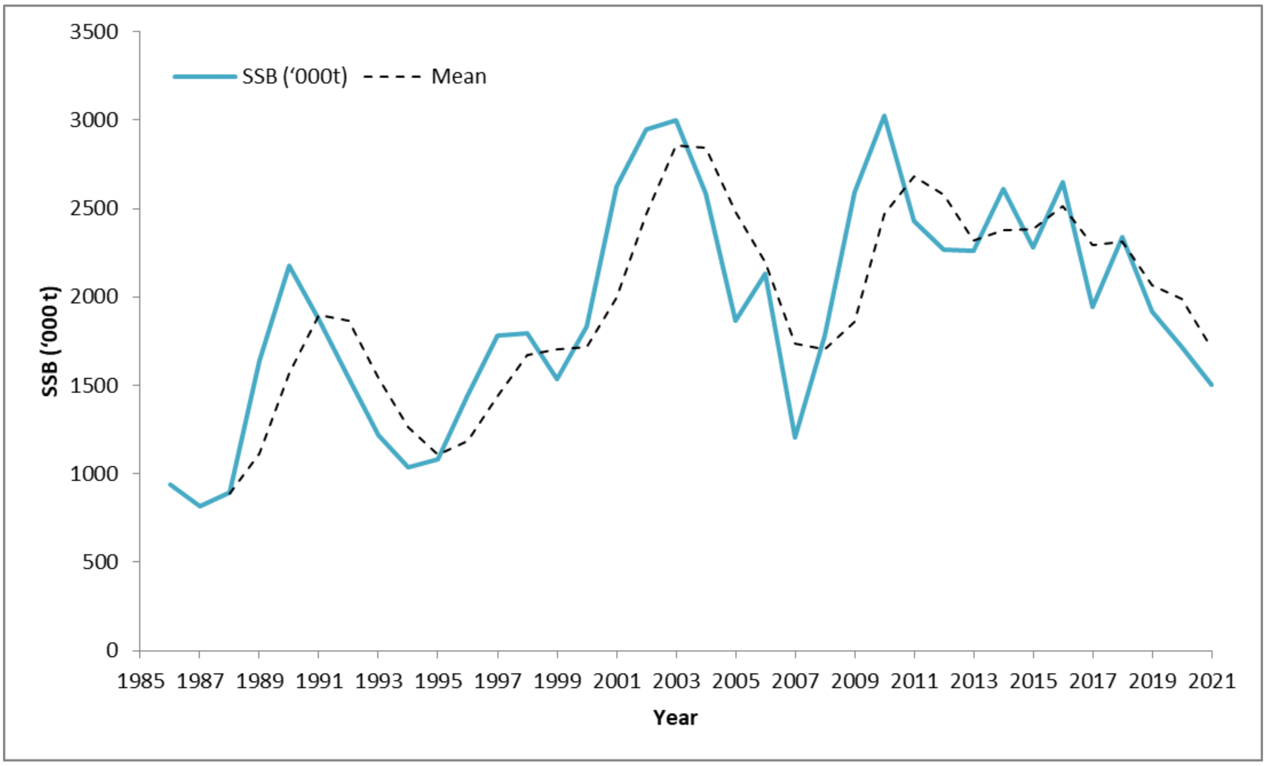


Figure 5.10. Sprat in Div. 3.a: HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 2006-2021. Note diverging scales of abundance between ages.

(a)



(b)

Figure 5.11. Time series of SSB of North Sea Autumn Spawning herring. (a) HERAS SSB for the period1986 – 2021 with three year running mean. (b) Comparison of the HERAS index for 1986 – 2020 with the 2021 NSAS herring assessment (HAWG 2021).

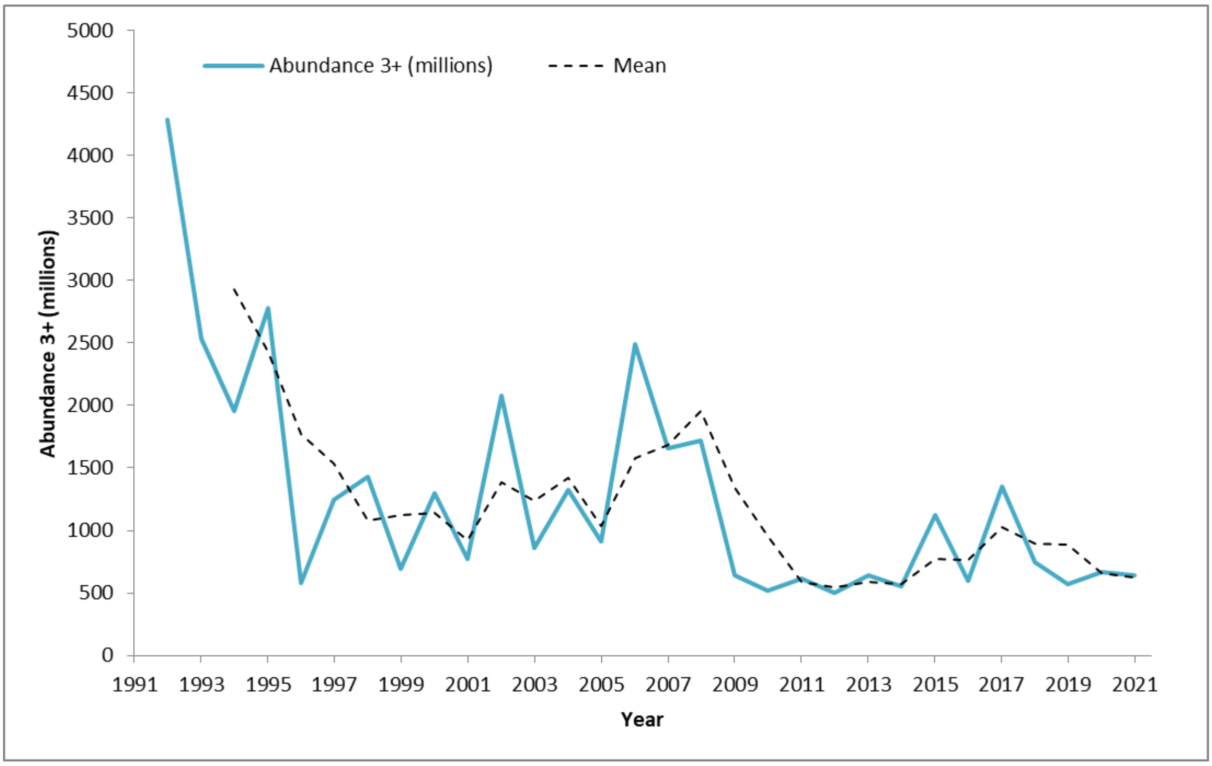


Figure 5.12. Time series of 3+ abundance of Western Baltic Spring Spawning herring with three year running mean.

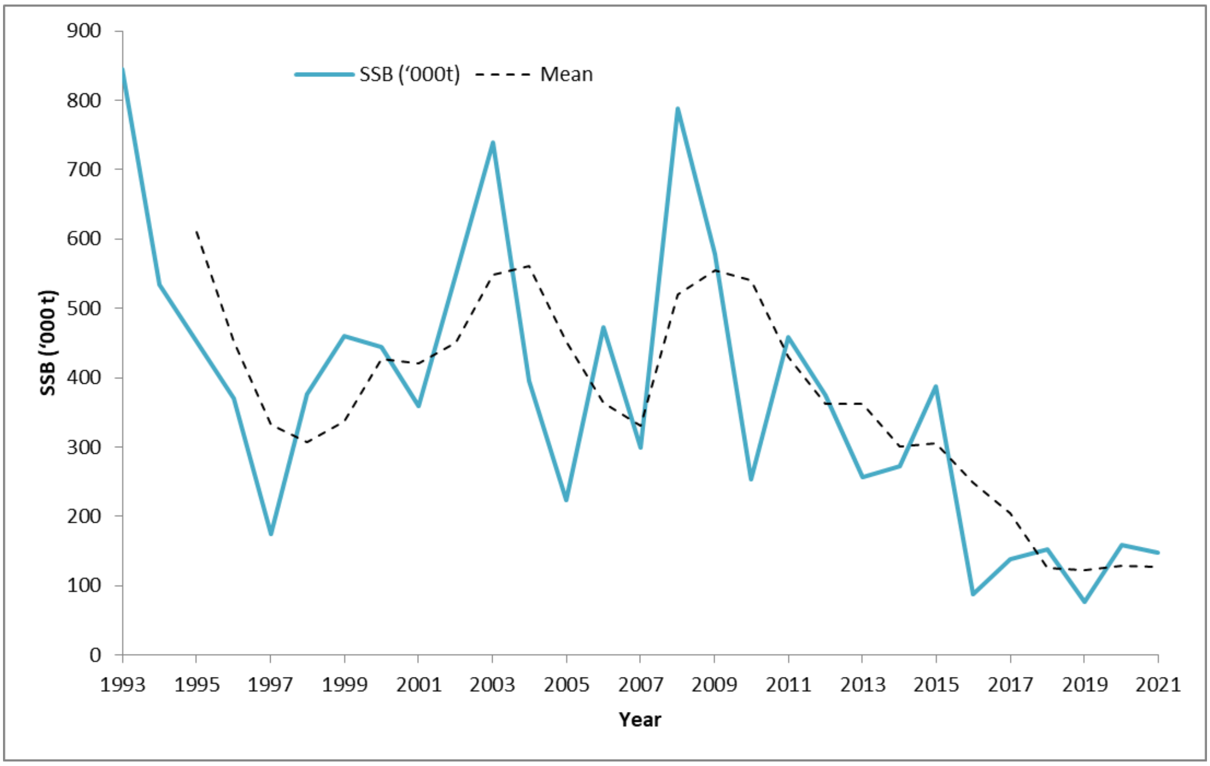


Figure 5.13. Time series of SSB of West of Scotland herring (geographical subset of Malin Shelf herring) with three year running mean.

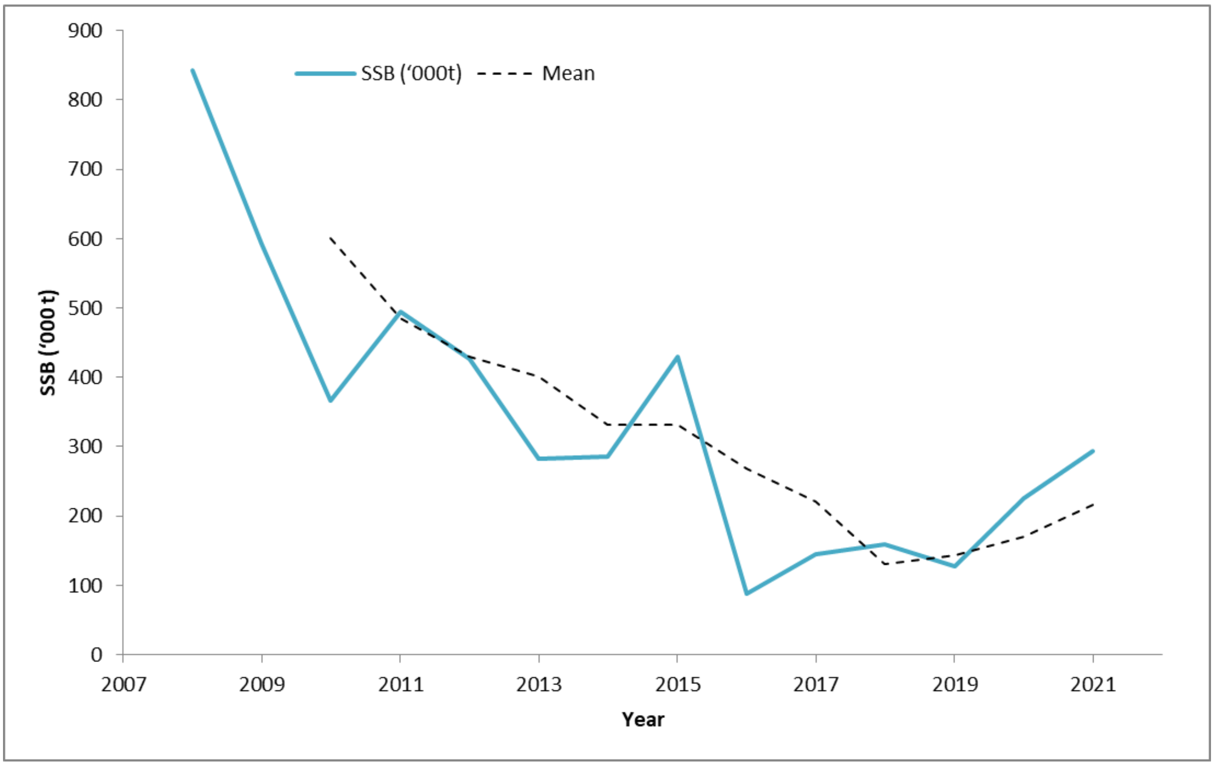


Figure 5.14. Time series of SSB of Malin Shelf herring with three year running mean.

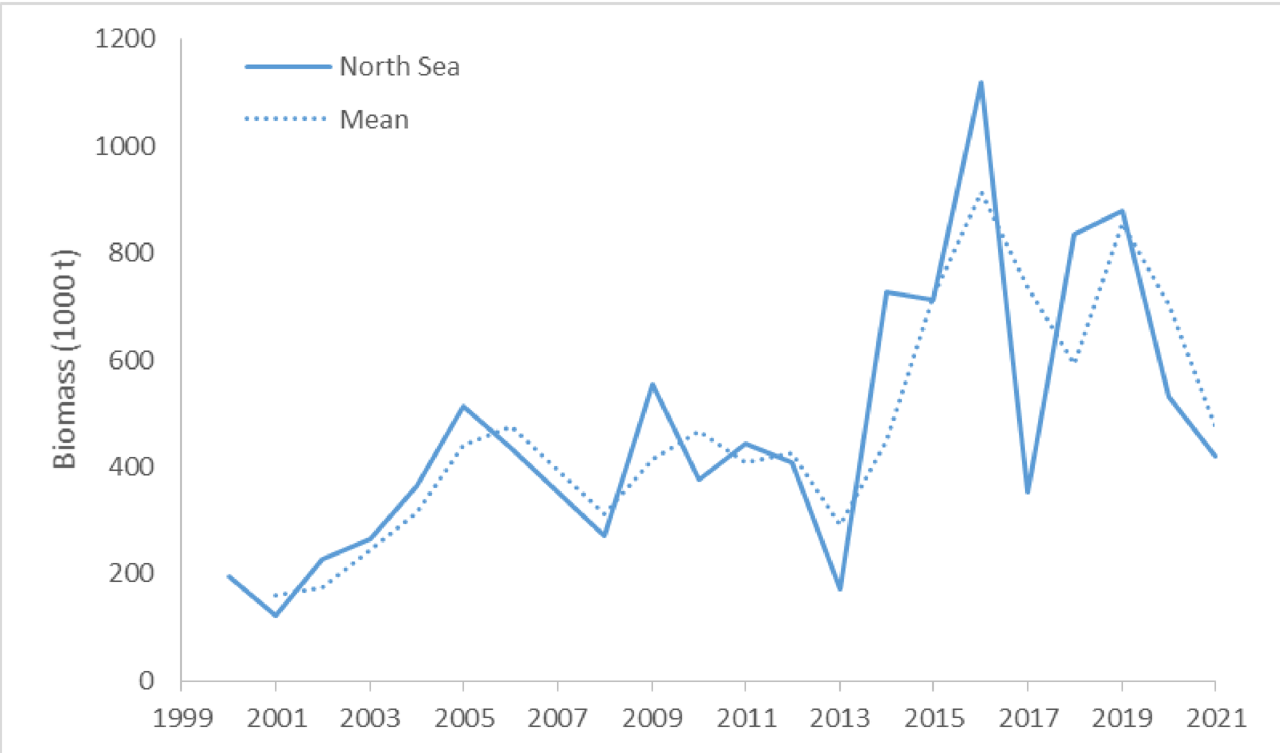


Figure 5.15. Time series of SSB of North Sea sprat (ICES Subarea 4) with three year running mean.

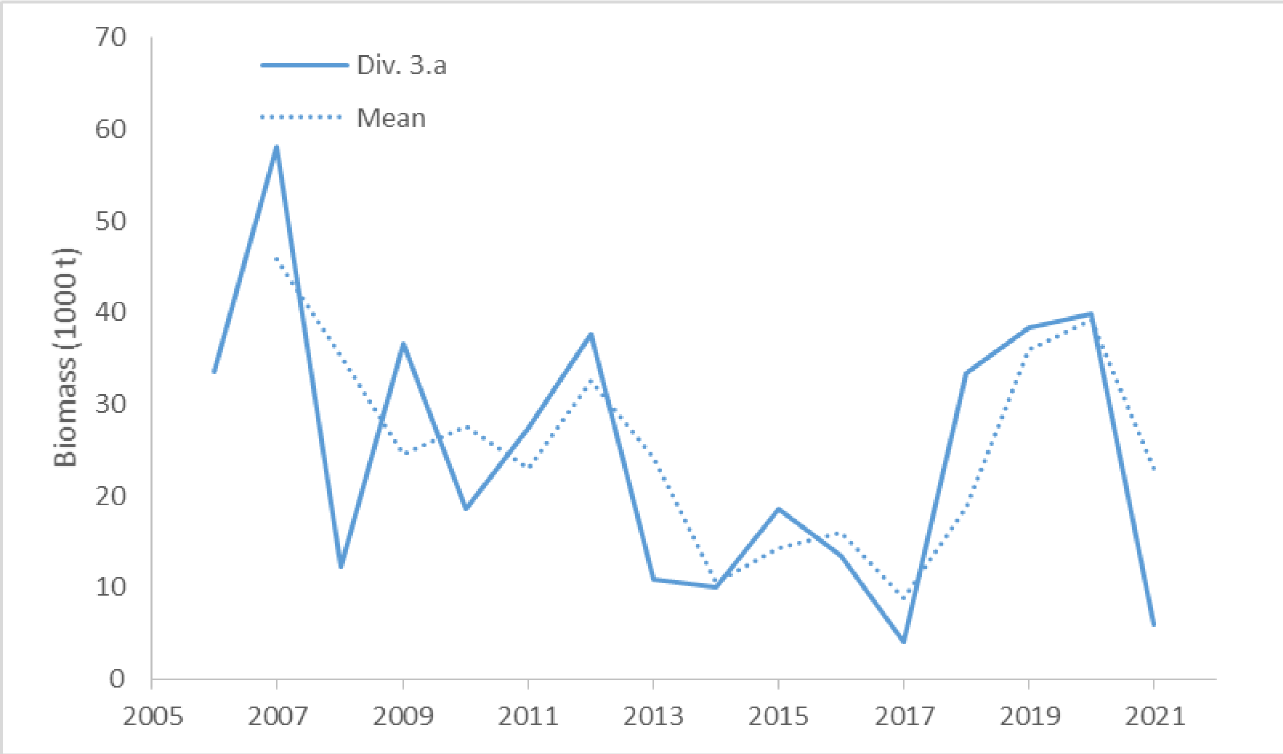


Figure 5.16. Time series of SSB of sprat in Div. 3.a with three year running mean.

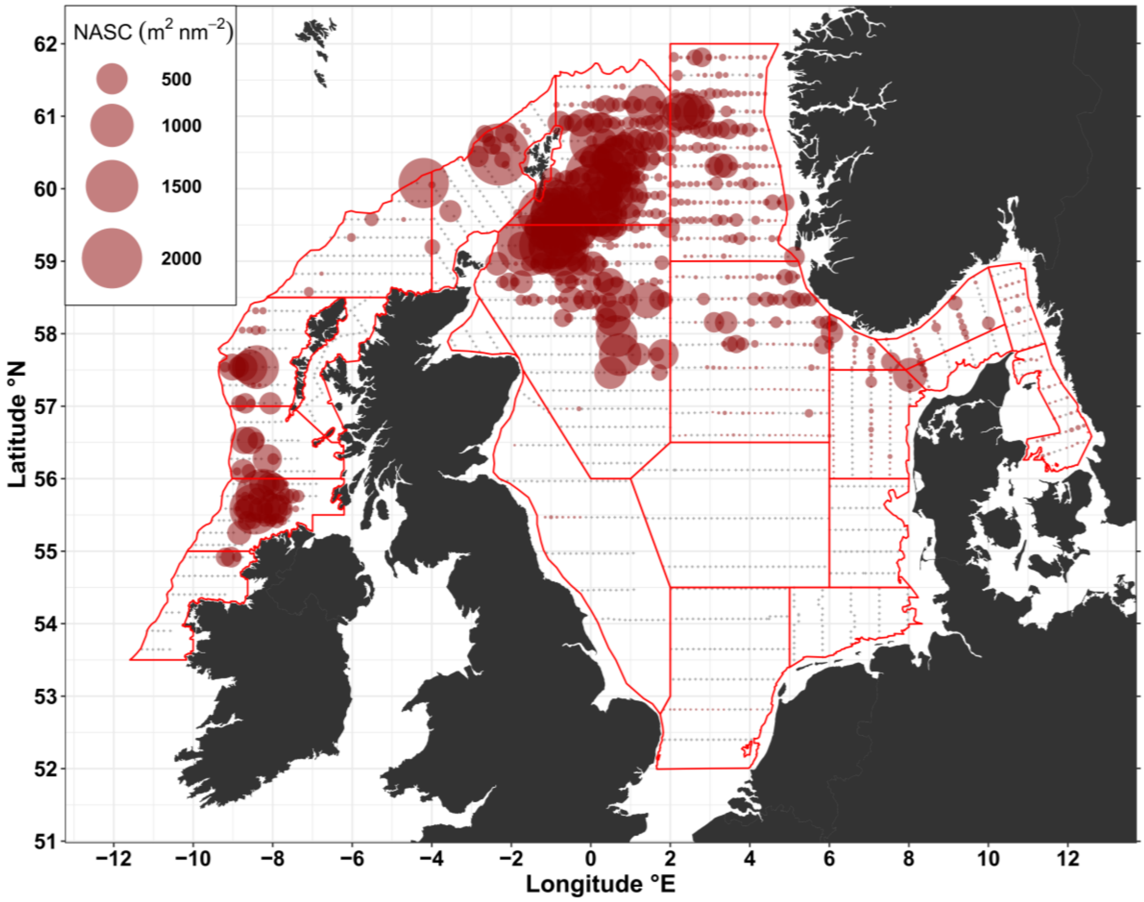


Figure 5.17. Distribution of NASC attributed to mature herring in HERAS 2021. Acoustic intervals represented by light grey dots with red bubbles representing size and location of herring aggregations. NASC values are resampled at 5 n.mi. intervals along the cruise track and split into mature and immature within each stratum following the proportion of mature herring in the stratum. The red lines show the strata system.

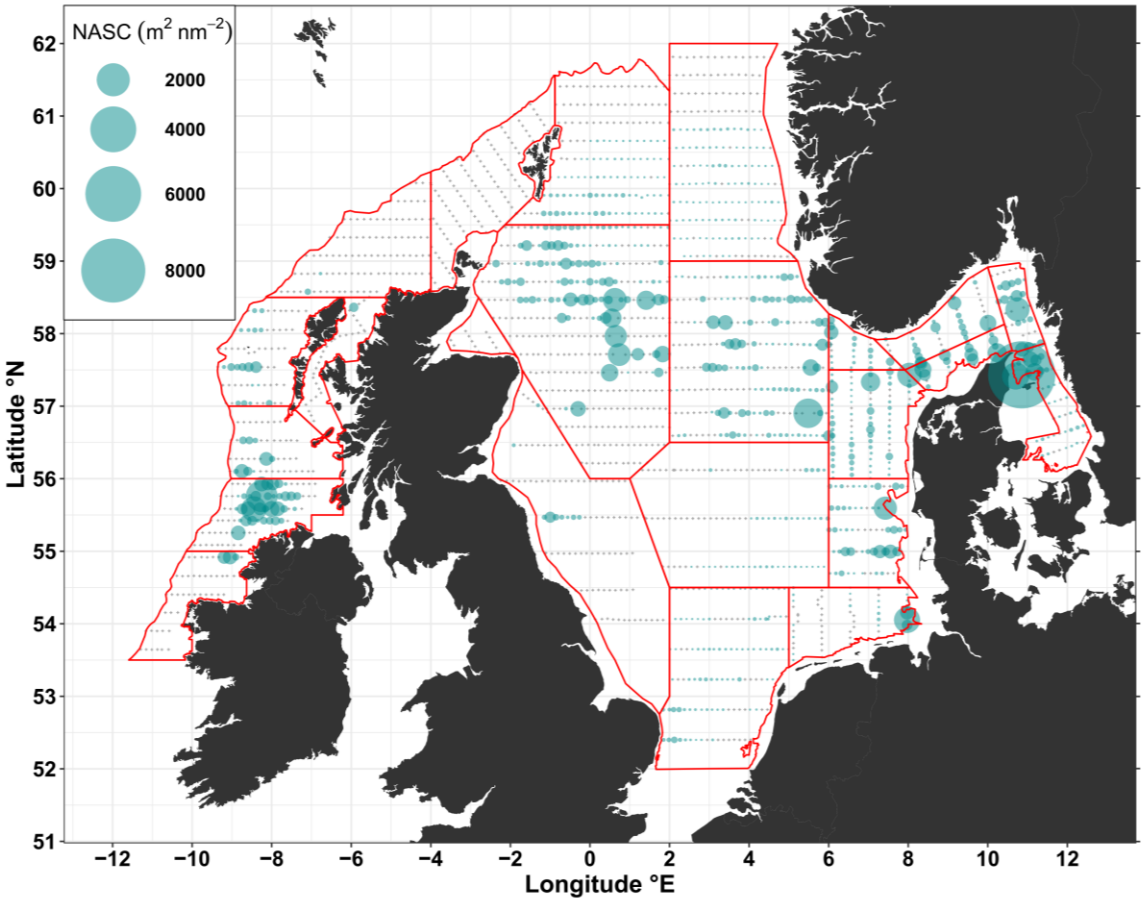


Figure 5.18. Distribution of NASC attributed to immature herring in HERAS 2021. Acoustic intervals represented by light grey dots with red bubbles representing size and location of herring aggregations. NASC values are resampled at 5 n.mi. intervals along the cruise track and split into mature and immature within each stratum following the proportion of mature herring in the stratum. The red lines show the strata system.

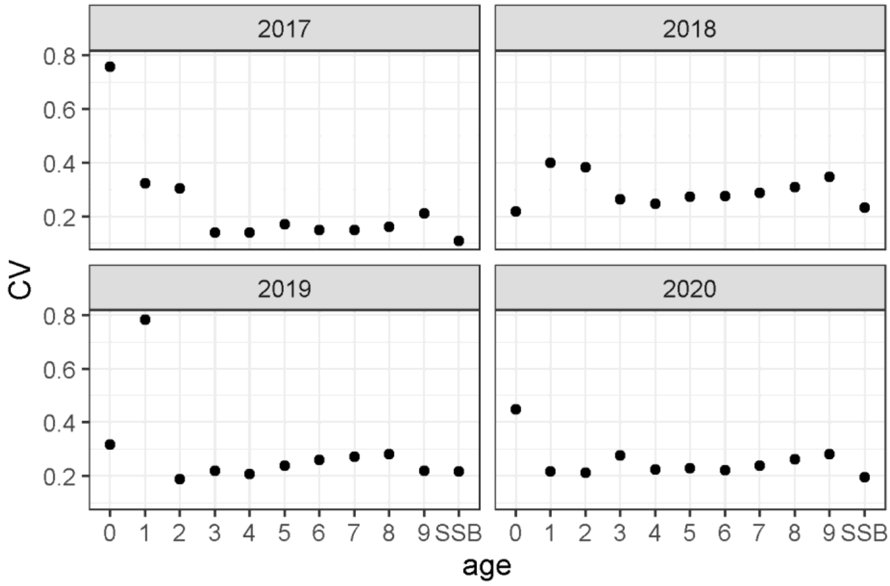


Figure 5.19. NSAS herring Coefficient of Variation (CV) for abundance at age and SSB as estimated using bootstrapping results from StoX. Data are shown for the 2017-2020 period for comparison.

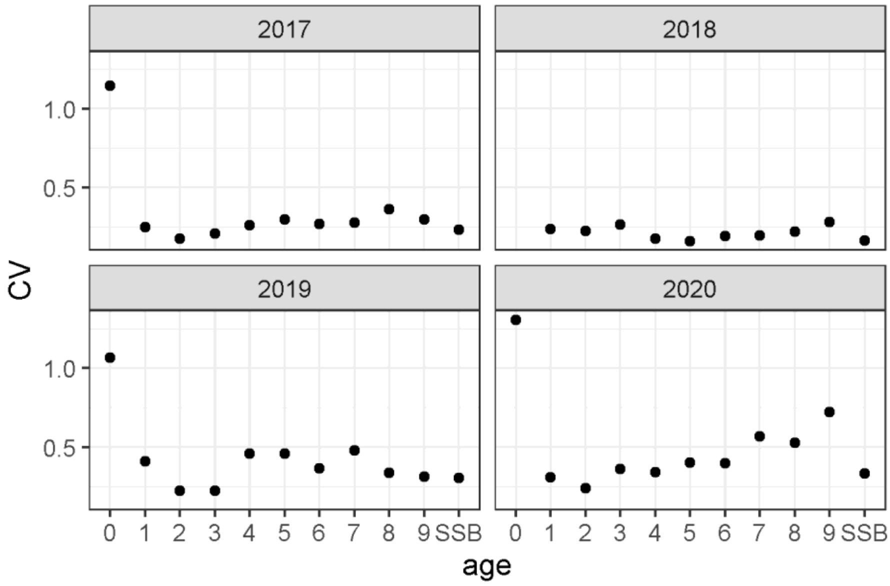


Figure 5.20. WBSS herring Coefficient of Variation (CV) for abundance at age and SSB as estimated using bootstrapping results from StoX. Data are shown for the 2017-2020 period for comparison.

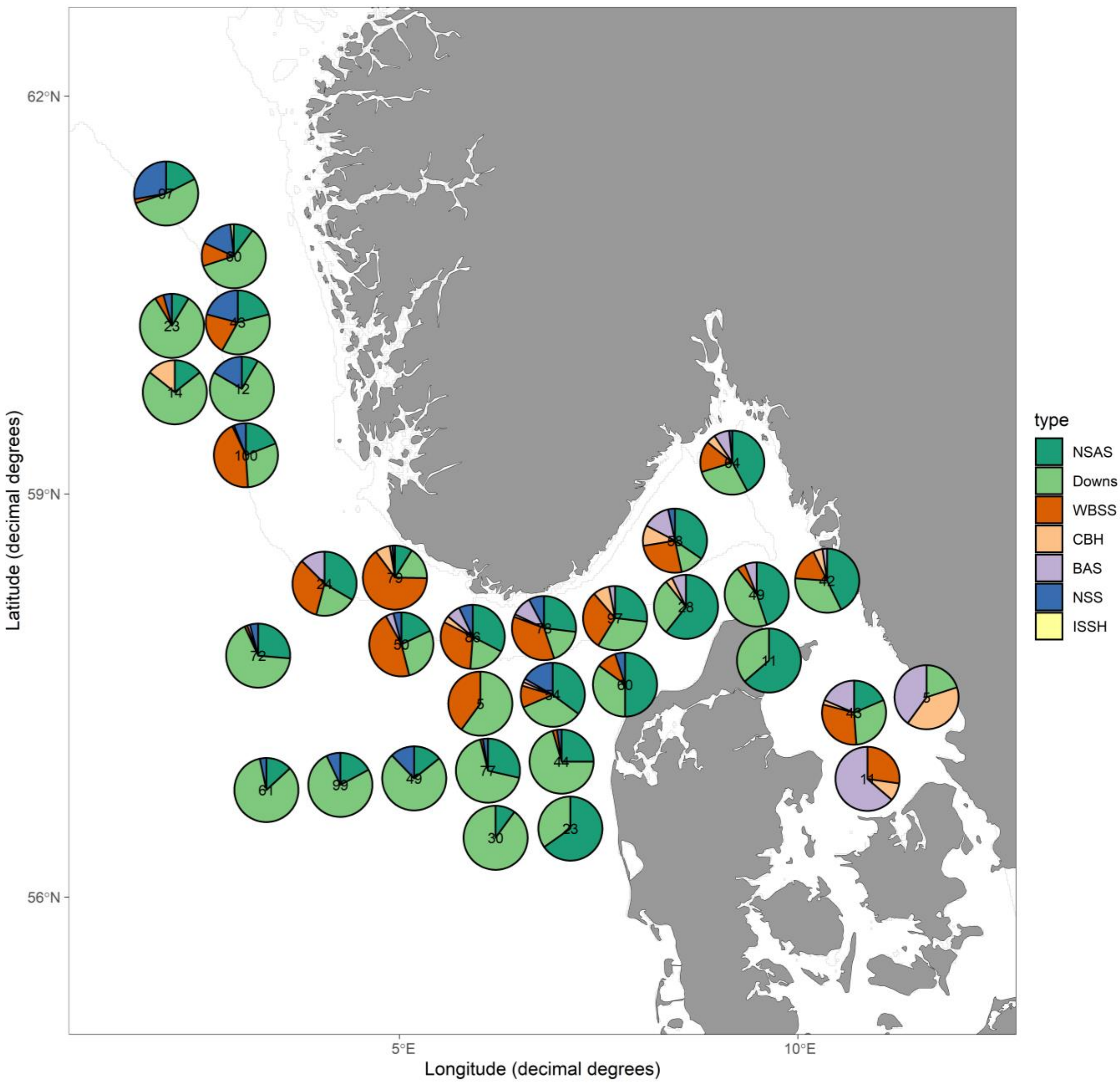


Figure 5.21. Results of genetic analyses (Single Nucleotide Polymormhism panels; Farrell et al., 2021; Han et al., 2020) for stock splitting. The analysis was conducted in areas where previously North Sea Autumn Spawning (NSAS) and Western Baltic Spring Spawning (WBSS) herring had been identified using otololith microstructure and vertebrae counts. Aside from 3 populations identified with the previous methods (NSAS, Downs –included in NSAS indices-, and WBSS), the genetic method also identified herring from several adjacent populations in the survey area: CBH – Central Baltic herring, BAS – Baltic Autumn Spawning herring, NSS – Norwegian Spring Spawning herring, ISSH – Icelandic Summer Spawning Herring (1 individual).

Annex 6: 2021 IESSNS Survey Summary Table and Survey Report

Document 6a: IESSNS 2021 survey summary table

Survey Summary table WGIPS 2022	
Name of the survey (abbreviation):	International Ecosystem Summer Survey in the Nordic Seas (IESSNS)
Target Species:	NEA mackerel
Survey dates:	30th June – 3rd August 2021
Summary:	
The International Ecosystem Summer Survey in the Nordic Seas (IESSNS) was performed within approximately 5 weeks from July 1st to August 5th in 2021 using five vessels from Norway (2), Iceland (1), Faroe Islands (1) and Denmark (1). Survey effort and timing in 2021 were comparable to previous years. The survey coverage area included in calculations of the mackerel index was 2.2 million km^2 in 2021, which is 24% less than last year. Greenlandic waters, Iceland basin (south of latitude 62°45′) and the Reykjanes ridge (south of latitude 62°45′) were not surveyed in 2021. Furthermore, 0.29 million km^2 was surveyed in the North Sea in July 2021, but those stations are excluded from the mackerel index calculations. The swept-area mackerel index decreased by 58.5% for biomass and 53.4% for abundance (numbers of individuals) in 2021 compared to 2020. Reduced survey coverage in the western area did not contribute to the observed decline as the zero mackerel boundary was established north, west, and south of Iceland. In 2021, the most abundant year classes were 2019, 2016, 2014, 2017 and 2012, respectively. The cohort internal consistency was slightly reduced compared to last year, particularly for ages 5-8 years (for years 2010, 2012-2021). The NEA mackerel population during summer 2021, like in 2019 and 2020, were mainly in the Norwegian Sea, extending into waters southeast and east of Iceland and into the North Sea. Distribution zero boundaries were found in most parts of the survey area, but not towards northwest in the Norwegian Sea, or towards south in the North Sea or west of the British Isles. Highest density of mackerel was in the central Norwegian Sea. in 2020. Mackerel biomass declined in all parts of the survey area except in the North Sea where it doubled.. The total number of Norwegian spring-spawning herring (NSSH) recorded during IESSNS 2021 was 19.6 billion and the total biomass index was 5.91 million tonnes, which are similar results to 2020. The 2016 year-class (5year olds) dominated in the stock and contributed to 54% and 59% to the total biomass and total abundance, respectively, whereas the 2013 year-class (8-year olds) contributed 13% and 11% to the total biomass and total abundance, respectively. The 2016 year-class is considered fully recruited to the spawning stock in 2021, and also fully	

recruited to the survey area. The survey is considered to contain the whole adult part of the NSSH stock during the 2021 IESSNS. The total biomass of blue whiting registered during IESSNS 2021 was 2.2 million tonnes, which is a 22% increase compared to 2020. Stock abundance (ages 1+) was estimated to 26.2 billion compared to 16.5 billion in 2020. The 2020 year-class dominate the estimate in 2021 and contributed 51% and 69% to the total biomass and abundance, respectively. As in previous years, there was overlap in the spatio-temporal distribution of mackerel and herring. This overlap occurred between mackerel and North Sea herring in major parts of the North Sea and partly in the southernmost part of the Norwegian Sea. There were also some overlapping distributions of mackerel and Norwegian spring-spawning herring (NSSH) in the western, north-western and north-eastern part of the Norwegian Sea.	

	Description
Survey design	Swept-area systematic trawl survey with a random starting point and fixed spacing between stations in each stratum. Totally eight permanent and two 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 is calculated using stratified approach. StoX v. 2.7 and v. 3.10 (2021) (via 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	Some problems due to bad weather for a acoustic recordings, but in general favourable conditions for acoustic recordings during IESSNS 2021
Extinction (shadowing)	N/A
Blind zone	Upper 8-12 m not covered by acoustics. No attempts made to correct for loss of herring in the blind zone.

Dead zone	N/A
Allocation of backscatter to species	Only allocated backscatter identified as herring or blue whiting using 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	Considered to have covered the adult spawning stock adequately, with exception of northernmost area and areas west and southwest of the British Isles from 60°N and below.
Stock ID and mixing issues	N/A for mackerel Yes for NSS herring (adults): Concern of similar mixing issues as for the IESNS in May, with uncertainty whether the Icelandic summer-spawning herring southeast of Iceland and the autumn-spawning herring types (e.g. North Sea herring) in the south (east of the Faroes) and southeast (around Shetland).
Measures of uncertainty (CV)	The estimated survey uncertainty for the main age groups in the estimate was around 0.2-0.25
Biological sampling	Sampling levels was considered representative.
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*

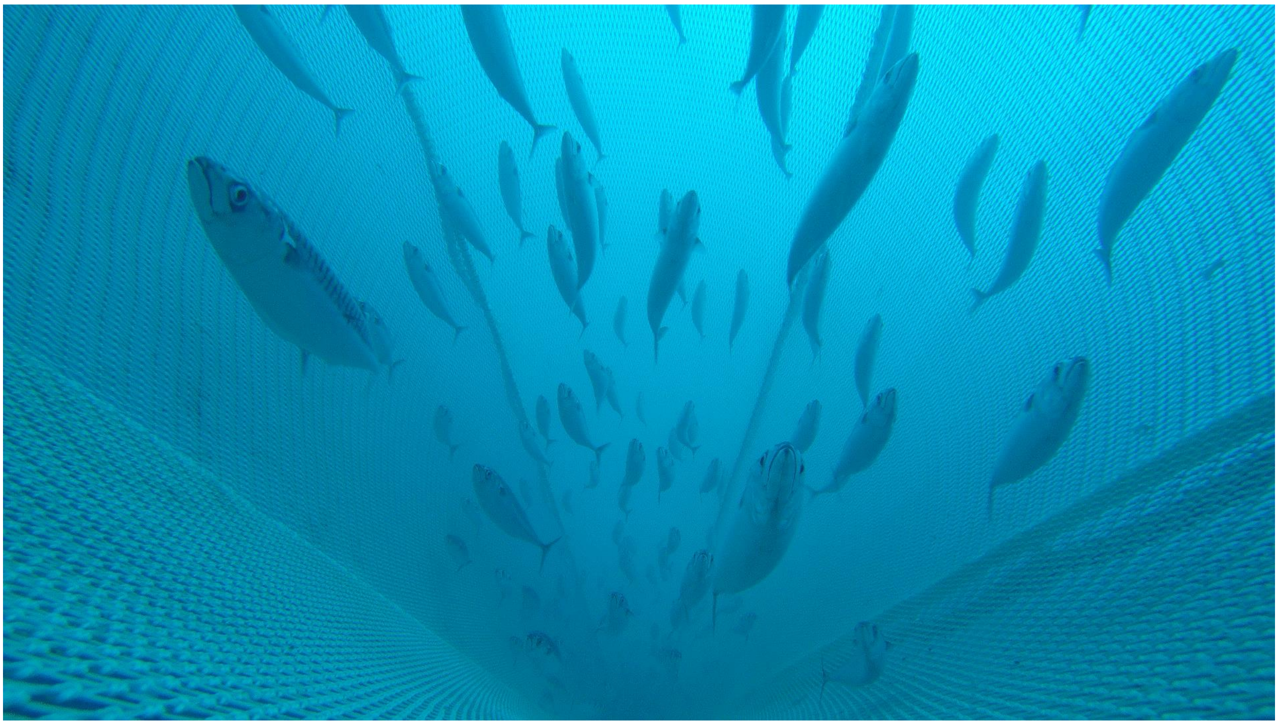
Document 6b: IESSNS 2021 survey report

*Please find report on the next page.

Working Document to

ICES Working Group on Widely Distributed Stocks (WGWIDE, No. 09)
ICES HQ, Copenhagen, Denmark, (digital meeting) 25. – 31. August 2021

Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS)
30th June – 3rd August 2021



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Contents

1 Executive summary

The International Ecosystem Summer Survey in the Nordic Seas (IESSNS) was performed within approximately 5 weeks from June 30th to August 3rd in 2021 using five vessels from Norway (2), Iceland (1), Faroe Islands (1) and Denmark (1). The main objective is to provide annual age-segregated abundance index, with an uncertainty estimate, for northeast Atlantic mackerel (*Scomber scombrus*). The index is used as a tuning series in stock assessment according to conclusions from the 2017 and 2019 ICES mackerel benchmarks. A standardised pelagic swept area trawl method is used to obtain the abundance index and to study the spatial distribution of mackerel in relation to other abundant pelagic fish stocks and to environmental factors in the Nordic Seas, as has been done annually since 2010. Another aim is to construct a new time series for blue whiting (*Micromesistius poutassou*) abundance index and for Norwegian spring-spawning herring (NSSH) (*Clupea harengus*) abundance index. This is obtained by utilizing standardized acoustic methods to estimate their abundance in combination with biological trawling on acoustic registrations. The time series for blue whiting and NSSH now consists of six years (2016-2021).

The survey coverage area included in calculations of the mackerel index was 2.2 million km^2 in 2021, which is 24% smaller coverage compared to 2020. Survey coverage was reduced in the western area as Greenlandic waters, Iceland basin (south of latitude 62°45′) and the Reykjanes ridge (south of latitude 62°45′) were not surveyed in 2021. Furthermore, 0.29 million km^2 was surveyed in the North Sea in July 2021 but those stations are excluded from the mackerel index calculations.

The total swept-area mackerel index in 2021 was 5.15 million tonnes in biomass and 12.2 billion in numbers, a decreased by 58% for biomass and 54% for abundance compared to 2020. Reduced survey coverage in the western area did not contribute to the observed decline as the zero mackerel boundary was established north, west, and south of Iceland. In 2021, the most abundant year classes were 2019, 2016, 2014, 2017 and 2012, respectively. The cohort internal consistency was slightly reduced compared to last year, particularly for ages 5-8 years.

Mackerel was distributed mostly in the central and northern Norwegian Sea, with low densities and limited distribution in Icelandic waters. Mackerel distribution in the North Sea was similar to 2020, but the biomass nearly doubled compared to 2020. Zero boundaries of the summer distribution of mackerel were found in most parts of the survey area, except towards northwest in the Norwegian Sea, southward boundaries in the North Sea and west of the British Isles.

The total number of Norwegian spring-spawning herring (NSSH) recorded during IESSNS 2021 was 19.6 billion and the total biomass index was 5.91 million tonnes, which are similar results to 2020. The 2016 year-class (5year olds) dominated in the stock and contributed to 54% and 59% to the total biomass and total abundance, respectively, whereas the 2013 year-class (8-year olds) contributed 13% and 11% to the total biomass and total abundance, respectively. The 2016 year-class is considered fully recruited to the spawning stock in 2021, and also fully recruited to the survey area. The survey is considered to contain the whole adult part of the NSSH stock during the 2021 IESSNS.

The total biomass of blue whiting registered during IESSNS 2021 was 2.2 million tonnes, which is a 22% increase compared to 2020. Stock abundance (ages 1+) was estimated to 26.2 billion compared to 16.5 billion in 2020. The 2020 year-class dominate the estimate in 2021 and contributed 51% and 69% to the total biomass and abundance, respectively.

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

Other fish species also monitored are lumpfish (*Cyclopterus lumpus*) and Atlantic salmon (*Salmo salar*). Lumpfish was caught at 78% of surface trawl stations distributed across the surveyed area from

southwestern part of Iceland, central part of North Sea to southwestern part of the Svalbard. Abundance was greater north of latitude 72°N compared to southern areas. A total of 35 North Atlantic salmon were caught in 25 stations both in coastal and offshore areas from 60°N to 76°N in the upper 30 m of the water column. The salmon ranged from 0.089 kg to 6.5 kg in weight, dominated by postsmolt weighing 89-425 grams and 1 sea-winter individuals (grilse) weighing 1.9-2.4 kg.

Satellite measurements of the sea surface temperature (SST) showed that the central and eastern part of the Norwegian Sea were roughly on same level as average for July 1990-2009. SST was 1-3 °C warmer than the long-term average in the Iceland Sea and the Greenland Sea. The North Sea SST was 1-2 °C warmer than long term average. CTD measurements from the central part of the Norwegian Sea indicated more stratification in the surface layer than in 2020.

Average zooplankton biomass in the Norwegian Sea has been relatively stable since 2013. There was, however, a small decrease in 2021 compared to last year, especially in the central and southern areas. A small increase was observed in the Iceland region compared to last year.

2 Introduction

During approximately five weeks of survey in 2021 (30th of June to 3rd of August), five vessels; the M/V "Eros" and M/V "Vendla" from Norway, R/V "Jákup Sverri" operating from Faroe Islands, the R/V "Árni Friðriksson" from Iceland and M/V "Ceton" operating in the North Sea by Danish scientists, participated in the International Ecosystem Summer Survey in the Nordic Seas (IESSNS).

The 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 from Norway, Iceland and Faroe Islands. The wide geographical coverage, standardization of methods, sampling on many trophic levels and international cooperation around this survey facilitates research on the pelagic ecosystem in the Nordic Seas, see e.g. Nøttestad et al. (2016), 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. Greenland did not participate in 2021.

The North Sea was included in the survey area for the fourth time in 2021, 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 39 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 - 2020 results).

3 Material and methods

Coordination of the IESSNS 2021 was done during the WGIPS 2021 virtual meeting in January 2021, and by correspondence in spring and summer 2021. The participating vessels together with their effective survey periods are listed in Table 1.

Overall, the weather conditions were rougher in 2021 with periods of less favourable survey conditions for the Norwegian vessels for oceanographic monitoring, plankton sampling, acoustic registrations and pelagic trawling. The weather was windier and rougher sea conditions in longer periods than usual, especially during the last part of the first part and during the second part of the survey for the two Norwegian vessels in central and northern Norwegian Sea. There were also more days with fog in both the southern, central and northern part of the Norwegian Sea than previous years, influencing the visual observations. The Icelandic vessel, operating in Icelandic waters, experienced mostly calm weather with only 12-hours storm delay in total. The weather was mostly calm for the Faroese vessel operating mainly in Faroese, east Icelandic and international waters. The chartered vessel Ceton had excellent weather throughout the survey.

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

Table 1. Survey effort by each of the five vessels during the IESSNS 2021. The number of predetermined ("fixed") trawl stations being part of the swept-area stations for mackerel in the IESSNS are shown after the total number of trawl stations.

Vessel	Effective survey period	Length of cruise track (nmi)	Total trawl stations/ Fixed stations	CTD stations	Plankton stations
Árni Friðriksson	5/7-26/7	4322	64/54	53	50
Jákup Sverri	2-19/7	3050	41/34	34	34
Ceton	30/6-9/7	2100	39/39	39	-
Vendla	1/7-3/8	5967	96/74	75	75
Eros	1/7-3/8	5836	79/69	75	75
Total	30/6-3/8	21275	319/270	276	234

3.1 Hydrography and Zooplankton

The hydrographical and plankton stations by all vessels combined are shown in Figure 1. Eros, Vendla, Árni Friðriksson and Jákup Sverri were all equipped with a SEABIRD CTD sensor and Árni Friðriksson and Jákup Sverri moreover also had a water rosette. Eros used a SEABIRD 19+V2 CTD sensor. Ceton used a Seabird SeaCat offline CTD. The CTD-sensors were used for recording temperature, salinity and pressure (depth) from the surface down to 210 m, or to the bottom when at shallower depths.

Zooplankton was sampled with a WP2-net on 4 of 5 vessels, since Ceton did not take any plankton samples. Mesh sizes were 180 µm (Eros and Vendla) and 200 µm (Árni Friðriksson and Jákup Sverri). The net was hauled vertically from a depth of 200 m (or bottom depth at shallower stations) to the surface at a speed of 0.5 m/s. All samples were split in two, one half preserved for species identification and enumeration, and the other half dried and weighed. 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. The Icelandic and Norwegian vessels sorted the whole catch to species but the Faroese vessel sub-sampled the catch before sorting if catches were more than 500 kg. Sub-sample size ranged from 90 kg (if it was clean catch of either herring or mackerel) to 200 kg (if it was a mixture of herring and mackerel). The biological sampling protocol for trawl catch varied between nations in number of specimens sampled per station (Table 3).

Results from the survey expansion southward into the North Sea are analyzed separately from the traditional survey grounds north of latitude 60°N as per stipulations from the 2017 mackerel benchmark meeting (ICES 2017). However, data collected with the IESSNS methodology from the Skagerrak and the northern and western part of the North Sea are now available for 2018, 2019, 2020 and 2021.

Table 2. Trawl settings and operation details during the international mackerel survey in the Nordic Seas from 30th June to 3rd August 2021. The column for influence indicates observed differences between vessels likely to influence performance. Influence is categorized as 0 (no influence) and + (some influence).

Properties	**Árni Friðriksson**	**Vendla**	**Ceton**	**Jákup Sverri**	**Eros**	**Influ-ence**
Trawl producer	Hampiðjan new 2017 trawl	Egersund Trawl AS	Egersund Trawl AS	Vónin	Egersund Trawl AS	0
Warp in front of doors	Dynex-34 mm	Dynex -34 mm	Dynex	Dynex – 38 mm	Dynex-34 mm	+
Warp length during towing	350	350	300-350	350	350-400	0
Difference in warp length port/starb. (m)	16	2-10	10	0-7	5-10	0
Weight at the lower wing ends (kg)	2×400 kg	2×400	2×400	2×400	2×400	0
Setback (m)	14	6	6	6	6	+
Type of trawl door	Jupiter	Seaflex 7.5 m² adjustable hatches	Thybron type 15	Injector F-15	Seaflex 7.5 m² adjustable hatches	0
Weight of trawl door (kg)	2200	1700	1970	2000	1700	+
Area trawl door (m²)	6	7.5 with 25% hatches (effective 6.5)	8	6	7 with 50% hatches (effective 6.5)	+
Towing speed (knots) mean (min-max)	5.2 (4.4-5.7)	4.6 (4.1-5.5)	4.8 (4.3-5.3)	4.5 (3.5-5.3)	4.7 (4.1-5.725)	+
Trawl height (m) mean (min-max)	33 (27-48)	28-37	27 (22-36)	45.1 (39 – 56)	25-32	+
Door distance (m) mean (min-max)	113 (102 - 118)	121.8 (118-126)	140 (125-153)	98.7 (89 – 111)	135 (113-140)	+
Trawl width (m)*	65.6	63.8	75.4	56.6	67.5	+
Turn radius (degrees)	5	5-12	5-10	5-6 BB turn	5-8 SB turn	+
Fish lock front of cod-end	Yes	Yes	Yes	Yes	Yes	+
Trawl door depth (port, starboard, m) (min-max)	4-14, 5-28	6-22, 8-23	4-16	5-24, 6-26	(6-20)	+
Headline depth (m)	0	0	0	0	0	+
Float arrangements on the headline	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 + 2 buoys on each wingtip	Kite + 2 buoy on each wingtips	+
Weighing of catch	All weighted	All weighted	All weighted	All weighed	All weighted	+

* calculated from door distance (Table 6)

Table 3. Protocol of biological sampling during the IESSNS 2021. Numbers denote the maximum number of individuals sampled for each species for the different determinations.

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

*Length measurements / weighed individuals
**Sampled at every third station
*** One fish per cm-group ≤ 28 cm and two fish > 28 cm from each station was weighed and aged.
^All live lumpfish were tagged and released, only otoliths taken from fish which were dead when brought aboard

This year's survey was well synchronized in time and was conducted over a relatively short period (less than 5 weeks) given the large spatial coverage of around 2.2 million km^2 (Figure 1). This was in line with recommendations put forward in 2016 that the survey period should be around four weeks with mid-point around 20th July. The main argument for this time period was to make the survey as synoptic as possible in space and time, and at the same time be able to finalize data and report for inclusion in the assessment for the same year.

Underwater camera observations during trawling

M/V "Eros" and M/V "Vendla" employed an underwater video camera (GoPro HD Hero 4 and 5 Black Edition, www.gopro.com) to observe mackerel aggregation, swimming behaviour and possible escapement from the cod end and through meshes. The camera was put in a waterproof box which tolerated pressure down to approximately 100 m depth. No light source was employed with cameras; hence, recordings were limited to day light hours. Some recordings were also taken during night-time when there was midnight sun and good underwater visibility. Video recordings were collected at 95 trawl stations. The camera was attached on the trawl in the transition between 200 mm and 400 mm meshes.

Deep Vision underwater stereo-camera system

A pilot study was conducted onboard M/V "Vendla" during first part of the IESSNS 2021 survey in the southern part of the Norwegian Sea using the underwater stereo camera system Deep Vision (Rosen et al. 2013). The major goal of this pilot study was to explore the practical and operational feasibility of applying and quantifying the use of stereo camera technology related correct species identification, catch numbers and size distribution of different species caught in the Multpelt 832 pelagic trawl, with particular focus on NEA mackerel. A total number of five trawl hauls were conducted onboard Vendla with the deep vision system from 1-18 July 2021. Results will be available later including an evaluation of whether Deep Vision can be used to quantify mackerel catches in a reliable way without collecting the mackerel, but rather trawl with an open cod-end.

3.3 Marine mammals

Opportunistic observations of marine mammals were conducted by scientific personnel and crew members from the bridge between 1st July and 2nd August 2021 onboard M/V "Eros" and M/V "Vendla", and aboard R/V Árni Friðriksson from 5st until 26th July 2021. On board Jákup Sverri (between 1st and 19th July 2021) opportunistic observations were done from the bridge by crew members.

3.4 Lumpfish tagging

Lumpfish caught during the survey by vessels R/V "Árni Friðriksson", M/V "Eros" 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 Vendla and Eros were calibrated 30th June and 1st July 2021 respectively, for 18, 38, 70, 120 and 200 kHz. Árni Friðriksson was calibrated on May 4th 2021 for frequencies 18, 38, 70, 120 and 200 kHz. Jákup Sverri was calibrated on 22nd April 2021 for 18, 38, 120, 200 and 333 kHz. Ceton did not conduct any acoustic data collection because no calibrated equipment was available, and acoustics are done in the same area and period of the year during the ICES coordinated North Sea herring acoustic survey (HERAS). All the other vessels used standard hydro-acoustic calibration procedure for each operating frequency (Foote 1987). CTD measurements were taken in order to get the correct sound velocity as input to the echosounder calibration settings.

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

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

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

Table 4. Acoustic instruments and settings for the primary frequency (38 kHz) during IESSNS 2021.

	R/V Árni Friðriksson	M/V Vendla	Jákup Sverri	Eros
Echo sounder	Simrad EK80	Simrad EK60	Simrad EK80	Simrad EK80
Frequency (kHz)	18, 38, 70, 120, 200	18, 38, 70, 120, 200	18, **38**, 70, 120, 200, 333	18, 38, 70, 120, 200, 333
Primary transducer	ES38-7	ES38B	ES38-7	ES38B
Transducer installation	Drop keel	Drop keel	Drop keel	Drop keel
Transducer depth (m)	8	9	6-9	8
Upper integration limit (m)	15	15	15	15
Absorption coeff. (dB/km)	10.5	10.1	10.7	9.3
Pulse length (ms)	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.43	3.064	2.43
Transmitter power (W)	2000	2000	2000	2000
Angle sensitivity (dB)	18	21.90	21.9	21.9
2-way beam angle (dB)	-20.3	-20.70	-20.4	-20.7
TS Transducer gain (dB)	27.05	25.46	26.96	25.50
s_A correction (dB)	-0.02	-0.02	-0.16	-0.6
3 dB beam width alongship:	6.42	0.19	6.55	6.87
3 dB beam width athw. ship:	6.47	0.08	5.45	6.83
Maximum range (m)	500	500	500	500
Post processing software	LSSS v.2.10.1	LSSS v.2.8.1	LSSS 2.10.1	LSSS v.2.8

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

Multibeam sonar

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

Cruise tracks

The five participating vessels followed predetermined survey lines with predetermined surface trawl stations (Figure 1). Calculations of the mackerel index are based on swept area approach with the survey area split into 13 strata, of which 11 are permanent and two dynamic (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 2021 is shown in Figure 3. The cruising speed was between 10-11 knots if the weather permitted, otherwise the cruising speed was adapted to the weather situation.

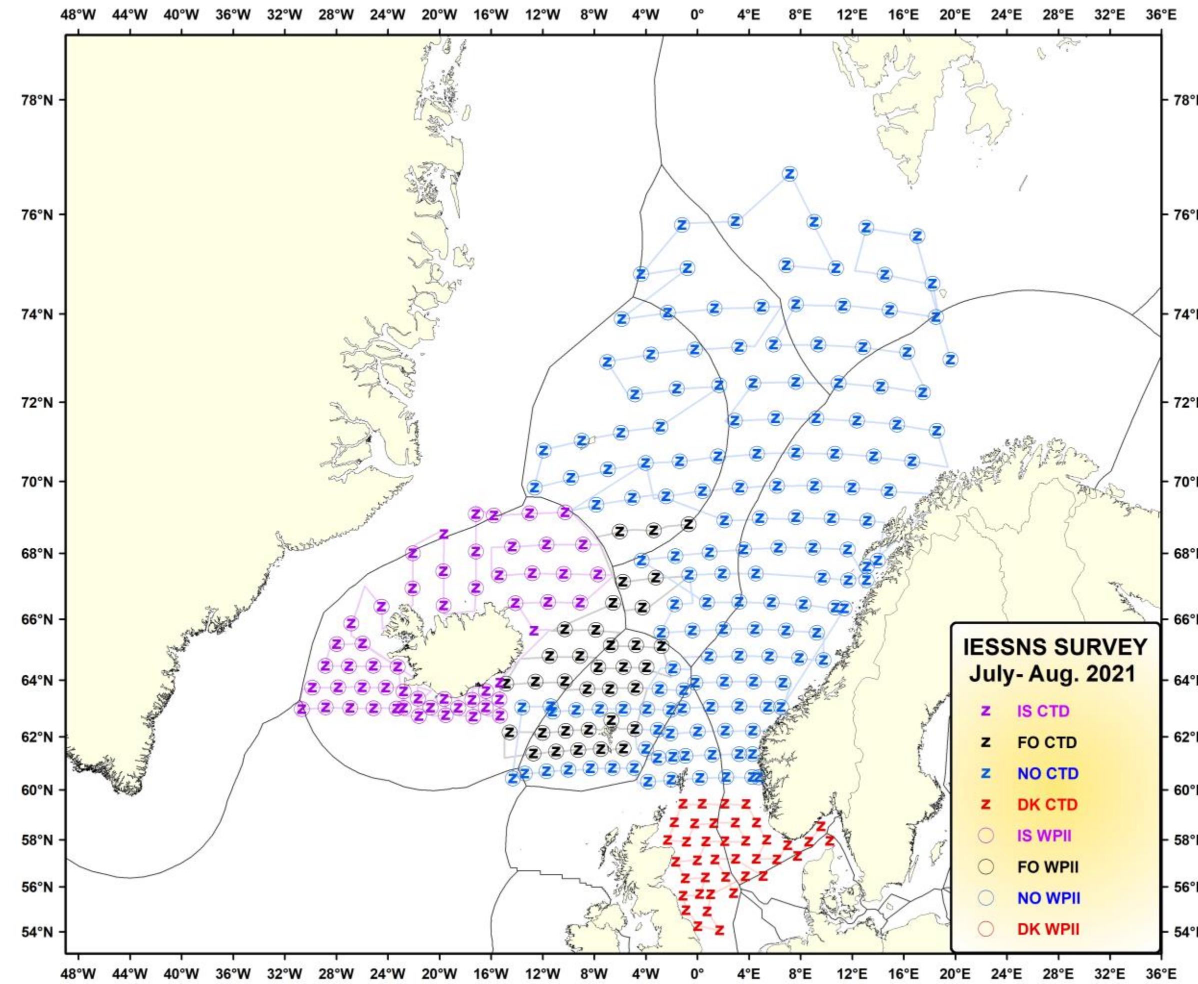


Figure 1. Fixed predetermined trawl stations (shown for CTD and WP2) included in the IESSNS from June 30th to August 3rd 2021. At each station a 30 min surface trawl haul, a CTD station (0-500 m) and WP2 plankton net samples (0-200 m depth) was performed. The colour codes, Árni Friðriksson (purple), Jákup Sverri (black), Vendla and Eros (blue), and Ceton (red).

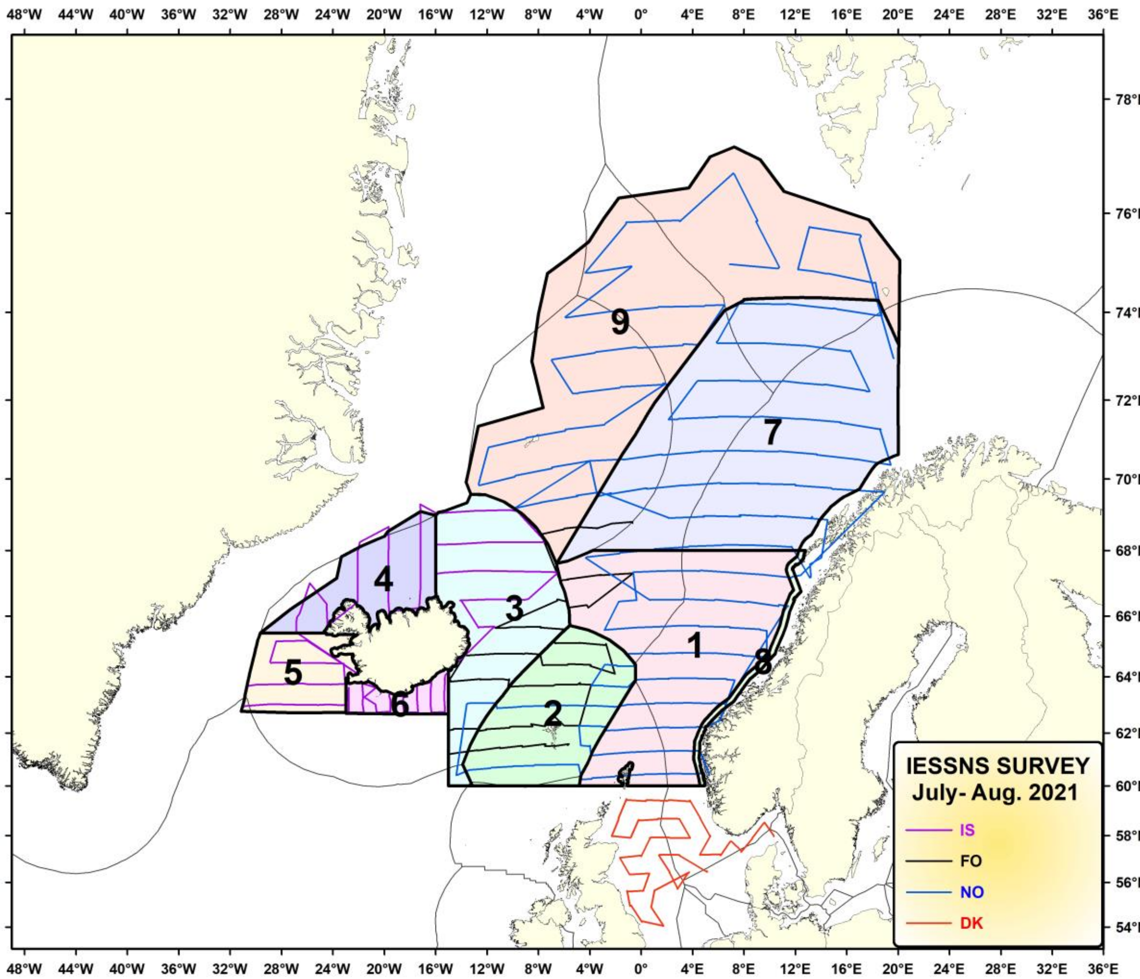


Figure 2. Permanent and dynamic strata used in StoX for IESSNS 2021. The dynamic strata are: 4 and 9.

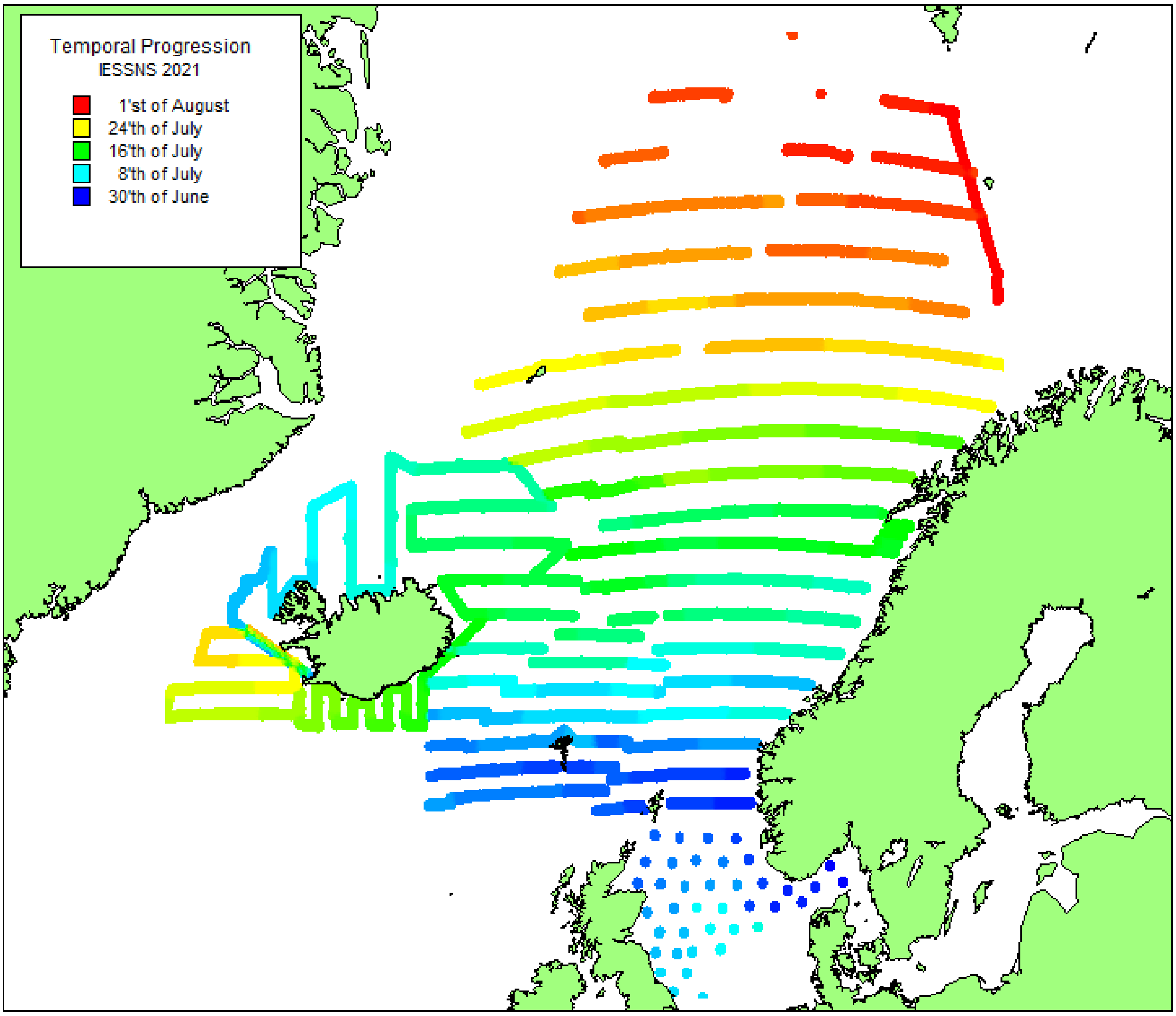


Figure 3. Temporal survey progression by vessel along the cruise tracks during IESSNS 2021: blue represents effective survey start (30th of June) progressing to red representing a five-week span (survey ended 3rd of August). As Ceton did not record acoustics, they have been represented by station positions.

3.6 StoX

The recorded acoustic and biological data were analysed using the StoX software package which has been used for some years now for WGIPS coordinated surveys. A description of StoX can be found in Johnsen et al. (2019) and here: www.imr.no/forskning/prosjekter/stox. Mackerel (swept-area), excluding the North Sea, herring and blue whiting indices were calculated using StoX version 3.1.0. Mackerel index including catch data from the North Sea was calculated using 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 60°N and 77°N and 31°W and 20°E in 2021. The density of mackerel on a trawl station is calculated by dividing the total number caught by the assumed area swept by the trawl. The area swept is calculated by multiplying the towed distance by the horizontal opening of the trawl. The horizontal opening of the trawl is vessel specific, and the average value across all hauls is calculated based on door spread (Table 5 and Table 6). For the Faroese vessel the average door spread was 98.5 m, 1½ m less than the minimum spread in Table 6, so a calculation was done from the standard formulae for 4.5 knots to obtain the trawl width. 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 2021. Number of trawl stations used in calculations is also reported. Horizontal trawl opening was calculated using average vessel values for trawl door spread and tow speed (details in Table 6).

	Jákup Sverri	RV Árni Friðriksson	Eros	Vendla	Ceton
Trawl doors horizontal spread (m)					
Number of stations	32	53	59	52	39
Mean	98.7	113	122	113	140
max	111	118	136	125	153
min	89	102	115	105	125
st. dev.	4.6	3.6	4.8	4.6	5.1
Vertical trawl opening (m)					
Number of stations	31	54	59	52	39
Mean	45.1	33.8	28.4	30.4	27
max	56	48.2	33	32	36
min	39	27.5	25	23	22
st. dev.	3.5	3.7	2.9	3.0	3.9
Horizontal trawl opening (m)					
mean	56.6	65.6	67.5	63.8	75.4
Speed (over ground, nmi)					
Number of stations	32	53	59	52	39
mean	4.5	5.2	4.6	4.7	4.8
max	5.3	5.7	5.5	5.6	5.3
min	3.5	4.4	4.1	4.2	4.3
st. dev.	0.4	0.2	0.3	0.3	0.2

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

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

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

Table 6. Horizontal trawl opening as a function of trawl door spread and towing speed. Relationship based on simulations of horizontal opening of the Multpelt 832 trawl towed at 4.5 and 5 knots, representing the speed range in the 2014 survey, for various door spread. See text for details. In 2017, the towing speed range was extended from 5.0 to 5.2, 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 (NOAA OISST) of sea surface temperature (SST) in the central and eastern part of the Norwegian Sea in July 2021 were roughly on same level as the long-term average for July 1990-2009 based on SST anomaly plots (Figure 4). In the western areas, north of Iceland and the coastal regions of Greenland (The Iceland Sea and the Greenland Sea) the SST was 1-3 °C warmer than the long-term average. South of Iceland and in the Irminger Sea, the SST was on level with the long-term average. Further south, all the way from Greenland to the European Shelf, the SST was slightly warmer (~1 °C). However, along the southern part of the Norwegian Shelf and in the North Sea, the temperatures were 1-2 °C warmer than long term average.

It should be mentioned that the NOAA SST are sensitive to the weather conditions (i.e. wind and cloudiness) prior to and during the observations and do therefore not necessarily reflect the oceanographic condition of the water masses in the areas, as seen when comparing detailed in situ features of SSTs between years (Figures 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 from the survey showed that the upper layer (10 m depth) in 2021 generally was similar to 2020, except for the cold tongue of East Icelandic water, which penetrates into the Norwegian Sea from the Iceland Sea. In 2020 the tongue was clearly visible in the surface layer, but during the 2021 survey it was much less pronounced in the surface layer, indicating that stratification was stronger in this region in 2021 compared to last year (Figure 5). In the deeper layers (50 m and deeper; Figures 6-8), the hydrographical features in the area were similar to previous years. At all depths there is a clear signal from the cold East Icelandic Current which carries cold and fresh water into the central and south-eastern part of the Norwegian Sea. Along the Norwegian Shelf and in the southernmost areas, the water masses are dominated by warmer waters of Atlantic origin.

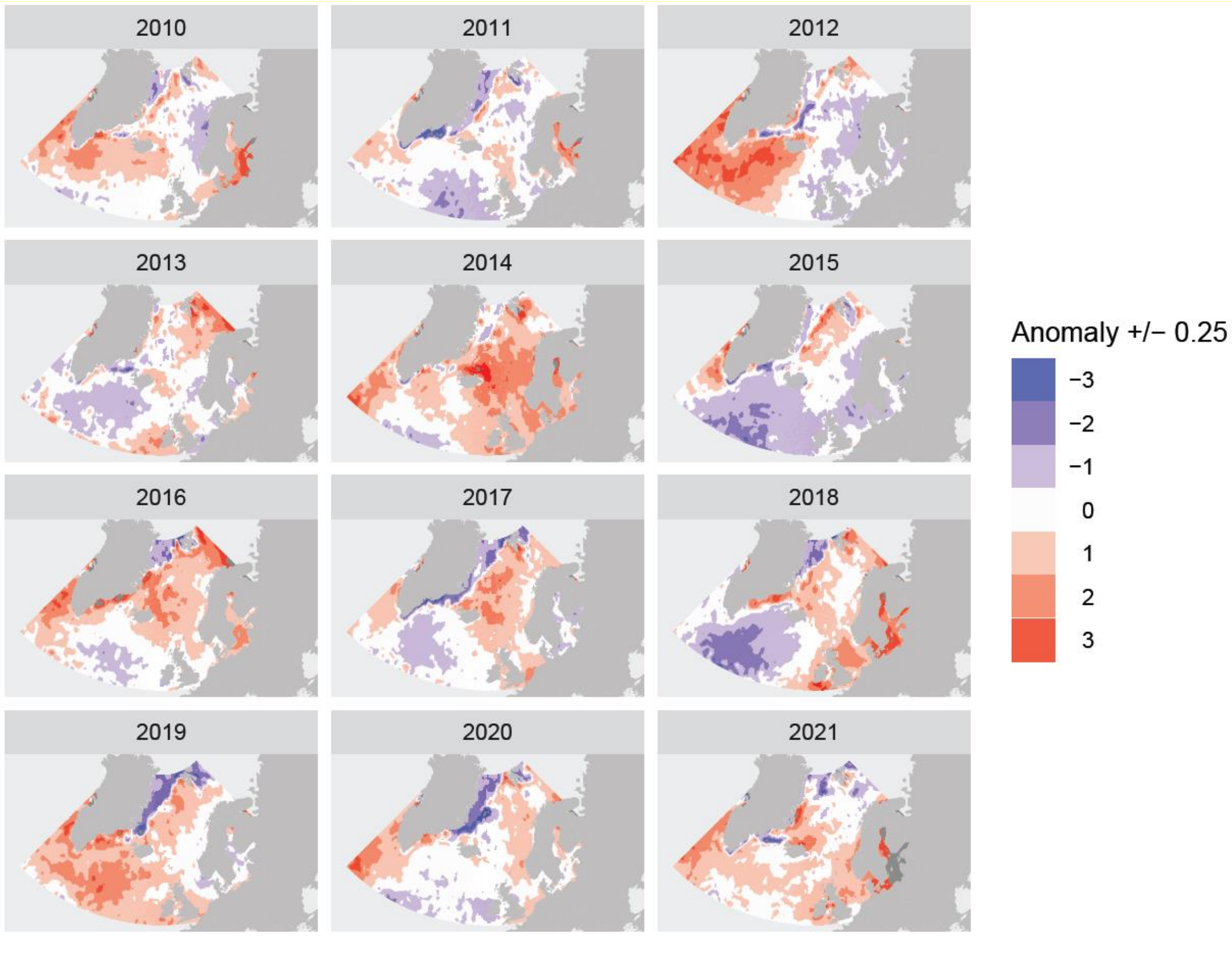


Figure 4. Annual sea surface temperature anomaly (-3 to +3°C) in Northeast Atlantic for the month of July from 2010 to 2021 showing warm and cold conditions in comparison to the average for July 1990-2010. Based on monthly averages of daily Optimum Interpolation Sea Surface Temperature (Ver. 2.1 NOAA OISST, AVHRR-only, Banzon et al. 2016, https://www.ncdc.noaa.gov/oisst).

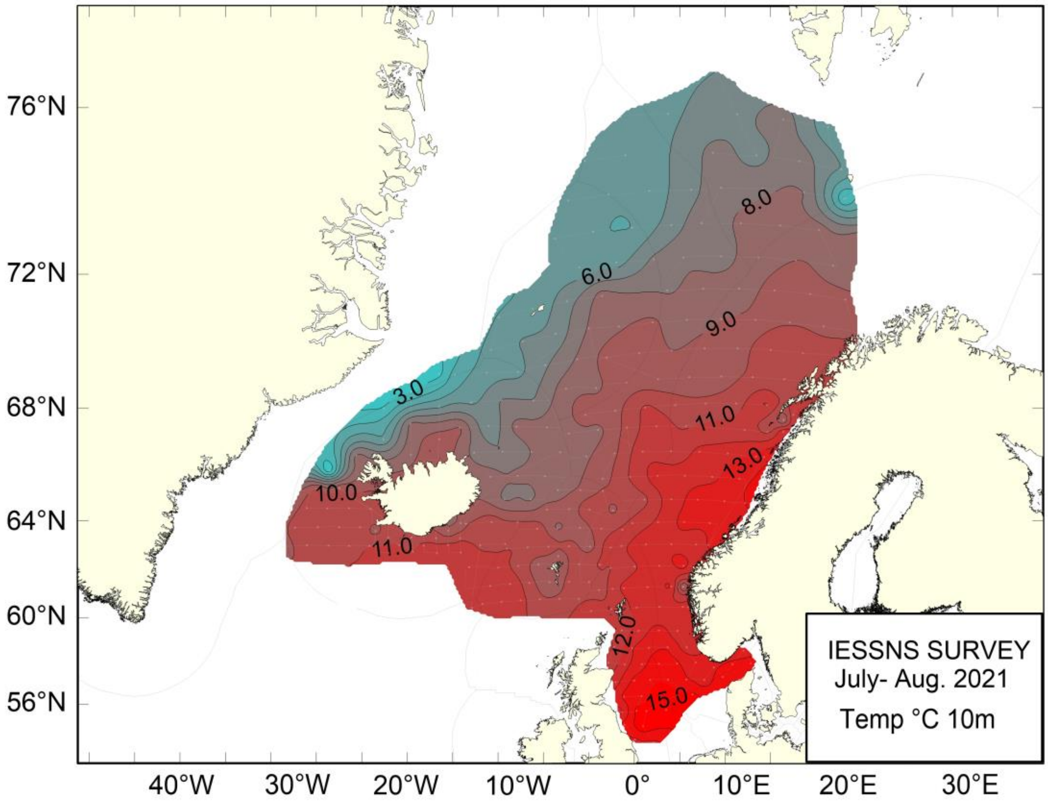


Figure 5. Temperature (°C) at 10 m depth in Nordic Seas and the North Sea in July-August 2021.

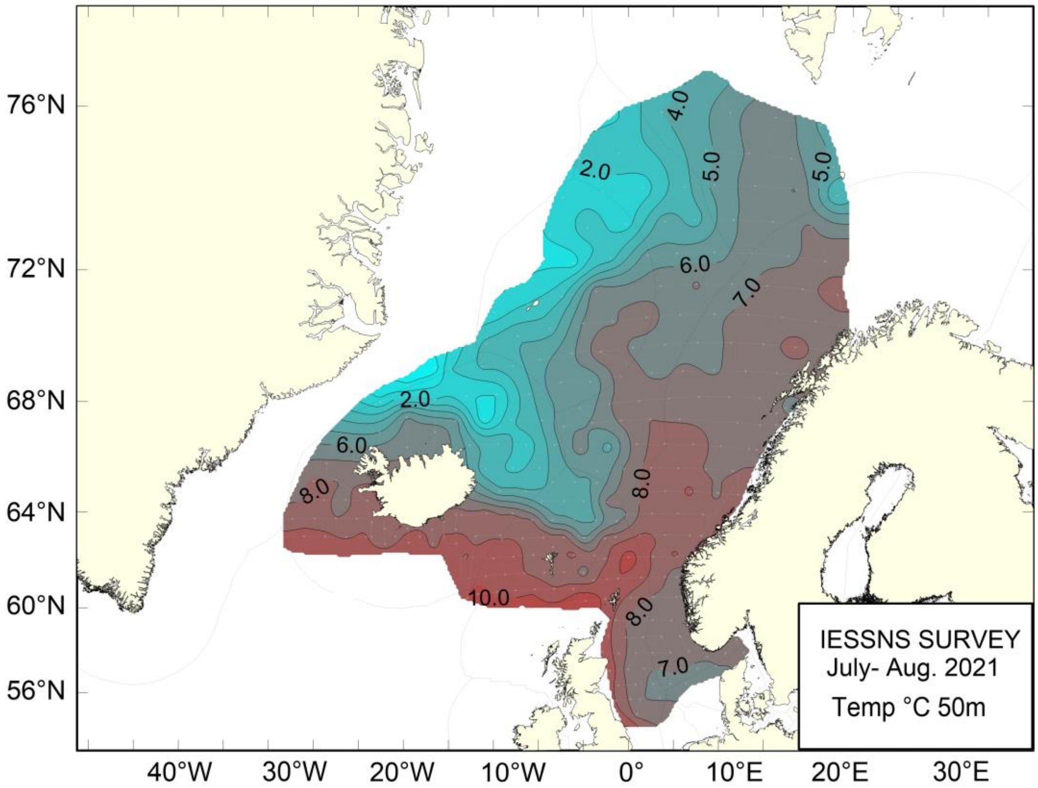


Figure 6. Temperature (°C) at 50 m depth Nordic Seas and the North Sea in July-August 2021.

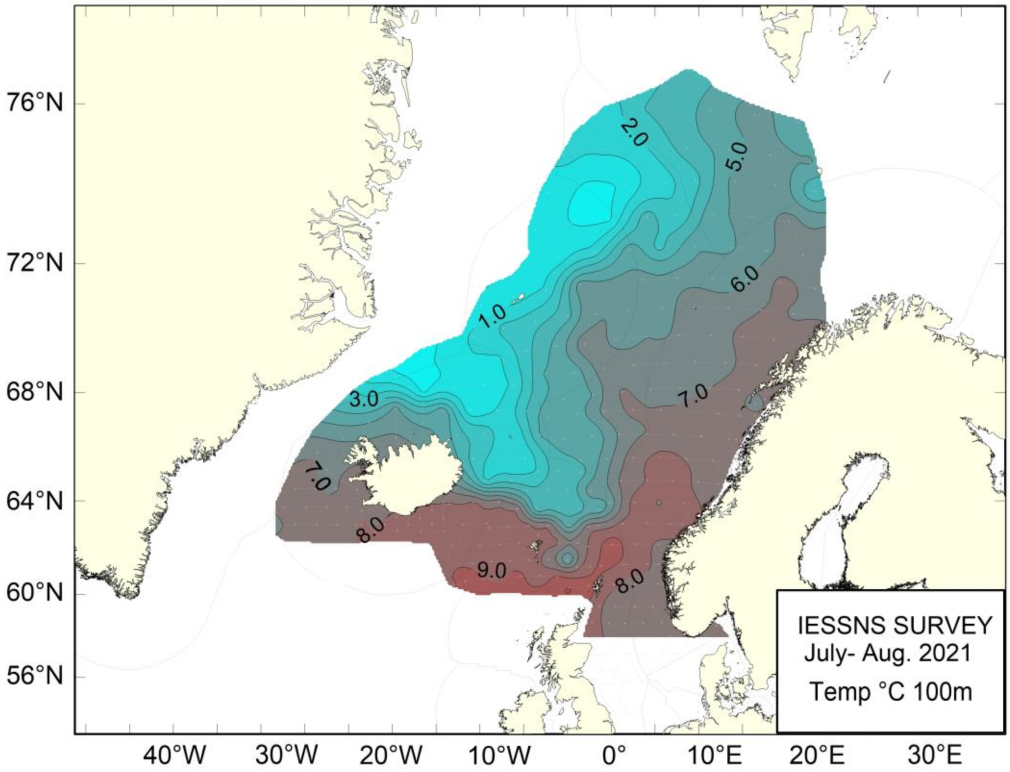


Figure 7. Temperature (°C) at 100 m depth in Nordic Seas and the North Sea in July-August 2021.

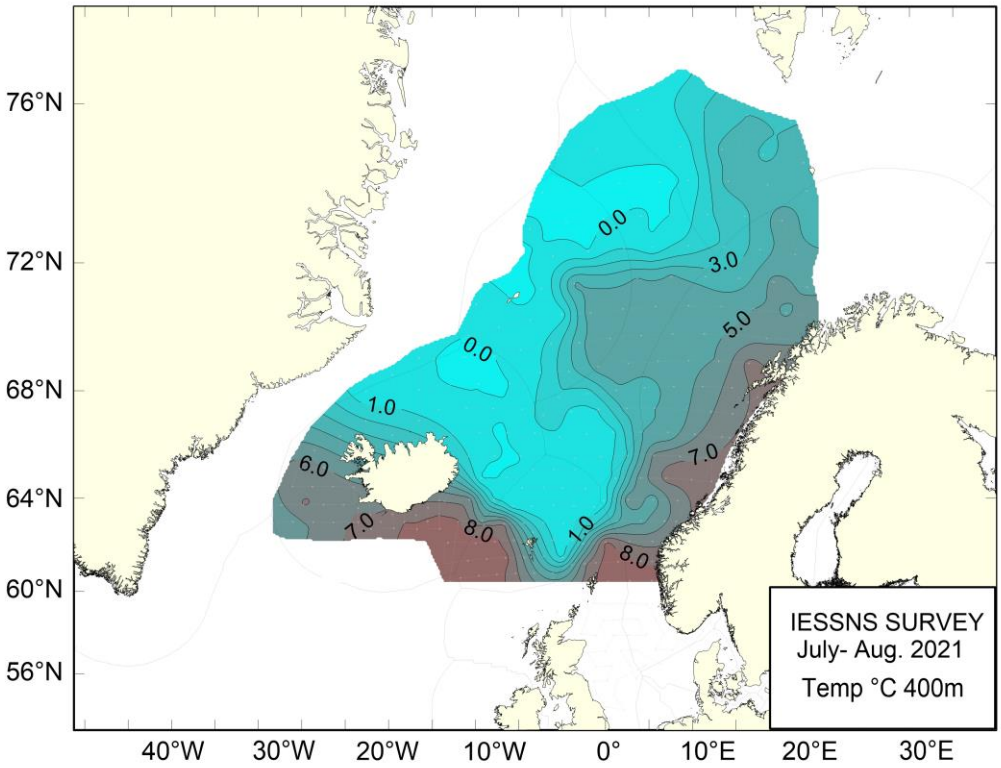


Figure 8. Temperature (°C) at 400 m depth in Nordic Seas and the North Sea in July-August 2021.

4.2 Zooplankton

The zooplankton biomass varied between areas with a patchy distribution throughout the area (Figure 9a). Greenland waters were not covered in 2021. In the Norwegian Sea areas, the average zooplankton biomass was slightly lower than last year as seen from Figure 9a, and this was especially apparent in the central and southern areas.

The time-series of average zooplankton biomass averaged by three subareas: Greenland region, Iceland region and the Norwegian Sea region is shown in Figure 9b (see definitions in legend). In the Greenland area a decrease was observed in 2019 and further in 2020 from very high values in 2017-2018 (no survey in 2021). A similar trend was also observed in the Icelandic region with somewhat less variations, and a levelling out in 2021 (Figure 9b). The two time-series co-vary (2014-2020, r = 0.89). The biomass indices has varied substantially less ion the Norwegian Sea areas, with a decrease in 2021 from a relatively stable level since 2013 (Figure 9b). The lower variability might in part be explained by the more homogeneous oceanographic conditions in the area defined as Norwegian Sea.

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

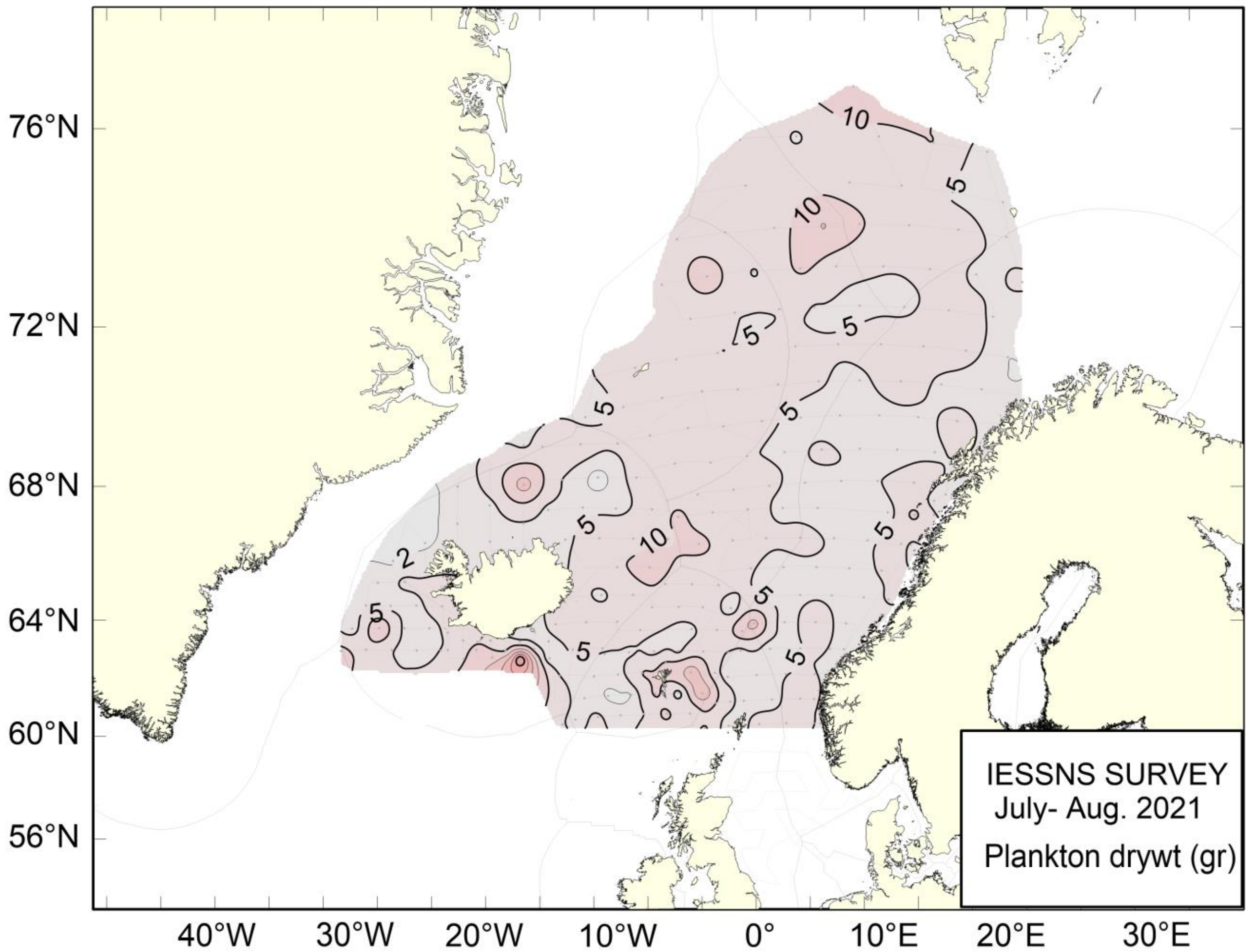


Figure 9a. Zooplankton biomass (g dw/m², 0-200 m) in Nordic Seas in July-August 2021.

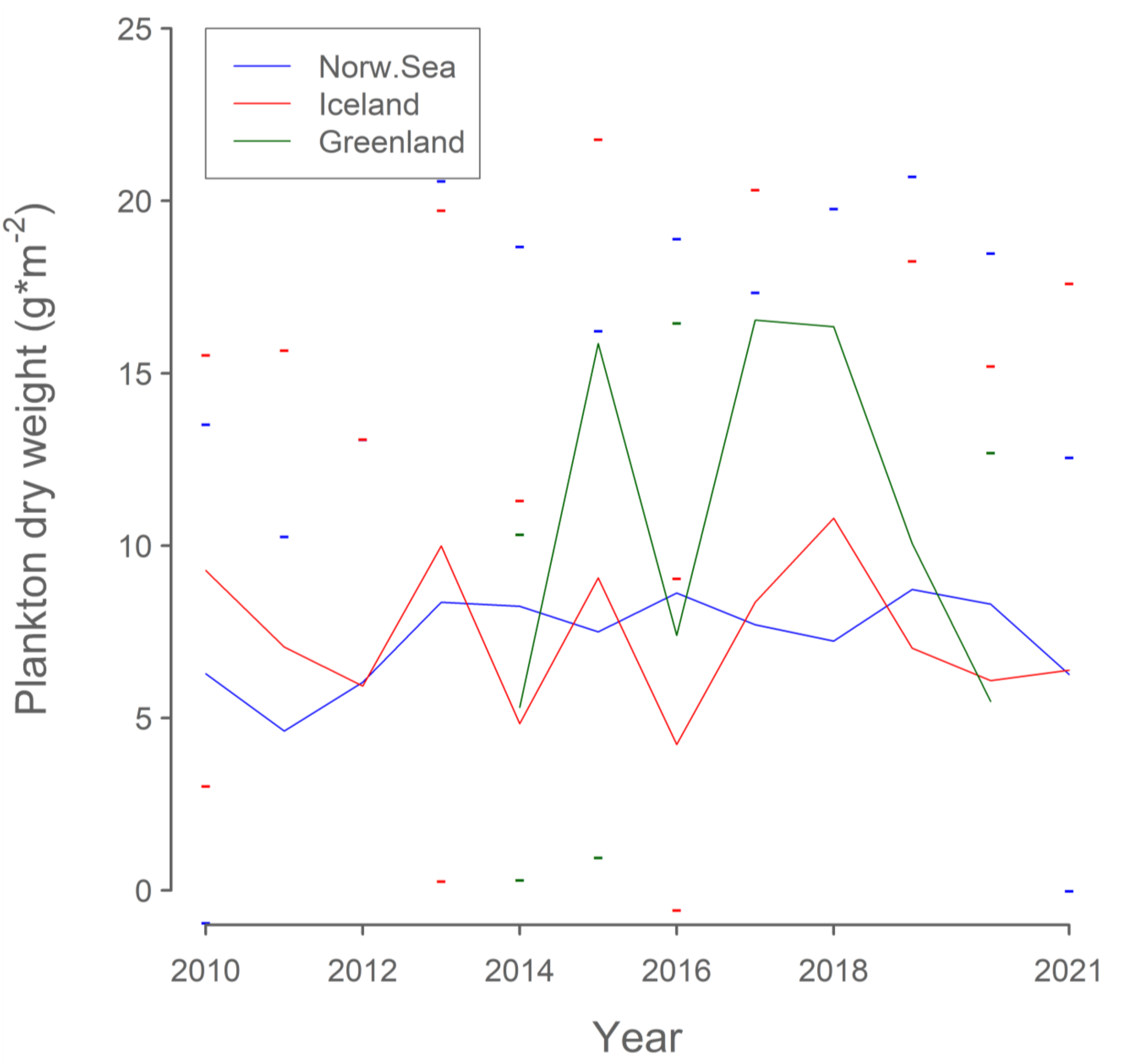


Figure 9b. Zooplankton biomass indices (g dw/m², 0-200 m). Time-series (2010-2021) of mean zooplankton biomass for three subareas within the survey range: Norwegian Sea (between 14°W-17°E & north of 61°N), Icelandic waters (14°W-30°W) and Greenlandic waters (2014-2020, west of 30°W).

4.3 Mackerel

The total swept-area mackerel index in 2021 was 5.15 million tonnes in biomass and 12.2 billion in numbers, a decreased by 58% for biomass and 54% for abundance compared to 2020. The survey coverage area (excl. the North Sea, 0.29 million km²) was 2.2 million km² in 2021, which is 24% smaller compared to previous years from 2018 to 2020. Reduced survey coverage in the western area did not contribute to the observed decline as the zero mackerel boundary was established north, west, and south of Iceland. The mackerel catch rates by trawl station (from zero to 17 tonnes/km², mean = 2.2 tonnes/km²) measured at predetermined surface trawl stations in 2021 is presented in Figure 10 together with the mean catch rates per 2° lat. x 4° lon. rectangles. The mackerel was mainly distributed in the central Norwegian Sea, extending south into waters southeast of Iceland and into the North Sea. High density areas were only found in international waters in the central Norwegian Sea in 2021. Medium density areas were found in the central and partly northern Norwegian Sea in 2021, with very small concentrations in the western areas (Figure 10), as was also the case in 2020. In Icelandic waters, mackerel density was low, and distribution limited to waters east and southeast of Iceland. This was similar to the 2020 observations. The North Sea, on the other hand, experienced a notable increase. There was a doubling in mean catch rates of mackerel in 2021 compared to previous years, dominated by 1- and 2-year olds. The time series (2010-2021) of absolute distribution maps (Figure 11) and relative distribution maps (Figure 12) show western expansion from 2010 to 2017, then in 2018 there was an obvious decline in geographical distribution and abundance in the west, in 2019 limited abundance of mackerel was measured in Greenland waters, and in 2020 distribution in Icelandic waters had retracted to the southeast coast.

Greenland waters were not surveyed in 2021. However, the zero-line was reached west, south and north of Iceland and the Greenlandic industry did not catch mackerel in Greenlandic waters. Therefore, it is highly unlikely that any mackerel migrated into Greenlandic waters during summer 2021. It is assumed that IESSNS coverage mackerel geographical distribution range in the western area despite reduced survey area size.

The swept area results from the North Sea in 2021 showed almost a doubling in the biomass index from last year (Appendix 1). The increase was mainly due to the high abundances of 1- and 2-year old mackerel.

In summary, we found a substantial decrease in estimated biomass and abundance index of NEA mackerel in the main feeding area during summer for mackerel in 2021 compared to 2020. On the positive side, there seems to be high recruitment and a considerably higher estimated biomass and abundance of juvenile mackerel (1- and 2-years olds) in the North Sea in 2021 compared to 2020.

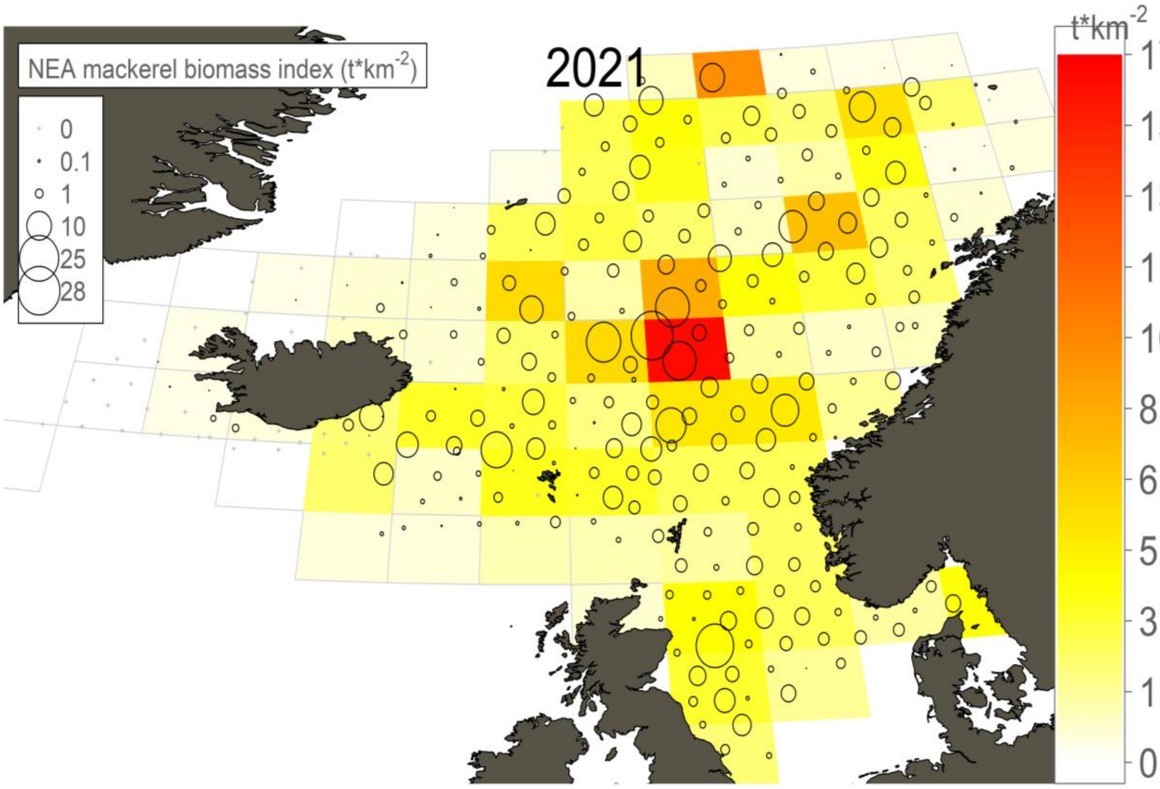


Figure 10. Mackerel catch rates by Multpelt 832 pelagic trawl haul at predetermined surface trawl stations (circle areas represent catch rates in kg/km²) overlaid on mean catch rates per standardized rectangles (2° lat. x 4° lon.).

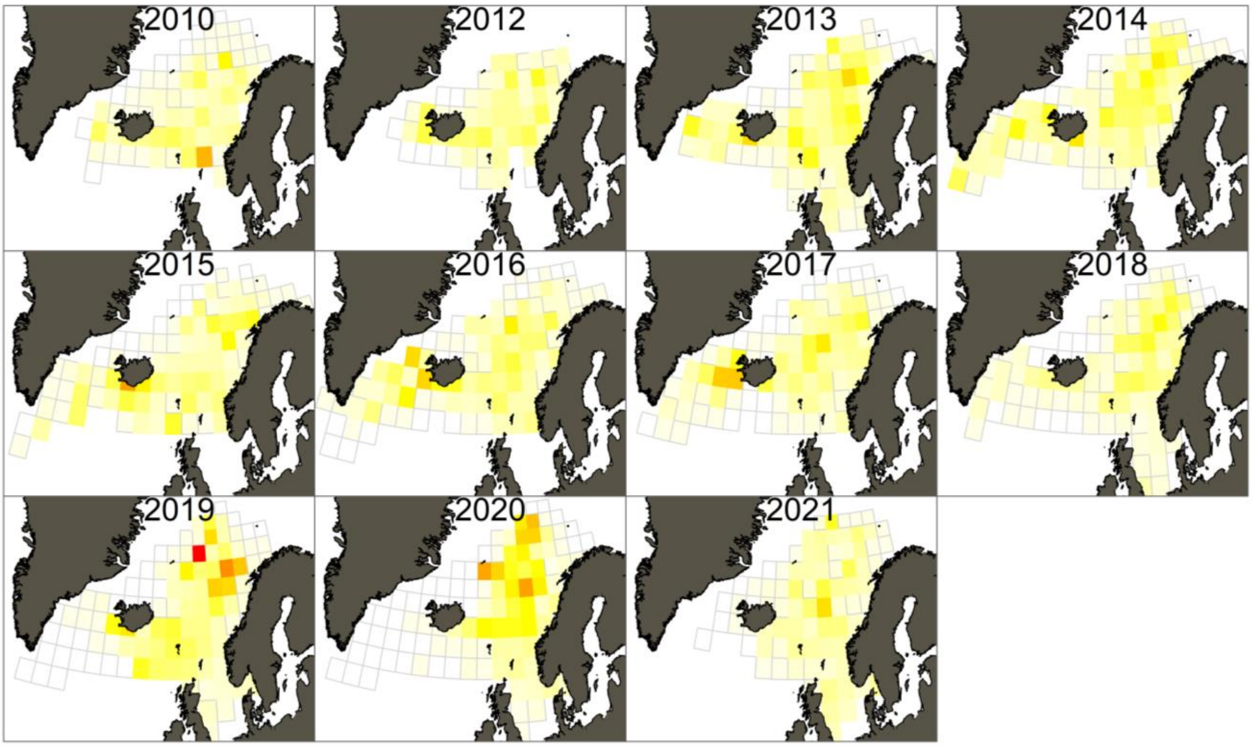


Figure 11. Annual distribution of mackerel proxied by the absolute distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations. Colour scale goes from white (= 0) to red (= maximum value for the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

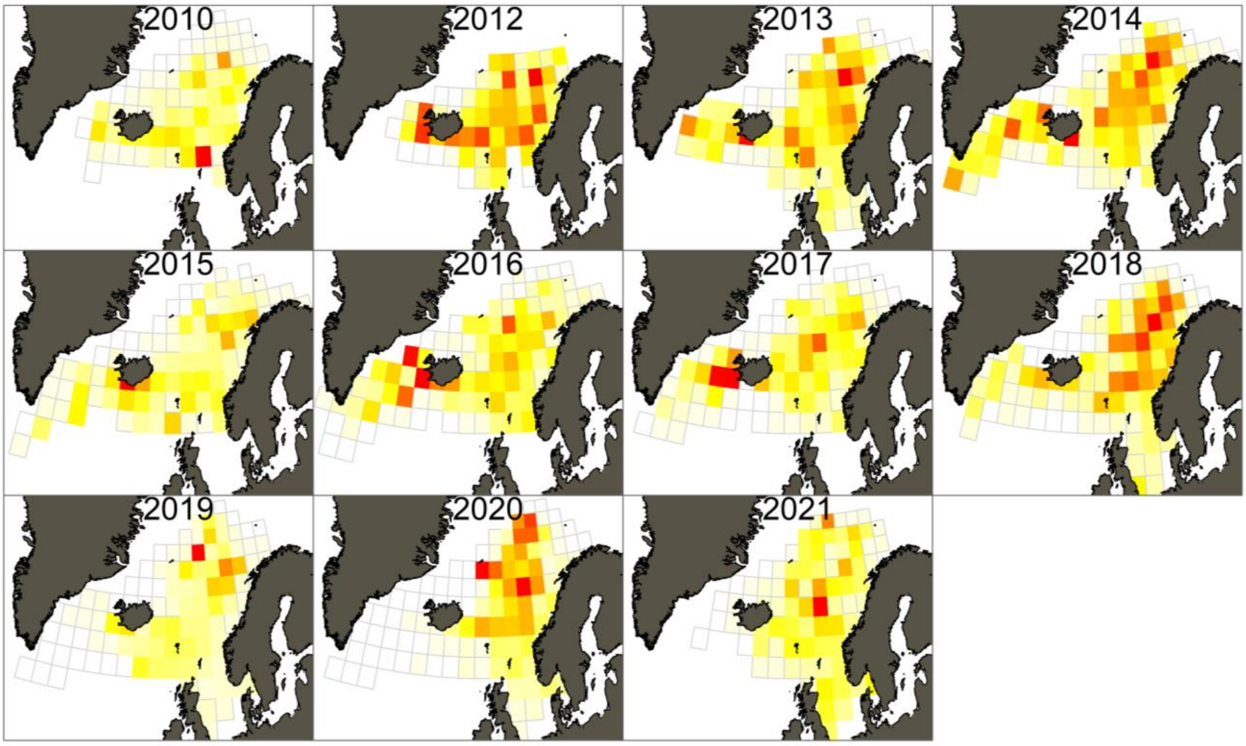


Figure 12. Annual distribution of mackerel proxied by the relative distribution of mean mackerel catch rates per standardized rectangles (2° lat. x 4° lon.), from Multpelt 832 pelagic trawl hauls at predetermined surface trawl stations. Colour scale goes from white (= 0) to red (= maximum value for the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

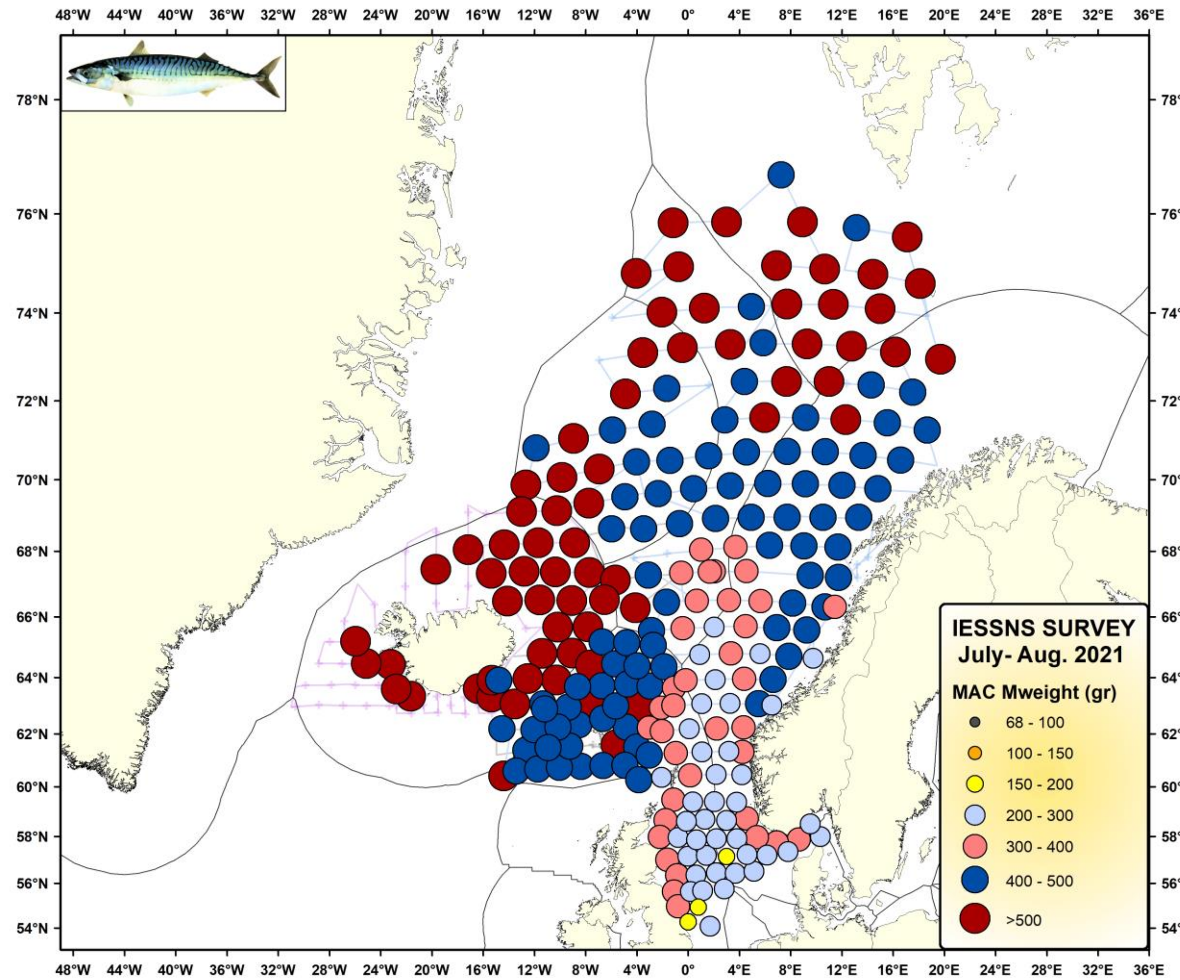


Figure 13. Average weight of mackerel at predetermined surface trawl stations during IESSNS 2021.

The mackerel weight varied between 51 to 874 g with an average of 421 g. The length of mackerel caught in the pelagic trawl hauls onboard the five vessels varied from 21.0 to 43.5 cm, with an average of 35.6 cm. Individuals in the length range 32–36 cm dominated in numbers and biomass. 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 2021 according to the catches are shown in Figure 14.

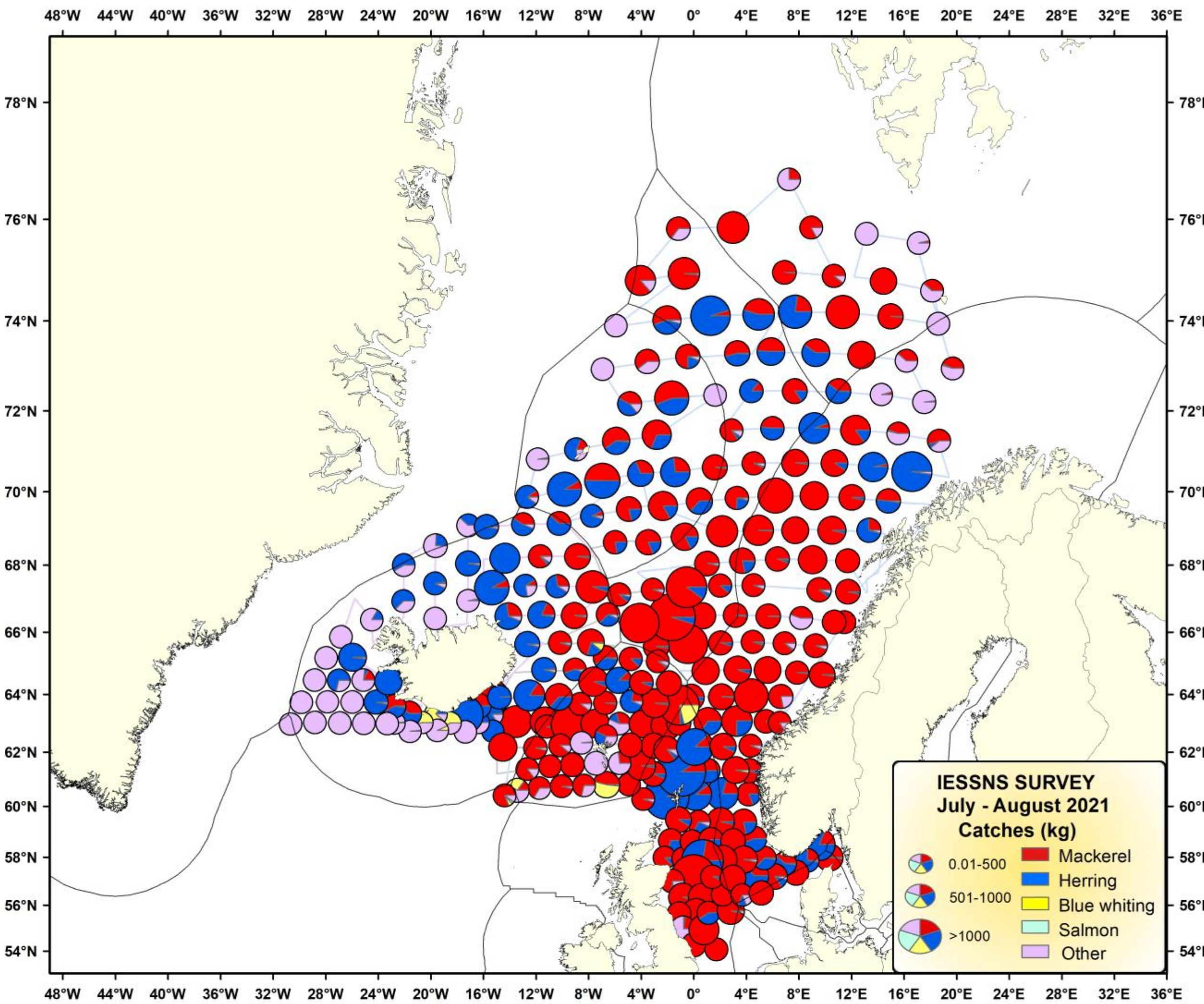


Figure 14. Distribution and spatial overlap between various pelagic fish species (mackerel, herring, blue whiting, salmon, and other (lumpfish)) in 2021 at all surface trawl stations. Vessel tracks are shown as continuous lines.

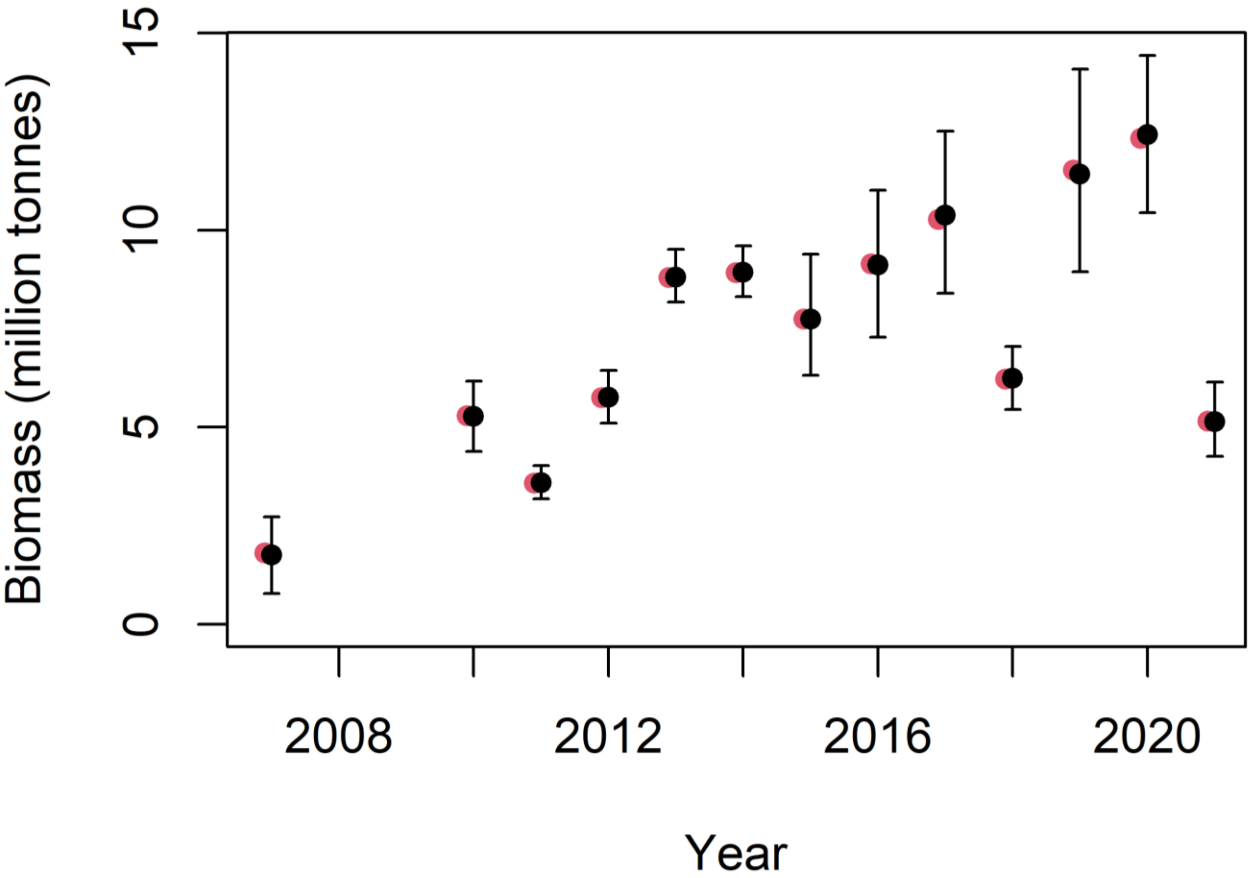
Swept area analyses from standardized pelagic trawling with Multpelt 832

The swept area estimates of mackerel biomass from the 2021 IESSNS were based on abundance of mackerel per stratum (see strata definition in Figure 2) and calculated in StoX version 3.10. The mackerel biomass and abundance indices in 2020 were the highest in the time series that started in 2010 (Table 7, Figure 15). In 2021 a drop of more than 50% was observed (Figure 15). The most abundant year-classes were 2019, 2016, 2014, 2017 and 2012, respectively (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- and 2-year olds from the 2019 and 2020 year-classes was quite high, particularly in the North Sea in July 2021, suggesting that these new year-classes may be promising. Variance in age index estimation is provided in Figure 17.

The overall internal consistency plot for age-disaggregated year classes was slightly reduced compared to last year (Figure 19). There is a good to strong internal consistency for the younger ages (1-4 years) and older ages (8-14+ years) with r between 0.70 and 0.89. However, the internal consistency is very poor to moderate ($0.02 < r < 0.64$) between age 4 to 8. The reason for this poor consistency is not clear.

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

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



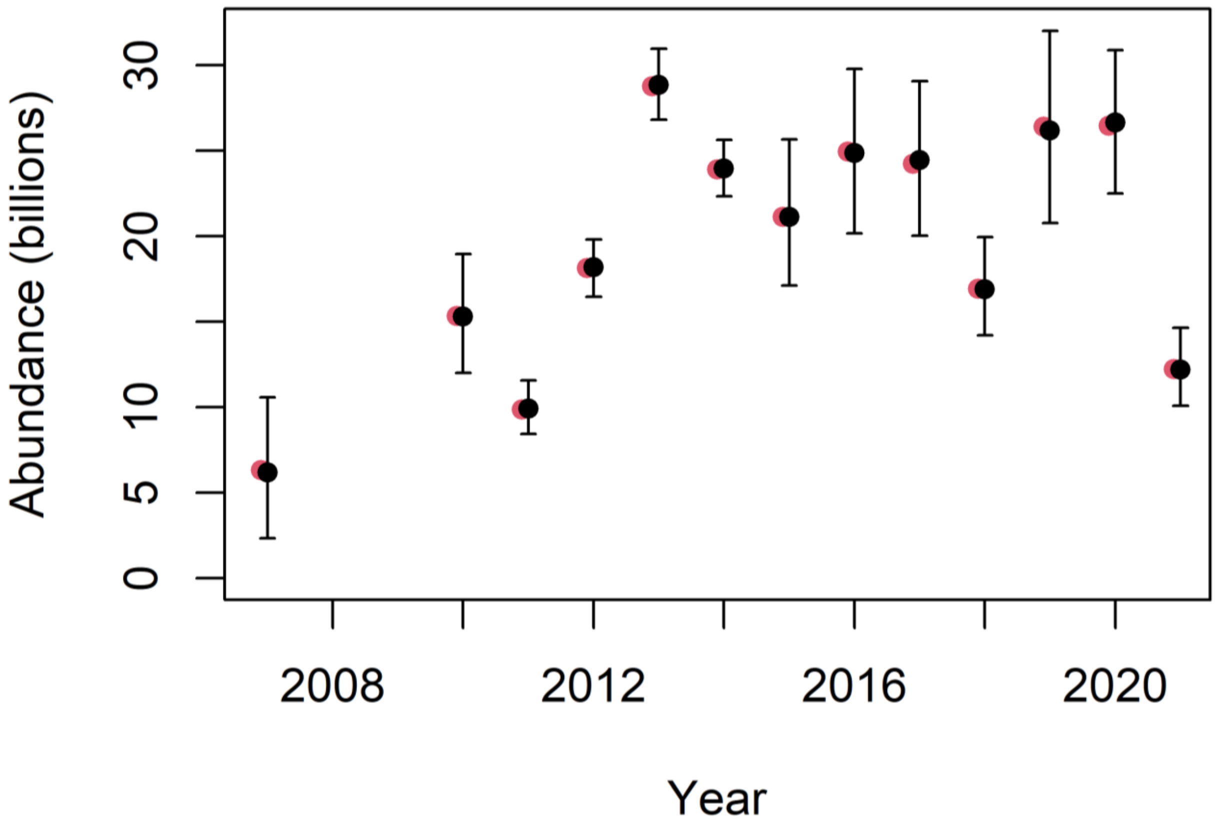


Figure 15. Estimated total stock biomass (upper panel) and total stock numbers (lower panel) of mackerel from StoX for the years 2007 and from 2010 to 2021. The red dots are baseline estimates, the black dots are mean of 1000 bootstrap replicates while the error bars represent 90 % confidence intervals based on the bootstrap.

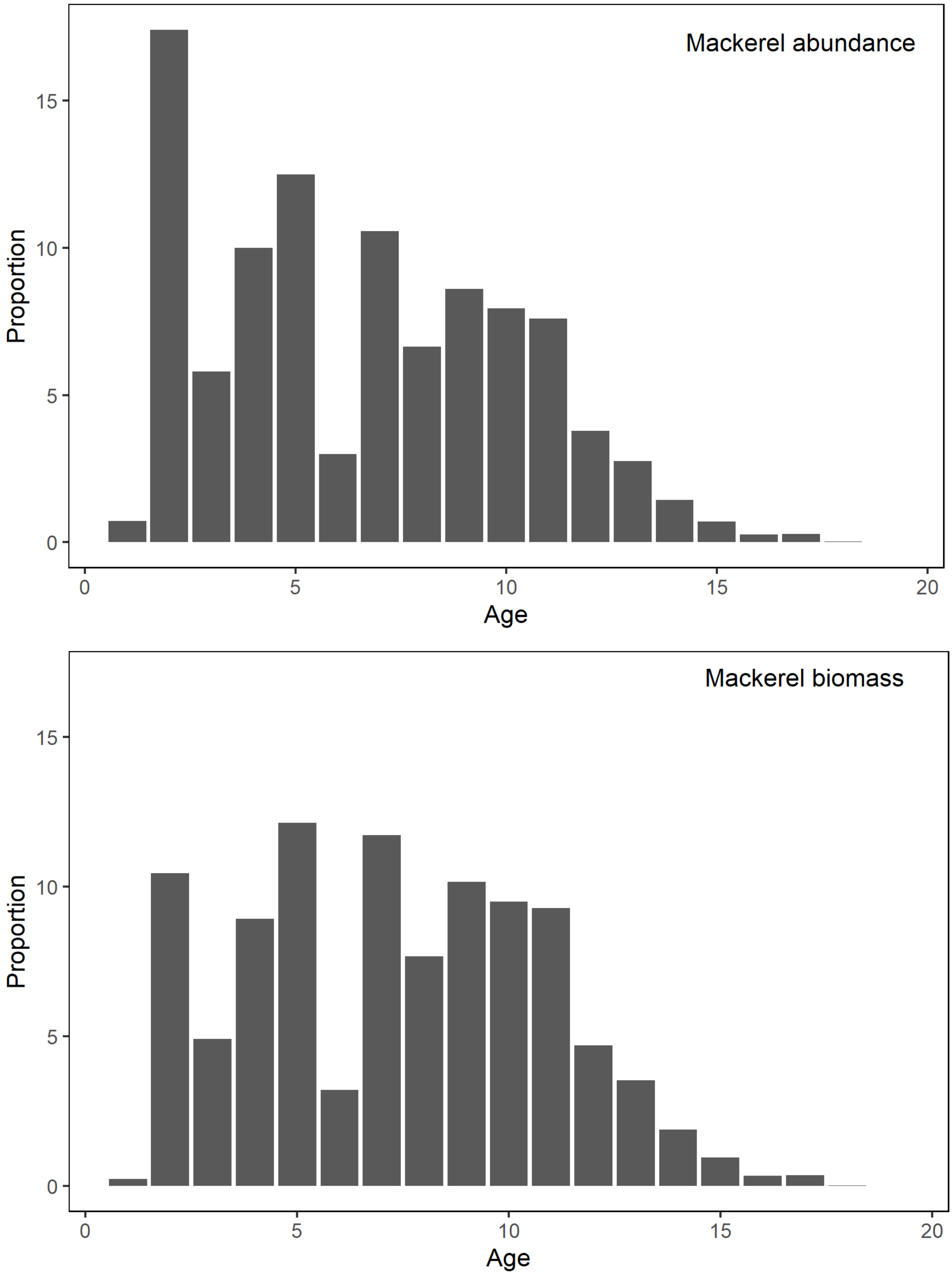


Figure 16. Age distribution in proportion represented as a) % in numbers and b) % in biomass of Northeast Atlantic mackerel in 2021.

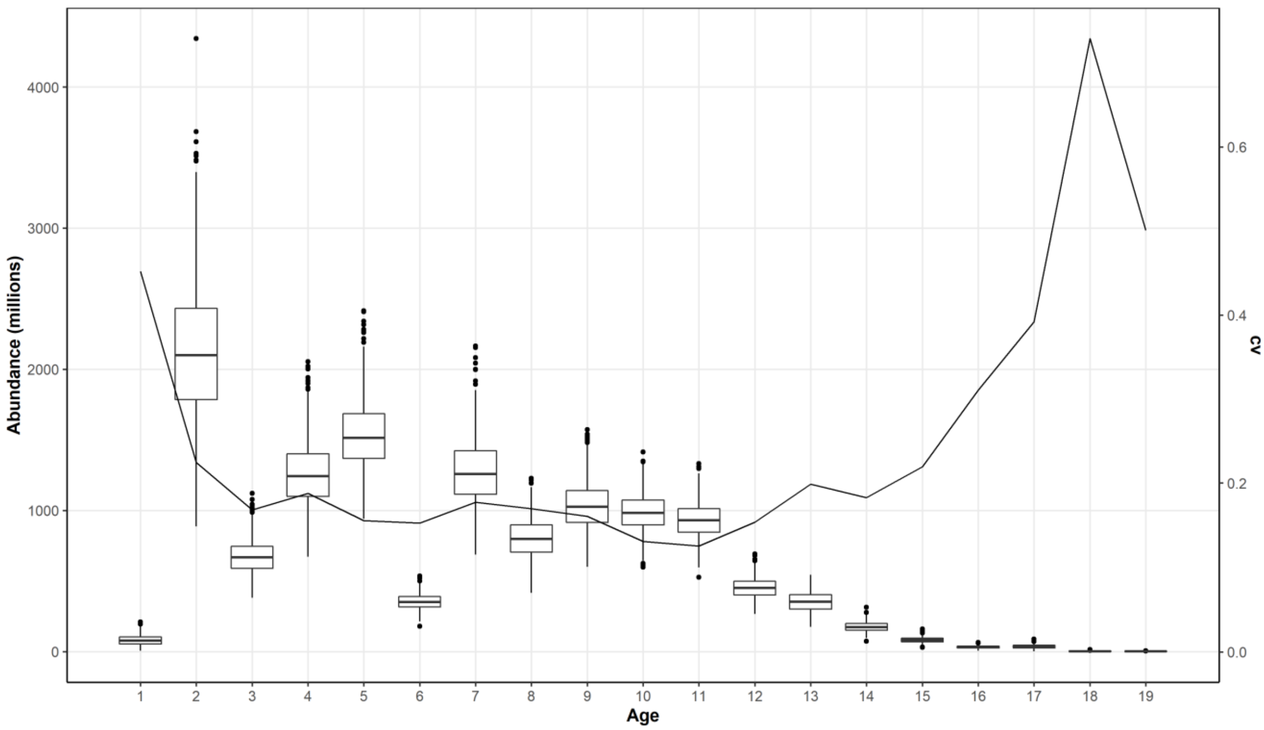


Figure 17. Number by age for mackerel in 2021. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 7. a-d) StoX baseline time series of the IESSNS showing (a) age-disaggregated abundance indices of mackerel (billions), (b) mean weight (grams) per age, (c) estimated biomass at age (million tonnes) in 2007 and from 2010 to 2021, and (d) estimates of abundance, biomass and mean weight by age and length, including coefficient of variation (cv) based on calculation in StoX for IESSNS 2021 (d). cv* values are from bootstrap calculations but other values from baseline calculations (point estimates).

a)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)	Tot N
2007	1.33	1.86	0.90	0.24	1.00	0.16	0.06	0.04	0.03	0.01	0.01	0.00	0.01	0.00	5.65
2010	0.03	2.80	1.52	4.02	3.06	1.35	0.53	0.39	0.20	0.05	0.03	0.02	0.01	0.01	13.99
2011	0.21	0.26	0.87	1.11	1.64	1.22	0.57	0.28	0.12	0.07	0.06	0.02	0.01	0.00	6.42
2012	0.50	4.99	1.22	2.11	1.82	2.42	1.64	0.65	0.34	0.12	0.07	0.02	0.01	0.01	15.91
2013	0.06	7.78	8.99	2.14	2.91	2.87	2.68	1.27	0.45	0.19	0.16	0.04	0.01	0.02	29.57
2014	0.01	0.58	7.80	5.14	2.61	2.62	2.67	1.69	0.74	0.36	0.09	0.05	0.02	0.00	24.37
2015	1.20	0.83	2.41	5.77	4.56	1.94	1.83	1.04	0.62	0.32	0.08	0.07	0.04	0.02	20.72
2016	<0.01	4.98	1.37	2.64	5.24	4.37	1.89	1.66	1.11	0.75	0.45	0.20	0.07	0.07	24.81
2017	0.86	0.12	3.56	1.95	3.32	4.68	4.65	1.75	1.94	0.63	0.51	0.12	0.08	0.04	24.22
2018	2.18	2.50	0.50	2.38	1.20	1.41	2.33	1.79	1.05	0.50	0.56	0.29	0.14	0.09	16.92
2019	0.08	1.35	3.81	1.21	2.92	2.86	1.95	3.91	3.82	1.50	1.25	0.58	0.59	0.57	26.4
2020	0.04	1.10	1.43	3.36	2.13	2.53	2.53	2.03	2.90	3.84	1.50	1.18	0.92	0.98	26.47
2021	0.09	2.13	0.71	1.22	1.53	0.37	1.29	0.81	1.05	0.97	0.93	0.46	0.34	0.33	12.22

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
2021	140	253	357	377	409	451	467	487	497	505	516	523	544	559

c)

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)	Tot B
2007	0.18	0.43	0.29	0.09	0.47	0.09	0.03	0.02	0.02	0.01	0.01	0.00	0.01	0.00	1.64
2010	0.00	0.59	0.44	1.42	1.19	0.59	0.27	0.20	0.11	0.03	0.02	0.01	0.01	0.00	4.89
2011	0.03	0.07	0.28	0.41	0.67	0.54	0.29	0.15	0.07	0.04	0.03	0.01	0.01	0.00	2.69
2012	0.06	0.94	0.35	0.73	0.72	1.00	0.72	0.30	0.17	0.06	0.03	0.01	0.00	0.00	5.09
2013	0.01	1.43	2.32	0.70	1.09	1.15	1.15	0.56	0.22	0.10	0.08	0.02	0.01	0.01	8.85
2014	0.00	0.16	2.24	1.72	1.05	1.14	1.23	0.80	0.36	0.19	0.05	0.03	0.01	0.00	8.98
2015	0.15	0.24	0.80	1.97	1.76	0.87	0.85	0.50	0.30	0.16	0.04	0.04	0.02	0.01	7.72
2016	<0.01	1.15	0.45	0.95	1.95	1.72	0.83	0.76	0.53	0.37	0.22	0.10	0.04	0.04	9.11
2017	0.07	0.03	1.18	0.73	1.43	2.04	2.15	0.86	1.04	0.33	0.28	0.07	0.05	0.03	10.29
2018	0.15	0.57	0.16	0.93	0.50	0.63	1.07	0.85	0.51	0.26	0.30	0.16	0.08	0.05	6.22
2019	0.01	0.29	1.24	0.43	1.25	1.26	0.92	1.86	1.87	0.77	0.65	0.33	0.32	0.32	11.52
2020	<0.01	0.23	0.45	1.24	0.84	1.18	1.22	1.03	1.51	2.03	0.81	0.67	0.53	0.58	12.33
2021	0.01	0.54	0.25	0.46	0.62	0.17	0.60	0.39	0.52	0.49	0.48	0.24	0.18	0.19	5.15

d)	Age in years (year class)																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Abundance	Biomass	Mean
Length (cm)	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	num. 10^6	1000 ton	weight (g)
21	5																			5	0	84
22	22																			22	2	90
23	14																			14	1	97
24	7																			7	1	119
25	6																			6	1	141
26	8	2																		11	2	159
27	3	26																		30	5	178
28	10	134	0																	144	29	200
29	13	486	42																	542	122	226
30		708		1																709	178	251
31		548	5	8																561	156	278
32		178	43	30	5															257	76	298
33		37	161	129	55			12												395	129	326
34		6	157	317	214	12	8													713	253	355
35		2	225	416	428	38	58	18		5	0	0								1190	458	385
36		0	67	260	482	93	138	63	22	3	11	10	1							1149	484	422
37			6	55	273	134	386	257	177	169	87	25	1	0	3					1575	722	459
38			2	5	48	41	542	202	411	310	230	90	47	17	8	5	7			1964	954	486
39			0		21	48	131	166	272	298	298	157	129	29	8	8	2			1568	810	517
40						1	28	81	140	150	182	111	70	62	36	8	14		1	884	485	548
41					1	0		10	16	31	105	61	61	49	10	1	6	0		351	204	581
42							1	2	13	3	14	8	24	14	16	11	1			107	67	627
43													3	2	7		4			16	10	655
44											1			1						2	1	687
45																				0	1	738
46																		2		2	2	748
TSN (mil)	88	2128	709	1221	1528	367	1292	811	1052	970	927	462	336	174	87	32	34	2	1	12222	5155	
cv (TSN)*	0.45	0.22	0.17	0.19	0.16	0.15	0.18	0.17	0.16	0.13	0.13	0.15	0.20	0.18	0.22	0.31	0.39	0.86	0.97			
TSB (1000 t)	12	539	253	460	625	166	604	395	523	490	478	242	183	98	49	18	19	2	1	5154		
cv (TSB)*	0.42	0.23	0.17	0.19	0.15	0.15	0.18	0.17	0.16	0.13	0.13	0.15	0.20	0.19	0.22	0.32	0.38	0.87	0.98			
Mean len. (cm)	24.7	30.1	33.9	34.7	35.6	36.8	37.5	37.8	38.4	38.5	39.0	39.2	39.7	40.1	40.4	40.2	40.1	45.9	40.0			
Mean wei. (g)	140	253	357	377	409	451	467	487	497	505	516	523	544	559	568	558	544	743	545			

Table 8. Bootstrap estimates from StoX (based on 500 replicates) of mackerel in 2021. 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	22.6	77.0	144.1	79.8	36.1	0.45
2	1397.9	2100.0	2935.7	2124.0	477.8	0.22
3	498.1	666.6	864.6	671.5	113.3	0.17
4	891.4	1243.2	1686.4	1258.5	236.9	0.19
5	1178.3	1514.8	1929.9	1536.0	239.2	0.16
6	268.5	350.8	445.7	353.1	54.0	0.15
7	962.1	1257.9	1688.1	1278.2	227.0	0.18
8	585.5	797.5	1037.3	801.7	136.4	0.17
9	773.9	1025.1	1329.6	1035.5	166.6	0.16
10	780.8	982.3	1198.9	986.9	129.3	0.13
11	756.2	930.6	1135.3	932.2	117.2	0.13
12	340.5	450.0	569.2	451.4	69.5	0.15
13	242.5	353.8	471.7	354.1	70.6	0.20
14	125.4	173.2	226.1	174.6	32.0	0.18
15	54.3	82.0	113.2	82.3	18.1	0.22
16	15.7	31.4	48.2	31.5	9.8	0.31
17	13.5	33.7	59.6	34.9	13.7	0.39
18	0.0	2.4	7.1	2.8	2.4	0.86
19	0.0	1.3	3.8	1.4	1.3	0.97
Unknown	1.4	6.2	19.3	7.7	5.9	0.77
TSN	10078	12133	14637	12198	1376	0.11
TSB	4.26	5.13	6.15	5.14	0.58	0.11

Figure 18. Catch curves in 2021. Each cohort of mackerel is marked by a uniquely coloured line that connects the estimates indicated by the respective ages.

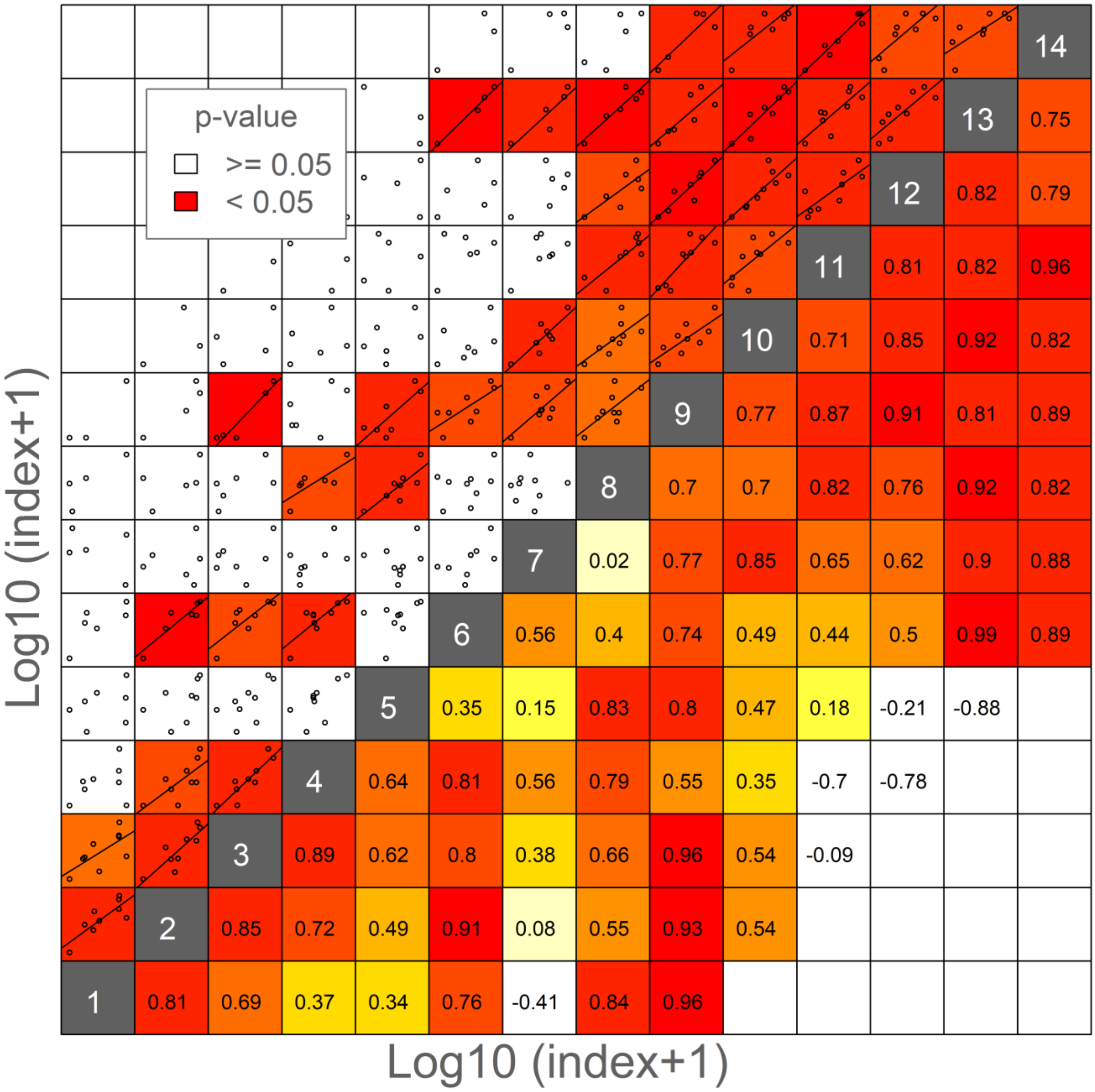


Figure 19. Internal consistency of the of mackerel density index from 2012 to 2021. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half.

The zero boundaries for mackerel distribution were found in majority of survey area with a notable exception of some mackerel abundance in the north-western region of the Norwegian Sea particularly towards the Fram Strait west of Svalbard.

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, such that it covers the southwestern waters south of 60°N, e.g. UK waters.

The standard swept area method using the average horizontal trawl opening by each participating vessel (ranging 56.6.5-75.4 m; Table 5), assuming that a constant fraction of the mackerel inside the horizontal trawl opening are caught. Further, that if mackerel is distributed below the depth of the trawl (footrope), this fraction is assumed constant from year to year.

The large variation in the swept area index in recent years might be due to the large spread in catch rates with a varying proportion taken each year of some few extremely large catches (>10 t/30min). It is suspected that these extreme catches might have relatively high impact on the calculated average, with a potential to bias the survey index. The problem arises if the number of these extreme catches is linked to the distribution of mackerel but not to the biomass. The group recommends investigating this potential problem. In 2021 we had no large or extremely large catch of mackerel compared to e.g. 2019 and 2020.

As in previous years, there was overlap in the spatio-temporal distribution of mackerel and herring (Figure 14). This overlap occurred between mackerel and North Sea herring in major parts of the North Sea and partly in the southernmost part of the Norwegian Sea. There were also some overlapping distributions of mackerel and Norwegian spring-spawning herring (NSSH) in the western, north-western and north-eastern part of the Norwegian Sea.

4.4 Norwegian spring-spawning herring

Norwegian spring-spawning herring (NSSH) was recorded in the southwestern (east and north of Iceland) and northern part of the Norwegian Sea basin (Figure 20a). The acoustic registrations in the southern and eastern parts of the Norwegian Sea were low or absent in July 2021. This is in contrast to the more southerly distribution of the adult stock in May, where the herring was observed from the area north of the Faroes northwest towards Iceland. In July 2021 a relatively large part of the adult NSSH stock was distributed north of 68°N (Figure 20a). Herring registrations south of 62°N in the eastern part were allocated to a different stock, North Sea herring, while the herring to the south and west in Icelandic waters (west of 14°W south of Iceland) were allocated to Icelandic summer-spawners, and these were removed from the biomass estimation of NSSH, except some putative North Sea herring in the southeastern area north of Shetland (Figure 20b).

The total number of NSSH recorded during IESSNS 2021 was 20.3 billion and the total biomass index was 6.10 million tonnes, which at the same level as in 2020 (20.3 and 5.93, respectively) (Table 10 and 11). The 2016 year-class (5 year olds) dominated in the stock and contributed to 55% and 60% to the total biomass and total abundance, respectively, whereas the 2013 year-class (8 year olds) contributed 13% and 11% to the total biomass and total abundance, respectively (Figure 21 and Table 9). The 2016 year-class was considered to be fully recruited to the adult stock in 2021, and also fully recruited to the survey area.

Bootstrap estimates of numbers by age are shown in Figure 21. The uncertainty (CV) around the age disaggregated abundance indices from the 2021 survey varied around 0.25-0.3 for age groups 4-15 (Figure 21), which is considered satisfactory.

The internal consistency among year classes was generally high, with the lowest correlation (r = 0.57) between age 5 and 6 (Figure 22).

The 0-boundary of the distribution of the adult part of NSSH was considered to be reached in all directions. The herring was mainly observed in the upper surface layer as relatively small schools. This shallow distribution of herring might have lead to an unknown portion of herring being in the "blind zone" above the transducer depth of the vessels (i.e. shallower than 10-15 m, Table 4), and therefore not being registered by the vessels. However, the group considered the acoustic biomass estimate of herring to be of good quality in the 2021 IESSNS as in the previous survey years.

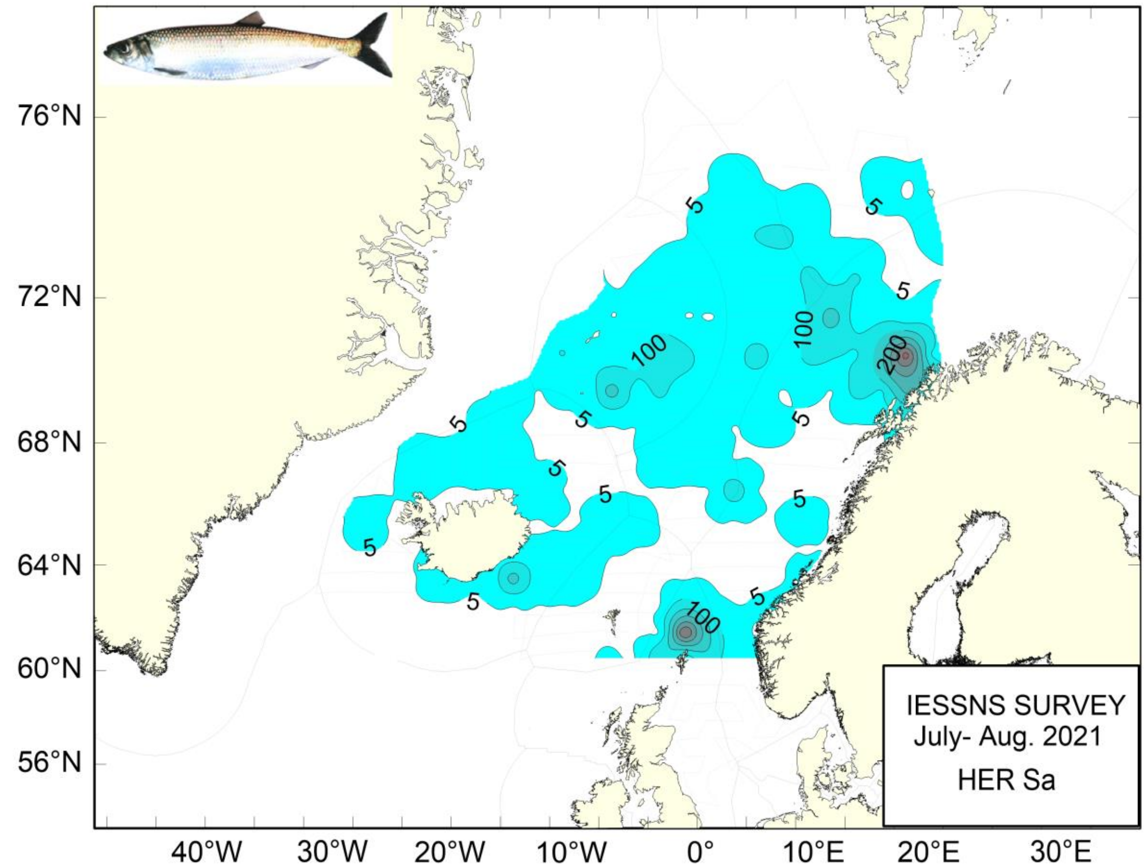


Figure 20a. The sA/Nautical Area Scattering Coefficient (NASC) values of herring along the cruise tracks in 2021 presented as contour lines. Values north of 62ºN, and east of 14ºW, are considered to be Norwegian spring-spawning herring. South and west of this area the herring observed are other stocks, *i.e.* Icelandic summer spawners, Faroese autumn spawners and North Sea herring in the southeast.

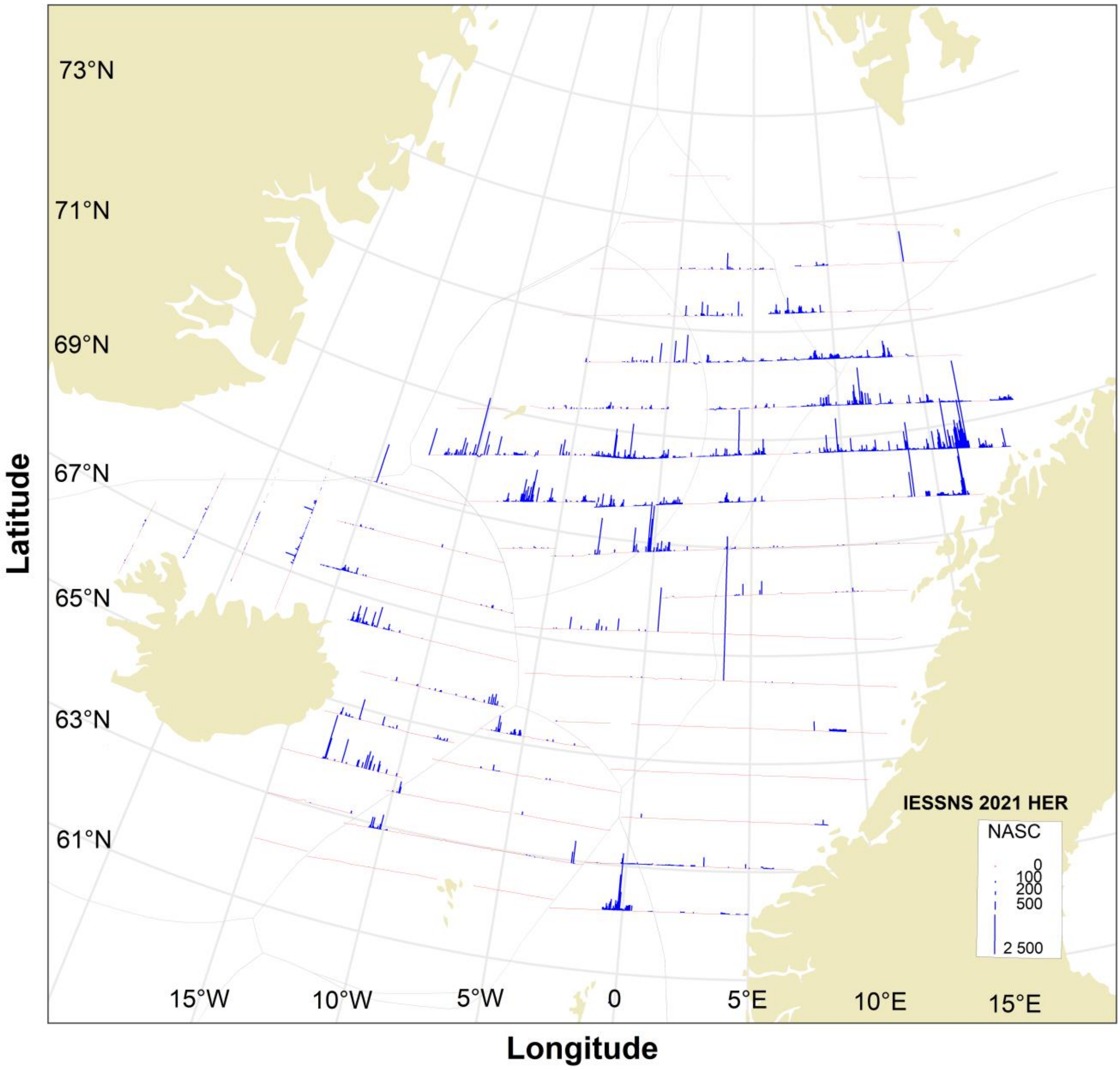


Figure 20b. The sA/Nautical Area Scattering Coefficient (NASC) values of Norwegian spring-spawning herring along the cruise tracks in 2021, presented as bar plot.

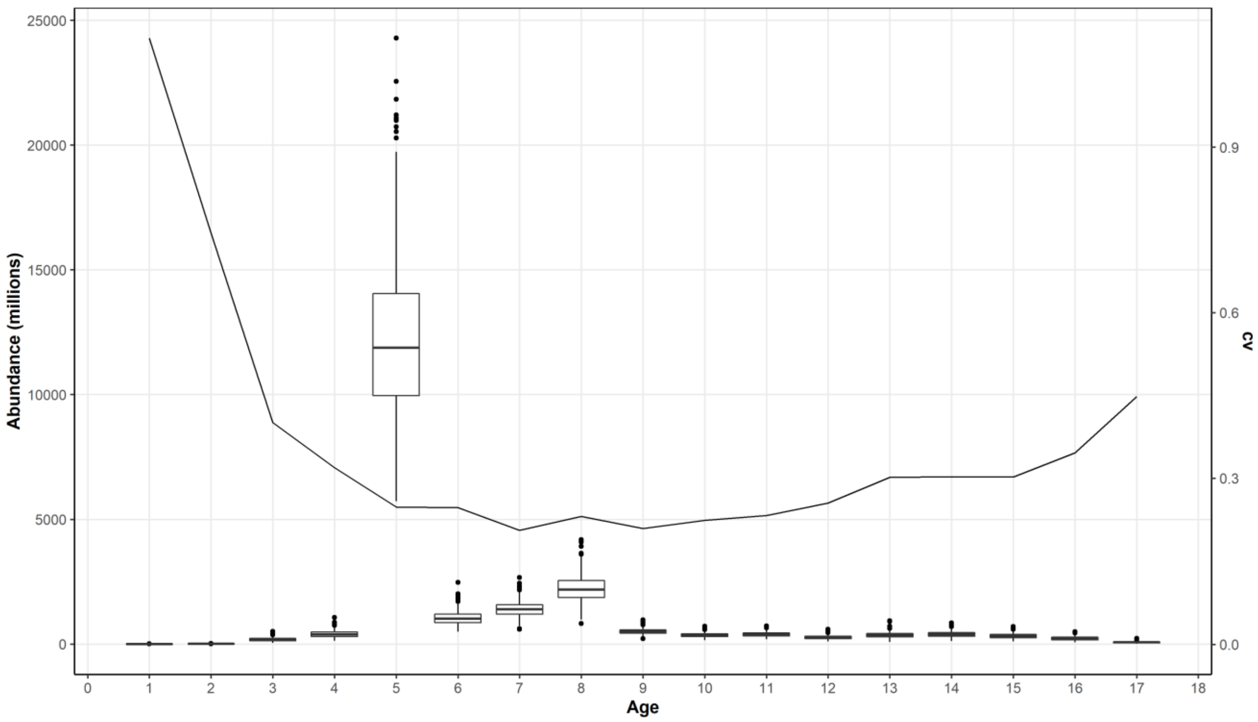


Figure 21. Abundance by age for Norwegian spring-spawning herring during IESSNS 2021. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 9. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring based on calculation in StoX for IESSNS 2021.

Length	Age in years (year class)																		Number	Biomass	Mean
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18			weight
(cm)	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	(10^6)	(10^6 kg)	(g)
15-16																					26.5
16-17																					31.8
17-18																					36.0
18-19	0.5																		0.5	0.0	47.8
19-20																				0.2	57.3
20-21			12.8																12.8	0.8	62.5
21-22			18.0																18.0	1.3	69.2
22-23			26.6																26.6	2.3	83.9
23-24			3.3																3.3	0.3	92.0
24-25			5.0																5.0	0.7	126.6
25-26			18.5	6.4															25.0	3.7	153.6
26-27		4.0	29.1	17.5	4.6														55.3	8.9	166.3
27-28			17.1	78.2	56.4	7.5	8.7	1.7											169.6	30.5	184.2
28-29			25.0	40.1	167.9	23.5	7.4	22.2	2.5	3.7									292.2	59.2	205.2
29-30			16.1	73.9	695.0	9.9	18.3	7.5	28.8	11.7	6.0				0.5				867.8	199.4	230.3
30-31			10.9	86.0	2895.6	156.0	25.5	30.6	13.8	12.6	9.5	5.9	7.5	0.6	1.8				3 256.5	823.7	252.4
31-32				48.3	3743.5	146.3	94.3	51.9	24.1	12.7	8.8	13.6	0.7	5.6	0.6				4 150.4	1133.2	273.2
32-33			2.0	28.0	3040.3	161.3	229.2	89.7	27.0	23.1	14.8	8.9	11.8	0.8		0.8	1.8		3 639.4	1080.8	296.8
33-34				16.3	1354.5	279.8	398.2	473.7	68.9	25.8	4.7	6.3	2.9						2 631.0	848.7	320.6
34-35					154.7	230.4	404.9	862.9	97.6	28.3	12.8	15.5	1.4		5.4				1 814.0	626.8	341.3
35-36						30.5	185.3	580.3	122.1	103.0	52.2	30.2	7.6	15.4	3.6	17.7			1 147.8	422.2	359.8
36-37							25.4	94.4	102.4	76.2	131.0	83.6	127.2	112.3	83.3	32.7	17.2		885.7	340.7	378.7
37-38				3.8				11.4	15.2	52.4	132.1	71.5	144.5	165.3	139.5	38.2	24.4		798.2	318.9	394.8
38-39					3.3		0.9			12.0	21.1	32.8	35.3	66.3	89.3	93.3	17.0		371.4	154.5	416.2
39-40													21.0	21.1		45.5	3.4		91.0	40.8	451.0
40-41					1.3									4.5			5.1		10.9	5.2	460.9
																				0.4	
TSN(mill)	0.5	4.0	184.5	398.5	12117.0	1045.4	1398.1	2226.3	502.4	361.5	393.1	268.2	359.8	391.9	324.0	228.2	69.0		20 279.7		
cv (TSN)	1.55	0.87	0.40	0.32	0.25	0.25	0.21	0.23	0.21	0.22	0.23	0.26	0.30	0.30	0.30	0.35	0.45		0.20		
TSB(1000 t)	0.0	0.7	27.4	92.5	3 348.2	316.7	456.3	763.2	173.3	128.5	146.5	101.1	141.9	154.0	128.4	95.3	28.3		6 103.2		
cv (TSB)	1.55	0.87	0.37	0.30	0.25	0.25	0.21	0.23	0.21	0.23	0.24	0.26	0.31	0.30	0.31	0.35	0.45		0.20		
Mean length(cm)	15.3	26.0	26.0	29.3	31.1	32.2	33.0	33.8	33.7	34.6	35.8	35.6	36.4	36.9	36.9	37.6	37.4				
Mean weight(g)	28.7	165.6	166.2	233.9	276.7	300.9	320.5	336.3	333.8	349.9	370.6	371.2	388.1	389.2	392.0	419.5	414.5				

Table 10. IESSNS bootstrap time series (mean of 1000 replicates) from 2016 to 2021. StoX abundance estimates of Norwegian spring-spawning herring (millions).

	Age												
Year	1	2	3	4	5	6	7	8	9	10	11	12+	TSB(1000 t)
2016	38	119	747	577	1,622	1,636	1,967	1,588	1,274	2,001	2,164	6,245	6,676
2017	1,232	240	1,318	4,653	1,003	1,184	795	1,716	1,004	1,115	1,657	4,040	5,821
2018	0	587	656	864	3,054	924	1,172	746	971	1,078	663	2,704	4,379
2019	0	143	1,910	616	1,101	3,487	814	751	510	780	470	4,660	4,794
2020	0	15	117	8,280	1,710	2,367	4,087	696	520	305	594	1,827	5,991
2021	1	4	184	398	12,117	1,045	1,398	2,226	502	361	393	1,641	6,103

Table 11. IESSNS baseline time series from 2016 to 2021. StoX abundance estimates of Norwegian spring-spawning herring (millions).

	Age												
Year	1	2	3	4	5	6	7	8	9	10	11	12+	TSB(1000 t)
2016	41	146	752	604	1,637	1,559	2,010	1,614	1,190	2,023	2,151	6,467	6,753
2017	1,216	248	1,285	4,586	1,056	1,188	816	1,794	1,022	1,131	1,653	4,119	5,885
2018	0	577	722	879	3,078	931	1,264	734	948	1,070	694	2,792	4,465
2019	0	153	1,870	590	1,067	3,475	859	702	520	700	463	4,808	4,780
2020	0	7	111	8,082	1,697	2,335	4,102	714	491	294	590	1,833	5,930
2021	1	3	196	388	11,988	1,109	1,342	2,292	491	365	386	1,649	6,085

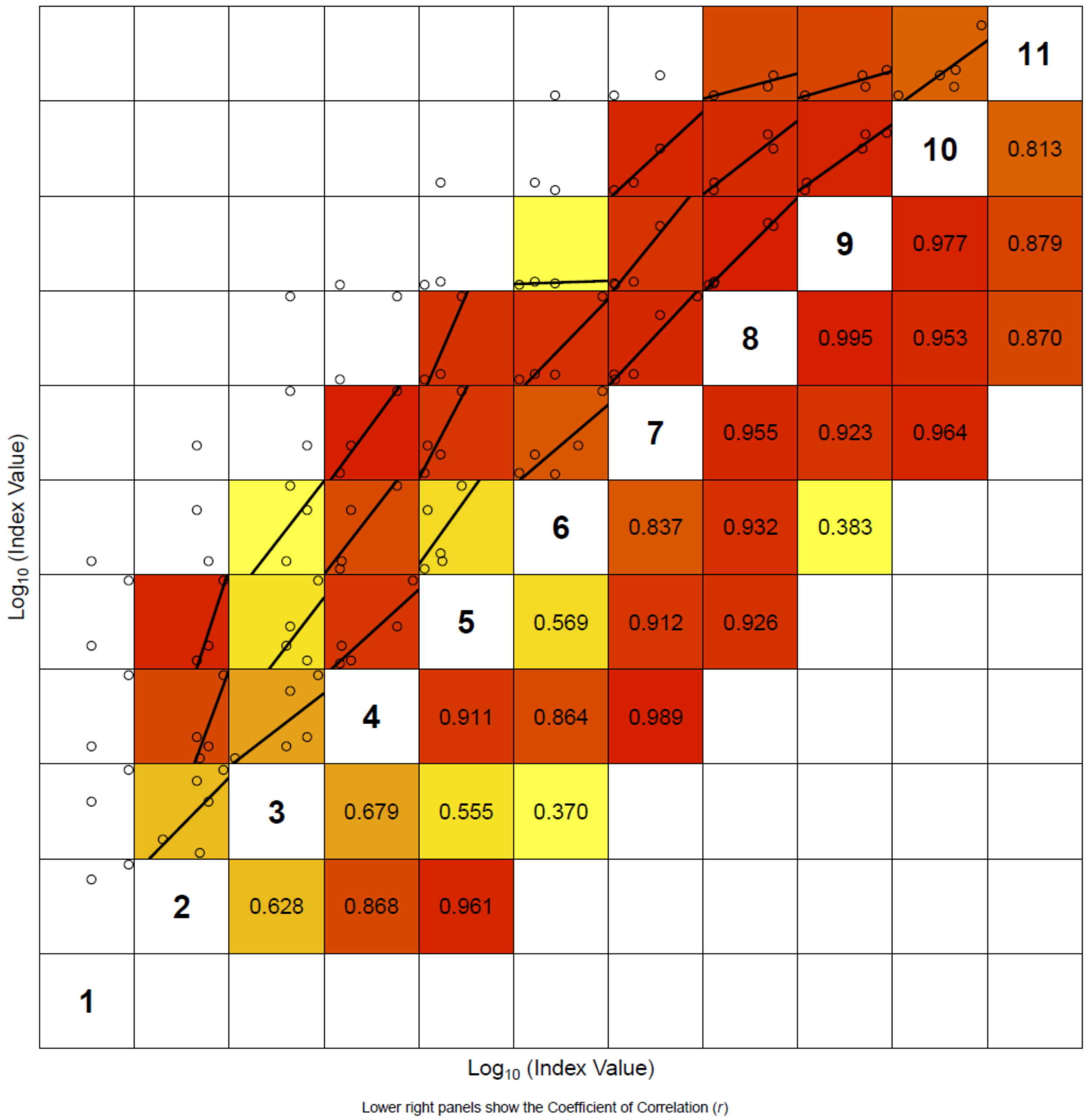


Figure 22. Internal consistency for Norwegian spring-spawning herring within the IESSNS 2021. The upper left part of the plots shows the relationship between log index-at-age within a cohort. Linear regression line shows the best fit to the log-transformed indices. The lower-right part of the plots shows the correlation coefficient (r) for the two ages plotted in that panel. The background colour of each panel is determined by the r value, where red equates to r=1 and white to r<0.

4.5 Blue whiting

Blue whiting was distributed in parts of the survey area dominated by warm Atlantic waters and had a continuous distribution from the southern boundary of the survey area (60 °N) to Spitsbergen (72 °N). High blue whiting density (s_A-values) was observed in the southern part of the Norwegian Sea, along the Norwegian continental slope, around the Faroe Islands, and southeast of Iceland. Concentrations of older fish (age2+) were low and they were mainly observed on the continental slope, both in the eastern and the southern part of the Norwegian Sea (Figure 23). The distribution in 2021 is comparable to 2020 with the exception of more blue whiting recorded south and southwest of Iceland, mostly age-0 fish. As in previous years no blue whiting was registered in the cold East Icelandic Current, between Iceland and Jan Mayen.

The total biomass of blue whiting registered during IESSNS 2021 was 2.2 million tons (Table 12), which is an increase of 24% compared to 2020 (1.8 mill tons). Estimated stock abundance (ages 1+) was 26.2 billion compared to 16.5 billion in 2020, which is an increase of 60%. Age 1 dominated the estimate in 2021 as it contributed 51% and 69% of biomass and abundance, respectively.

Bootstrap estimates of numbers by age, with uncertainty estimates, for blue whiting during IESSNS 2021 are shown in Figure 24. The baseline point estimates from 2016-2021 are shown in table 13. The internal consistency among year classes is shown in Figure 25 and indicates good to moderate consistency for ages 3-6, but poorer fit for other ages.

The group considered the acoustic biomass estimate of blue whiting to be of good quality in the 2021 IESSNS as in the previous survey years.

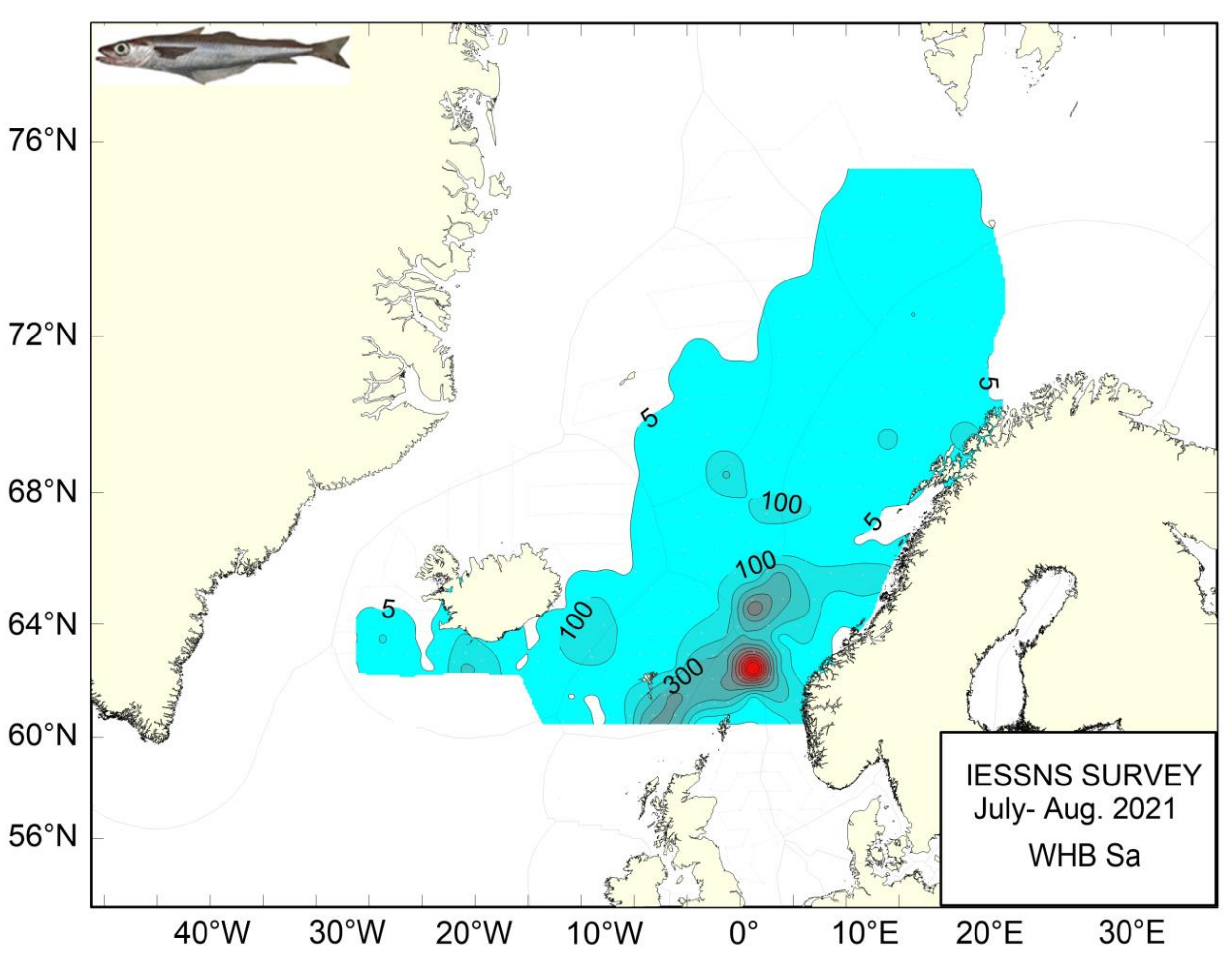


Figure 23a. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2021. Presented as contour lines.

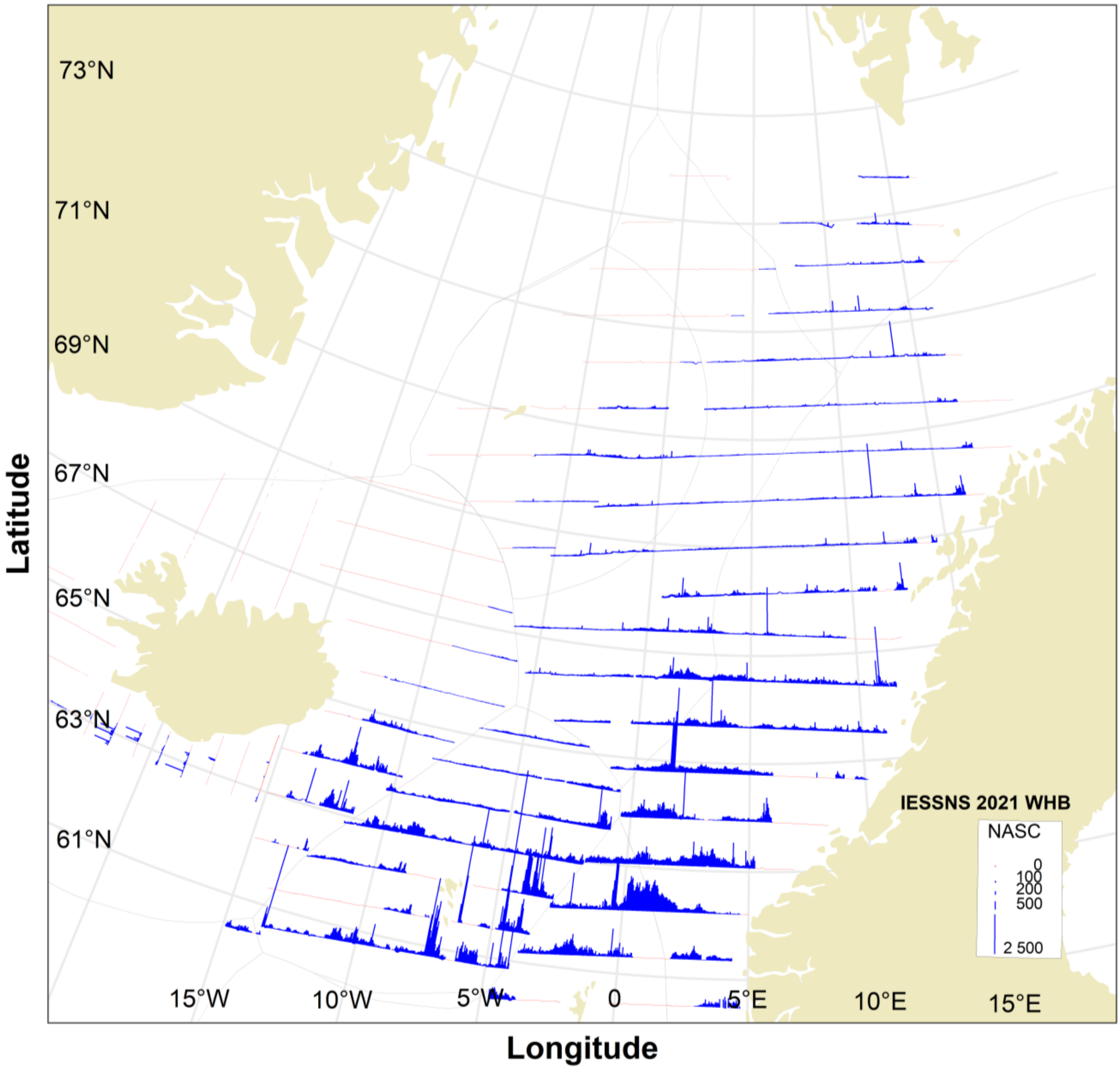


Figure 23b. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2021. Presented as bar plot.

Table 12. Estimates of abundance, mean weight and mean length of blue whiting based on calculation in StoX for IESSNS 2021.

Length	Age in years (year class)											Number	Biomass	Mean
	0	1	2	3	4	5	6	7	8	9	10			weight
(cm)	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	(10^6)	(10^6 kg)	(g)
10-11	27.8											27.8		
11-12	311.1											311.1	0.1	5.0
12-13	961.4											961.4	0.2	5.9
13-14	989.4											989.4	2.6	8.5
14-15	753.9											753.9	9.8	10.5
15-16	588.3											588.3	12.9	14.1
16-17	329.0											329.0	12.8	17.6
17-18	284.6											284.6	12.7	22.2
18-19	175.5	299.0										474.5	9.1	27.9
19-20	34.2	1020.9										1 055.1	9.5	33.3
20-21	14.6	3304.4	19.3									3 338.3	17.5	37.7
21-22		5998.2		57.5								6 055.7	43.6	40.6
22-23		5077.7	31.5									5 109.2	163.6	48.6
23-24		1799.3	255.7	13.6								2 068.6	346.8	57.5
24-25		632.2	276.3	25.3	7.5							941.3	323.9	63.9
25-26		250.5	529.6	279.0	14.0							1 073.1	145.7	71.9
26-27		72.8	754.5	212.8	13.5	8.9						1 062.5	77.9	84.3
27-28		24.5	261.8	427.7	23.1	54.8		13.7				805.6	106.3	98.8
28-29		3.2	167.9	290.8	314.5	83.3	227.2	97.4			11.0	1 195.5	115.6	110.9
29-30		1.4	75.6	79.0	149.1	188.0	321.5	162.6	57.4	33.8	57.8	1 126.2	96.3	120.8
30-31				96.1	234.6	179.0	327.7	128.5		31.4		997.1	156.5	132.8
31-32					89.0	204.0	301.1	98.6				692.7	161.5	146.0
32-33						133.1	234.0	44.8				411.9	156.6	159.7
33-34				12.0			67.4	43.3				122.7	122.8	179.0
34-35							13.2	20.7	13.8	14.1		61.8	80.0	192.7
35-36							0.8	8.2			8.2	17.3	26.3	214.0
36-37								17.0				17.0	14.1	223.5
37-38													4.6	274.2
38-39											7.1	7.1	5.1	330.2
TSN(mill)	4470	18484	2372	1494	845	851	1493	635	71	79	84	30 896.0		
cv (TSN)	0.46	0.17	0.21	0.27	0.32	0.30	0.34	0.37	0.58	0.64	0.72	0.12		
TSB(1000 t)	79.1	1 093.1	242.4	177.4	121.2	134.7	245.4	105.9	11.5	12.2	13.6	2 237.3		
cv (TSB)	0.40	0.17	0.21	0.27	0.32	0.30	0.34	0.36	0.60	0.63	0.62	0.11		
Mean length(cm)	14.5	21.5	25.0	26.7	28.8	29.9	30.3	30.4	29.8	30.8	31.3			
Mean weight(g)	21	62	97	119	145	159	168	175	156	162	197			

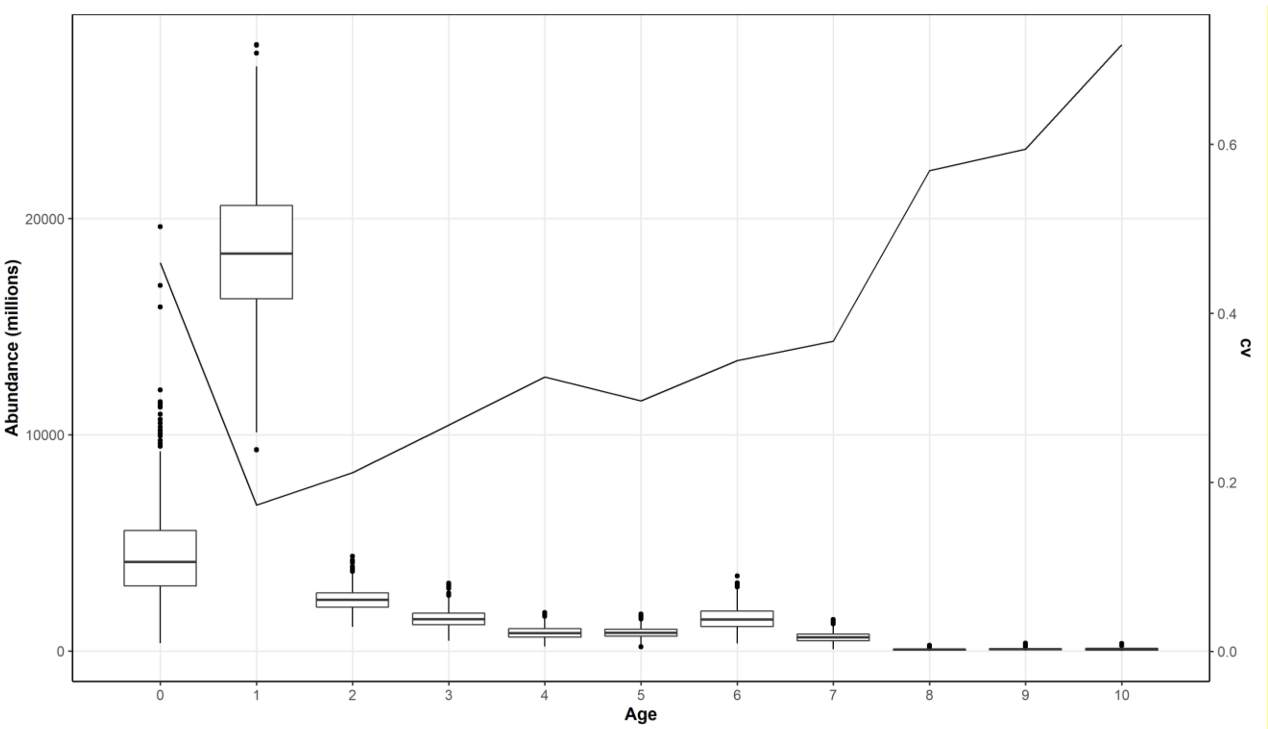


Figure 24. Number by age with uncertainty for blue whiting during IESSNS 2021. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 1000 replicates using the StoX software.

Table 13. IESSNS baseline time series from 2016 to 2021. StoX abundance estimates of blue whiting (millions).

	Age											
Year	0	1	2	3	4	5	6	7	8	9	10+	TSB(1000 t)
2016	3,869	5,609	11,367	4,373	2,554	1,132	323	178	177	8	233	2,283
2017	23,137	2,558	5,764	10,303	2,301	573	250	18	25	0	25	2,704
2018	0	915	1,165	3,252	6,350	3,151	900	385	100	52	41	2,039
2019	2,153	640	1,933	2,179	4,348	5,434	1,151	209	229	5	8	2,028
2020	4,066	5,804	2,996	1,629	1,205	1,718	1,990	939	201	21	30	1,806
2021	4,023	18,056	2,300	1,664	841	982	1,543	609	60	91	74	2,238

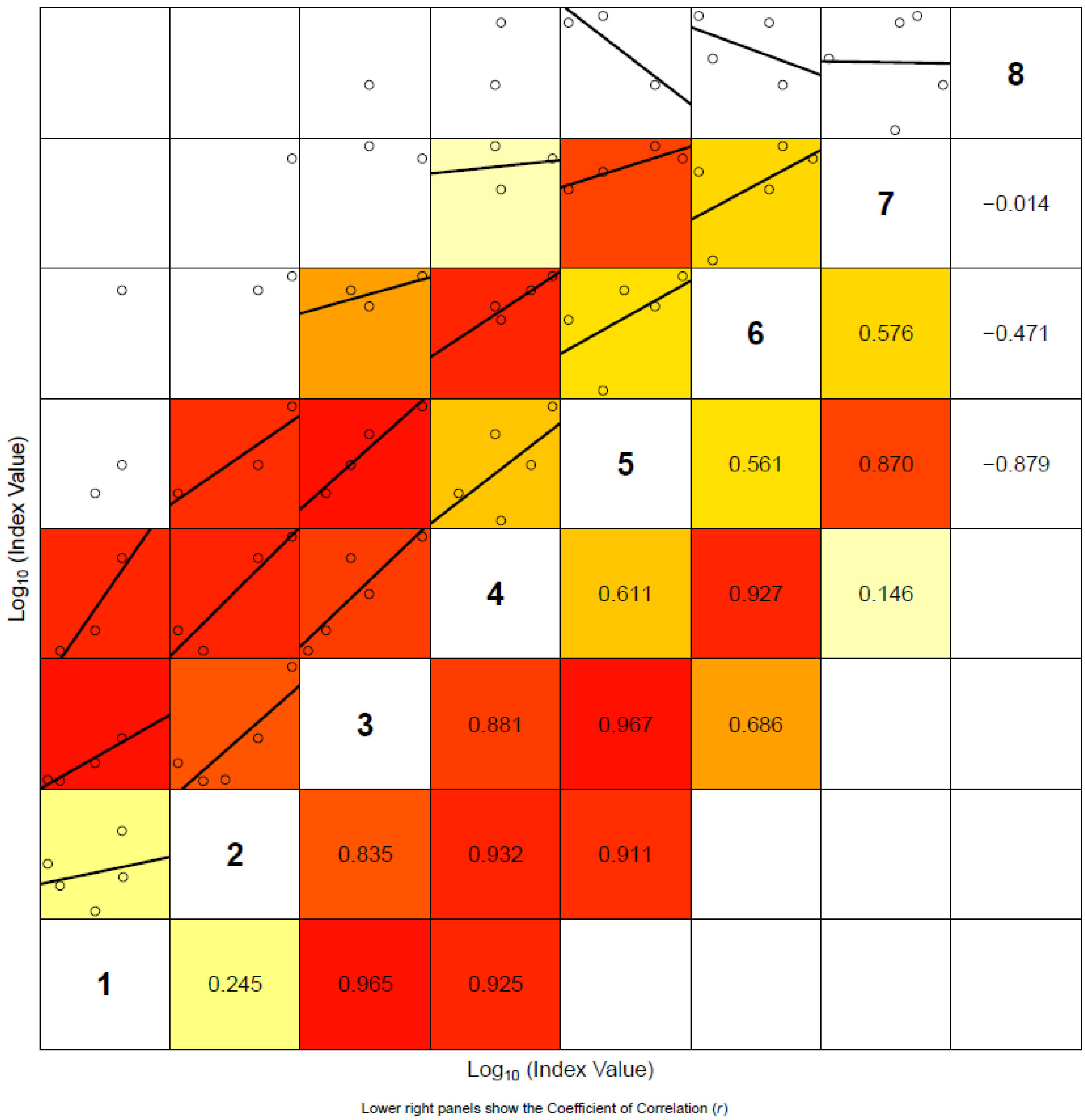


Figure 25. Internal consistency for blue whiting within the IESSNS. The upper left part of the plots shows the relationship between log index-at-age within a cohort. Linear regression line shows the best fit to the log-transformed indices. The lower-right part of the plots shows the correlation coefficient (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 82% of trawl stations across the five vessels (Figure 26) and where lumpfish was caught, 69% of the catches were ≤10kg. Lumpfish was distributed across the entire survey area, from west of Iceland to the central Barents Sea in the northeast part of the covered area.

Abundance was greatest north of 72°N, and lowest directly south of Iceland, and western side of the North Sea and central part of the Norwegian 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 5 to 56 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 bimodal distribution but with a peak around 22-30 cm and another around 35-44 cm. Generally, the mean length and mean weight of the lumpfish was highest in Faroese waters, southern part of Iceland and the coastal waters and along the shelf edges of Norway and lowest in the central and northern Norwegian Sea.

A total of 606 fish (451 by R/V "Árni Friðriksson", 55 by M/V "Eros" and 100 by M/V Vendla) between 7 and 56 cm were tagged during the survey (Figure 28).

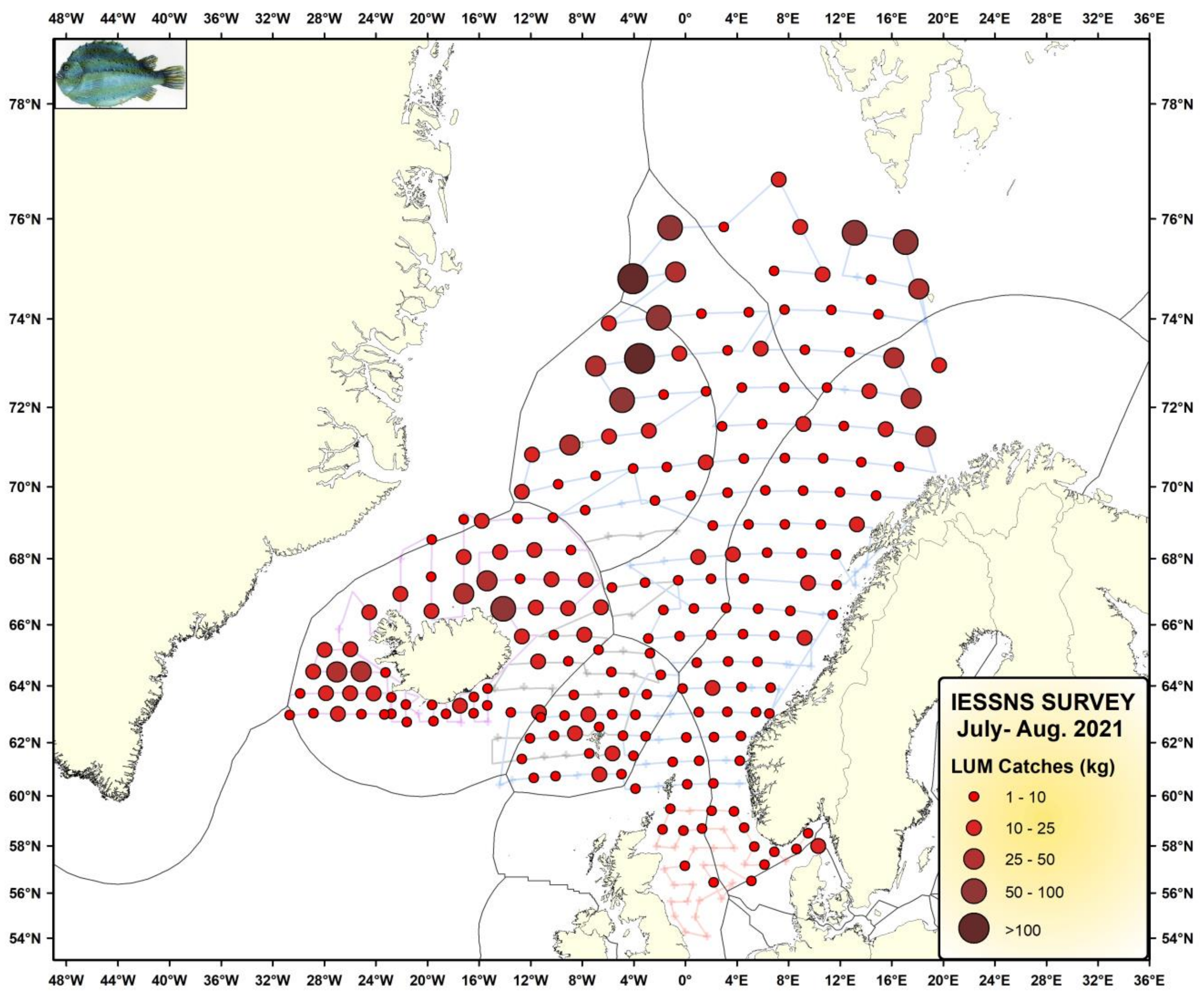


Figure 26. Lumpfish catches at surface trawl stations during IESSNS 2021.

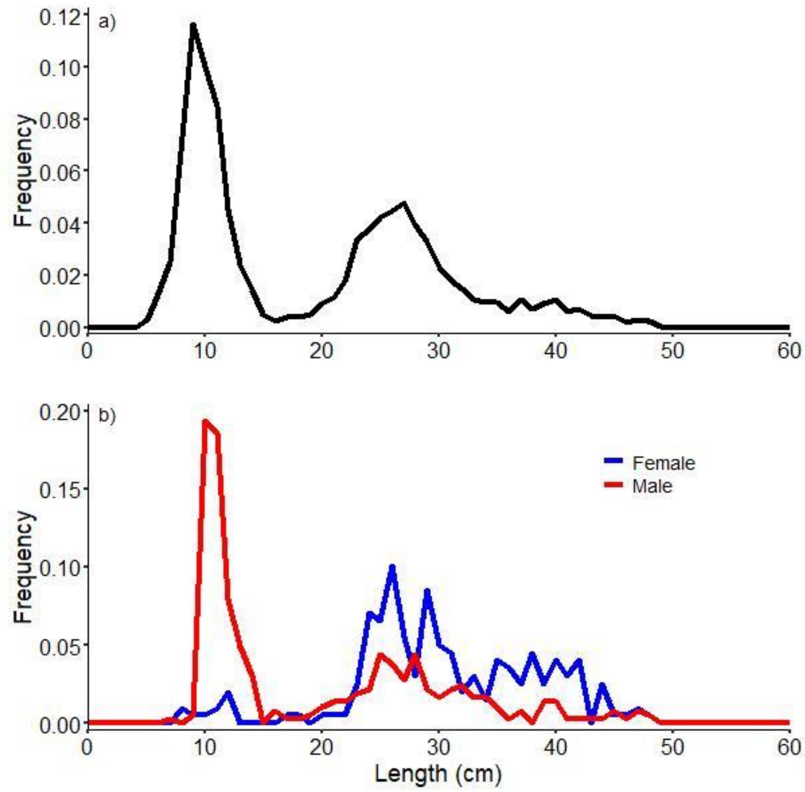


Figure 27. Length distribution of a) all lumpfish caught during the survey and b) length distribution of fish in which sex was determined.

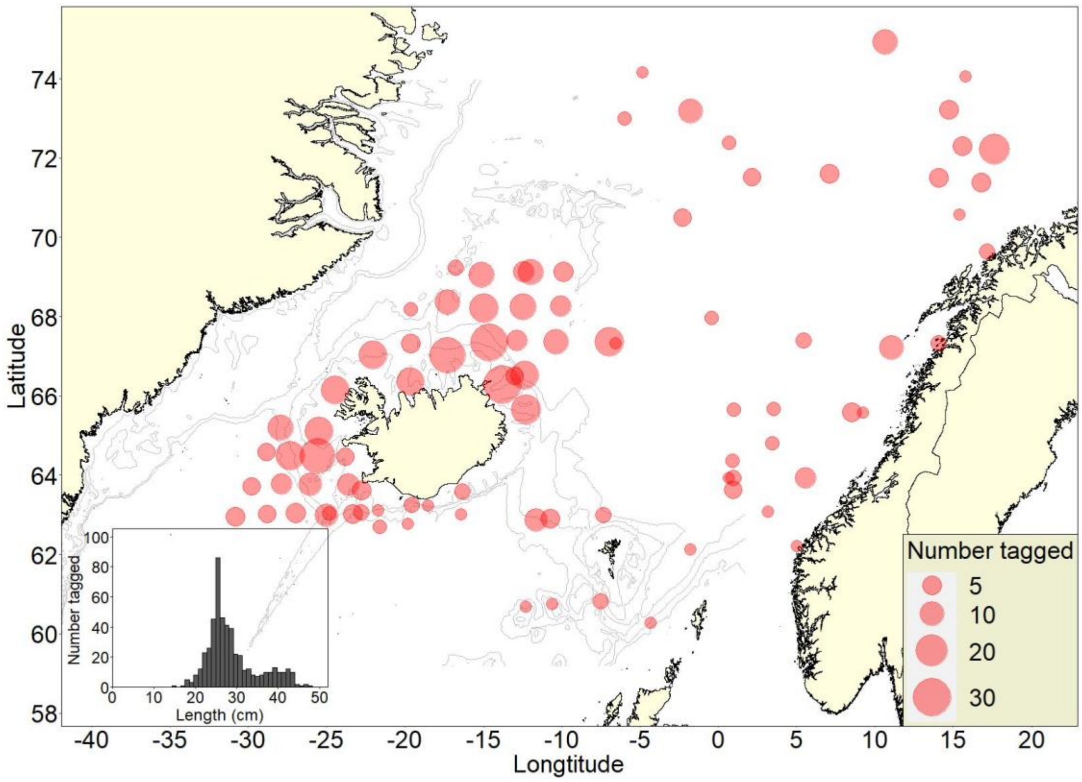


Figure 28. Number tagged, and release location, of lumpfish. Insert shows the length distribution of the tagged fish.

Salmon (*Salmo salar*)

A total of 35 North Atlantic salmon were caught in 25 stations both in coastal and offshore areas from 60°N to 76°N in the upper 30 m of the water column during IESSNS 2020 (Figure 29). The salmon ranged from 0.089 kg to 6.5 kg in weight, dominated by post-smolt weighing 89-425 grams and 1 sea-winter individuals weighing 1.9-2.4 kg. We caught from 1 to 4 salmon during individual surface trawl hauls. The length of the salmon ranged from 21.5 cm to 87 cm, with a pronounced bimodal distribution of <30 cm and >53 cm long salmon. The entire time series on post-smolt distribution, ecology and genetics with many sampled specimens originating from the IESSNS 2007-2020 surveys, have now been included in two new publications (Utne et al. in press, Gilbert et al. 2021)

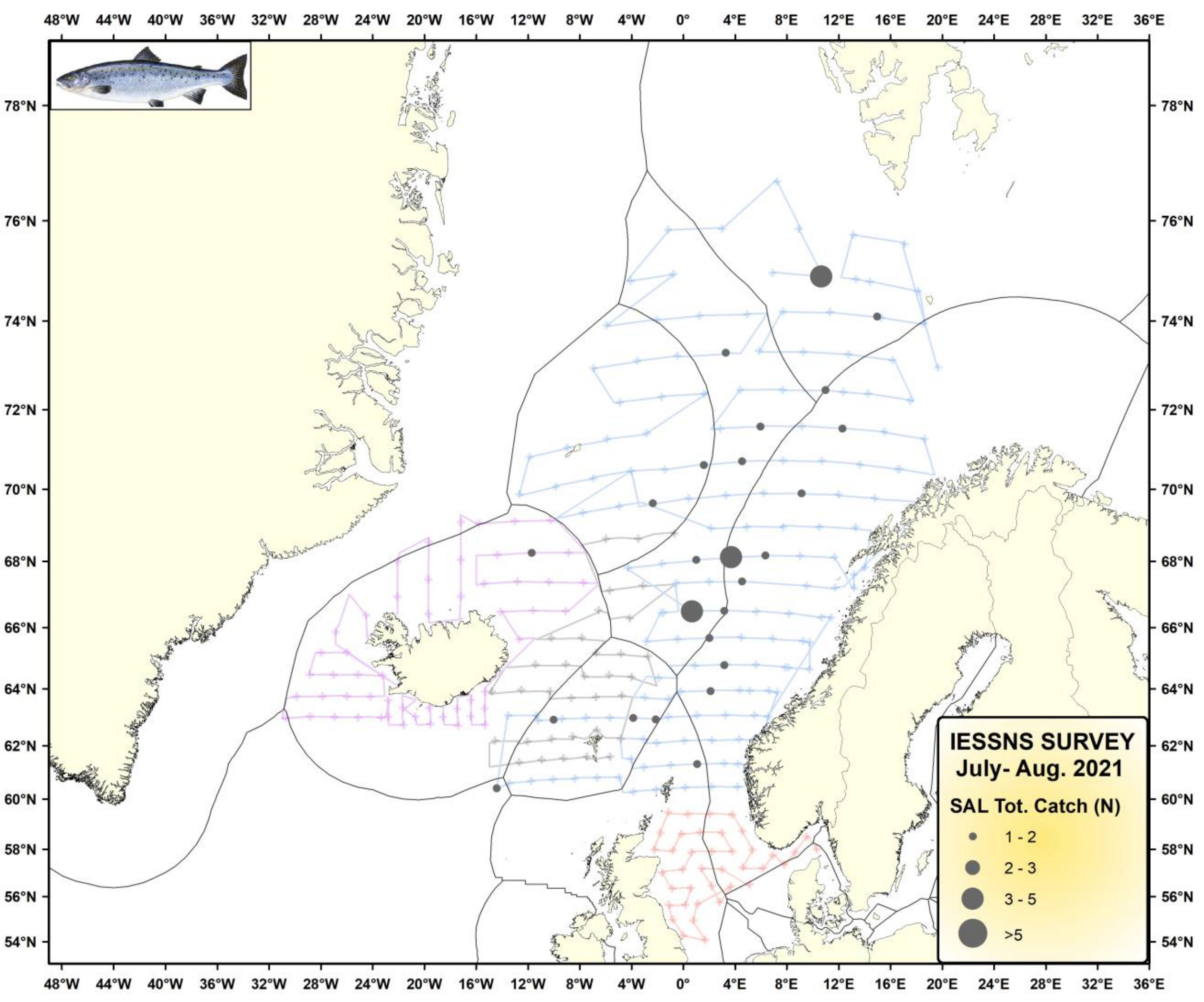


Figure 29. Catches of salmon at surface trawl stations during IESSNS 2021.

Capelin (*Mallotus villosus*)

Capelin was caught in the surface trawl on 12 stations primarily along the cold fronts: Between East Greenland and Iceland, west and North-East of Jan Mayen and at the entrance to the Barents Sea (Figure 30). This was less than in 2020, where 28 hauls contained capelin (plus 14 in the Greenlandic survey). (Figure 30). Large capelin, total length range 13 cm to 19 cm, was caught at three stations north of Iceland, and the catch weight ranged from 23 kg to 240 kg. This is the first time that such large capelin has been caught in the survey as usually juvenile capelin is caught, length < 12 cm.

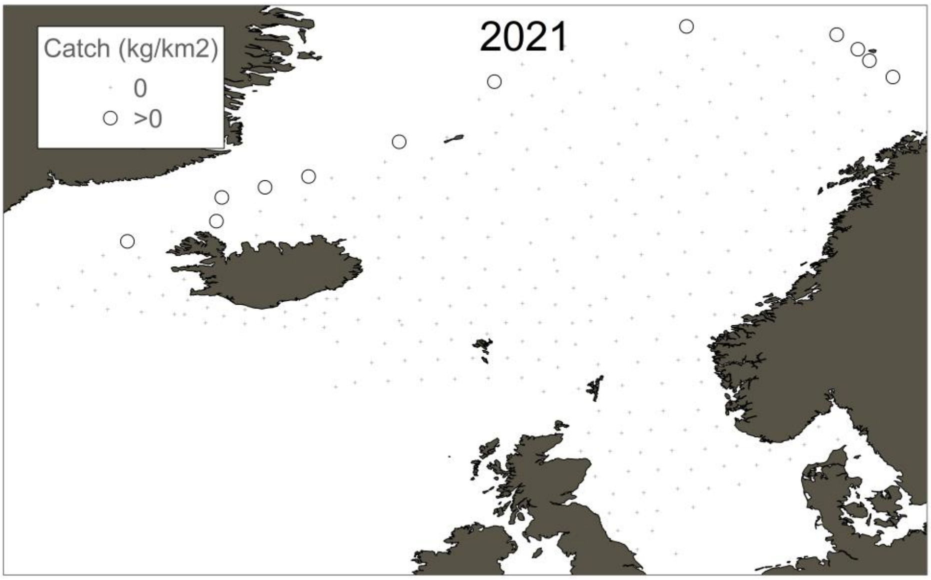


Figure 30. Presence of capelin in surface trawl stations.

4.7 Marine Mammals

Opportunistic whale observations were done by M/V "Eros" and M/V "Vendla" from Norway in addition to R/V "Árni Friðriksson" from Iceland and R/V "Jákup Sverri" from Faroe Islands in 2021 (Figure 31). Overall, 1029 marine mammals of 9 different species were observed, which was an increase from 802 marine mammals observed in 2020, The increase in number of marine mammals observed was primarily because R/V "Jákup Sverri" from Faroe Islands participated with opportunistic whale observations in 2021 and not in previous years. Both Eros and Vendla experienced several days with fog and very reduced visibility in the central and north-western region (Jan Mayen area) and northernmost areas between Bear Island and Svalbard. An increased number of days with low visibility possibly influenced the reduced number of marine mammals observed on Eros and Vendla in the normally abundant marine mammal habitats in the northernmost part of the surveyed area. R/V "Árni Friðriksson" had also occasional periods with fog north and south of Iceland, whereas R/V "Jákup Sverri" experienced primarily good visibility throughout the survey.

The species that were observed included; 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*) and white beaked dolphins (*Lagenorhynchus albirostris*). The dominant number of marine mammal observations were found around Iceland, Faroe Islands and along the continental shelf between the north-eastern part of the Norwegian Sea and in a line between Finnmark to southwest of Svalbard. We observed very few marine mammals in the central part of the Norwegian Sea in July 2021. Fin whales (n = 86, group size = 1-8 (average groups size = 2.2)) and humpback whales (n = 21, group size = 1-4 (average groups size = 1.6)) dominated among the large whale species, and they were present west and northwest of Iceland and from Norwegian coast outside Finnmark stretching north/northwest via Bear Island to southwest of Svalbard. Fin whales also appeared to be present in the northeastern and northern part of the Norwegian Sea feeding where they probably were feeding on the abundant 2016 herring year-class. Very few sperm whales (n = 9, group size =

1-2 (average groups size = 1.1)) where observed. Killer whales (n = 127, group size = 1-30 (average groups size = 6.4)) dominated in the southern, northern and north-eastern part of the Norwegian Sea, partly overlapping and presumably feeding on NEA mackerel in the upper water masses. Pilot whales (n = 559, group size = 2-150 (average groups size = 37.3)) dominated totally in numbers of observations during IESSNS 2021, with more than 50% of all marine mammal observations. They were exclusively observed around Faroe Islands and east of Iceland, with a hot-spot area north of Faroe Islands. White beaked dolphins (n = 162, group size = 3-15 (average groups size = 7.0)) were present in the northern part of the Norwegian Sea. Minke whales (n = 56, group size = 1-9 (average groups size = 1.8)) were distributed over large areas from western coast of Norway to western part of Iceland, and from 60°N to 75°N, including overlapping and likely feeding on NSS herring in the upper 40 m of the water column. There is now available a new publication summarizing the main results on marine mammals from the IESSNS surveys from 2013 to 2018, with major focus on hot spot areas of fin whales and humpback whales from 2013 to 2018 (Løviknes et al. 2021)

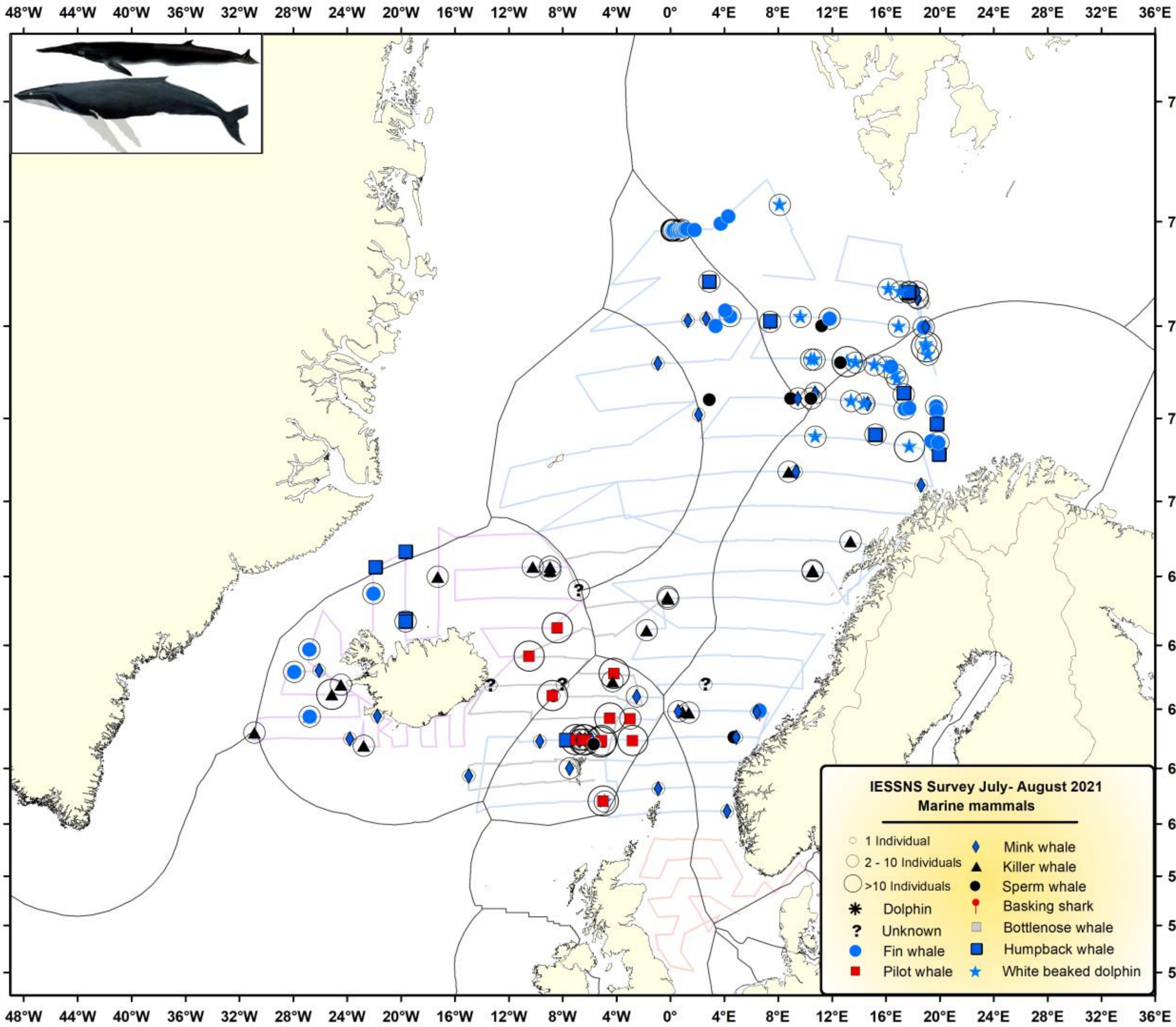


Figure 31. Overview of all marine mammals sighted during IESSNS 2021.

5 Recommendations

The group suggested the following recommendation from WGIPS	To whom
The occasional large catches of mackerel have a relatively large impact on the overall results and possibly bias the stock indices. WGIPS recommends that the ability of the present and alternative methods (such as more advanced statistical models) to represent this overdispersion is evaluated.	National institutes and WGISDAA
The surveys conducted by Denmark in 2018, 2019, 2020 and 2021 have clearly demonstrated that the IESSNS methodology works also for the northern North Sea (i.e. north and west from Doggerbank) and the Skagerrak area deeper than 50 m. The survey provides essential fishery-independent information on the stock during its feeding migration in summer and WGIPS recommends that the Danish survey should continue as a regular annual survey.	WGWIDE, RCG NANSEA
In 2022 the IESSNS survey in the North Sea have been conducted for five consecutive years (2018-2022). It is recommended that a comprehensive report is written about the major results from the NEA mackerel time series from the IESSNS surveys in the North Sea, where the internal consistency between years in the survey for selected age groups is also evaluated. A major aim will be to at some stage evaluate and consider the possibility to include and implement the IESSNS survey in the North Sea as an abundance index used in ICES for NEA mackerel.	

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.
We recommend continuing the international tagging of lumpfish for two new year's; 2022 and 2023, and we encourage all participating country to contribute.
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 slightly change the both the strata system and transect system to accommodate better the curvature of the long east-west transects to avoid empty areas in the overall spatial coverage.
For next year's survey, the group should consider distributing transects differently among vessels, such that synoptic coverage becomes even better than this year and survey time is optimally used.

7 Survey participants

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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. No problems applying the IESSNS methods were encountered. Area coverage, however, was restricted to the northern part of the North Sea at water depths larger 50 m. No plankton samples were taken, and no acoustic data were recorded because this is covered by the HERAS survey in June/July in this area.

In 2021, 39 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 2021 amounted 2429 kg/km^2, which was considerably higher than in the previous years (2020: 1318 kg/km^2, 2019: 1009 kg/km^2, 2018: 1743 kg/km^2). 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 (version 2.7) baseline estimate of mackerel abundance in the North Sea was 560 198 tonnes (Table A1-1). This is based on a preliminary defined polygon for the surveyed area in which the northern border was set to 60°N (border to stratum 1; Fig. 2), and the eastern, southern and western limits were either the coastline or extrapolated using half the longitudinal or latitudinal distance between the adjacent stations.

Table A1-1. StoX (version 2.7) baseline estimate of age segregated and length segregated mackerel index for the North Sea in 2021. Also provided is average length and weight per age class.

Length bin (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Number (thousand)	Biomass (ton)	Mean Weight (g)
18-19	85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	85	4.3	50
19-20	403	-	-	-	-	-	-	-	-	-	-	-	-	-	-	403	17.5	43.37
20-21	9604	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9604	637.2	66.35
21-22	25212	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25212	1979.4	78.51
22-23	176284	-	-	-	-	-	-	-	-	-	-	-	-	-	-	176284	15888.7	90.13
23-24	349744	-	-	-	-	-	-	-	-	-	-	-	-	-	-	349744	35918.1	102.7
24-25	301762	-	-	-	-	-	-	-	-	-	-	-	-	-	-	301762	34876.6	115.58
25-26	120019	1780	-	-	-	-	-	-	-	-	-	-	-	-	-	121800	15346.9	126
26-27	42253	8853	-	-	-	-	-	-	-	-	-	-	-	-	-	51107	7816	152.93
27-28	91118	42581	-	-	-	-	-	-	-	-	-	-	-	-	-	133699	24132.3	180.5
28-29	384792	157557	-	-	-	-	-	-	-	-	-	-	-	-	-	542349	108574.4	200.19
29-30	312039	148579	1624	1624	-	-	-	-	-	-	-	-	-	-	-	463866	99842.9	215.24
30-31	83197	75339	1584	556	812	-	-	-	-	-	-	-	-	-	-	161488	39089.4	242.06
31-32	5225	64241	5172	2804	781	-	-	-	-	-	-	-	-	-	-	78224	20794.3	265.83
32-33	-	72348	14581	4014	36	283	-	-	-	-	-	-	-	-	-	91262	26475.4	290.1
33-34	-	21964	25330	24418	242	72	-	-	255	-	-	-	-	-	-	72281	22558.5	312.1
34-35	-	5047	27231	35559	17920	2371	1346	255	-	-	-	-	-	-	-	89729	30551.4	340.49
35-36	-	526	-	25732	30513	9483	1088	-	490	-	-	406	-	-	-	68238	25902	379.58
36-37	-	-	-	13000	12936	25200	3039	-	3104	191	-	1413	-	-	-	58885	23118.2	392.6
37-38	-	-	-	1776	2502	11611	10330	1698	122	36	590	1561	-	-	-	30226	12833.9	424.6
38-39	-	-	-	-	-	1557	2113	7946	796	813	648	363	-	-	-	14236	6320.4	443.96
39-40	-	-	-	-	-	-	243	1373	4579	382	-	543	346	-	-	7466	3841.3	514.54
40-41	-	-	-	-	-	-	-	609	281	292	100	109	-	36	-	1425	815.7	572.3
41-42	-	-	-	-	-	-	-	-	373	4171	-	-	324	-	-	4867	2545.5	522.99
42-43	-	-	-	-	-	-	-	36	-	-	-	36	-	-	-	72	51.4	714
43-44	-	-	-	-	-	-	-	-	-	-	-	-	260	36	-	296	221.9	749.27
44-45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45-46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	64	64	44.5	700
TSN(1000)	1901737	598817	75522	109484	65742	50577	18160	11916	9999	5884	1337	4431	930	72	64	2854671	-	-
TSB(1000kg)	291990.5	139041.2	23664.1	37357.4	24174	20502.6	7260.4	5400.4	4774.7	2986.7	563	1850	540.1	48.3	44.5	-	560197.9	-
Mean length (cm)	25.73	29.44	32.88	34.05	34.88	35.98	36.63	38	37.72	40.22	37.71	36.94	40.81	41.5	45	-	-	-
Mean weight (g)	153.54	232.19	313.34	341.21	367.71	405.38	399.8	453.21	477.52	507.57	421.06	417.5	580.52	672	700	-	-	196.24

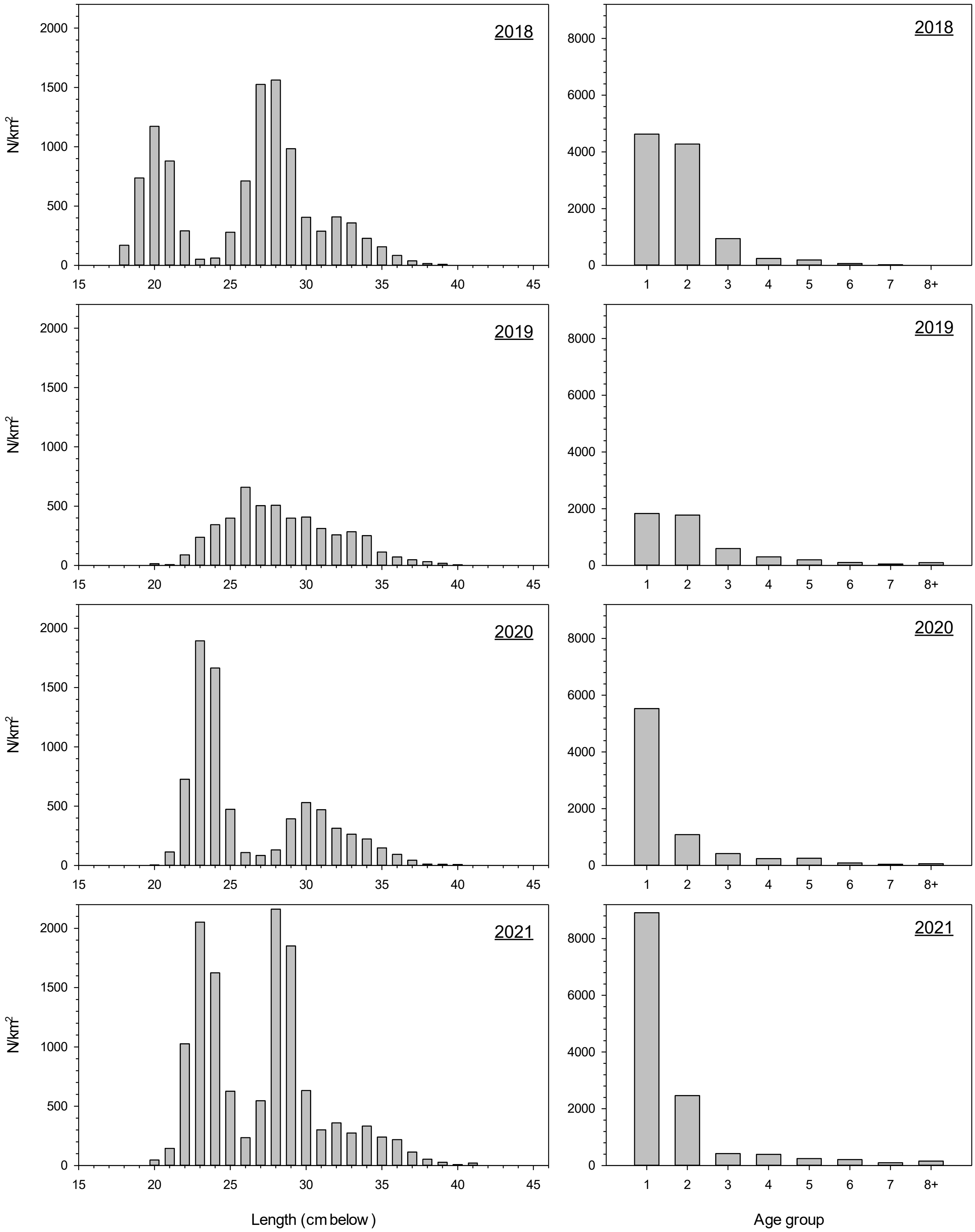

Fig. A1. Comparison of length and age distribution of mackerel in the North Sea 2018, 2019, 2020 and 2021.

2 Appendix 2:

The mackerel index is calculated on all valid surface stations. That means, that invalid and potential extra surface stations and deeper stations need to be excluded. Below is the exclusion list used when calculating the mackerel abundance index for IESSNS 2021.

Table A2-1: Trawl station exclusion list and average horizontal trawl opening per vessel for IESSNS 2021 for calculating the mackerel abundance index.

Vessel	Country	Horizontal trawl opening (m)	Exclusion list	
			Cruise	Stations
Vendla	Norway	63.8	2021816	58,61,62,66,69,71,74,75,80,81,83,87,89,93,98,100, 105,111,122,132,142,146
Eros	Norway	67.5	2021817	32,43,51,61,62,67,69,70,71,73
Árni Friðriksson	Iceland	65.6	A12-2021	298,318,325,333,337,340,343,349,351,357
Jákup Sverri	Faroe Islands	56.6	2130	13,14,27,34,53,68,73 *
Ceton	EU (Denmark)	75.4	IESSNS2021	none

* Observe that in PGNAPES and the national database station numbers are 4-digit numbers preceded by 2130 (e.g. ‘21300025’)

Annex 7: 2021 GERAS Survey Summary Table and Survey Report

Document 7a: GERAS 2021 survey summary table

Survey Summary Table WGIPS 2022	
Name of the survey (abbreviation):	GERAS / BIAS (GER) (FRV "Solea" SB798)
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:	08-28 Oct 2021
Summary:	
The objectives of the survey were carried out successfully and mostly as planned in all of the covered ICES Subdivisions. Altogether, 1124 nautical miles of hydroacoustic transects (plus 67 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 50 fishery hauls were conducted. Vertical hydrography profiles were measured on 90 stations. In all subdivisions covered, mean NASC values per nautical mile per ICES statistical rectangle were equally either distinctly lower or distinctly higher than the values measured in 2020. However, compared to the long-time survey mean since 1991, mean NASC values were lower in all but two rectangles covered. On ICES subdivision scale, mean NASC values were overall distinctly lower than in the previous year in subdivisions 21 and 22, slightly increased in SD 24 and almost fivefold increased in SD 23 (high NASC values in SD 23 could not be allocated to WBSSH however). After excluding the Central Baltic Herring fraction from the estimates via the Separation Function, the present Western Spring Spawning Herring biomass estimate again 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, 22, 24). 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.

	2021 survey: Due to adverse weather conditions, the survey area was not fully covered as planned (The two northernmost statistical rectangles in SD 21 were not covered). However, the standard area of the GERAS-Index for HAWG was covered.
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). 2021 survey: The application of the Separation Function (SF) to remove CBH from the index calculation again yielded robust results despite the “contamination” of WBSSH baseline samples with CBH in ICES SD 21 and SD 23. The majority of WBSSH could be allocated to the corresponding stock using the SF established with parameters from 2005-2010 (Gröhsler & Schaber, 2022 WD WGIPS). 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. A conspicuous peak of abundance of mostly 2-4 years old herring that otherwise could not be explained vanished after removing the CBH fraction. Haul 32 (41G2, SD 23) targeting a large aggregation of herring yielded a substantial sample of almost exclusively large, old herring that were spawning (maturity 6). Since the herring could not be allocated to WBSSH, both the hydroacoustic data from that aggregation as well as the biological data from haul 32 were removed from the further analysis for producing a biomass and abundance estimate for WBSSH. Genetic samples have been taken and are currently being analysed to identify stock origin of that herring.
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. 2021 survey: Biological information for ICES statistical rectangles 41G0 (SD 21), 40G1 (SD 22), 39G2, 41G2 (SD 23) and 37G4 (SD 24) used/amended from neighbouring rectangles.
Were any concerns raised during the meeting regarding the fitness of the survey for use in the	*To be answered by Assessment Working Group*

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 7b: GERAS 2021 survey report

*Please find report on the next page.

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Survey Report FRV "Solea" SB798

German Acoustic Autumn Survey (GERAS)

08 – 28 October 2021

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 on 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 34th 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. It 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 in the Western Baltic area (Kattegat/Subdivision 21 and Subdivisions 22, 23 and 24) and sprat in the Baltic area (Subdivisions 22-32).

The following objectives were planned for SB798:

- 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 mostly as planned in all of the covered ICES Subdivisions.

Altogether, 1124 nautical miles of hydroacoustic transects (plus 67 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 50 fishery hauls were conducted. Vertical hydrography profiles were measured on 90 stations.

In all subdivisions covered, mean NASC values per nautical mile per ICES statistical rectangle were equally either distinctly lower or distinctly higher than the values measured in 2020. However, compared to the long-time survey mean since 1991, mean NASC values were lower in all but two rectangles covered. On ICES subdivision scale, mean NASC values were overall distinctly lower than in the previous year in subdivisions 21 and 22, slightly increased in SD 24 and almost fivefold increased in SD 23 (note that the increase in SD 23 originated from large aggregations of herring that did not contribute to the WBSSH index estimate).

2. SURVEY DESCRIPTION & METHODS APPLIED

2.1 Cruise narrative

The 798th cruise of FRV “Solea” represents the 34th subsequent GERAS survey. Generally, survey operations during the GERAS/BIAS are conducted during nighttime to account for a more pelagic distribution of clupeids at that time. Equipment of the vessel as well as calibration of echosounders took place on October 8th. After leaving Rostock port, the survey commenced in ICES SD24 (Arkona Sea) on October 9th. Due to deteriorating weather and sea state, survey operations had to be interrupted for one day on October 11th, and parts of a transect in that SD had to be repeated after weather conditions had improved. After accomplishing the southern transects in SD24, the survey continued in SD22 (Mecklenburg Bight) from October 13th. On October 14th, due to again deteriorating weather conditions, the survey had to be interrupted in the Kiel Bight. FRV "Solea" steamed into Kiel port, where an exchange of scientific crew members took place. In the evening of October 15th, the survey commenced from the position where the interruption had occurred. Subdivision 22 was accomplished in the early morning of October 19th. Due to the weather forecast indicating deteriorating conditions in SD 24 the survey continued in the comparatively sheltered SD 23 (the Sound), and this subdivision was accomplished in the morning of October 20th. In the evening of that day, the survey continued in still inclement but workable conditions in the southern Kattegat (SD 21). With the weather deteriorating, survey operations had to be interrupted for another 2 days.

Since conditions in the Kattegat only improved slowly but seemed acceptable in SD 24, it was decided to steam south and accomplish the two missing transects in SD 24 (Arkona Sea) on October 23rd and 24th. Afterwards, the remaining transects in SD 21 were covered. However, the previous loss of survey time due to several days of inclement weather required shortening of the transects and omitting the two northernmost statistical rectangles in SD 21. In the early morning of October 26th, survey operations were accomplished and FRV "Solea" returned to Rostock harbor, where the survey ended on October 28th.

Altogether, the following survey schedule was accomplished:

Arkona Sea	(SD 24)	09. - 12.10. & 23.-24.10.
Belt Sea	(SD 22)	13. - 18.10.
Sound	(SD 23)	19. - 20.10.
Kattegat	(SD 21)	20. 10. & 25. - 26.10.

Total survey time	18 nights (incl. 3.5 days loss due to bad weather)
Fishery hauls	50
CTD-casts	90
Hydroacoustic transects	1124 nmi (+ 67 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 realized cruise track length was 1124 nautical miles (2020: 1204 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 12 software (Echoview Software Pty Ltd, 2021). 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 acceptable weather conditions from a drifting vessel in the Mecklenburg Bight (54°12.5 N, 11°45.7 E) on October 8th. Overall calibration results were considered good based on calculated RMS values. 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 50 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, 90 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 –if applicable- 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 required 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 and 2021 support the applicability of the SF (Oeberst et al., 2013; Oeberst et al., 2014, 2015, 2016, 2017; Gröhsler and Schaber, 2018, 2019, 2021, 2022).

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 2021. In general, the majority of these NASC measurements can be allocated to clupeids. Altogether, 25 ICES statistical rectangles were covered in the survey 2021 (27 in 2020). In 10 of those, the mean NASC was higher than in 2020 (partly significantly), in three rectangles the mean NASC was in the range of 2020. In the 12 other rectangles, mean NASC values were partly well below the already low values measured in 2020. In all but one rectangles, the mean NASC measured in 2021 was below the long term survey mean (1991-2020). On ICES subdivision scale, mean NASC values were distinctly lower than in the previous year in SD 21 and SD 22, but slightly higher in SD 24 - and significantly higher in SD 23 (the Sound).

In the rectangles of SD 21 covered both in 2021 and 2020, overall NASC values measured were lower than those measured in the previous year along the Swedish coast of the Kattegat (41G2, 42G2). In the central and southern Kattegat (42G1, 41G1, 41G0), the mean NASC per 1 nmi EDSU measured was higher or similar to the values measured in the previous year. As in before, aggregations were mostly patchy along the cruisetrack.

In SD 22, the mean overall NASC values recorded were lower than in the previous year in 5 out of 11 rectangles surveyed. In the southern parts of that subdivision (rectangles 37G0 and 37G1) as well as in areas north of the Belt Sea adjacent to the Kattegat (40F9, 40G1, 41G0) mean NASC was higher than in 2020, but at generally low values measured.

As in the previous years, the large aggregations of big herring that usually could be observed in the inner Sound area of SD 23 were not present in autumn 2021 to the extent observed prior to 2016. NASC values in rectangles 39G2 and 40G2 were again below the survey mean and also lower than the - slightly increased- values measured in 2020. In rectangle 41G2 however, the mean NASC measured was about 70-fold higher compared to the measurements made in 2020. This was, however, based on the detection of one massive school of fishes located at the narrow isthmus in the northern Sound in an otherwise rather "empty" rectangle. Since that school consisted of spawning herring and accordingly did not yield a NASC value considered valid for providing an WBSSH estimate, the corresponding NASC was omitted from further analyses (see below).

In SD 24, mean NASC values were comparable (1) or distinctly lower (4) than the levels measured in 2020 in 5 out of 9 rectangles. Increased NASC was measured in southern coastal areas and east of Rügen Island (37G2, 37G3) as well as in the southwestern (38G2) and southeastern Arkona Sea bordering the Bornholm Basin (38G4). As in the years before, somewhat notable aggregations were detected around Rügen Island.

3.2 Biological data (T. Gröhsler)

Fishery hauls according to ICES Subdivision (Figure 1):

SD	Hauls (n)
21	10
22	18
23	3
24	19

Altogether, 1 215 individual herring, 727 sprat, 400 European anchovies and 16 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, 29 different species were recorded. Herring were caught in 41, sprat in 40 hauls. SD 23 showed the highest mean herring catch rate per station (kg 0.5 h^{-1}) in the data series since 2002. However, this high mean value was only caused by one haul with exceptional large herring catches in the northern part of the Sound (Haul 32). Anchovy (*Engraulis encrasicolus*), which were present last year in the whole survey area, were not caught in SD 23 in 2021 but dominated catches in other parts of the survey area (SD 22). Sardines (*Sardina pilchardus*) appeared in catches from SD 21 and SD 22, whereas they were only caught in SD 21 in 2020.

Altogether, the following fish species were sampled and processed:

Species	Length measurements (n)	Prevalence (n of hauls)
Aphia minuta	390	17
Belone belone	6	5
Clupea harengus	5,628	41
Engraulis encrasicolus	3,862	37
Gadus morhua	68	23
Gasterosteus aculeatus	1,296	35
Limanda limanda	15	8
Platichthys flesus	22	12
Pleuronectes platessa	12	12
Pomatoschistus minutus	295	18
Sardina pilchardus	16	4
Scomber scombrus	291	16
Sprattus sprattus	4,421	40
Trachinus draco	297	15
Trachurus trachurus	118	27
Others	80	-

Figures 3 and 4 show relative length-frequency distributions of herring and sprat in ICES subdivisions 21, 22, 23 and 24 for the years 2020 and 2021. Compared to results from the previous survey in 2020, the following conclusions for **herring** can be drawn (Figure 4):

- In 2021 catches in SD 21 were dominated by herring larger 15 cm with a mode at 18.75 cm and some minor contribution of the incoming year class (ca. ≤15 cm). This is in contrast to the results in 2020, which were dominated by the incoming year class (ca. ≤15 cm) with a mode at 13.75 cm and a minor contribution of larger herring (>15 cm).
- Catches in SD 22, which were dominated by larger herring >15 cm in 2020 with a mode at 22.25-22.75 cm, were in 2021 dominated by the incoming year class (ca. ≤15 cm) with a mode at 11.25-12.75 cm.
- In SD 23 the contribution of herring larger 20 cm increased in 2021 compared to 2020. Catches in 2020 showed a mode at 19.25 cm, in 2021 at 26.25 cm.
- In 2020 catches in SD 24 showed a bimodal distribution with modes at 13.25-14.25 cm and 17.75-18.75 cm, whereas catches in 2021 were characterized by a trimodal distribution with

modes at 9.25 cm, 13.25-14.25 cm and 17,25 cm. Both in 2021 as well as in the previous survey, herring larger than ca. 25 cm were almost absent.

Relative length-frequency distributions of **sprat** in the years 2020 and 2021 (Figure 5) can be characterized as follows:

- In SD 21 the incoming year class (ca. ≤10 cm) was virtually absent from catches in 2021, whereas some contribution of this year class had been observed in in 2020. The catches in 2021 were dominated by the contribution of larger sprat (mode at 14.25 cm) compared to 2020 (mode at 11.25 cm).
- Catches in SD 22 show a tri-modal distribution with a contribution of the incoming year class (ca. ≤10 cm, mode at 9.75 cm) as well as of larger sprat (>10 cm, modes at 11.25 cm and at 13.25 cm, respectively). This is contrast to the results of 2020, when catches showed a bimodal distribution with a contribution of 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 incoming year class (ca. ≤10 cm) was almost absent from the catches, as also had been observed in the previous year. In both years the catches were dominated by larger sprat (>10 cm) with modes at 11.75 cm (2020) and 13.25-14.25 cm (2021).
- While catches in SD 24 had been dominated almost exclusively by larger sprat (>10 cm, mode at 11,75 cm) in 2020, a bimodal distribution with a higher contribution of the incoming year class (ca. ≤10 cm, mode at 8.75 cm) and lower contribution of larger older sprat (>10 cm, mode at 12.75 cm) was observed in 2021 in this subdivision.
- Altogether, the present contribution of the incoming year class (ca. ≤10 cm) seemed to be as low as in 2020.

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

<u>Fish species considered:</u>

Herring	(*Clupea harengus*)
Transparent goby	(*Aphia minuta*)
European anchovy	(*Engraulis encrasicolus*)
Cod	(*Gadus morhua*)
Three-spined stickleback	(*Gasterosteus aculeatus*)
Whiting	(*Merlangius merlangus*)
Sand goby	(*Pomatoschistus minutus*)
Mackerel	(*Scomber scombrus*)
Sprat	(*Sprattus sprattus*)
Greater weever	(*Trachinus draco*)

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

Haul No.	Rectangle	Subdivision (SD)
4	38G4	24
12, 13	37G1	22
24	40G0	22
31	40G2	23
34	41G1	21
36	39G3	24
39	39G4	24
46	42G1	21
48	42G2	21
50	41G2	21

<u>Exclusion of trawl hauls due to other reasons:</u>

Haul 32 (SD 23, 41G2) was removed from the analysis, since it consisted almost exclusively of large, old herring that all were spawning at the time of capture (maturity 6). Since it can be assumed that these herring were not WBSSH, the biological data (i.e. that haul) was removed from further analyses, as had the corresponding NASC data (see above).

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	22
2, 10, 11	38G2	22
15	38G1	22
16, 18, 19, 29	38G0	22
17	37G0	22
20	39F9	22
23	41G0	22
26, 27	39G0	22
28	39G1	22
21	40F9	22
22, 25	40G0	22
33	41G1	21
38	39G4	24
43	41G1	21
45, 49	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
37G4/24	6, 7	37G3/24, 38G4/24
40G1/22	25	40G0/22
41G0/21	33	41G1/21
39G2/23	35, 42	39G2/24
41G2/23	30	40G2/23

3.3 Stock Splitting / Application of the Separation Function (SF)

The age-length distribution of herring in SD 21, SD 22 and in SD 23 in 2021 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 and SD 22 in 2021.

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 2021. 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, 2022).

3.4 Biomass and abundance estimates

The total abundance of herring and sprat per ICES statistical rectangle and Subdivision is presented in Table 6. Estimated numbers of herring and sprat by age group and SD/rectangle are given in Tables 7 and 10, respectively. Corresponding mean weights by age group and SD/rectangle are provided in

Tables 8 and 11. Estimates of herring and sprat biomass by age group and SD/rectangle are summarized in Tables 9 and 12.

3.4.1 Herring incl. Central Baltic Herring (CBH)

The total herring stock in Subdivisions 21-24 was estimated to be 2.0 x 10^9 fish (Table 7) or 68.8 x 10^3 tons (Table 9). For the included area of Subdivisions 22-24 the number of herring was calculated at be 1.9 x 10^9 fish or 63.5 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	23(39G2) & 24	21, 22, 23 (39G2), 24
SDs 21-24	2 007.4	877.6	870.4
Percentage of Total	100.0%	43.7%	43.4%
Difference		-56.3%	-56.6%
Biomass (t)	Total	excluding CBH in SD:	
	incl. CBH	23(39G2) & 24	21, 22, 23 (39G2), 24
SDs 21-24	68 812.8	31 324	31 102
Percentage of Total	100.0%	45.5%	45.2%
Difference		-54.5%	-54.8%

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 2021 also resulted in biomass reductions of 53 % with corresponding reductions in numbers of 55 % (2020: - 37 % and -27 %, 2019: -36 % and - 24 %, 2018: -20 % and -11 %, respectively (Figure 6).

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

3.4.3 Sprat

The estimated sprat stock in Subdivisions 21-24 was 1.9 x 10^9 fish (Table 10) or 22.5 x 10^3 tons (Table 12). For the included area of Subdivisions 22-24 the number of sprat was calculated at 1.7 x 10^9 fish or 19.8 x 10^3 tons. The overall abundance estimate in 2021 was dominated by two year old sprat (Figure 5 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, 90 CTD casts were conducted during this survey (Figure 8).

Surface temperatures were lower than in the previous year ranging from ca. 11°C in the central Kattegat area (SD 21) to > 14°C in the southern Mecklenburg Bight (SD 22) and eastern Arkona Basin (SD 24). In general, surface temperatures were higher in the southern part of the survey area. 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 (< 7°C) and the deep parts of the Sound and the Kattegat (ca. 10.5°C) but distinctly higher in the shallower areas of SD 21-24. Also in the central and eastern parts of the Arkona Sea (SD 24), bottom temperatures were relatively high at > 14 °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 > 29 PSU in the Kattegat). Surface salinities in the western parts of the survey area were higher than the values recorded in the previous years and exceeded 15 PSU south of the Belt Sea. Salinity near the seafloor ranged from 9 PSU in the Arkona Sea to ca. 34 PSU in the deep parts of the Kattegat. Especially in the Sound (SD 23), a very strong stratification with steep salinity gradients was again observed.

Surface waters were well oxygenated throughout the survey area. In contrast, pronounced oxygen depletion was measured in the inner Mecklenburg Bight (SD 22) and the western SD 22 area of the southern Little Belt. In those regions, lowest oxygen concentrations measured near the seafloor were below 0.5 ml/l and occasionally in in the anoxic range.

4. DISCUSSION

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

Herring (incl. CBH)	Difference compared to 2020	
Area	Numbers (%)	Biomass (%)
Subdivisions 21-24	-6	+3

The present results **incl. CBH** are mainly driven by a far lower contribution of the 0-group (-58 % in numbers and -63 % in biomass), together with far higher contributions of 2-4 years old herring (+136 % in numbers and +83 % in biomass).

The present estimates of herring **excl. CBH** compared to 2020 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 2020	
Area	Numbers (%)	Biomass (%)
Subdivisions 21-24	-41	-21

The low number of 0-group herring together with the exclusion of a large part of 2-7 years old CBH in the main mixing area of SD 24 (by applying SF) lead to the overall significant decrease in stock biomass and abundance values (**excl. CBH**) compared to 2020.

The application of the Separation Function (SF) to remove CBH from the index calculation again yielded robust results despite the “contamination” of WBSSH baseline samples with CBH in ICES SD 21 and SD 23 (Gröhsler & Schaber, 2022 WD). Estimates of parameters of the Bertalanffy-Growth-Function (BGF) in 2021 showed a decreasing trend compared to the period 2005-2010 which can be explained by a distinctly lower contribution of older/larger herring in 2021 together with some contributions of CBH in the baseline sample. However, the majority of WBSSH could be allocated to the corresponding stock using the SF established with BGF parameters from 2005-2010. Again, 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 mostly 2-4 years old herring that otherwise could not be explained vanished after removing the CBH fraction.

After over 6 years of consecutive decline, the present Western Spring Spawning Herring biomass estimate (HAWG-GERAS Index) again 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 2021, the second year after 2020 and 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 since 2016 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, 2021) supports this assumption. Methodological biases leading to presence or absence of 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. An 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 2021 some 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.

In the "isthmus" of the Sound between Helsingör and Helsingborg, a large school of fish was recorded on the echosounder along a ridge in less than 20 m depth. A similar but much smaller aggregation of fishes had been recorded at the same position in the previous year. Due to navigational constraints as well as the difficult bathymetry, no targeted trawl haul could be conducted on this aggregation before. In 2021, due to the large size of the school and the significant contribution to the overall NASC measured in the rectangle and the whole Subdivision 23, it was attempted to collect a trawl sample from that school. The catch (Haul 32) yielded a large amount of large herring that were all spawning (maturity 6). It can be assumed that the herring sampled were no WBSSH but possibly originated from an autumn spawning stock component (Western Baltic Autumn Spawning Herring, WBASH or immigrated North Sea Autumn Spawning Herring, NSASH). Accordingly, both the biological samples and the hydroacoustic records originating from that school of spawning herring were removed from the further analysis of survey indices for WBSSH. Genetic analyses on the origin of these herring are currently ongoing.

5. SURVEY PARTICIPANTS

Name	Function	Institute
Dr. M. Schaber (15.-28.10.)	Cruise Leader (Hydroacoustics, Hydrography)	TI-SF
L. Hartkens	Cruise Leader (Hydroacoustics, Hydrography)	TI-SF
M. Koth	Fishery biology	TI-OF
L. Schmidt (8.-15.10.)	Fishery biology	TI-OF
S. Winning (8.-15.10.)	Fishery biology	TI-SF
A. Finke (15.-28.10.)	Fishery biology	TI-OF
P. Christiansen (8.-15.10.)	Fishery biology	DTU-Aqua (DK)
N. Kolding (15.-28.10.)	Fishery biology	DTU-Aqua (DK)

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7. FIGURES

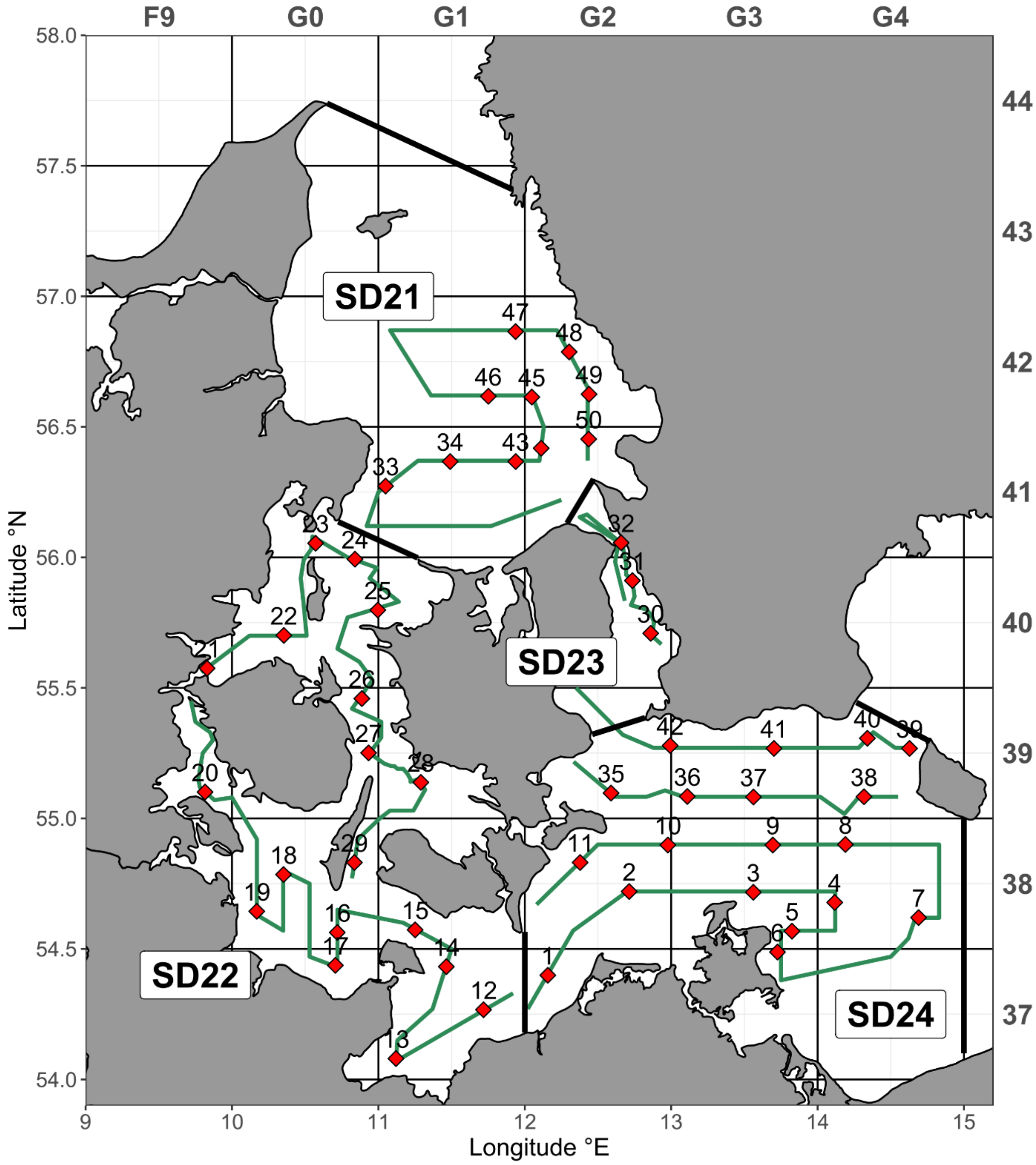


Figure 1: FRV "Solea" cruise 798/2021. Cruise track (dark green lines) and fishery hauls (red diamonds). ICES statistical rectangles are indicated in the top and right axis. Thick black lines separate ICES subdivisions (SD).

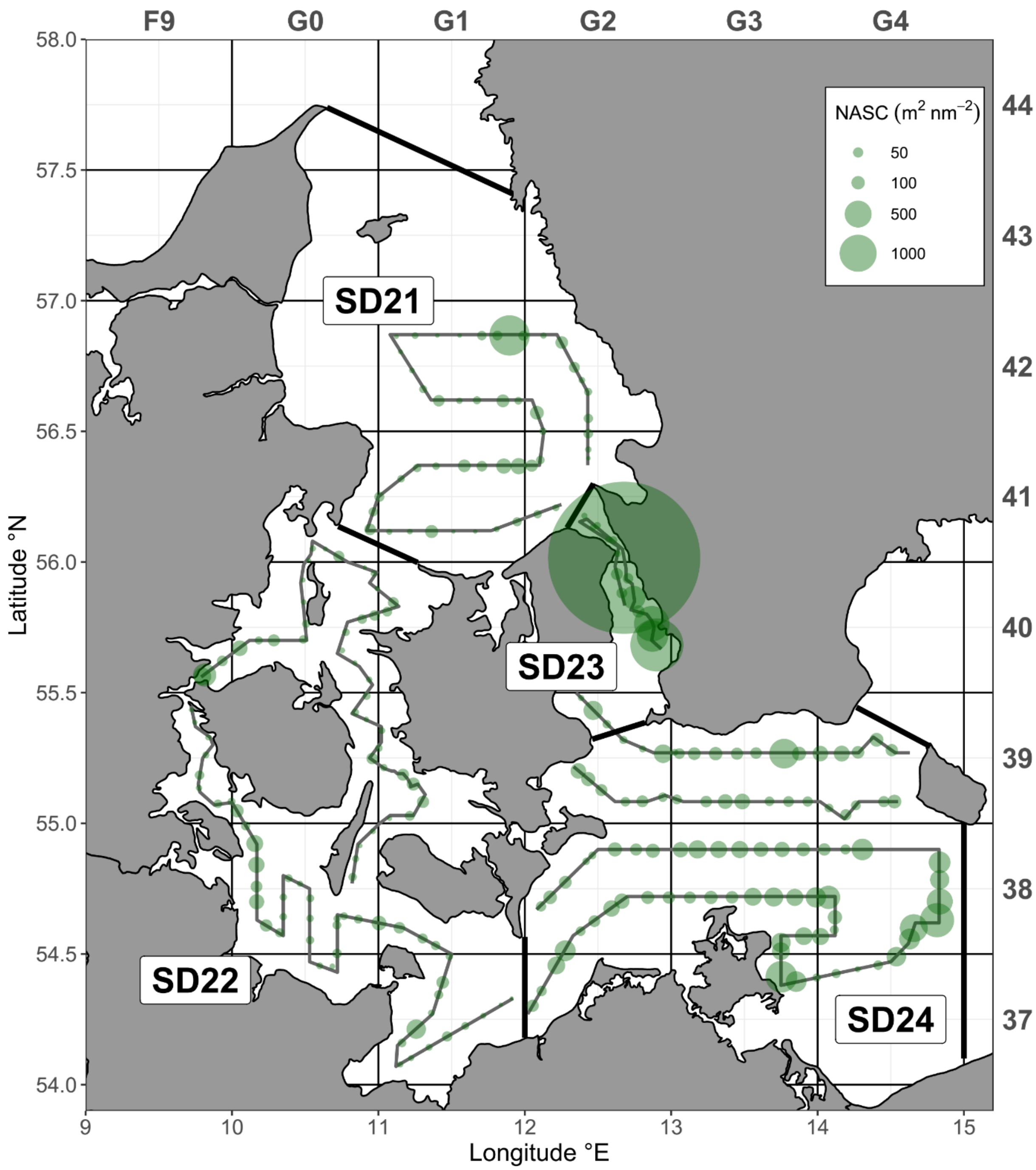


Figure 2: FRV "Solea" cruise 798/2021. Cruise track (thin grey lines) and mean NASC (5 nmi intervals, dots). ICES statistical rectangles are indicated in the top and right axis. Thick black lines separate ICES subdivisions. Note the large NASC value measured in 41G2 (SD 23) which had to be removed from the WBSSH estimate (see results).

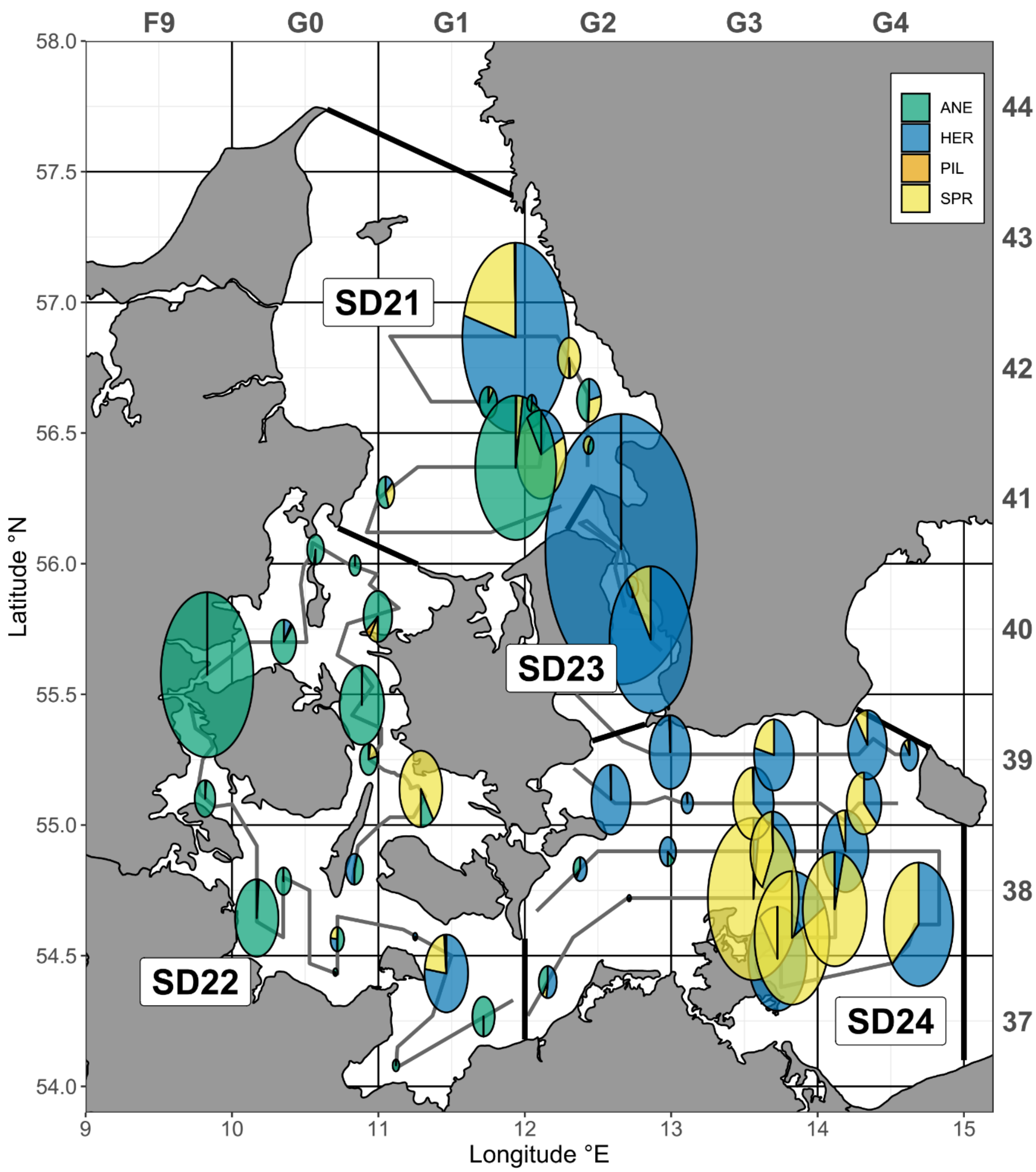


Figure 3: FRV "Solea" cruise 798/2021. Clupeid catch per haul (kg 30min^{-1}). ANE = European anchovy (*Engraulis encrasicolus*), HER = Herring (*Clupea harengus*), PIL = Sardine (*Sardina pilchardus*), SPR = Sprat (*Sprattus sprattus*). ICES statistical rectangles are indicated in the top and right axis. Thick black lines separate ICES subdivisions. Thin grey lines indicate cruise track.

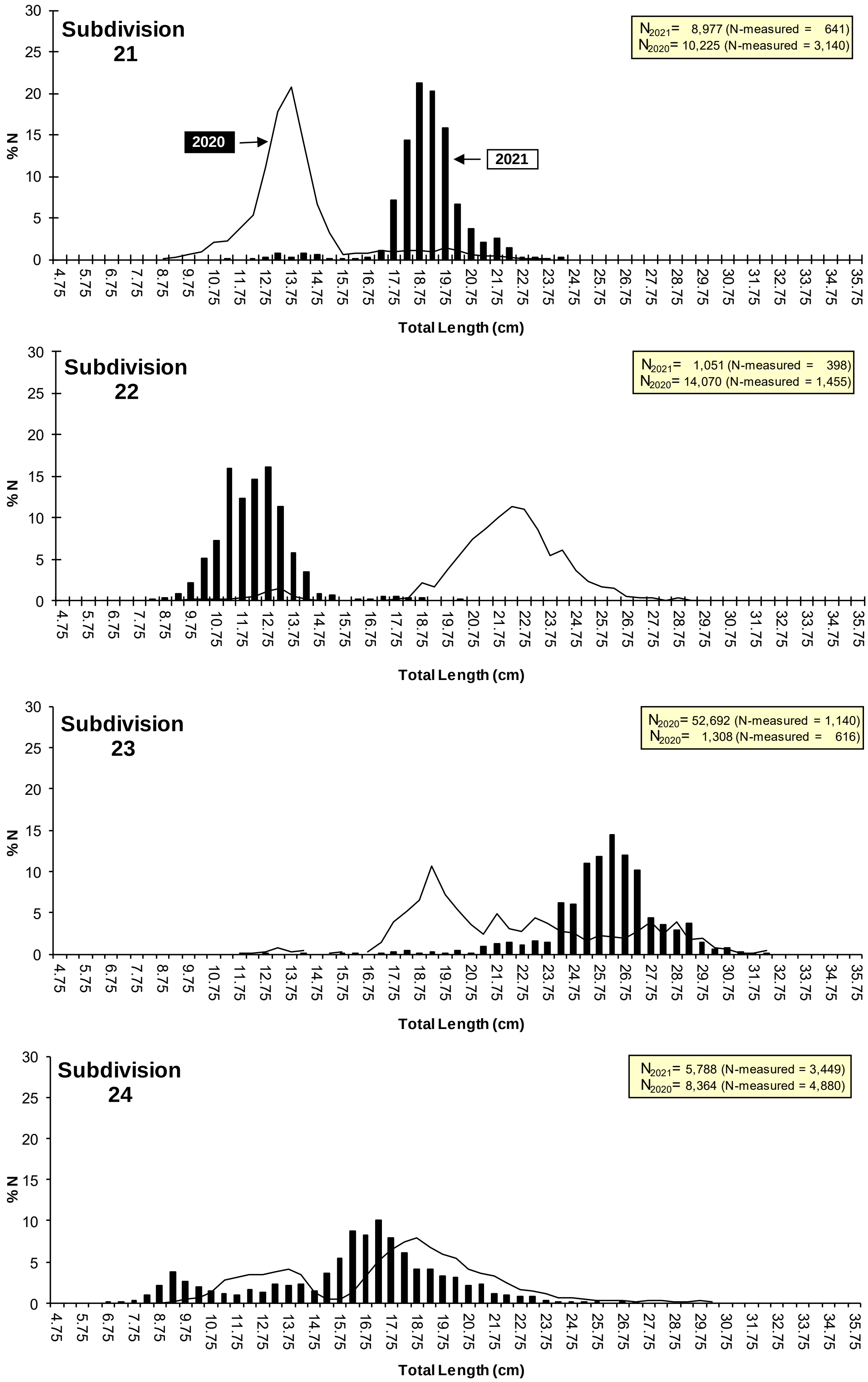


Figure 4: FRV "Solea" cruise 798/2021. Herring (*Clupea harengus*) length-frequency distribution (bars) compared to the previous year (cruise 783/2020, lines). Note that the LFD in SD 23 contains data from haul 32 which had to be removed from the calculation of WBSSH abundance/biomass indices.

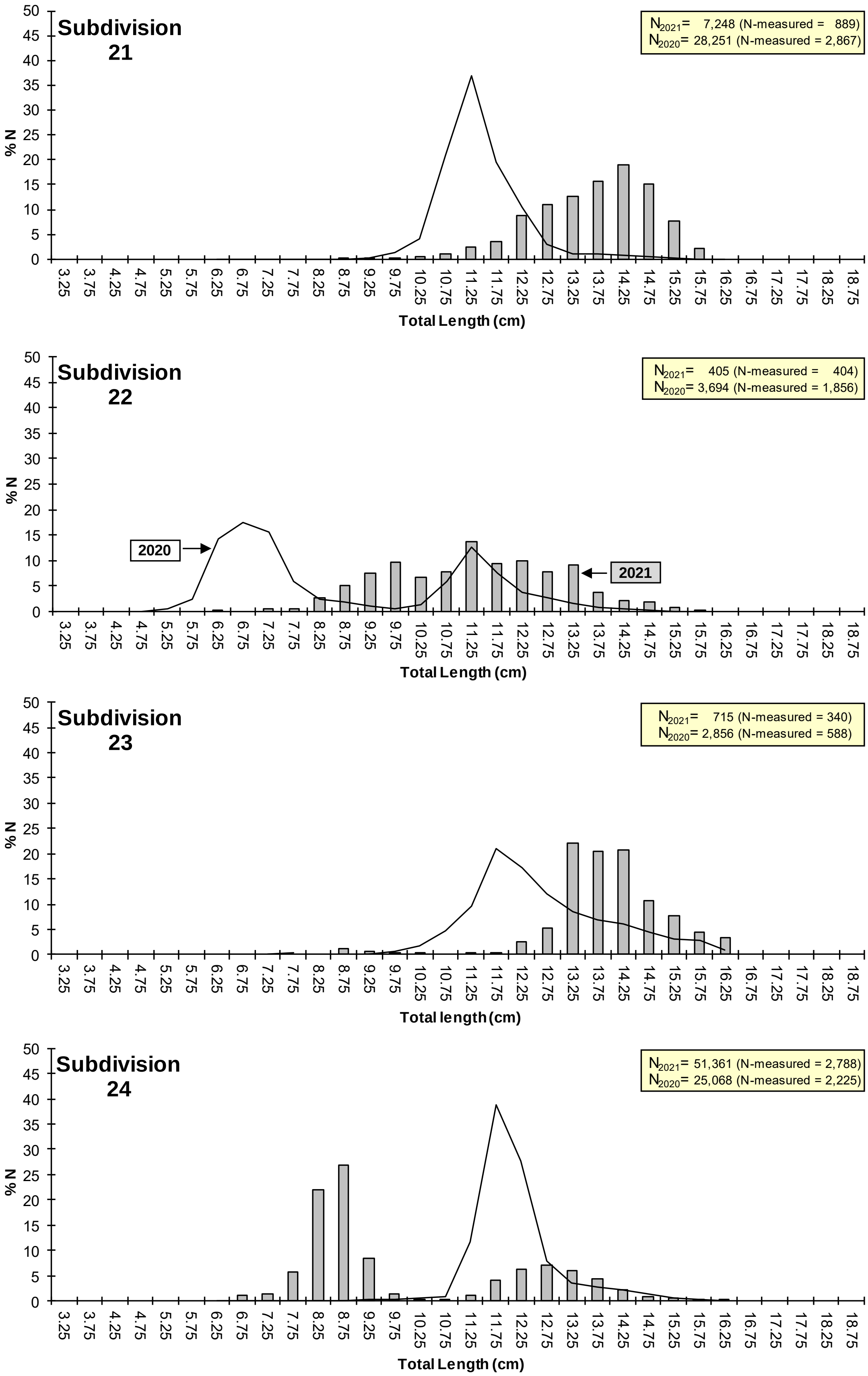


Figure 5: FRV "Solea" cruise 798/2021. Sprat (*Sprattus sprattus*) length-frequency distribution (bars) compared to the previous year (cruise 783/2020, lines).

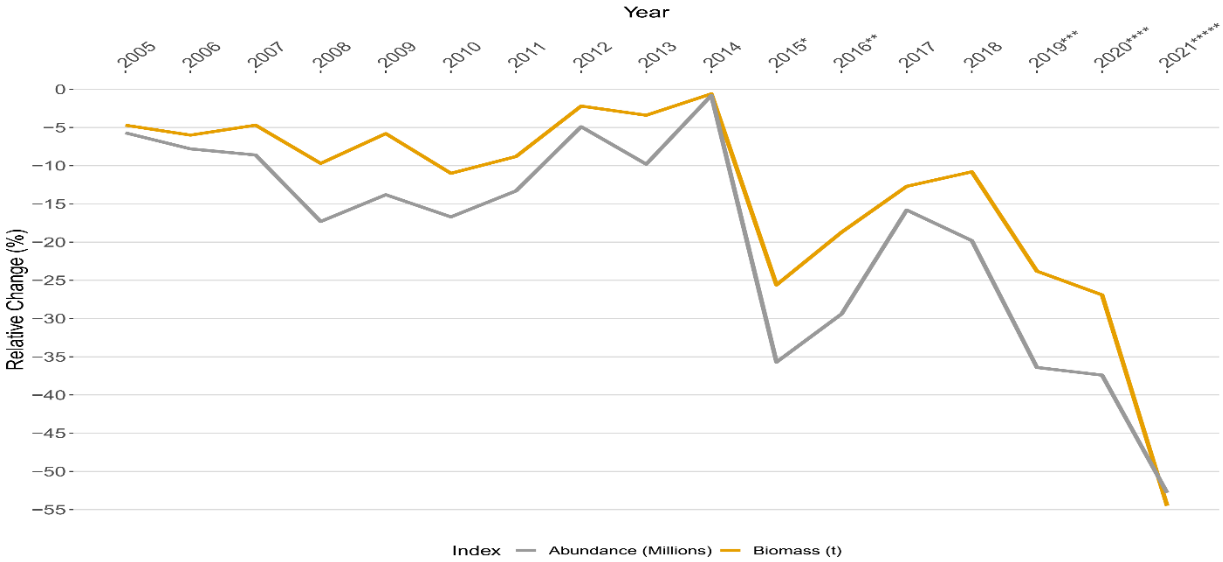


Figure 6: Relative changes in abundance and biomass of Western Baltic Spring Spawning herring in ICES Subdivisions 21-24 (2005-2021) after application of the stock Separation Function (SF, Gröhsler et al., 2013) to the abundance and biomass index generated from German acoustic survey data (GERAS) from 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 SD 21, ******excl. of CBH in SDs 21-22 and excl. haul 32 with almost exclusively mature herring in SD 23.

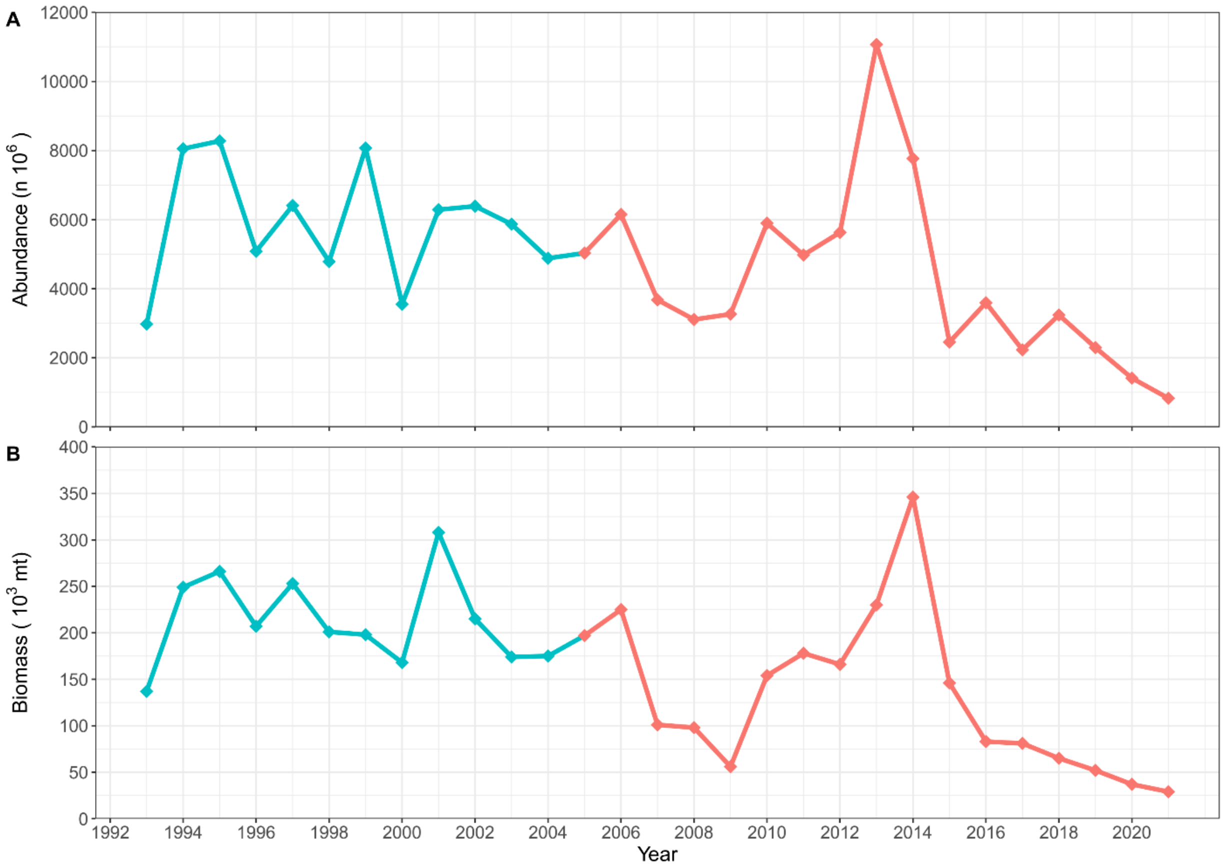


Figure 7: HAWG time series of GERAS survey indices for Western Baltic Spring Spawning Herring (WBSSH) age groups 0-8$^+$. A) Abundance and B) Biomass of herring in ICES Subdivisions 21 (Southern Kattegat, ICES statistical rectangles 41G0 - 42G2) – 24 (excl. ICES statistical rectangles 37G3 & 37G4). Blue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

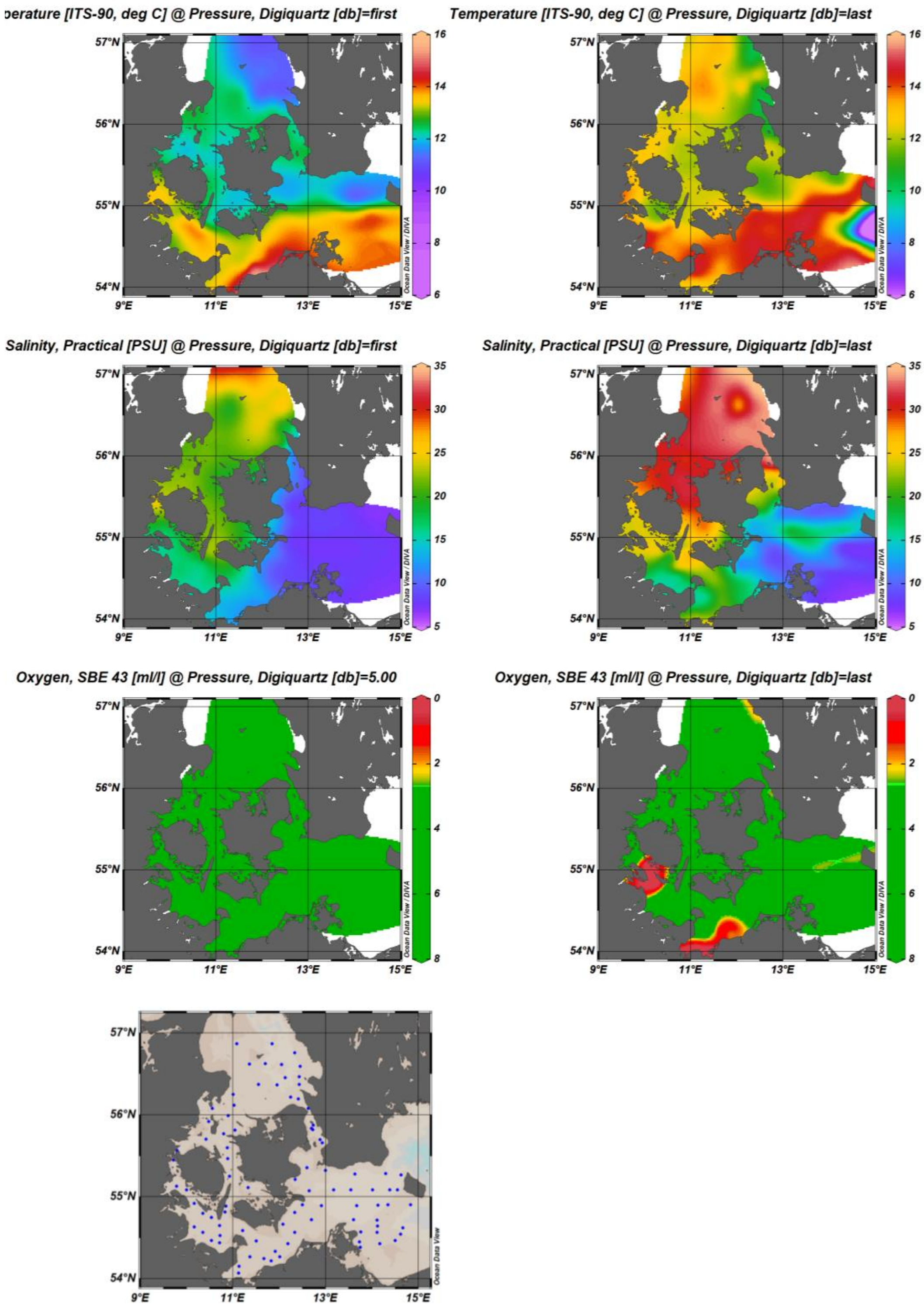


Figure 8: FRV "Solea" cruise 798/2021: Hydrography. CTD stations are depicted as blue dots in the area map. Temperature (°C, top panels), salinity (PSU, middle panels and oxygen concentration (ml/l, lower panels) at the surface (left) and near the seafloor (right).

8. TABLES

Table 1: FRV “Solea” cruise 798/2021: Simrad EK80 calibration report (38 kHz Transducer).

Date:	08.10.2021		
Calibration Site:	Mecklenburg Bight (54°12.5 N, 11°45.7 E)		
Transceiver Type:	WBT		
Software Version:	EK80 2.0.1.0		
Reference Target:	Tungsten (WC-Co) 38.1 mm		
Transducer:	ES38-7 Serial No. 147		
Frequency:	38000 Hz	Beamtype:	Split/Narrow
Gain:	26.98 dB	Equivalent Beam Angle:	-20.7 dB
Beamwidth Athw.:	6.59 deg	Beamwidth Along.:	6.67 deg
Offset Athw.:	-0.03 deg	Offset Along.:	-0.06 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.:	0.000	Sound Velocity:	1479.95m/s
Temperature:	14.6 °C	Salinity:	13.0 PSU
Calibration results:			
Transducer Gain:	26.99 dB	SaCorrection:	-0.0618 dB
Beamwidth Athw.:	6.51 deg	Beamwidth Along.:	6.46 deg
Offset Athw.:	0.04 deg	Offset Along.:	-0.14 deg
RMS-Error:	0.05		

Table 2: FRV "Solea" cruise 798/2021: Catch composition (kg 0.5 h^{-1}) by haul in SD 21.

Haul No.	33	34	43	44	45	46	47	48	49	50	Total
Species/ICES Rectangle	41G1	41G1	41G1	41G2	42G2	42G1	42G1	42G2	42G2	41G2	
ALLOTEUTHIS	+	+	0.04	0.06	0.04	0.19	0.01	0.07	0.03	0.04	**0.48**
APHIA MINUTA	+					+		0.02	0.01	+	**0.03**
CLUPEA HARENGUS	0.41		0.27	3.46	0.59	0.04	417.77		0.91	0.02	**423.47**
ELEDONE				0.01	0.01			0.02	0.01		**0.05**
ENGRAULIS ENCRASICOLUS	1.58		114.54	1.79	0.82	2.54	1.70	+	2.00	0.23	**125.20**
EUTRIGLA GURNARDUS				0.02							**0.02**
GASTEROSTEUS ACULEATUS			0.01							+	**0.01**
LIMANDA LIMANDA									0.04		**0.04**
MERLANGIUS MERLANGUS	0.01		0.15	0.10	0.01	+		0.05	0.25	0.03	**0.60**
PLEURONECTES PLATESSA						0.03		0.01			**0.04**
SARDINA PILCHARDUS									0.04		**0.04**
SCOMBER SCOMBRUS	0.78	75.58	0.08	6.14	0.31	0.52	16.12	0.04	0.05	0.07	**99.69**
SPRATTUS SPRATTUS	0.84		3.06	13.42	0.32	0.25	110.88	0.26	1.20	0.31	**130.54**
TRACHINUS DRACO	1.17	0.26	0.21	1.59	5.74	0.38	25.86	0.03	0.09	0.06	**35.39**
TRACHURUS TRACHURUS	0.06	0.01	0.05	0.01	0.01	0.01			0.01	0.03	**0.19**
Total	**4.85**	**75.85**	**118.41**	**26.60**	**7.85**	**3.96**	**572.34**	**0.50**	**4.64**	**0.79**	**815.79**
Medusae	0.24	1.09	1.43	0.08	1.11	1.83	0.00	1.38	2.36	2.68	12.20

+ = < 0.01 kg

Table 3: FRV "Solea" cruise 798/2021: Catch composition (kg 0.5 h^{-1}) by haul in SD 22.

Haul No.	12	13	14	15	16	17	18	19	20	21	22	23	24
Species/ICES Rectangle	37G1	37G1	37G1	38G1	38G0	37G0	38G0	38G0	39F9	40F9	40G0	41G0	40G0
AGONUS CATAPHRACTUS				+									
ALLOTEUTHIS											0.01	0.01	0.01
APHIA MINUTA			+			+							
BELONE BELONE		0.07		0.02	0.06	0.01	0.09						
CLUPEA HARENGUS		0.01	10.04	0.61	0.12	0.03		0.15		0.05	0.43		
CTENOLABRUS RUPESTRIS				+			+						
ENGRAULIS ENCRASICOLUS	0.27	1.47	0.21	0.17	0.22	0.55	2.48	12.70	3.31	233.44	3.81	0.36	1.97
GADUS MORHUA	+	0.01	0.02	0.13		0.02	+		0.01	0.04			
GASTEROSTEUS ACULEATUS	0.07	0.03	0.02	0.05		0.15	0.20	1.31	0.95	0.95	0.02		+
LIMANDA LIMANDA		0.15	0.47	0.32		0.07		0.20					
MERLANGIUS MERLANGUS	0.03	0.01	0.47	+		0.04	0.03	0.14	0.03	0.03	0.01		
MYOXOCEPHALUS SCORPIUS													
PLATICHTHYS FLESUS		0.45	0.22										
PLEURONECTES PLATESSA		0.17		0.06			0.16		0.11				
POMATOSCHISTUS MINUTUS	+		0.01			0.01					+		
SARDINA PILCHARDUS										0.12			0.01
SCOMBER SCOMBRUS										0.09	0.20		
SPRATTUS SPRATTUS			2.82		0.11	0.19		0.06	0.06	0.09	0.09	0.01	
TRACHINUS DRACO										0.08		0.31	0.18
TRACHURUS TRACHURUS	+	0.01	0.02	+		0.04		0.01		0.28	0.01		0.00
Total	**0.37**	**2.38**	**14.30**	**1.36**	**0.51**	**1.11**	**2.96**	**14.57**	**4.47**	**235.17**	**4.58**	**0.69**	**2.17**
Medusae	15.68	14.18	5.25	5.80	1.64	3.89	10.51	13.90	1.72	0.27	1.50	1.54	1.12

Haul No.	25	26	27	28	29	Total
Species/ICES Rectangle	40G0	39G0	39G0	39G1	38G0	
AGONUS CATAPHRACTUS				+		**+**
ALLOTEUTHIS	0.02		+	0.01		**0.06**
APHIA MINUTA	0.07	+	+	4.89		**4.96**
BELONE BELONE						**0.25**
CLUPEA HARENGUS		0.05	0.10		0.30	**11.89**
CTENOLABRUS RUPESTRIS						**+**
ENGRAULIS ENCRASICOLUS	0.16	13.78	2.19	0.01	0.24	**277.34**
GADUS MORHUA					0.15	**0.38**
GASTEROSTEUS ACULEATUS		0.02		1.36	6.72	**11.85**
LIMANDA LIMANDA					0.09	**1.30**
MERLANGIUS MERLANGUS		+				**0.79**
MYOXOCEPHALUS SCORPIUS	0.06					**0.06**
PLATICHTHYS FLESUS						**0.67**
PLEURONECTES PLATESSA						**0.50**
POMATOSCHISTUS MINUTUS				0.01		**0.03**
SARDINA PILCHARDUS	0.01					**0.14**
SCOMBER SCOMBRUS	1.24					**1.53**
SPRATTUS SPRATTUS	0.02		0.51	0.07		**4.03**
TRACHINUS DRACO	0.03	0.13				**0.73**
TRACHURUS TRACHURUS	0.02	0.01	0.03	0.02		**0.45**
Total	**1.63**	**13.99**	**2.83**	**6.37**	**7.50**	**316.96**
Medusae	2.80	8.33	2.47	4.18	0.80	95.58

+ = < 0.01 kg

Table 4: FRV “Solea” cruise 798/2021: Catch composition (kg 0.5 h^{-1}) by haul in SD 23.

Haul No. Species/ICES Rectangle	30 40G2	31 40G2	32 41G2	Total
APHIA MINUTA		+		**+**
CLUPEA HARENGUS	116.20	0.49	7565.28	**7681.97**
GADUS MORHUA	10.37	9.70		**20.07**
GASTEROSTEUS ACULEATUS	0.10	0.01		**0.11**
MERLANGIUS MERLANGUS	0.83			**0.83**
PLEURONECTES PLATESSA		0.49		**0.49**
POMATOSCHISTUS MINUTUS	+			**+**
SCOMBER SCOMBRUS			17.15	**17.15**
SPRATTUS SPRATTUS	12.05	0.01	0.98	**13.04**
TRACHURUS TRACHURUS	0.23	0.01	0.47	**0.71**
Total	**139.78**	**10.71**	**7583.88**	**7734.37**
Medusae	0.33	0.45	0.00	**0.78**

+ = < 0.01 kg

Table 5: FRV “Solea” cruise 798/2021: Catch composition (kg 0.5 h^{-1}) by haul in SD 24.

Haul No. Species/ICES Rectangle	1 37G2	2 38G2	3 38G3	4 38G4	5 38G3	6 37G3	7 38G4	8 38G4	9 38G3	10 38G2	11 38G2	35 39G2	36 39G3
ALOSA FALLAX							0.03						
APHIA MINUTA	+	+						+			+	+	
CLUPEA HARENGUS	1.51	0.59	4.90	2.00	14.16	27.90	37.80	14.00	8.12	0.32	1.33	9.95	1.97
CRANGON CRANGON		+	+		+	+	+			+			
CYCLOPTERUS LUMPUS								0.12					
ENGRAULIS ENCRASICOLUS	1.15	0.20		0.01		0.02			0.07	0.06	0.78		0.02
GADUS MORHUA				0.19	0.02	0.07	1.70	0.58	1.06	0.02	0.02		
GASTEROSTEUS ACULEATUS	0.13	0.03	0.23	+	0.05		0.07	0.06	0.21	0.01	0.58	+	+
LIMANDA LIMANDA	0.13												
MERLANGIUS MERLANGUS	0.06		0.01		0.03	7.92	+	0.16	0.70		+	0.02	0.03
NEOGOBIUS MELANOSTOMUS										+	+		
PLATICHTHYS FLESUS		0.32	0.80		0.49	0.66	0.19	0.72				0.74	
PLEURONECTES PLATESSA	0.07		0.20					0.11					
POMATOSCHISTUS MINUTUS	0.01	0.02	0.02		+	+	0.01	+	0.03	0.05	+		
SCOMBER SCOMBRUS		0.19			0.36								
SPRATTUS SPRATTUS	0.22	0.02	208.55	41.58	67.91	3.23	21.44	0.95	5.89		0.11	0.05	
STIZOSTEDION LUCIOPERCA					0.06	3.44							
TRACHURUS TRACHURUS	0.01	0.03										0.02	
Total	**3.29**	**1.40**	**214.71**	**43.78**	**83.08**	**43.24**	**61.24**	**16.70**	**16.08**	**0.46**	**2.82**	**10.78**	**2.02**
Medusae	1.59	0.96	0.30	0.63	0.39	3.07	0.50	0.66	3.10	3.05	2.58	0.72	16.50

Haul No. Species/ICES Rectangle	37 39G3	38 39G4	39 39G4	40 39G4	41 39G3	42 39G2	Total
ALOSA FALLAX							**0.03**
APHIA MINUTA							**+**
CLUPEA HARENGUS	3.89	2.84	2.52	8.80	8.19	11.33	**162.12**
CRANGON CRANGON							**+**
CYCLOPTERUS LUMPUS							**0.12**
ENGRAULIS ENCRASICOLUS	0.05		0.07				**2.43**
GADUS MORHUA	1.64		0.01	0.86	0.01		**6.18**
GASTEROSTEUS ACULEATUS	0.03	+	0.01		0.03	0.02	**1.46**
LIMANDA LIMANDA							**0.13**
MERLANGIUS MERLANGUS			0.25		0.67		**9.85**
NEOGOBIUS MELANOSTOMUS							**+**
PLATICHTHYS FLESUS	0.24				0.31	0.23	**4.70**
PLEURONECTES PLATESSA				0.13	0.16		**0.67**
POMATOSCHISTUS MINUTUS					0.01	+	**0.15**
SCOMBER SCOMBRUS							**0.55**
SPRATTUS SPRATTUS	6.96	4.90	0.23	1.02	2.29	0.09	**365.44**
STIZOSTEDION LUCIOPERCA							**3.50**
TRACHURUS TRACHURUS							**0.06**
Total	**12.81**	**7.74**	**3.09**	**10.81**	**11.67**	**11.67**	**557.39**
Medusae	27.46	4.89	14.97	4.09	2.70	1.40	**89.56**

+ = < 0.01 kg

Table 6: FRV "Solea", cruise 798/2021. 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	53.2	2.674	21.51	4.67	24.30	1.01	5.23
21	41G1	946.8	43.4	2.252	182.47	2.45	13.82	4.48	25.22
21	41G2	432.3	30.4	1.679	78.27	8.76	69.11	6.86	54.09
21	42G1	884.2	63.0	3.051	182.58	57.74	38.38	105.41	70.07
21	42G2	606.8	43.2	3.386	77.42	9.29	15.87	7.19	12.29
21	Total	**2,978.2**			**542.25**			**124.95**	**166.90**
22	37G0	209.9	86.1	0.696	259.66	1.22	7.76	3.18	20.14
22	37G1	723.3	42.9	1.361	227.99	72.77	22.26	165.91	50.74
22	38G0	735.3	41.7	0.949	323.10	4.83	6.08	15.60	19.65
22	38G1	173.2	60.6	1.116	94.05	39.67	0.00	37.31	0.00
22	39F9	159.3	19.7	0.718	43.71	0.00	1.49	0.00	0.65
22	39G0	201.7	38.5	1.317	58.96	1.52	5.83	0.90	3.44
22	39G1	250.0	41.8	0.138	757.25	0.00	0.07	0.00	0.52
22	40F9	51.3	118.6	1.695	35.89	0.01	0.10	0.004	0.03
22	40G0	538.1	29.0	0.770	202.66	4.22	1.07	8.55	2.18
22	40G1	174.5	44.0	0.161	476.89	0.00	0.27	0.00	1.31
22	41G0	173.1	31.7	2.624	20.91	0.00	3.03	0.00	0.63
22	Total	**3,389.7**			**2501.07**			**231.45**	**99.29**
23	39G2	130.9	110.7	2.835	51.11	92.85	1.16	47.45	0.59
23	40G2	164.0	434.7	4.501	158.39	57.99	36.87	91.85	58.40
23	41G2	72.3	19.2	4.501	3.08	57.99	36.87	1.79	1.14
23	Total	**367.2**			**212.58**			**141.09**	**60.13**
24	37G2	192.4	120.7	1.057	219.70	23.81	6.52	52.31	14.32
24	37G3	167.7	322.6	3.201	169.01	66.88	29.25	113.04	49.44
24	37G4	875.1	35.9	2.533	124.03	56.48	40.62	70.05	50.38
24	38G2	832.9	96.9	0.649	1243.57	12.56	1.07	156.20	13.32
24	38G3	865.7	134.8	1.317	886.08	17.40	77.49	154.19	686.64
24	38G4	1034.8	285.2	2.635	1120.02	58.80	33.62	658.58	376.56
24	39G2	406.1	62.4	2.835	89.38	92.85	1.16	82.99	1.04
24	39G3	765.0	113.5	1.997	434.79	31.95	62.29	138.90	270.83
24	39G4	524.8	85.1	2.603	171.57	48.80	50.06	83.73	85.89
24	Total	**5,664.5**			**4,458.15**			**1509.99**	**1548.42**
22-24	Total	**9,421.4**			**7,171.80**			**1882.53**	**1707.84**
21-24	Total	**12,399.6**			**7,714.05**			**2007.48**	**1874.74**

Table 7: FRV "Solea", cruise 798/2021. Numbers (millions) of herring incl. CBH by age/W-rings and area. ("+" indicates abundances <0.01).

Sub-division	Rectangle/ W-rings	0	1	2	3	4	5	6	7	8+	Total
21	41G0	0.37	0.30	0.16	0.16	0.01					1.00
21	41G1	3.06	0.67	0.35	0.36	0.03					4.47
21	41G2	2.70	3.71	0.14	0.17	0.11		0.03			6.86
21	42G1	1.46	93.70	6.13	2.46	0.57		1.09			105.41
21	42G2	4.56	1.98	0.42	0.15	0.06		0.01			7.18
21	Total	12.15	100.36	7.20	3.30	0.78	0.00	1.13	0.00	0.00	124.92
22	37G0	3.18									3.18
22	37G1	163.50	1.21	0.20	0.60	0.20	0.20				165.91
22	38G0	12.57	0.91	0.34	1.11	0.34	0.34				15.61
22	38G1	35.76	1.04	0.26	0.26						37.32
22	39F9										0.00
22	39G0	0.90									0.90
22	39G1										0.00
22	40F9		+	+							0.00
22	40G0	8.23	0.21	0.11							8.55
22	40G1										0.00
22	41G0										0.00
22	Total	224.14	3.37	0.91	1.97	0.54	0.54	0.00	0.00	0.00	231.47
23	39G2	2.58	3.26	9.88	13.24	11.57	3.62	1.94	1.32	0.04	47.45
23	40G2	0.35	7.07	33.16	23.83	15.7	8.42	2.42	0.65	0.24	91.84
23	41G2	0.01	0.14	0.65	0.46	0.31	0.16	0.05	0.01		1.79
23	Total	2.94	10.47	43.69	37.53	27.58	12.20	4.41	1.98	0.28	141.08
24	37G2	28.24	9.26	3.05	4.87	4.85	1.38	0.49	0.17		52.31
24	37G3	4.24	6.75	23.12	28.24	28.18	10.70	6.41	5.19	0.19	113.02
24	37G4	4.62	3.87	17.29	18.06	15.84	5.17	2.91	2.22	0.07	70.05
24	38G2	25.93	16.46	22.27	38.29	36.53	8.81	5.03	2.88		156.20
24	38G3	72.83	20.88	15.12	20.07	18.21	4.34	2.08	0.66		154.19
24	38G4	34.63	30.70	169.33	160.42	138.10	53.08	39.69	32.24	0.39	658.58
24	39G2	4.51	5.70	17.27	23.16	20.24	6.34	3.39	2.31	0.07	82.99
24	39G3	30.80	13.41	24.86	25.95	23.97	9.80	5.54	4.49	0.07	138.89
24	39G4	3.12	3.34	21.75	20.97	18.62	7.39	4.22	4.15	0.18	83.74
24	Total	208.92	110.37	314.06	340.03	304.54	107.01	69.76	54.31	0.97	1,509.97
22-24	Total	436.00	124.21	358.66	379.53	332.66	119.75	74.17	56.29	1.25	1,882.52
21-24	Total	448.15	224.57	365.86	382.83	333.44	119.75	75.30	56.29	1.25	2,007.44

Table 8: FRV "Solea", cruise 798/2021. 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	18.28	37.63	78.86	69.37	32.99					42.10
21	41G1	15.69	37.63	78.86	69.37	32.99					28.36
21	41G2	16.29	38.51	40.77	28.91	33.07		45.05			29.51
21	42G1	17.33	44.59	59.64	68.69	33.87		45.05			45.60
21	42G2	15.41	40.04	56.61	41.43	32.41		45.05			25.34
21	Total	15.99	44.21	60.46	65.51	33.60		45.05			42.91
22	37G0	9.44									9.44
22	37G1	10.35	36.17	28.67	33.00	31.67	28.67				10.69
22	38G0	11.59	35.19	28.67	29.45	31.67	28.67				15.42
22	38G1	11.14	41.67	47.67	35.67						12.42
22	39F9										
22	39G0	14.33									14.33
22	39G1										
22	40F9		47.67	47.67							47.67
22	40G0	13.30	47.67	47.67							14.59
22	40G1										
22	41G0										
22	Total	10.66	38.32	36.40	31.35	31.67	28.67				11.43
23	39G2	16.37	29.41	32.89	32.66	32.96	38.67	41.62	48.36	79.17	32.97
23	40G2	14.25	70.06	104.04	109.79	122.77	128.88	125.92	112.25	156.74	108.83
23	41G2	14.25	70.06	104.04	109.79	122.77	128.88	125.92	112.25		108.48
23	Total	16.11	57.40	87.95	82.58	85.09	102.11	88.84	69.66	145.66	83.31
24	37G2	9.46	12.98	28.51	29.75	29.74	32.62	32.01	39.06		15.88
24	37G3	11.35	31.2	38.55	36.98	36.42	43.65	48.30	55.76	72.44	38.05
24	37G4	15.14	29.8	32.31	33.29	33.94	41.50	45.59	53.12	72.44	33.59
24	38G2	7.32	16.09	30.16	30.05	29.88	33.89	39.97	44.78		25.59
24	38G3	7.16	12.69	28.94	29.69	30.09	33.87	34.99	43.96		16.97
24	38G4	15.97	33.10	35.79	35.98	38.17	44.63	48.85	54.77	72.44	37.62
24	39G2	16.37	29.41	32.89	32.66	32.96	38.67	41.62	48.36	79.17	32.97
24	39G3	16.01	23.43	34.65	35.09	35.25	40.48	45.18	49.65	72.44	30.95
24	39G4	19.02	35.34	33.77	35.34	36.13	45.44	46.51	66.22	78.23	37.58
24	Total	10.89	23.48	34.61	34.46	35.48	42.23	46.71	54.27	74.00	32.49
22-24	Total	10.81	26.74	41.11	39.20	39.58	48.27	49.21	54.81	90.05	33.71
21-24	Total	10.95	34.55	41.49	39.43	39.57	48.27	49.15	54.81	90.05	34.28

Table 9: FRV “Solea”, cruise 798/2021l biomass (t) of herring incl. CBH by age/W-rings and area. (“+”indicates abundances <0.01).

Sub-division	Rectangle/ W-rings	0	1	2	3	4	5	6	7	8+	Total
21	41G0	6.8	11.3	12.6	11.1	0.3					42.1
21	41G1	48.0	25.2	27.6	25.0	1.0					126.8
21	41G2	44.0	142.9	5.7	4.9	3.6		1.4			202.5
21	42G1	25.3	4,178.1	365.6	169.0	19.3		49.1			4,806.4
21	42G2	70.3	79.3	23.8	6.2	1.9		0.5			181.9
21	Total	194.3	4,436.7	435.3	216.2	26.2	0.0	50.9	0.0	0.0	5,359.6
22	37G0	30.0									30.0
22	37G1	1,692.2	43.8	5.7	19.8	6.3	5.7				1,773.6
22	38G0	145.7	32.0	9.8	32.7	10.8	9.8				240.7
22	38G1	398.4	43.3	12.4	9.3						463.4
22	39F9										0.0
22	39G0	12.9									12.9
22	39G1										0.0
22	40F9		+	+							0.0
22	40G0	109.5	10.0	5.2							124.7
22	40G1										0.0
22	41G0										0.0
22	Total	2,388.7	129.1	33.1	61.76	17.1	15.5	0.00	0.00	0.0	2,645.3
23	39G2	42.2	95.9	325.0	432.4	381.4	140.0	80.7	63.84	3.2	1,564.6
23	40G2	5.0	495.3	3,450.0	2,616.3	1,927.5	1,085.2	304.7	73.0	37.6	9,994.6
23	41G2	0.1	9.8	67.6	50.5	38.1	20.6	6.3	1.1		194.2
23	Total	47.4	601.0	3,842.6	3,099.2	2,346.9	1,245.8	391.8	137.9	40.8	11,753.3
24	37G2	267.2	120.2	87.0	144.9	144.2	45.0	15.7	6.6		830.8
24	37G3	48.12	210.3	891.28	1044.32	1026.32	467.05	309.60	289.39	13.76	4,300.2
24	37G4	69.95	115.4	558.64	601.22	537.61	214.56	132.67	117.93	5.07	2,353.1
24	38G2	189.8	264.8	671.7	1,150.6	1,091.5	298.6	201.1	129.0		3,997.0
24	38G3	521.5	265.0	437.6	595.9	547.9	147.0	72.8	29.0		2,616.6
24	38G4	553.0	1,016.2	6,060.3	5,771.9	5,271.3	2,369.0	1,938.9	1,765.8	28.3	24,774.6
24	39G2	73.8	167.6	568.0	756.4	667.1	245.2	141.1	111.7	5.5	2,736.5
24	39G3	493.1	314.2	861.4	910.6	844.9	396.7	250.3	222.9	5.1	4,299.2
24	39G4	59.3	118.0	734.5	741.1	672.7	335.8	196.3	274.8	14.1	3,146.7
24	Total	2,275.8	2,591.8	10,870.3	11,716.9	10,803.7	4,518.8	3,258.3	2,947.2	71.8	49,054.6
22-24	Total	4,711.8	3,322.0	14,746.0	14,877.9	13,167.7	5,780.1	3,650.1	3,085.1	112.6	63,453.2
21-24	Total	4,906.2	7,758.7	15,181.3	15,094.1	13,193.9	5,780.1	3,701.0	3,085.1	112.6	68,812.8

Table 10: FRV "Solea", cruise 798/2021. 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		0.15	3.89	1.02	0.11	0.05				5.22
21	41G1		7.03	15.00	2.77	0.28	0.13				25.21
21	41G2		8.08	40.85	4.74	0.29	0.13				54.09
21	42G1		0.86	30.54	31.62	5.53	1.07	0.45			70.07
21	42G2		4.74	6.31	1.12	0.08	0.04				12.29
21	Total	0.00	20.86	96.59	41.27	6.29	1.42	0.45	0.00	0.00	166.88
22	37G0	9.28	3.15	5.78	0.79	0.43	0.71				20.14
22	37G1	12.64	19.81	14.80	2.06	0.92	0.50				50.73
22	38G0	7.14	7.73	2.52	1.96	0.06	0.25				19.66
22	38G1										0.00
22	39F9	0.60		0.05							0.65
22	39G0		0.38	1.99	0.67	0.19	0.21				3.44
22	39G1	0.49	0.01	0.02							0.52
22	40F9	0.03									0.03
22	40G0		0.70	1.10	0.20	0.06	0.12				2.18
22	40G1		0.75	0.56							1.31
22	41G0			0.63							0.63
22	Total	30.18	32.53	27.45	5.68	1.66	1.79	0.00	0.00	0.00	99.29
23	39G2		0.03	0.11	0.20	0.12	0.08	0.04			0.58
23	40G2	1.42	5.01	28.84	13.02	6.97	0.93	1.86	0.18	0.18	58.41
23	41G2	0.03	0.10	0.56	0.25	0.14	0.02	0.04			1.14
23	Total	1.45	5.14	29.51	13.47	7.23	1.03	1.94	0.18	0.18	60.13
24	37G2	8.58	1.72	1.30	1.19	0.84	0.50	0.15	0.05		14.33
24	37G3	16.41	13.43	8.67	5.54	2.79	1.63	0.95	0.01		49.43
24	37G4	8.36	10.60	12.28	8.12	4.87	3.94	2.12	0.09		50.38
24	38G2	4.84	0.51	0.91	2.46	1.98	1.33	0.99	0.30		13.32
24	38G3	289.18	134.22	120.73	75.10	35.98	19.56	11.70	0.17		686.64
24	38G4	8.43	72.21	115.06	76.78	44.45	37.24	21.29	1.10		376.56
24	39G2		0.06	0.20	0.35	0.22	0.15	0.06			1.04
24	39G3	102.83	32.84	50.79	33.93	21.66	18.54	9.54	0.70		270.83
24	39G4		10.08	25.42	18.49	13.45	11.47	6.41	0.57		85.89
24	Total	438.63	275.67	335.36	221.96	126.24	94.36	53.21	2.99	0.00	1,548.42
22-24	Total	470.26	313.34	392.32	241.11	135.13	97.18	55.15	3.17	0.18	1,707.84
21-24	Total	470.26	334.20	488.91	282.38	141.42	98.60	55.60	3.17	0.18	1,874.72

Table 11: FRV “Solea”, cruise 798/2021. 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		14.57	15.93	17.72	18.81	18.67				16.33
21	41G1		10.95	14.68	17.38	18.80	18.67				14.00
21	41G2		12.30	14.24	16.49	18.91	18.67				14.18
21	42G1		13.82	16.81	20.16	21.66	18.67	24.00			18.74
21	42G2		10.31	13.97	16.93	18.67	18.67				12.87
21	Total		11.47	15.17	19.40	21.32	18.67	24.00			16.04
22	37G0	4.94	9.69	12.41	17.66	17.24	18.17				9.05
22	37G1	5.93	9.91	12.86	15.76	17.29	16.80				10.22
22	38G0	5.84	9.50	13.30	16.57	13.23	16.88				9.47
22	38G1										
22	39F9	4.07		11.89							4.67
22	39G0		12.54	14.08	16.05	19.03	16.66				14.72
22	39G1	3.96	13.23	13.23							4.49
22	40F9	4.12									4.12
22	40G0		11.67	13.24	15.94	15.80	16.88				13.25
22	40G1		11.43	11.43							11.43
22	41G0			11.89							11.89
22	Total	5.53	9.90	12.86	16.34	17.28	17.34				10.01
23	39G2		13.5	15.37	21.01	21.39	16.67	16.95			18.75
23	40G2	4.63	15.63	17.67	18.91	20.57	24.71	22.35	25.58	23.69	18.1
23	41G2	4.63	15.63	17.67	18.91	20.57	24.71	22.35			18.06
23	Total	4.63	15.62	17.66	18.94	20.58	24.09	22.24	25.58	23.69	18.11
24	37G2	3.61	11.06	14.31	15.27	15.92	16.52	18.00	18.00		7.82
24	37G3	3.69	11.70	13.58	13.61	14.18	15.79	16.29	18.00		9.95
24	37G4	3.69	12.25	14.26	14.67	15.53	16.20	16.24	18.27		12.51
24	38G2	4.32	12.17	15.45	17.44	17.73	17.73	17.68	18.00		12.44
24	38G3	4.15	12.25	13.76	13.68	14.44	15.69	15.67	19.45		9.53
24	38G4	5.03	12.96	14.38	14.84	15.78	16.25	15.99	18.16		14.44
24	39G2		13.50	15.37	21.01	21.39	16.67	16.95			18.71
24	39G3	4.82	12.52	14.50	15.03	15.95	16.34	16.11	18.60		10.96
24	39G4		13.57	14.77	15.64	16.64	16.64	16.69	18.57		15.53
24	Total	4.29	12.48	14.18	14.55	15.52	16.21	16.08	18.40		11.43
22-24	Total	4.37	12.27	14.35	14.83	15.81	16.32	16.30	18.80	23.69	11.59
21-24	Total	4.37	12.22	14.51	15.50	16.05	16.35	16.36	18.80	23.69	11.98

Table 12: FRV "Solea", cruise 798/2021. 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		2.2	62.0	18.1	2.1	0.9				85.2
21	41G1		77.0	220.2	48.1	5.3	2.4				353.0
21	41G2		99.4	581.7	78.2	5.5	2.4				767.2
21	42G1		11.9	513.4	637.5	119.8	20.0	10.8			1,313.3
21	42G2		48.9	88.2	19.0	1.5	0.8				158.2
21	Total	0.0	239.3	1,465.4	800.8	134.1	26.5	10.8	0.0	0.0	2,676.9
22	37G0	45.8	30.5	71.7	14.0	7.4	12.9				182.4
22	37G1	75.0	196.3	190.3	32.5	15.9	8.4				518.4
22	38G0	41.7	73.4	33.5	32.5	0.8	4.2				186.2
22	38G1										0.0
22	39F9	2.4		0.6							3.0
22	39G0		4.8	28.0	10.8	3.6	3.5				50.7
22	39G1	1.9	0.1	0.3							2.3
22	40F9	0.1									0.1
22	40G0		8.2	14.6	3.2	1.0	2.0				28.9
22	40G1		8.6	6.4							15.0
22	41G0			7.5							7.5
22	Total	167.0	321.9	352.9	92.8	28.7	31.1	0.0	0.0	0.0	994.4
23	39G2		0.4	1.7	4.2	2.6	1.3	0.7			10.9
23	40G2	6.6	78.3	509.6	246.2	143.4	23.0	41.6	4.6	4.3	1,057.5
23	41G2	0.1	1.6	9.9	4.7	2.9	0.5	0.9			20.6
23	Total	6.7	80.3	521.2	255.1	148.8	24.8	43.1	4.6	4.3	1,088.9
24	37G2	31.0	19.0	18.6	18.2	13.4	8.3	2.7	0.9		112.0
24	37G3	60.6	157.1	117.7	75.4	39.6	25.7	15.5	0.2		491.8
24	37G4	30.9	129.9	175.1	119.1	75.6	63.8	34.4	1.6		630.5
24	38G2	20.9	6.2	14.1	42.9	35.1	23.6	17.5	5.4		165.7
24	38G3	1,200.1	1,644.2	1,661.2	1,027.4	519.6	306.9	183.3	3.3		6,546.0
24	38G4	42.4	935.8	1,654.6	1,139.4	701.4	605.2	340.4	20.0		5,439.2
24	39G2		0.8	3.1	7.4	4.7	2.5	1.0			19.5
24	39G3	495.6	411.2	736.5	510.0	345.5	302.9	153.7	13.0		2,968.4
24	39G4		136.8	375.5	289.2	223.8	190.9	107.0	10.6		1,333.7
24	Total	1,881.4	3,441.0	4,756.3	3,228.9	1,958.6	1,529.8	855.6	55.0	0.0	17,706.6
22-24	Total	2,055.1	3,843.2	5,630.4	3,576.9	2,136.1	1,585.6	898.7	59.6	4.3	19,789.9
21-24	Total	2,055.1	4,082.5	7,095.8	4,377.7	2,270.2	1,612.1	909.5	59.6	4.3	22,466.8

Table 13: FRV “Solea”, cruise 798/2021. Numbers (m) of herring excl. CBH in SD 21, SD 22, 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	0.37	0.30	0.14	0.11						0.93	
21	41G1	3.06	0.67	0.31	0.25						4.29	
21	41G2	2.70	3.71	0.05							6.45	excl. CBH
21	42G1	1.46	93.70	5.60	1.97						102.73	
21	42G2	4.56	1.98	0.39							6.93	
21	Total	12.15	100.36	6.49	2.33	0.00	0.00	0.00	0.00	0.00	121.34	
22	37G0	3.18									3.18	
22	37G1	163.49	1.21								164.70	
22	38G0	12.57	0.91								13.48	
22	38G1	35.76	1.04	0.26							37.05	
22	39F9										0.00	
22	39G0	0.90									0.90	excl. CBH
22	39G1										0.00	
22	40F9										0.00	
22	40G0	8.23	0.21	0.11							8.55	
22	40G1										0.00	
22	41G0										0.00	
22	Total	224.13	3.37	0.36	0.00	0.00	0.00	0.00	0.00	0.00	227.86	
23	39G2	2.58	2.24	2.88	0.54	0.24	0.03				8.51	excl. CBH
23	40G2	0.35	7.07	33.16	23.83	15.7	8.42	2.42	0.65	0.24	91.84	
23	41G2	0.01	0.14	0.65	0.46	0.31	0.16	0.05	0.01		1.79	
23	Total	2.94	9.45	36.69	24.83	16.25	8.61	2.47	0.66	0.24	102.14	
24	37G2	28.24	0.90	0.23							29.37	
24	37G3	4.24	5.04	10.61	4.37	1.31	0.13	0.19	0.13		26.02	
24	37G4	4.62	2.70	4.69	1.56	0.45	0.04	0.06	0.04		14.16	
24	38G2	25.93	5.39	2.90	0.75						34.97	
24	38G3	72.83	2.73	2.14	0.14						77.84	excl. CBH
24	38G4	34.63	24.07	73.92	17.10	4.42	0.43	0.22	1.72		156.51	
24	39G2	4.51	3.92	5.04	0.95	0.42	0.04				14.88	
24	39G3	30.80	5.08	9.30	1.93	0.70		0.09			47.90	
24	39G4	3.12	3.10	7.56	1.91	0.63	0.31		0.80		17.43	
24	Total	208.92	52.93	116.39	28.71	7.93	0.95	0.56	2.69	0.00	419.08	
22-24	Total	435.99	65.75	153.44	53.54	24.18	9.56	3.03	3.35	0.24	749.08	
21-24	Total	448.14	166.11	159.94	55.87	24.18	9.56	3.03	3.35	0.24	870.42	

Table 14: FRV "Solea", cruise 798/2021. Mean weight (g) of herring excl. CBH in SD 21, SD 22, 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	18.25	37.98	84.97	89.76						43.48	
21	41G1	15.68	37.98	84.97	89.76						28.48	
21	41G2	16.28	38.72	57.93							29.47	excl. CBH
21	42G1	17.33	44.68	62.36	72.50						45.79	
21	42G2	15.41	40.31	59.13							25.01	
21	Total	15.99	44.31	63.71	75.15						43.10	
22	37G0	9.44									9.44	
22	37G1	10.35	36.00								10.54	
22	38G0	11.59	34.95								13.18	
22	38G1	11.14	41.58	47.67							12.25	
22	39F9											
22	39G0	14.33									14.33	excl. CBH
22	39G1											
22	40F9											
22	40G0	13.30	47.67	47.67							14.58	
22	40G1											
22	41G0											
22	Total	10.66	38.16	47.67							11.13	
23	39G2	16.37	36.76	46.80	73.02	90.69	84.00				37.96	excl. CBH
23	40G2	14.25	70.06	104.04	109.79	122.77	128.88	125.92	112.25	156.74	108.83	
23	41G2	14.25	70.06	104.04	109.79	122.77	128.88	125.92	112.25		108.48	
23	Total	16.11	62.17	99.55	108.99	122.30	128.72	125.92	112.25	156.74	102.92	
24	37G2	9.44	34.92	40.55							10.46	
24	37G3	11.35	38.98	51.01	64.57	74.96	104.00	79.20	104.00		46.44	
24	37G4	15.13	38.07	49.48	64.30	74.74	104.00	79.20	104.00		38.97	
24	38G2	7.27	31.87	48.75	55.67						15.54	
24	38G3	7.14	34.81	44.15	56.89						9.22	excl. CBH
24	38G4	15.97	38.90	48.90	63.26	74.81	104.00	79.20	102.50		43.16	
24	39G2	16.37	36.76	46.80	73.02	90.69	84.00				37.94	
24	39G3	15.96	38.58	48.53	63.65	75.45		79.20			27.59	
24	39G4	18.97	38.01	49.18	69.25	71.93	97.05		124.25		49.10	
24	Total	10.87	37.63	48.91	64.03	75.50	100.89	79.20	109.06		30.60	
22-24	Total	10.80	41.18	61.01	84.88	106.95	125.96	117.29	109.69	156.74	34.54	
21-24	Total	10.94	43.07	61.12	84.48	106.95	125.96	117.29	109.69	156.74	35.73	

Table 15: FRV "Solea", cruise 798/2021. Total biomass (t) of herring excl. CBH in SD 21, SD 22, 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	6.8	11.5	12.0	10.0						40.3	
21	41G1	48.0	25.5	26.6	22.1						122.3	
21	41G2	44.0	143.5	2.7							190.2	excl. CBH
21	42G1	25.4	4,186.1	348.9	143.2						4,703.6	
21	42G2	70.2	79.8	23.3							173.4	
21	Total	194.4	4,446.4	413.7	175.3	0.0	0.0	0.0	0.0	0.0	5,229.7	
22	37G0	30.0									30.0	
22	37G1	1,692.8	43.5								1,736.3	
22	38G0	145.7	32.0								177.7	
22	38G1	398.4	43.1	12.3							453.9	
22	39F9										0.0	
22	39G0	12.9									12.9	excl. CBH
22	39G1										0.0	
22	40F9										0.0	
22	40G0	109.5	10.1	5.0							124.6	
22	40G1										0.0	
22	41G0										0.0	
22	Total	2,389.4	128.6	17.4	0.00	0.0	0.0	0.00	0.00	0.0	2,535.3	
23	39G2	42.2	82.3	134.8	39.4	21.8	2.5				323.1	excl. CBH
23	40G2	5.0	495.3	3,450.0	2,616.3	1,927.5	1,085.2	304.7	73.0	37.6	9,994.6	
23	41G2	0.1	9.8	67.6	50.5	38.1	20.6	6.3	1.1		194.2	
23	Total	47.4	587.5	3,652.4	2,706.2	1,987.3	1,108.3	311.0	74.1	37.6	10,511.8	
24	37G2	266.6	31.4	9.3							307.4	
24	37G3	48.1	196.5	541.2	282.2	98.2	13.5	15.1	13.5		1,208.3	
24	37G4	69.9	102.8	232.1	100.3	33.6	4.2	4.8	4.2		551.8	
24	38G2	188.5	171.8	141.4	41.8						543.4	
24	38G3	520.0	95.0	94.5	8.0						717.5	excl. CBH
24	38G4	553.0	936.3	3,614.7	1,081.8	330.7	44.7	17.4	176.3		6,754.9	
24	39G2	73.8	144.1	235.9	69.4	38.1	3.4				564.6	
24	39G3	491.6	196.0	451.3	122.8	52.8		7.1			1,321.7	
24	39G4	59.2	117.8	371.8	132.3	45.3	30.1		99.4		855.9	
24	Total	2,270.8	1,991.7	5,692.2	1,838.4	598.7	95.9	44.4	293.4	0.0	12,825.4	
22-24	Total	4,707.5	2,707.8	9,361.9	4,544.7	2,586.0	1,204.2	355.4	367.5	37.6	25,872.5	
21-24	Total	4,901.8	7,154.2	9,775.6	4,719.9	2,586.0	1,204.2	355.4	367.5	37.6	31,102.3	

Annex 8: 2021 ISAS Survey Summary Table and Survey Report

Document 8a: ISAS 2021 survey summary table

Survey Summary table WGIPS 2022	
Name of the survey (abbreviation):	**Irish Sea Acoustic Survey (ISAS)**
Target Species:	**Herring**
Survey dates:	**27th August – 11th September 2021**
Summary:	
The vessel departed Belfast at 22:00 on the 27th August and proceeded to the east coast of the Isle of Man for acoustic calibration off Laxey on the 28th August. The survey started on the peripheral Irish Sea transects to the west of the Solway Firth at 06:15 on the 29th August and continued to the completion of transect 102 North of Anglsey on the 30th August. From here, the ship made way to the northeast of the Isle of Man and recommencing the survey at the start of transect 1 on the 31st August at 01:30 and ended on transect 81 to the northwest of the Mull of Galloway 03rd Sept. The survey recommenced on the morning of 03rd Sept at 05:00 on the western Irish Sea peripheral transects working south along the Northern Ireland coast, additional survey transects in the vicinity of Rig Bank and Slieve Na Griddle were conducted on 03rd and 04th Sept. respectively. The final set of transects for the first phase of the survey ended on transect 101 on 06th Sept and a further set of transects around the Isle of Man were conducted. Sea conditions were calm throughout the duration of the survey. 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 Eastern Northern Irish coast. Cohorts, ages 0 -9 are visible within the survey. The major contribution of age to the total estimates in the 2021 survey is from age 2 accounting for 43.5% 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 very favourable throughout the duration of the survey; negating potential for 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 31 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 2021 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 pre-spawning 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 2021 survey: No additional issues
Measures of uncertainty (CV)	CV of biomass and numbers at age
Biological sampling	2021 Survey: The biological sampling is deemed 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.

Document 8b: ISAS 2021 survey report

*Please find report on the next page.

Irish Sea acoustic survey (Northern Ireland)

Survey report for RV Corystes

27th August – 11th September 2021

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
Conall Hamill

2.2 Narrative

The vessel departed Belfast at 21:00 on the 274h August and proceeded to the east coast of the Isle of Man for acoustic calibration off Laxey on the 28th August. The survey started on the peripheral Irish Sea transects to the west of the Solway Firth at 05:55 on the 29th August and continued to the completion of transect 102 North of Anglesey on the 30th 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 31th August at 01:30 and end on transect 81 to the northwest of the Mull of Galloway 03rd September. After a brief overnight break, the survey continued along the western Irish Sea peripheral transects 03rd September at 05:00. Working south along the Northern Ireland coast, additional survey transects in the vicinity of Rig Bank was conducted on 03rd September and again at Slieve na Griddle on the 04th September. The final set of transects for the first phase of the survey ended on transect 101 on 06th September and a further set of transects around the Isle of Man were completed with the survey concluding on 10th September. Sea conditions were very favourable for the entirety 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 26th August off Laxey on the east coast of the Isle of Man and again at the end of the survey in Brodick Bay off the Isle of Aaron on the 10th September. 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 2021 survey with 31 successful trawls completed Figure 5B.2. Table 5B.2 gives the positions, catch composition and mean length by species for these trawl hauls. Twenty-three 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 2020 survey have been included in this report as otoliths from the 2021 survey are still to be analysed. Age-length data will be updated for the 2021 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 east coast of Northern Ireland.

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 ~15% age 0, 32% age 1, ~36% age 2, ~14% age 3, ~2% age 4 and 2% age 5+.

4. DISCUSSION

The herring stock estimate in the survey area (Irish Sea/North Channel) was estimated to be 99,589t 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 east coast of Northern Ireland. (western side of stratum 7 and northern end stratum 3 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 64,271t is within the observed range for the time series and the biomass estimate of 98,277t 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), off the east coast of Northern Ireland (strata 3) 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 early October 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

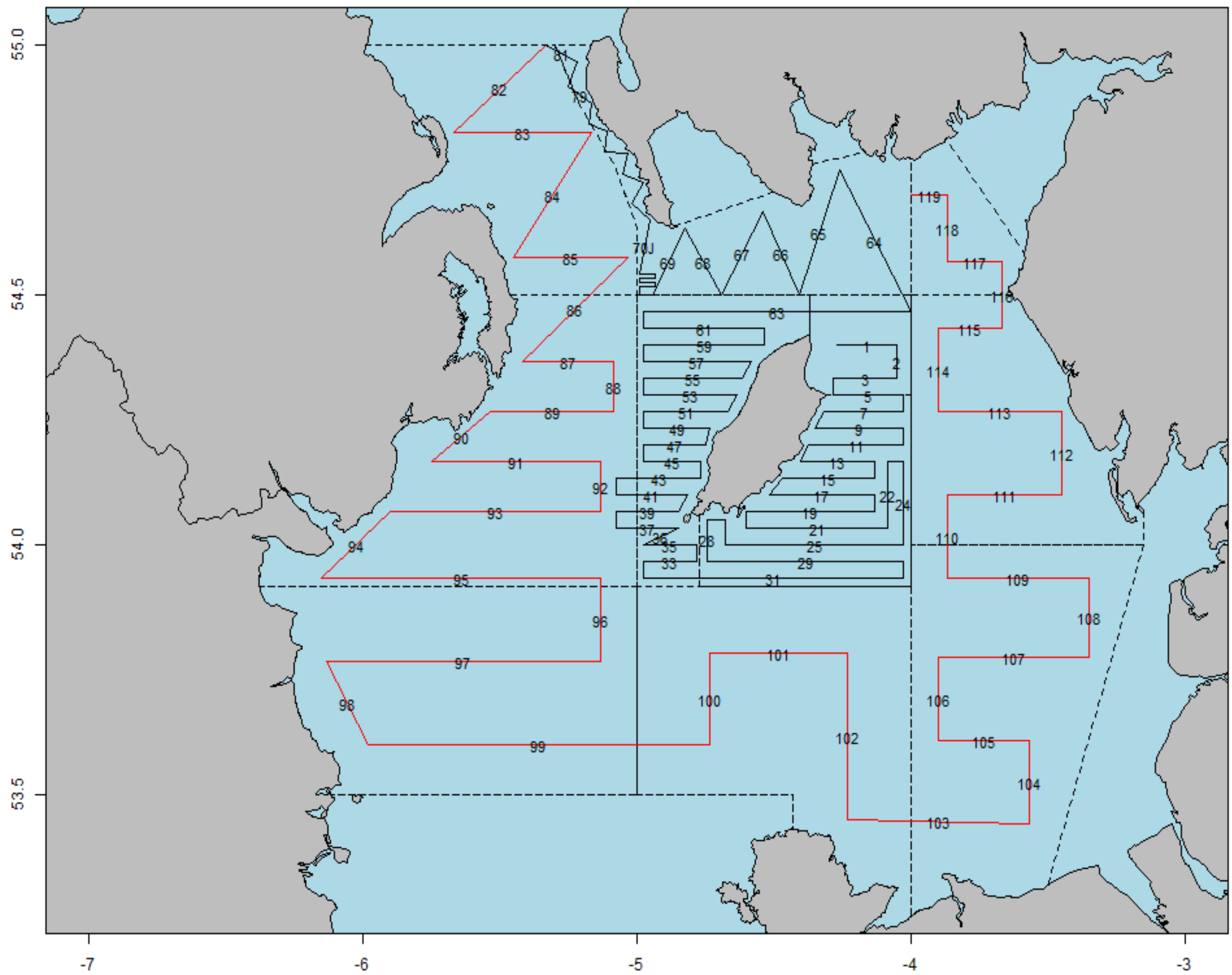


Figure 5B.1: Acoustic survey tracks for the 2021 Irish Sea acoustic survey. Survey design of systematic, parallel transects covers approximately 620 nm

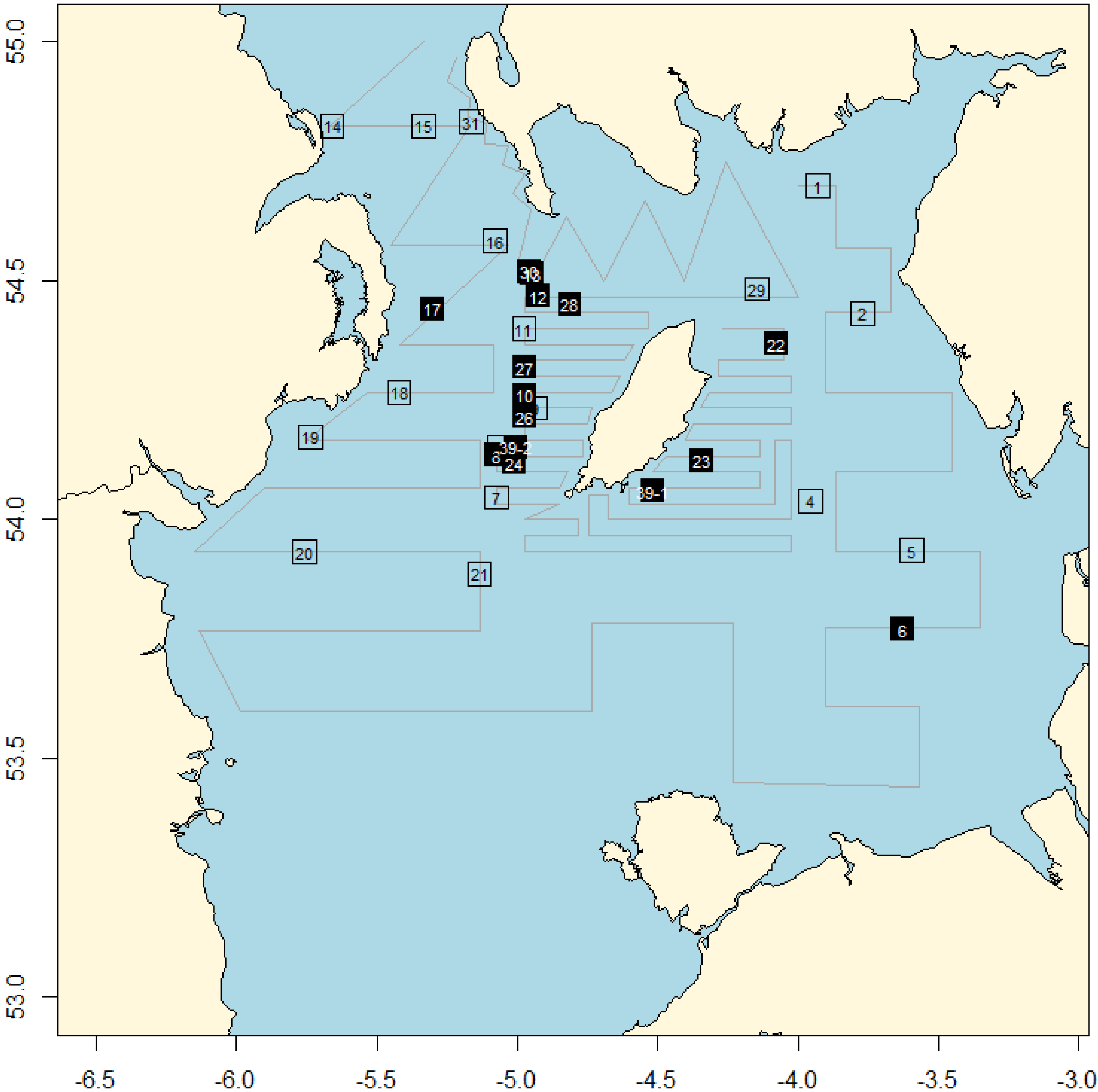
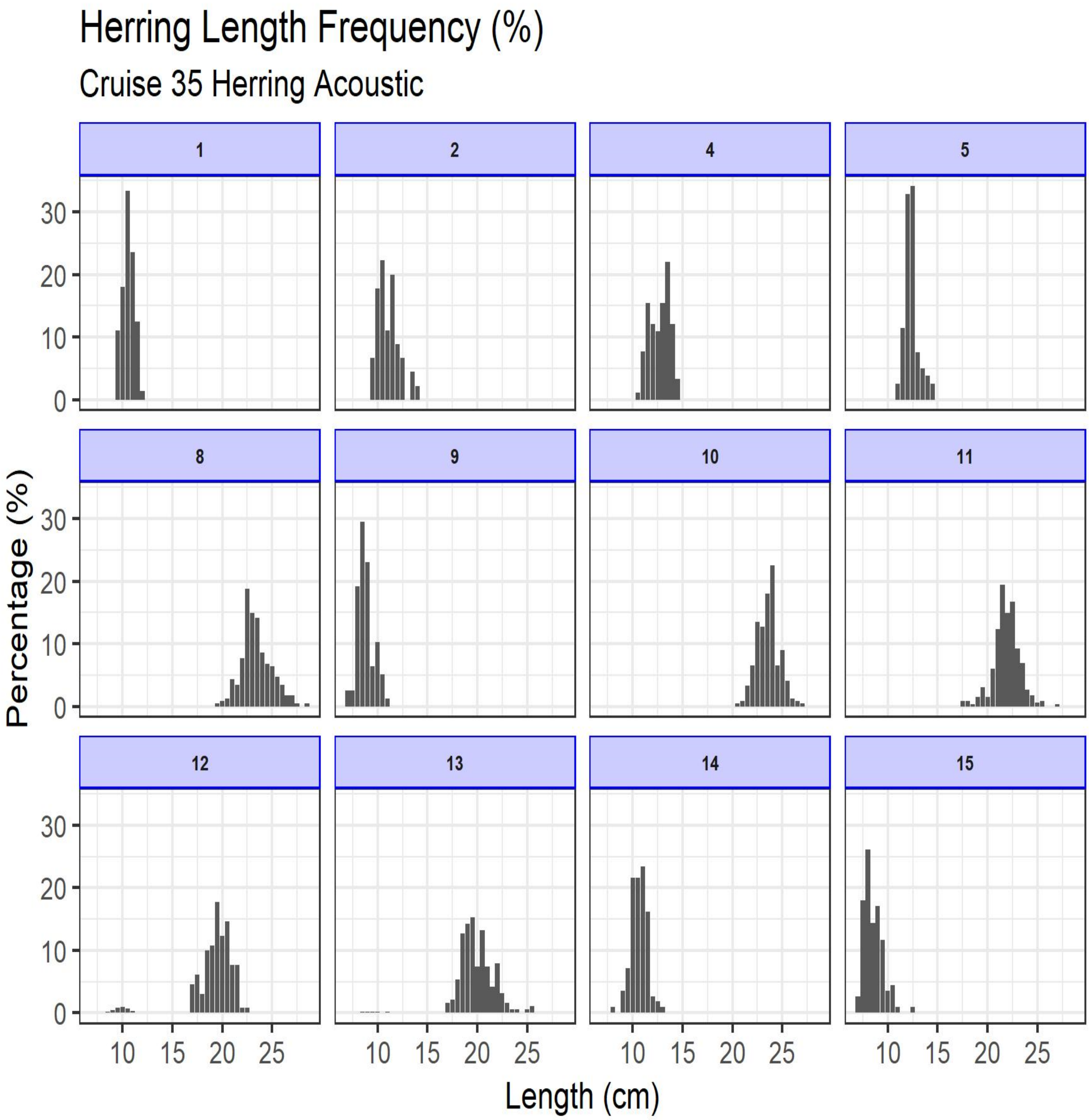


Figure 5B.2 Acoustic survey tracks with trawl positions of the 2021 Irish Sea and North Channel survey on RV "Corystes". Filled squares indicate trawls in which significant numbers of herring were caught or trawls with a high proportion of herring, while open squares indicate trawls with few or no herring.


Herring Length Frequency (%)
Cruise 35 Herring Acoustic
1
2
4
5
8
9
10
11
12
13
14
15
Percentage (%)
0
10
20
30
10
15
20
25
Length (cm)

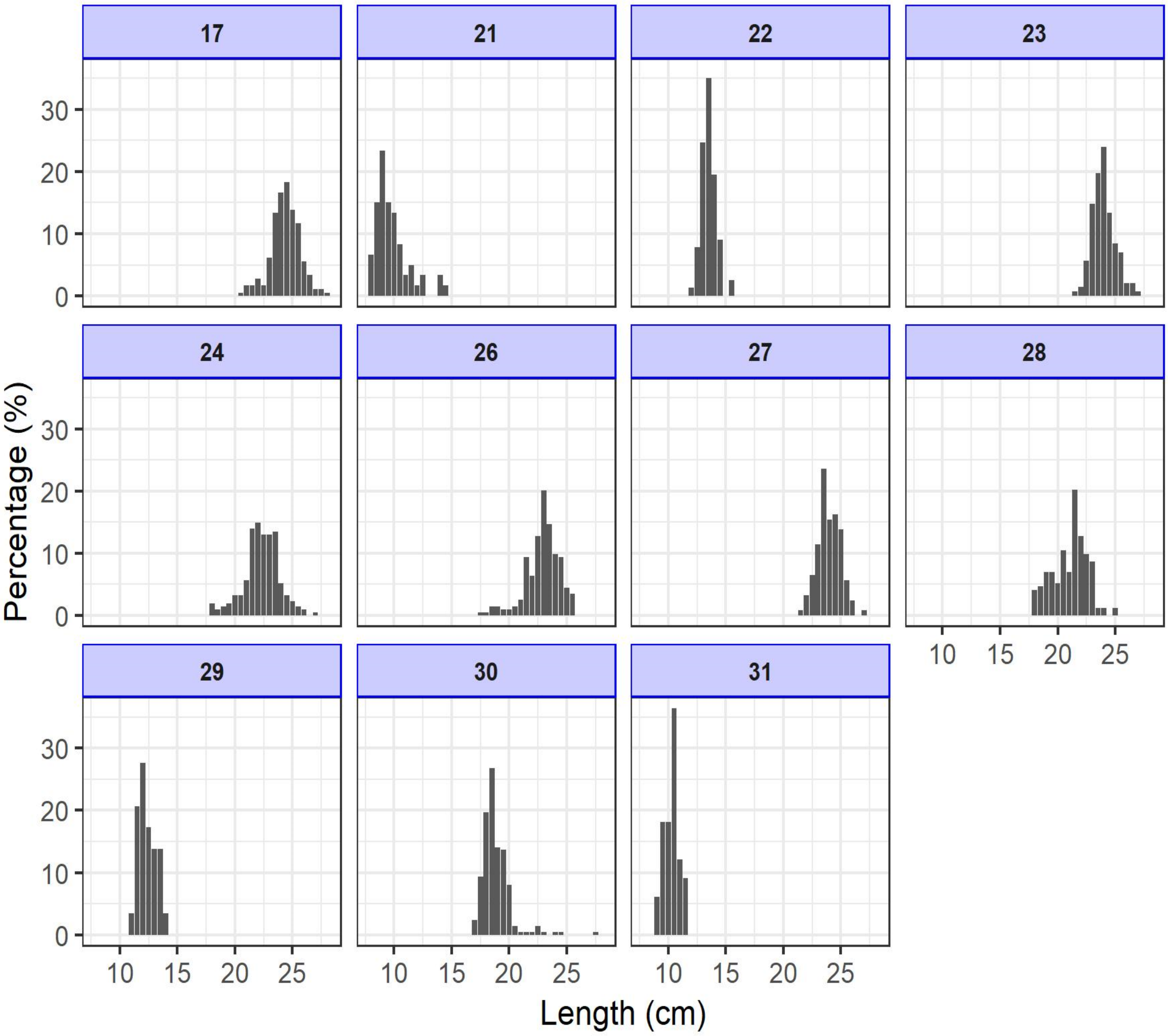


Figure 5B.3: Percentage length compositions of herring in each trawl sample in the 2021 Irish Sea and North Channel acoustic survey on RV "Corystes".

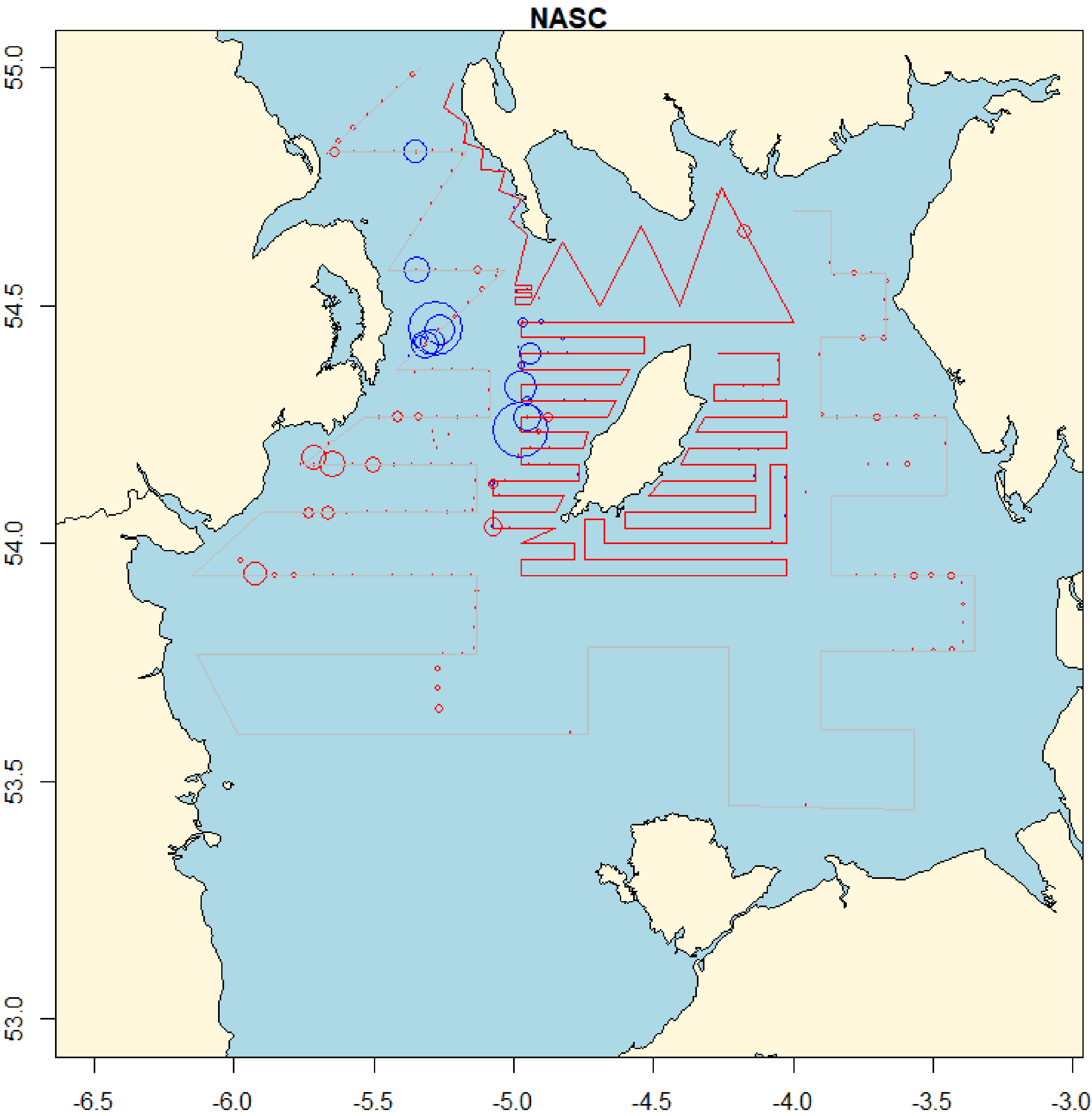


Figure 5B.4: Map of the Irish Sea and North Channel with a post plot showing the distribution of NASC values (size of elipses is proportional to square root of the NASC value per 15-minute interval) obtained during the 2021 acoustic survey on RV "Corystes". (a) Open blue circles are for herring NASC values (maximum value was 103526 and (b) open red circles are for clupeoid mix NASC, which include juvenile herring and sprat (maximum value was 4925).

Table 5B.1: Simrad EK60 and analysis settings used on the 2020 and 2021 Irish Sea and North Channel herring acoustic survey on RV "Corystes"

TRANSCEIVER MENU		
Year	2020	2021
Frequency	38 kHz	38 kHz
Sound speed	1511.6m.s^{-1}	1508.1m.s^{-1}
Max. Power	2000 W	2000 W
Default Transducer Sv gain	26.65dB	26.81dB
Athw. Beam Angle Athw. Offset Angle Along. Beam Angle Along. Offset Angle	6.95 deg 0.00 deg 6.90 deg 0.00 deg	6.98 deg 0.01 deg 6.97 deg 0.01 deg
Calibration details		
TS of sphere	-33.6 dB	-33.6 dB
Range to sphere in calibration	11.5 m	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 2021.

		Shooting details.						Total	Percentage composition of fish by weight.							Mean length (cm)	
Tow	Date	Time	Lat.		Long.		Depth (m)	Catch kg	herring	sprat	mackrel	scad	anchovy	whiting	other fish	herring	sprat
1	29/08/2021	07:13	54	41.900	3	55.746	27.19	122	2.10	98.07	0.00	0.00	0.00	0.03	0.00	11	7.5
2	29/08/2021	10:57	54	25.888	3	46.275	24.8	97	0.43	98.79	0.25	0.01	0.11	0.01	0.00	11.8	10.6
4	29/08/2021	20:33	54	2.349	3	57.220	44.71	7	47.06	54.51	0.00	0.01	0.00	0.00	0.07	12.7	12.3
5	30/08/2021	09:56	53	56.081	3	35.758	24.76	5	78.72	12.16	1.02	1.00	3.50	0.00	2.20	13	7.7
6	30/08/2021	12:46	53	46.183	3	37.694	36.3	0.339	20.94	0.00	66.67	10.91	0.00	1.47	0.00	16.6	
7	01/09/2021	08:08	54	2.794	5	4.533	62.4	97	0.02	99.69	0.00	0.00	0.00	0.00	0.00	9.2	6.7
8	01/09/2021	11:26	54	8.097	5	4.354	94.9	400	99.74	0.00	0.00	0.00	0.00	0.20	0.06	23.6	
9	01/09/2021	17:54	54	14.002	4	56.105	81.89	19	9.62	85.51	3.85	0.00	0.00	0.00	0.00	9.3	7.6
10	01/09/2021	18:53	54	15.642	4	58.362	101	570	100.00	0.00	0.00	0.00	0.00	0.00	0.00	24	
11	02/09/2021	00:20	54	23.953	4	58.529	139	317	94.04	0.00	0.00	0.00	0.00	2.88	3.08	22.2	
12	02/09/2021	06:30	54	28.044	4	55.522	75.34	253	99.18	0.00	0.00	0.00	0.00	0.43	0.22	16.8	
13	03/09/2021	21:46	54	30.909	4	56.789	84.2	246	88.33	0.00	0.67	0.00	0.00	1.62	9.39	21.2	
14	03/09/2021	08:43	54	49.455	5	39.520	105.74	5	23.04	81.26	0.00	0.00	0.00	0.18	0.00	10.9	10.1
15	03/09/2021	10:44	54	49.459	5	19.980	203	136	22.31	77.03	0.03	0.00	0.00	0.57	0.04	9.6	8.7
16	03/09/2021	19:39	54	34.948	5	4.795	150.6	41	0.00	99.39	0.00	0.00	0.00	0.00	0.00		7.9
17	04/09/2021	08:16	54	26.485	5	18.006	114.1	650	91.33	0.00	0.00	0.00	0.00	6.43	2.26	24	
18	04/09/2021	11:47	54	15.989	5	25.211	43.4	41	0.00	99.15	0.00	0.00	0.00	0.08	0.00		6.9
19	04/09/2021	14:23	54	10.412	5	44.046	20.6	38	0.00	100.66	0.00	0.00	0.00	0.00	0.00		8.5
20	05/09/2021	10:44	53	55.953	5	45.309	54.8	90	0.00	99.94	0.00	0.00	0.00	0.00	0.00	9.2	7
21	05/09/2021	13:36	53	53.229	5	8.051	61.87	220	0.18	99.09	0.03	0.00	0.00	0.00	0.47	11.1	8.5
22	06/09/2021	14:14	54	22.067	4	4.566	23.3	70	96.18	0.00	1.72	0.04	0.00	0.08	0.55	14.4	
23	08/09/2021	22:28	54	7.406	4	20.427	31.5	36	49.17	0.00	44.17	0.07	0.00	1.41	4.12	23.9	
24	08/09/2021	05:34	54	7.080	5	0.667	65.23	120	100.00	0.00	0.00	0.00	0.00	0.20	0.11	22.2	
26	08/09/2021	10:13	54	12.900	4	58.496	86	1021	97.94	0.00	0.00	0.00	0.00	0.97	1.09	9.3	6.2
27	08/09/2021	16:02	54	19.065	4	58.466	106	551	99.82	0.00	0.00	0.00	0.00	0.00	0.24	219.2	
28	09/09/2021	23:43	54	27.063	4	48.680	60	370	69.57	0.00	0.00	0.00	0.00	0.00	30.56	24.3	
29	09/09/2021	07:21	54	28.944	4	8.755	44.8	340	1.57	98.43	0.00	0.00	0.00	0.04	0.04	21.7	
30	09/09/2021	17:15	54	31.130	4	57.384	82.47	181	99.45	0.00	0.29	0.00	0.00	0.19	0.01	12.4	12.3
31	09/09/2021	22:28	54	49.971	5	9.793	41.4	131	0.80	98.44	0.00	0.00	0.00	0.89	0.00	20.6	

Table 5B.3: Preliminary age-length key for herring from which otoliths were removed at sea during the Irish Sea/North Channel survey 2020. 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	4	0	0	0	0	0	0	0	7
16	1	9	0	0	0	0	0	0	0	10
16.5	2	14	0	0	0	0	0	0	0	16
17	0	34	0	0	0	0	0	0	0	34
17.5	0	31	0	0	0	0	0	0	0	31
18	0	39	0	0	0	0	0	0	0	39
18.5	0	37	0	0	0	0	0	0	0	37
19	0	29	0	0	0	0	0	0	0	29
19.5	0	25	5	0	0	0	0	0	0	30
20	0	20	9	0	0	0	0	0	0	29
20.5	0	21	12	0	0	0	0	0	0	33
21	0	10	17	0	0	0	0	0	0	27
21.5	0	11	23	0	0	0	0	0	0	34
22	0	0	24	0	0	0	0	0	0	24
22.5	0	0	26	1	0	0	0	0	0	27
23	0	0	30	0	1	0	0	0	0	31
23.5	0	0	19	4	1	0	0	0	0	24
24	0	0	14	6	0	1	0	0	0	21
24.5	0	0	12	8	2	3	0	0	0	25
25	0	0	2	9	4	4	1	0	0	20
25.5	0	0	1	11	4	9	0	0	0	25
26	0	0	0	2	7	7	4	0	0	20
26.5	0	0	0	1	3	10	4	0	0	18
27	0	0	0	0	2	7	2	2	1	14
27.5	0	0	1	0	0	6	2	2	1	12
28	0	0	0	0	0	3	2	1	0	6
28.5	0	0	0	0	1	0	1	0	1	3
29	0	0	0	0	0	0	0	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 2021.

Stratum	No. sprat	Biomass sprat	No. Her	Biomass Her
1	2462346	7117	364093	21649
2	5903	18	17128	982
3	7588412	22092	286715	27227
4	8252534	23696	95	0
5	784811	2365	112554	643
6	1278637	4764	5136	43
7	724282	1753	387034	35830
8	73241	256	420	3
9	10348	36	7255	650
10	3064546	10702	17577	143
11	123214	354	1	0
12	3219905	11245	18468	150
13	0	0	95271	12268
Totals	27588179	84398	1311748	99589

Annex 9: 2021 ISSS Survey Summary Table and Survey Report

Document 9a: ISSS 2021 survey summary table

Survey Summary table WGIPS 2022	
Name of the survey (abbreviation):	**Irish Sea Acoustic Spawning Survey (ISSS)**
Target Species:	**Herring**
Survey dates:	**03th October – 07th October 2021**
Summary:	
The Irish Sea Acoustic Spawning Survey (ISSS) 2020 was conducted on the FV Haviliah. The vessel departed Belfast at 0400 on the 03rd October and proceeded to the east coast of the Isle of Man The survey starting on transect 1 to the northeast of The Isle of Man on the 03rd October at 12:47 proceeding through to the end of transect 81 on the 06th October at 02:35, with the ship returning to Belfast at 20:00 on the 07th October. Sea conditions were variable during the survey but not severe enough to prevent full completion of survey grid without interruption. Targets were identified by aimed midwater trawls, 2 successful tows were completed in 2021, which is consistent 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 2021 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 0 accounting for 41% of total estimates by number. (~10% age 1, 29% age 2, 15% age 3, 2% age 4, 3% age 5+)	
	Description
Survey design	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.

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 but not severe enough to prevent full completion of survey grid without interruption.
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	Two 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 07th October 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. 2021 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. 2021 survey: No additional issues
Measures of uncertainty (CV)	CV of biomass and numbers at age
Biological sampling	2021 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 2020 are used for initial biomass estimates and population age structure.

Document 9b: ISSS 2021 survey report

*Please find report on the next page.

Irish Sea commercial acoustic survey (Northern Ireland)

Survey report for FV Haviliah

03rd October – 07th October 2021

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)
Ian McCausland
Conor Sloan

2.2 Narrative

The Irish Sea Acoustic Spawning Survey (ISSS) 2020 was conducted on the FV Haviliah. The vessel departed Belfast at 0400 on the 03rd October and proceeded to the east coast of the Isle of Man The survey starting on transect 1 to the northeast of The Isle of Man on the 03rd October at 12:47 proceeding through to the end of transect 81 on the 06th October at 02:35, with the ship returning to Belfast at 20:00 on the 07th October. Sea conditions were variable during the survey but not severe enough to prevent full completion of survey grid without interruption.

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 07th October 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 31 successful trawls completed, an additional 2 trawls were successfully completed during the 2021 Irish Sea Acoustic Spawning Survey Figure 5B.2. Table 5B.2 gives the positions, catch composition and mean length by species for the 31 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 2 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 70,859t

4. DISCUSSION

The herring stock estimate for the Irish Sea commercial survey area was estimated to be 94,252t. The major contribution of ages to the total estimates is from ages 0 fish by number and 2 by 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 2021 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 70,859t and biomass estimate of 89,416t for 1+ ringers for 2021 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

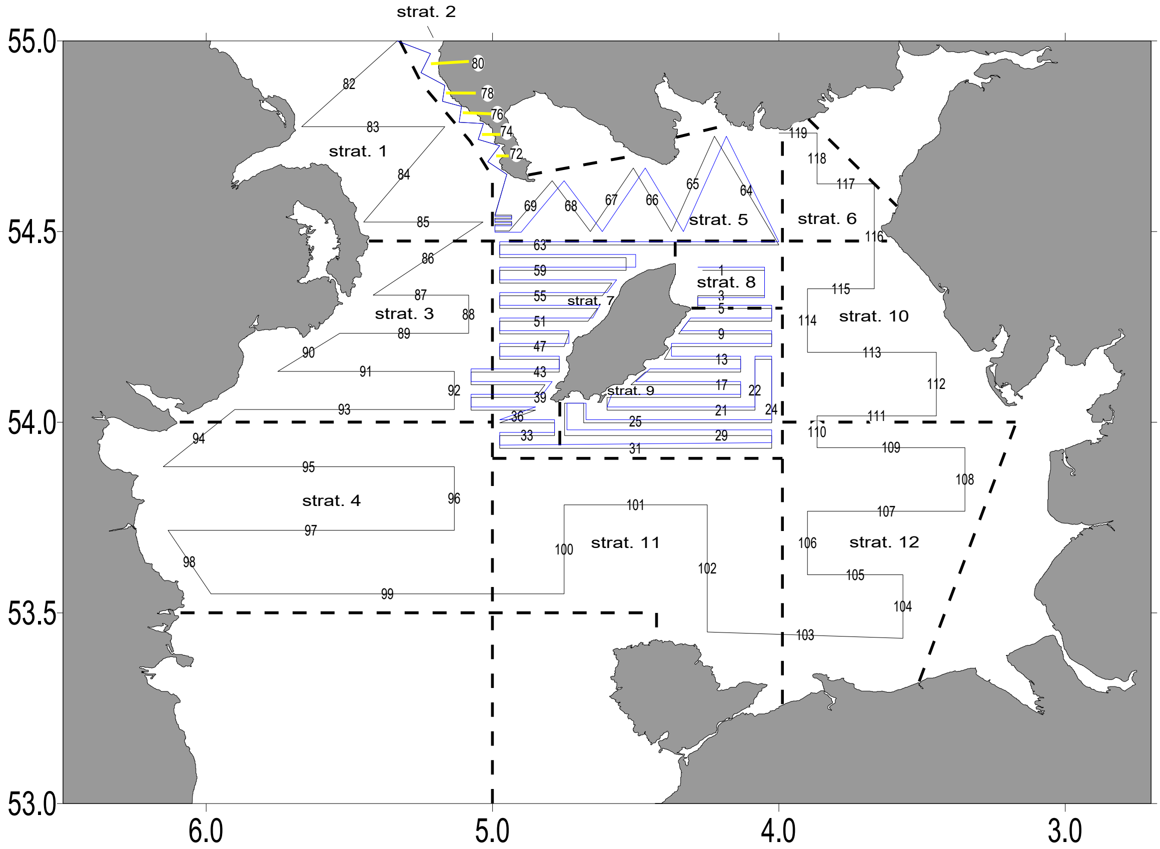


Figure 5B.1: Acoustic survey tracks (highlighted in blue) for the 2021 Irish Sea acoustic survey. Survey design of systematic, parallel transects covers approximately 620nm.

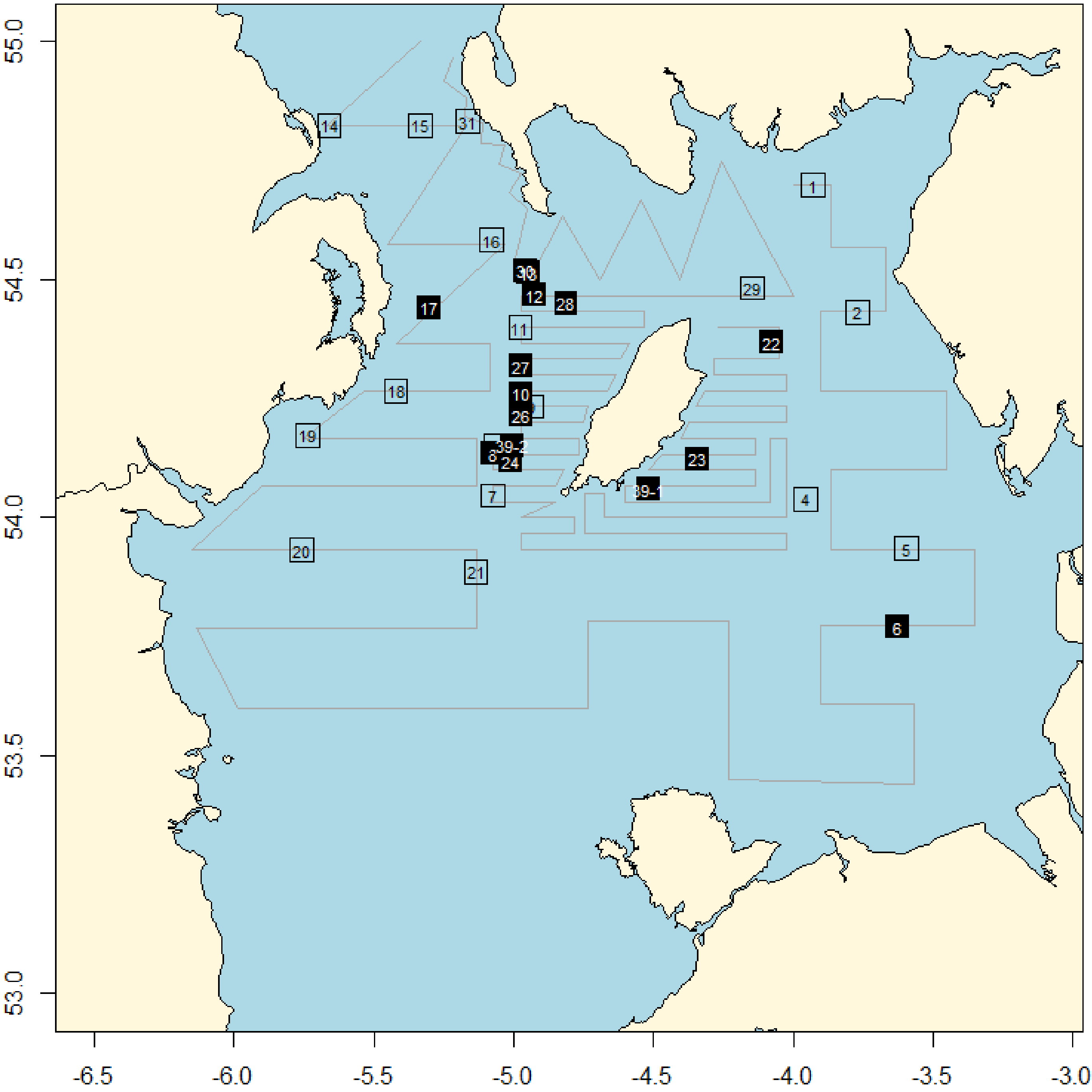
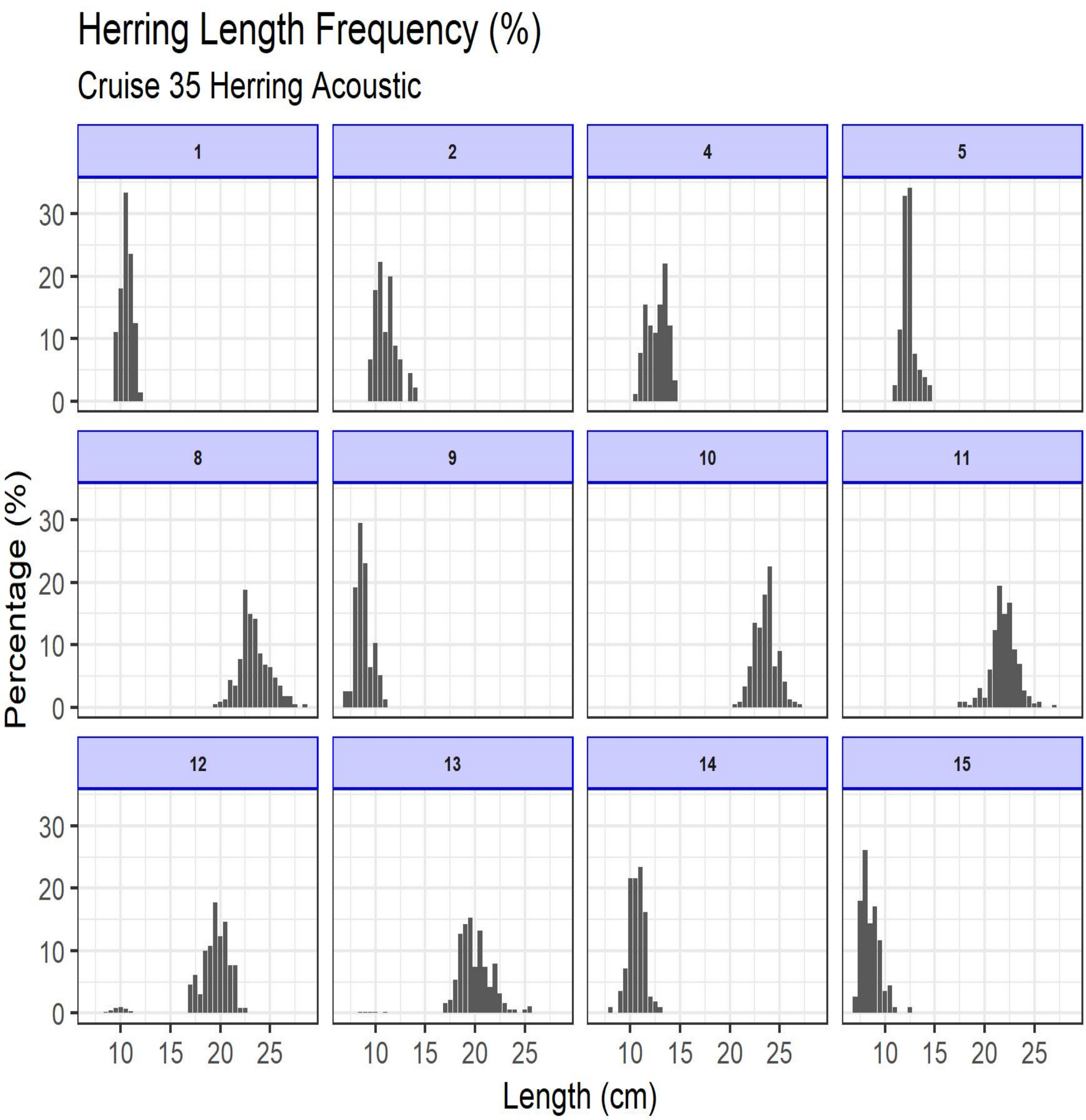


Figure 5B.2 Acoustic survey tracks with trawl positions of the 2021 Irish Sea and North Channel survey on FV "Haviliah" and 2021 Irish Sea and North Channel commercial survey on RV "Corystes". Filled squares indicate trawls in which significant numbers of herring were caught or trawls with a high proportion of herring, while open squares indicate trawls with few or no herring.


Herring Length Frequency (%)
Cruise 35 Herring Acoustic
1
2
4
5
8
9
10
11
12
13
14
15
Percentage (%)
0
10
20
30
10
15
20
25
Length (cm)

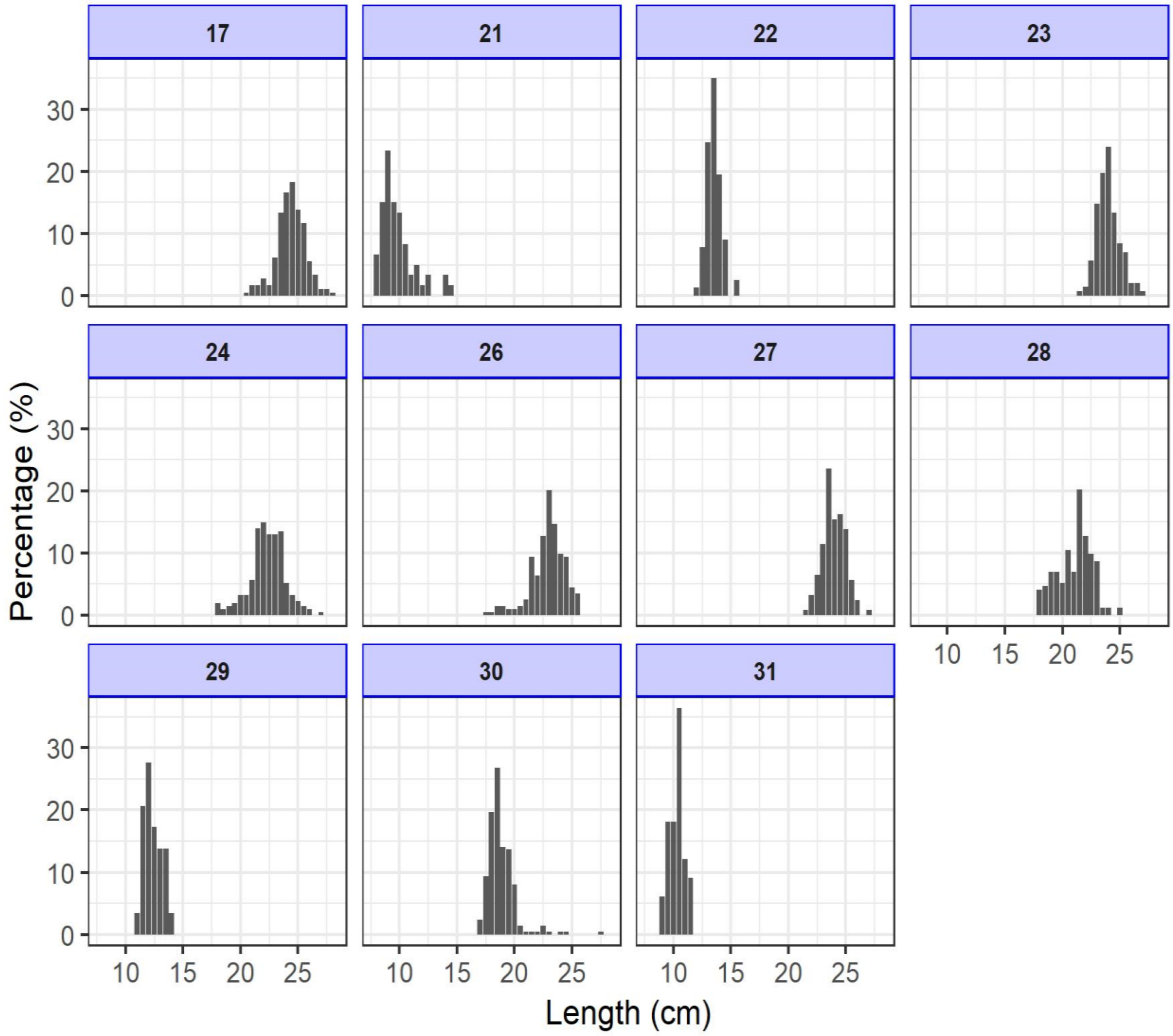
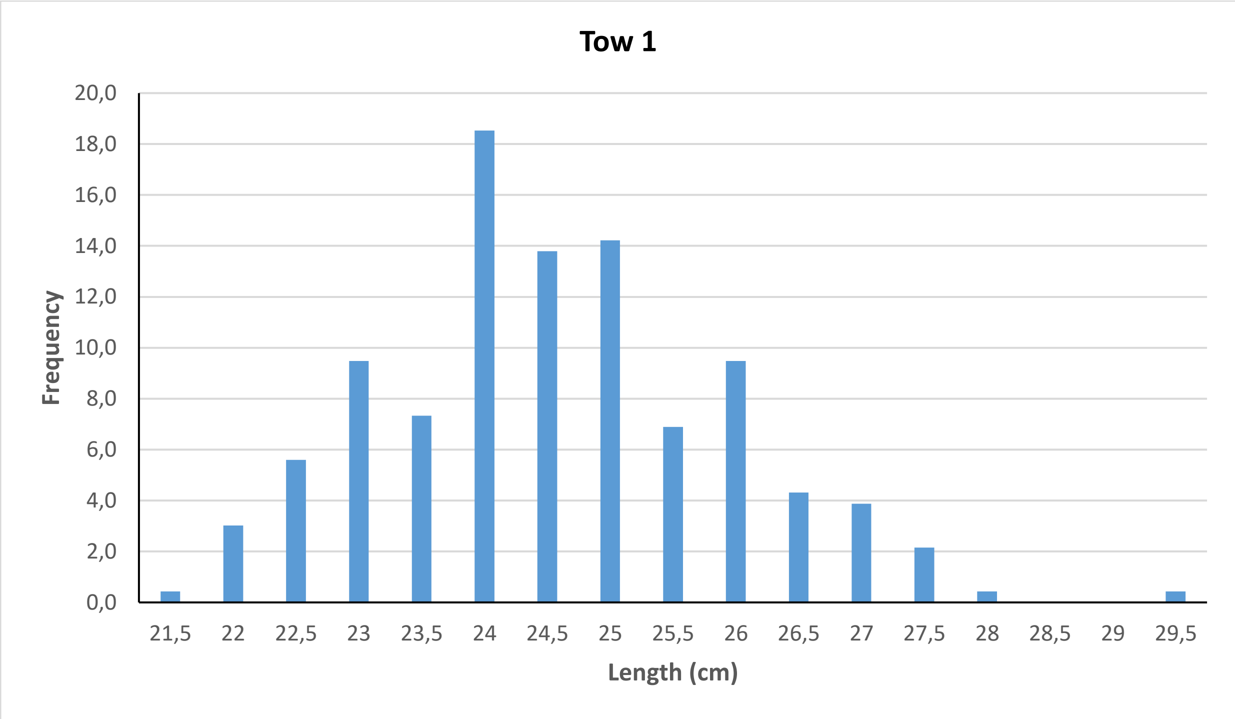


Figure 5B.3: Percentage length compositions of herring in each trawl sample in the August/September 2021 Irish Sea and North Channel acoustic survey on RV "Corystes".

Herring Length frequency (%)
Cruise 39 Herring Acoustic



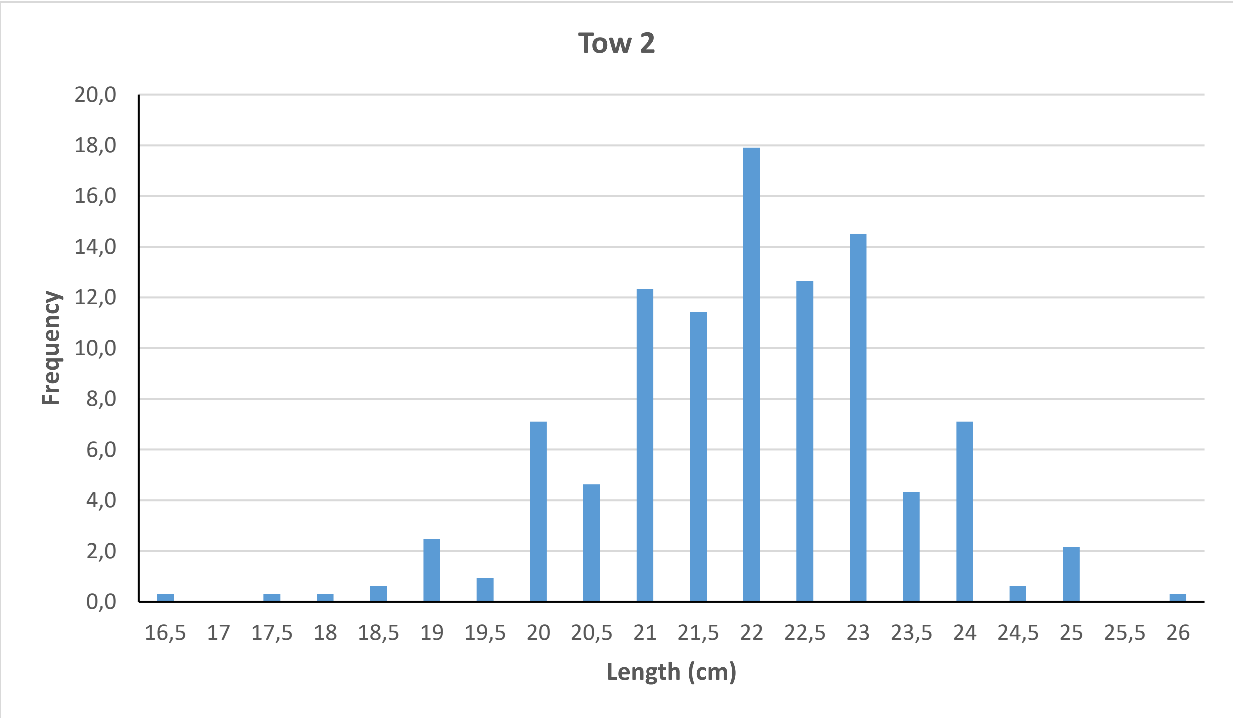


Figure 5B.4: Percentage length compositions of herring in each trawl sample in the 2021 Irish Sea and North Channel commercial acoustic survey on the FV "Haviliah".

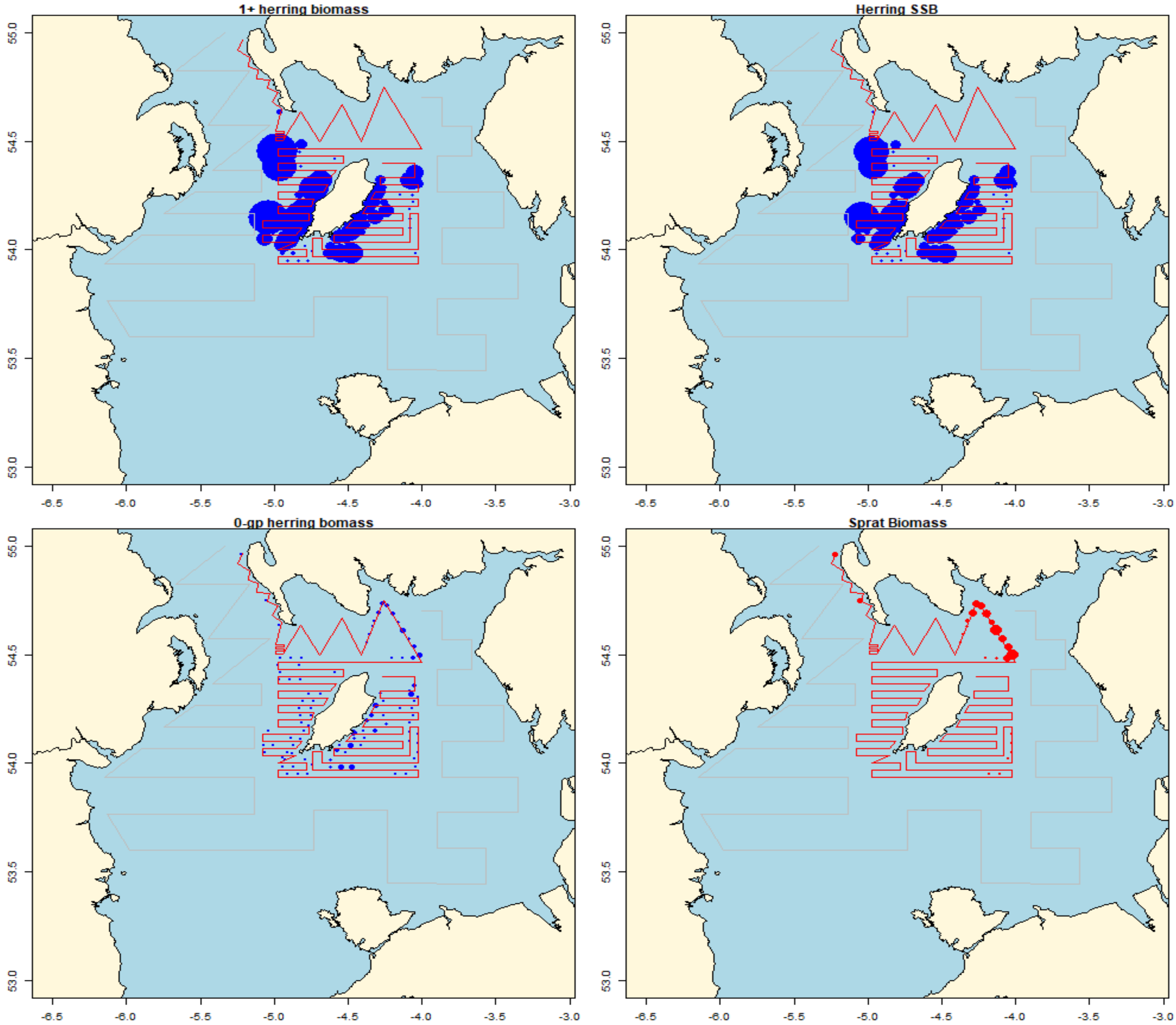


Figure 5B.5: Map of the Irish Sea and North Channel with a post plot showing the distribution of NASC values (size of elipses is proportional to square root of the NASC value per 15-minute interval) obtained during the 2021 commercial acoustic survey on FV "Haviliah". (a) Solid blue circles are for herring 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 2020 and 2021 Irish Sea and North Channel herring acoustic survey.

TRANSCEIVER MENU		
Year	2020	2021
Frequency	38 kHz	38 kHz
Sound speed	1504.4m.s^{-1}	1504.0 m.s^{-1}
Max. Power	2000 W	2000 W
Default Transducer Sv gain	26.96dB	26.90 dB
Athw. Beam Angle Athw. Offset Angle Along. Beam Angle Along. Offset Angle	6.98 deg -0.05 deg 6.97 deg -0.00 deg	6.98 deg -0.06 deg 6.99 deg -0.01 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 2021.

		Shooting details.						Total	Percentage composition of fish by weight.							Mean length (cm)	
Tow	Date	Time	Lat.		Long.		Depth (m)	Catch kg	herring	sprat	mackrel	scad	anchovy	whiting	other fish	herring	sprat
1	29/08/2021	07:13	54	41.900	3	55.746	27.19	122	2.10	98.07	0.00	0.00	0.00	0.03	0.00	11	7.5
2	29/08/2021	10:57	54	25.888	3	46.275	24.8	97	0.43	98.79	0.25	0.01	0.11	0.01	0.00	11.8	10.6
4	29/08/2021	20:33	54	2.349	3	57.220	44.71	7	47.06	54.51	0.00	0.01	0.00	0.00	0.07	12.7	12.3
5	30/08/2021	09:56	53	56.081	3	35.758	24.76	5	78.72	12.16	1.02	1.00	3.50	0.00	2.20	13	7.7
6	30/08/2021	12:46	53	46.183	3	37.694	36.3	0.339	20.94	0.00	66.67	10.91	0.00	1.47	0.00	16.6	
7	01/09/2021	08:08	54	2.794	5	4.533	62.4	97	0.02	99.69	0.00	0.00	0.00	0.00	0.00	9.2	6.7
8	01/09/2021	11:26	54	8.097	5	4.354	94.9	400	99.74	0.00	0.00	0.00	0.00	0.20	0.06	23.6	
9	01/09/2021	17:54	54	14.002	4	56.105	81.89	19	9.62	85.51	3.85	0.00	0.00	0.00	0.00	9.3	7.6
10	01/09/2021	18:53	54	15.642	4	58.362	101	570	100.00	0.00	0.00	0.00	0.00	0.00	0.00	24	
11	02/09/2021	00:20	54	23.953	4	58.529	139	317	94.04	0.00	0.00	0.00	0.00	2.88	3.08	22.2	
12	02/09/2021	06:30	54	28.044	4	55.522	75.34	253	99.18	0.00	0.00	0.00	0.00	0.43	0.22	16.8	
13	03/09/2021	21:46	54	30.909	4	56.789	84.2	246	88.33	0.00	0.67	0.00	0.00	1.62	9.39	21.2	
14	03/09/2021	08:43	54	49.455	5	39.520	105.74	5	23.04	81.26	0.00	0.00	0.00	0.18	0.00	10.9	10.1
15	03/09/2021	10:44	54	49.459	5	19.980	203	136	22.31	77.03	0.03	0.00	0.00	0.57	0.04	9.6	8.7
16	03/09/2021	19:39	54	34.948	5	4.795	150.6	41	0.00	99.39	0.00	0.00	0.00	0.00	0.00		7.9
17	04/09/2021	08:16	54	26.485	5	18.006	114.1	650	91.33	0.00	0.00	0.00	0.00	6.43	2.26	24	
18	04/09/2021	11:47	54	15.989	5	25.211	43.4	41	0.00	99.15	0.00	0.00	0.00	0.08	0.00		6.9
19	04/09/2021	14:23	54	10.412	5	44.046	20.6	38	0.00	100.66	0.00	0.00	0.00	0.00	0.00		8.5
20	05/09/2021	10:44	53	55.953	5	45.309	54.8	90	0.00	99.94	0.00	0.00	0.00	0.00	0.00	9.2	7
21	05/09/2021	13:36	53	53.229	5	8.051	61.87	220	0.18	99.09	0.03	0.00	0.00	0.00	0.47	11.1	8.5
22	06/09/2021	14:14	54	22.067	4	4.566	23.3	70	96.18	0.00	1.72	0.04	0.00	0.08	0.55	14.4	
23	08/09/2021	22:28	54	7.406	4	20.427	31.5	36	49.17	0.00	44.17	0.07	0.00	1.41	4.12	23.9	
24	08/09/2021	05:34	54	7.080	5	0.667	65.23	120	100.00	0.00	0.00	0.00	0.00	0.20	0.11	22.2	
26	08/09/2021	10:13	54	12.900	4	58.496	86	1021	97.94	0.00	0.00	0.00	0.00	0.97	1.09	9.3	6.2
27	08/09/2021	16:02	54	19.065	4	58.466	106	551	99.82	0.00	0.00	0.00	0.00	0.00	0.24	219.2	
28	09/09/2021	23:43	54	27.063	4	48.680	60	370	69.57	0.00	0.00	0.00	0.00	0.00	30.56	24.3	
29	09/09/2021	07:21	54	28.944	4	8.755	44.8	340	1.57	98.43	0.00	0.00	0.00	0.04	0.04	21.7	
30	09/09/2021	17:15	54	31.130	4	57.384	82.47	181	99.45	0.00	0.29	0.00	0.00	0.19	0.01	12.4	12.3
31	09/09/2021	22:28	54	49.971	5	9.793	41.4	131	0.80	98.44	0.00	0.00	0.00	0.89	0.00	20.6	

Table 5B.3: Catch composition and position of hauls undertaken by the FV "Haviliah" during the Irish Sea/North Channel commercial survey, October 2021.

Tow	Date	Shooting details.				Total	Percentage composition of fish by weight,							Mean length (cm)	
		Time	Lat.	Long.	Depth (m)	catch (kg)	sprat	herring	mackerel	scad	anchovy	whiting	other fish	sprat	herring
1	04/10/2021	02:10	54 03.620	04 30.996	31	10 000	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	24.0
2	04/10/2021	21:31	54 09.081	05 00.397	86	1 000	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	22.0

Table 5B.4: Preliminary age-length key for herring from which otoliths were removed at sea during the Irish Sea/ North Channel survey 2020. 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	4	0	0	0	0	0	0	0	7
16	1	9	0	0	0	0	0	0	0	10
16.5	2	14	0	0	0	0	0	0	0	16
17	0	34	0	0	0	0	0	0	0	34
17.5	0	31	0	0	0	0	0	0	0	31
18	0	39	0	0	0	0	0	0	0	39
18.5	0	37	0	0	0	0	0	0	0	37
19	0	29	0	0	0	0	0	0	0	29
19.5	0	25	5	0	0	0	0	0	0	30
20	0	20	9	0	0	0	0	0	0	29
20.5	0	21	12	0	0	0	0	0	0	33
21	0	10	17	0	0	0	0	0	0	27
21.5	0	11	23	0	0	0	0	0	0	34
22	0	0	24	0	0	0	0	0	0	24
22.5	0	0	26	1	0	0	0	0	0	27
23	0	0	30	0	1	0	0	0	0	31
23.5	0	0	19	4	1	0	0	0	0	24
24	0	0	14	6	0	1	0	0	0	21
24.5	0	0	12	8	2	3	0	0	0	25
25	0	0	2	9	4	4	1	0	0	20
25.5	0	0	1	11	4	9	0	0	0	25
26	0	0	0	2	7	7	4	0	0	20
26.5	0	0	0	1	3	10	4	0	0	18
27	0	0	0	0	2	7	2	2	1	14
27.5	0	0	1	0	0	6	2	2	1	12
28	0	0	0	0	0	3	2	1	0	6
28.5	0	0	0	0	1	0	1	0	1	3
29	0	0	0	0	0	0	0	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 2021.

Stratum	No. sprat	Biomass sprat	No. Her	Biomass Her
2	220137	636	5872	335
3	0	0	95261	9256
5	2811945	8472	403275	2305
7	0	0	521409	50665
8	401556	1210	117247	5715
9	21744	76	287817	25976
Total	3455383	10395	1430880	94252

Annex 10: 2021 CSHAS Survey Summary Table and Survey Report

Document 10a: CSHAS 2021 survey summary table

Survey Summary table WGIPS 2021	
Name of the survey (abbreviation):	Celtic Sea Herring Acoustic Survey (CSHAS) 2021
Target Species:	Herring (7aS, 7g-j) and sprat (7aS, 7g-j)
Survey dates:	08 October – 28 October, 2021
Summary:	**Cruise Report Link:** http://hdl.handle.net/10793/1732
The objectives of the survey were carried out successfully and as planned. Approximately 12 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 comparable to 2020 (2%) and acoustic sampling effort or survey miles increased (15%). Offshore areas were covered comprehensively with replicate and adaptive survey effort, including the western Celtic Deep and Trench area. Mature fish were observed offshore in a discreet location and persisted at this site for several weeks pre-survey.Mature fish were also observed within the Waterford estuary. Immature herring (0-wr) were well represented in the wider survey area. The age profile of herring taken from the survey catches were representative of thse observed from landings data and from observations during WESPAS 2021. The 2021 TSB estimate (Pass 1) is 9,877.2 t and 310 million individuals (CV 0.44) and an increase on the 2020 estimate (4,716.8 t and a total abundance of 67.3 million individuals). Age composition was dominated by 3-wr, 0-wr, 2-wr and 4-wr fish respectively by weight. The dominant 3-wr fish contributed 43.1% to the TSB and 11.4% TSN. Immature 0-wr fish accounted for 32.5% of TSB and 81.4% of TSN. Two-wr fish made up 17.4% of TSB and 5.5% of TSN followed by 4.3% of TSB and 1.1% of TSN for 4-wr fish. The biomass of sprat was higher than observed in 2020 but is considered an underestimate due to inshore containment. For the second consecutive year thehighest densities of sprat were observed close inshore. The 2020 TSB estimate (Pass 1) is 12,375.5 t and 3,018 mil individuals and an increase on the 2020 estimate (4,716.8 t and 67.3 individuals).	
	Description
Survey design	Stratified systematic parallel design with randomised starting point within each stratum. Replicate core surveys and adaptive survey effort. Survey estimate is generated from the same core effort since 2016.
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. Behaviour of offshore aggregations (bottom carpeting) limits effective quantification
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	12 hrs lost due to poor weather and surveying stopped when conditions deteriorated
Extinction (shadowing)	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, an issue during the 2021 survey
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 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	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 uncertainty (CV)	Pass 1: 9,877.2 t (CV abundance: 0.44) Pass 2: 12,199.1 t (CV abundance: 0.67). Calculation carried out using StoX (V3.5) and R-StoX (V1.11)
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 assessment either for the whole times series or	*To be answered by Assessment Working Group*

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*

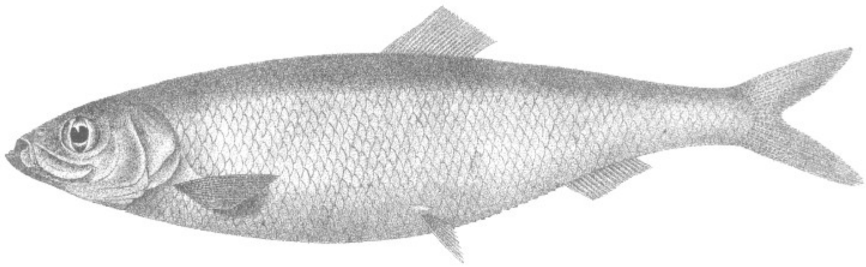
Document 10b: CSHAS 2021 survey report

*Please find report on the next page.

FSS Survey Series: 2021/04

Celtic Sea Herring Acoustic Survey Cruise Report 2021

08 - 28 October, 2021



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Rinville, Oranmore, Co. Galway.

[2]The Marine Institute, Ocean Climate and information Services

[3] Under contract to National Parks and Wildlife Service

Cláir Chistí Eorpacha Struchtúrtha agus Infheistíochta na hÉireann 2014–2020
Cómhaoinithe ag Rialtas na hÉireann agus ag an Aontas Eorpach
An Roinn Talmhaíochta, Bia agus Mara
Department of Agriculture, Food and the Marine
EUROPEAN MARITIME AND FISHERIES FUND

Fisheries Ecosystems Advisory Services

Table of Contents

1 Introduction

In the southwest of Ireland and the Celtic Sea (ICES Divisions VIIaS, g and j), herring are an important commercial species to the pelagic and polyvalent fleet. The local fleet is composed of dry hold polyvalent vessels and a smaller number of large purpose built refrigerated seawater vessels (RSW). The stock is composed of both autumn and winter spawning components with the latter dominating. The fishery targets pre-spawning and spawning aggregations in Q3-4. The Irish commercial fishery has historically taken place within 1-20nmi (nautical miles) of the coast. Since the mid-2000s RSW fleet have actively targeted offshore aggregations migrating from summer feeding in the south Celtic Sea. In VIIj, the fishery is traditionally active from mid-November and is concentrated within several miles of the coast. The VIIaS fishery peaks towards the year end in December, but may be active from mid-October depending on location. In VIIg, along the south coast herring are targeted from October (offshore) to January at a number of known spawning sites and surrounding areas. Overall, the protracted spawning period of the two components extends from October through to February, with annual variation of up to 3 weeks. Spawning occurs in successive waves in a number of well known locations including large scale grounds and small discreet spawning beds. Since 2008 ICES division VIIaS (spawning box C) has been closed to fishing for vessels over 15m to protect first time spawners. For those vessels less than 15m a small allocation of the quota is given to this ‘sentinel’ fishery operating within the closed area.

The stock structure and discrimination of herring in this area has been investigated recently. Hatfield et al. (2007) has shown the Celtic Sea stock to be fairly discrete. However, it is known that fish in the eastern Celtic Sea recruit from nursery areas in the Irish Sea, returning to the Celtic Sea as young adults (Brophy et al. 2002; Molloy et al., 1993). The stock identity of VIIj herring is less clear, though there is evidence that they have linkages with VIIb and VIaS (ICES, 1994; Grainger, 1978). Molloy (1968) identified possible linkages between young fish in VIIj and those of the Celtic Sea herring. For the purpose of stock assessment and management divisions VIIaS, VIIg and VIIj have been combined since 1982.

For a period in the 1970s and 1980s, larval surveys were conducted for herring in this area. However, since 1989, acoustic surveys have been carried out, and currently are the only tuning indices available for this stock. In the Celtic Sea and VIIj, herring acoustic surveys have been carried out since 1989. Since 2004 the survey has been fixed in October and carried out onboard the RV *Celtic Explorer.*

Survey design and geographical coverage have been modified over the time series to adapt to changes in stock size and behaviour. Since 2016, the wider core distribution area has been surveyed by means of two independent surveys and supplemented with small high resolution adaptive surveys focusing on areas of high abundance.

2 Materials and Methods

2.1 Scientific Personnel

Leg	Leg 1	Date	Leg 2	Date
Start	Galway	08.10.21	Dunmore East	18.10.21
End	Dunmore East	18.10.21	Galway	28.10.21

Organisation	Name	Name	Capacity
FEAS	Ciaran O'Donnell	Ciaran O'Donnell	Acou (Chief Sci)
FEAS	Graham Johnston	Graham Johnston	Acou
FEAS	Robert Bunn	Mike O'Malley	Acou
FEAS	Tobi Rapp	Eugene Mullins	Acou
FEAS	Dermot Fee	Dave Tully	Bio (Deck Sci)
FEAS	John Enright	Gráinne Ni Chonchuir	Bio
FEAS	Mairead O'Sullivan	Karl Bently	Bio
Student*	Larence Manning	Rebecca Stokes	Bio
Student	Aylis Emerit	Aylis Emerit	CTD/Zoo
MMO	John Collins	John Collins	MMO
SBO	Niall Keogh	Niall Keogh	SBO

SBO- Seabird observer, MMO- marine mammal observer, *SmartSea student placement

2.2 Survey Plan

2.2.1 Survey objectives

The primary survey objectives are listed below:

- Carry out a two phase survey cruise track covering the core survey area
- Carry out additional adaptive surveys as required in areas of interest
- Collect biological samples from directed trawling on insonified fish echotraces
- Collect biological data on the age, length and maturity of herring and sprat
- Determine an age stratified estimate of relative abundance of herring within the survey area (ICES Divisions VIIj, VIIg and VIIaS)
- Determine an estimate of relative abundance of sprat within the survey area (ICES Divisions VIIj, VIIg and VIIaS)
- Collect physical oceanography data from vertical profiles from a deployed sensor array
- Carry out Zooplankton net sampling to determine dry weight biomass and retain fixed samples for further analysis of species composition.
- Visual surveys to determine the distribution and abundance of apex predators (marine mammals, tuna and seabirds)

2.2.2 Area of operation

The autumn 2021 survey covered the area from Mizen Head and extended along the south coast into the Celtic Sea (Divisions VIIj, VIIg and VIIaS), see Figure 1. The survey worked in an easterly direction covering the larger core survey area during the first pass before turning westwards to complete the second pass using interlaced transects.

The survey was broken into two components. The first used a double survey approach to contain the stock within the core survey area. The second adaptive component focused on high abundance areas of herring identified during the core surveys using higher intensity sampling effort.

2.2.3 Survey design

2.2.3.1 Core survey

In 2016, a change in survey design was implemented by consolidating all existing strata into a single core survey stratum. This broad scale survey composed of 8 nmi (nautical miles) spaced transects. A second pass was then carried out interlacing transects from the previous pass. Interlaced transects providing an effective coverage of 4 nmi resolution. Each pass represents an independent estimate of abundance.

A parallel transect design was applied with transects running perpendicular to the coastline and lines of bathymetry where possible. Offshore extension reached up to 90 nmi. Transect start points within each stratum are randomised each year within established baseline stratum bounds.

In total the core surveys accounted for 1,989 nmi of transects covering an area of over 15,211 nmi^2.

2.2.3.2 Adaptive survey

Adaptive surveys were carried out on areas of interest identified during the core survey.

Arears of specific interest are surveyed using adaptive techniques such as high intensity and/or replicate coverage. Offshore candidate areas were scouted to determine geographical extent of target aggregations where possible. A survey plan was then designed using parallel transects running perpendicular to the lines of bathymetry. Transect spacing is determined on an individual survey basis. The EK60 split beam data is supplemented with either EM2040 bathymetric multibeam data or Omni sonar data (Simrad SU90) to provide increased spatial resolution on the extent of aggregations. Survey design followed methods described in Simmonds and MacLennan (2005) for adaptive surveys. Individual transects were run in parallel crossing the extent of the herring aggregation with the end point determined when no further herring were observed for 0.5 nmi.

Directed fishing trawls and in-trawl optics were used to determine echotrace identification as applied during routine surveying operations.

Six adaptive surveys were carried out (three inshore and three offshore) and accounted for 468 nmi of transects and an area coverage of 1,107 nmi^2. Two scouting surveys were undertaken in the Trench area accounting for 95 nmi of search effort.

2.3 Equipment and system details and specifications

2.3.1 Acoustic array

Equipment settings for the acoustic equipment were determined before the start of the survey program and were based on established settings employed by FEAS on previous surveys (O'Donnell et al*.,* 2004). The acoustic settings for the EK60 38 kHz transducer are shown in Table 1.

Acoustic data were collected using the Simrad EK60 scientific echosounder. The Simrad split-beam transducers are mounted within the vessel's drop keel and lowered to the working depth of 3.3m below the vessel's hull or 8.8m sub surface. Four operating frequencies were used during the survey (18, 38, 120 and 200 kHz) for trace recognition purposes, with the 38 kHz data used to generate the abundance estimate.

While on survey track the vessel is normally propelled using DC twin electric motor propulsion system with power supplied from 1 main diesel engine, so in effect providing "silent cruising" as compared to normal operations (ICES 2002). During fishing operations normal two-engine operations were employed to provide sufficient power to tow the net.

2.3.2 Calibration of acoustic equipment

A calibration of the EK60 was carried out at the beginning of the survey in Dunmanus Bay. The procedure followed methods described by Demer et al. (2015). Calibration results and settings are provided in Table 1.

2.4 Survey protocols

2.4.1 Acoustic data acquisition

The "RAW files" were logged via a continuous Ethernet connection to the vessels server and the ER60 hard drive as a backup in the event of data loss. In addition, as a further back up a hard copy was stored on an external hard drive. Myriax Echoview® live viewer was used to display the echogram during data collection to allow the scientists to scroll through echograms noting the locations and depths of fish shoals. A member of the scientific crew monitored the equipment continually. Time and location (GPS position) data was recorded for each transect within each strata. This log was used to monitor the time spent off track during fishing operations and hydrographic stations plus any other important observations.

2.4.2 Biological sampling

A single pelagic midwater trawl with the dimensions of 19 m in length (LOA) and 6 m at the wing ends and a fishing circle of 330 m was employed during the survey (Figure 15). Mesh size in the wings was 3.3 m through to 5 cm in the cod-end. The net was fished with a vertical mouth opening of approximately 9 m, which was observed using a cable linked Simrad FS70 netsonde. The net was also fitted with a Scanmar depth sensor. Spread between the trawl doors was monitored using Scanmar distance sensors, all sensors being configured and viewed through a Scanmar Scanbas system.

All components of the catch from the trawl hauls were sorted and weighed; fish and other taxa were identified to species level. Fish samples were divided into species composition by weight. Species other than the herring were weighed as a component of the catch. Length frequency and length weight data were collected for each component of the catch. Length measurements of herring, sprat and pilchard were taken to the nearest 0.5 cm below. Age, length, weight, sex and maturity data were recorded for individual herring within a random 50 fish sample from each trawl haul, where possible. All herring were aged onboard. The appropriate raising factors were calculated and applied to provide length frequency compositions for the bulk of each haul.

Decisions to fish on particular echo-traces were largely subjective and an attempt was made to target marks in all areas of concentration not just high density schools. No bottom trawl gear was used during this survey. However, the small size of the midwater gear used and its manoeuvrability in relation to the vessel power allowed samples at or below 1 m from the bottom to be taken in areas of clean ground.

2.4.3 Oceanographic data collection

Oceanographic stations were carried out during the survey at predetermined locations along the track. Data on temperature, depth and salinity were collected using a calibrated Seabird 911 sampler at 1 m subsurface and 3 m above the seabed.

2.4.4 Marine mammal and seabird observations

2.4.4.1 Marine Mammal sighting survey

During the survey, a single observer kept a daylight watch on marine mammals from the crow's nest (18 m above sea level) when weather allowed or from the bridge (11 m).

During cetacean observations, watch effort was focused on an area dead ahead of the vessel and 45° to either side using a transect approach. Sightings in an area up to 90° either side of the vessel were recorded. The area was constantly scanned during these hours by eye and with binoculars. Ship's position, course and speed were recorded, environmental conditions were recorded every 15 minutes and included, sea state, visibility, cloud cover, swell height, precipitation, wind speed and wind direction. For each sighting the following data were recorded: time, location, species, distance, bearing and number of animals (adults, juveniles and calves) and behaviour. Relative abundance (RA) of cetaceans was calculated in terms of number of animals sighted per hour surveyed (aph). RA calculations for porpoise, dolphin species and minke whales were made using data collected in Beaufort Sea state ≤ 3. RA calculations for large whale species were made using data collected in Beaufort Sea state ≤ 5.

2.4.4.2 Seabird sighting survey

A single seabird surveyor worked each leg of the survey. A standardized line transect method with sub-bands to allow correction for species detection bias and 'snapshots' to account for flying birds was used (following recommendations of Tasker et al. 1984; Komdeur *et al*.1992; Camphuysen *et al*. 2004), as outlined below.

The seabird observer conducted visual survey effort while simultaneously recording all data. The observer's survey effort was maximized and optimized during periods of sea state less than or equal to sea state 6 and with visibility of greater than 300m. Additional visual point sampling (e.g., at oceanographic sampling stations or fishing stations) and incidental recording were also employed; however, line transect survey effort was prioritised by the observer. Seabird watches were conducted using a standard single platform line transect survey design while the vessel was travelling at a consistent speed and heading. All observations for seabirds were conducted from the monkey island (deck height 12 m above sea level).

The data collection methodology was based on that originally proposed by Tasker et al. (1984) with later adaptations applied to allow correction factors to be applied for missed birds (Camphuysen et al., 2004). The method employed used a single platform line transect survey design with sub-bands to survey birds associated with the water, while flying birds were surveyed using a 'snapshot' technique. Observer effort was concentrated in a bow-beam arc of 90° to one side (i.e., to port or starboard) of the vessel's track-line, however, all seabirds observed outside this area were also recorded.

Survey effort for seabirds associating with the water were concentrated within a survey strip of 300m running parallel and adjacent to the vessels track-line and extending to the horizon. All birds surveyed within this region were be recorded as 'in-transect' and assigned to one of four distance sub-bands (A: 0-50m, B: 50-100m, C: 100-200m, D: 200-300m) according to their perpendicular distance from the track-line. This approach allows for the evaluation of biases caused by specific differences in detection probability with increasing distance from the trackline (Camphuysen et al. 2004). Seabirds occurring outside of this survey strip were recorded as 'off-transect' and assigned to a separate sub-band (E: >300m). The perpendicular distance to an animal was estimated using a fixed interval range finder (Heinemann, 1981), ensuring each animal is allocated to the correct distance sub-band.

Flying birds were surveyed using 'snapshots', where instantaneous counts of flying birds within a survey quadrant of 300m x 300m were conducted. The periodicity of these 'snapshots' was vessel speed dependent but timed to allow counts to occur as the vessel passes from one survey quadrant to the next. This method minimises biases in counts of flying birds relative to the movement of the vessel (Pollock et al., 2000, Camphuysen et al. 2004).

Seabirds remaining with the vessel for more than 2 minutes were deemed to be associating with the vessel (Camphuysen et al. 2004) and were recorded as such. Seabirds seen associating with other vessels (i.e. fishing vessels) were also recorded as such.

Searching for seabirds was done with the naked eye, however, Leika Ultravid 8x42 HD binoculars were used to confirm parameters such as species identification, age, moult, group size and behaviour (Mackey et al. 2004). A Canon EOS 7D Mark II DSLR camera with a Canon EF 100-400mm F4.5-5.6 IS II USM telephoto lens was used to visually document other information of scientific interest. Data was also collected on all migratory/ transient waterfowl and terrestrial birds encountered.

The Cybertracker (http://www.cybertracker.org/) data collection software package (Version 3.514) was used to collect all positional, environmental and sightings data, and save it to a Microsoft Access database. Positional data was collected using a portable GPS receiver with a USB connection and recorded every 5 seconds.

Each line transect was assigned a unique transect number, and a new transect was started anytime the vessel activity changed (i.e. changing from on-transect to inter-transect). Each subsequent sighting was also assigned to this unique transect number.

Environmental data was timestamped and recorded with GPS data at the beginning and end of each line transect and also as soon as any change in environmental conditions occurred. Environmental data recorded included; wind speed, wind direction, sea state, swell, visibility, cloud cover and precipitation.

Each sighting was timestamped and recorded with GPS data using Cybertracker. Sighting data such as; species identification, distance band, group size, composition, heading, age, moult, behaviour and any associations with cetaceans or other vessels were also recorded on the time stamped Cybertracker sighting record page. Where species identification could not be confirmed, sightings were recorded at an appropriate taxonomic level (i.e. large gull sp., Larus sp., Common tern, etc.).

Ancillary data such as line changes, changes in survey activity (e.g. fishing/CTD cast) and fishing vessel activity were also recorded.

2.4.5 Zooplankton sampling

Zooplankton sampling was carried out alongside CTD stations. A weighted 1 m diameter Hydro-bios ring net was used with a 200 µm mesh size and the net was fitted with a Hydro-Bios® calibrated mechanical flow meter to determine the volume of water filtered. Vertical plankton tows were carried out to within 5 m of the seabed for stations where total depth was less than 100 m and to a 100 m maximum for all other stations depths.

Station samples were split in 50:50 for wet and dry processing for stations 1-44 (Celtic Sea and SW coast). Sample splitting was carried out using a Hydro-Bios® sample splitter. The wet component was fixed for further analysis back at the lab. Fixing was carried using a 4% fix volume of buffered formalin.

Dry processing was carried out with each sample filtered through 2000 µm, 1000 µm and 125 µm sieves. For finer gauge samples (1000 and 125 µm) dry weight analysis was carried out. Samples were transferred to petri-dishes and dried onboard (70 °C oven) for a minimum of 24 hrs before sealing and freezer storage. Back in the lab dry weight analysis was carried out on defrosted frozen samples using a Sartorius MSE225S-000-DA fine scale balance (uncertainty of +/- 0.00016 g).

2.5 Analysis methods

2.5.1 Echogram partitioning

Acoustic data was backed up every 24 hrs and scrutinised using Echoview® (V 11) post processing software.

The RAW files were imported into Echoview for post-processing. The echograms were divided into transects. Echotraces belonging to target species were identified visually and echo integration was performed on the enclosed regions. The echograms were analysed at a threshold of -70 dB and where necessary plankton was filtered out by thresholding at –65 dB.

Partitioning of echograms to identify individual schools was carried out to species level where possible and mixed scattering layers where it was not possible to identify monospecific schools. For scattering layers or mixed schools containing target species the total NASC (Nautical Area Scattering Coefficient) was split by Target strength to provide a species specific NASC value using a function within StoX.

The echogram scrutinisation process was carried out by a scientist experienced in scrutinising echograms and with the aid of accompanying trawl catch data.

The allocated echo integrator counts (NASC values) from these categories were used to estimate the herring numbers according to the method of Dalen and Nakken (1983).

The TS/length relationships used predominantly for the Celtic Sea Herring Survey are those recommended by the acoustic survey planning group based at 38 kHz (ICES, 1994):

Herring	TS =	20logL – 71.2 dB per individual (L = length in cm)
Sprat	TS =	20logL – 71.2 dB per individual (L = length in cm)
Mackerel	TS =	20logL – 84.9 dB per individual (L = length in cm)
Horse mackerel	TS =	20logL – 67.5 dB per individual (L = length in cm)
Anchovy	TS =	20logL – 71.2 dB per individual (L = length in cm)

The TS length relationship used for gadoids was a general physoclist relationship (Foote, 1987):

Gadoids	TS =	20logL – 67.5 dB per individual (L = length in cm)

2.5.2 Abundance estimate

Acoustic data were analysed using the StoX software package as adopted for all WGIPS coordinated surveys (ICES 2016). A description of StoX is provided by Johnsen *et al.* (2019). Estimation of abundance from acoustic surveys within StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990).

3 Results

3.1 Celtic Sea herring stock

3.1.1 Herring biomass and abundance

Total herring biomass (TSB) and spawning stock biomass (SSB) by strata are provided in Table 3. The biomass presented below was determined using Pass 1 (core survey) data representing the largest geographical area surveyed.

Herring	Abund ('000)	Biomass (t)
Total stock	310,236.0	9,877.2
Spawning stock	57,327.0	6,634.5

3.1.2 Herring distribution

A total of 27 trawl hauls were carried out during the survey (Figure 1). Of which, 12 contained herring (Table 2). Supplementary data was provided from a commercial haul undertaken in Waterford Harbour where survey trawling was not possible due to vessel size.

Core Surveys

Two core surveys were carried out; Pass 1 and Pass 2. A total of 39 herring echotraces were identified (Pass 1: 14, Pass 2: 25). Herring were observed either within 10 nmi of the coast and made up of immature individuals or as offshore aggregations clustered around one particular area and composed of mature fish (Figure 2). Immature herring observed inshore were most commonly found in mixed species catches where sprat was the major component by weight and number. Ten hauls contained immature herring from 1-14% of the catch by weight (Table 2). Offshore aggregations were composed of mature fish, the location of which was centred on a localised area that was the focus of the adaptive survey effort.

Adaptive Surveys

Six adaptive surveys were conducted; three offshore (''Smalls x1 and 'Ella' x2) and three inshore (Kinsale to Ram Head x1, Helvick to Baginbun x1 and Waterford Harbour), see Figure 3. Inshore, immature herring were observed during both inshore surveys occurring as mixed species catches containing sprat.

Offshore, herring were observed during the first 'Ella' survey but not during the second. No herring were observed during the Trench scouting survey or the Smalls survey.

Inshore distribution was divided into two focus areas where single surveys were carried out; Kinsale eastwards to Ram Head and from Helvick eastwards to Baginbun. Survey effort was inter-laced both with the Core surveys and also with successive adaptive effort to ensure comprehensive and high resolution ground coverage. Individual survey used a transects spacing of 4 nmi and extended up to 10 nmi offshore (Figure 3). The first survey (Kinsale to Ram Head) was conducted on the 13th October and the second occurred on the 18th (Helvick to Baginbun). A short survey was carried out in Waterford Harbour based on information provided by the inshore fleet. Coverage was restricted to the shipping channel due to vessel size and extended as far as Passage East. Acoustic backscatter was supplemented with a commercial sample containing herring to generate an estimate of biomass.

No herring were observed during the 'Smalls' adaptive survey. Historically this area has been an offshore hotspot where herring aggregate prior to migrating inshore to the spawning grounds. Previous surveys have shown that herring in this area are known to lie in close proximity to the seabed making echo-counting difficult. A blind trawl was conducted within this adaptive survey to ensure no herring were present.

An area containing herring, located approximately 30 nmi to the west of the 'Smalls', was identified by pelagic vessels targeting herring. Herring were persistent in this area for approximately five weeks, prior to, and during the survey. Two surveys were conducted at this site named the 'Ella' surveys. Survey 1, was conducted during daylight hours on the 12th Oct and the second was carried out at night on the 20th October. Herring were observed during the first survey but not the second, with blind trawls conducted during both surveys. The behavioural characteristics of herring in this region were very similar to those observed previously in the 'Smalls'- with fish in close proximity to the seabed.

Herring were observed in varying densities during each of the four adaptive inshore surveys (Figures 8a-d).

3.1.3 Herring stock composition

A total of 426 herring were aged from survey samples, in addition to 985 length measurements and 539 length-weights. Herring age samples ranged from 0-8 winter-rings (Figures 4 and 5, Tables 3 and 4). Length at age and maturity by strata are presented in Figures 1-6 in Appendix 1.

Core survey

The Pass 1 survey estimate represents the 2021 estimate based on the largest geographical area surveyed and follows the procedure adopted in 2017. Pass 1 represents a total biomass of 9,877.2 t and a total abundance of 310,236,000 individuals (CV 0.44). Age composition of Pass 1 was dominated by 3-wr, 0-wr, 2-wr and 4-wr fish respectively. The dominant 3-wr fish contributed 43.1% to the TSB and 11.4% TSN. Immature 0-wr fish accounted for 32.5% of TSB and 81.4% of TSN. Two-wr fish made up 17.4% of TSB and 5.5% of TSN followed by 4.3% of TSB and 1.1% of TSN for 4-wr fish.

Maturity analysis showed that 98.1% of 2-wr fish were mature, higher than observed for the corresponding previous year class in 2020 (91%). Immature fish accounted for 32.8% (34.3% in 2020) of the 9,877.2 t TSB estimate.

Adaptive surveys

Of the six adaptive surveys carried out, four were found to contain herring. Estimates of biomass and abundance by strata are presented in Table 3 and Figure 4 respectively.

3.2 Other pelagic species

3.2.1 Sprat

Sprat	Abund ('000)	Biomass (t)
Total stock	3,017,927.0	12,375.5

High density aggregations of sprat were predominantly distributed within 15 nmi of the coast. Further offshore, aggregations of sprat were more scattered and of lower acoustic density (Figure 6). This pattern of distribution, with the highest aggregations occurring inshore, follows a similar distribution observed in 2020 also. In total, 2,646 individual length measurements and 1,435 length/weight measurements were recorded. Mean length was 8 cm and mean weight was 3.78 g (11.8 cm and 12.93 g in 2020). Individuals ranged from 6 to 13 cm in length and 1 to 16 g in weight. Biomass and abundance by survey strata is presented in Table 5 and the survey time series in Table 6.

A total of 275 (222 in 2020) individual sprat echotraces were identified from combined survey effort (Figure 6). Distribution of sprat in close proximity to the coast observed during the 2020 and 2021 survey was also noted again this year during the CEFAS Peltic survey along the southwest coast of the UK (J. Vanderkooij, pers. comm.). The distribution of a high proportion of fish close inshore raises concerns about the containment of the stock within the survey boundary and the proportion unaccounted for in shallow inshore waters.

Overall, the size profile of sprat observed was dominated by smaller individuals (mean length 8 cm and mean weight was 3.8 g), in contrast to the 2020 survey (mean length 11.8 cm and mean weight was 12.93 g).

3.2.2 Anchovy

Anchovy were not present in high abundances similar to what was observed during the 2020 survey for the same survey effort. No echotraces of anchovy were observed (6 echotraces in 2019, verses 26 in 2020), and biological samples amounted to 105 individuals in total, taken as part of mixed species catches dominated by sprat. The number and distribution of anchovy observed during the survey is similar to that observed over the longer time series. The abundance and distribution of anchovy in 2020 was significantly higher than observed previously and was likely a consequence of inshore feeding opportunities influenced by the hydrographic conditions observed in that year.

In total, 105 individual length/weight measurements were recorded. Mean length was 6.7 cm and mean weight was 2.53 g (15 cm and mean weight was 27.07 g in 2020). Individuals ranged from 4.5 to 17 cm in length and 1 to 29 g in weight.

No estimate of anchovy biomass or abundance was calculated in 2021 due to the low numbers encountered.

3.2.3 Sardine

A total of 17 low density and one medium density echotraces were identified as sardine during the survey, all of which were encountered within 10 nmi of the coast. Individual sardines were observed in mixed catches dominated by sprat in weight and number.

In total, 285 individual length measurements and 414 length/weight measurements were recorded. Mean length was 12.9 cm and mean weight was 16.6 g. Individuals ranged from 9.5 to 17.5 cm in length and 10 to 42 g in weight.

No estimate of sardine biomass or abundance was calculated in 2021 due to the low numbers encountered.

3.3 Oceanography

A total of 43 CTD stations were carried out during the survey area. Surface plots of temperature and salinity are presented using 5 m and 20 m depth profiles (Figures 9 and 10), while near bottom profiles are overlaid with sprat and herring acoustic density respectively (Figures 11 and 12).

Horizontal plots of temperature and salinity at 5 and 20 m depths showed near surface conditions, above the thermocline, were relatively uniform (Figures 9 and10). The water column was stratified, as evident from the thermocline extending to c.40 m subsurface at offshore stations. Colder water plumes, evident above the thermocline in the eastern survey area, are likely associated with tidal mixing occurring within the Celtic Deep depression.

Bottom temperature at offshore stations were in the order of 2°C lower than during the same time last year (12°C compared to 14°C). Offshore aggregations of mature herring were observed to be distributed in the 12-13°C temperature range, whereas immature fish were located inshore in the warmer mixed coastal waters (Figure 12). Sprat were found distributed along the well mixed inshore waters, with the exception of some low density scattering layers observed further offshore (Figure 11).

The influence of cooler and more saline Atlantic water is evident west of 7°W compared to the warmer and less saline conditions further east.

3.3.1 Zooplankton

Zooplankton sampling was undertaken at 35 of the 43 hydrographic stations (Figure 13). This program will be adopted into the routine operations of future surveys to complement the work currently undertaken during the WESPAS survey in this area. This will provide multiple within-year observations in the Celtic Sea over time.

3.4 Marine mammal and seabird observations

3.4.1 Marine mammal abundance and distribution survey

Survey effort

In total, 17 days were spent surveying with 65 hours of survey time logged.

Environment

Environmental data were collected at 124 stations. On the second leg of the survey time spent observing was severely reduced due to persistent bad weather. Mean wind speed during survey effort was 15 km/h. Sea state was ≤3 at 38.7% of environmental stations and occurred between the 9th and 16th of October. Visibility was good (>5km) at 87% of stations, moderate (1–5km) at 11% of stations and poor (<1km) at 5% of stations. A heavy swell (2m+) was recorded at 41.1% of stations. Precipitation was recorded at 12.9% of stations

Sightings report

Six cetacean species were encountered during the survey i.e. harbour porpoise (*Phocoena phocoena*); short-beaked common dolphin (*Delphinus delphis*); bottlenose dolphin (*Tursiops truncates*); minke whale (*Balaenoptera acutorostrata*); humpback whale (*Megaptera novaeangliae*); fin whale (*Balaenoptera physalus*). Other non-cetacean species recorded were Basking shark (*Cetorhinus maximus)*; and blue shark (*Prionace glauca*) (Table 7 and Figure 14).

Additional sightings of unidentified whales occurred (likely either Fin or Humpback whales) at various locations in the Celtic Sea.

Common dolphins (*Delphinus delphis*) and Fin whales (*Balaenoptera Physalus*) were the most frequently recorded species accounting for 64% and 17.4% of recordings respectively (114 and 31 sightings respectively). Common dolphins were also the most abundant species recorded on the survey (2,723) Common dolphins recorded accounting for 64% of all animals counted across all species). The observed group size for common dolphins ranged from 1 to 300 individuals. The observed group size for Fin whales ranged from 1 to 8 individuals.

The third most frequently observed species were Humpback whale *(Megaptera novaeangliae)* which accounted for 2.2% of sightings. Subsequently Minke whale *(Balaenoptera acutorostrata)* and Basking shark *(Cetorhinus maximus)* accounted for 1.7% of sightings respectively, Harbour porpoise *(Phocoena)* and Blue shark *(Prion glauca)* accounted for 1.1% of sightings each and bottlenose dolphin *(Tursiops truncates)* for 0.6% of sightings.

Basking sharks *(Cetorhinus maximus*) were recorded on three occasions with 8 individuals observed at the surface. Two of these sightings of 6 individuals occurred in an area with feeding common dolphins *(Delphinus delphis)* and fin whales (*Balaenoptera physalus)*, two individuals exhibited circling behaviour which may be indicative of courtship behaviour. Excellent weather conditions for the first leg of the survey improved detectability for Basking sharks.

3.4.2 Seabird abundance and distribution survey

In total, 71 hours and 26 minutes of survey effort were conducted over the course of CSHAS 2021. In total, 66 hours and 14 minutes of survey effort were conducted using a line transect methodology, while 5 hours of effort were conducted using the point sampling methodology. A further 12 minutes of effort were conducted as a casual watch.

A total of 2,879 seabird observations were recorded throughout the survey, totalling 14,797 individuals (Table 8). In total, 4,181 seabirds were recorded as “in transect”, while 10,616 were recorded “off transect”. The species encountered included 29 species, hybrids or species groups, from eight families. A further 41 observations of terrestrial/migratory birds were also recorded, comprising of 150 individuals (Table 9).

Gannet (*Morus bassanus*) were the most frequently encountered species, recorded on 1006 separate occasions, accounting for 34.9% of all records. Gannet records comprised of a total of 5,667 individuals (38.3% of all individual birds recorded) making gannet the most abundant species recorded on the survey. However, of these, only 758 individuals were recorded as 'in transect'.

Guillemot (*Uria aalge*) were both the second most frequently encountered and the second most abundant species accounting for 644 records (22.4% of all encounters) and comprising of 2,257 individuals in total (15.3% of all encountered individuals.) Of these, 1,904 individuals were recorded as 'in transect'.

Kittiwake (*Rissa tridactyla*) were the third most frequently observed species accounting for 316 sightings (11.0% of all sightings). Kittiwake were also the third most abundant species comprising of 1398 individuals in total (9.4% of all encountered individuals.) Of these, 379 individuals were recorded as 'in transect'.

A number of terrestrial/ migratory birds were encountered during the survey. A total of 41 observations of terrestrial/ migratory bird species were recorded during the survey (Table 9). These records comprised of 150 individuals from 19 species'. Species recorded included a Siberian chiffchaff (*Phylloscopus collybita tristis*), a black redstart (*Phoenicurus ochruros*), a wren (*Troglodytes troglodytes*) and a lone juvenile whooper swan (*Cygnus cygnus*).

4 Discussion and Conclusions

4.1 Discussion

The objectives of the survey were carried out successfully and as planned. Approximately 12 hrs was lost due to poor weather conditions. However, planned area coverage was achieved.

In terms of survey effort, geographical coverage was comparable to 2020 (+2%) and acoustic sampling effort or survey miles increased by 15%. Additional adaptive survey effort was focused on offshore areas where mature herring were located. Coastal effort was also maintained to ensure coverage of nursery areas. Surveying of Waterford Harbour was conducted to quantify the abundance, as far as was possible, of mature herring located within the harbour area and further upriver.

Overall, mature fish were located in two areas; offshore (west of the Smalls grounds) and within the confines of Waterford Harbour. The main offshore aggregation was identified by a number of vessels targeting herring and was persistent in the same area over several weeks. Herring within this area were located in close proximity to the seabed and spread over an area of approximately 10 nmi^2. Echo-counting close to the seabed is problematic as fish occurring within the 'acoustic deadzone' are often underestimated. This limitation restricts the effective use of acoustics in for example bottom trawl surveys targeting demersal fish. Estimates of biomass from this site must therefore be treated with a degree of caution and as an underestimate of the quantity of fish present. Trawling provided herring samples but catches did not reflect the acoustic density and vice versa.

Reports from the inshore fleet regarding a persistent inshore aggregation of mature herring upriver from Dunmore were investigated. Surveying was restricted to the shipping channel, so not all areas where fish were reported were surveyed. Biological data (length, weight and ages profile) from a commercial sample was applied during the analysis to estimate abundance. The estimate of biomass from Waterford should be treated as an underestimate due to coverage limitations and that species ratios of sprat and herring were unavailable when echo-counting to accurately split the two species.

For the mature herring observed, the age and length profile is consistent with the dominant two and three winter ring fish from commercial catch data and observations from the WESPAS summer survey, and so is considered representative of the stock profile.

Immature (0-wr) fish were well represented during both the core and inshore adaptive surveys, occurring as components of mixed catches containing sprat. Immature fish accounted for 32.8% (34.3% in 2020) of the 9,877.2 t TSB estimate. The potential of this year class will be monitored through successive summer and autumn surveys.

The biomass of sprat in 2021 was higher than observed in 2020 (2021: 12,376t and 2020: 4,523t). As in 2020, the distribution of sprat was concentrated in inshore waters. Given the inshore distribution this year it is possible that the sprat stock was not fully contained within the survey area and so an unknown proportion of the stock remains unaccounted for. The size profile of sprat was dominated by smaller fish compared to 2020 and lacked the larger length cohorts that dominated catches.

The abundance and distribution of sardine and anchovy during the survey was notably lower than observed in 2020. However, it should be noted that 2020 was an exceptional year in this regard compared to previous years and likely driven by the hydrographic conditions and/or feeding opportunities leading to a concentration of these, and other small pelagic fish species, along the south and southwest coasts of Ireland. Sardine and anchovy are encountered every year during the survey, generally in low background numbers.

4.2 Conclusions

- In terms of survey effort, geographical coverage was comparable to 2020 (+2%) and acoustic sampling effort or survey miles increased by 15%. The survey was carried out during the same time period
- The herring stock was considered contained within the Celtic Sea survey area with no aggregations observed along the survey periphery, inshore or offshore
- Immature herring were observed primarily in coastal waters and were well represented in the survey estimate (32.8% of TSB and 81.5% of TSN)
- Mature herring were observed in two main areas; offshore in a discreet patch and inshore within the confines of Waterford Harbour. Both sites were surveyed using adaptive survey effort. Offshore mature herring were also encountered and included within the Pass 1 core survey.
- The 2021 TSB estimate (Pass 1) is 9,877.2 t and 310 million individuals (CV 0.44) and an increase on the 2020 estimate (4,716.8 t and a total abundance of 67.3 million individuals).
- Age composition of Pass 1 was dominated by 3-wr, 0-wr, 2-wr and 4-wr fish respectively by weight. The dominant 3-wr fish contributed 43.1% to the TSB and 11.4% TSN. Immature 0-wr fish accounted for 32.5% of TSB and 81.4% of TSN. Two-wr fish made up 17.4% of TSB and 5.5% of TSN followed by 4.3% of TSB and 1.1% of TSN for 4-wr fish.
- Maturity analysis showed that 98.1% of 2-wr fish were mature, higher than observed for the corresponding previous year class in 2020 (91%). Immature fish accounted for 32.8% (34.3% in 2020) of the 9,877.2 t TSB estimate.
- Adaptive survey effort on the ‘Ella’ survey site was hampered with fish carpeted on the seabed and likely resulted in an underestimate.
- The abundance of sprat observed this year was higher than that observed in 2020, the lowest in the recent time series. The 2021 estimate is considered an underestimate of the size of the standing stock as an unknown proportion of the stock may be unaccounted as not full contained in the survey area.
- The length profile of survey samples of sprat was dominated by small, 0-group fish in contrast to 2020.
- The numbers of sardine and anchovy observed were low in comparison to 2020 and more in line with previous observation within the time series. Sardine and anchovy biomass are not routinely reported due to the low and inconsistent densities observed.

- The hydrographic conditions observed in the Celtic Sea showed relatively uniform bottom temperatures (11-12°C) in offshore areas where herring were located, in contrast to the high bottom temperatures observed offshore in 2020 (14°C). Similar conditions and fish distribution were reported during the co-occurring UK survey covering the Bristol channel and north Cornwall

5 Acknowledgements

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Fisheries Ecosystems Advisory Services

7 Tables and Figures

Table 1. Calibration report: Simrad EK60 echosounder at 38 kHz.

Vessel : R/V Celtic Explorer		Date : 09.10.2021	
Echo sounder : EK60 PC		Locality : Dunmanus Bay	
Type of Sphere : WC-38,1	TS Sphere: -42.40 dB (Corrected for soundvel	Depth(Sea fl 37 m	

Calibration Version 2.1.0.12

Comments:
Dunmanus_CSHAS_2021

Reference Target:

TS	-42.40 dB	Min. Distance	13.00 m
TS Deviation	5.0 dB	Max. Distance	16.00 m

Transducer: ES38B Serial No. 30227

Frequency	38000 Hz	Beamtype	Split
Gain	25.34 dB	Two Way Beam Angle	-20.6 dB
Athw . Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw . Beam Angle	7.80 deg	Along. Beam Angle	6.85 deg
Athw . Offset Angle	-0.03 deg	Along. Offset Angl	-0.04 deg
SaCorrection	-0.60 dB	Depth	8.80 m

Transceiver: GPT 38 kHz 009072033933 2-1 ES38B

Pulse Duration	1.024 ms	Sample Interval	0.192 m
Power	2000 W	Receiver Bandwidth	2.43 kHz

Sounder Type:
EK60 Version 2.4.3

TS Detection:

Min. Value	-50.0 dB	Min. Spacing	100 %
Max. Beam Comp.	6.0 dB	Min. Echolength	80 %
Max. Phase Dev.	8.0	Max. Echolength	180 %

Environment:

Absorption Coeff.	9.5 dB/km	Sound Velocity	1499.4 m/s

Beam Model results:

Transducer Gain =	25.63 dB	SaCorrection =	-0.64 dB
Athw . Beam Angle =	7.01 deg	Along. Beam Angle =	6.96 deg
Athw . Offset Angle =	-0.03 deg	Along. Offset Angle=	-0.06 deg

Data deviation from beam model:
RMS = 0.14 dB
Max = 0.54 dB No. = 173 Athw . = -2.5 deg Along = 4.2 deg
Min = -0.69 dB No. = 201 Athw . = -2.3 deg Along = 4.4 deg

Data deviation from polynomial model:
RMS = 0.09 dB
Max = 0.52 dB No. = 105 Athw . = 0.6 deg Along = -4.5 deg
Min = -0.46 dB No. = 201 Athw . = 2.3 deg Along = -4.4 deg

Comments :
Dunmanus Bay
Wind Force : 11 Kts **Wind Direction :** W
Raw Data File: E:\CE21012_CSHAS 2021\Calibration\38 kHz Cal\CSHAS2021-D20190705-T090459.raw
Calibration File: E:\CE21012_CSHAS 2021\Calibration\38 kHz Cal\Cal 38 kHz.txt

Calibration: Ciaran O'Donnell

Table 2. Catch table from directed trawl hauls.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target btm (m)	Bulk Catch (Kg)	Herring %	Mackerel %	Scad %	Sprat %	Pilchard %	Others* %
1	10.10.21	50.97	-8.48	01:02	103	0	56.3						100.0
2	10.10.21	51.72	-8.05	15:26	63	15	55.5		3.7	0.5	87.9	0.4	7.5
3	11.10.21	51.86	-7.75	10:23	40	20							100.0
4	11.10.21	51.02	-7.62	18:50	100	50	6.4		0.5	21.3	0.1		78.1
5	12.10.21	51.06	-7.46	13:10	94	0	4.3			7.2	3.3	0.4	89.1
6	12.10.21	51.22	-7.58	13:44	89	0	3500.0	97.4			0.5		2.1
7	13.10.21	51.77	-7.98	08:18	46	10	119.7		5.8		82.8	9.7	1.8
8	13.10.21	51.75	-7.78	19:26	70	20	153.3	1.4	0.4	0.1	89.3	2.5	6.3
9	14.10.21	51.07	-7.19	09:50	92	0	5.8		0.9	5.9	3.3	0.2	89.7
10	16.10.21	51.60	-6.34	14:37	81	0	120.6	13.6	0.1	0.3	80.8		5.2
11	16.10.21	51.31	-6.53	18:37	91	0	172.8	0.4		2.1			97.5
12	17.10.21	51.46	-6.02	14:13	110	0	750.0	0.1					99.9
13	18.10.21	51.87	-7.04	22:15	65	0	10.9	0.3	1		84.67	0.34	14.2
14	19.10.21	51.99	-7.46	06:45	45	0	186.9		16.7	1.1	81.0		1.2
15	19.10.21	51.48	-6.44	14:37	82	0	119.7	4.5			0.3		95.2
16	19.10.21	51.28	-6.45	17:39	126	20	129.7						100.0
17	20.10.21	51.71	-6.88	10:45	68	10	52.2			0.2	96.0	2.0	1.8
18	20.10.21	51.11	-6.87	16:56	93	0	76.6	0.3			0.1		99.6
19	21.10.21	51.14	-7.55	07:00	93	0	109.4	0.9	0.2	0.5			98.4
20	22.10.21	51.27	-7.52	07:19	93	0	137.4	84.1		0.7			15.3
21	22.10.21	51.90	-7.52	13:05	46	0	122.9	0.7	31.1		64.9	2.7	0.6
22	23.10.21	51.80	-7.97	05:20	38	10	98.7		0.6		88.2	0.2	11.0
23	23.10.21	51.00	-8.20	15:58	95	0	0.0						
24	24.10.21	51.24	-8.80	08:19	109	90	9.0		0.3		0.1		99.6
25	24.10.21	52.21	-6.94	02:24	25	0	10.0	100.0					0.0
26	25.10.21	51.45	-9.29	00:10	58	5	117.0		0.4		92.4	1.9	5.3
27	25.10.21	51.31	-9.63	09:54	92	0	130.2	9.57	0.72		22.01		67.7

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Table 3. Herring biomass and abundance by strata. Highlighted strata (Pass 1) presented as total stock biomass based on largest stratum area surveyed.

Strata	Name	Type	Area (nmi²)	Transects	TSN ('000)	TSB (t)	SSN ('000)	SSB (t)	CV (Abun)
1	Pass 1	Core	7,748.7	12	310,236.0	9,877.2	57,327.0	6,634.5	0.44
2	Pass 2	Core	7,462.6	19	452,652.0	12,199.1	61,018.0	7,053.2	0.67
3	Smalls 1	Adaptive	101.0	8	-	-	-	-	-
4	Ella #1	Adaptive	51.9	9	652.0	76.0	652.0	76.0	0.47
5	Ella #2	Adaptive	85.0	6	-	-	-	-	-
6	Inshore 1	Adaptive	415.7	9	102,698.0	1,384.9	-	-	0.59
7	Inshore 2	Adaptive	445.2	8	26,853.0	362.5	-	-	0.64
8	Waterford	Adaptive	8.6	1	15,247.0	1,442.6	8,149.0	947.7	0.00
	Total		16,318.7	72					

Table 4. Celtic Sea herring survey time series.

Age (wr) Year	0	1	2	3	4	5	6	7	8	9	TSN (mils)	SSB ('000t)	Design	CV
2002	0	42	185	151	30	7	7	3	0	0	423	41	AR	0.49
2003	24	13	62	60	17	2	1	0	0	0	183	20	AR	0.34
2004	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2005	2	65	137	28	54	22	5	1	0	0	312	33	ARS	0.48
2006	0	21	211	48	14	11	1	0	0	0	305	36	ARS	0.35
2007	1	106	70	220	31	9	13	4	1	0	454	46	ARS	0.25
2008	2	63	295	111	162	27	6	5	0	0	671	93	ARS	0.20
2009	239	381	112	210	57	125	12	4	6	1	1147	91	ARS	0.24
2010	5	346	549	156	193	65	91	7	3	0	1414	122	ARS	0.20
2011	0.1	342	479	299	47	71	24	33	4	2	1300	122	ARS	0.28
2012	31	270	856	615	330	49	121	25	23	3	2322	246	ARS	0.25
2013	3.8	698	291.4	197.4	43.7	37.9	9.8	4.7	0	0.2	1286	71	ARS	0.28
2014	0	41	117	112	69	20	24	7	17	1	408	48	ARM	0.59
2015	0	0	40	48	41	38	7	6	5	0	184	25	ARM	0.18
2016	0	125	21	43	40	36	25	5	6	0	301	30	CRM	0.33
2017	0	0	6	3	7	5	4	0	1	0	27	4	CRM	NA
2018	109	56	16	27	6	0	0	0	0	0	213	8	CRM	0.50
2019	87	19.5	0.1	0	0	0	0	0	0	0	106.9	0.009	CRM	0.55
2020	1	27.7	32.2	5	1	0	0	0	0	0	67	3.1	CRM	0.51
2021	25.3	0	1.7	3.5	0.3	0.1	0	0.1	0	0	310	6.6	CRM	0.44

AR= Adaptive random, ARS= Adapt, random stratified, ARM= Adaptive random with mini surveys, CRM= Core random replicates with mini surveys

Table 5. Sprat biomass and abundance by strata.

Strata	Name	Type	Area (nmi²)	Transects	TSN ('000)	TSB (t)
1	Pass 1	Core	7,748.7	12	3,017,927	12,375.5
2	Pass 2	Core	7,462.6	19	7,255,264	28,081.2
3	Smalls 1	Adaptive	101.0	8	-	-
4	Ella #1	Adaptive	51.9	9	30,298	154.1
5	Ella #2	Adaptive	85.0	6	-	-
6	Inshore 1	Adaptive	415.7	9	2,856,395	10,809.5
7	Inshore 2	Adaptive	445.2	8	258,874	950.4
8	Waterford	Adaptive	8.6	1	2,935	13.0
	Total		16,310	71		

Table 6. Celtic Sea sprat survey time series. Based on 24hr survey effort.

Year	Abundance ('000s)	Biomass (t)
2004	5,646	50,810
2005	2,571	29,017
2007	132	1,918
2008	540	5,493
2009	1,418	16,229
2011	5,832	31,593
2012	4,589	35,114
2013	10,748	44,685
2014	9,152	54,826
2015	21,398	83,779
2016	8,171	42,694
2017	40,276	70,745
2018	6,934	47,806
2019	10,344	60,608
2020	354	4,523
2021	3,018	12,376

Table 7. Marine mammal sightings, counts and group size ranges for cetaceans sighted.

Scientific name	No. sightings	No. of individuals	Group size
Delphinus delphis	114	2723	1-300
Balaenoptera physalus	31	48	1-8
Megaptera novaeangliae	4	6	1-2
Phocoena phocoena	2	4	1-3
Balaenoptera acutorostrata	3	3	1
Tursiops truncatus	1	14	14
Cetorhinus maximus	3	8	1-4
Prionace glauca	5	6	1-2
Unidentified Whale	2	2	1
	178	2,814	

Table 8. Totals for all seabird species recorded.

Common Name	Species name	No. of Records	No. of Individuals	In Transect	Off Transect
Fulmar	*Fulmarus glacialis*	160	274	28	246
Great Shearwater	*Ardenna graves*	5	11	2	9
Sooty Shearwater	*Ardenna griseus*	96	499	137	362
Manx Shearwater	*Puffinus puffinus*	38	169	9	160
Storm Petrel	*Hydrobates pelagicus*	16	53	40	13
Leach's Petrel	*Oceanodroma leucorhoa*	1	1	1	0
Gannet	*Morus bassanus*	1006	5667	758	4909
Pomarine Skua	*Stercoratius pomarinus*	5	5	1	4
Arctic Skua	*Stercoratius parasiticus*	5	5	1	4
Great Skua	*Stercoratius skua*	37	51	9	42
Mediterranean gull	*Larus melanocephalus*	14	53	14	39
Common Gull	*Larus canus*	24	50	26	24
Black-headed Gull	*Larus ridibundus*	16	32	19	13
Lesser Black-backed Gull	*Larus fuscus*	65	1157	47	1110
Herring Gull	*Larus argentatus*	44	269	20	249
Yellow-legged gull	*Larus michahellis*	1	1	0	1
Great Black-backed Gull	*Larus marinus*	102	366	29	337
Kittiwake	*Rissa tridactyla*	316	1398	379	1019
Large gull sp.	*Larus sp.*	4	230	0	230
Arctic Tern	*Sterna paradisaea*	2	3	0	3
Guillemot	*Uria aalge*	644	2257	1904	353
Razorbill	*Alca torda*	133	392	268	124
Razorbill / Guillemot	*Alca torda / Uria aalge*	42	1647	380	1267
Puffin	*Fratercula arctica*	89	174	107	67
Shag	*Phalacrocorax aristotelis*	5	24	1	23
Cormorant	*Phalacrocorax carbo*	1	1	0	1
Great Northern Diver	*Gavia immer*	4	4	1	3
Total		**2,879**	**14,797**	**4,181**	**10,616**

Table 9. Totals of migrant terrestrial bird species recorded.

Common Name	Species name	No. of Sightings	No. of Individuals
Black Redstart	*Phoenicurus ochruros*	1	1
Blackcap	*Sylvia atricapilia*	1	1
Chiffchaff	*Phylloscopus collybita*	1	1
Dunlin	*Calidris alpina*	1	1
Goldcrest	*Regulus regulus*	2	2
Goldfinch	*Carduelis carduelis*	1	4
Grey Wagtail	*Motacilla cinerea*	1	1
House Martin	*Delichon urbica*	1	1
Linnet	*Carduelis cannabina*	1	1
Meadow Pipit	*Anthus pratensis*	13	113
Merlin	*Falco columbarius*	3	3
Pied Wagtail	*Motacilla alba*	3	3
Redwing	*Turdus iliacus*	2	3
Robin	*Erithacus rubecula*	1	1
Rock Pipit	*Anthus spinoletta*	1	2
Siberian Chiffchaff	*Phylloscopus collybita tristis*	1	1
Skylark	*Alauda arvensis*	2	3
Swallow	*Hirundo rustica*	3	6
Whooper Swan	*Cygnus cygnus*	1	1
Willow Warbler	*Phylloscopus trochilus*	1	1
Wren	*Troglodytes troglodytes*	1	1
Total		**41**	**150**

Celtic Sea Herring Acoustic Survey Cruise Report, 2021

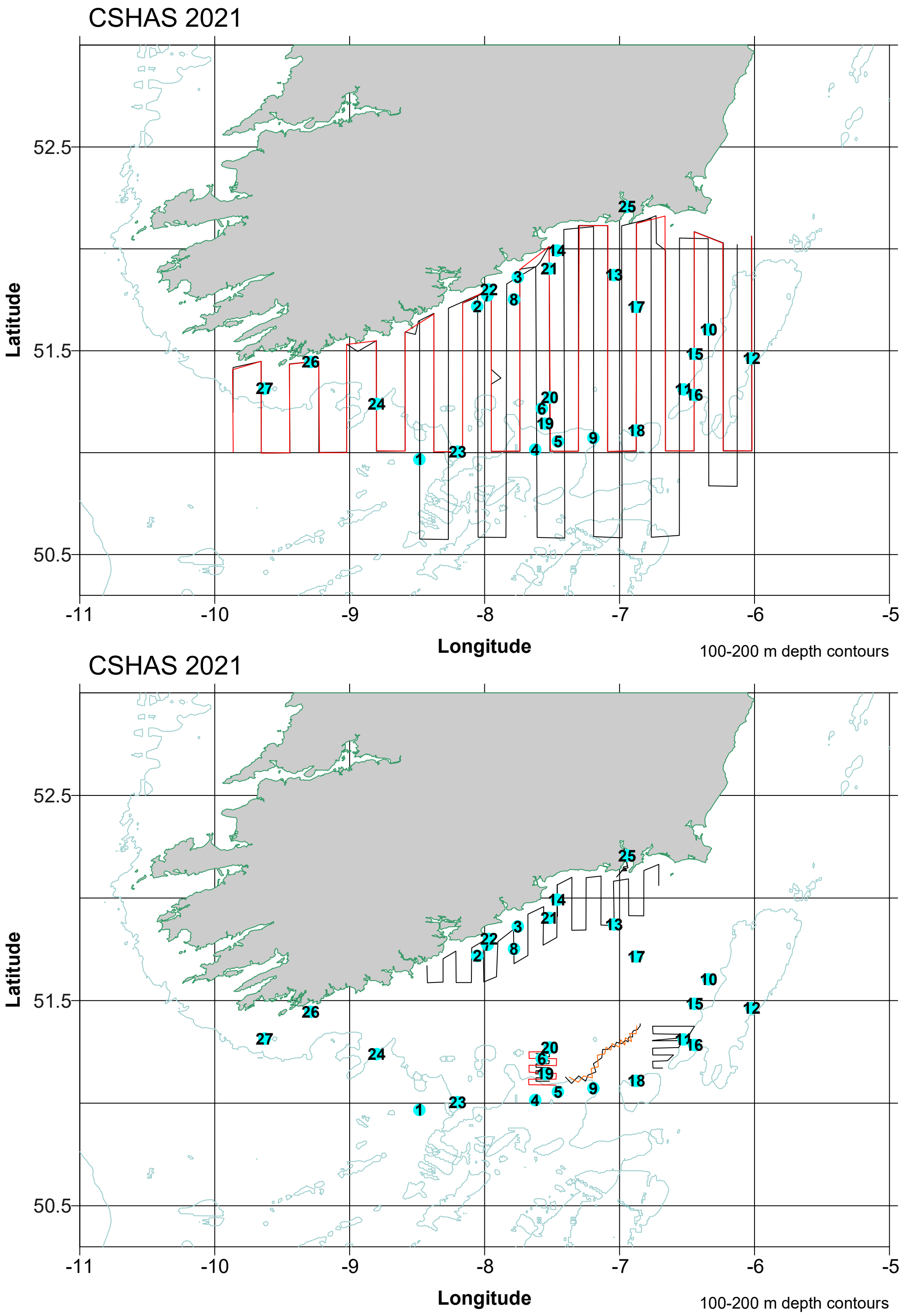

Figure 1. Top panel: Core replicate survey effort cruise tracks and numbered haul stations. (Pass 1: black track, Pass 2: orange track). Bottom panel: Adaptive and scouting survey effort mini surveys 1-6. Replicate coverage shown as orange track.

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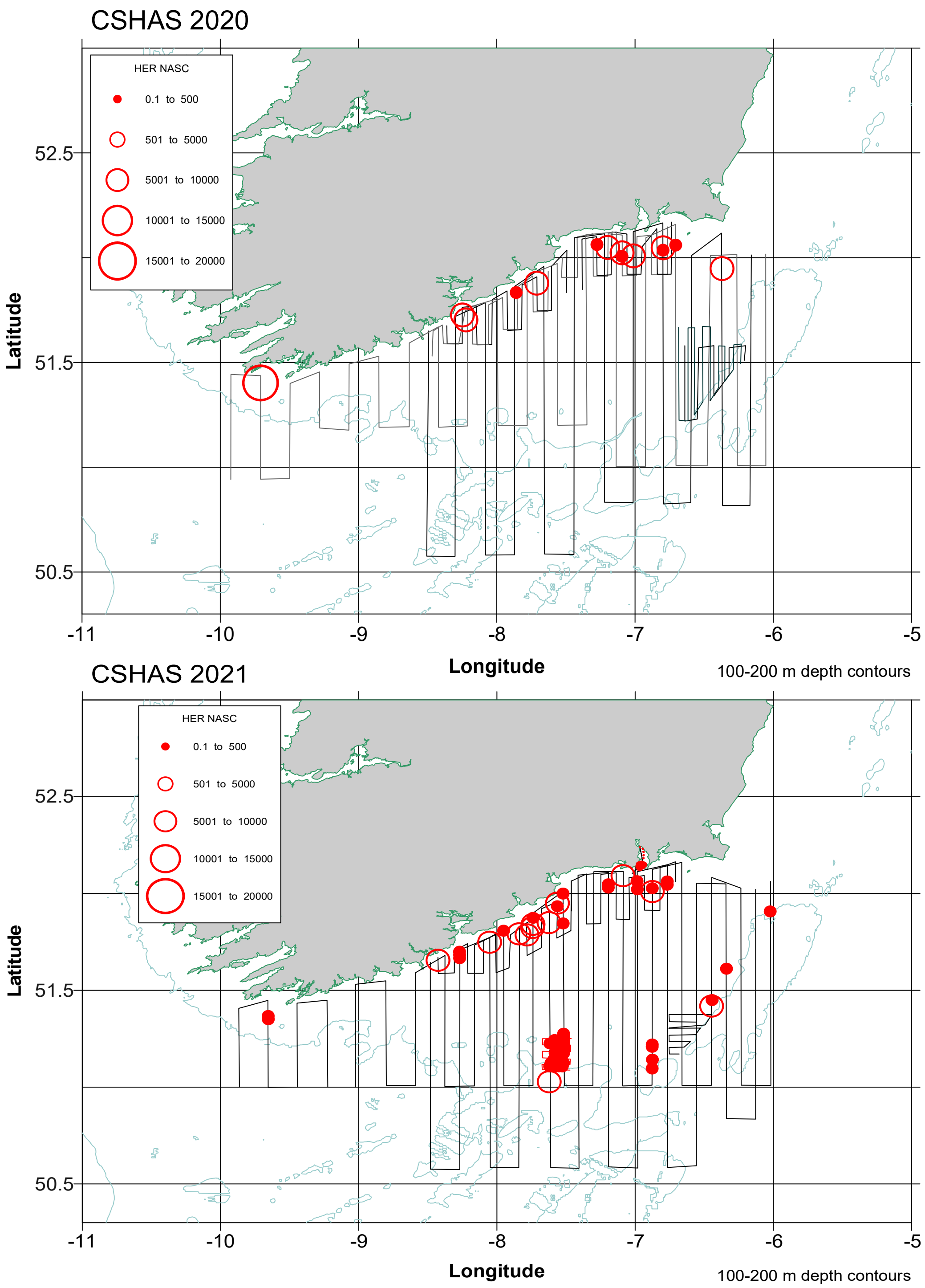

Figure 2. Herring NASC (Nautical area scattering coefficient) plot of herring distribution 2020 and 2021 from combined survey effort.

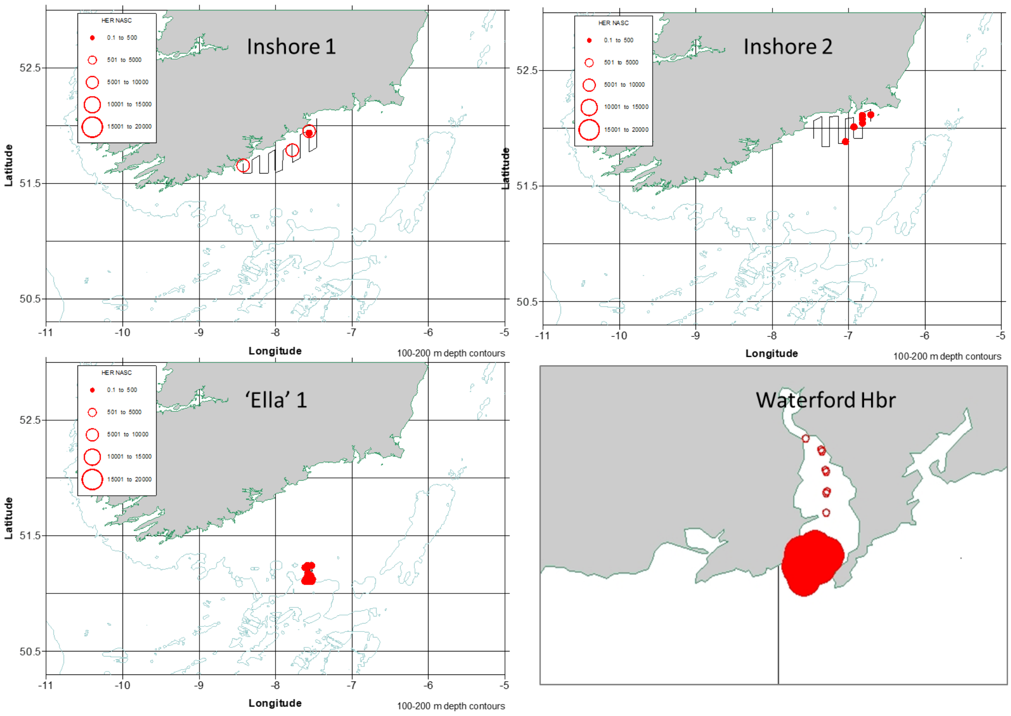

Figure 3. Herring NASC (Nautical area scattering coefficient) plot of the distribution from adaptive survey effort in 2021. Inshore 1: Kinsale to Ram Head, Inshore 2: Helvick to Baginbun, 'Ella' survey: site of commercial fishing activity and Waterford Harbour.

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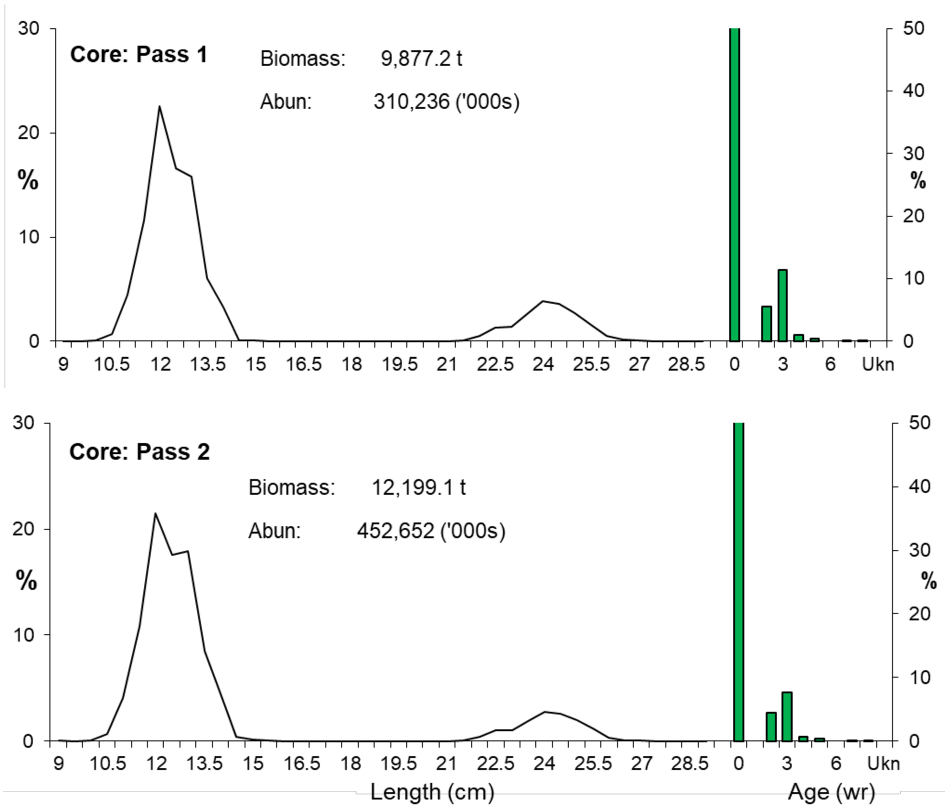

Figure 4. Age and length composition of herring from core survey strata in 2021.

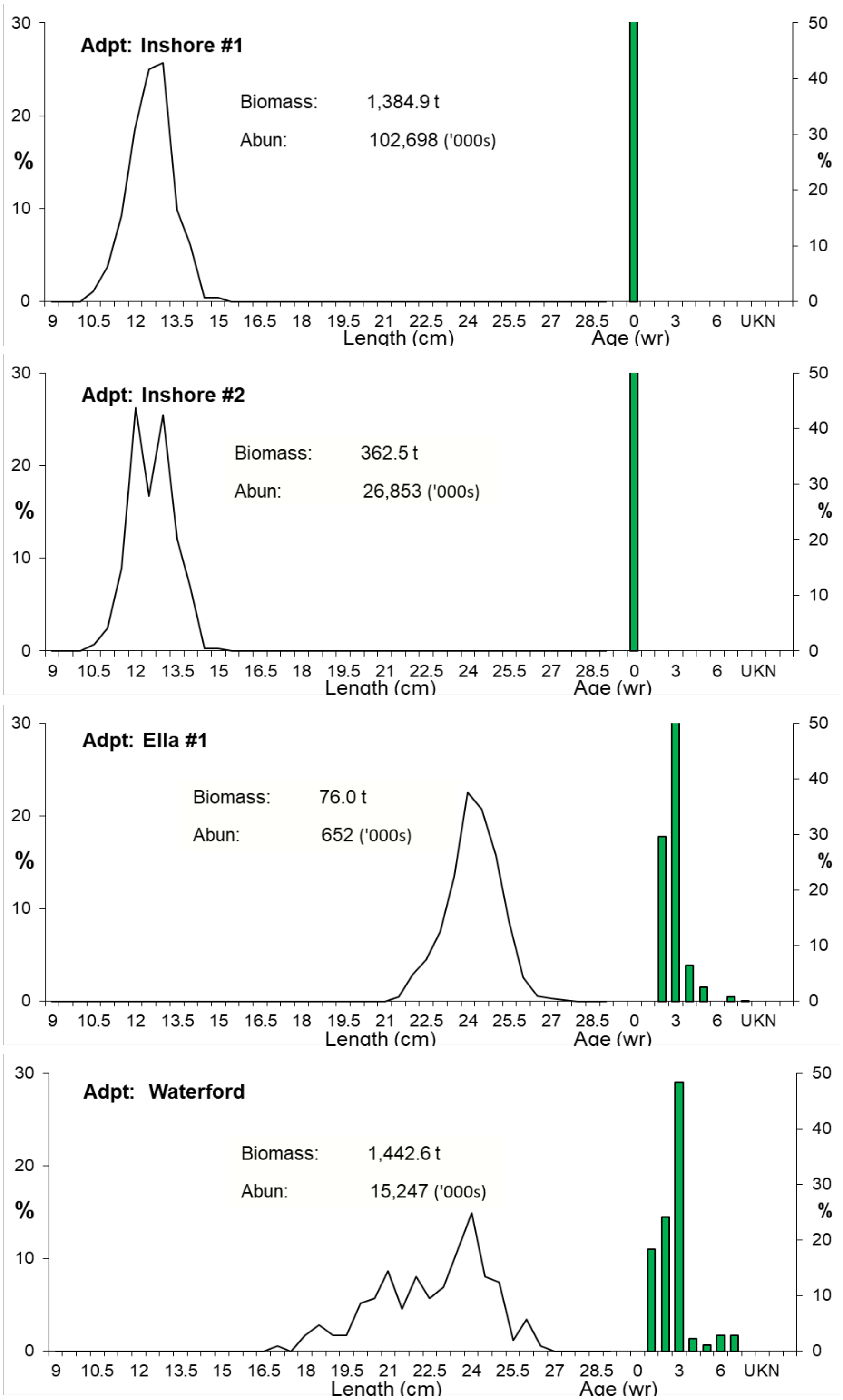

Figure 5. Age and length composition of herring from adaptive survey strata in 2021.

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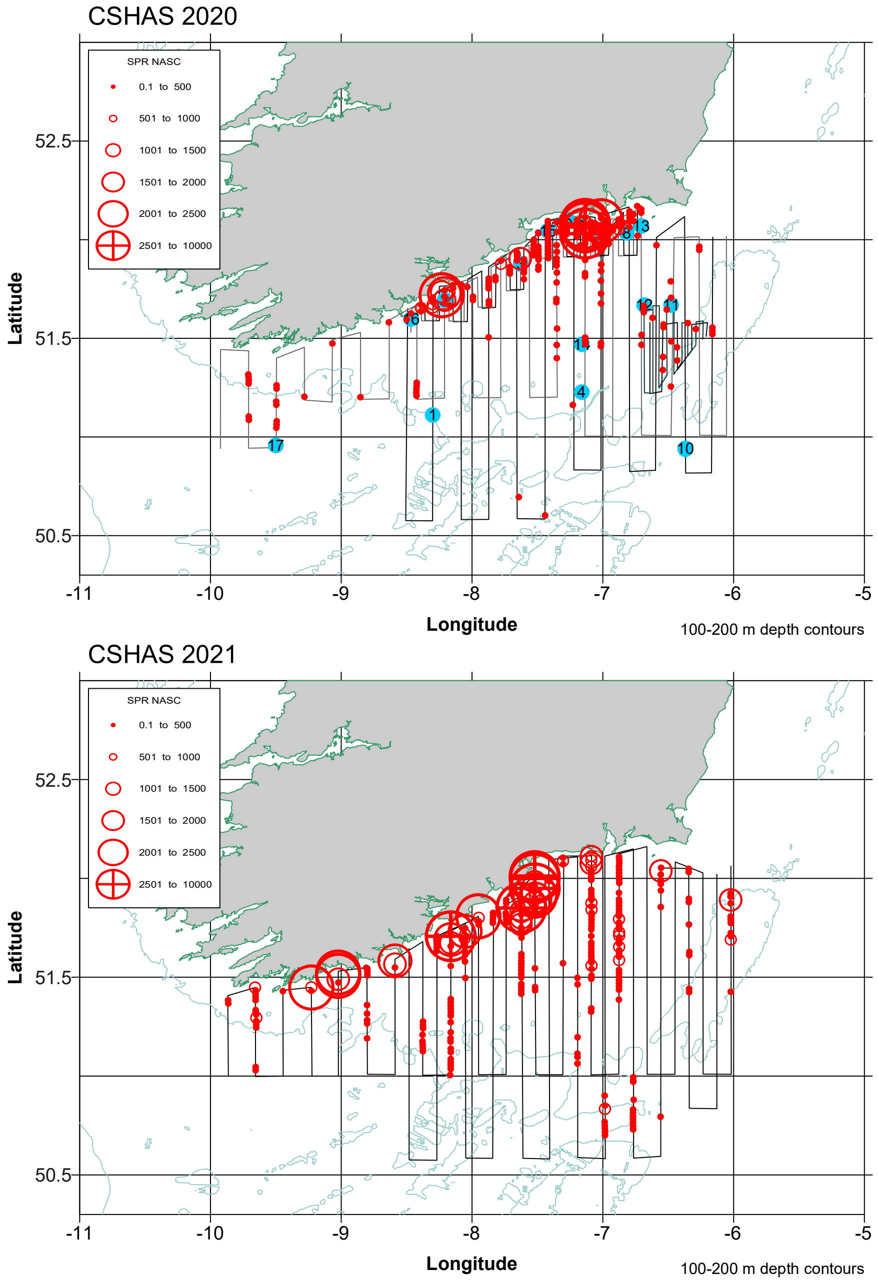

Figure 6. Sprat NASC (Nautical area scattering coefficient) plot of the distribution from combined survey effort, top 2020, bottom 2021.

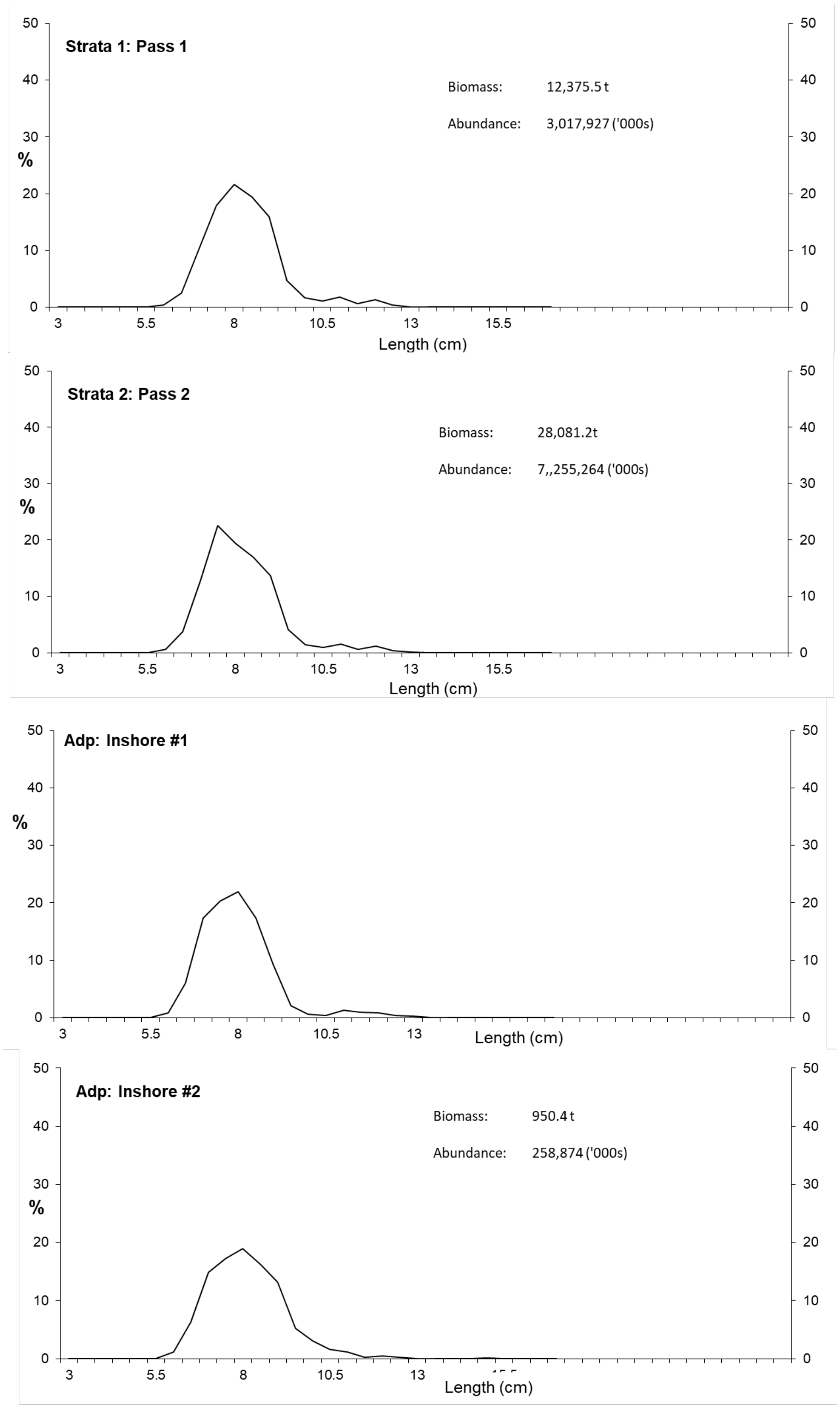

Figure 7. Length composition of sprat by strata and combined survey effort in 2021.

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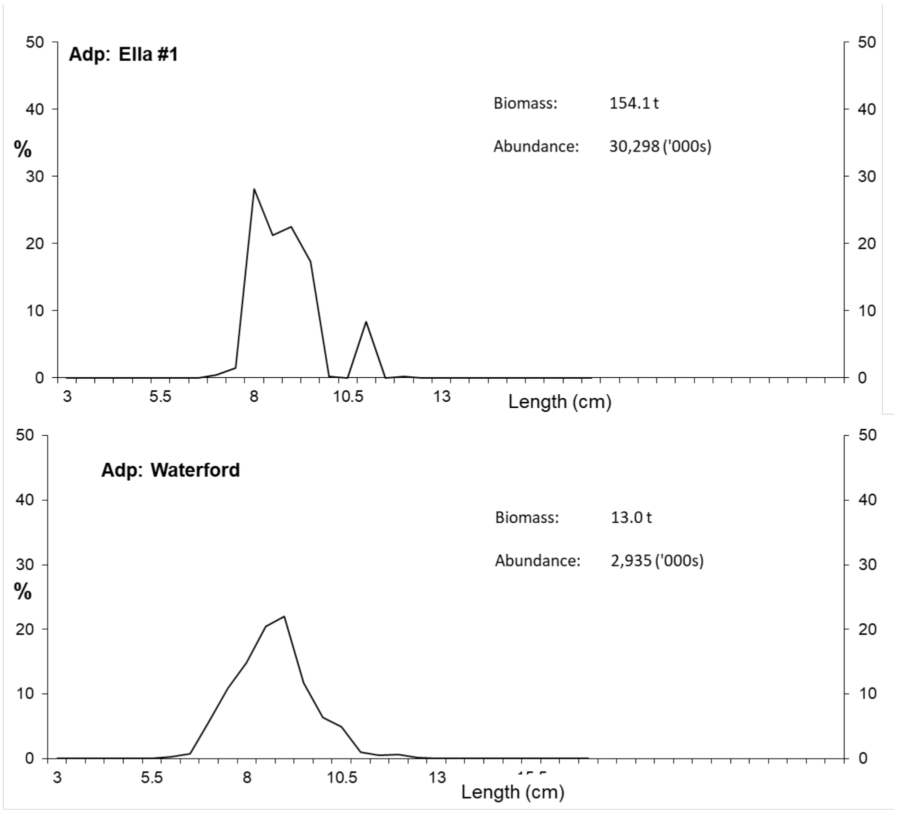
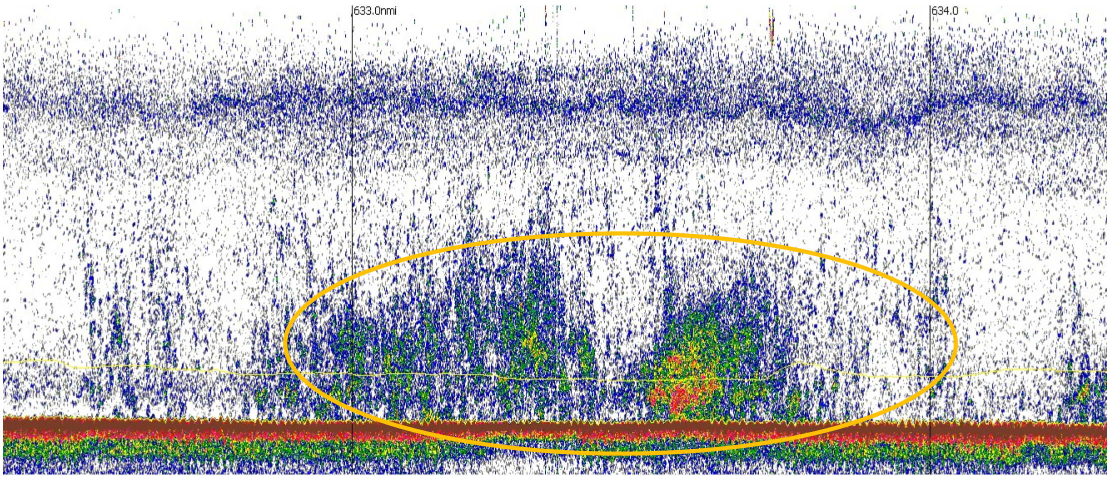
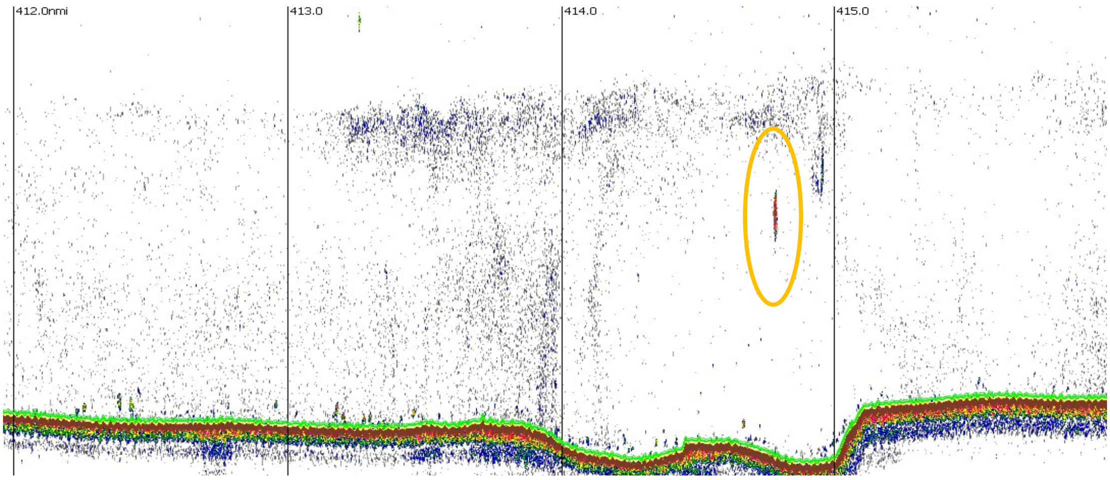


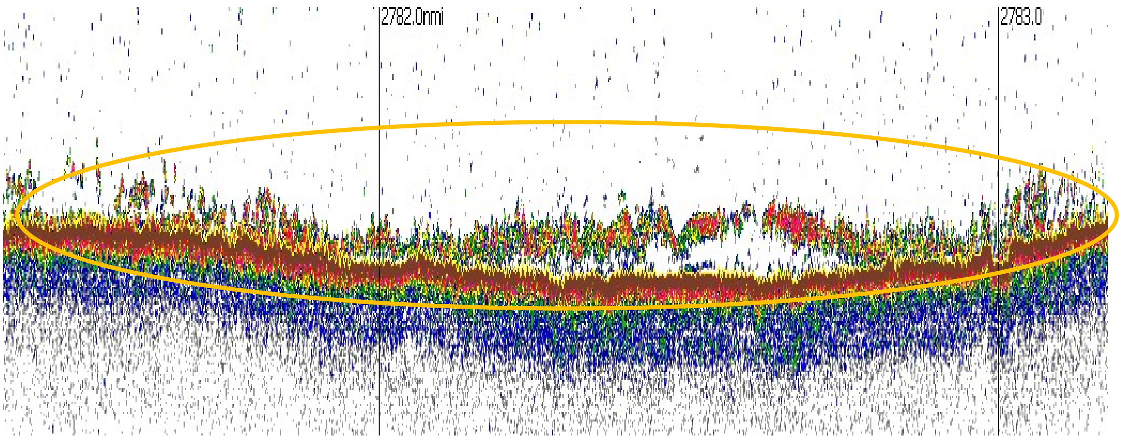
Figure 7. continued.



a). *Medium density echotrace herring observed on the 'Ella' adaptive survey site during trawling. Recorded in daylight hours. Water depth 89 m*

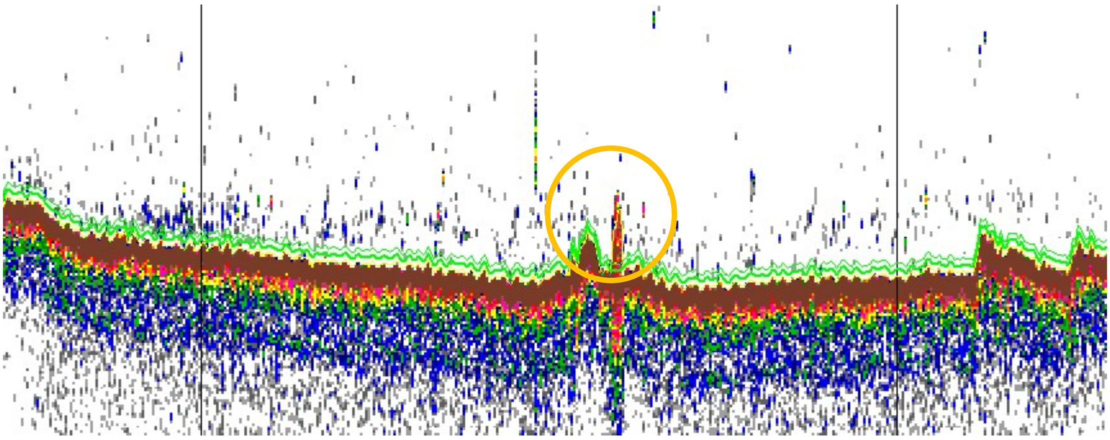


b). *Medium density midwater herring echotrace. Observed during daylight hours in close proximity to 'Ella' Survey area. Water depth 91 m.*

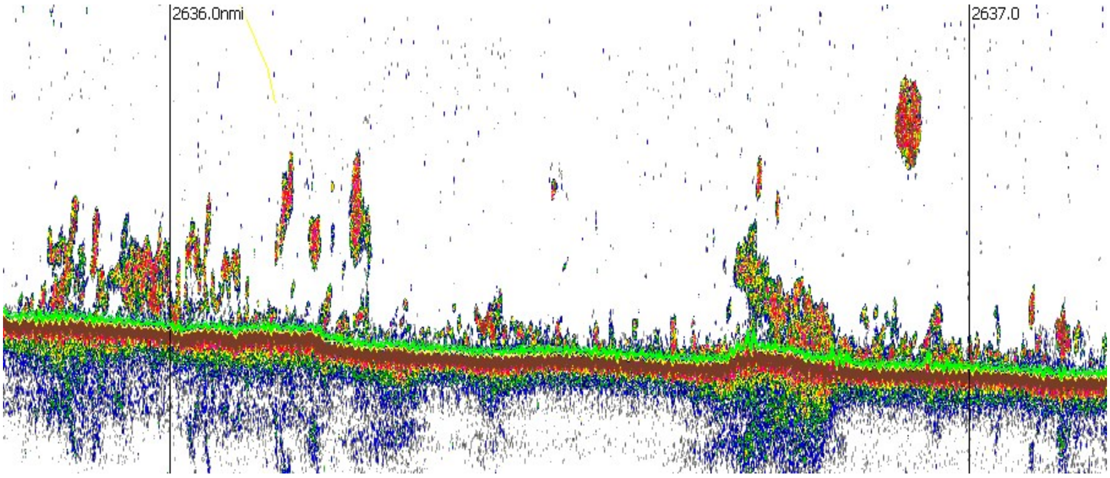


c). *Night time inshore scattering layer containing immature herring, sprat and pilchard. Recorded prior to Haul 22. Water depth 38 m.*

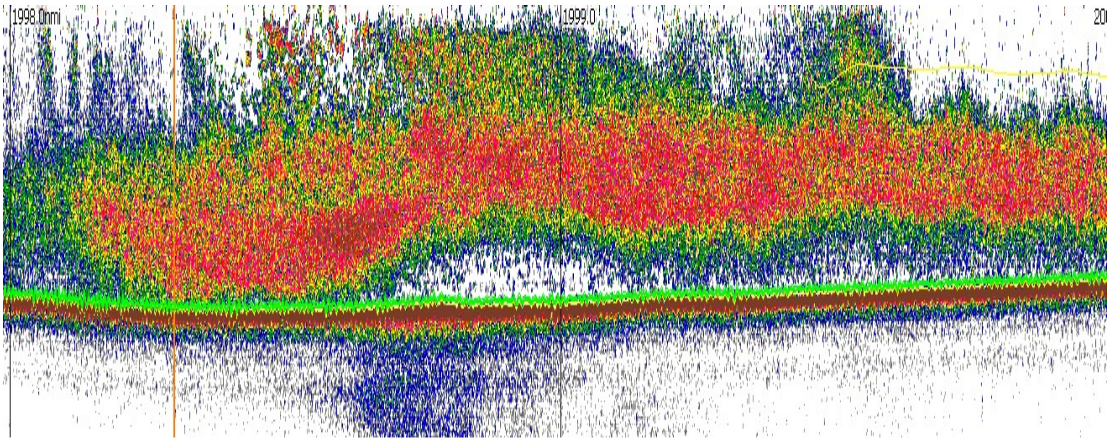
Figure 8. EK60 echograms (38 kHz) recorded prior to directed trawl stations.



d). *Medium density possible herring echotrace observed inshore during daylight hours, not possible to fish on because of poor ground. Water depth 37 m.*



e). *Typical inshore sprat echotraces located south of Ballycotton. Prior to Haul 21. Water depth 30 m.*



f). *High density sprat echotraces recorded inshore at dawn prior to Haul 14. Water depth is 45 m.*

Figure 8a-f. Continued

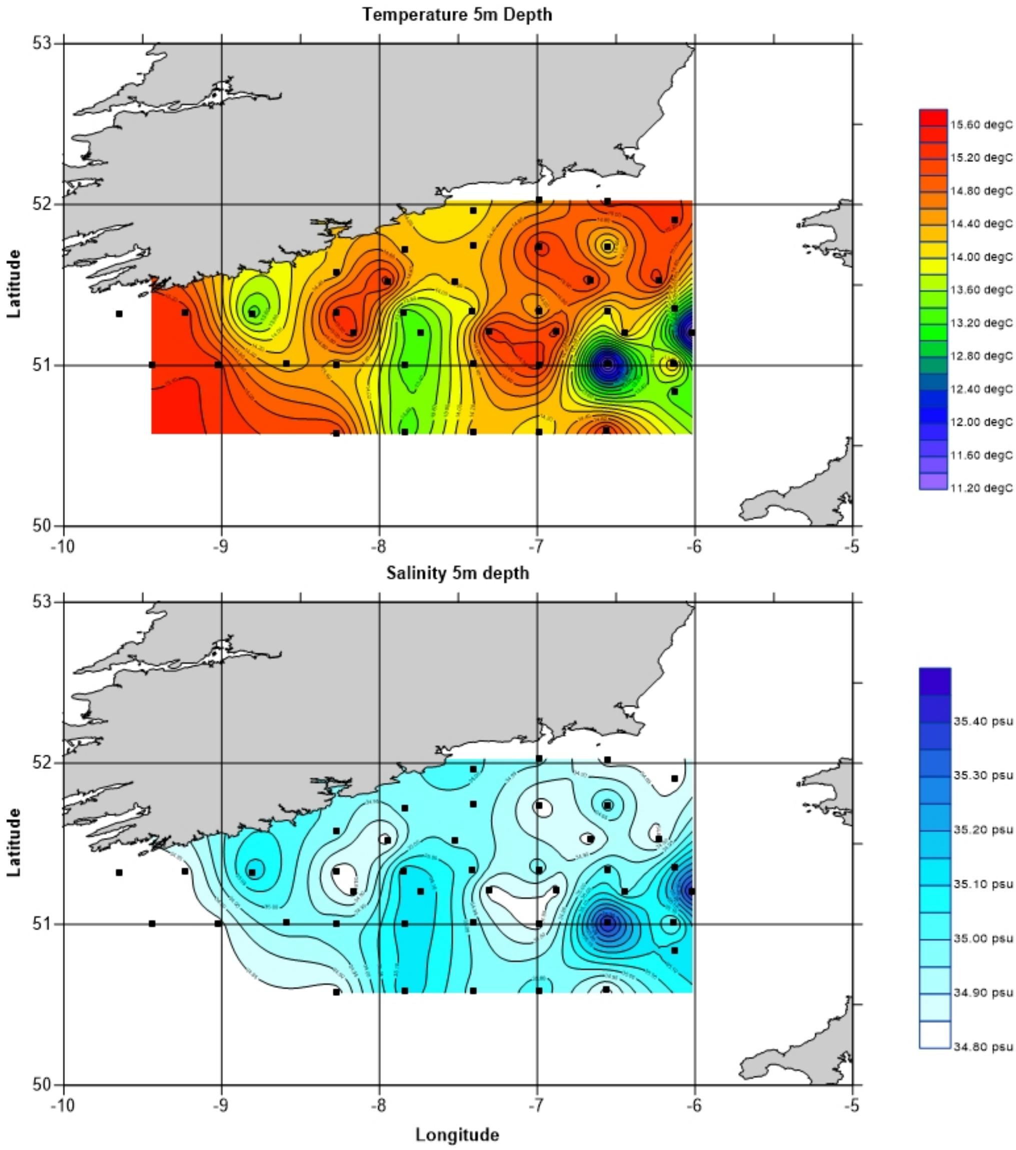


Figure 9. Surface (5 m) plots of temperature and salinity compiled from CTD cast data. Station positions shown as black circles (n=43).

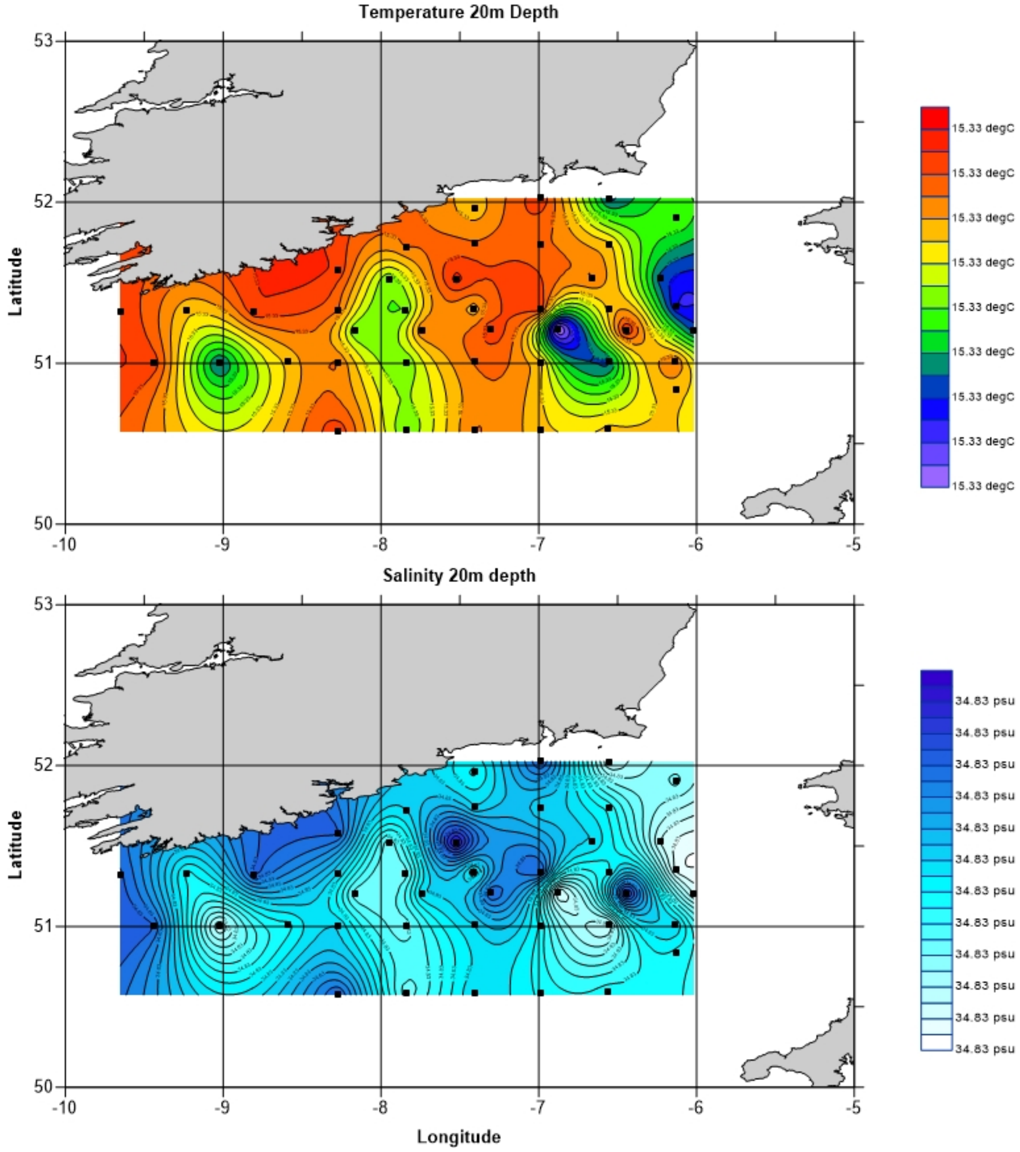


Figure 10. Surface (20 m) plots of temperature and salinity compiled from CTD cast data. Station positions shown as black circles (n=43).

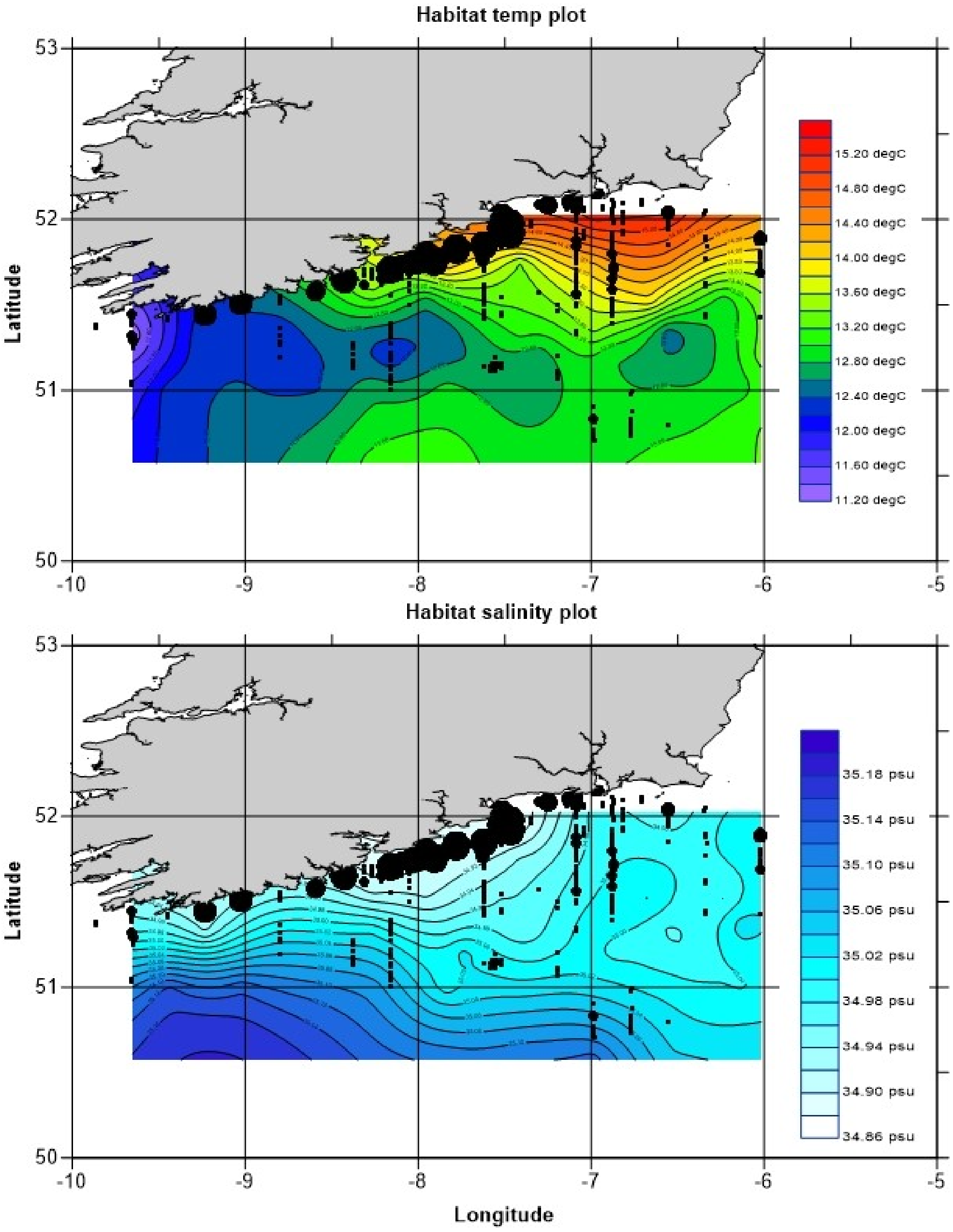


Figure 11. Habitat plots of temperature and salinity at the seabed overlaid with sprat NASC values (black circles).

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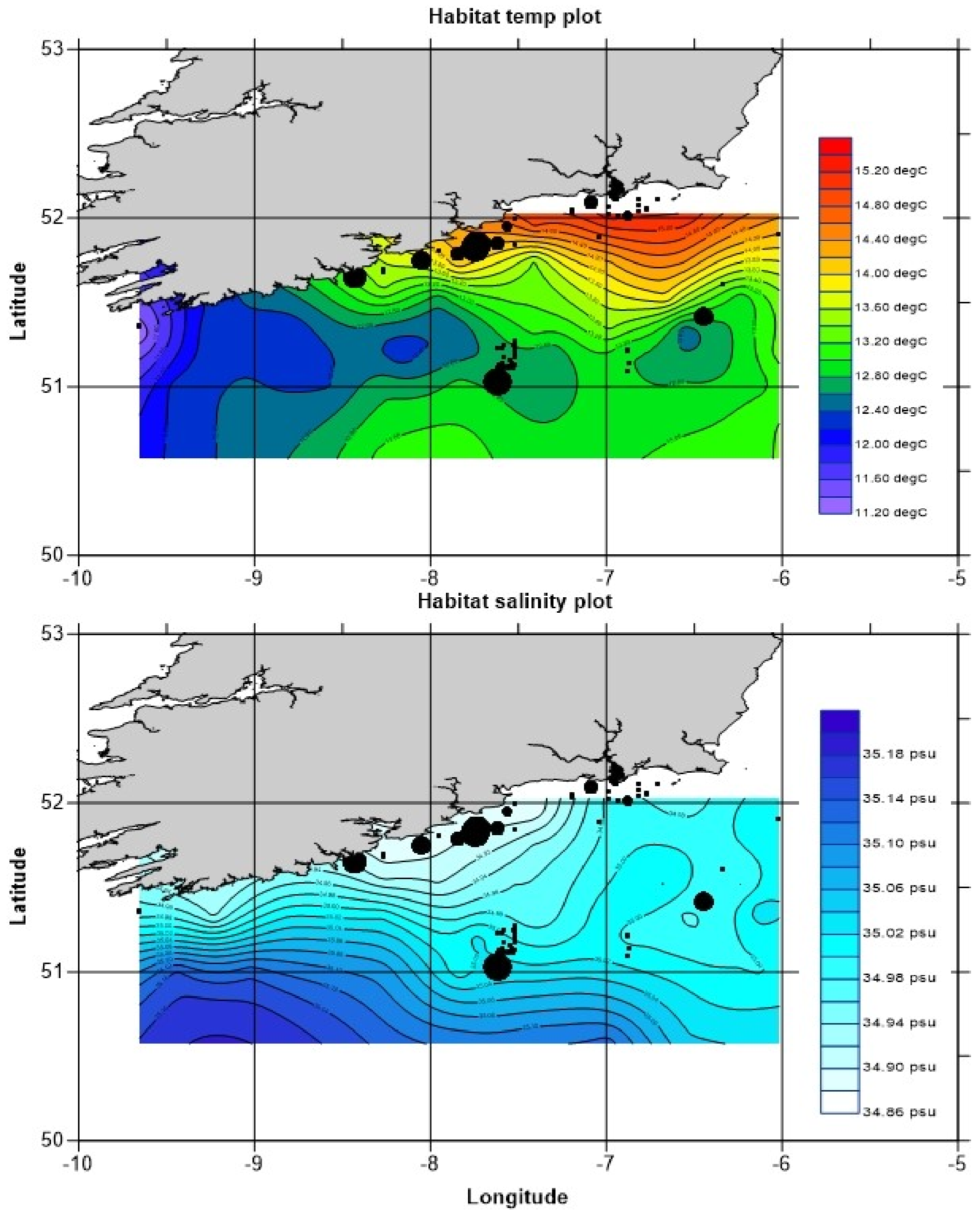

Figure 12. Habitat plots of temperature and salinity at the seabed overlaid with herring NASC values (acoustic density) shown as black circles.

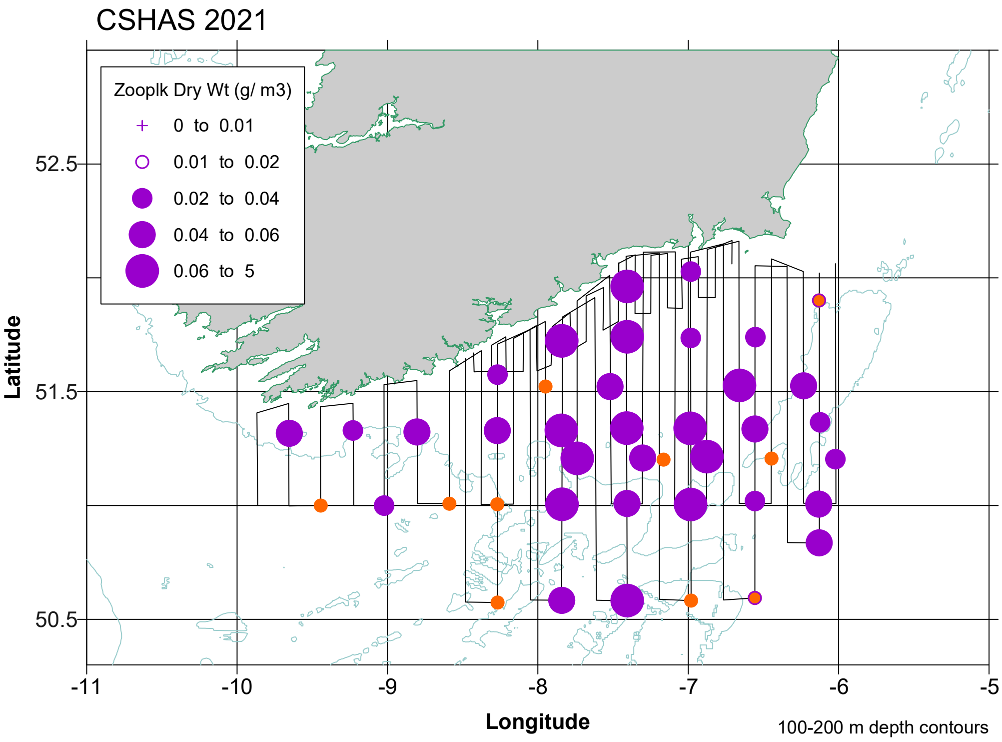

Figure 13. Zooplankton dry weight biomass by station (g dry Wt. m^3).

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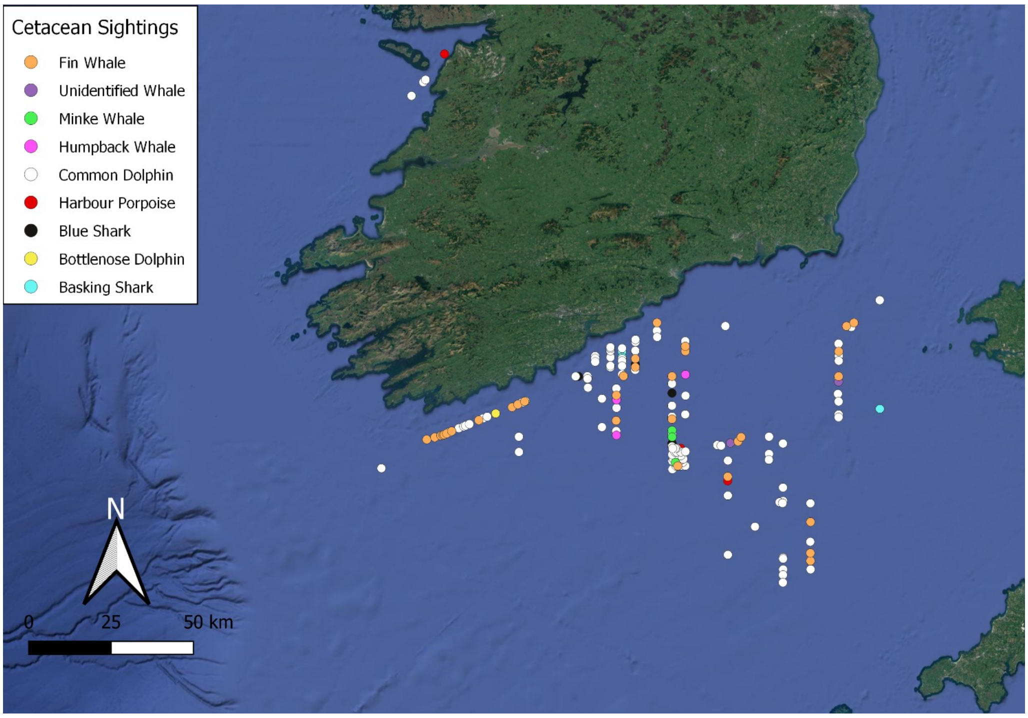


Figure 14. Distribution of all marine mammal sightings during the survey in 2021.

HERRING MIDWATER TRAWL

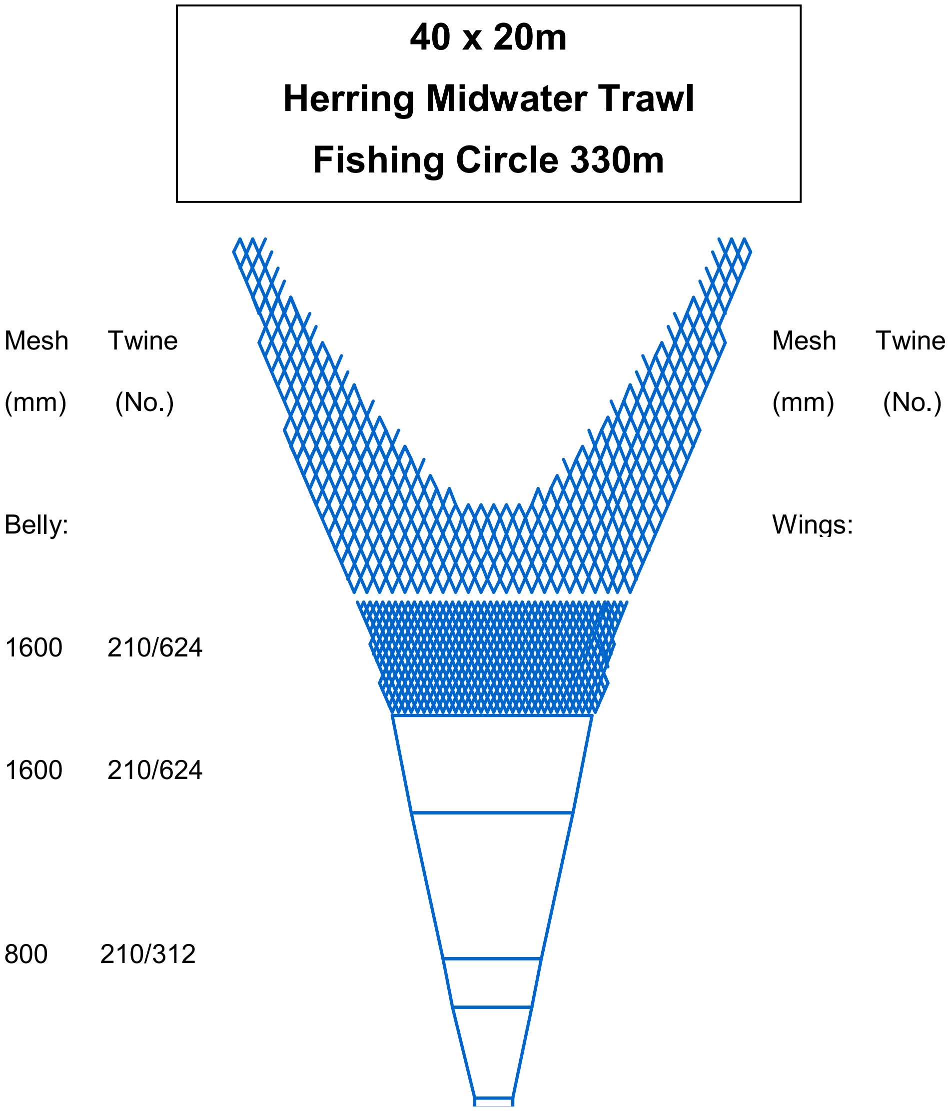


Figure 15. Single herring midwater trawl net plan and layout. Celtic Sea herring acoustic survey.

Note: All mesh sizes given in half meshes; schematic does not include 32m brailer. Centred

8 Appendix

	Age (years)										Numbers	Biomass	Mn Wt	Mature
Length	0	1	2	3	4	5	6	7	8	Ukn	(*10^{-6})	(t)	(g)	(%)
9	123										123	0.7	6	0
9.5														
10	369										369	2.6	7	0
10.5	2296										2296	20.7	9	0
11	13904										13904	128	9.21	0
11.5	35868										35868	380.2	10.6	0
12	70071										70071	817.2	12	0
12.5	51415										51415	658	13	0
13	48992										48992	708.9	14	0
13.5	18834										18834	299.7	16	0
14	10062										10062	179.7	18	0
14.5	313										313	6.3	20	0
15	313										313	7.2	23	0
15.5														
16														
16.5														
17														
17.5														
18														
18.5														
19														
19.5														
20														
20.5														
21														
21.5			272								272	21.7	80	0
22			1042	695							1737	150.8	86.84	55.5
22.5			4149								4149	383.9	92.52	83.3
23			2450	2030							4480	447.9	99.97	93
23.5			5597	2626							8223	853.1	103.75	93.7
24			2971	8245	669						11885	1345.6	113.22	100
24.5			732	10390	146						11268	1370.3	121.62	100
25				7181	1259						8440	1091.4	129.32	100
25.5				3878	494	635					5006	679.7	135.79	100
26				282	704	564					1550	216.2	139.5	100
26.5								397			397	63.1	159	100
27								187			187	30.3	162	100
27.5									84		84	13.9	165	100
28														
28.5														
29														
TSN (*10^{-3})	252559		17213	35326	3271	1198		584	84		310236			
TSB (t)	3209.2		1719.4	4254.7	424.6	162		93.4	13.9			9877.2		
Mean length (cm)	12.35		23.19	24.4	25.06	25.74		26.66	27.5					
Mean weight (g)	12.71		99.89	120.44	129.79	135.23		159.96	165				31.84	

Figure 1. Biomass and abundance at length and age for Core survey: Pass 1.

#VALUE!	Age (years)										Numbers	Biomass	Mn Wt	Mature
Length	0	1	2	3	4	5	6	7	8	Ukn	(*10-³)	(t)	(g)	(%)
9	163										163	1	6	0
9.5														
10	490										490	3.4	7	0
10.5	3047										3047	27.4	9	0
11	18457										18457	170.7	9.25	0
11.5	49308										49308	520.3	10.55	0
12	97253										97253	1135.7	12	0
12.5	79692										79692	1025.5	13	0
13	81138										81138	1188.8	15	0
13.5	38563										38563	629.9	16	0
14	20350										20350	360.7	18	0
14.5	1899										1899	37.5	20	0
15	840										840	18.2	22	0
15.5	212										212	5.3	25	0
16														
16.5														
17														
17.5														
18														
18.5														
19														
19.5														
20														
20.5														
21														
21.5			292								292	23.4	80	0
22			1335	519							1854	160.4	86.52	55.5
22.5			4782								4782	444.4	92.93	83.3
23			2534	2236							4771	481	100.83	93
23.5			6059	2734							8793	921.5	104.8	93.7
24			2948	8999	465						12413	1405.5	113.23	100
24.5			2380	9215	230						11825	1429.3	120.86	100
25				7354	1471						8824	1142.6	129.48	100
25.5				3445	300	1573					5317	717.6	134.96	100
26				75	973	599					1647	232.9	141.41	100
26.5								431			431	68.5	159	100
27								207			207	33.6	162	100
27.5									85		85	14	165	100
28														
28.5														
29														
TSN (*10-³)	391410		20331	34577	3439	2172		638	85		452652			
TSB (t)	5124.5		2062.7	4160.2	449.4	286.3		102.1	14			12199.1		
Mean length (cm)	12.46		23.26	24.37	25.16	25.64		26.66	27.5					
Mean weight (g)	13.09		101.45	120.32	130.68	131.83		159.98	165				26.95	

Figure 2. Biomass and abundance at length and age for Core survey: Pass 2.

Fisheries Ecosystems Advisory Services

	Age (years)										Numbers	Biomass	Mn Wt	Mature
Length	0	1	2	3	4	5	6	7	8	Ukn	(*106)	(t)	(g)	(%)
9														
9.5														
10														
10.5	1141										1141	10.3	9	0
11	3804										3804	36.9	9.7	0
11.5	9509										9509	100.8	10.6	0
12	19018										19018	229	12	0
12.5	25675										25675	336.3	13	0
13	26435										26435	383.3	15	0
13.5	10080										10080	160.6	16	0
14	6276										6276	111.4	18	0
14.5	380										380	7.6	20	0
15	380										380	8.7	23	0
15.5														
16														
16.5														
17														
17.5														
18														
18.5														
19														
19.5														
20														
20.5														
21														
21.5														
22														
22.5														
23														
23.5														
24														
24.5														
25														
25.5														
26														
26.5														
27														
27.5														
28														
28.5														
29														
TSN (*10^3)	102698										102698			
TSB (t)	1384.9											1384.9		
Mean length (cm)	12.57													
Mean weight (g)	13.49												13.49	

Figure 3. Biomass and abundance at length and age for Adaptive survey: Inshore #1 (Offshore).

Length	Age (years) 0	1	2	3	4	5	6	7	8	Ukn	Numbers (*10-6)	Biomass (t)	Mn Wt (g)	Mature (%)
9														
9.5														
10														
10.5	199										199	1.8	9	0
11	663										663	6.4	9.7	0
11.5	2403										2403	25.4	10.58	0
12	7045										7045	84.1	12	0
12.5	4475										4475	58.6	13	0
13	6846										6846	98.8	14	0
13.5	3249										3249	51.4	16	0
14	1840										1840	33.1	18	0
14.5	66										66	1.3	20	0
15	66										66	1.5	23	0
15.5														
16														
16.5														
17														
17.5														
18														
18.5														
19														
19.5														
20														
20.5														
21														
21.5														
22														
22.5														
23														
23.5														
24														
24.5														
25														
25.5														
26														
26.5														
27														
27.5														
28														
28.5														
29														
TSN (*10-3)	26853										26853			
TSB (t)	362.5											362.5		
Mean length (cm)	12.59													
Mean weight (g)	13.5												13.5	

Figure 4. Biomass and abundance at length and age for Adaptive survey: Inshore #2

Fisheries Ecosystems Advisory Services

	Age (years)										Numbers	Biomass	Mn Wt	Mature
Length	0	1	2	3	4	5	6	7	8	Ukn	(*10^{-6})	(t)	(g)	(%)
9														
9.5														
10														
10.5														
11														
11.5														
12														
12.5														
13														
13.5														
14														
14.5														
15														
15.5														
16														
16.5														
17														
17.5														
18														
18.5														
19														
19.5														
20														
20.5														
21														
21.5			3								3	0.2	80	0
22			15	4							19	1.6	86.2	55.5
22.5			29								29	2.8	93.77	83.3
23			34	15							49	4.9	100.02	93
23.5			58	29							88	9.2	104.79	93.7
24			38	101	8						147	16.5	112.79	100
24.5			17	114	4						135	16.4	121.6	100
25				85	18						103	13.3	128.85	100
25.5				42	3	11					56	7.5	134.58	100
26				3	8	6					17	2.4	141.14	100
26.5								4			4	0.6	159	100
27								2			2	0.2	162	100
27.5									1		1	0.2	165	100
28														
28.5														
29														
TSN (*10^{-3})			193	393	42	17		5	1		652			
TSB (t)			19.7	47.6	5.4	2.3		0.8	0.2			76		
Mean length (cm)			23.3	24.44	24.98	25.68		26.64	27.5					
Mean weight (g)			101.84	120.87	128.39	133.99		159.86	165				116.46	

Figure 5. Biomass and abundance at length and age for Adaptive survey: ‘Ella’ #1

	Age (years)										Numbers	Biomass	Mn Wt	Mature
Length	0	1	2	3	4	5	6	7	8	Ukn	$(*10^{-6})$	(t)	(g)	(%)
9														
9.5														
10														
10.5														
11														
11.5														
12														
12.5														
13														
13.5														
14														
14.5														
15														
15.5														
16														
16.5														
17		88									88	3.3	38	0
17.5														
18		263									263	11	42	0
18.5		438									438	20.2	46	0
19		263									263	12.6	48	0
19.5		263									263	15	57	0
20		789									789	45.7	58	0
20.5		701	175								876	52.9	60.4	0
21			701	613							1314	97.9	74.47	0
21.5			701								701	49.5	70.63	0
22			1052	175							1227	97.5	79.5	55.5
22.5			526	351							876	84.6	96.6	83.3
23				1052							1052	109.4	104	93
23.5			526	1139							1665	162.9	97.84	93.7
24				1928	351						2278	263.7	115.73	100
24.5				1227							1227	150.5	122.64	100
25				701			88	351			1139	144.1	126.46	100
25.5				175							175	24.1	137.5	100
26						175	351				526	83.8	159.33	100
26.5								88			88	13.9	159	100
27														
27.5														
28														
28.5														
29														
TSN $(*10^{-3})$		2804	3680	7361	351	175	438	438			15247			
TSB (t)		149.4	296.5	794.5	41.7	22.3	71.7	66.5				1442.6		
Mean length (cm)		19.47	21.93	23.63	24	26	25.8	25.3						
Mean weight (g)		53.28	80.57	107.94	119	127	163.6	151.8					94.61	

Figure 6. Biomass and abundance at length and age for Adaptive survey: Waterford Harbour (commercial sample origin).

Annex 11: 2021 WESPAS Survey Summary Table and Survey Report

Document 11a: WESPAS 2021 survey summary table

Survey Summary table WGIPS 2022	
Name of the survey (abbreviation):	WESPAS / MSHAS (IRL)
Target Species:	Herring, boarfish, horse mackerel
Survey dates:	09 June – 20 July, 2021
Summary: **Cruise Report Link:** https://oar.marine.ie/handle/10793/1720	

The objectives of the survey were carried out successfully and as planned. Good weather conditions dominated during the survey and no weather induced downtime occurred. Comprehensive trawling was carried out (n=65) an increase of 86% compared to 2020. Acoustic sampling effort (-10%) and geographical survey coverage were comparable (-3%) to 2020.

Malin Shelf herring SSB in the WESPAS survey area was ~67% higher in 2021 compared to 2020 (SSB2021 = 297,027 t SSB2020 =177,000 t). The Malin Shelf herring TSB in 2021 was ~ 9% higher than 2020, driven mainly by a large increase in 2-wr herring (TSB2021 = 401,884 t TSB2020 = 370,000t). The CV on the survey for Malin Shelf herring was the same as 2020 (0.25); lower when compared with 2019 (0.37); the CV in 2021 is comparable to previous years in the time series and is benefitting from a better spread of herring and good biological sampling through the area Malin Shelf herring were distributed in the south again in 2021, similar to 2019 and 2020 with adult herring again found south of 56°N. This is the fourth year in a row in recent years that herring were found in this area. For instance, there was very little herring distributed south of 56°N in both 2016 and 2017. The 2021 survey estimate was dominated by 2-wr (44% TSB and 53% TSN) and 3-wr (30% TSB and 26% TSN). This compares well to the 2020 Malin Shelf herring survey estimate which was dominated by 1-wr (24% TSB and 43% TSN) and 2-wr (32% TSB and 29% TSN). There were good signs of young immature Malin Shelf herring (1-wr and 2-wr fish) found in discrete areas in both 6.a.S and 6.a.N

Boarfish distribution was similar to previous years. Total stock biomass (TSB) saw an 11% increase and total stock numbers (TSN) increased by 121% compared to 2020. This increase was largely driven by the high numbers of immature fish observed in the Celtic Sea and along the irish west coast. Increased trawl sampling was required to determine the northern distributuion line of immature boarfish from traditional southern Celtic Sea nursery areas. Of the five survey strata, three saw an increase in biomass (W Hebrides +30%, S Hebrides +47% and W coast +68%) and two saw a decrease (Porcupine Bank -48% and Celtic Sea -11%). Overall, the increase in observed biomass in the northern strata balances the decrease in the Celtic Sea in terms of the distribution of spawning stock biomass (SSB); -2% compared to 2020. The oldest (15+ year) cohort remain the largest contributors to the total stock biomass within the time series. Seven, eight and nine-year-old fish reamin important cohorts within the stock and have track well through the survey index. From 2018 onwards, the boarfish stock has seen a continuued positive growth

phase and the particularly strong 1-year-old fish observed this year will no doubt contribute further. Immature fish from the 2021 estimate represent over 60.3% of the TSN and 20.7% of TSB (91,823t). Aggregations of Celtic Sea herring were encountered during the survey in the historic western and southern feeding grounds around the Pistola and Labadie Banks respectively. Small amounts of herring were observed as by-catch in trawls undertaken as far south as 49°10'N and as far west as the shelf slope margins. Genetic samples were taken from the southernmost herring and it is hoped that the stock origin can be established. Three winter ring fish dominated the total estimate, representing 62.8% of TSB and over 63.7% of TSN. Four winter ring fish ranked second contributing 14% of TSB and 12.8% of TSN. Ranked third are the two winter ring fish representing 12.8% and 14.8% respectively. The survey has successfully tracked the dominate year classes. Maturity analysis of Celtic Sea herring samples indicated 60.9% of 2-wr fish were mature, rising to 95.2% of 3-wr fish. Over 91% of the TSB was mature and 88.6% of TSN. Horse mackerel were found distributed along the Irish west coast and Celtic Sea. Geographical distribution was comparable to 2020. However, no fish were observed northward of 53°30'N as in 2020. The 2021 estimate is 25% lower in terms of TSB and 51% lower in terms of TSN compared to 2020. The 2021 estimate is the lowest in the current time series. No monospecific echotraces of horse mackerel were observed during the survey and biological samples were taken as part of mixed species by-catch. To that end, the 2021 estimate, although reflective of what was present on the ground during the survey, is not considered a true representation of the wider stock and should be treated as such. 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 (V3.1.0, V2.7 and RStoX 1.11) Data uploaded to the ICES Trawl acoustic portal
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	Aggregations of immature boarfish tend to be located above the thermocline in near surface waters and so it is likely that an unknown proportion was unaccounted for in the estimate

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 (Malin Shelf): stock estimate fom the WESPAS Malin Shelf area will be combined with data from Scottish HERAS in 6aN to complete the overall 6a (Malin Shelf) estimate. The stock is considered largely contained within the survey area, although there are concerns in some years about herring around the 4° dividing line to the north of Scotland which separates 6a and 4a stocks. Herring (Celtic Sea); Yes Boarfish and horse mackerel; Good geographical alignment on the southern boundary (Fra: PELGAS) but temporal mis-match (~1 month). No survey coverage in the western Channel area.
Stock ID and mixing issues	Herring (Celtic Sea); Potential mixing with unidientified stocks on the feeding grounds. Genetic sampling underway. There is mixing of 6a and 7.b,c herring in the Malin Shelf area, genetic sampling of all hauls in this area to determine stock identification. Stock splitting of the Malin Shelf herring reults for assessment purposes will be considered in the 6a benchmark in 2022.
Measures of uncertainty (CV)	*CV on abundance* Herring (Malin Shelf): 0.25 Boarfish: 0.31 Horse mackerel: 0.54 Herring (Celtic Sea): 0.71 *Calculation carried out using StoX (V3.5) and R-StoX (V1.1)
Biological sampling	Good sampling carried out for boarfish and herring (Celtic Sea). Poor sampling of horse mackerel (by-catch only).
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole times	*To be answered by Assessment Working Group*

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*

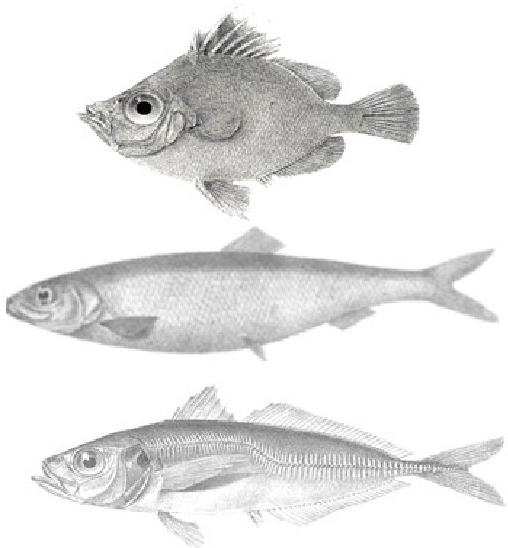
Document 11b: WESPAS 2021 survey report

*Please find report on the next page.

FSS Survey Series: 2021/03

Western European Shelf Pelagic Acoustic Survey (WESPAS)

09 June –20 July, 2021



Ciaran O'Donnell[1], Michael O'Malley[1], Eugene Mullins[1], Paul Connaughton[2*], Niall Keogh[2*], Justin Judge[2*], Peter Croot[3*]

[1]The Marine Institute, Fisheries Ecosystems Advisory Services, Galway

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*Contributing author

Cláir Chistí Eorpacha Struchtúrtha agus Infheistíochta na hÉireann 2014–2020
Cómhaoinithe ag Rialtas na hÉireann agus ag an Aontas Eorpach

Department of Agriculture, Food and the Marine
An Roinn Talmhaíochta, Bia agus Mara

EUROPEAN MARITIME AND FISHERIES FUND

Table of Contents

1 Introduction

The WESPAS survey program is the consolidation of two existing survey programs carried out by FEAS, the Malin Shelf herring acoustic survey, and the boarfish acoustic survey. The Malin Shelf herring acoustic survey has been carried out annually since 2008 and reports on the annual abundance of summer feeding aggregations of herring to the west of Scotland and to the north and west of Ireland from 53°30'N to 58°30'N. The boarfish survey was conducted from 2011 using a chartered fishing vessel and reported the abundance of spawning aggregations of boarfish from 47°N to 57°N. In 2016 both surveys were combined into the WESPAS survey and have been carried out onboard the RV *Celtic Explorer* over a 42-day period, providing synoptic coverage of shelf waters from 47°30'N northwards to 58°30'N.

Age stratified relative stock abundance estimates of boarfish, herring and horse mackerel within the survey area were calculated using acoustic data and biological data from trawl sampling. Stock estimates of boarfish and horse mackerel were submitted to the ICES assessment Working Group for Widely Distributed Stocks (WGWIDE) meeting in August 2021. Herring estimates are submitted to the Herring Assessment Working Group (HAWG) meeting in March every year. Survey performance will be reviewed at the ICES Planning Group meeting for International Pelagic Surveys (WGIPS) meeting in January 2022.

2 Materials and Methods

2.1 Scientific Personnel

Leg	CE21009	CE21009
Dates	09-29 Jun	30 Jun-20 Jul
Days	20	20
Start	Galway	Galway
End	Galway	Galway
Acou (Chief Sci)	Ciaran O'Donnell	Michael O'Malley
Acou	Turloch Smith	Emma White
Acou	Sinead O'Brien	Brendan O'Hea
Acou	Alina Wieczorek	Eugene Mullins
Bio (Deck Sci)	Marcin Blaszkowski	Tobi Rapp
Bio	Sean O'Connor	Ross Fitzgerald
Bio	Roxanne Duncan	Dermot Fee
Bio	Amy Mundye*	Christina Winkler*
MMO	Justin Judge	Justin Judge
SBO	Paul Connaughton	Niall Keogh
Zoo/Salps	Maria McGuinness	Briana Casserly*
CDOM +	Erin Molloy	Kobee Fawkes
CDOM +	Nadeeka Rathnayake	Sean Haughton

* SmartSea student placements

2.2 Survey Plan

2.2.1 Survey objectives

The primary survey objectives are listed below:

- Collect acoustic density measurements of boarfish, herring and horse mackerel within a pre-determined survey area using a split-beam echosounder (EK60) over multiple frequencies
- Determine an age stratified estimate of biomass and abundance for the above target species from survey data
- Collect biological samples from directed trawling on fish echotraces to determine age structure and maturity state of standing stocks
- Take genetic samples of individual herring within ICES divisions 6a and 7b, c for stock identification analysis
- Use vertical CTD casts to determine hydrographic conditions and the extent of shelf front regions
- Collect plankton samples using dedicated vertical trawls to determine biomass of zooplankton and the spatial extent of areas of concentration

- Carry out visual surveys to determine the abundance and distribution of marine mammals and seabirds
- Collect Omni sonar (Simrad SU92) data on the aggregation morphology and behaviour of target species

2.2.2 Survey design and area coverage

Survey coverage began in the southern Celtic Sea at 47°30'N (northern Biscay) and worked northwards to 58°30'N (northern Hebrides), including the Porcupine Bank (Figure 1). Area coverage was based on the distribution of catches from the previous surveys (e.g. O'Donnell et al. 2007, 2011).

The survey area was stratified based on acoustic sampling effort strata and geographical stock boundaries. Transect start points were randomised within each stratum. Parallel transect spacing was set at 15nmi (nautical miles) for the main body of the survey and 10nmi in 2 strata to the northwest of Ireland (NW coast and North Malin strata). Zigzag transects were used in the Minch region due to geographical and depth constraints. High-intensity small scale surveys were carried out in specific areas of interest using established methods. Coverage extended from the 50 m contour inshore to the shelf-slope (350 m). An elementary distance sampling unit (EDSU) of 1 nmi was used during the analysis of acoustic data throughout the survey area. In total, the planned survey covered 4,986 nmi using 63 transects relating to total area coverage of 60,424 nmi².

The survey was carried out from 04:00–00:00 each day to coincide with the hours of daylight when target species are most often observed in homogenous schools. During the hours of darkness, schools generally disperse into mixed-species scattering layers and are not readily available to acoustic sampling techniques.

Survey design and analysis methods for the WESPAS survey adhere to guidelines laid out in the Manual for International Pelagic Surveys (ICES, 2015).

2.3 Fisheries acoustics

2.3.1 EK60 Calibration

All frequencies of the Simrad EK60 were calibrated in 09 June in Galway Bay. Calibration procedures followed methods laid out in Demer *et al.* (2015). The results of the 38 kHz calibration are provided in Table 1.

2.3.2 Acoustic array

Equipment settings for the acoustic equipment were determined before the start of the survey program, and based on established settings employed by FEAS on previous surveys (O'Donnell *et al.,* 2004, ICES, 2015).

Acoustic data were collected using the Simrad EK60 scientific echosounder. Simrad split-beam transducers are mounted within the vessel's drop keel and lowered to the working depth of 3.3m below the vessel's hull or 8.8m below sea surface. Four operating frequencies were used during the survey (18, 38, 120 and 200 kHz) for trace recognition purposes, with the 38 kHz data used to generate the abundance estimate.

While on survey track the vessel is normally propelled using DC twin electric motor propulsion system with power supplied from 1 main diesel engine, so in effect providing “silent cruising” as compared to normal operations. During fishing operations normal two-engine operations were employed to provide sufficient power to tow the net.

2.3.3 Acoustic data acquisition

Acoustic data were recorded onto the hard-drive of the processing unit. The “RAW files” were logged via a continuous Ethernet connection to the vessels server and the EK60 hard drive as a backup in the event of data loss. In addition, as a further back up a hard copy was stored on an external hard drive. Echoview® Echolog (Version 11) live viewer was used to display the echogram during data collection to allow the scientists to scroll through echograms noting the locations and depths of fish schools. A member of the scientific crew monitored the equipment continually. Time and location (GPS position) data was recorded for each transect within each stratum. This log was used to monitor the time spent off track during fishing operations and hydrographic stations plus any other important observations.

2.3.4 Echogram scrutinisation

Acoustic data was backed up every 24 hrs and scrutinised using Echoview® (V 11) post processing software.

The RAW files were imported into Echoview for post-processing. The echograms were divided into transects. Echotraces belonging to one of the target species (herring, boarfish and horse mackerel) were identified and echo integration was performed on the enclosed regions. The echograms were analysed at a threshold of -70 dB and where necessary plankton was filtered out by thresholding at –65 dB.

Partitioning of echograms to identify individual schools was carried out to species level where possible and mixed scattering layers where it was not possible to identify monospecific schools. For scattering layers or mixed schools containing target species the total NASC (Nautical Area Scattering Coefficient) was split using Target Strength (TS) to provide a species specific NASC value. This process was conducted within the StoX program (Johnsen et al., 2019).

The echogram scrutinisation process was carried out by a scientist experienced in scrutinising echograms and with the aid of accompanying trawl catch data.

The allocated echo integrator counts (s_A (NASC, m^2/nmi^2) values) from these categories were used to estimate the herring numbers according to the method of Dalen and Nakken (1983).

The TS/length relationships used predominantly for the survey are those recommended by the acoustic survey planning group based at 38 kHz (ICES, 1994):

Herring	TS = 20logL – 71.2 dB per individual (L = length in cm)
Sprat	TS = 20logL – 71.2 dB per individual (L = length in cm)
Mackerel	TS = 20logL – 84.9 dB per individual (L = length in cm)
Horse mackerel	TS = 20logL – 67.5 dB per individual (L = length in cm)
Anchovy	TS = 20logL – 71.2 dB per individual (L = length in cm)

The TS length relationship used for boarfish is from Fässler et al. (2013):

Boarfish TS = 20logL – 66.2 dB per individual (L = length in cm)

The TS length relationship used for gadoids was a general physoclist relationship (Foote, 1987):

Gadoids TS = 20logL – 67.5 dB per individual (L = length in cm)

2.3.5 Calculation of acoustic abundance

Acoustic data were analysed using the StoX (V 2.7 and R StoX V1.11) software package (Johnsen *et. al.,* 2019). Estimation of abundance from acoustic surveys within StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990).

2.4 Biological sampling

A single pelagic midwater trawl with the dimensions of 85 m in length (LOA) and a fishing circle of 420 m was employed during the survey (Figure 26). Mesh size in the wings was 2.4 m through to 10 cm in the cod-end. The net was fished with a vertical mouth opening of approximately 25 m and was observed using a cable linked Simrad FS70 netsonde. Spread between the trawl doors was monitored using Scanmar distance sensors, all sensors being configured and viewed through a Scanmar Scanbas system.

All components of the catch from the trawl hauls were sorted and weighed; fish and other taxa were identified to species level. Fish samples were divided into species composition by weight. Species other than the herring/boarfish/horse mackerel/mackerel were weighed as a component of the catch. Length frequency and length weight data were collected for each component of the catch. Length measurements of herring, boarfish, sprat and pilchard were taken to the nearest 0.5 cm below. Horse mackerel and mackerel were taken to the nearest 1.0 cm below. Age, length, weight, sex and maturity data were recorded for individual herring, boarfish and horse mackerel within a random 50 fish sample from each trawl haul, where applicable. Length and weight measurements were taken of a further 100 random fish, and for the remainder a random sub-sample of length only fish were measured until 60 fish in one length class was reached. All herring were aged onboard. The appropriate raising factors were calculated and applied to provide length frequency compositions for the bulk of each haul.

Decisions to fish on particular echo-traces were largely subjective and an attempt was made to target marks in all areas of concentration not just high density schools. No bottom trawl gear was used during this survey. However, the small size of the midwater gear used and its manoeuvrability in relation to the vessel power allowed samples from the bottom to be taken in areas of clean ground.

2.4.1 Herring stock identification

A sample of 120 individual herring were taken from each haul in the Malin Shelf area (6a and 7b,c) for genetic analysis to determine the stock identification of herring in this area. All fish sampled for genetics were also fully sampled for length, weight, age, sex, maturity. When less than 120 herring were available to sample from a haul, all the herring were sampled for genetics from the haul. This is part of an on-going effort to determine stock identification of herring on the Malin Shelf using baseline information from spawning fish from numerous areas (Farrell et al. 2021). The aim is ultimately to work towards a split acoustic survey estimate for the herring stocks in this area.

2.5 Hydrography and biogeochemical data collection

Oceanographic stations were carried out during the survey at predetermined locations along the survey track using a calibrated SeaBird 911 rosette sampler. Data were collected from 1 m subsurface and 3-5 m above the seabed.

2.5.1 Hydrography and water sampling

Seawater samples were collected from up to 6 depths on the up cast of the profile by triggering Niskin bottles at predetermined depths related to the hydrography observed during the down cast. The CTD data comprises continuous downcast and up casts records of the pressure, temperature, conductivity (salinity), dissolved oxygen, chlorophyll fluorescence and turbidity. The raw CTD data are processed according to GO-SHIP guidelines via the Seabird software and incorporated into ODV files for the continuous downcast data and the discrete bottle data collected during the up cast.

2.5.2 Coloured Dissolved Organic Matter (CDOM)

Samples for the analysis of CDOM absorption were collected from the CTD cast directly from the Niskin bottles. They were then immediately filtered through an 0.2 µm syringe filter and part of the filtrate used for CDOM analysis onboard and the rest frozen at -20° C for later nutrient and FDOM analysis. CDOM measurements were performed using an Ocean Optics Maya spectrophotometer coupled to a 1m liquid wave guide capillary cell (LWCC), supplied by World Precision Instruments, and an Ocean Optics DH-mini light source.

2.5.3 Nutrient (NO2-, NO3-, PO43-, Si(OH)4) sampling

Seawater samples are collected from the CTD and immediately filtered through 0.2 µm syringe filters. The filtrate is then frozen at -20° C until analysis in the laboratory in Galway. For analysis in the laboratory samples are thawed overnight and then analysed for Nitrite, Nitrate, Phosphate and Silicate using specially adapted low volume methods based on standard green chemistry methods for nutrient analysis in seawater. Selected stations will also be analysed for urea and ammonia as we look to increase our capacity for measuring nitrogen species in connection with a related EPA/Marine Institute funded project, 'Nuts and Bolts' which is focused on the marine transitional zones.

2.5.4 Bacteria, Heterotrophic nanoflagellates, Pico and nanoplankton abundance

Unfiltered seawater samples collected directly from the CTD were run on an Accuri C6 flow cytometer while at sea according to established protocols (Marie et al., 1997; Marie et al., 2014). Briefly we initially run an untreated raw sample to identify the phytoplankton by size and fluorescence, Synechococcus species can be identified at this step by their unique combination of cell size and phycoerythrin fluorescence. A second raw sample is treated with Lysotracker Green to determine heterotrophic nanoplanktonic protists (Rose et al., 2004). While a third sample is fixed with glutaraldehyde and then treated with the DNA stain Syber Green to enumerate marine bacteria and phytoplankton via the combination of chlorophyll fluorescence (red) and the dna stain (green). We also use the Syber Green staining to identify heterotrophic flagellates (Christaki et al., 2011).

2.5.5 Hyperspectral measurements

In order to more directly compare field data with satellite data, a pair of hyperspectral sensors were mounted above the bridge of the *Celtic Explorer*. The sensor pair incorporated an irradiance and radiance sensor for the purposes of determining the hyperspectral reflectance from the surface of the ocean for comparison to the reflectance measured by the ocean colour satellites.

Particulate absorption of fresh water and seawater can be determined by filtering a known amount of sample through a Glass Fibre Filter (GF/F) and measuring the particulate absorption coefficient $a_p(\lambda)$ concentrated on the filter. This technique is called quantitative filter technique (QFT) and corrects for the path length amplification, an effect of scattering. Measurements were made shipboard using a QFT-1 filter holder (WPI) after filtering 200-1000 mL of seawater through a 25 mm GF/F filter. An Ocean Optics Maya spectrophotometer was coupled to the QFT-1 using 600 µm diameter fibre optical cable with a DH mini light source.

2.5.6 Chlorophyll measurements and Ocean Colour (Chlorophyll)

The frozen filters previously measured onboard for the QFT-1 measurements were analysed in the laboratory for chlorophyll a (b & c) concentrations after extraction with 90% acetone after overnight extraction in a -20° C freezer and subsequent measurement of the solution absorbance using an Ocean Optics Flame spectrophotometer with a low volume 10 cm pathlength cell and DT-mini light source. The concentration of chlorophyll a was calculated using the trichromatic equation.

2.6 Zooplankton

2.6.1 Zooplankton

Zooplankton sampling was carried out alongside CTD stations. A weighted 1 m diameter Hydro-bios ring net was used with a 200 µm mesh size and the net was fitted with a Hydro-Bios® calibrated mechanical flow meter to determine the volume of water filtered. Vertical plankton tows were carried out to within 5 m of the seabed for stations where total depth was less than 100 m and to a 100 m maximum for all other stations depths.

Station samples were split in 50:50 for wet and dry processing for stations 1-44 (Celtic Sea and SW coast). Sample splitting was carried out using a Hydro-Bios® sample splitter. The wet component was fixed for further analysis back at the lab. Fixing was carried using a 4% fix volume of buffered formalin.

Dry processing was carried out with each sample filtered through 2000 µm, 1000 µm and 125 µm sieves. For finer gauge samples (1000 and 125 µm) dry weight analysis was carried out. Samples were transferred to petri-dishes and dried onboard (70 °C oven) for a minimum of 24 hrs before sealing and freezer storage. Back in the lab dry weight analysis was carried out on defrosted frozen samples using a Sartorius MSE225S-000-DA fine scale balance (uncertainty of +/- 0.00016 g).

2.7 Marine mammal and seabird surveys

2.7.1 Marine mammal abundance and distribution

The cetacean survey was conducted by a single marine mammal observer (MMOs), with one cetacean observer deployed per survey leg.

Cetacean watches were conducted using a standard single platform line transect survey design while the vessel was travelling at a consistent speed and heading. When the vessel was stationary at oceanographic stations, cetacean watches were conducted using a standard single platform point sampling survey design. Visual watches were undertaken from the vessel's crow's nest, located 17.45 m above sea level, during all daylight hours, when weather conditions permitted. During periods of unfavourable weather conditions, observations were carried out from the bridge (10.63 m above sea level).

Survey effort was concentrated in periods of sea state 6 or less, and in moderate or good visibility. Survey effort conducted outside of these parameters was conducted at the discretion of the observers. Survey effort for cetaceans was concentrated within an arc of 60° either side (i.e., to port and to starboard) of the vessel's track-line but all sightings to 90° both side of the track-line and further aft were also recorded. Searching for cetaceans was predominantly done with the naked eye, however, Nikon Prostaff 7 8x42 binoculars and a Canon EOS 7D DSLR camera with a Sigma 100-400 mm zoom lens was used to confirm species identification and group size, and assess behaviour. Survey effort was also carried out during hauls and when at CTD stations.

The Cybertracker (http://www.cybertracker.org/) data collection software package (Version 3.501) was used to collect all positional, environmental and sightings data, and save it to a Microsoft Access database. Positional data was collected using a portable GPS receiver with a USB connection and recorded every 5 seconds.

Each line transect was assigned a unique transect number, and a new transect was started anytime the vessel activity changed (i.e. changing from on-transect to inter-transect). Each subsequent sighting was also assigned to this unique transect number.

Environmental data was time-stamped and recorded with GPS data at the beginning and end of each line transect. Environmental data was recorded at least every 15-30 minutes, or sooner if there was a change in environmental conditions. Environmental data recorded included; wind speed, wind direction, sea state, swell, visibility, cloud cover and precipitation. All data entry was time stamped by Cybertracker and saved in the Access database.

The distance of each sighting from the ship was estimated using a fixed interval range finder (Heinemann, 1981), while the bearing from the ship was estimated with an angle board. This data, along with data such as species identification, group size, composition, heading, sighting cues, surfacing interval, behaviour and any associations with birds or other cetaceans was also recorded on the time stamped Cybertracker sighting record page. Where species identification could not be confirmed, sightings were recorded at an appropriate taxonomic/confidence level (i.e. probable, possible, unidentified whale, unidentified dolphin etc.). Auxiliary and incidental sightings were also recorded.

Ancillary data such as line changes, changes in survey activity (e.g. fishing/CTD cast) and fishing vessel activity were also recorded.

2.7.2 Seabird abundance and distribution

The seabird survey was conducted from the 10/06/21 to the 19/07/21 using a single seabird surveyor on each survey leg. The seabird observer conducted visual survey effort, while also collecting and recording all survey data. The seabird observer conducted visual survey effort while simultaneously recording all data.

The observer's survey effort was maximized and optimized during periods of sea state less than or equal to sea state 6 and with visibility of greater than 300m. Additional visual point sampling (e.g., at oceanographic sampling stations or fishing stations) and incidental recording were also employed; however, line transect survey effort was prioritised by the observer. Seabird watches were conducted using a standard single platform line transect survey design while the vessel was travelling at a consistent speed and heading. Observations for seabirds were conducted from the monkey island (deck height 12 m above sea level) or the bridge (deck height 10 m above sea level). Observations were conducted from the monkey island preferably, however, as in previous surveys aboard the RV *Celtic Explorer*, access to the monkey island was dependent on weather conditions.

The data collection methodology was based on that originally proposed by Tasker *et al.* (1984) with later adaptations applied to allow correction factors to be applied for missed birds (Camphuysen *et al*., 2004). The method employed used a single platform line transect survey design with sub-bands to survey birds associated with the water, while flying birds were surveyed using a 'snapshot' technique. Observer effort was concentrated in a bow-beam arc of 90^o to one side (i.e., to port or starboard) of the vessel's track-line, however, all seabirds observed outside this area were also be recorded.

Survey effort for seabirds associating with the water were concentrated within a survey strip of 300m running parallel and adjacent to the vessels track-line and extending to the horizon. All birds surveyed within this region were be recorded as 'in-transect' and assigned to one of four distance sub-bands (A: 0-50 m, B: 50-100 m, C: 100-200 m, D: 200-300m) according to their perpendicular distance from the track-line. This approach allows for the evaluation of biases caused by specific differences in detection probability with increasing distance from the track line (Camphuysen *et al.* 2004). Seabirds occurring outside of this survey strip were recorded as 'off-transect' and assigned to separate sub-band (E: >300 m). The perpendicular distance to an animal was estimated using a fixed interval range finder (Heinemann, 1981), ensuring each animal is allocated to the correct distance sub-band.

Flying birds were surveyed using 'snapshots', where instantaneous counts of flying birds within a survey quadrant of 300 m x 300 m were conducted. The periodicity of these 'snapshots' was vessel speed dependent but timed to allow counts to occur as the vessel passes from one survey quadrant to the next. This method minimises biases in counts of flying birds relative to the movement of the vessel (Pollock *et al.,* 1997, Camphuysen *et al.* 2004).

Seabirds remaining with the vessel for more than 2 minutes were deemed to be associating with the vessel (Camphuysen *et al.* 2004) and were recorded as such. Seabirds seen associating with other vessels (i.e. fishing vessels) were also recorded as such.

Searching for seabirds was done with the naked eye, however, Leika Ultravid 8x42 HD binoculars were used to confirm parameters such as species identification, age, moult, group size and behaviour (Mackey *et al.* 2004). A Canon EOS 7D Mark II DSLR camera with a Canon EF 100-400 mm F4.5-5.6 IS II USM telephoto lens was used to visually document other information of scientific interest. Data was also collected on all migratory/ transient waterfowl and terrestrial birds encountered.

The Cybertracker (http://www.cybertracker.org/) data collection software package (Version 3.501) was used to collect all positional, environmental and sightings data, and save it to a Microsoft Access database. Positional data was collected using a portable GPS receiver with a USB connection and recorded every 5 seconds.

Each line transect was assigned a unique transect number, and a new transect was started anytime the vessel activity changed (i.e. changing from on-transect to inter-transect). Each subsequent sighting was also assigned to this unique transect number.

Environmental data was time-stamped and recorded with GPS data at the beginning and end of each line transect and also as soon as any change in environmental conditions occurred. Environmental data recorded included; wind speed, wind direction, sea state, swell, visibility, cloud cover and precipitation.

Each sighting was time-stamped and recorded with GPS data using Cybertracker. Sighting data such as; species identification, distance band, group size, composition, heading, age, moult, behaviour and any associations with cetaceans or other vessels were also recorded on the time stamped Cybertracker sighting record page. Where species identification could not be confirmed, sightings were recorded at an appropriate taxonomic level (i.e. large gull sp., Larus sp., common tern, etc.).

Ancillary data such as line changes, changes in survey activity (e.g. fishing/CTD cast) and fishing vessel activity were also recorded.

3 Results

3.1 Malin Shelf herring (6.a.S, 7.b, c and 6.a.N south of 58°30'N)

3.1.1 Biomass and abundance

Herring	Abund ('000)	Biomass (t)
Total stock (TSB)	2,987,573	401,884
Spawning stock (SSB)	1,932,887	297,027

The Malin Shelf Herring total stock biomass (TSB) was 401,884 t and total stock numbers (TSN) was 2,987,573,000 (Table 3). The spawning stock biomass (SSB) was 297,027 t and spawning stock numbers (SSN) was 1,932,887,000. The CV for the survey was 0.25.

The Malin Shelf survey area was divided into 6 strata representing a total area coverage of 23,490 nmi^2 (Figure 2 & Table 5). A breakdown of herring stock abundance and biomass by age, maturity and stratum is detailed in Table 3 and Figure 4. The Malin Shelf survey time series is provided in Table 4.

3.1.2 Stock distribution

In the Malin Shelf area 18 hauls contained herring and 5 hauls contained >50% herring by weight of catch (Figure 1 and Table 2). A total of 659 echotraces were assigned to herring compared to 965 in 2020 in this area.

The area covered by the RV *Celtic Explorer* was similar to the 2020 survey. The area of 6.a.N to the north of 58°30'N was covered by RV Scotia in 2021; the overall estimate of the survey for the stock assessment of herring in 6.a will therefore be complete when both surveys are combined at WGIPS 2022. Herring were distributed in all of the six strata (Table 5). A total of 211 EDSUs (1nmi. long) contained herring in the Malin Shelf survey area in 2021, compared to 261 in 2020. This included a number of high NASC value EDSUs, with areas of high density occurring to the north of Tory Island, northwest of the mouth of Lough Swilly in 6.a.S, and south of St. Kilda in 6.a.N (Figure 3). Herring were again found in large numbers south of 56 ˚N in 2021, similar to the historical distribution of herring found during this time series. There were adult herring distributed south of the 56°N in 2021 similar to 2020 and 2019; herring had been largely absent for a number of years prior to this. Herring school morphology was mixed in 2021, with schools found in midwater as fast-moving pillars, in strong pillars attached to the seabed and in dispersed marks in close proximity to the seabed (Figures 11h, 11j, 11l and 11m). Overall the stock was distributed throughout a similar area to 2020 but in greater numbers in 6aS, including immature fish similar to 2020 (Figures 3 and 4). The distribution of herring during the survey period is usually observed in 3 particular regions; north of 57°N (west of the Hebrides), between 56-57°N (south and west of Barra Head) and south of 56°N (north and west of Donegal and Stanton Bank). The survey in 2021 largely followed this distribution.

3.1.3 Stock composition

A total of 922 herring were aged from survey samples with 3,742 length measurements and 1,615 length-weights recorded. Herring age samples ranged from 0-10 year olds

(Table 3 & Figure 4). Samples of flesh (~1cm^3) were also taken from all 922 herring for genetic analysis to establish stock identification.

The 2021 survey estimate was dominated by 2-wr (44% TSB and 53% TSN) and 3-wr (30% TSB and 26% TSN) (Table 3). The third most dominate age group was 4-wr herring contributing 9% to the TSB and 7% to TSN. Combined these three age classes represented 83% of TSB and 86% of TSN.

Maturity analysis of herring samples in 2020 indicated overall 74% of herring (TSB) were mature. In 2020, only 48% of herring (TSB) were mature. Maturity analysis by age class (TSN) showed that 1% of 1-wr, 45% of 2-wr, 97% of 3-wr fish, and 100% of fish of 4-wr and older were mature (Table 3).

3.2 Boarfish

3.2.1 Biomass and abundance

Boarfish	Abund ('000)	Biomass (t)
TSB estimate	21,804,545	443,777
SSB estimate	8,583,660	351,954

Boarfish TSB (total stock biomass) and abundance (TSN) estimates were 443,777 t and 21,804,545,000 individuals (CV 0.31) respectively. The 2021 estimate of total stock biomass is 11% more than observed in 2020 with a corresponding increase of 121% in abundance, largely driven by the amount of immature fish observed.

Spawning stock biomass (SSB) was comparable to 2020 (-3%). However, distribution of these mature fish was different, with the centre of gravity located further north than in previous years.

The boarfish survey area was divided into five strata representing a total area coverage of 50,552 nmi^2 (Figure 2). A breakdown of boarfish stock abundance and biomass by age, maturity and stratum is detailed in Table 6 & 7 and Figures 5 & 6. The boarfish survey time series is provided in Table 8.

3.2.2 Stock distribution

A total of 65 trawl hauls were carried out during the survey (Figure 1), with 23 hauls containing >50 % boarfish by weight (Table 2).

A total of 976 echotraces were assigned to boarfish compared to 928 in 2020. Boarfish were observed in all survey strata (Table 7). Geographical range was comparable to previous years with the greatest biomass occurring in the Celtic Sea (53.1 % of total biomass and 56.6% of total abundance), followed by the Irish west coast (33.4% TSB & 37.8% TSN). Within the Celtic Sea, the highest density of fish was observed in the southern survey area, south of 50°N. Juvenile boarfish dominated catches throughout the Celtic Sea (Figures 11a-b). Mature fish were present in trawl samples throughout the area but were largely dominated by the presence of immature fish. Of the 28 hauls undertaken in the Celtic Sea stratum, two catches, one in the extreme south (Haul 1) and in the northern Celtic Sea (Haul 24) contained a higher proportion of mature to immature fish by number (Figure 11c). Overall, the biomass is comparable to 2020 for the Celtic Sea strata for the same effort, but the age profile is dominated by immature fish as described.

The west coast stratum ranked second contributing 33.4% of total biomass (37.8% abundance). A notable increase in biomass was observed in the west coast stratum with more than double the amount of boarfish observed in 2021 compared to 2020. This can be accounted for in part by a very high density aggregation of immature fish observed north of 54°N (Haul, 37, Table 2). Overall, immature boarfish dominated in the southern part of the west coast strata (south of 52°N) whereas, north of 52°N no immature boarfish were observed in this stratum.

The distribution of boarfish north of 55°N (South and West Hebrides strata), was characterised by medium and high density aggregations occurring in close proximity to the shelf edge and were observed in the northernmost latitudes of the survey (Figure 5). In both strata, increased biomass was observed as compared to 2020 (+47% South Hebrides and +30% West Hebrides).

Overall, the most notable feature in regards to stock distribution was that the centre of gravity for the mature component of the stock which was located further north than in previous years and the high abundance of immature fish, especially in the Celtic Sea.

3.2.3 Stock composition

A total of 1,474 boarfish were aged from survey samples in addition to 5,724 length measurements and 2,651 length-weights recorded. Boarfish age samples ranged from 1-15+ years (Table 6 & Figure 6). The age structure of the stock was determined using an established age length key.

The 15+ year age classes dominate the 2021 estimate contributing over 23% of TSB and 5.6% of TSN (Table 6). However, the contribution of the 1, 2 and 3-year-old fish combined represents over 33.1% of the TSB and over 72.8% of TSN. For the 2021 estimate, the strong year classes of 7, 9 and 10-year-old fish are represented but in lower numbers. The 2021 stock estimate is dominated by the new, and newly recruiting cohorts of 1-3-year fish.

Maturity analysis of boarfish indicated 79.3% of observed biomass was mature (39.7% total abundance) compared to 89.5% biomass and 58.6% abundance in 2020. The year-on-year increase in the contribution of immature fish to the standing stock estimate beginning in 2018 continues in to 2021, indicating a continued positive trend of growth for the stock.

3.3 Horse mackerel

3.3.1 Biomass and abundance

Horse mackerel	Abund ('000)	Biomass (t)
TSB estimate	129,431.0	35,506.4
SSB estimate	129,063.0	35,478.2

Horse mackerel TSB (total stock biomass) and abundance (TSN) estimates were 35,506 t and 129,431,000 individuals (CV 0.54) respectively. The 2021 estimate is 25% lower in terms of biomass and 51% lower in terms of abundance compared to 2020.

The horse mackerel survey area was composed of 7 strata relating to an area coverage of 57,102 nmi^2 as shown in Figure 2. A breakdown of horse mackerel stock abundance and biomass by age, maturity and stratum is detailed in Tables 9 & 10 and Figures 7 & 8.

3.3.2 Stock distribution

A total of 65 trawl hauls were carried out during the survey (Figure 1), with no hauls containing >50% horse mackerel by weight. Fifteen hauls contained horse mackerel (Table 2).

A total of 59 echotraces were assigned to horse mackerel (136 in 2020). Horse mackerel were observed in the Celtic Sea and west coast strata (Figure 7). No schools were observed north of 53° 30N or on the Porcupine Bank. Observations of horse mackerel along the west coast and Celtic Sea were comparable to previous years with the exception of the limited northern distribution this year. However, the overall acoustic density was lower and is the lowest in the time series (Table 11).

Of the seven strata surveyed, two contained horse mackerel; the Celtic Sea contained the largest proportion of biomass observed (52.5% of TSB) and the west coast stratum (47.5%). Overall, aggregations of horse mackerel were low density. No monospecific horse mackerel aggregations were detected and biological samples were taken only as part of mixed species catches.

3.3.3 Stock composition

A total of 257 horse mackerel were aged from survey samples in addition to 231 length measurements and 22 length-weights recorded. Horse mackerel age samples ranged from 2-16 years (Table 9 & Figure 8). Age structure of the stock was determined using an age length key from constructed from the previous years aged survey samples.

The 9-year-old fish (2012-year class) dominated this year’s survey estimate representing 25.4% of TSB and 22.9% of TSN (Table 9). The 7-year-old fish ranked second representing over 15.2% of TSB and 16.9% of TSN (Table 9). Fourteen-year-old fish were ranked third contributing 9.6% to TSB and 7.6% to TSN. Combined these three age classes represented 50.3% of TSB and 47.4% of TSN.

Maturity analysis of horse mackerel samples indicated 99.9% of the total stock biomass was mature and over 99.7% of total abundance. Maturity analysis by age class showed that all 3-year-old fish and older were mature and fully recruited to the spawning stock (Table 9). The number of 2-year-old fish sampled was low and may therefore not fully reflect the actual spread of maturities in this transitional year class.

3.4 Celtic Sea herring (7g and j)

3.4.1 Biomass and abundance

CS Herring	Abund ('000)	Biomass (t)
Total stock	710,696.0	93,785.8
Spawning stock	629,625.0	85,399.2

The estimate of Celtic Sea (CS) herring TSB (total stock biomass) and relative abundance (TSN) estimates were 93,785.8 t and 710,696,000 individuals (CV 0.71) respectively.

The herring survey area was composed of a single stratum in the Celtic Sea, representing an area of over 30,958 nmi² and was surveyed using the standard survey transect spacing of 15 nmi. No high intensity surveys were carried out for herring in 2021. A breakdown of CS herring stock abundance and biomass by age, maturity and stratum is detailed in Tables 12 & 13 and Figures 9 & 10.

Estimates of Celtic Sea herring biomass are not comparable to the stock index survey carried out in October and should not be used for comparative purposes due to differences in survey design and area coverage.

3.4.2 Stock distribution

Forty-two echotraces of various sizes and acoustic density were assigned to herring (40 in 2021) in the Celtic Sea and herring were sampled in eight targeted hauls, three of which contained over >50% by weight (Table 2). Herring were observed in two areas; in the western and eastern areas of the mid-Celtic Sea (Figure 11e-f and Figure 9). Herring were caught as by-catch in trawls as far south as 49°30N. Samples were retained for genetic analysis to possibly identify stock origin.

3.4.3 Stock composition

A total of 513 CS herring were aged from survey samples in addition to 831 length measurements and 406 length-weights recorded. CS herring age samples ranged from 1-9 winter rings (wr) (Table 12 & 13 and Figure 10). Age structure of the stock was determined from survey aged otoliths.

Three winter ring fish dominated the total estimate, representing 62.8% of total biomass and over 63.7% of total abundance (Table 12). Four winter ring fish ranked second contributing 14% of the total biomass and 12.8% of total abundance. Ranked third are the two winter ring fish representing 12.8% total biomass and 14.8% of total abundance. In terms of age structure, the survey has tracked the strong 2018-year class successfully into 2021.

Maturity analysis of Celtic Sea herring samples indicated 60.9% of 2-wr fish were mature, rising to 95.2% of 3-wr fish. Over 91% of the TSB was mature and 88.6% of TSN (Table 12).

3.5 Hydrography and biogeochemical sampling

3.5.1 Hydrography and water sampling

In total, 84 CTD casts were carried out (Figure 12). Horizontal temperature and salinity maps for the survey area are provided for depths 5 m, 20 m, 50 m and at the seabed in Figures 13-16 respectively.

For 2021, a single oxygen sensor was employed on the CTD and no measurement of discrete oxygen concentrations were made using independent methods (e.g. wet chemical (Winkler) measurements or oxygen optode). It is planned that future expeditions include sampling for oxygen and salinity samples that can be preserved for post cruise validation of the CTD sensors.

Preliminary investigation of the CTD data has involved determining the mixed layer depth (MLD) using a threshold method, here defined as the depth at which the seawater density, σt, is greater than 0.03 kg m-3 than that of the surface value (usually taken as 5 m). Using this approach, the MLD ranged from 11 to 50 m, with a mean of 16.9 ± 6.5 m (n =84). Regionally, MLD were greatest at the shelf edge and shallowest in the Celtic Sea (Figure 21). A similar analysis was also undertaken for the depth of the chlorophyll maximum as shown in Figure 1 below. During WESPAS 21 the chlorophyll maximum was on average at 31.6 ± 12.9 m (n =84) with a range from 5 to 65 m (Figure 21). At most stations the chlorophyll maximum was below the MLD as would likely be expected for a summer survey when mixed layers are shallowest due to summer warming of surface waters and nutrients are depleted in the mixed layer.

Surface waters, above the thermocline, showed a similar pattern of salinity in the 5 and 20 m depth profiles. Slightly lower salinity waters were found around coastal fringes and in the eastern Celtic Sea and are likely influenced by terrestrial run-off (Figures 13 &14). The temperature profile of surface waters showed the highest values in the south and in the eastern Celtic Sea as expected. Thermocline depth varied between sampling location ranging from of 35-50 m in the most part. Below the thermocline, (Figures 15 & 16), a pool of colder water (~10°C) dominates the Celtic Sea, southwest and western coastal margins of Ireland above the seabed (Figure 15). Seabed (+3-5m from seabed) profiles indicate a near consistent temperature profile in the Celtic Sea and along the southwest coast (Figure 16).

Comparing hydrographic conditions (derived from near bottom temperature profiles) with the acoustic observations of herring, it appears that as in previous years herring distribution was closely aligned with the 10 ºC isotherm for Malin Shelf herring at least (Figure 17). However, for herring in the Celtic Sea this is not the case. Distribution appeared less influenced by salinity than temperature and is in agreement with previous years' observations during summer feeding phase.

For boarfish, thermal preference appears as important as salinity (Figure 18). The greatest density of boarfish is aligned with full strength seawater and off the west coast this occurs on the oceanic side of the Irish Shelf Front. The extensive distribution of immature boarfish observed this year in the Celtic Sea, and the more northern distribution of the mature spawning stock component, may be in some part described by the uniform and relatively warm conditions observed in the Celtic Sea and along the southwest Irish coast.

Horse mackerel (Figure 19) distribution appears to follow a similar pattern to that of boarfish in that full strength seawater is the preferred habitat with a variable temperature distribution profile from north to south. However, this is not well described from this year's survey results.

3.5.2 CDOM measurements

The filtered samples frozen at -20° C will also be analysed, after thawing, back in the laboratory in Galway for nutrients and 3D EEM FDOM analysis (Horiba Aqualog). The 3D EEM FDOM dataset will be analysed using PARAFAC (Murphy et al., 2013) will allow the determination of independent fluorophore components in seawater which can be used to identify sources of FDOM from terrestrial or marine processes.

3.5.3 Nutrient (NO2-, NO3-, PO43-, Si(OH)4) sampling

Analysis of samples requires further processing and was carried out back at the laboratory.

3.5.4 Bacteria, Heterotrophic nanoflagellates, Pico and nanoplankton abundance

An example cytogram is shown below (Figure 22) for Station 60 from leg 2, where it can be seen the picoplankton is dominated by the phycoerythrin containing cyanobacteria Synechococcus, with smaller abundances of pico and nanoplankton.

3.5.5 Hyperspectral analysis

The first measurements of in situ reflectance from the Celtic Explorer were collected in 2018 using a pair of hyperspectral sensors which were mounted above the bridge of the Celtic Explorer. This data allows us to compare with satellite reflectance data used in ocean colour estimates of chlorophyll and primary productivity. Given that the satellite record along the west coast of Ireland is often impacted by clouds this approach also gives us valuable information along the WESPAS transect that can't be gathered using remote sensing data.

For WESPAS 2019, the hyperspectral array was supplemented with a 3rd sensor. The use of a 3 sensor suite (Garaba et al., 2014; Garaba et al., 2015) incorporating an irradiance (measuring in the vertical) and two radiance sensors (pointing up - measuring the upwelling solar radiance and pointing down – measuring the sky leaving radiance) significantly improves our ability to more accurately determine the reflectance spectrum and remove solar glint (Garaba and Zielinski, 2013).

During 2021, a further sensor pair was added to enable data collection from the port and starboard sides of the ship, thus theoretically enabling increased data coverage as essentially duplicate measurements were being made of the reflectance and the impact of shading by the ship or solar glint could be minimized by choosing the most appropriate sensor pairing. However just before WESPAS 2021, one of the new sensors failed and had to be sent back to Germany for repair. Thus for the duration of WESPAS2021 there was only the original setup plus one other sensor. Despite this setback we still obtained several thousand spectra and the dataset is currently being quality assessed according to standard approaches (Garaba et al., 2015; Garaba and Zielinski, 2013) by Catherine Jordan (Cullen Fellow).

We will also compare the shipboard reflectance chlorophyll estimates with the satellite and in situ observations and examine the influence of the particulate absorption (QFT-1 measurements) on the results. Later in 2021 we plan to use the data obtained during this expedition and include it in a hyperspectral model of the ocean using Hydrolight software. Further comparisons to the underway pCO2 measurements and the discrete biogeochemical measurements will hopefully give more context to interpreting the spatial and temporal signals observed during WESPAS 2021.

3.5.6 Chlorophyll measurements and Ocean Colour (Chlorophyll)

During WESPAS 2021, for leg 1 most stations included a full depth profile (6 samples) for chlorophyll, while for leg 2 only the near surface and chlorophyll maximum samples were analysed (Figure 23).

Ocean colour chlorophyll data (satellite derived) for April-June 2021 is shown in Figure 24, the data for July was not yet available as a monthly composite at the time of writing. As for previous years' data coverage during WESPAS 2021 were limited by the number of cloud free images, while we have collected the daily images for direct comparison to the field data, the monthly composites are used here to give an impression of the seasonal coverage over the North West European shelf. The ocean colour images show high chlorophyll levels along the shelf edge and porcupine mound with lower concentrations in the Celtic Sea during June 2021. As seen in 2019 the peak of the spring bloom offshore was in April-May with lower levels encountered in June-July when the WESPAS 2021 survey was carried out.

3.6 Zooplankton biomass

3.6.1 Zooplankton

Plankton samples were collected at 74 stations during the survey (Figure 20). Analysis of zooplankton dry weight shows a north-south divide in terms of secondary productivity, with the Celtic Sea showing consistently higher stations values than those north of 53°N. Overall, values north of 53°N are comparable to 2020 while those in the Celtic Sea are higher.

3.7 Marine mammals and seabirds

3.7.1 Marine mammal visual abundance survey

In total, 38 days were spent surveying with 301 hours of survey time logged. Sea state varied between 1 and 6 across the survey duration with <5 accounting for 91.6% of surface conditions.

Thirteen cetacean species were encountered during the survey i.e. harbour porpoise (*Phocoena phocoena*); grey seal (*Halichoerus grypus*); common seal (*Phoca vitulina*); short-beaked common dolphin (*Delphinus delphis*); bottlenose dolphin (*Tursiops truncates*); Risso's dolphin (*Grampus griseus*); white-beaked dolphin (*Lagenorhynchus albirostris*); Atlantic white-sided dolphin (*Leucopleurus acutus*); long-finned pilot whale (*Globicephala melas*); minke whale (*Balaenoptera acutorostrata*); humpback whale (*Megaptera novaeangliae*); fin whale (*Balaenoptera physalus*); and 'possible' false killer whales (*Pseudorca crassidens*). Other non-cetacean species recorded were: ocean sunfish (*Mola mola*), leatherback turtle (*Dermochelys coriacea*) and blue shark (*Prionace glauca*) (Table 15).

Additional sightings were made of unidentified dolphins and whales (thought to be various dolphin species and an unidentified large whale) at various locations on the continental shelf as well as at the shelf edge. Sightings of dolphin species occurred on the continental shelf whereas pilot whale sightings occurred at the continental shelf edge, which is considered one the preferred habitats for this species. Sightings of larger whale species (i.e. fin whales, humpback whales and an unidentified large whale) all occurred in shelf waters (Figure 25).

A single sighting of two probable false killer whales occurred over the Porcupine Bank, close to the shelf edge. The animals were seen twice within the same sighting but high winds and sea state meant they could not be positively identified nor was it possible to capture photographs. However, comprehensive analysis of observed morphological characteristics using identification keys led to the conclusion, by process of elimination, that the probability of species identification was such.

Common dolphins (*Delphinus delphis*) and minke whales (*Balaenoptera acutorostrata*) were the most frequently recorded species accounting for 23.5% of recordings each (27 sightings of each species). Common dolphins were also the most abundant species recorded on the survey (502 animals recorded accounting for 60% of all animals counted across all species). Sightings of both common dolphins and minke whales occurred primarily in coastal water with the furthest record from the coast logged at 60km. The observed group size for common dolphins ranged from 2 to 100 individuals. The observed group size for minke whales ranged from one to five individuals.

The second most frequently observed species were bottlenose dolphin (*Tursiops truncates*) (Figure 11), Risso's dolphin (*Grampus griseus*) and ocean sunfish (*Mola mola*) accounting for 7% of recordings each (8 recordings of each species). Bottlenose dolphins were the most abundant species recorded of the three (92 animals recorded accounting for 11% of all animals across all species), followed by Risso's dolphins (46 animals, 6% of all animals) and ocean sunfish (8 animals, 1% of all animals). Sightings of bottlenose dolphins occurred primarily in offshore habitats at various location around Ireland. Sightings of Risso's dolphins occurred primarily offshore of the north and north-west coast of Ireland and west coast of Scotland. Ocean sunfish were recorded in varying areas of the continental shelf, shelf edge and in both Irish and UK waters.

Long-finned pilot whales (*Globicephala melas*), fin whales (*Balaenoptera physalus*) and grey seals (*Halichoerus grypus*) were the third most frequently record species accounting for 4.4% of recordings (5 recordings of each species). Long-finned pilot whales were the most abundant species recorded of the three (20 animals recorded accounting for 2.4% of all animals across all species), followed by fin whales (12 animals, 1.4%) and grey seals (5 animals, 0.6%). Sightings of long-finned pilot whales occurred along the shelf edges, consistent with this species preferred habitat. One of the sightings of long-finned pilot whales was of a deceased animal to which the interaction with blue sharks scavenging on it was observed. Sightings of fin whales occurred along shelf edges and adjacent shelf waters to the west of Ireland on the Porcupine Bank and also off the coast of St. Kilda, Scotland. Sightings of grey seals occurred in offshore in continental shelf waters to the west and north-west of Ireland.

The forth most frequently observed species was the humpback whale (*Megaptera novaeangliae*) accounting for 2.6% of recordings (3 recordings of this species). A total of 10 individual animals were recorded during the survey accounting for 1.2% of all animals across all species. Sightings of humpback whales were recorded in nearshore and offshore waters to the south-west, west and north-west coasts of Ireland.

The fifth most frequently observed species was white-beaked dolphin (*Lagenorhynchus albirostris*) (Figure 18) accounting for 1.7% of recordings (2 recordings of this species). A total of 7 animals were recorded accounting for 0.9% of all animals across all species. Sightings of white-beaked dolphins were recorded off the west coast of the Outer Hebrides, Scotland.

Single sightings of harbour porpoise (*Phocoena phocoena*) on the Porcupine Bank, harbour seal (*Phoca vitulina*) and Atlantic white-sided dolphins (*Lagenorhynchus acutus*) over the Stanton Banks, false killer whales (*Pseudorca crassidens*) over the Porcupine Bank, blue sharks (*Prionace glauca*) and leatherback turtle (*Dermochelys coriacea*) at the shelf edge – south of Ireland, were also recorded.

3.7.2 Seabird abundance and distribution

In total, 274 hours and 33 minutes of survey effort were conducted over the course of WESPAS 2021. In total, 218 hours and 48 minutes of survey effort were conducted using a line transect methodology, while 54 hours and 13 minutes of effort were conducted using the point sampling methodology. A further 1 hour and 32 minutes of effort were conducted as a casual watch.

A total of 7,392 seabird observations were recorded throughout the survey, totalling 35422 individuals (Table 15). In total, 12,391 seabirds were recorded as “in transect”, while 23,031 were recorded “off transect”. The species encountered included 33 species, subspecies or species groups from eight families. A further 22 sightings of terrestrial/migratory birds were also recorded, comprising of 80 individuals (Table 15).

Gannet (*Morus bassanus*) were the most frequently encountered species, recorded on 2,236 separate occasions, accounting for 30.2% of all encounters. Gannet records comprised of a total of 6,213 individuals (17.6% of all individuals) making gannet the second most abundant species recorded on the survey. However, of these, only 1,059 individuals were recorded as ‘in transect’.

Manx shearwater (*Puffinus puffinus*) were the most abundant species recorded on the survey with 14,714 individuals recorded. These individuals accounted for 41.7% of all individuals recorded, and were recorded during 983 separate encounters (13.3% of encounters), making them the fourth most frequently encountered species. Of the 14,714 individuals recorded, 7,368 individuals were recorded as ‘in transect’.

Fulmar (*Fulmarus glacialis*) were the second most frequently encountered and the third most abundant species accounting for 1,704 records (23.1% of all encounters) and comprising of 5,667 individuals in total (16.1% of all encountered individuals.) Of these, 800 individuals were recorded as ‘in transect’.

European storm petrel (*Hydrobates pelagicus*) were the third most frequently sighted and the fourth most abundant species accounting for 578 sightings (7.8% of all sightings) and comprising of 2,258 individuals in total (6.4% of all encountered individuals.) Of these, 692 individuals were recorded as ‘in transect’.

A number of terrestrial/ migratory birds were encountered during the survey. A total of 22 sightings of terrestrial/ migratory bird species were recorded during the survey (Table 15). These sightings comprised of 80 individuals from 12 species' or species groups. Species recorded included a ringed plover (*Charadrius hiaticula*), a quail (*Coturnix coturnix*), a collared dove (*Streptopelia decaocto*) and a flock of 45 whimbrel (Numenius phaeopus).

4 Discussion and Conclusions

4.1 Discussion

The objectives of the survey were carried out successfully and as planned. Overall, weather conditions were generally good throughout the survey, with no time lost due to poor weather. A total of 5 zooplankton stations were cancelled due to high winds.

Malin Shelf herring distribution was concentrated in an area to the north and west of Tory Island (south of 56˚N) and north of the mouth of Lough Swilly in 6.a.S and to the west of the Hebrides in 6.a.N, south of St. Kilda (Figure 3). There was an approximately 67% increase in overall the SSB in 2020 compared to 2020 in the survey area (O'Donnell et al 2020), driven mainly by an abundance of 2-wr and 3-wr fish. The final estimate of herring in 6.a (combined 6.a.S, 7.b,c and 6.a.N) will be completed by including the biomass and abundance of herring from the survey of 6.a.N to the north of 58˚30N and west of 4˚W carried out by the RV Scotia. This final estimate will be presented at WGIPS in 2022. There have been issues with stock identification and containment with this survey in the past, particularly in relation to the boundary of the North Sea stock at the 4˚W line, and the distribution of herring north and south of the 56˚N line (6.a.N/6.a.S), for example. Fish distributed either side of these boundary lines influence the respective survey estimates annually. There is genetic discrimination work ongoing to try to better split the survey into 6.a.N and 6.a.S components and it is hoped that this will be possible in the future. This will be examined during the 6a benchmark in early 2022.

There were good signs of young and immature herring in the Malin Shelf area again in 2021, particularly and 2-wr herring distributed in 6.a.S in the area to the north of Lough Swilly. This survey is not generally a good design for juvenile herring (e.g. 0-wr and 1-wr fish) but immature fish can show up in some years. The age profile of survey samples in 2021 is dominated by 2-wr and 3-wr herring dominate the survey (74% in terms of biomass, and 79% in terms of abundance). The CV estimate for the 2021 survey is the same as 2020 (0.25); comparable to previous years in the time-series. There has been an increased and better spread of herring marks across transects and strata in 2021, similar to 2020.

The geographical distribution of boarfish was comparable to earlier years in the time series in terms of latitudinal range. Within this range, clusters of individual schools were found concentrated towards the shelf margin in the northern and western strata and more widespread across the shelf in the Celtic Sea. Overall, the most notable feature in regards to stock distribution was that the centre of gravity for the mature component of the stock which was located further north than in previous years, while the Celtic Sea was dominated by immature fish.

The number of echotraces of boarfish was comparable to 2020. Overall acoustic density was increased for comparable survey effort (2020 to 2021: -10% transect effort and +3% area coverage).

Comprehensive trawl sampling was carried out in the southern Celtic Sea to determine the northern boundary of the extent of immature fish distribution. Directed trawl sampling is important not only to identify species composition of echotraces but also to determine the age, length and maturity of individuals. This becomes increasingly important in areas where immature and mature mixing occurs.

Over the recent time series, the southernmost transects, around northern Biscay, have contained higher proportions of immature fish compared the larger survey area. That said, this year immature fish dominated the Celtic Sea strata and high density aggregations were observed as far north as 53°30'N. Northern latitudes are shown to contain spawning boarfish during the survey, indicating preferred spawning habitat are being met across years and boarfish are likely year-resident in the area. Likewise, the presence of immature fish, restricted not only to this year's survey, is an indication of the suitability of northern latitudes as suitable nursery habitat.

Total biomass saw a 11% increase and total abundance increased by 121% compared to results from 2020. This increase was largely driven by the higher numbers of immature fish observed. Of the five survey strata, three saw an increase in biomass (W Hebrides +30%, S Hebrides +47% and W coast +68%) and two saw a decrease (Porcupine Bank -48% and Celtic Sea -11%). Overall, the increase in observed biomass in the northern strata balances the decrease in the Celtic Sea. The abundance of mature fish usually observed in the Celtic Sea were likely located further north. The large increase in total abundance is driven by the high numbers of immature fish observed in both the Celtic Sea and southern west coast strata and by a single high density aggregation located in the mid-west strata.

The oldest (15+ year) cohort remain the largest contributors to the total stock biomass within the time series. Seven, eight and nine-year-old fish (2013, 2012 and 2011 year classes respectively) are important cohorts within the stock and have track well through the survey index. During the period 2018-present, the contribution of immature fish has increased as strong year classes continue to emerge. As these year classes recruit to the spawning stock (~3 yrs.) the stock will continue to show positive growth. The strong 1-year-old fish observed this year will no doubt contribute further. Immature fish from the 2021 estimate represent over 60.3% of the TSN and 20.7% of TSB (91,823t).

Horse mackerel were found distributed along the Irish west coast and Celtic Sea. Geographical distribution was comparable to 2020. However, no fish were observed northward of 53°30'N as in 2020. The 2021 estimate is 25% lower in terms of biomass and 51% lower in terms of abundance compared to 2020. The 2021 estimate is the lowest in the current time series. No monospecific echotraces of horse mackerel were observed during the survey and biological samples were taken as part of mixed species by-catch. To that end, the 2021 estimate, although reflective of what was present on the ground during the survey, is not likely a true representation of the wider stock.

Aggregations of Celtic Sea herring were encountered during the survey in the historic western and southern feeding grounds around the Pistola and Labadie Banks respectively. Small amounts of herring were observed as by-catch in trawls undertaken as far south as 49°10'N and as far west as the shelf slope margins. Genetic samples were taken from the southernmost herring and it is hoped that the stock origin can be established. Three winter ring fish dominated the total estimate, representing 62.8% of total biomass and over 63.7% of total abundance. Four winter ring fish ranked second contributing 14% of the total biomass and 12.8% of total abundance. Ranked third are the two winter ring fish representing 12.8% total biomass and 14.8% of total abundance. The survey has successfully tracked the dominate year classes.

Estimates of Celtic Sea herring biomass are not comparable to the stock index survey carried out in October and should not be used for comparative purposes due to differences in survey design and area coverage.

Maturity analysis of Celtic Sea herring samples indicated 60.9% of 2-wr fish were mature, rising to 95.2% of 3-wr fish. Over 91% of the TSB was mature and 88.6% of TSN.

4.2 Conclusions

- Malin Shelf herring SSB in the WESPAS survey area was ~67% higher in 2021 compared to 2020 (SSB_{2021} = 297,027 t SSB_{2020} =177,000 t)
- The Malin Shelf herring TSB in 2021 was ~ 9% higher than 2020, driven mainly by a large increase in 2-wr herring (TSB_{2021} = 401,884 t TSB_{2020} = 370,000t)
- The CV on the survey for Malin Shelf herring in 2021 was the same as 2020 (0.25); lower when compared with 2019 (0.37); the CV in 2021 is comparable to previous years in the time series and is benefitting from a better spread of herring and good biological sampling through the area
- Malin Shelf herring were distributed in the south again in 2021, similar to 2019 and 2020 with adult herring again found south of 56°N. This is the fourth year in a row in recent years that herring were found in this area. For instance, there was very little herring distributed south of 56°N in both 2016 and 2017.
- The 2021 survey estimate was dominated by 2-wr (44% TSB and 53% TSN) and 3-wr (30% TSB and 26% TSN). This compares well to the 2020 Malin Shelf herring survey estimate which was dominated by 1-wr (24% TSB and 43% TSN) and 2-wr (32% TSB and 29% TSN). There were good signs of young immature Malin Shelf herring (1-wr and 2-wr fish) found in discrete areas in both 6.a.S and 6.a.N
- Boarfish distribution showed a similar pattern to previous years for comparable survey effort and timing. However, the centre of gravity of mature fish biomass was located further north than in previous years, while the Celtic Sea was dominated by immature individuals.
- Boarfish TSB (total stock biomass) and abundance (TSN) estimates were 443,777 t and 21,804,545,000 individuals (CV 0.31) respectively.
- The 2021 estimate of total stock biomass is 11% more than observed in 2020 with a corresponding increase of 121% in abundance, largely driven by the amount of immature fish observed.
- The 15+ year age classes dominate the 2021 estimate contributing over 23% of TSB and 5.6% of TSN (Table 6). However, the contribution of the 1, 2 and 3-year-old fish combined represents over 33.1% of the TSB and over 72.8% of TSN.
- The contribution of immature boarfish to the 2021 estimate surpassed levels observed in 2020 and represent 20.7% of total biomass and 60.6 % of total abundance. The proportion of immature fish is driven by a continued period of successful spawning beginning in 2017
- The southern Celtic Sea and northern Biscay region continues to be an important nursery area for boarfish during the recent successful spawning period (2017-2021).
- Horse mackerel were found distributed along the Irish west coast and Celtic Sea. Geographical distribution was comparable to 2020. However, no fish were observed northward of 53°30'N as in 2020.

- Horse mackerel TSB (total stock biomass) and abundance (TSN) estimates were 35,506 t and 129,431,000 individuals (CV 0.54) respectively.
- The 2021 horse mackerel estimate is 25% lower in terms of biomass and 51% lower in terms of abundance compared to 2020. The 2021 estimate is the lowest in the current time series. The survey is not currently considered to be performing sufficiently to accurately report horse mackerel abundance.
- Of the 7 strata surveyed, two contained horse mackerel; the Celtic Sea contained the largest proportion of biomass observed (52.5% of TSB) and the west coast stratum (47.5%).
- The 9-year-old fish (2012-year class) dominated this year's survey estimate representing 25.4% of TSB and 22.9% of TSN (Table 9). The 7-year-old fish ranked second representing over 15.2% of TSB and 16.9% of TSN. Fourteen-year-old fish were ranked third contributing 9.6% to TSB and 7.6% to TSN. Combined these three age classes represented 50.3% of TSB and 47.4% of TSN.
- Maturity analysis of horse mackerel samples indicated 99.9% of the total stock biomass was mature and over 99.7% of total abundance. Maturity analysis by age class showed that all 3-year-old fish and older were mature and fully recruited to the spawning stock. The number of 2-year-old fish sampled was low and may therefore not fully reflect the actual spread of maturities in this transitional year class.
- Aggregations of Celtic Sea herring were observed around traditional feeding areas off the southwest and mid-Celtic Sea.
- The estimate of Celtic Sea (CS) herring TSB (total stock biomass) and relative abundance (TSN) estimates were 93,785.8 t and 710,696,000 individuals (CV 0.71) respectively.
- Three winter ring fish dominated the total estimate, representing 62.8% of TSB and over 63.7% of TSN. Four winter ring fish ranked second contributing 14% of the TSB and 12.8% of TSN. Ranked third are the two winter ring fish representing 12.8% TSB and 14.8% of TSN.
- Over 91% of the TSB was mature and 88.6% of TSN giving the indication that immature fish are present in the stock and have yet to recruit to the spawning stock biomass. Further review will be carried out during the spawning stock survey in October.
- Analysis of zooplankton dry weight shows a north-south divide in terms of secondary productivity, with the Celtic Sea showing consistently higher stations values than those north of 53°N.

5 Acknowledgements

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Fisheries Ecosystems Advisory Services

7 Tables and Figures

Table 1. Calibration report: Simrad EK60 echosounder at 38 kHz.

Echo Sounder System Calibration

Vessel : R/V Celtic Explorer		Date : 09.06.2021	
Echo sounder : EK60 PC		Locality : Galway Bay	
Type of Sphere : WC-38,1	TS Sphere: -42.40 dB (Corrected for Soun vel)	Depth(btm) : 32 m	

Calibration Version 2.1.0.12

Comments:
WESPAS 2021_L1 Galw ay Bay- WC38.1mm

Reference Target:

TS	-42.40 dB	Min. Distance	16.00 m
TS Deviation	5.0 dB	Max. Distance	21.00 m

Transducer: ES38B Serial No. 30227

Frequency	38000 Hz	Beamtype	Split
Gain	25.34 dB	Tw o Way Beam Angle	-20.6 dB
Athw . Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw . Beam Angle	6.96 deg	Along. Beam Angle	6.85 deg
Athw . Offset Angle	-0.06 deg	Along. Offset Angl	-0.04 deg
SaCorrection	-0.69 dB	Depth	8.80 m

Transceiver: GPT 38 kHz 009072033933 2-1 ES38B

Pulse Duration	1.024 ms	Sample Interval	0.193 m
Pow er	2000 W	Receiver Bandw idth	2.43 kHz

Sounder Type:
EK60 Version 2.4.3

TS Detection:

Min. Value	-50.0 dB	Min. Spacing	100 %
Max. Beam Comp.	6.0 dB	Min. Echolength	80 %
Max. Phase Dev.	8.0	Max. Echolength	180 %

Environment:

Absorption Coeff.	9.4 dB/km	Sound Velocity	1499.4 m/s

Beam Model results:

Transducer Gain =	25.34 dB	SaCorrection =	-0.6 dB
Athw . Beam Angle =	6.92 deg	Along. Beam Angle =	6.88 deg
Athw . Offset Angle =	-0.01 deg	Along. Offset Angle=	-0.03 deg

Data deviation from beam model:
RMS = 0.37 dB
Max = 0.59 dB No. = 245 Athw . = 4.0 deg Along = 2.6 deg
Min = -0.67 dB No. = 340 Athw . = -3.9 deg Along = 2.9 deg

Data deviation from polynomial model:
RMS = 0.34 dB
Max = 0.54 dB No. = 337 Athw . = -3.2 deg Along = 1.7 deg
Min = -0.67 dB No. = 154 Athw . = -3.0 deg Along = -3.3 deg

Comments :
Galway Bay
Wind Force : 15 kn **Wind Direction :** SW
Raw Data File: E:\CE21009_WESPAS2021\Calibration\38 kHz Cal\WESPAS2021-D20190705-T090459.raw
Calibration File: E:\CE21009_WESPAS2021\Calibration\38 kHz Cal\Cal 38 kHz.txt

Calibration: Ciaran O'Donnell

Table 2. Catch table from directed trawl hauls.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target btm (m)	Bulk Catch (Kg)	Boarfish %	Mackerel %	Herring %	H Mack %	Others^ %
1	12.06.21	47.60	-7.09	08:24	164	0-50	118	100.0				
2	12.06.21	47.86	-6.02	20:11	141	0-15	125	93.7			0.2	6.1
3	13.06.21	48.11	-6.61	08:36	162	50-110	1,500	100.0				
4	13.06.21	48.11	-7.51	13:53	173	0-70	2,500	98.9			1.1	
5	14.06.21	48.36	-8.32	09:06	180	75-150	222	69.5			24.8	5.7
6	15.06.21	48.61	-7.60	07:27	163	140	300	85.3	14.7			
7	16.06.21	48.86	-8.69	11:15	167	100	600	99.9				0.1
8	16.06.21	48.86	7.69	19:59	160	135	205	100.0				
9	17.06.21	49.11	-7.97	08:06	147	120	2,200	99.5	0.2			0.3
10	17.06.21	49.11	-9.27	17:03	148	88	216	94.7	5.0		0.3	
11	18.06.21	49.11	-10.86	06:41	168	100	1,000	99.9				0.1
12	18.06.21	49.36	-9.97	16:25	151	110	2,800	98.9	1.1			
13	19.06.21	49.61	-7.85	13:37	134	0	277	0.2	0.6	0.5	12.4	86.3
14	20.06.21	49.87	-10.63	14:18	146	120	3,000	99.2	0.4		0.4	
15	20.06.21	49.87	-9.56	20:49	136	100	209	81.6	7.9	0.7	9.8	
16	21.06.21	49.88	-7.94	11:33	82	0	320	2.6	0.2	92.6		4.6
17	21.06.21	50.03	-7.31	19:19	114	100	250		0.2	2.2		97.6
18	22.06.21	50.12	-9.13	09:00	97	30	3,000		3.1	95.0	1.9	
19	22.06.21	50.12	-10.86	17:22	171	100	338	83.7	5.1		11.2	
20	23.06.21	50.37	-8.04	13:44	124	0	2,200		0.2	3.8		96.0
21	23.06.21	50.50	-7.23	19:10	107	90	1,200		2.1	23.0		74.9
22	24.06.21	50.62	-9.90	12:03	140	80	2,700					
23	24.06.21	50.68	-11.31	20:21	1029	150-200	200					100.0
24	25.06.21	50.87	-9.47	10:20	118	75	1,200	96.0	3.3			0.7
25	25.06.21	50.87	-8.30	17:30	100	0	3,000		2.8	95.1	0.3	1.8
26	26.06.21	51.12	-9.62	17:55	121	0	3,000	0.3	0.3			99.4
27	27.06.21	51.12	-11.58	08:07	710	219	125					100.0
28	27.06.21	51.37	-11.17	13:08	194	100	329	83.36	3.3		13.4	
29	28.06.21	51.87	-10.77	10:41	123	0	69	0.2				99.8
30	01.07.21	53.14	-11.31	08:22	148	120	300	92.2	2.8			5.0
31	02.07.21	52.89	-13.24	07:43	311	50	1,000					100.0
32	02.07.21	53.14	-13.35	12:21	227	220	1,000		1.0			99.0
33	03.07.21	53.76	-12.06	15:48	331	100	35	3.6	93.8			2.6
34	04.07.21	53.40	-10.87	04:53	137	100	1,500					100.0
35	04.07.21	53.64	-11.32	11:10	200	180	1,500	5.3			0.2	94.5
36	04.07.21	53.90	-10.77	16:49	160	50	2,000	95.4	4.4		0.2	
37	05.07.21	54.40	-9.51	07:30	78	50	2,000	100.0				
38	05.07.21	54.66	-9.71	14:40	104	80	7		48.0		1.1	50.9
39	06.07.21	54.92	-9.11	08:26	80	70	34		45.2	0.4		54.4
40	06.07.21	55.08	-10.06	17:42	210	190	2,000	100.0				
41	07.07.21	55.42	-8.58	16:49	103	90	46			51.2		48.8
42	07.07.21	55.42	-8.51	18:17	101	95	97		7.4	86.4		6.2
43	08.07.21	55.58	-7.87	12:12	75	70	4,000			100.0		
44	08.07.21	55.58	-8.89	17:41	103	85	40	73.0	10.5	14.3		2.2
45	09.07.21	55.76	-8.25	07:01	110	86	110		16.0	84.0		
46	09.07.21	55.93	-8.04	18:34	175	155	1,500			15.0		85.0
47	10.07.21	56.25	-7.52	18:29	138	135	60	0.0	0.2			99.8
48	11.07.21	56.53	-8.63	09:04	143	430	48		76.2	0.9		22.9
49	11.07.21	56.53	-8.63	10:03	149	130	152		14.3	22.7		63.0
50	11.07.21	56.53	-8.09	14:12	158	148	14		20.2			79.8
51	12.07.21	56.76	-9.00	06:11	156	140	3,000	100.0				
52	12.07.21	57.04	-8.48	11:33	145	135	15	2.1	80.9	4.1		12.9
53	12.07.21	57.04	-8.05	14:33	131	101	38		52.5	0.3		47.2
54	13.07.21	57.54	-9.16	08:51	147	135	107	15.1	74.1	1.2		9.6
55	13.07.21	57.54	-8.87	11:45	147	130	89		22.8	13.6		63.6
56	13.07.21	57.54	-8.56	14:41	160	130	750			96.8		3.2
57	13.07.21	57.79	-7.82	21:10	125	60	60		0.5			99.5
58	15.07.21	58.32	-8.31	05:45	155	145	59		59.7	4.5		35.8
59	15.07.21	58.58	-7.02	15:45	93	80	60		80.1	1.1		18.8
60	15.07.21	58.58	-7.10	18:17	91	85	296		8.3	1.1		90.7
61	16.07.21	58.52	-5.55	07:32	123	30	25		0.0			100.0
62	16.07.21	58.33	-6.01	11:23	117	100	200			2.8		97.2
63	17.07.21	57.06	-7.06	07:47	143	125	70	0.0			0.3	99.7
64	17.07.21	56.81	-6.95	11:44	181	140	19	0.0				100.0
65	17.07.21	56.64	-7.23	16:13	190	100	5	0.4				99.6

Table 3. Malin Shelf herring stock estimate 2021 (6.a.S, 7.b,c and 6.a.N (south of 58°30’N) in the WESPAS 2021 survey area.

	Age (years)													Numbers	Biomass	Mn Wt	Mature
Length	0	1	2	3	4	5	6	7	8	9	10	11	12+	(*10-3)	(t)	(g)	(%)
5.5		-	-	-	-	-	-	-	-	-	-	-	-	0			0
6		-	-	-	-	-	-	-	-	-	-	-	-	0			0
6.5		-	-	-	-	-	-	-	-	-	-	-	-	0			0
7		-	-	-	-	-	-	-	-	-	-	-	-	0			0
7.5		-	-	-	-	-	-	-	-	-	-	-	-	0			0
8		-	-	-	-	-	-	-	-	-	-	-	-	0			0
8.5		-	-	-	-	-	-	-	-	-	-	-	-	0			0
9		-	-	-	-	-	-	-	-	-	-	-	-	0			0
9.5		-	-	-	-	-	-	-	-	-	-	-	-	0			0
10		-	-	-	-	-	-	-	-	-	-	-	-	0			0
10.5		-	-	-	-	-	-	-	-	-	-	-	-	0			0
11		-	-	-	-	-	-	-	-	-	-	-	-	0			0
11.5		-	-	-	-	-	-	-	-	-	-	-	-	0			0
12		-	-	-	-	-	-	-	-	-	-	-	-	0			0
12.5		-	-	-	-	-	-	-	-	-	-	-	-	0			0
13		-	-	-	-	-	-	-	-	-	-	-	-	0			0
13.5		-	-	-	-	-	-	-	-	-	-	-	-	0			0
14		-	-	-	-	-	-	-	-	-	-	-	-	0			0
14.5		-	-	-	-	-	-	-	-	-	-	-	-	0			0
15		-	-	-	-	-	-	-	-	-	-	-	-	0			0
15.5		-	-	-	-	-	-	-	-	-	-	-	-	0			0
16		-	-	-	-	-	-	-	-	-	-	-	-	0			0
16.5		-	-	-	-	-	-	-	-	-	-	-	-	0			0
17		4050	-	-	-	-	-	-	-	-	-	-	-	4050	166	41	0
17.5		8100	-	-	-	-	-	-	-	-	-	-	-	8100	337	41.625	0
18		11567	-	-	-	-	-	-	-	-	-	-	-	11567	551	46	0
18.5		9491	-	-	-	-	-	-	-	-	-	-	-	9491	503	53.1659	0
19		11609	-	-	-	-	-	-	-	-	-	-	-	11609	696	59.297	0
19.5		23770	-	-	-	-	-	-	-	-	-	-	-	23770	1515	63.6994	0
20		25158	-	-	-	-	-	-	-	-	-	-	-	25158	1726	69.2196	0
20.5		18095	9195	-	-	-	-	-	-	-	-	-	-	27290	2022	74.266	0
21		25292	48776	-	-	-	-	-	-	-	-	-	-	74069	6030	82.1188	11
21.5		12817	89597	2724	-	-	-	-	-	-	-	-	-	105138	9153	83.7965	8
22		-	195496	-	-	-	-	-	-	-	-	-	-	195496	18432	95.1505	13
22.5		-	264601	6944	-	-	-	-	-	-	-	-	-	271546	27693	105.727	34
23		-	300401	10006	-	-	-	-	-	-	-	-	-	310407	34203	109.935	46
23.5		-	284559	26348	6885	-	-	-	-	-	-	-	-	317793	37388	116.879	56
24		-	156521	63506	2520	-	-	-	-	-	-	-	-	222548	28240	129.85	58
24.5		-	133423	87207	8970	494	-	-	-	-	-	-	-	230094	31483	135.026	92
25		-	67599	167479	34255	-	-	-	-	-	-	-	-	269333	40237	148.712	100
25.5		-	28196	145630	23828	2477	2765	-	-	-	-	-	-	202896	31553	155.254	99
26		-	6903	103243	40543	382	-	-	-	-	-	-	-	151072	24891	163.602	100
26.5		-	4716	101080	20412	24841	5296	-	383	-	-	-	-	156728	27409	173.808	100
27		-	-	24875	41475	6962	2218	13265	-	2821	-	-	-	91616	16574	183.072	100
27.5		-	-	18944	12142	13239	12596	7075	1039	-	-	-	-	65035	12462	190.882	100
28		-	-	19789	15311	4834	4973	10369	557	-	-	-	-	55834	11027	202.643	100
28.5		-	-	-	5174	-	2112	5286	-	-	1742	-	-	14315	3052	204.946	100
29		-	-	-	7249	8083	-	30170	3063	7359	2677.6	-	-	58601	12403	209.862	100
29.5		-	-	-	-	-	1158	1784	1479	2071	-	-	-	6494	1483	225.279	100
30		-	-	-	-	29253	-	-	-	-	1803	-	-	31056	7280	245.603	100
30.5		-	-	-	-	-	-	472	1197	620	-	-	-	2289	574	247	100
31		-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
31.5		-	-	-	-	-	-	-	1862	-	-	-	-	1862	507	276.3	100
32		-	-	-	-	1715	-	-	-	-	-	-	-	1715	431	250.667	100
32.5		-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
33		-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
33.5		-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
34		-	-	-	-	-	-	485	-	-	-	-	-	485	149	307	100
34.5		-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
35		-	-	-	-	-	-	1551	-	-	-	-	-	1551	600	387	100
35.5		-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
36		-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
36.5		-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
37		-	-	-	-	-	-	-	-	28566	-	-	-	28566	11112	389	100
TSN (1000)		149951	1589985	777777	218764	92278.4	31119.7	70457.7	9580.05	41437.6	6223.5			2987573			
TSB (t)		9956.85	178274	120376	36903.8	18387.1	5789.63	14779.4	2095.45	13773.3	1436.4				401884		
Mean length (cm)		19.99	22.64	25.34	25.84	27.12	27.09	28.39	29.23	30.55	28.84						
Mean weight (g)		69.4816	105.064	154.448	162.492	186.654	181.835	202.102	212.131	246.88	210.8					102.34	
SSB (t)		143.017	86486.3	117121	36903.8	18447.1	5789.63	14779.4	2147.45	13773.3	1436.4				297027.2		
% mature		1	45	97	100	100	100	100	100	100	100						

Fisheries Ecosystems Advisory Services

Table 4. Malin Shelf herring survey time series 2008-2021. Survey coverage: - ^ 6.a.S & 7.b,c; *6.a.S, 7.b,c & 6.a.N (south of 58°28'N) ** 6.a & 7.b,c. *Survey known as WESPAS since 2016.*

Age	2008^	2009^	2010*	2011*	2012*	2013*	2014*	2015**	2016*	2017*	2018*	2019*	2020*	2021*
0	-	-	-	-	-	-	-	-	-	-	264.6			
1	6.1	416.4	524.8	82.1	608.3	-	1,115.4	4.9	-	-	395.8	21.6	1541.7	150.0
2	75.9	81.3	504.3	202.5	451.5	96.2	214.7	162.1	9.7	11.0	339.2	212.4	1059.2	1590.0
3	64.7	11.4	133.3	752.0	444.6	254.3	166.3	291.7	102.3	273.4	112.5	174.5	506.8	777.8
4	38.4	15.1	107.4	381.0	516.1	265.8	380.0	580.7	91.4	111.0	314.1	86.3	191.1	218.8
5	22.3	7.7	103.0	110.8	180.3	78.7	352.1	487.3	91.4	71.6	137.5	55.3	82.8	92.3
6	26.2	7.1	83.7	124.0	115.4	26.9	125.0	513.4	58.2	94.4	43.7	29.1	175.9	31.1
7	9.1	7.5	57.6	118.4	116.9	18.5	18.9	143.9	46.5	28.0	59.5	3.4	33.2	70.5
8	5.0	0.4	35.3	70.7	83.8	10.8	9.7	33.4	2.7	9.9	16.8	11.7	15.7	9.6
9	3.7	0.9	17.5	41.6	56.3	4.1	4.7	-	0.5	2.6	8.2	3.8	9.3	41.4
10+	-	-	-	25.6	42.0	1.2	-	8.3	-	-	6.4			6.2
TSN (mil)	251.4	547.7	1,566.9	1,908.7	2,615.0	756.6	2,386.8	2,225.5	402.8	601.8	1,698.3	598.0	3,615.8	2,987.6
TSB (t)	44,611.0	46,460.0	192,979.0	313,305.0	397,797.0	118,946.0	294,200.0	449,343.0	70,745.0	107,900.0	183,187.5	86,641.1	370,048.2	401,883.6
SSB (t)	43,006.0	20,906.0	170,154.0	284,632.0	325,835.0	92,700.0	200,200.0	425,392.0	69,269.5	106,657.0	129,740.0	68,607.0	177,493.7	297,026.8
CV	34.2	32.2	24.7	22.4	22.8	21.5	28.6	28.6	31.3	46.6	28.3	37.3	24.9	24.8

^ Survey coverage: 6aS & 7bc

* Survey coverage: 6aS,7bc and 6aN (south of 58˚28')

** Survey coverage: 6a & 7bc

Table 5. Malin Shelf herring SSB and SSN by strata in the WESPAS survey area 2021.

Strata	Name	Area (nmi^2)	Transects	SSN ('000)	SSB (t)
1	Minches	3322	8	0	0
2	W Hebrides	6015	7	425,569	82,012
3	SW Hebrides	4682	4	321,323	47,273
4	NW Coast	2181	3	128,067	17,570
5	W Coast	4344	6	58,993	7,791
6	N Malin	2946	3	998,932	142,381
	Total	23,490	31	1,932,884	297,027

Table 6. Total boarfish stock estimate.

Length (cm)	Age (years) 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Numbers (000's)	Biomass (t)	Mn Wt (g)	Matur (%)
3.5	4846																4846	4.8	1	0
4	75427																75427	96.8	1.28	0
4.5	178711																178711	367.1	2	0
5		651459															651459	1857.1	3	0
5.5		1944426															1944426	7519.2	4	0
6		4381049															4381049	22151.8	5	0
6.5		2317111															2317111	14586.5	6	0
7		179334	252317														431651	3326.8	8	0
7.5		49444	243200														292644	2936.9	10	0
8			1399895														1399895	16692.2	12	0
8.5			881406	747571													1628977	23452.6	14	0
9			614956	708947													1323903	22037	17	95
9.5				521033													521033	10248.3	20	100
10				911739													911739	20465.9	22	100
10.5				65928	845466	80719											992113	25790.5	26	100
11					453412	277043											730455	21909.9	30	100
11.5					16621	105003	149913	113816									385354	13258.5	34	100
12								202748									202748	7677.8	38	100
12.5								166588	48267								214854	9030.6	42	100
13								269806	39036	45763							354605	16983.2	48	100
13.5								200339	119717	64201	11816						396072	20670.5	52	100
14										268459	163309	9703				86418	527888	31066.1	59	100
14.5											73387	98238	118099	26909	40714	100678	458025	29322.6	64	100
15												43322	69778	54097	123214	329081	619491	45328.9	73	100
15.5															162944	186997	349941	27565.8	79	100
16																315134	315134	29215.6	93	100
16.5																125097	125097	12584	101	100
17																47947	47947	5153.3	107	100
17.5																17350	17350	1885.7	109	100
18																4600	4600	591.4	129	100
18.5																				
19																				
TSN (10⁻³)	258,983	9,522,823	3,391,774	2,955,217	1,315,500	462,765	149,913	953,297	207,019	378,423	248,511	151,262	187,877	81,006	326,872	1,213,301	21,804,545			
TSB (t)	468.7	47,869.2	42,969.8	55,963.6	35,508.1	14,515.9	5,258.3	41,224.3	10,589.7	21,229.6	14,972.5	9,569.4	12,151.0	5,457.3	24,178.5	101,851.4		443,777		
Mean length (cm)	4.3	6.0	8.2	9.3	10.7	11.0	11.5	12.6	13.2	13.8	14.1	14.6	14.7	14.8	15.2	15.5				
Mean weight (g)	1.8	5.0	12.7	18.9	27.0	31.4	35.1	43.2	51.2	56.1	60.3	63.3	64.7	67.4	74.0	84.0			20.35	
% mature*	0.0	0.0	23.6	81.1	99.9	100.0	100.0	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0				
SSB (t)	0.0	0.0	10,144.4	45,386.3	35,461.2	14,515.9	5,258.3	41,188.9	10,589.7	21,229.6	14,972.5	9,569.4	12,151.0	5,457.3	24,178.5	101,851.4		351,955		

Table 7. Boarfish biomass and abundance by strata.

Strata name	Area (nmi²)	Transects	Abundance ('000)	Biomass (t)
W Hebrides	2,798.8	6	627,096	21,129
S Hebrides	1,909.0	5	467,291	30,908
W Coast	10,917.8	21	8,257,209	146,781
Porcupine Bank	3,968.1	6	103,724	6,671
Celtic Sea	30,958	15	12,349,225	233,287
Total	50,552.0	53	21,804,545	443,777

Table 8. Boarfish survey time series.

Age (Yrs)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
0	-	-	-	-	-	-	-	-	-	1083.9	259.0
1	5.0	21.5	-	-	198.5	4.6	110.9	76.7	782.3	896.5	9522.8
2	11.6	10.8	78.0	-	319.2	35.7	126.7	31.2	389.1	1156.7	3391.8
3	57.8	174.1	1,842.9	15.0	16.6	45.5	344.6	115	96.8	966.5	2955.2
4	187.4	64.8	696.4	98.2	34.3	43.6	367.3	68.3	93.1	112.6	1315.5
5	436.7	95.0	381.6	102.3	80.0	6.0	156.0	106.7	88.2	157.3	462.8
6	1,165.9	736.1	253.8	104.9	112.0	10.0	209.0	165.9	105.9	183.3	149.9
7	1,184.2	973.8	1,056.6	414.6	437.4	169.0	493.1	320.7	445.7	912.9	953.3
8	703.6	758.9	879.4	343.8	362.9	112.6	468.3	197.7	182.6	884.5	207.0
9	1,094.5	848.6	800.9	341.9	353.5	117.6	397.2	293.4	288	720.7	378.4
10	1,031.5	955.9	703.8	332.3	360.0	96.6	285.8	624.7	290.1	330.9	248.5
11	332.9	650.9	263.7	129.9	131.7	17.0	120.9	339.2	49.5	80.6	151.3
12	653.3	1,099.7	202.9	104.9	113.0	32.0	82.1	264.1	192.2	194.9	187.9
13	336.0	857.2	296.6	166.4	174.0	48.7	74.4	198.4	79.1	298.7	81.0
14	385.0	655.8	169.8	88.5	108.0	18.3	220.4	116.5	57.2	266.7	326.9
15+	3,519.0	6,353.7	1,464.3	855.1	1,195.0	400.1	931.0	302.4	758.9	1641.0	1213.3
TSN (10⁻³)	11,104	14,257	9,091	3,098	3,996	1,157	4,387	3,221	3,899	9,888	21,805
TSB (t)	670,176	863,446	439,890	187,779	232,634	69,690	223,860	186,252	179,156	399,872	443,777
SSB (t)	669,392	861,544	423,158	187,654	226,659	69,103	218,810	184,235	169,216	357,871	351,955
CV	0.21	0.11	0.18	0.15	0.17	0.16	0.22	0.20	0.25	0.35	0.31

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Table 9. Horse mackerel stock estimate.

Length (cm)	Age (years) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	UNK	Numbers (000's)	Biomass (t)	Mn Wt (g)	Mature (%)
11																										
12																										
13																										
14																										
15																										
16																										
17																										
18																										
19																										
20																										
21		92																					92	7.2	78	0
22																						92	92			100
23																						184	184	21	115	100
24			1471																				1471	187.8	128	100
25			4688																				4688	644	137	100
26			3632	1362																			4994	754.2	151	100
27			234	3984	469																		4688	756.1	161	100
28				605	1211	202	605																2624	504.9	192	100
29				3725	532	532																	4789	1007.2	210	100
30					1520	3909	2713																8143	1838.5	226	100
31					2039	2650	9725	2039	2998														19451	4798.7	247	100
32					2357		7576	2020	5263														17217	4577.3	266	100
33							1305	1305	6375	2982	2423	1417		1864									17672	5066.3	286.69	100
34								1929	5773	147	1193	1193	147	1635	1193	1193							14405	4526	314.2	100
35								160	9250					2546		1353							13309	4664.1	350.43	100
36												1443		3746	2553	2470							10211	3829.6	375.03	100
37															1786	1786							3572	1495.6	418.7	100
38																1349							1349	588.6	436.23	100
39																483							483	239.2	495.67	100
40																										
41																										
42																										
TSN (10^{-3})		92	10024	9676	8128	7293	21925	7453	29659	3130	3616	4053	147	9791	5532	8634						276	129,431.0			
TSB (t)		7.2	1410.6	1729.5	1804.9	1653.8	5406.9	2025.7	9026.5	901.7	1091.7	1311.8	47.9	3439.7	2015	3612.6						21		35,506.4		
Mean length (cm)		20	24.26	26.69	29.29	29.24	30.26	31.48	32.44	32.05	32.33	33.36	33	33.83	34.89	35.25						22				
Mean weight (g)		78	140.72	178.73	222.07	226.76	246.6	271.79	304.34	288.12	301.88	323.67	325	351.31	364.25	418.43						115			274.52	
% mature*		0	100	100	100	100	100	100	100	100	100	100	100	100	100	100										
SSB (t)		0	1,411	1,730	1,805	1,654	5,407	2,026	9,027	902	1,092	1,312	48	3,440	2,015	3,613								35,478.2		

Table 10. Horse mackerel biomass and abundance by strata.

Strata name	Area (nmi²)	Transects	Abundance ('000)	Biomass (t)
W Hebrides	4,778.5	6	0	0
S Hebrides	1,909.0	5	0	0
N Stanton	1,759.0	5	0	0
S Stanton	1,615.3	4	0	0
W Coast	12,114.6	21	51,305	16,883
Porc Bank	3,968.1	6	0	0
Celtic Sea	30,958.2	15	78,126	18,624
Total	57,102.7	62	129,431	35,507

Table 11. Horse mackerel survey time series.

Age (Yrs)	2016	2017	2018	2019	2020	2021
0						
1	1.1	11.7	1.0	63.7		
2	100.2	181.8	72.4	14.3	6.2	0.1
3	4.9	147	243.3	9.2	91.9	10.0
4	43.5	45.4	85.3	46.4	51.5	9.7
5	19.0	16.2	10.5	30.9	24.3	8.1
6	7.6	46	7.6	18.5	27.0	7.3
7	40.6	113	49.3	29.8	35.1	21.9
8	66.6	67.7	13.3	6.2	5.2	7.5
9	8.5	25.4	10.0	26.7	13.1	29.7
10	1.8	33.2	1.5	0.4	1.5	3.1
11	9.5	32.6	1.5	1.9	0.5	3.6
12	10.6	37.7	7.4	3.9		4.10
13	4.7	37.6	8.5	0.6	0.6	0.1
14	21.1	160.8	27.5	23.2	5.5	9.8
15	6.5	8.6		10.0		5.5
16	1.6	5.2		28.4	2.1	8.6
17	5.3		0.3			0.3
18				17.7		
19						
20						
21	1.1					
TSN (10^{-3})	354.5	969,655	540,422	333,501	264,314	129,431
TSB (t)	69,267	228,116	92,932	79,026	47,553	35506
SSB (t)	65,194	227,395.6	89,050	77,529	43,527	35,478
CV	0.42	0.26	0.37	0.34	0.31	0.54

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Table 12. Celtic Sea herring stock estimate.

Length	Age (years)											Numbers	Biomass	Mn Wt	Mature
(cm)	1	2	3	4	5	6	7	8	9	10	11	Ukn	(10^{-3})	(t)	(g)	(%)
11.5																
12																
12.5																
13																
13.5																
14																
14.5																
15																
15.5																
16																
16.5																
17																
17.5																
18																
18.5																
19																
19.5																
20																
20.5												313	313			0
21	6876												6876	596.3	87	0
21.5		4671	2180										6850	650.8	95	20
22		13431	5671										19102	1898.3	99.38	0
22.5		24935	3863	1756									30555	3192.8	104.49	47
23		25507	31884	607									57999	6548.1	112.9	67
23.5		14835	76648	2473									93955	11157.9	118.76	90
24		10666	110473	6476									127615	16274.1	127.53	99
24.5		11397	103051	15196		2849							132494	17778.9	134.19	100
25			75293	21352	3371	749							100766	14322.9	142.14	100
25.5			34571	19058	2216	886	443						57175	8490.8	148.5	100
26			4475	17086	6916	4068							32545	5119.3	157.3	100
26.5			4342	4962	1861	13026	1861	620					26671	4443	166.58	100
27				1967	2458	1475							5900	1064	180.33	100
27.5						3034	5057						8091	1503	185.75	100
28							586		1758				2344	449.5	191.75	100
28.5								1445					1445	296.1	205	100
29																
29.5																
30																
30.5																
31																
31.5																
TSN (10^{-3})	6,876.0	105,443.0	452,450.0	90,934.0	16,823.0	26,088.0	7,947.0	2,065.0	1,758.0			313.0	710696			
TSB (t)	596.3	11,995.9	58,922.5	13,170.9	2,600.0	4,352.4	1,395.2	402.2	350.4					93785.8		
Mean length (cm)	21.0	23.0	24.2	25.2	25.9	26.3	27.2	27.9	28.0			20.5				
Mean weight (g)	86.7	113.8	130.2	144.8	154.6	166.8	175.6	194.8	199.3						132.02	
% mature*	0.0	60.9	95.2	98.1	100.0	100.0	100.0	100.0	100.0							
SSB (t)	0.0	7,308.3	56,067.4	12,923.3	2,600.0	4,352.4	1,395.2	402.0	350.4					85399.2		

Table 13. Celtic Sea herring total stock biomass and total abundance by strata.

Strata name	Area (nmi²)	Transects	Abundance ('000)	Biomass (t)
Celtic Sea	30,958.0	16	710,696	93,785
Total	30,958.0	16	710,696	93,785

Table 14. Marine mammal and megafauna sightings, counts and group size ranges for cetaceans sighted during the survey (includes on and off effort).

Common name	Scientific name	No. of Sightings	No. of Individuals	Group Size Range
Harbor porpoise	*Phocoena phocoena*	1	2	2
Grey seal	*Halichoerus grypus*	5	5	1
Harbor seal	*Phoca vitulina*	1	1	1
Common dolphin	*Delphinus delphis*	27	502	2-100
Bottlenose dolphin	*Tursiops truncatus*	8	92	1-30
Risso's dolphin	*Grampus griseus*	8	46	1-12
White-beaked dolphin	*Lagenorhynchus albirostris*	2	7	2-5
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	1	25	25
Long-finned pilot whale	*Globicephala melas*	5	20	1-7
Minke whale	*Balaenoptera acutorostrata*	27	44	1-5
Humpback whale	*Megaptera novaeangliae*	3	10	1-4
Fin whale	*Balaenoptera physalus*	5	12	1-3
False killer whale	*Pseudorca crassidens*	1	2	2
Unidentified small whale		1	1	1
Unidentified whale		3	2	1
Unidentified dolphin		5	49	5-20
Unidentified cetacean		2	4	1
Blue shark	*Prionace glauca*	1	4	4
Leatherback turtle	*Dermochelys coriacea*	1	1	1
Ocean sunfish	*Mola mola*	8	8	1
	Totals	**115**	**837**	

Table 15. Totals for all seabird and terrestrial bird species recorded.

Common Name	***Species name***	***No. of Sightings***	***No. of Seabirds***	***In Tran-sect***	***Off Transect***
Fulmar	*Fulmarus glacialis*	1704	5667	800	4867
Great Shearwater	*Puffinus graves*	1	1	1	0
Sooty Shearwater	*Puffinus griseus*	20	26	2	24
Manx Shearwater	*Puffinus puffinus*	983	14714	7368	7346
Wilson's Petrel	*Oceanites oceanicus*	9	9	3	6
Storm Petrel	*Hydrobates pelagicus*	578	2258	692	1566
Leach's Petrel	*Oceanodroma leucorhoa*	1	1	0	1
Petrel sp.	*Hydrobatidae sp.*	1	1	0	1
Gannet	*Morus bassanus*	2236	6213	1059	5154
Pomarine Skua	*Stercoratius pomarinus*	4	4	2	2
Arctic Skua	*Stercoratius parasiticus*	3	3	0	3
Long-tailed Skua	*Stercoratius longicaudus*	5	5	0	5
Great Skua	*Stercoratius skua*	123	187	38	149
Small skua sp.	*Stercoratius parasiticus / longicaudus*	4	9	0	9
Skua sp.	*Stercoratius sp.*	1	1	0	1
Common Gull	*Larus canus*	1	1	0	1
Sabine's gull	*Larus sabini*	1	1	0	1
Black-headed Gull	*Larus ridibundus*	1	3	0	3
Lesser Black-backed Gull	*Larus fuscus*	232	1464	102	1362
'Scandinavian' LBB Gull	*Larus fuscus intermedius*	1	1	0	1
Herring Gull	*Larus argentatus*	23	46	9	37
Yellow-legged gull	*Larus michahellis*	1	1	0	1
Great Black-backed Gull	*Larus marinus*	35	73	2	71
Kittiwake	*Rissa tridactyla*	288	548	188	360
Common Tern	*Sterna hirundo*	1	2	2	0
Arctic Tern	*Sterna paradisaea*	12	18	10	8
Guillemot	*Uria aalge*	470	1897	1322	575
Black guillemot	*Cepphus grylle*	1	2	0	2
Razorbill	*Alea torda*	195	541	376	165
Razorbill / Guillemot	*Alea torda / Uria aalge*	28	886	92	794
Puffin	*Fratercula arctica*	422	822	306	516
Shag	*Phalacrocorax aristotelis*	6	21	17	4
Cormorant	*Phalacrocorax carbo*	1	1	0	1
	Total	**7392**	**35422**	**12391**	**23031**

Table 15 cont.

Common Name	*Species name*	*No. of Sightings*	*No. of Individuals*
Collared Dove	*Streptopelia decaocto*	1	1
Curlew/Whimbrel	*#N/A*	1	1
Dunlin	*Calidris alpina*	2	3
Feral/ racing pigeon	*Columba livia domestica*	5	8
House Martin	*Delichon urbica*	1	1
Quail	*Coturnix coturnix*	1	1
Ringed Plover	*Charadrius hiaticula*	1	1
Small waders sp	*#N/A*	1	10
Swallow	*Hirundo rustica*	4	5
Swift	*Apus apus*	2	2
Turnstone	*Arenaria interpres*	1	1
Whimbrel	*Numenius phaeopus*	2	46
	Total	**22**	**80**

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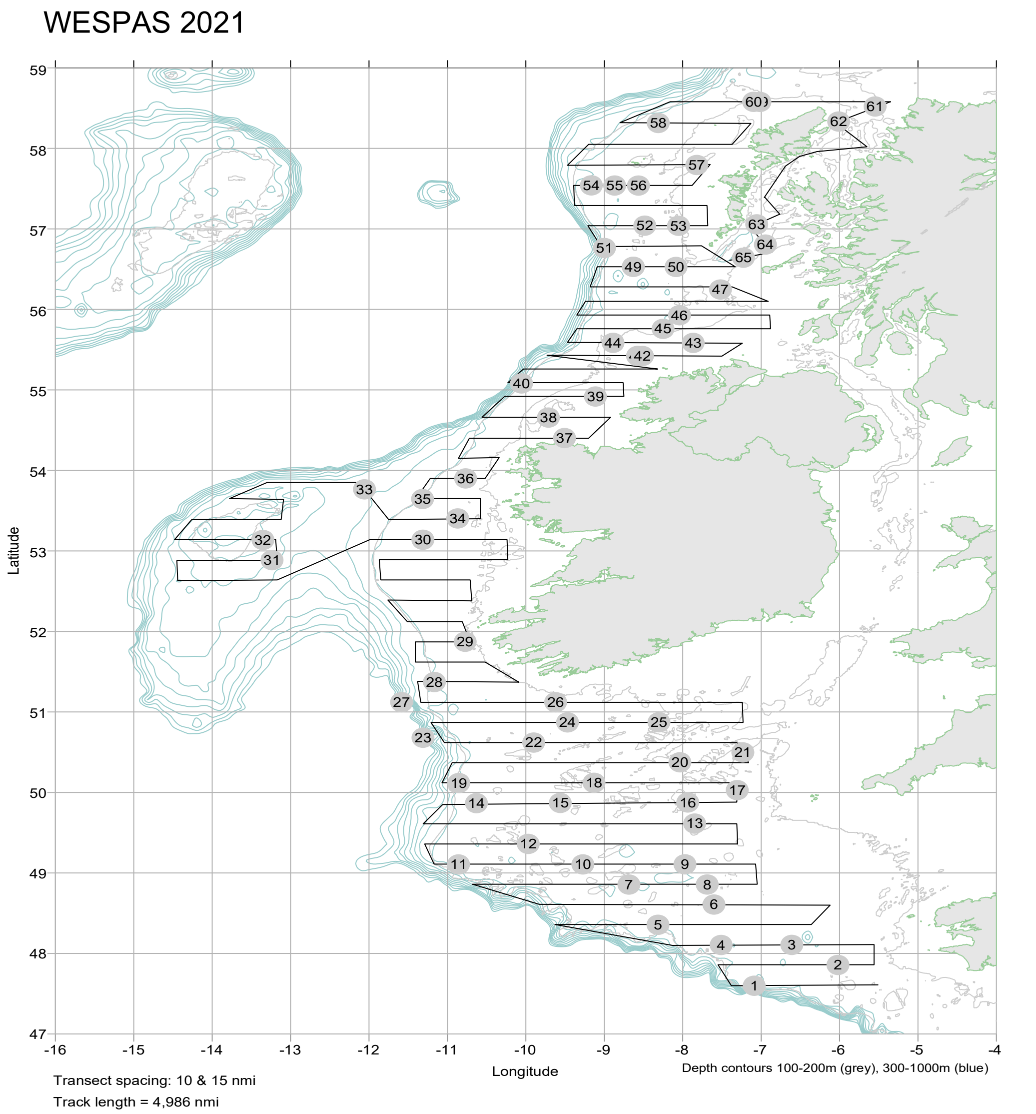

Figure 1. WESPAS 2021 survey cruise track (grey line) and numbered directed pelagic trawl stations. Corresponding catch details are provided in Table 2.

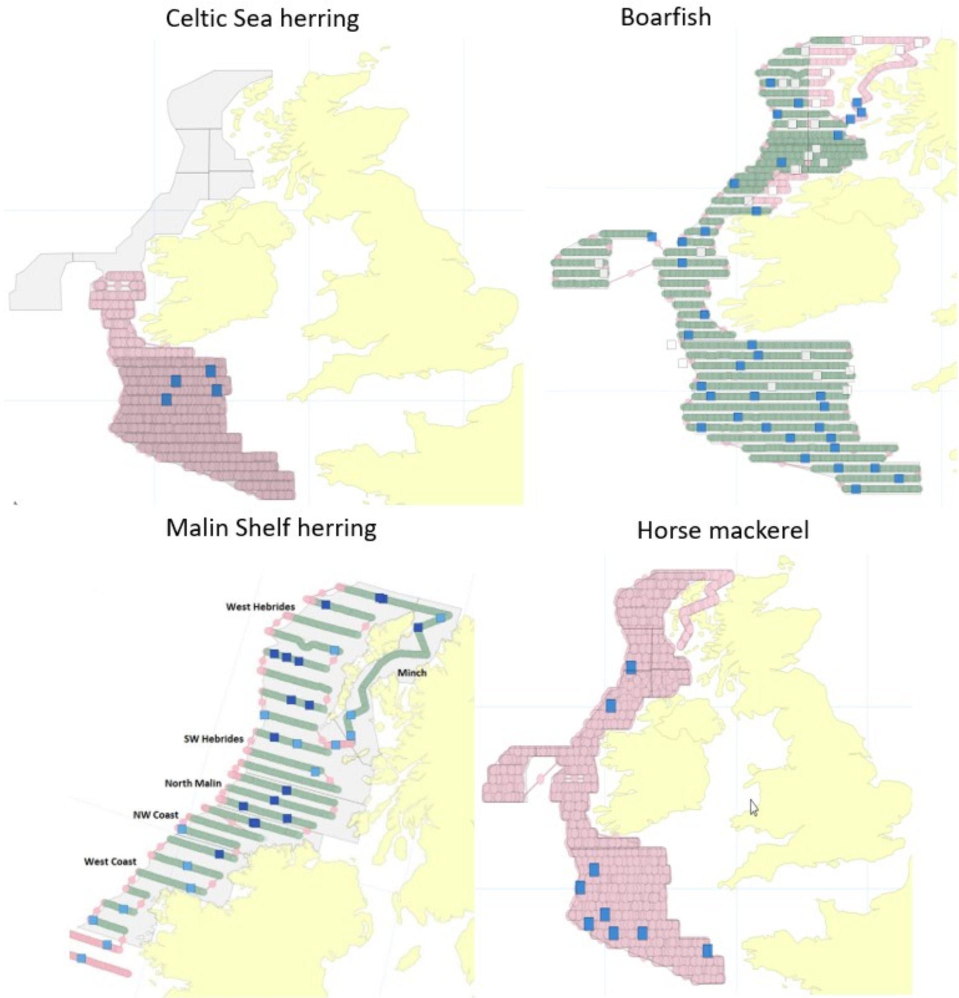

Figure 2. Species specific acoustic sampling stratification taken from StoX.

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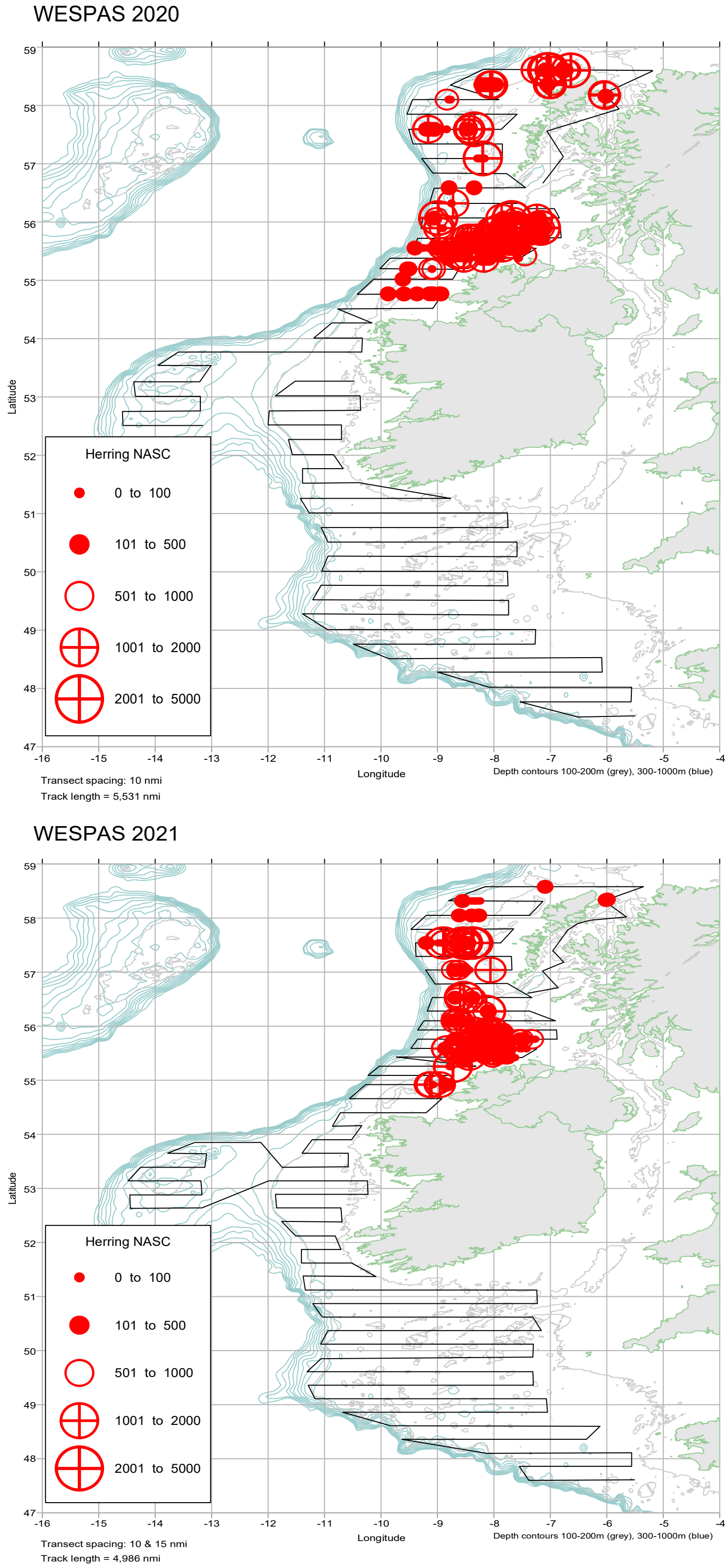

Figure 3. WESPAS Malin Shelf (north of 54°N) herring distribution by weighted acoustic density. Top panel 2020, bottom panel 2021.

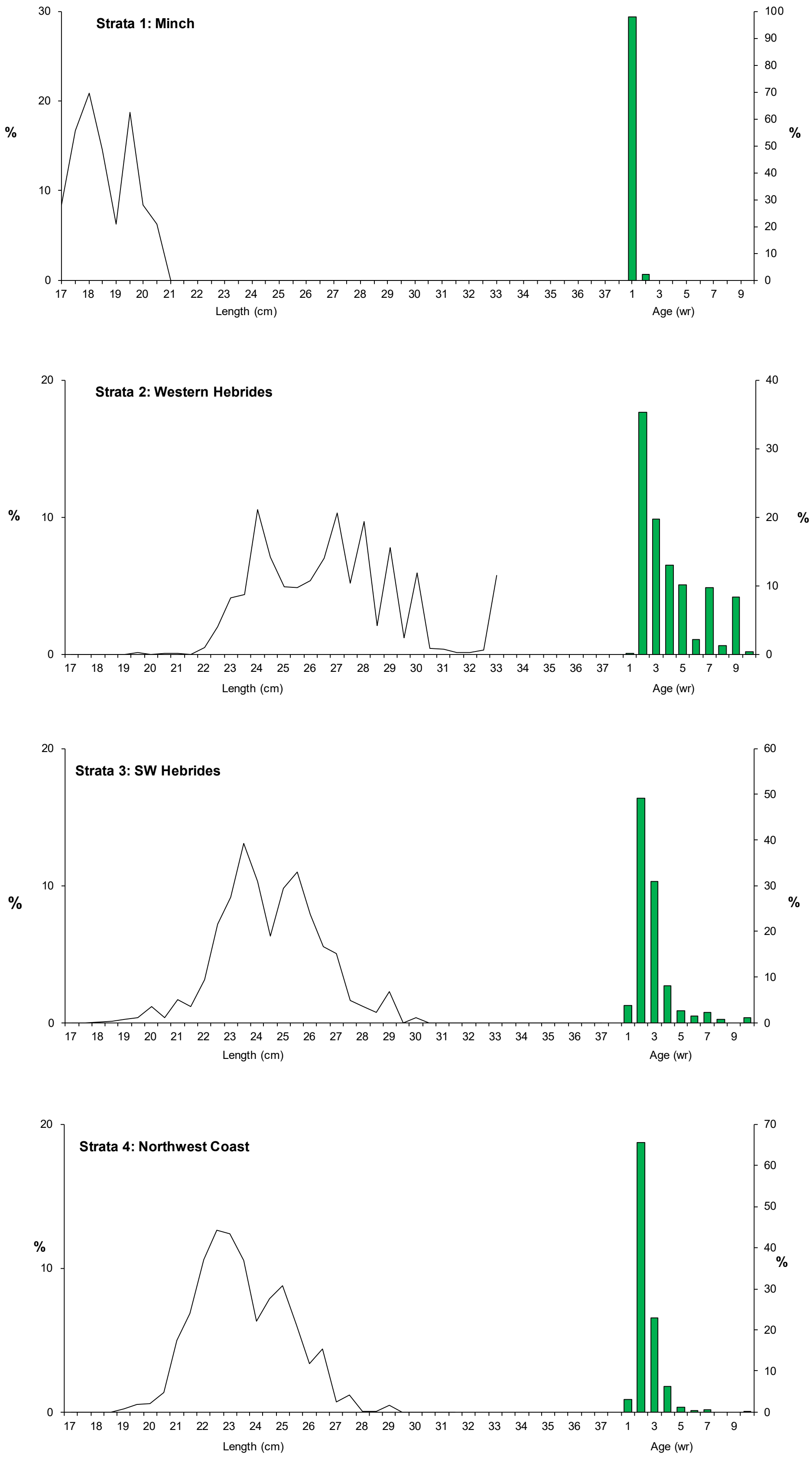

Figure 4. Length and age distribution of Malin Shelf herring by stratum and total survey area during WESPAS 2021.

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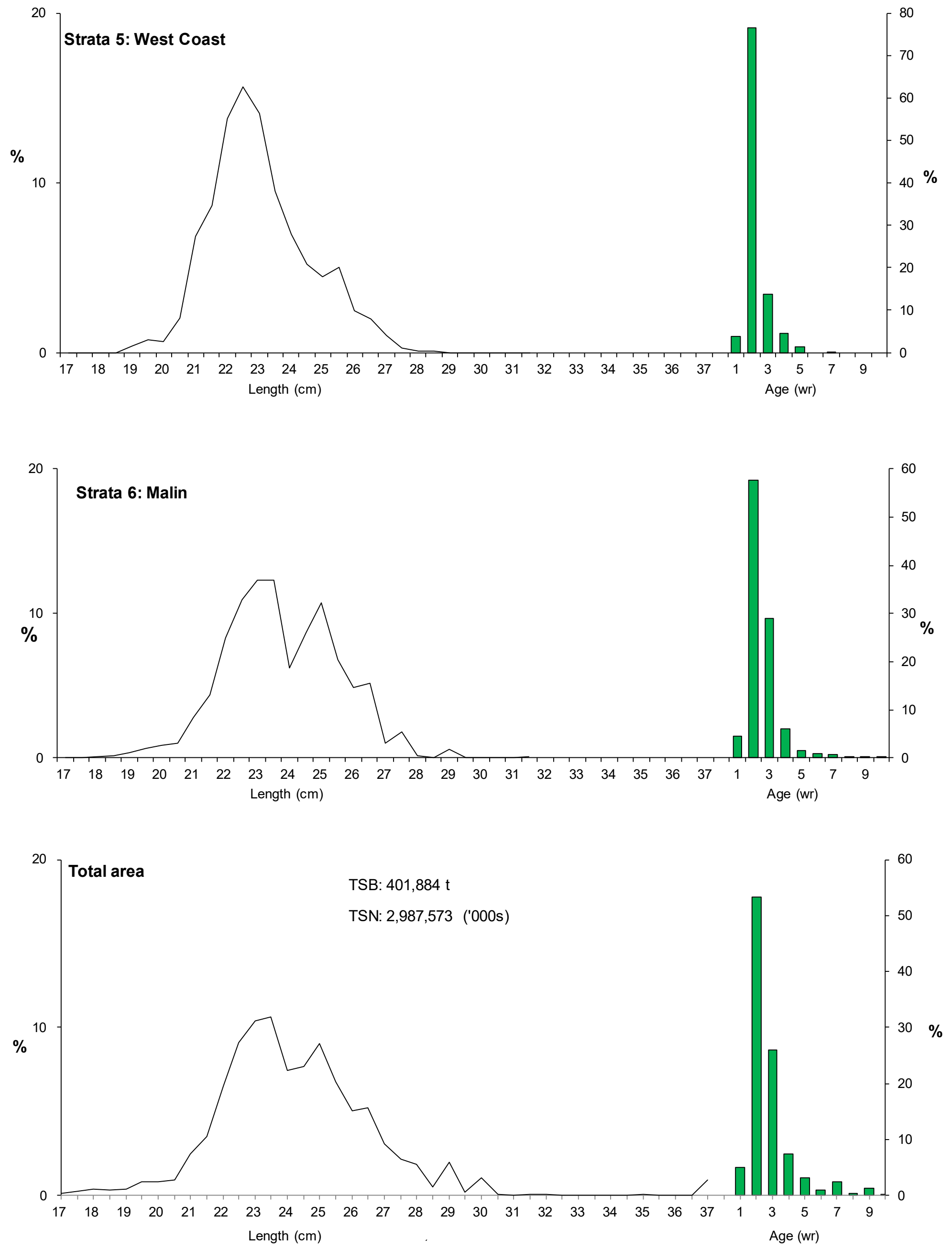
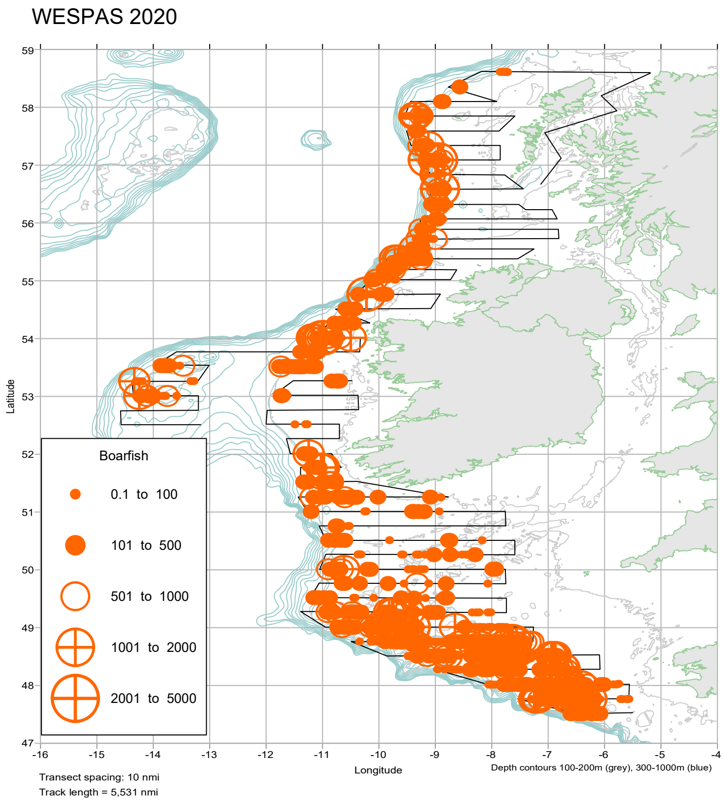


Figure 4. *continued.* Length and age distribution of Malin Shelf herring by stratum and total survey area during WESPAS 2021.



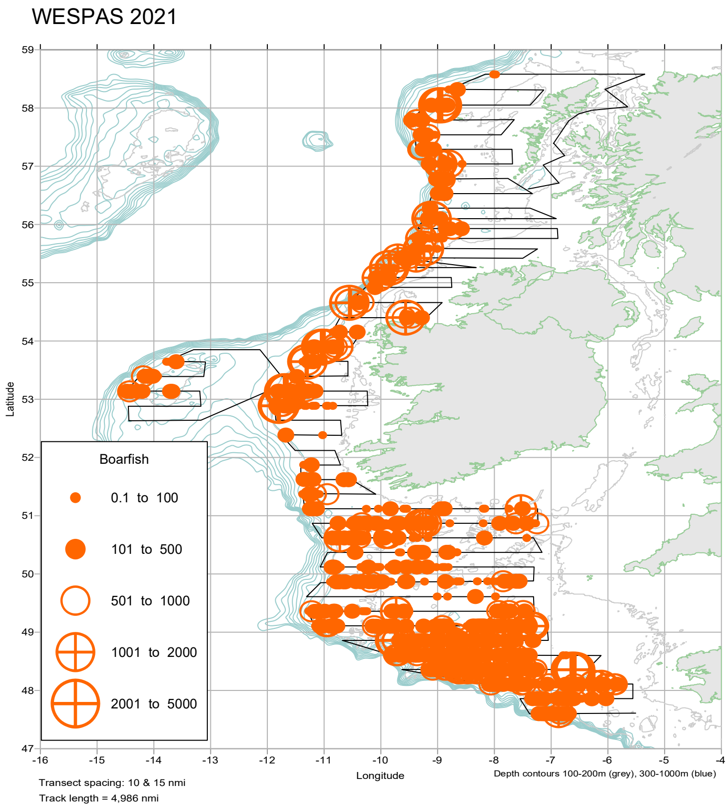


Figure 5. Boarfish distribution by weighted acoustic density. Top panel 2020, bottom panel 2021.

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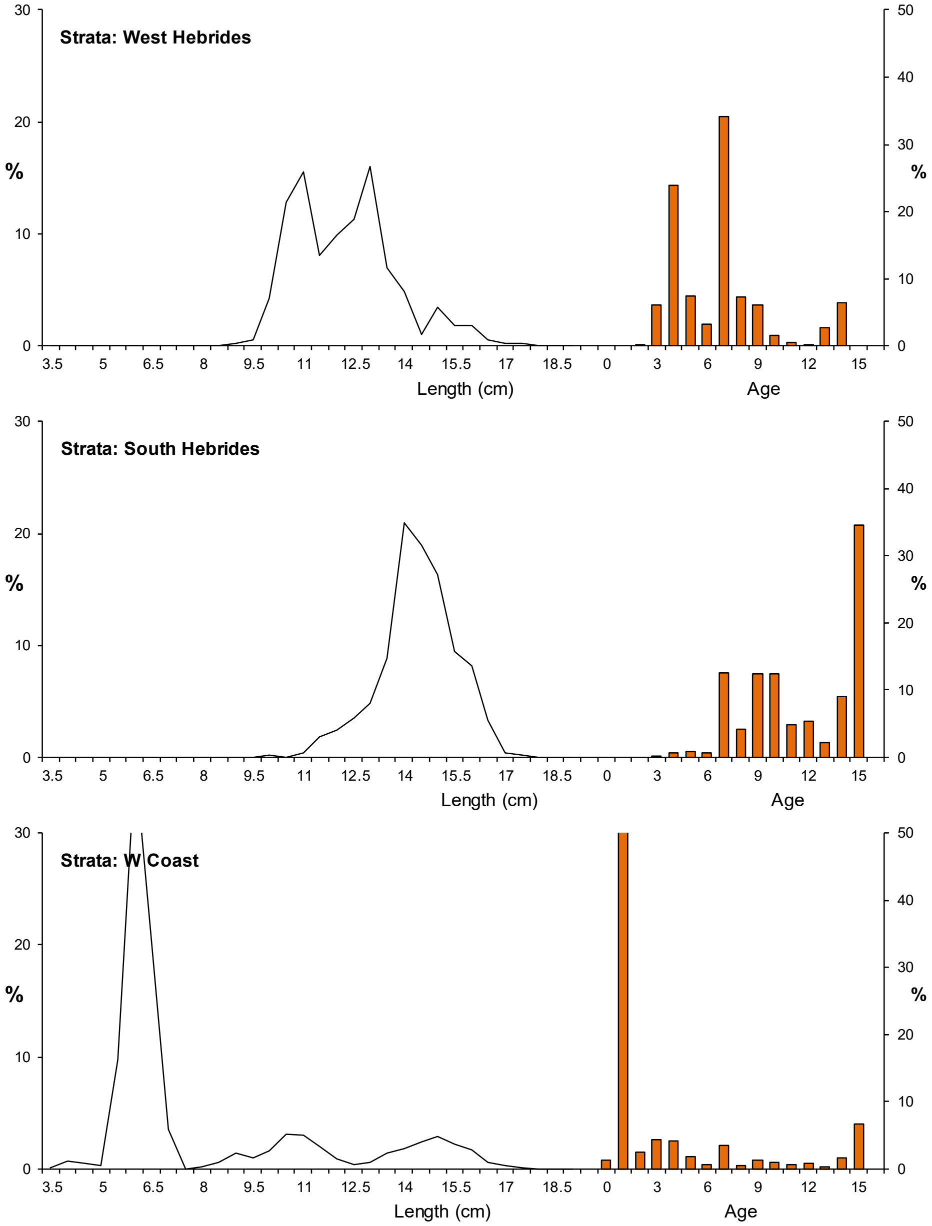

Figure 6. Abundance at length and age distribution of boarfish by stratum and total survey area.

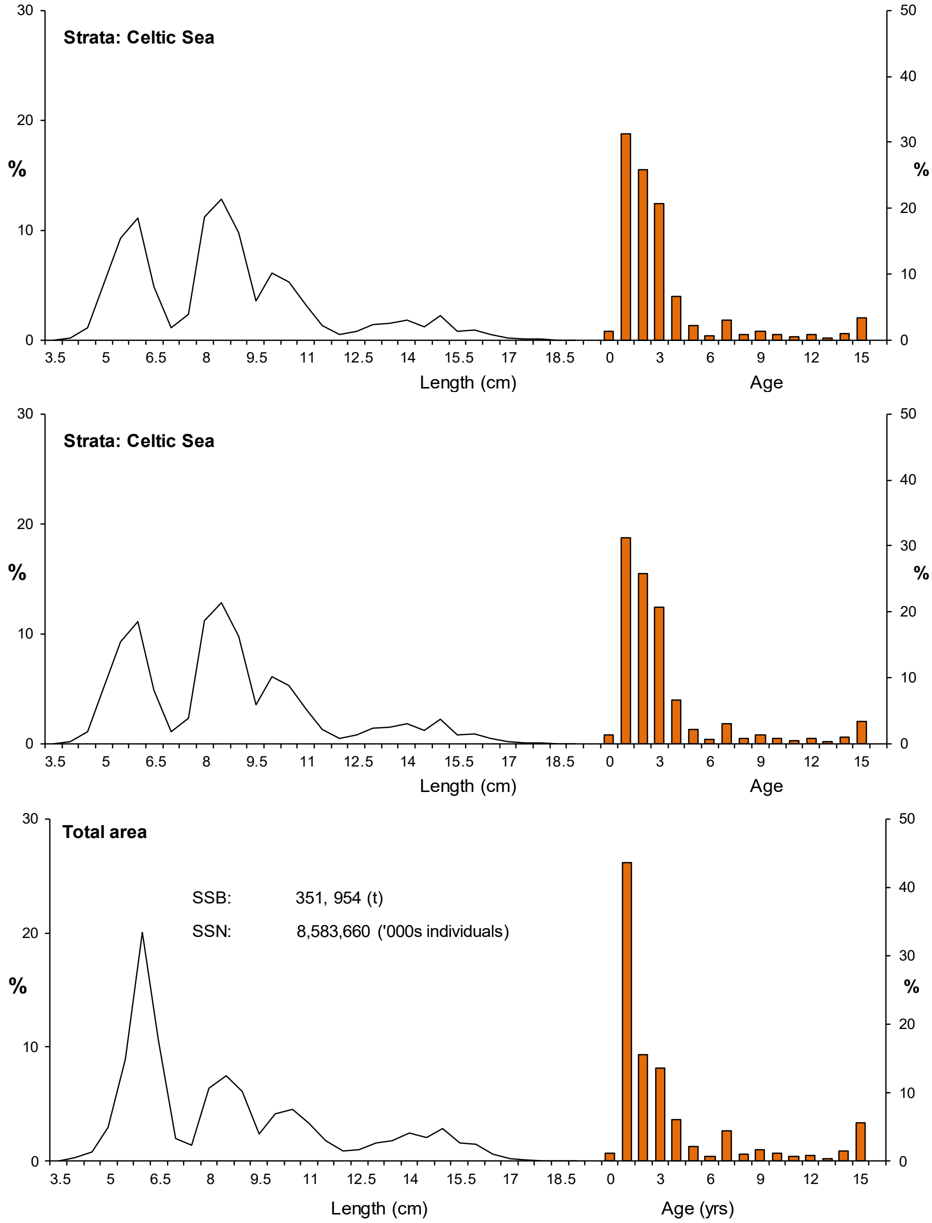

Figure 6. cont.

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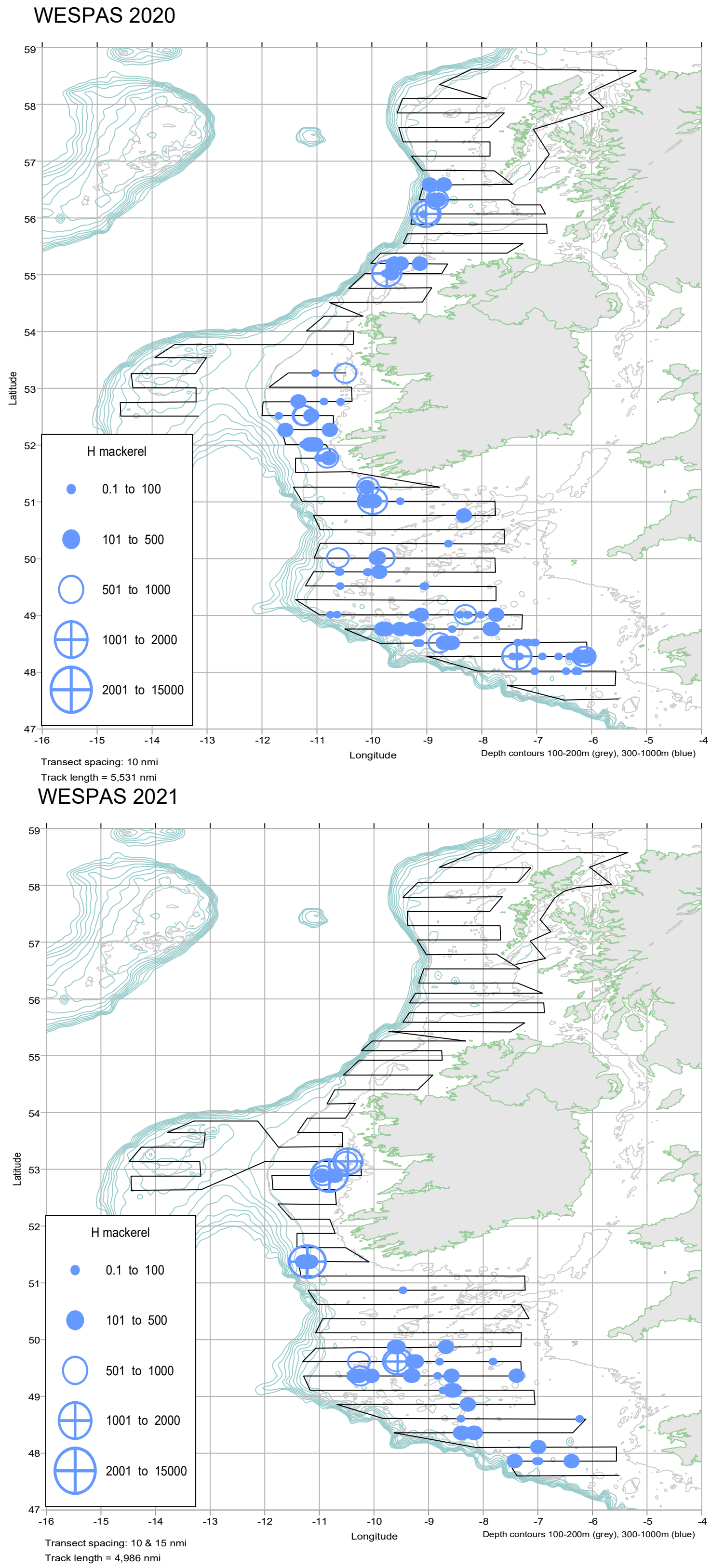

Figure 7. Horse mackerel distribution by weighted acoustic density. Top panel 2020, bottom panel 2021

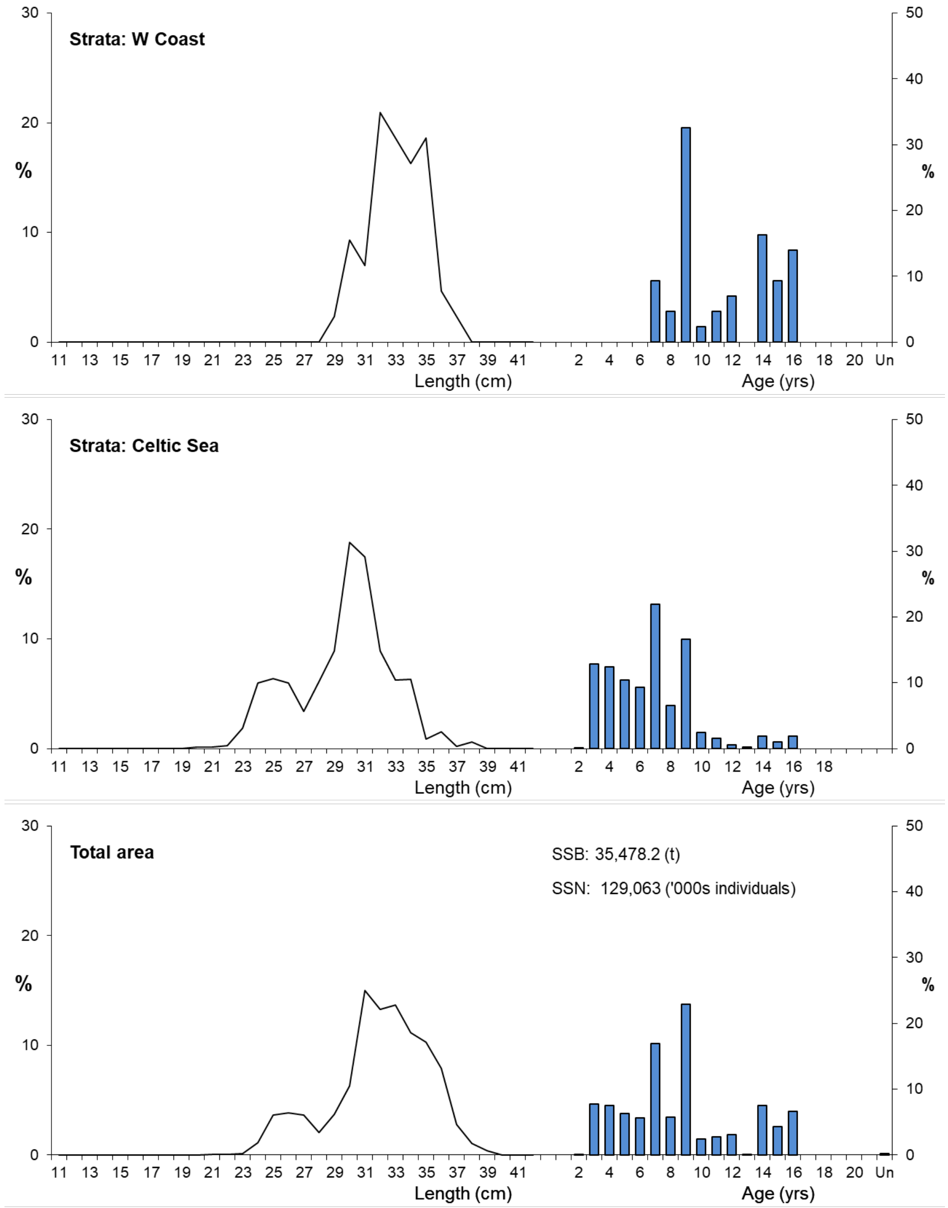

Figure 8. Length and age distribution of horse mackerel by stratum and total survey area.

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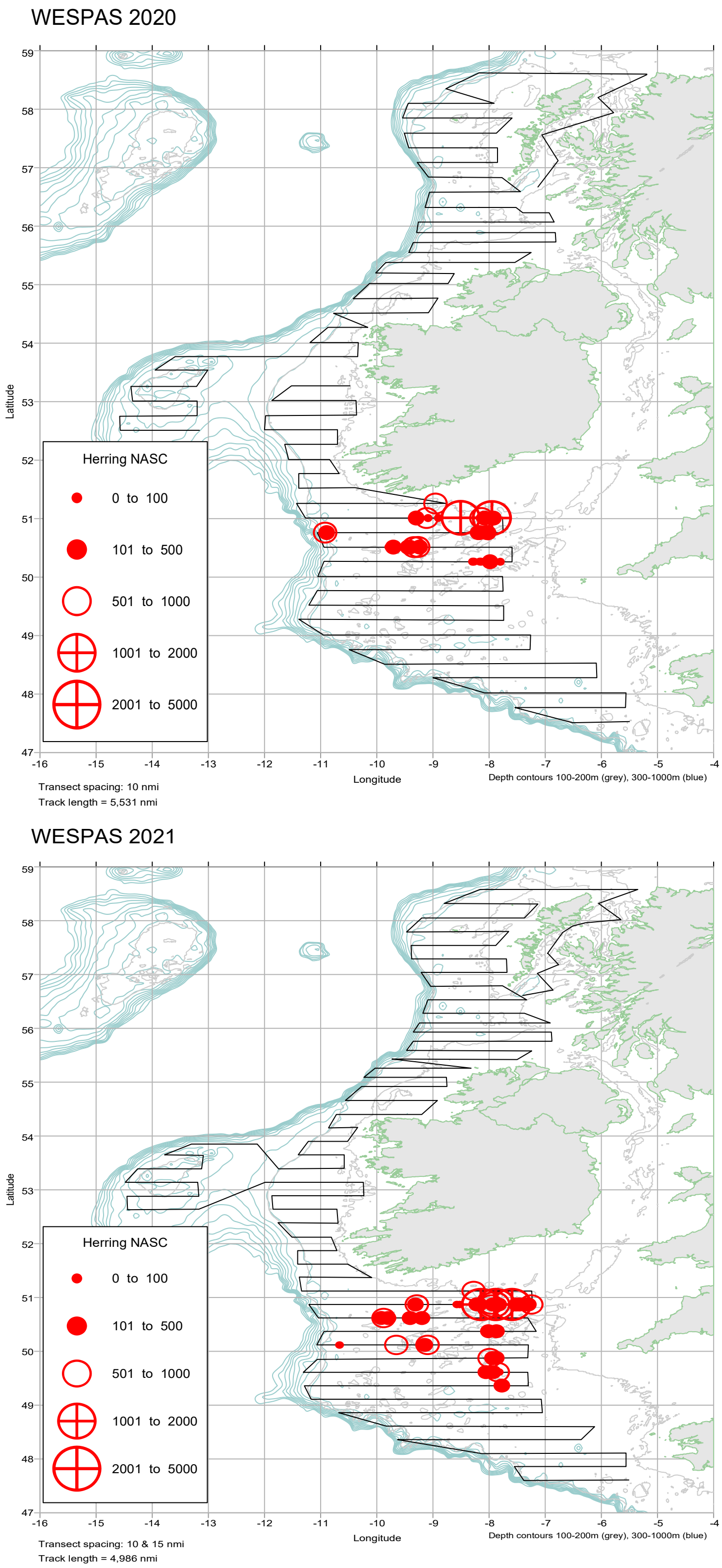


Figure 9. Celtic Sea herring distribution by weighted acoustic density. Top panel 2020, bottom panel 2021.

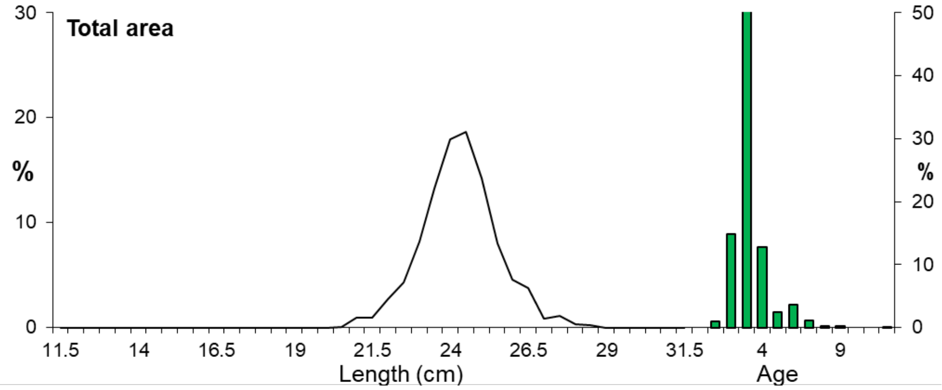
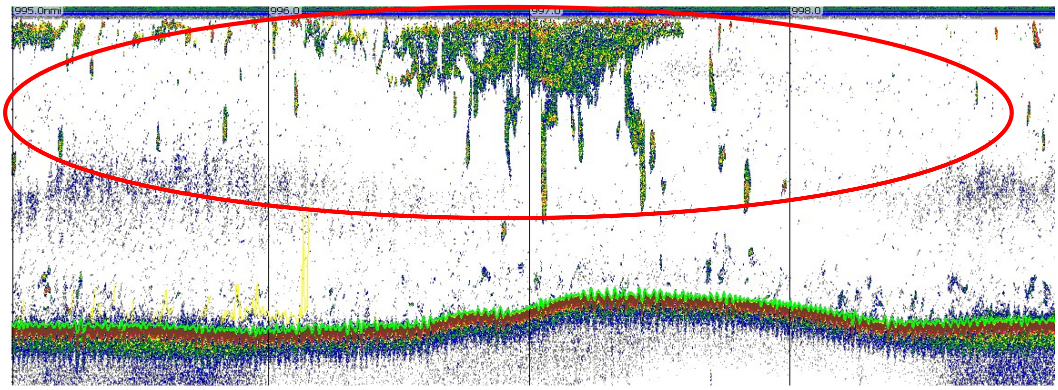
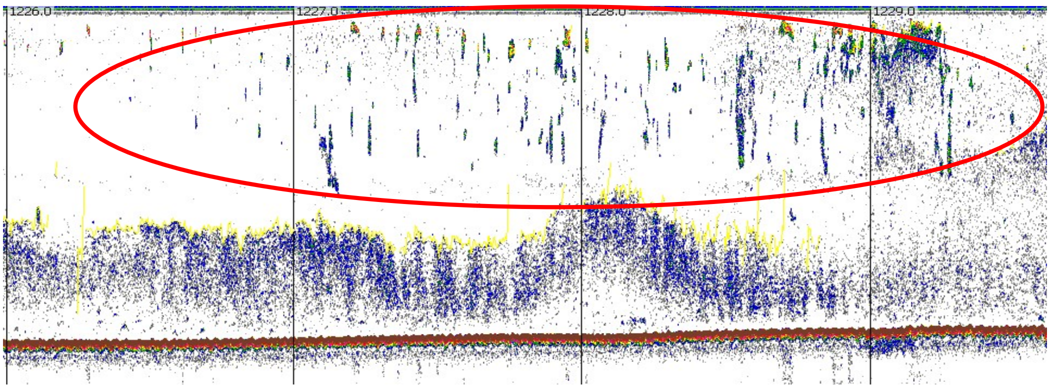


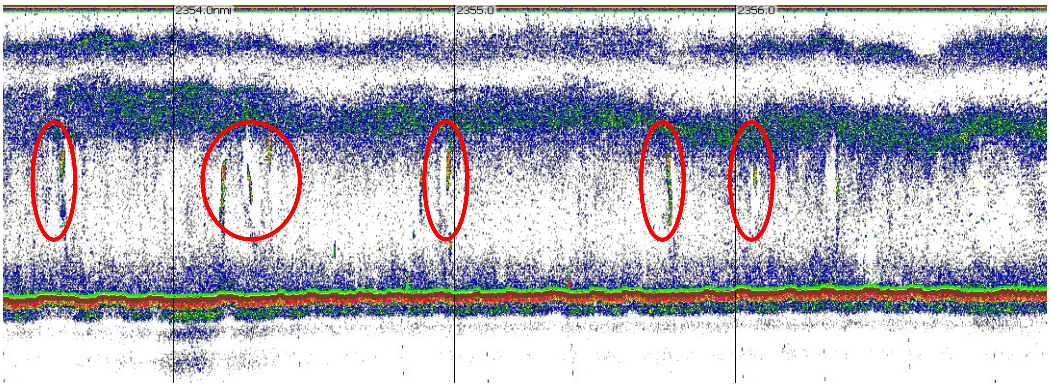
Figure 10. Length and age distribution of Celtic Sea herring within the Celtic Sea stratum (Total survey area).



a). *Southern Celtic Sea. Typical high density aggregations of immature boarfish as observed on the south of 49°N. Water depth 147m (Haul 09). Recorded at 18 kHz.*

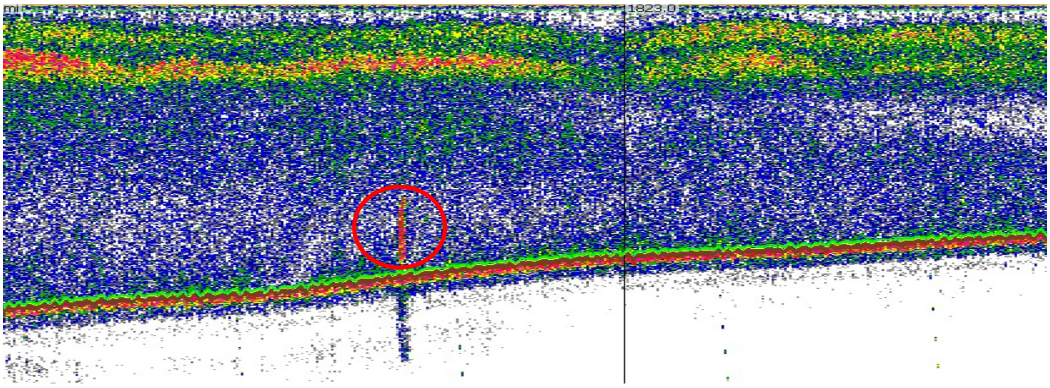


b). *Haul 12, Mid-Celtic Sea. Medium density surface aggregations of immature boarfish. Water depth 151 m. Recorded at 18 kHz.*

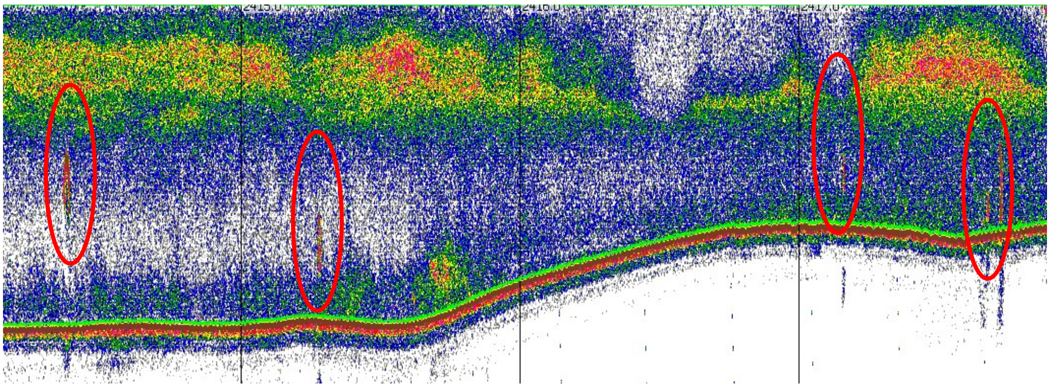


c). *Haul 24. Medium density midwater schools of mature boarfish encountered off the southwest Irish coast. Water depth 118 m.*

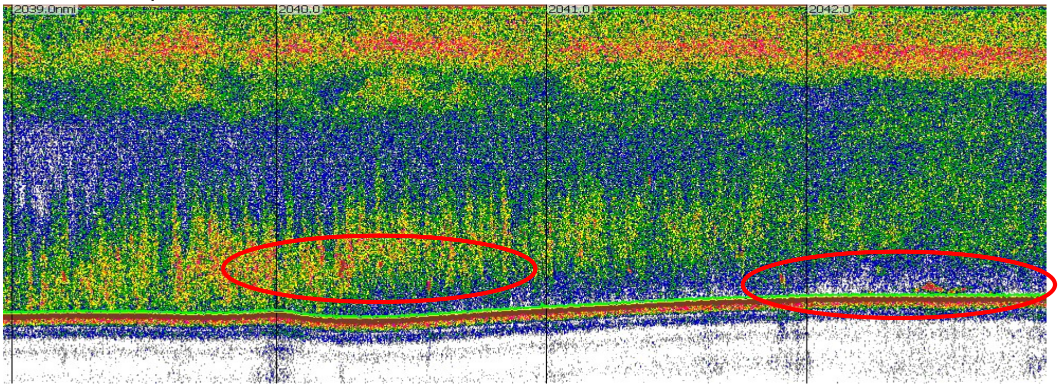
Figures 11a-l. Echotraces recorded on an EK60 echosounder (38 kHz, unless otherwise stated) with images captured from Echoview. Note: Vertical bands on echogram represent 1nmi (nautical mile) intervals.



d). *Haul 18. Mid-Celtic Sea. High density herring echotrace. Water depth 97 m.*

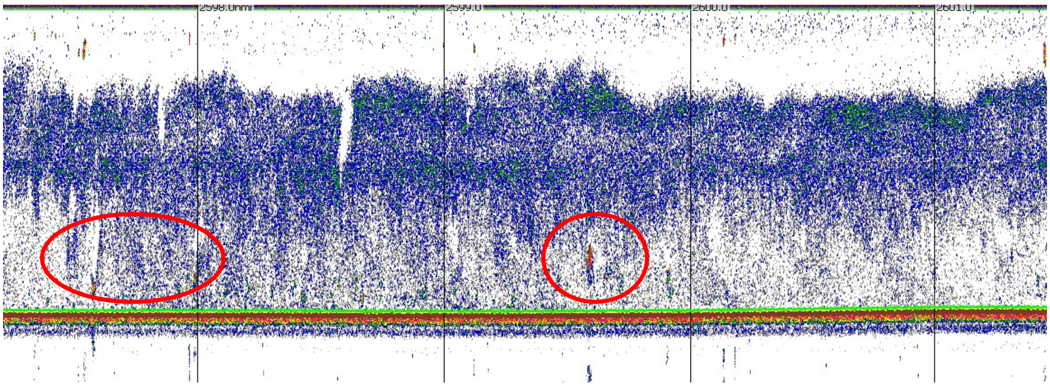


e). *Haul 25. High density cluster of herring echotraces off the south coast in the western Celtic Sea, water depth 100 m.*

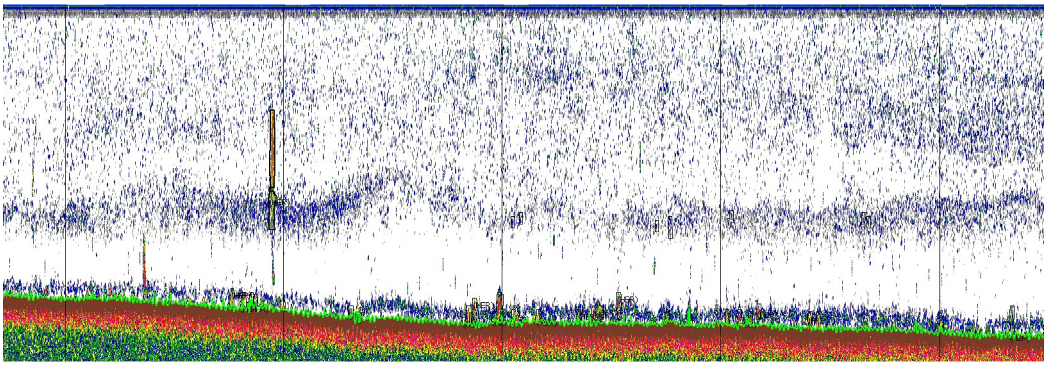


f). *Haul 20. Medium density scattering layer containing juvenile blue whiting in the mid-Celtic Sea, water depth 124 m.*

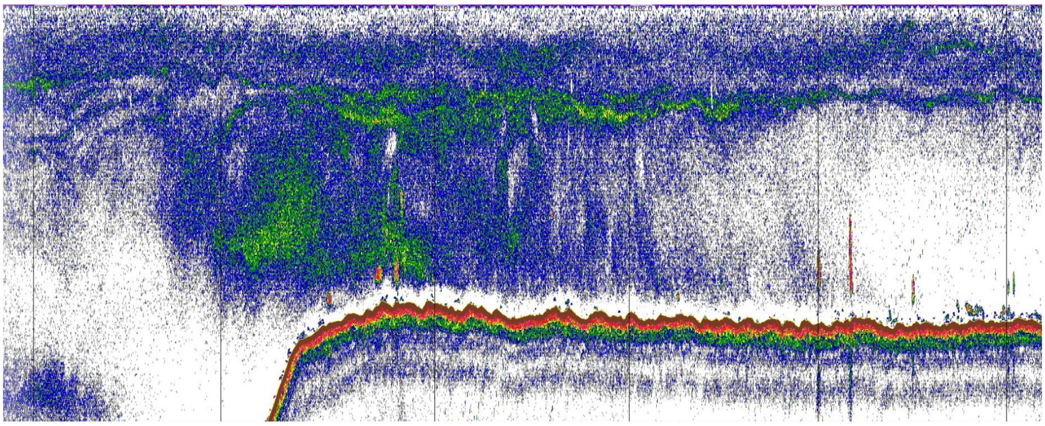
Figures 11a-l. continued



g). *Haul 26. Juvenile blue whiting echotraces, south coast Celtic Sea, water depth 121 m.*

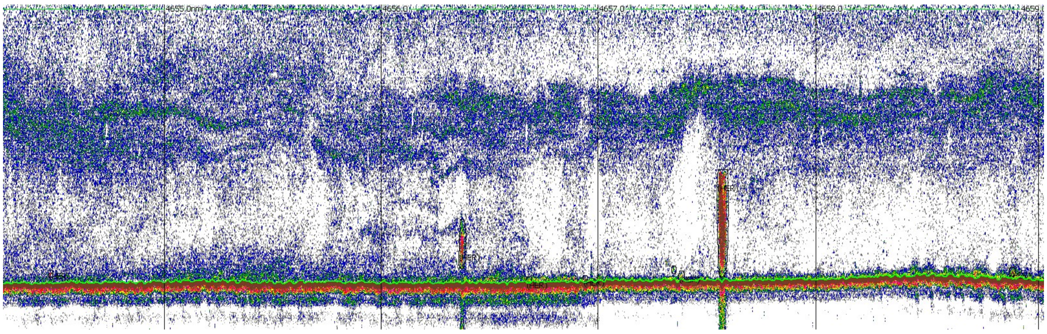


h). *Haul #43. North of Lough Swilly, fast moving herring marks mid-water and some on the sea-bed also (18 kHz), water depth 75 m.*

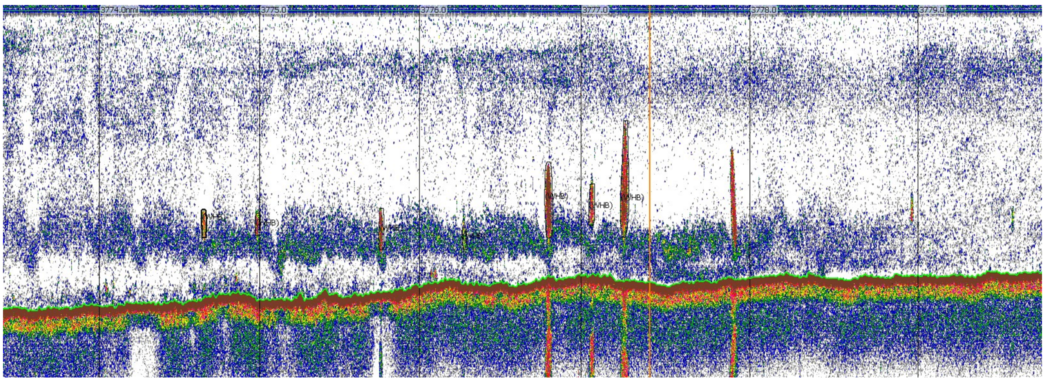


i). *Haul #51 Shelf edge. Boarfish marks close to the shelf edge (38 kHz), water depth ~150 m.*

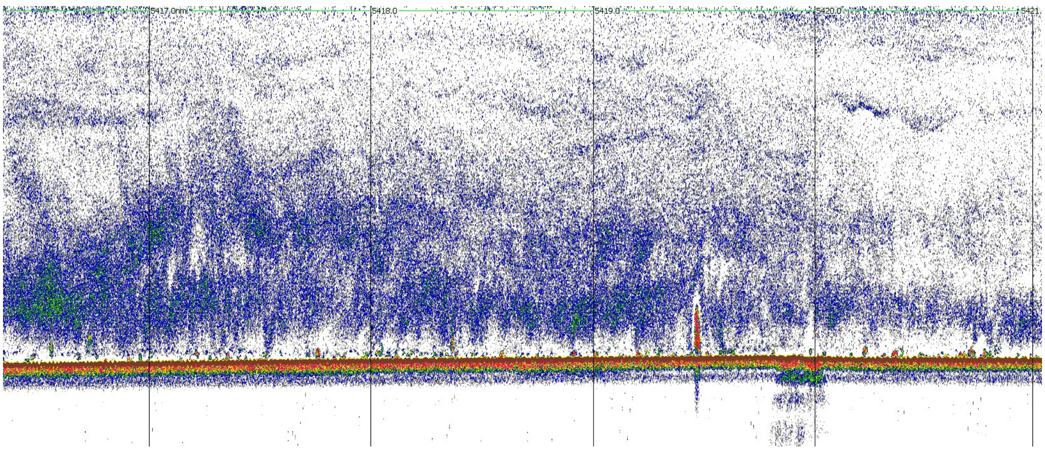
Figures11a-l. continued.



J). *Haul #45. Strong herring pillar marks north of Tory island (38 kHz), water depth ~110 m.*

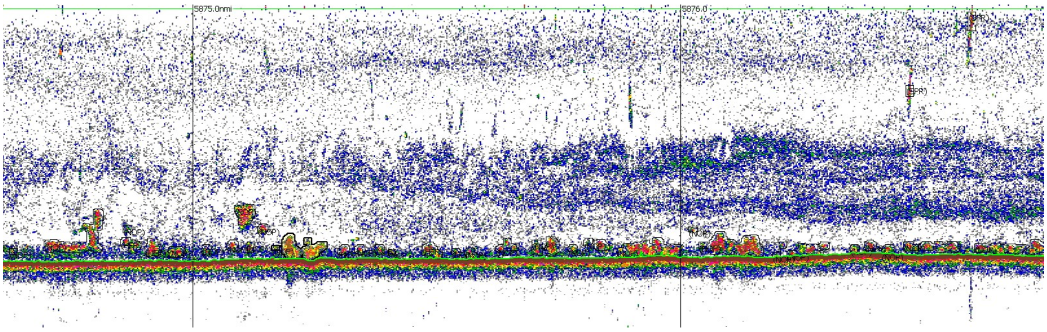


k). *Haul #34. Juvenile blue whiting west of Slyne Head (38 kHz), water depth ~110 m.*



l). *Haul #56. South of St. Kilda. Herring marks along bottom (38 kHz), water depth ~155 m.*

Figures11-l. continued.



m). *Haul #62. North Minch. Norway pout, juvenile herring (1 –wr) on bottom and sprat in midwater (38 kHz), water depth ~115 m.*

Figures11-l. continued.

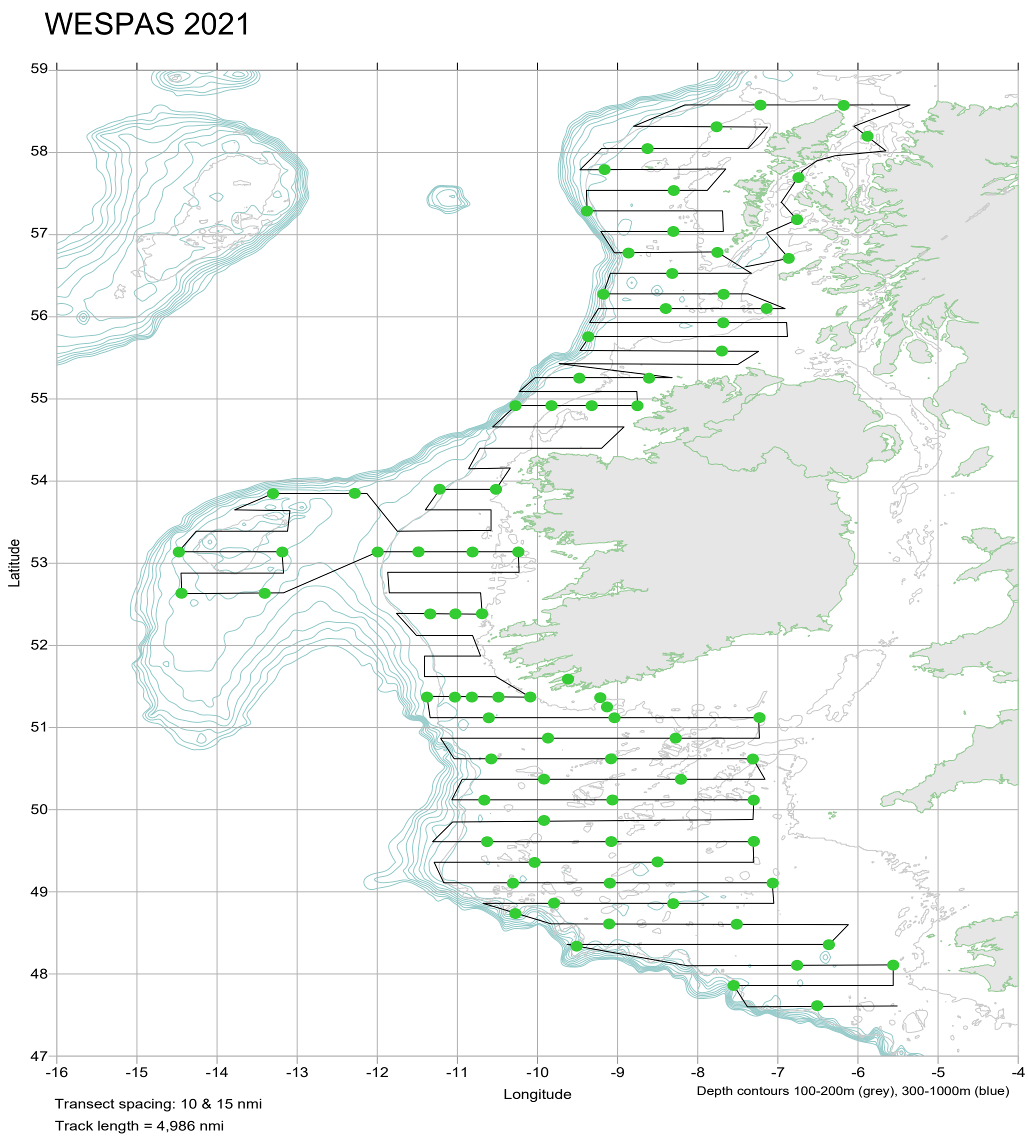


Figure 12. Position of hydrographic and co-occurring zooplankton sampling stations (CTD=84, WP2=78).

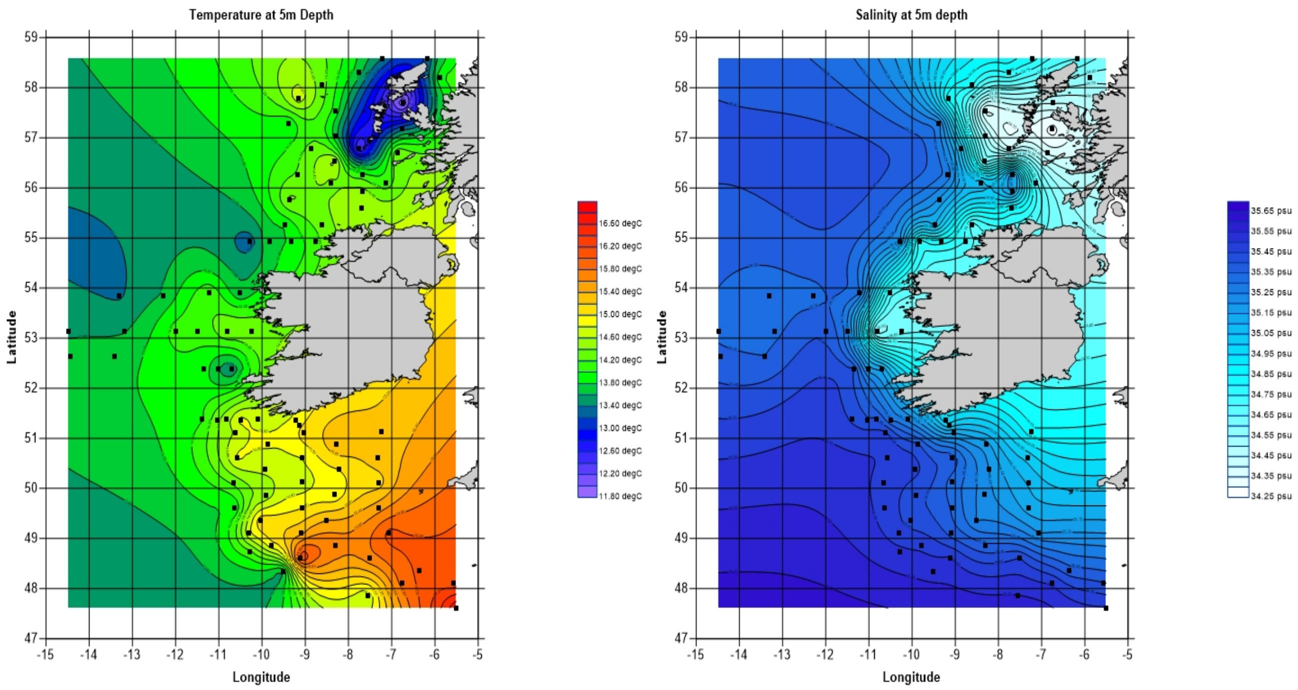


Figure 13. Surface (5m) plots of temperature and salinity compiled from CTD cast data. Station positions with valid data shown as block dots (n=84).

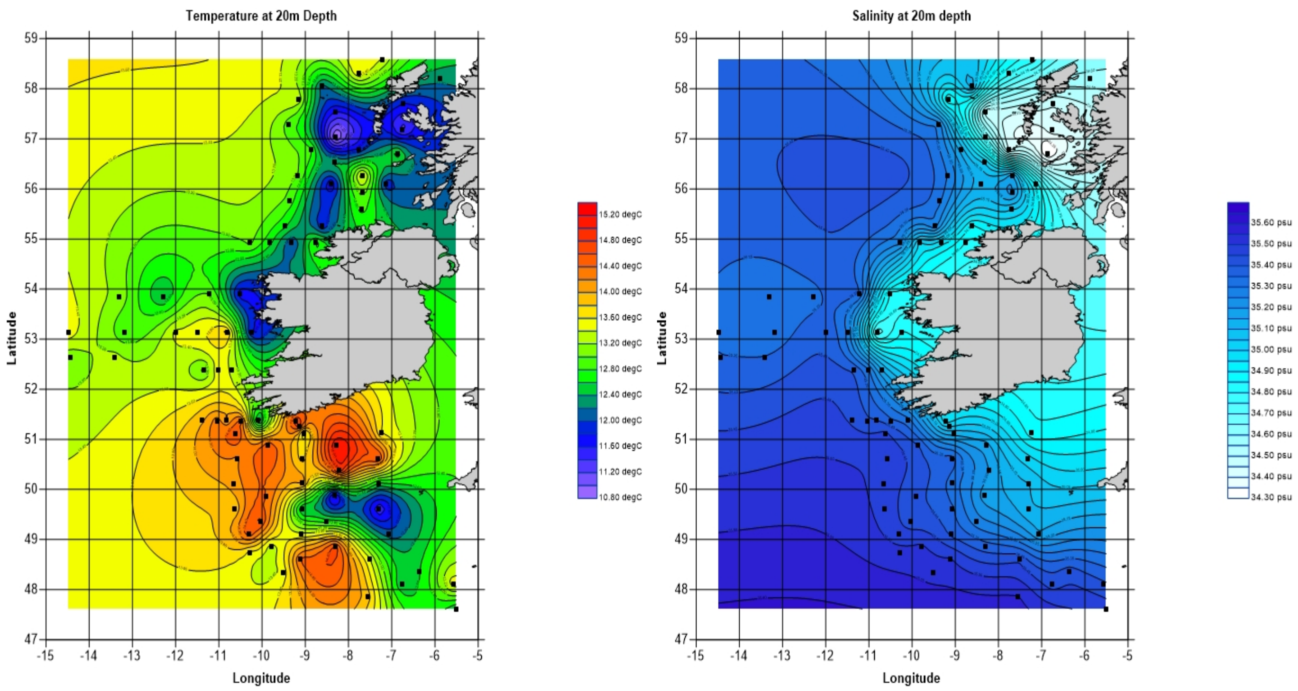


Figure 14. Plots of temperature and salinity compiled from CTD cast data at 20m depth. Station positions with valid data shown as block dots (n=84).

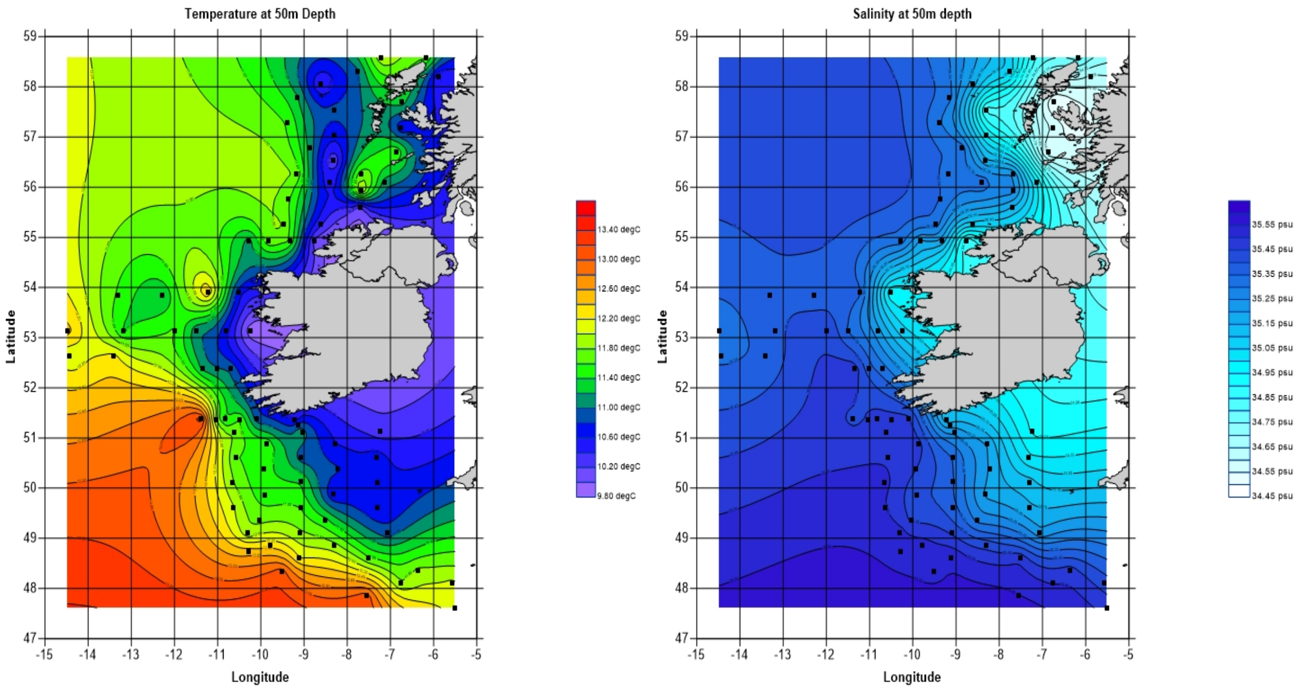


Figure 15. Plots of temperature and salinity compiled from CTD cast data at 50m depth. Station positions with valid data shown as block dots (n=84).

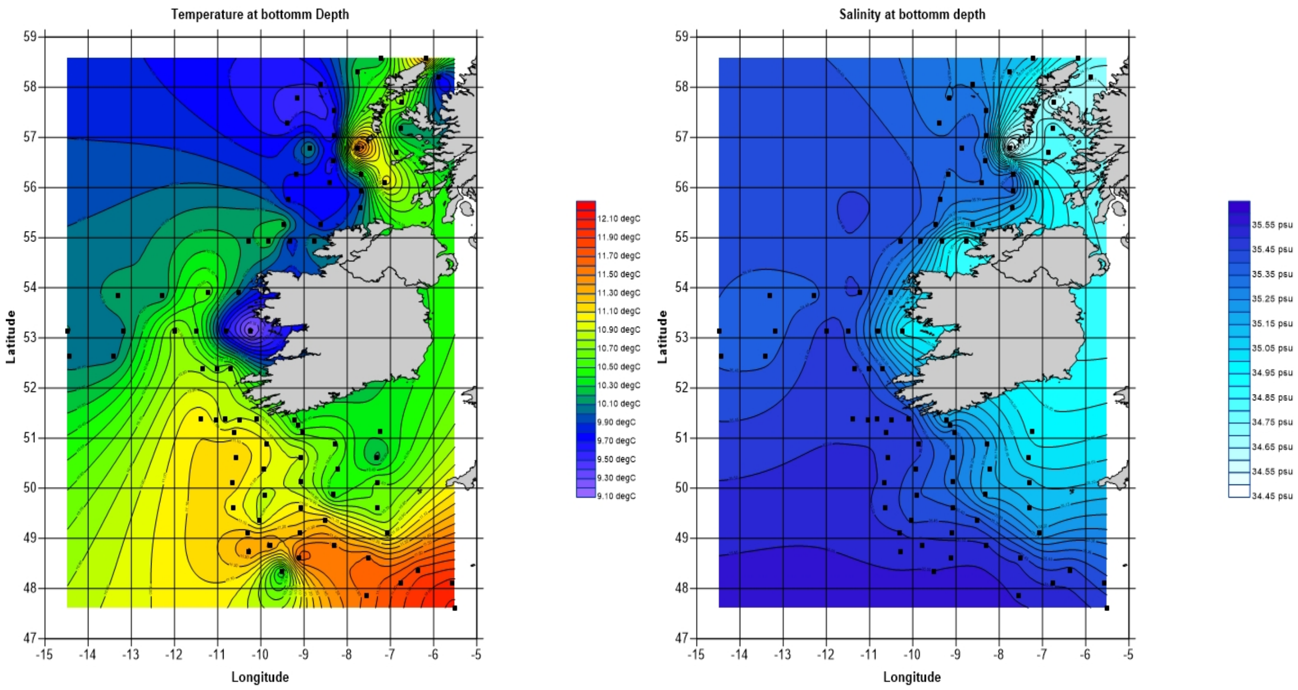


Figure 16. Plots of temperature and salinity compiled from CTD cast data at the seabed (+3-5m). Station positions with valid data shown as block dots (n=84).

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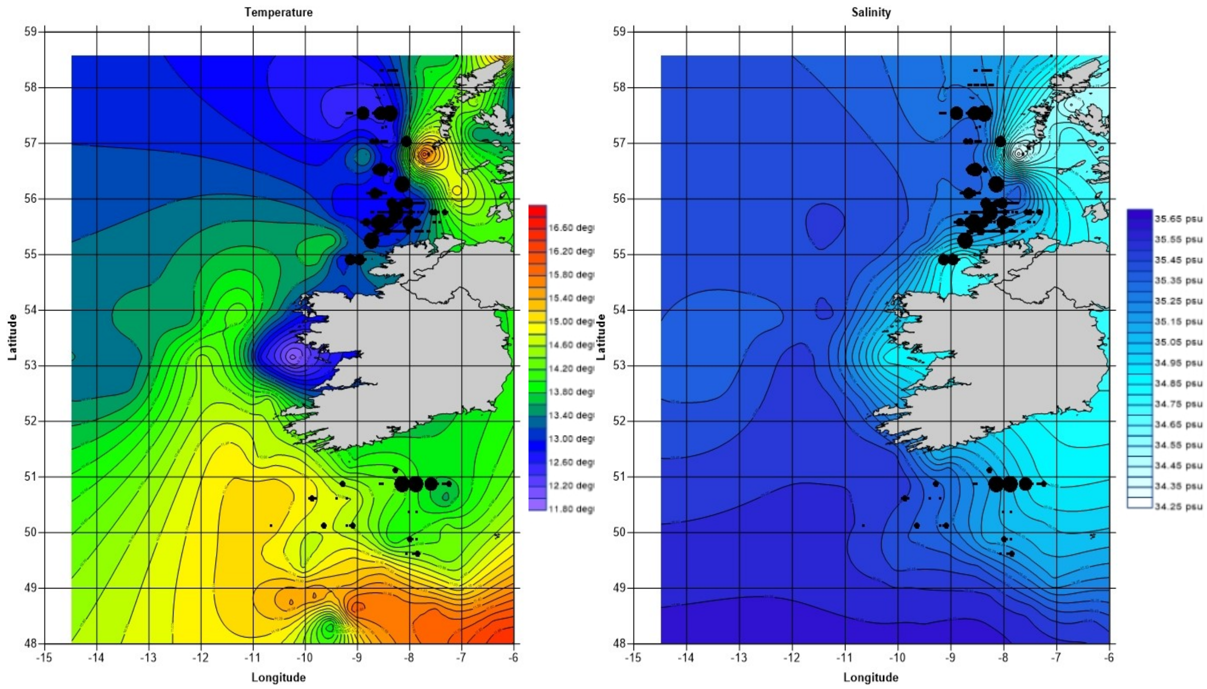

Figure 17. Habitat plots of temperature and salinity with herring distribution. Sea floor values overlaid with herring NASC values (black circles).

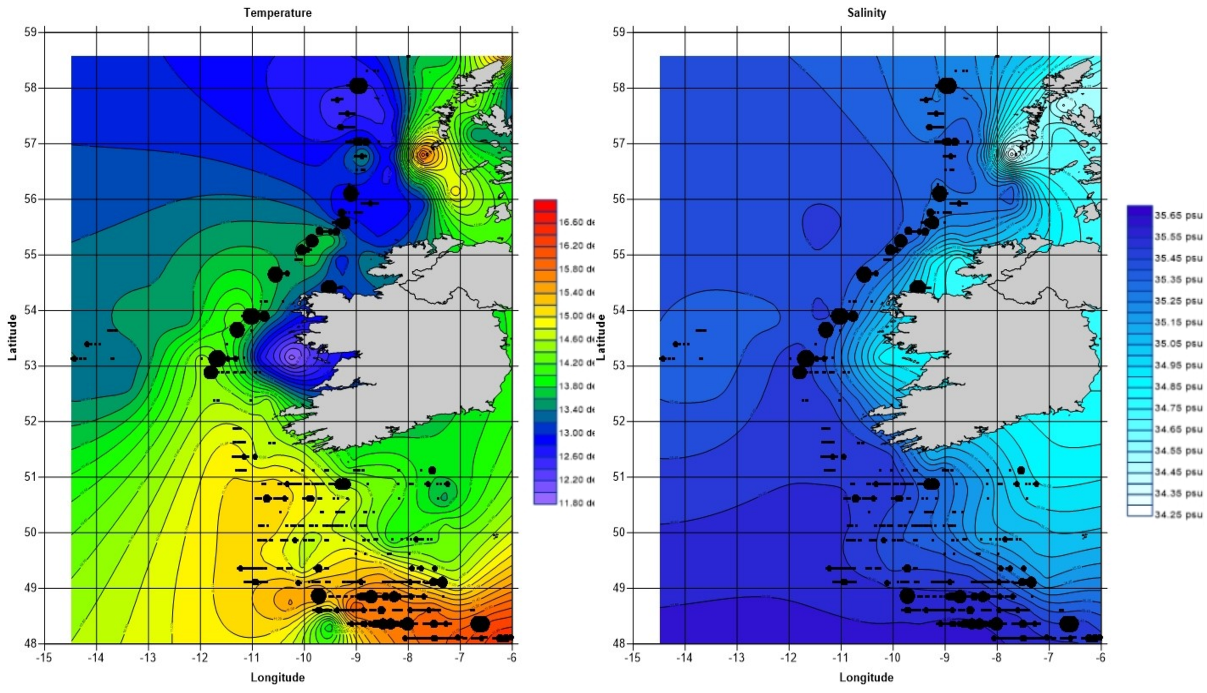

Figure 18. Habitat plots of temperature and salinity with boarfish distribution. Sea floor values overlaid with boarfish NASC values (black circles).

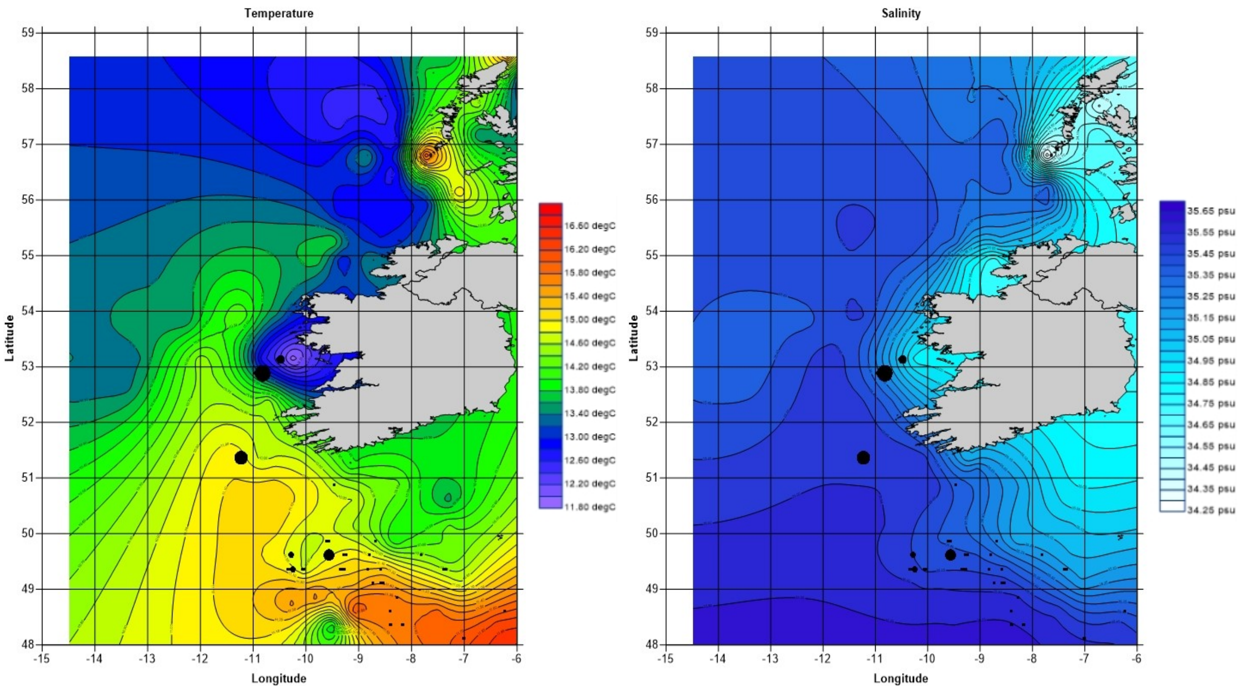

Figure 19. Habitat plots of temperature and salinity with horse mackerel distribution. Sea floor values overlaid with horse mackerel NASC values (black circles).

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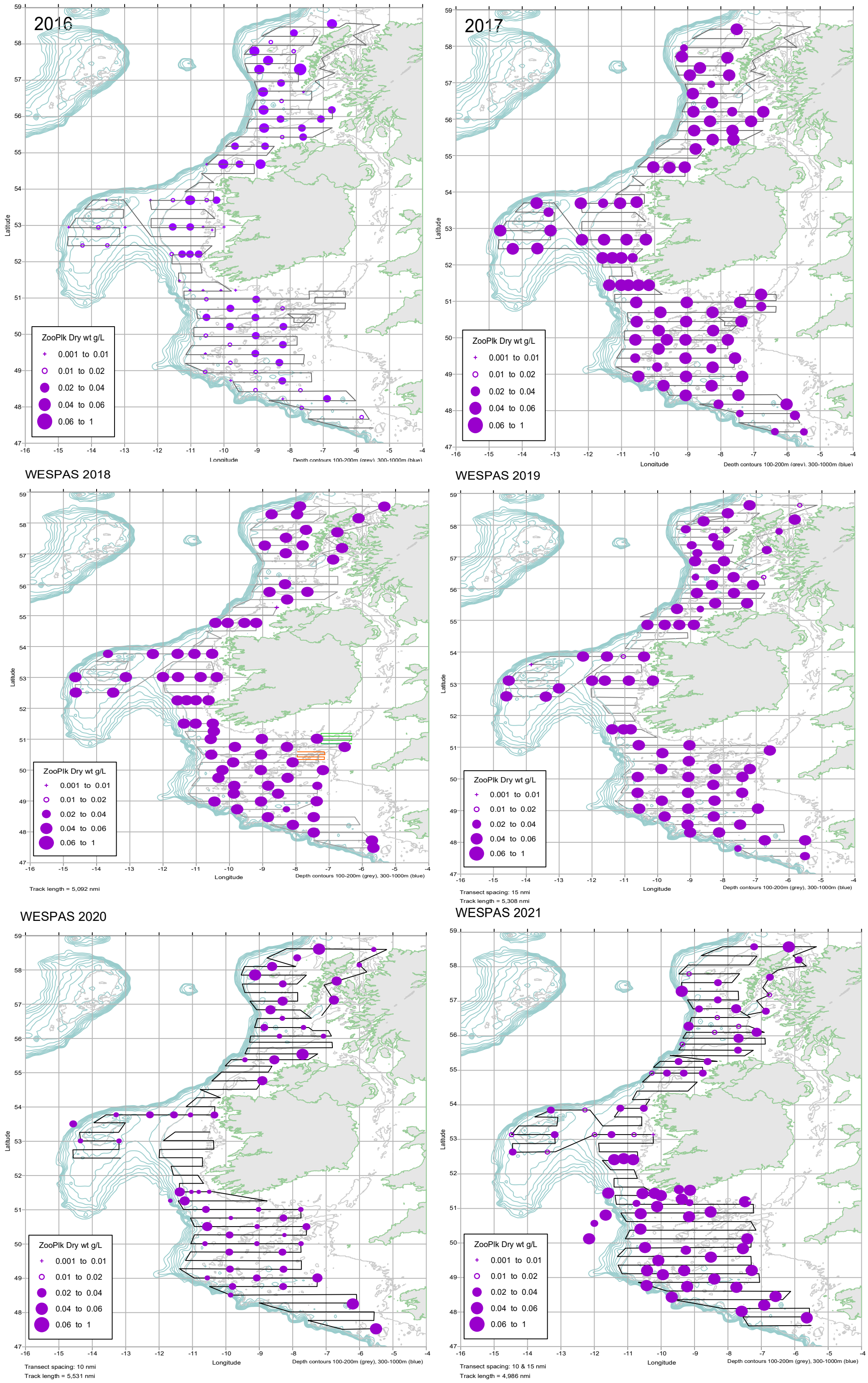


Figure 20. Zooplankton dry weight biomass by station (g dry Wt. m3) 2016-2021.

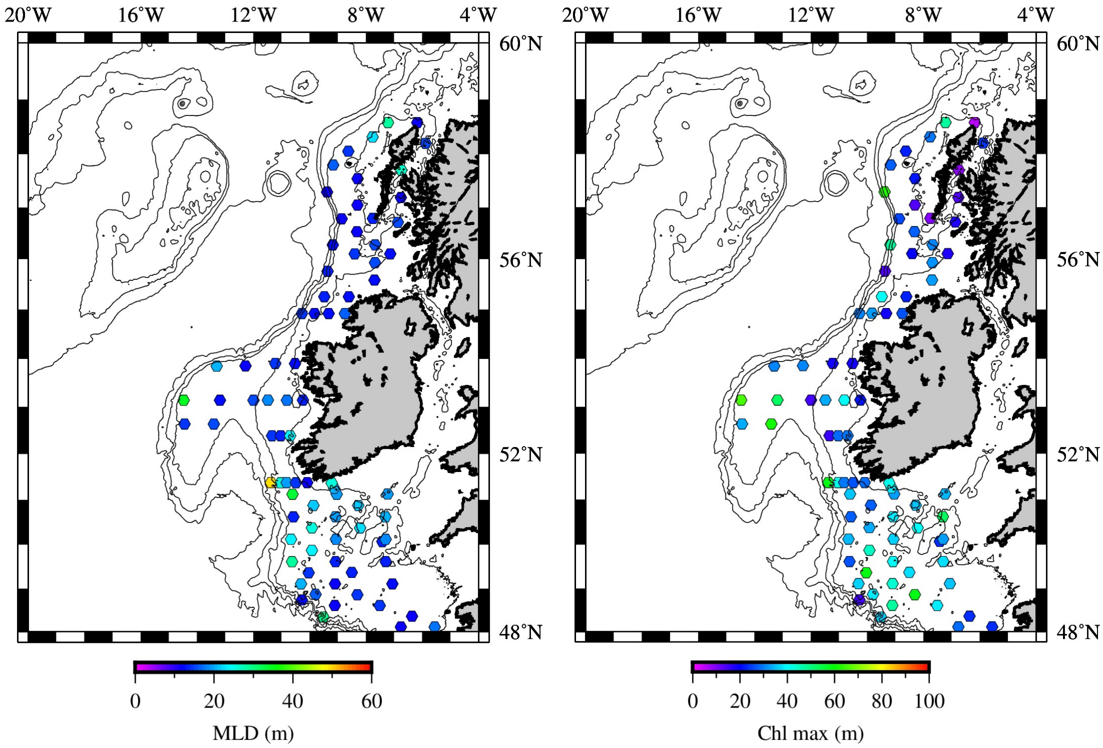
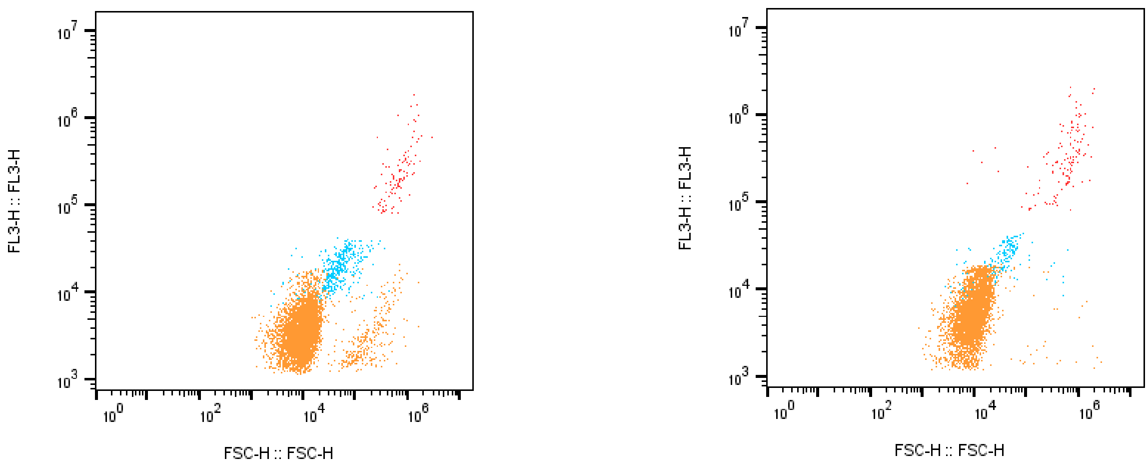


Figure 21. (left) Mixed layer depths at CTD stations during WESPAS 2021. (right) Depth of the chlorophyll maximum at CTD stations during WESPAS 2021.



	Sample Name	Subset Name	Count
	A05 060721_S60_N17_D7.fcs	Syn	5906
	A05 060721_S60_N17_D7.fcs	PicoEuk	419
	A05 060721_S60_N17_D7.fcs	NanoEuk	100

	Sample Name	Subset Name	Count
	A04 060721_S60_N16_D17.fcs	Syn	4503
	A04 060721_S60_N16_D17.fcs	PicoEuk	229
	A04 060721_S60_N16_D17.fcs	NanoEuk	132

Figure 22. Flow cytometric analysis from Station 60, leg 2 of WESPAS 2021. (left) near surface water and (right) chlorophyll maximum.

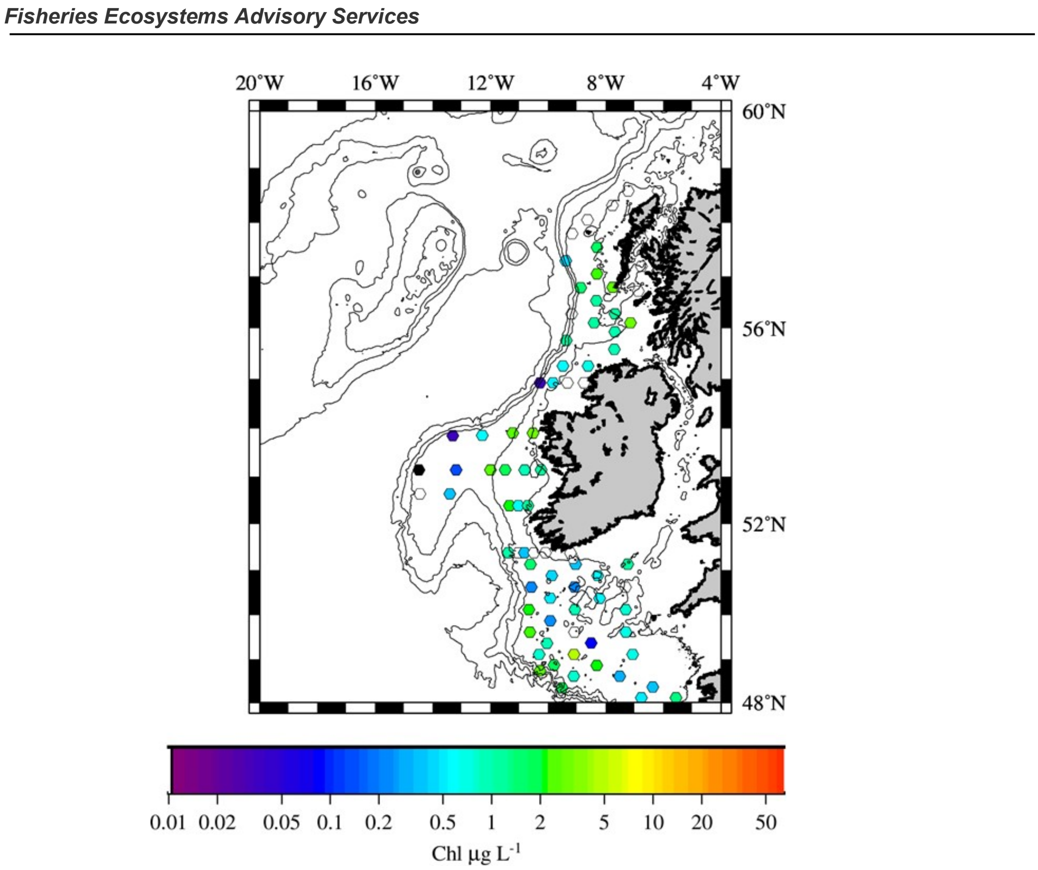


Figure 23. Near surface mixed layer chlorophyll measurements during WESPAS 2021.

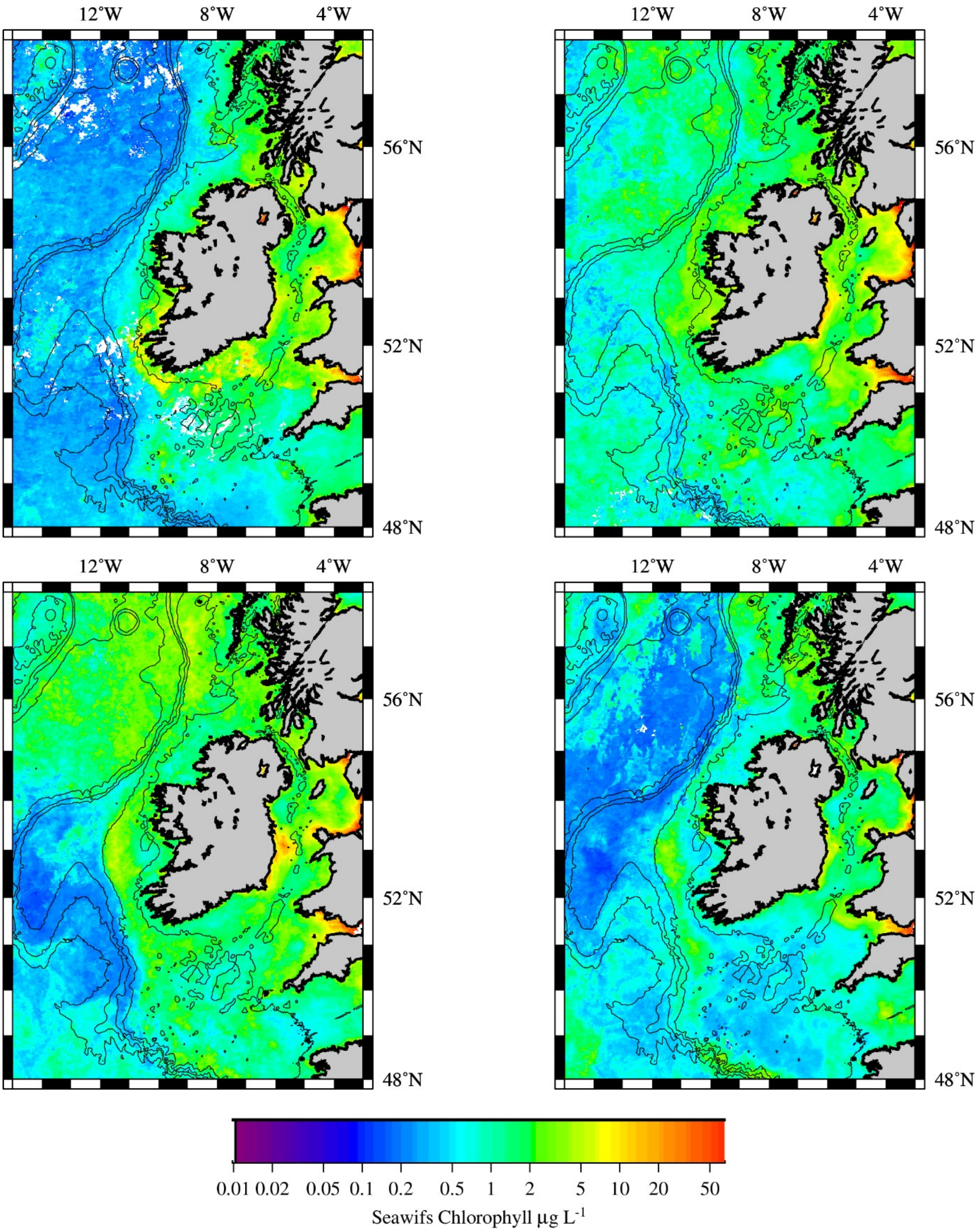


Figure 24. OC5CI Chlorophyll monthly composite images for March (top left), April (top right), May (bottom left) and June 2021 (bottom right) (Source: CMEMS).

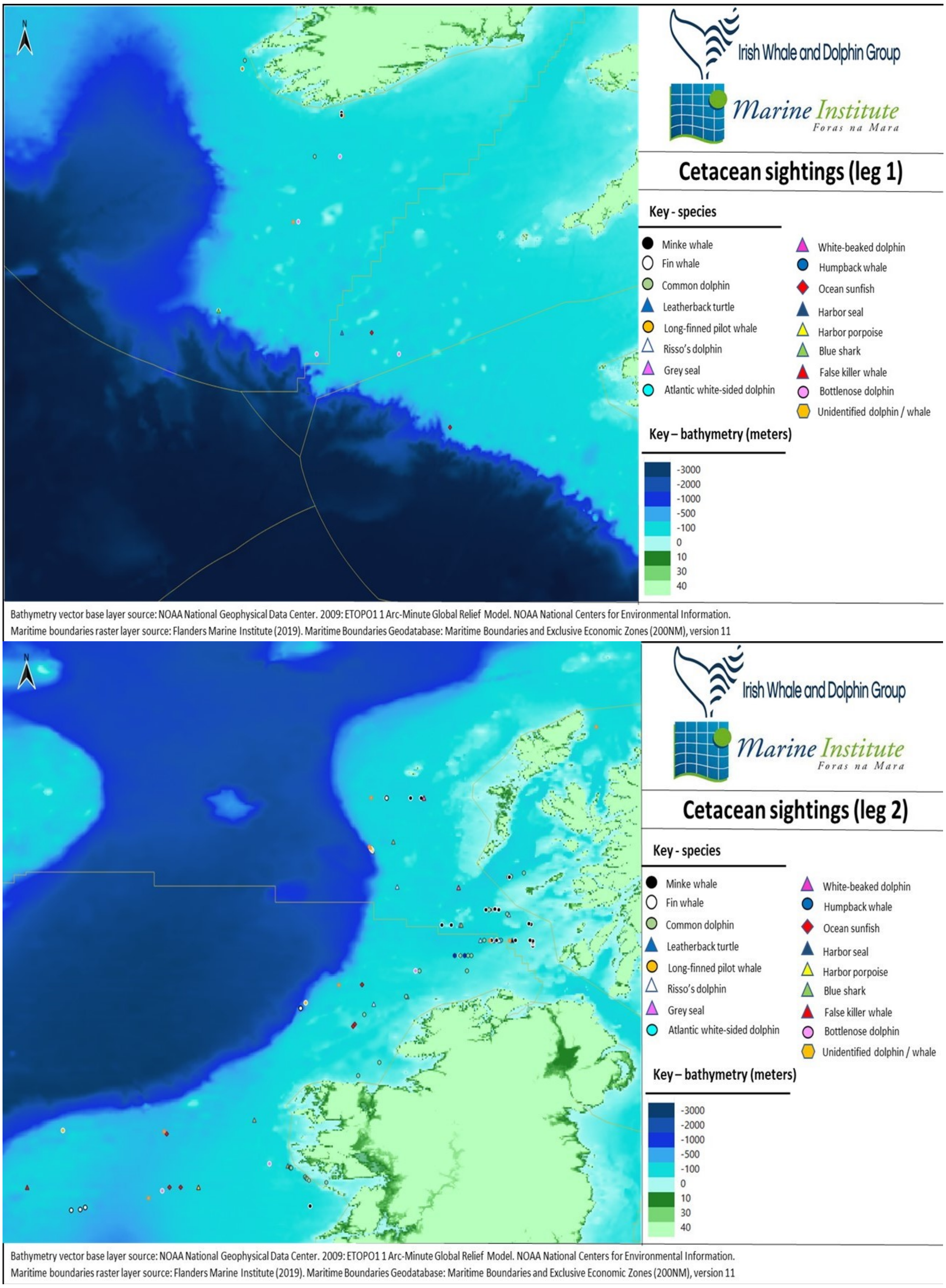


Figure 25. Sightings of all marine mammal species encountered during the WESPAS 2021. Top panel Leg 1 south and bottom panel Leg 2 north.

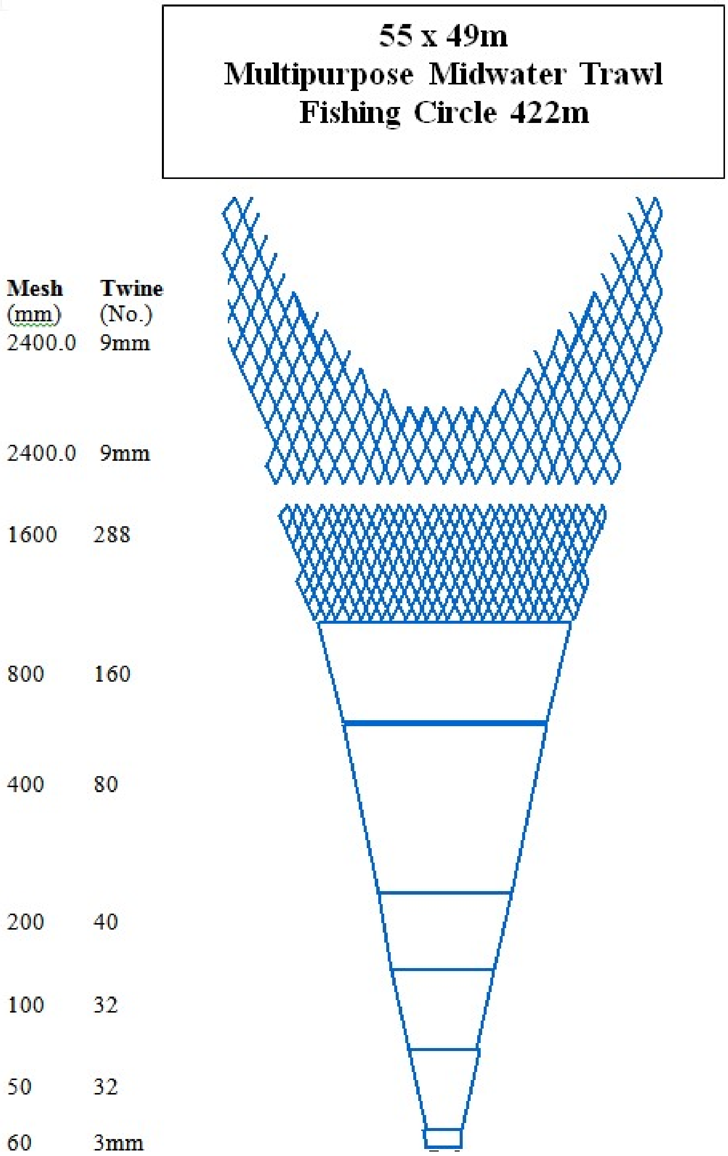


Figure 26. Single multipurpose midwater trawl net plan and layout.

Note: All mesh sizes given in half meshes; schematic does not include 32m brailer.

Annex 12: 2021 PELTIC Survey Summary Table and Survey Report

Document 12a: PELTIC 2021 survey summary table

Survey Summary table WGIPS 2022	
Name of the survey (abbreviation):	PELTIC21
Target Species:	Sprat, sardine, anchovy (mackerel, horse mackerel, herring)
Survey dates:	4^{th} October – 7^{th} of November 2021
Summary:	

Peltic21 constituted the 10th autumn survey on small pelagic fish and their ecosystem in the waters of the western English Channel and eastern Celtic Sea.

For the fifth year, the survey was extended beyond UK waters to also include the French waters of western English Channel. For the second time the survey was extended northwards into Cardigan Bay in the southern Irish Sea for the Welsh Government.

The survey commenced on the 4^{th} of October, delayed by 30 hours due to issues with covid testing results. However, despite the initial delays, exceptional weather conditions during the first 10 days of the survey meant it was completed successfully within the available 34 remaining survey days. The survey sailed from Lowestoft, starting in the western English Channel working into Cardigan Bay and the Bristol Channel. Just under 36 hours were lost to weather towards the end of the survey. The 2181 nautical miles of effective acoustic coverage were supplemented with 41 valid trawls which provided details on species composition and biological information. Several 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.

The biomass estimates for key pelagic species was deemed of good quality: sprat in ICES area 7de and sardine in area 7ef for stock assessment.

Sprat biomass in the strata used for the assessment was 107,355 t (CV 0.26) which was more than three times the 2020 estimate and the highest since the start of the PELTIC timeseries (in 2013). This was comprised of 0-group fish, confirming a very strong recruitment. As in previous years, the highest quantities were found in Lyme Bay, showing a more offshore distribution than in 2020, although sprat was also found in the Eddystone Bay. Larger than usual numbers of sprat were also found along the northern French coast, although this areas is not considered in the assessment. Outside the western Channel, sprat was again also found north of the Cornish Peninsula: offshore in the deeper waters of the Celtic Sea, in the Inner Bristol Channel and, in very high numbers, in Cardigan Bay.

Sardine biomass for the survey areas included in the new assessment was 227,117 t (CV 0.19). This represents a reduction by one third from peak values in 2020 (and 2019), although still higher than 2017 and 2018 and a close second most abundant small pelagic fish species after sprat. Sardine egg density maps matches those for the acoustics confirming the core distribution of the stock was captured.

Anchovy biomass increase slightly from 2020 to 45,616t (highest in time series) with again one year old fish dominating the population. There was no sign of significant presence of post-larval Bay of Biscay anchovy, observed during PELTIC 2020 across all southern English Channel transects.

Other species: unusually, two large juvenile **blue whiting** catches were obtained at the western edge of the survey (around Isles of Scilly), an area that normally is dominated by **boarfish** – although boarfish were also prevalent in this area. Atlantic bluefin tuna were regularly observed particularly around the Channel Islands.

	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 not jeopardised significantly.
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 (~30 hours lost). Exceptionally good weather conditions for 10 day period.
Extinction (shadowing)	Not an issue for areas used in stock assessment but one exceptionally large and dense sprat school in Cadigan Bay was possibly

	affected although still awaiting advice on how to deal with this (school backscatter explored *in situ* for high values >20,000 NASC)
Blind zone	*Time-series*: 12 m (drop keel+nearfield). 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 10-11 knots. *2021*: some juvenile surface schools observed but not thought to be undersampled as most schools seemed to be below the surface dead-zone (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, automatically derived from algorithms (swim bladdered fish/ mackerel), are allocated to trawls based on combination of nearest distance 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 calculations from 2020 used). 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, westerly and southerly (since 2017) boundary captured well (combining data with those collected during CSHAS); area further south (Bay of Biscay) thought to be different stock and is covered by JUVENA survey (AZTI); 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 (7d not included in survey for example) and beyond although Lyme Bay seemingly isolated in autumn. Sprat in Celtic Sea not captured fully as extending further west (covered by MI, Ireland during CSHAS) *2021 survey*: **Sardine** as above; **sprat** more widespread in channel than seen normally and 0-group sprat expanded outside stratum used for stock assessment (which is therefore an *underestimate*)
Stock ID and mixing issues	*Time series*:**Sprat** stock structure not clear although evidence of genetic links to wider NE Atlantic; likely to be some geographic separation; **Sardine** is thought to be single stock although likely to be interacting with sardine in North Sea and Bay of Biscay.Growth rate in aea 7 is different from 8; northern anchovy is separate stock from Biscay although some mixing may occur (2020 influx of juveniles). *2021 survey*: as above although sprat more widespread across the area.

Measures of uncertainty (CV)	StoX derived and both sardine and sprat good (0.26 and 0.19 respectively)
Biological sampling	*Time series*: good *2021 survey*: details provided in report and although numbers are lower than last year they thought to be good across species and sizes
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)	*SPR.27.7de*
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	*SPR27.7de*

Document 12b: PELTIC 2021 survey report

*Please find report on the next page.

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RESEARCH VESSEL SURVEY REPORT

RV CEFAS ENDEAVOUR
Survey: C END 16 - 2021.

STAFF:

Name	Role
Jeroen van der Kooij	SIC/Acoustics
Joana Silva*/Elisa Capuzzo**	2IC/Fish/Oceanography
Fabio Campanella	2IC/Acoustics
Eleanor Haigh	Oceanography
Richard Humphreys	Lead Fishroom
Sílvia Rodríguez Climent	Acoustic/Fish
Samantha Barnett**	Deckmaster/Fish
Allen (Spike) Searle	Fish
Matt Eade	Fish/Zooplankton
Nevena Almeida	Zooplankton
Amy Larter	Zooplankton
Izzy Lake	eDNA
Peter Howlett	ML Observer
Emma Neave-Webb	ML Observer

*** disembarking on 21/10/21**
****joining 21/10/21**

DURATION: **4th October – 7th November (35 days)**

LOCATION: Western English Channel, Celtic Sea, Cardigan Bay (ICES Divisions 7.e-f and parts of 7.a,g)

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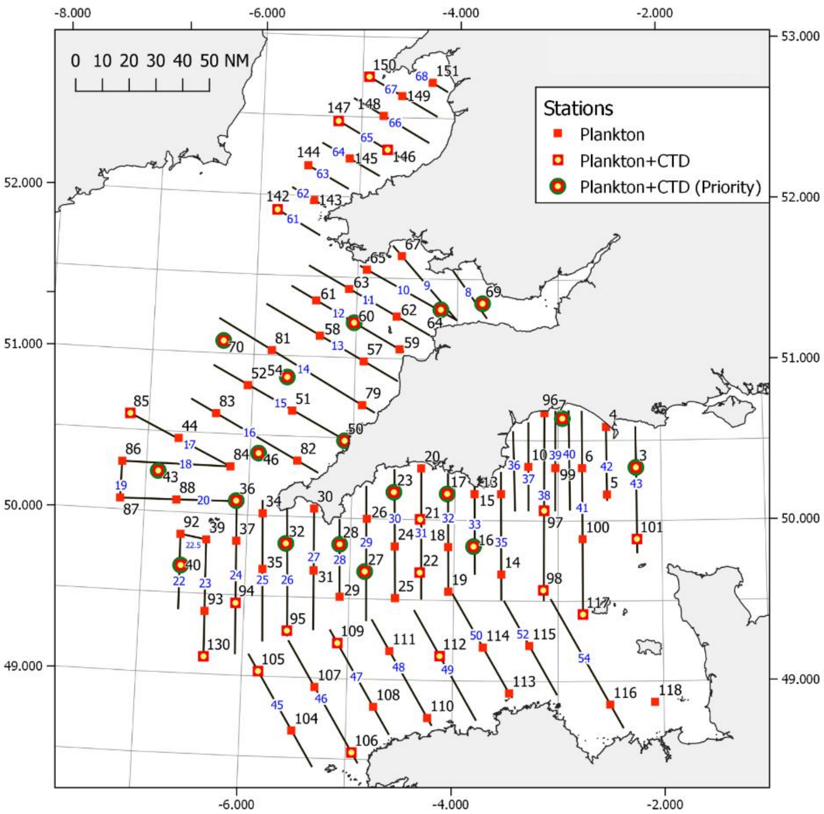

Figure 1. Overview of the planned survey area, with the acoustic transect (black lines, numbers in blue), plankton stations (red squares) and hydrographic stations (yellow circles). Priority stations indicated in green.

AIMS:

1. To carry out the tenth autumn PELTIC survey: pelagic ecosystem survey of the western English Channel, Celtic Sea, including (for the second time) Cardigan Bay (for Welsh Government), to estimate the biomass of-, and gain insight into the populations of the small pelagic fish community including sprat (*Sprattus sprattus)*, sardine (*Sardina pilchardus*), mackerel (*Scomber scombrus*) , anchovy (*Engraulis encrasicolus*), horse mackerel (*Trachurus trachurus*). The PELTIC derived sardine biomass in area 7 will feed into its stock assessment (WGHANSA) and sprat biomass data from the western English Channel will feed into the stock assessment of sprat in area 7de (HAWG).

    a. To carry out a fisheries acoustic survey during daylight hours only using four operating frequencies (38, 120, 200 and 333 kHz) to map and quantify the small pelagic species community.
    b. To trawl for small pelagic species using a 20x40m VDK herring (mid-water) trawl in order to obtain information on:
        - Species and size composition of acoustic marks
        - Age-composition and distribution, for small pelagic species
        - Length weight and maturity information of pelagic species
        - Stomach contents of selected species

2. To collect biological data (size, weight, age and maturity) on range of data-limited fish species, including European seabass (*Dicentrarchus labrax*), black seabream (*Spondyliosoma cantharus*), striped red mullet (*Mullus surmuletus*), garfish (*Belone belone*), saury pike (*Scomberesox saurus*).

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3. To collect plankton samples using two ring-nets with 80 µm, and 270 µm mesh sizes at fixed stations (red squares on map below). Carried out at night by vertical haul and samples will be processed onboard:
   a. Ichthyoplankton (eggs and larvae, 270 µm) of pelagic species will be identified, counted and (in case of clupeids) staged and measured onboard to identify spawning areas.
   b. Zooplankton (80 µm) will be stored for zooscan analysis back in the lab.

4. Water column profile and water sample (yellow stations on map below). At fixed stations along the acoustic transect, a CTD (ESM2 profiler or Seabird on Rosette sampler) will be deployed to obtain measurements of environmental properties within the water column: chlorophyll, dissolved oxygen, salinity, temperature, turbidity, dissolved inorganic nutrients as well as the relevant QA/QC samples for calibration of the equipment. Water samples will be collected and fixed on board for analysis post-survey. Samples for analysis of the phytoplankton and microzooplankton communities will also be collected at the subsurface at fixed sampling stations.

5. Seabirds and Marine Mammals. Locations, species, numbers and activities observed will be recorded continuously during daylight hours by two Marinelife observers located on the bridge.

6. Ferrybox Continuous CTD/Thermo-salinograph. Continuously collect oceanographic data at 4 m depth during steaming, including chlorophyll concentration (from calibrated fluorescence).

7. To collect water samples at 25 stations in the Bristol Channel and Cardigan Bay area to carry out an eDNA study on distribution and, where possible relative abundance of bluefin tuna (*Thunnus thynnus*) as well as biodiversity monitoring in Welsh waters.

8. To collect between 25-50 specimens per species (anchovy, boarfish, herring, horse mackerel, mackerel, sardine) and freeze for further analysis in the lab supporting a study on microplastics in fish stomachs (A. Bakir).

9. To collect a zooplankton sample using the 200 µm mesh ring-net at the West Gabbard2 SmartBuoy, for the Lifeform project (Defra) as part of the UK monitoring network of zooplankton.

10. To collect between 15-20 (similar sized) specimens per species (anchovy, boarfish, herring, horse mackerel, mackerel, sardine) and freeze (Stephen Smith, NMBAQC)

11. To collect 20 specimens each of anchovy and sardine at five different locations for a genetic study on both species (Naiara Rodriguez-Espeleta, AZTI, Spain)

12. To collect up to 24 specimens each of *Illex coindetii* and *Loligo forbesii* (V. Laptikhovsky)

13. Record macro-litter observations in the trawl (B. Silburn).

14. Collect ~25 sprat specimens from stations across the survey area for a genetic study on the stock structure of this species in the Celtic Sea ecoregion

15. Collect hourly samples of dissolved inorganic nutrients from the FerryBox flowthrough in the English Channel, for water quality assessment (winter nutrient concentratiom (N Greenwood)

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NARRATIVE[1]:

On the evening of the 1st of October, two (remote) staff joined the vessel, Cefas staff Allen (Spike) Searle, and MARINElife observer Pete Howlett who conducted COVID PCR tests upon arrival and proceeded to isolate in their cabins. The remaining Cefas staff and second MARINElife observer arrived at the quay from 15:00 on the 2nd of October, conducted a COVID PCR test after which they also joined the vessel one at the time, for cabin isolation. Negative test results for the two early arrivals and four of the remaining staff were received by 13:00 on the 3rd of October, with eight further test results still pending. The remaining eight test results were still not received by the rescheduled pilot slot the morning of the 4th of October (which had already been moved from 6:30 to 11:30 AM) and in the afternoon it was decided to conduct a second PCR test for the individuals, in case the first batch of tests was lost. Second test results were returned around 9:00 on the 5th of October, one of which was positive. After the positively tested staff member disembarked, the pilot joined and the RV sailed from Lowestoft at 11:30, with 30 hours delay, towards Portland, central English Channel. Safety inductions for scientists were completed *en route* and gear was unpacked and prepared followed by a muster drill.

Upon arrival in Weymouth Bay at 14:00 on the 6th of October, fresh winds meant that the planned echosounder calibration was postponed until the next day and, instead, the first acoustic transect was run (Tr43). Overnight the first plankton and rosette stations were successfully completed following relevant toolbox talks. On the morning of 7th of October, the echosounder calibrations were successfully completed at 13:15: three frequencies (38, 120 and 200 kHz) were calibrated at two pulse durations. The rest of the daylight was used to complete the two first mid-water trawls.

From the morning of the 8th of October, normal survey activities commenced, steaming along transects during the day, simultaneously recording fisheries acoustics and observing bird, mammal and tuna numbers and deploying the trawl to groundtruth acoustic data and collect biological data; at night plankton samples and CTD profiles (with either the rosette or ESM2) were collected at the prime stations. Exceptional weather conditions (winds <~10 knots) ensured very good progress for the next 10 days as the survey gradually proceeded west. From the 18th of October wind picked up although work could proceed. On the evening tide of the 20th of October, the RV docked in Fowey, 12 hours before planned due to storm coming through overnight, with the aim to drop a staff member off the following morning (7:45). Two other staff joined on the evening of the 20th following self-isolation and negative PCR tests. At 8:00 on the 21st of October the plot was picked up and the RV left Fowey and at 9:00 the survey resumed with Transect 30 and 29, which were shortened slightly to fit in the day. At the end of the 23rd of October, the whole of the western English Channel, including the transects south of the Isles of Scilly were completed.

A small weather window provided the opportunity to survey Cardigan Bay. In transit from the Isle of Scilly to Cardigan Bay, the first eDNA samples was collected (NW of Transect 11). Routine survey work commended in Cardigan Bay at first light on the 24th of October. Where possible, acoustic transects in the bay were extended inshore (until a depth of 17m was reached or 1 nmi from shore) to improve coverage of shallow water habitat. All seven transects were completed by last light on the 26th of October; Reasonable night conditions enabled completion of all 10 plankton and CTD stations with further eDNA samples at each of the stations being collected, over two nights (24 and 25th of October). In total the target number of 5 trawls were conducted providing useful groundtruth and biological data at the areas of highest fish densities.

After successful completion of Cardigan Bay, from the 27th of October, work commenced in the Bristol Channel. Starting at the inner transects, reasonable shelter was found from strong southerlies allowing work to continue. The RV progressively worked westwards, until on the 30th of October, after completion of the offshore halves of transects 13 and 14 during a good weather day,

[1] All times up to 30th of October in BST and in GMT for the rest of the survey

and two plankton stations (81 and 54), at 21:00 BST the vessel started the steam towards Bideford Bay to seek shelter from SW force 9 turning Westerly storm force 10 forecasted for the 31st of October. On the morning of the 1st of November at 5:30 the anchor was lifted and the RV started to make its way to the inshore start of transect 13, to resume surveying. Despite variable weather of the following few days, the RV completed the remaining transects and by 13:15 on Friday the 5th of November, she commenced the steam back to Lowestoft. The Gabbard plankton station was completed at the early hours of the 7th of November before picking up the pilot off Lowestoft at 9:00 AM and docking at 10:00.

RESULTS:

All aims were successfully completed, with the exception of the mackerel acoustic data due to noise on the 200 kHz. A summary of the echosounder calibration settings are provided in Table 1. Biological data (size, weight, age and maturity) on the following data-limited species were collected (objective 2): 11 European seabass (*Dicentrarchus labrax*); 8 black seabream (*Spondyliosoma cantharus*); 15 garfish (*Belone belone*); 29 John Dory (*Zeus faber*). eDNA samples (objective 7) were collected at 29 stations in Welsh waters. In total 18 samples of 25 whole specimens of small pelagic fish (6 species) were collected from 15 different stations for micro-litter analysis (objective 8, Annex 1). At four stations 15-20 (similar sized) specimens per species were collected for anchovy, boarfish, herring, horse mackerel, mackerel, sardine (objective 10, Annex 1). Genetic samples for sardine and anchovy were collected at five stations (objective 11, Annex 1). More details on the other aims are provided in the relevant sections below.

Table 1. Summary of echosounder (EK60 transceivers; EK80 operating software) calibration settings obtained on the 7th of October, in Weymouth Bay, and applied during PELTIC 2021. The 333 kHz was not calibrated and settings used are from the previous on-axis calibration performed in 2019.

Variable	38 kHz	120 kHz	200 kHz	333 kHz
Transducer type	ES38B	ES120-7C	ES200-7C	ES333-7C
Transducer depth (m)	5.3 (8.3)*	5.3 (8.3)*	5.3 (8.3)*	5.3 (8.3)*
Transducer power (W)	2000	250	120	50
Pulse length (milliseconds)	0.512	0.512	0.512	1.024
2-way beam angle (dB)	-20.7	-20.7	-20.7	-20.7
Transducer gain (dB)	22.67	26.45	25.82	27.58
Sa correction (dB)	-0.918	-0.397	-0.3415	-0.64
3dB beam along (°)	6.84	6.38	6.46	7
3dB beam athwart (°)	6.81	6.39	6.60	0
Along offset (°)	0.13	-0.03	0.00	7
Athwart offset (°)	0.06	-0.01	-0.25	0
RMS (Root Mean Square error)	0.068	0.097	0.11	-

*Drop-keel down

Pelagic Ichthyofauna

In total all 48 acoustic transects were completed covering a total of 2181 nmi of acoustic sampling units. Survey time was lost due to a COVID related delay in sailing (30 hours) and weather downtime (~30 hours). However, good coverage was achieved nonetheless and the relevant stocks were still captured in their entirety. A total of 41 trawl hauls were made (Fig 2) to provide groundtruth information about the species and size composition and to collect biological information.

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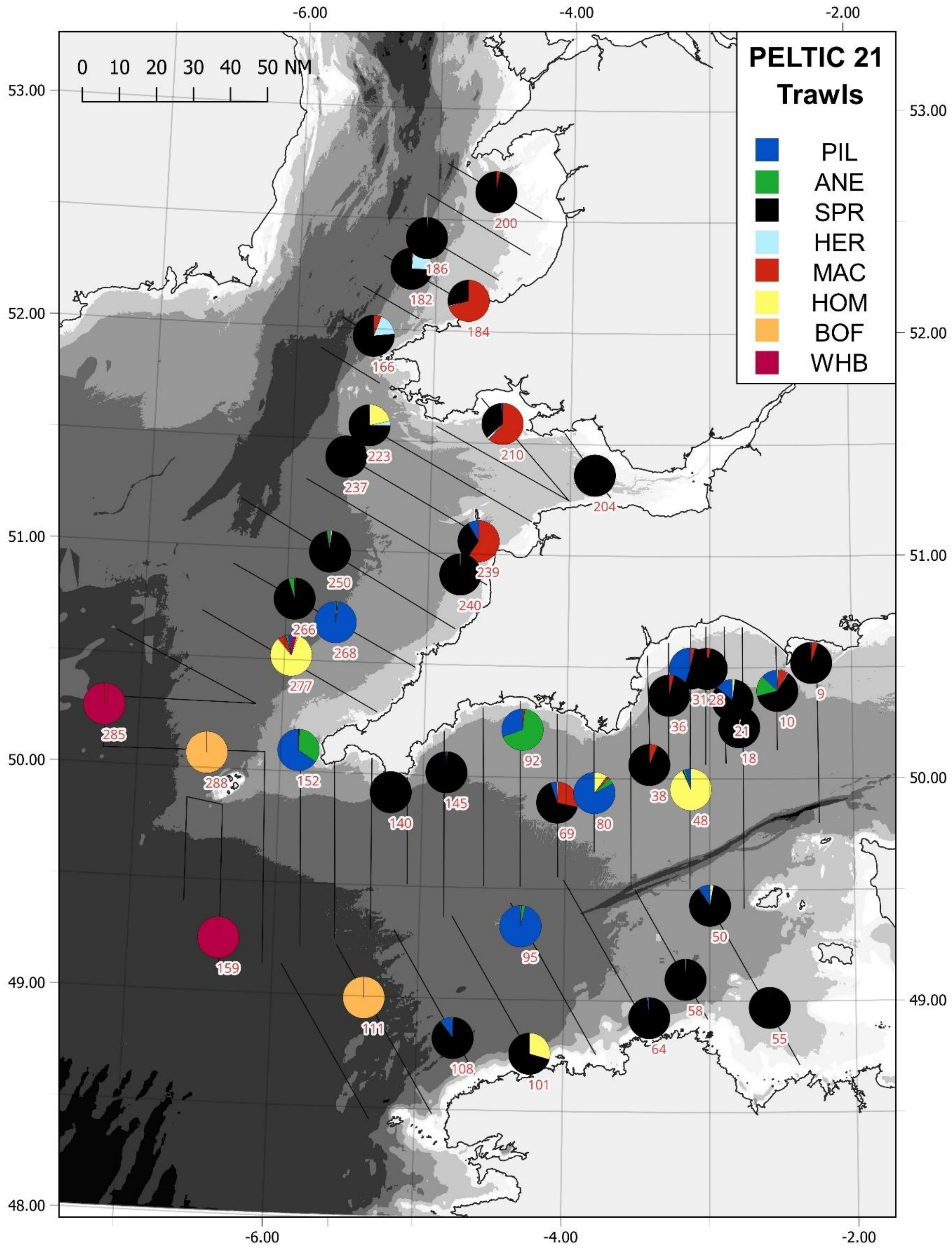

Figure 2. Overview map of the PELTIC21 survey area. Acoustic transects (black lines) and Trawl stations (pies) with relative catch composition by key species. Three letter codes: PIL=sardine, ANE=anchovy, SPR=sprat, HER=herring, MAC=mackerel , HOM= horse mackerel, BOF=Boarfish, WHB=Blue whiting

Like in 2020, many of the trawls in the English Channel were conducted at last light in areas where backscatter was highest, which, due to reduced effect of avoidance, provided a more unbiased insight into the species composition of the most important areas for pelagic fish. General patterns of fish distribution were similar to those observed for the time series although some species-specific differences were observed. Survey coverage included, for the fifth year running, the French waters of the western English Channel. For the second time PELTIC surveyed the coastal waters of Cardigan Bay (Wales). A summary of the number of individuals sampled for length and biological parameters is provided for key species (Table 2).

Table 2. Summary of lengths measured and biological parameters (including weight, age, maturity) collected for small pelagic fish species.

Species	Scientific name	Measured	Biological samples
Sprat	*Sprattus sprattus*	6661	874
Sardine	*Sardina pilchardus*	4306	752
European anchovy	*Engraulis encrasicolus*	1804	494
Horse mackerel	*Trachurus trachurus*	1826	272
European mackerel	*Scomber scombrus*	2169	322
Boar fish	*Capros aper*	405	75
Herring	*Clupea harengus*	956	260
Blue Whiting	*Micromesistius poutassou*	429	46

Sprat (*Sprattus sprattus*) was more widespread and abundant (Fig. 3) than previously observed, driven by a strong recruitment pulse (0-group, Fig 4). Highest densities were found in the usual two areas of Lyme Bay and the Bristol Channel and it was the most abundant small pelagic fish in Cardigan Bay (Fig 5). Sprat biomass in the western English Channel, the core area that is used in the assessment, increased more than 3-fold to 107,355 t (CV 0.26) which is the highest in the time series (Fig. 3). Compared to recent years, the highest sprat densities in Lyme Bay were further offshore (Fig 5) and there was a notable increase of sprat in French waters of the western English Channel. Lyme Bay was the first area surveyed following requests by the industry. Weather conditions during surveying the area were exceptionally calm.

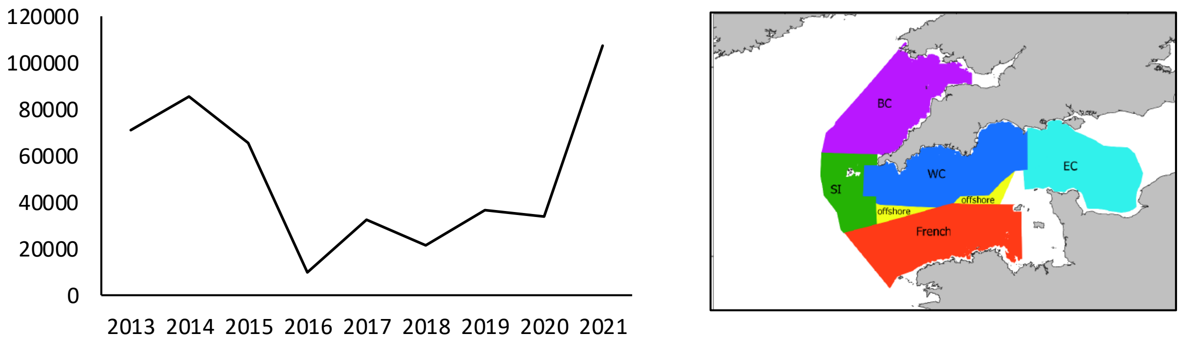

Figure 3. Sprat (*Sprattus sprattus*) biomass trend (left) for the consistently sampled stratum in the western English Channel: WC (blue) in map of strata (right).

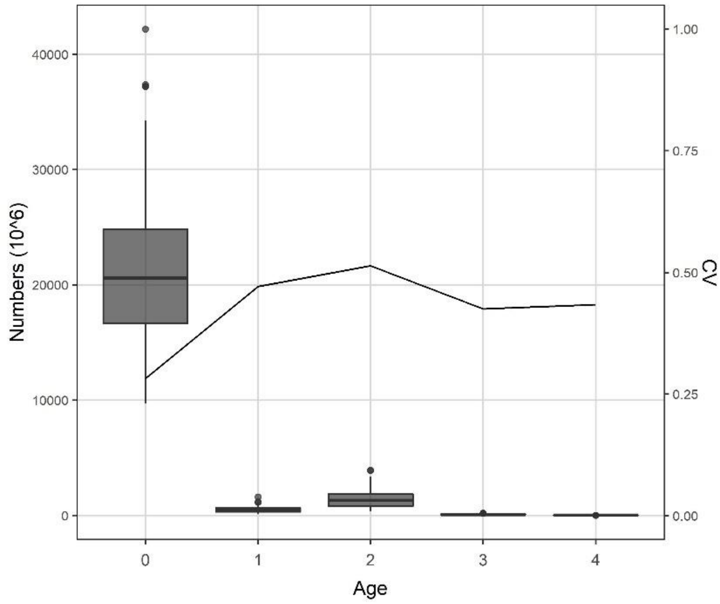

Figure 4. Sprat numbers at age (boxplots, primary y-axis) and CV (line, secondary y-axis) in the consistently sampled western Channel stratum (see Fig 3).

Sprat was more widespread in the northern part of the survey specifically in the inner waters of the Bristol Channel. This year sprat was found further west in the Bristol Channel and more inshore along the north Cornish Coast. Due to dominance of 0-group sprat no discernible difference in size was observed between the different areas although small numbers of bigger specimens were found in Lyme Bay (>10 cm, Fig 5).

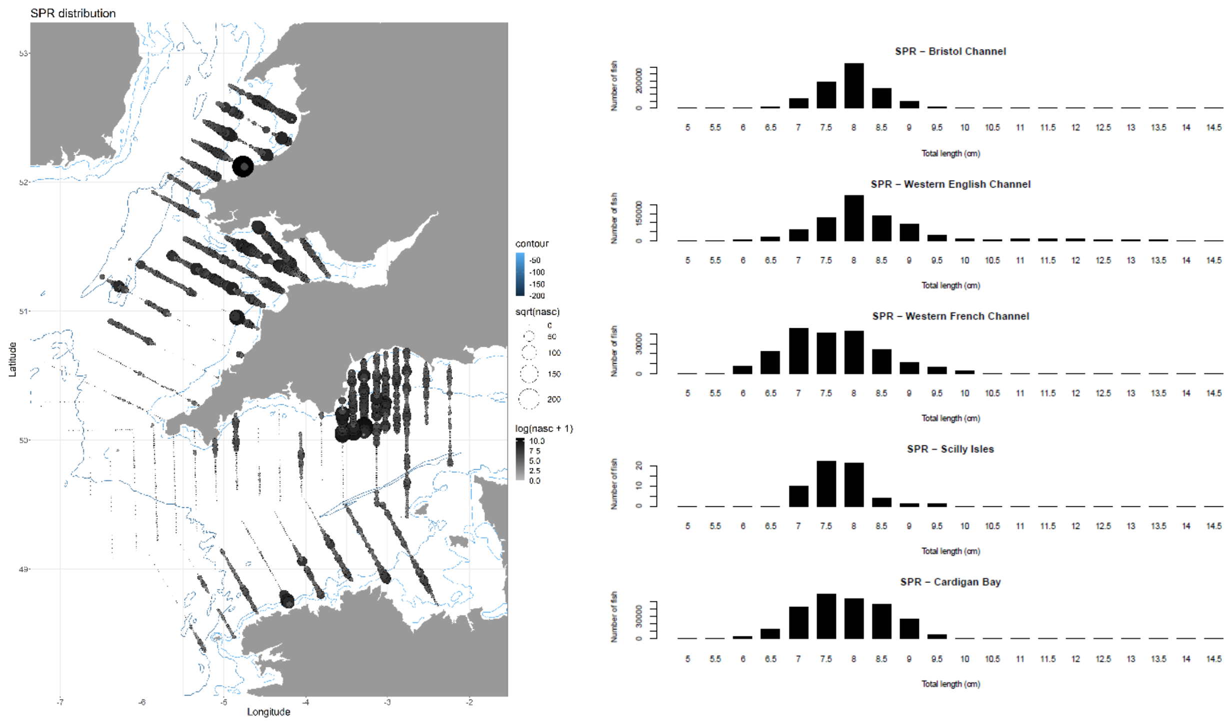

Figure 5. Relative acoustic sprat density distribution (Nautical Area Backscattering Coefficent - NASC, left) and trawl-based length frequency histogram for sprat in the subareas of the PELTIC survey (right).

Sprat was again the most dominant small pelagic species in Cardigan Bay, and, in contrast to 2020 when it was limited to very shallow inshore areas, was found to widespread throughout the Bay. Total biomass of sprat in Cardigan Bay was 102,762 tonnes (CV 0.25), a five-fold increase from 2020. The increase may be due to last year's inshore distribution, in water stoo shallow to survey. However, at least part of the increase is due to a strong recruitment given the dominance of 0-group size classes (Fig 5).

Sardine (*Sardina pilchardus*) was again the most abundant small pelagic fish species in the survey area with a total biomass (for the total area, consistently surveyed since 2017, Fig 6) of 227,117 t (CV 0.19), which was down from previous two years but still high.

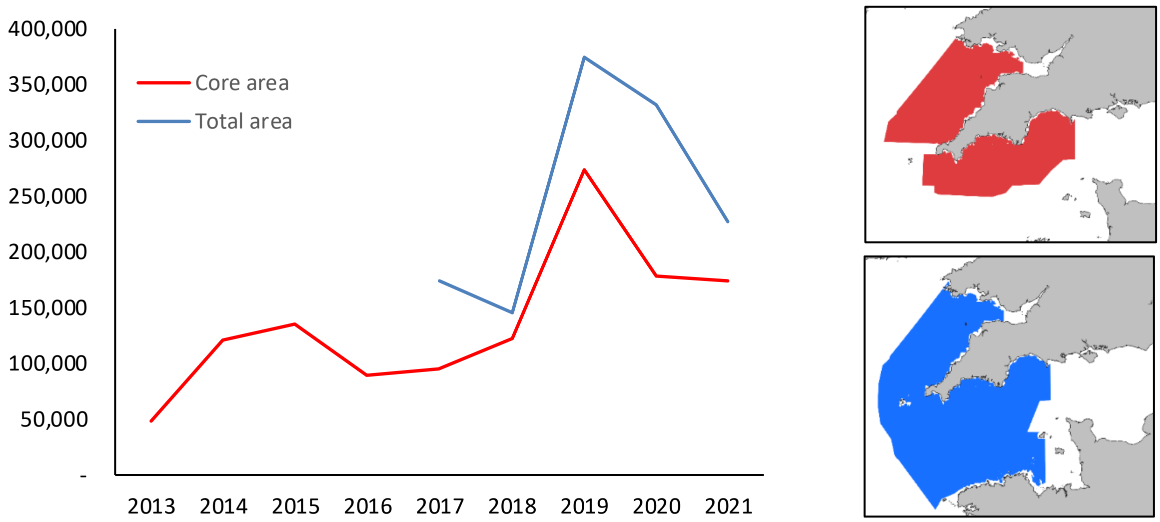

Figure 6. Sardine biomass (tonnes) trends (left) based on two available survey strata: the core area, consisting of the English waters of the western Channel and the Bristol Channel, surveyed consistently from 2013 (top right, red) and the total area, which also includes the Isles of Scilly and French waters of the western Channel, surveyed from 2017 (bottom right, blue).

Sardine was again widely distributed in the waters less than 100 m of the survey area, with highest densities from the Eddystone Bay to east of the Isles of Scilly (Fig 7). Sardine here comprised of fish from multiple cohorts, with the biggest fish further west. Good numbers of sardine were also found in western French waters, which included a broad range of sizes, including larger fish. (Fig 7). Sardine were again observed in the Bristol Channel comprising of both the largest and small size classes in the study area. Sardine was scarce in Cardigan Bay (305 t) and was dominated by fish with modal length of 14.5 cm.

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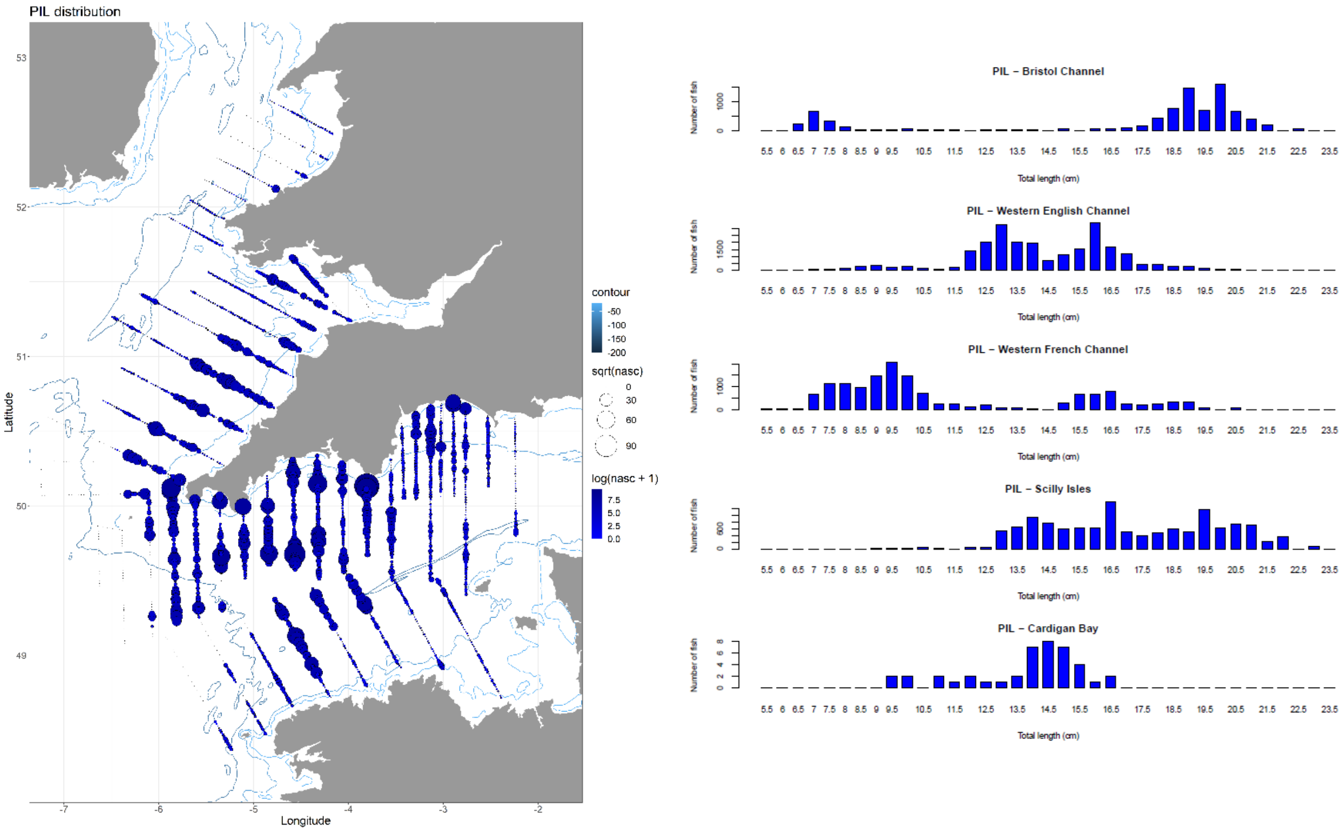

Figure 7. Relative acoustic sardine density distribution of sardine (Nautical Area Backscattering Coefficient - NASC, top left), and trawl-based length frequency histogram for sardine in the subareas of the PELTIC survey (top right).

Most sardine were between 0 and 2 years old with decreasing numbers at older ages (max 7 years old; Fig 8).

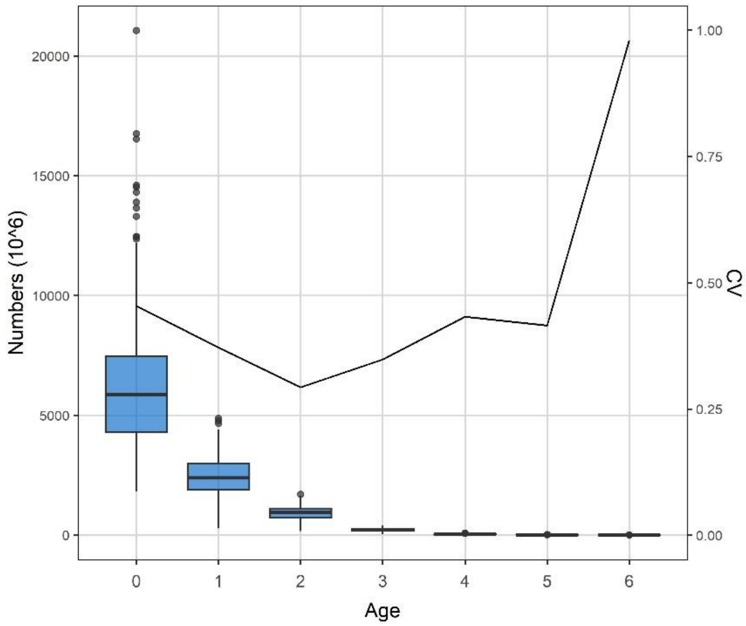

Figure 8. Sardine numbers at age (boxplots, primary y-axis) and CV (line, secondary y-axis) in the consistently sampled total area. Note that this graph excludes the 9,8 billion juvenile sardine recorded in French surface waters.

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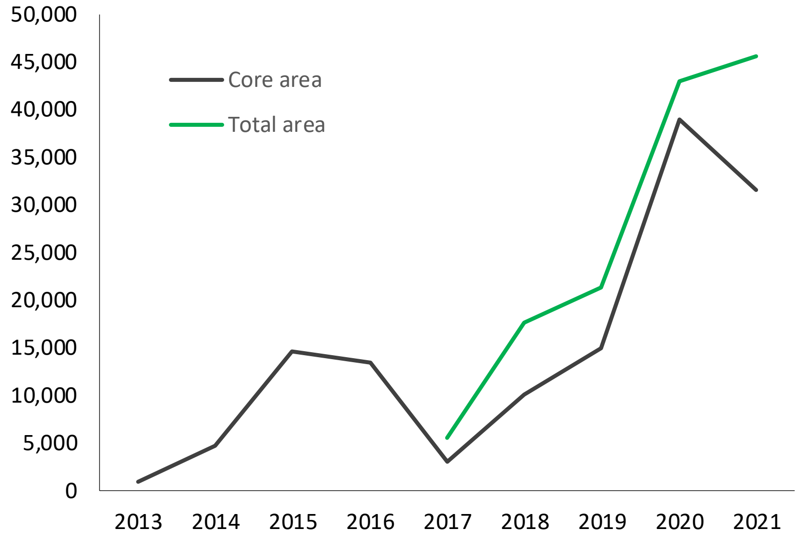
Northern **Anchovy (*Engraulis encrasicolus*)** biomass in PELTIC was the highest of the timeseries at 45,616 t (CV 0.23) for the total area (same consistently sampled strata as for sardine).



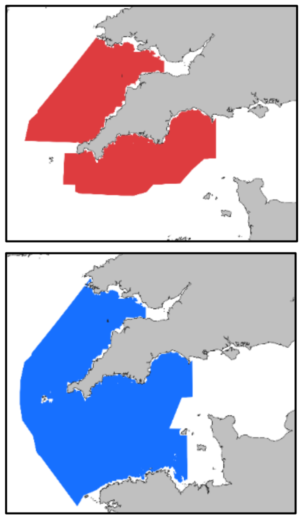


Figure 9. Anchovy biomass (tonnes) trends (left) based on two available survey strata: the core area, consisting of the English waters of the western Channel and the Bristol Channel, surveyed consistently from 2013 (top right, red) and the total area, which also includes the Isles of Scilly and French waters of the western Channel, surveyed from 2017 (bottom right, blue).

Anchovy was mainly distributed in the northwestern waters of the English Channel, off the Eddystone Bay between lands End and the Isles of Scilly (Fig 10). Fish in these areas comprised of the larger specimens (Fig 11). Smaller numbers consisting exclusively of smaller specimens (8 cm modal length) were found in deeper waters of the Celtic Sea and the inner Bristol Channel (Fig 10). Small numbers of anchovy were also found in Cardigan Bay (159 t), with a peak at 11.5 cm modal length (Fig 10). Post-larval surface anchovy schools, found previously (2019 and 2020) in French waters, were not observed this year.

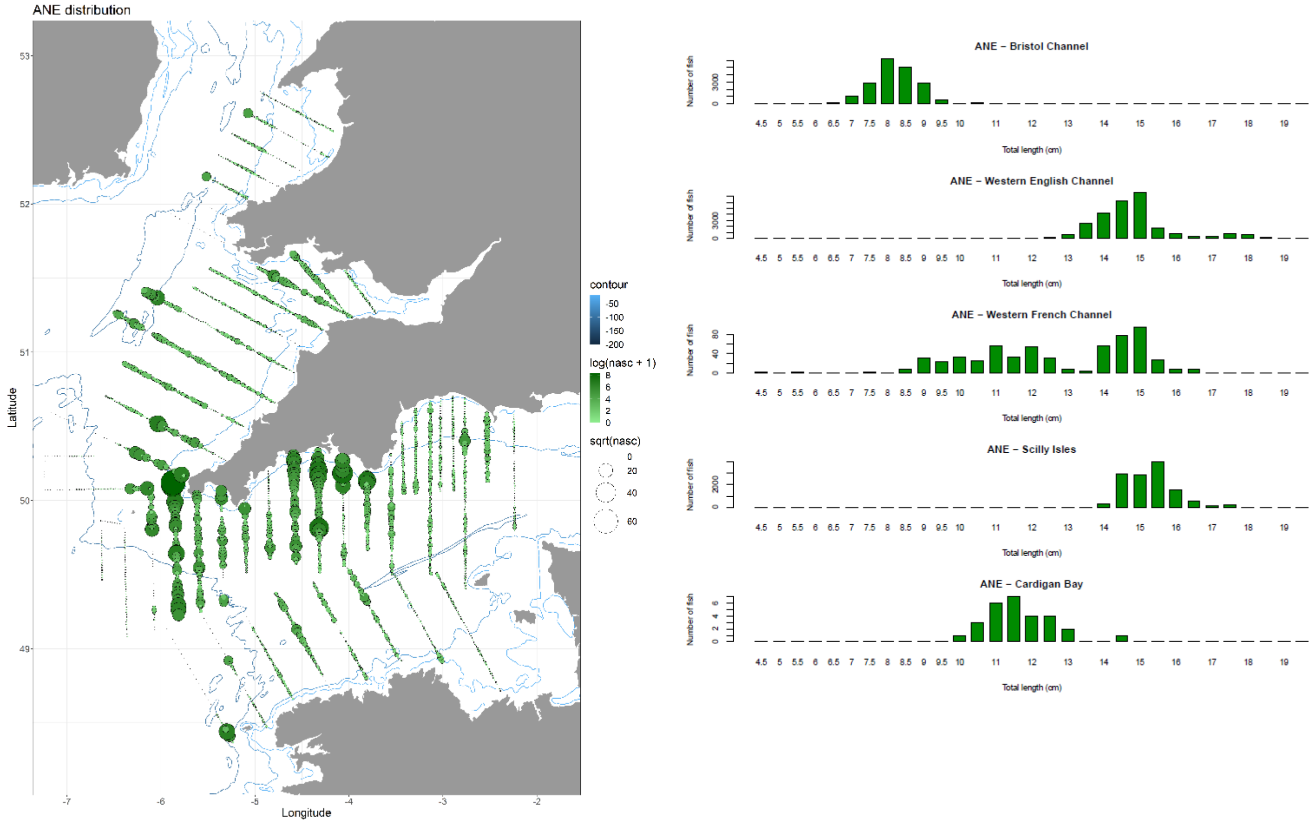


Figure 10. Relative acoustic anchovy density distribution for the northern population (NASC, top left), and trawl-based length frequency histogram for anchovy in the subareas of the PELTIC survey (top right).

Anchovy is the shortest lived small pelagic species in the study area and the oldest fish found during this survey were 2 year old (Fig 11). The dominant age were the 1 year olds.

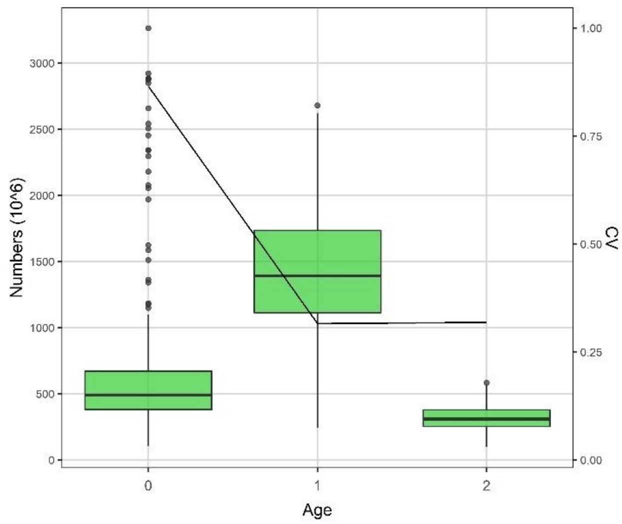


Figure 11. Anchovy numbers at age (boxplots, primary y-axis) and CV (line, secondary y-axis) in the consistently sampled total area. Note that this graph excludes the 13,5 billion post larval anchovy recorded in French surface waters.

Other pelagic fish species (no biomass estimates available at the time of reporting): **Horse mackerel (*Trachurus trachurus*)** was widespread, although typically in deeper waters of the survey area. As found in previous years, these were mainly made up of juvenile fish with modal length of 9 cm (age 0), with small numbers of larger fish (mode are 17 and 23 cm) also caught (Fig 12). **Herring (*Clupea harengus*)** numbers were higher than in previous two years and were found mainly in Lyme Bay, the inner Bristol Channel and Cardigan Bay, mixed in with sprat, all of which were juvenile with a mean modal length of 11 cm (Fig 12). **Mackerel (*Scomber scumbrus*)** was widespread in the area. No biomass estimate could be calculated due to a continuation of the noise issue with the 200 kHz which is the reference frequency used to calculate the biomass. Length frequency of mackerel suggested two cohorts (at 19 and 28 cm modal length, Fig 12). **Boarfish (*Capros aper*)** were, as per usual, found in the deeper waters of the western Channel, particularly off the Isles of Scilly although also further south this year. This area appears to be at the eastern-most range of this species which is typically associated with deeper waters of the Northeastern Atlantic Ocean. This year, a larger range of sizes was found (Fig 12), from juveniles (modal length of 2 cm) to the larger specimens but with intermediate sizes as well. For the first time since 2012 **blue whiting *(Micromesistius poutassou)*** was caught in significant numbers at two stations in similar areas to boarfish. The modal length of 17 cm suggests that these are predominantly juveniles. For the third year in the survey series (also in 2018 and 2020) **Atlantic bonito (*Sarda sarda*)** was observed. One specimen was caught in Lyme Bay.

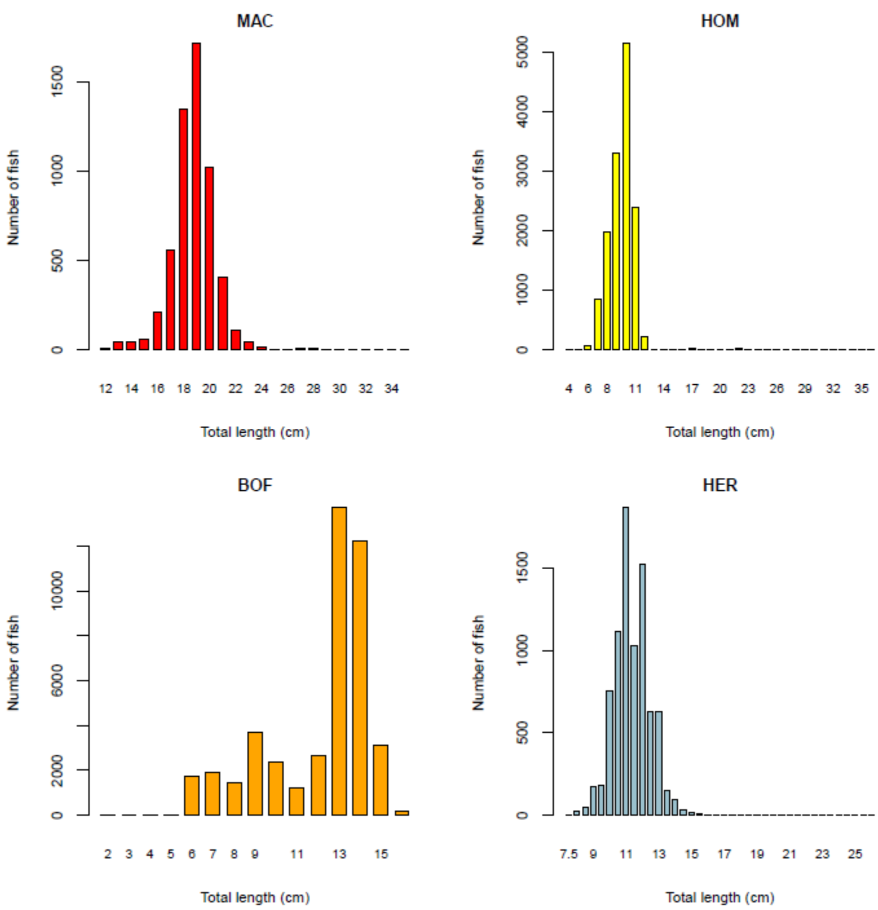


Figure 12. Length frequency histograms for mackerel (MAC), horse mackerel (HOM), boarfish (BOF) and herring (HER), derived from the PELTIC21 trawl catches. Note that these have not been raised by acoustic densities.

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Plankton and Oceanography

Mesozoo- and ichthyoplankton samples were collected at 95 stations with ring nets with mesh size of 80 µm and 270 µm, respectively (Table 3). One stations could not be completed (primary station 65), and another station (prime 15) was sampled twice. Mesozooplankton samples were stored on 4% buffered formaldehyde for zooscan processing post-survey. All results will be stored on the ZooTaxa database. Ichthyoplankton was processed aboard with all eggs and larvae staged and measured respectively. Sardine eggs and larvae dominated the ichthyofauna and numbers were among the highest in the time series, although not quite reaching the 2020 numbers. The location of highest densities of sardine eggs corresponded well with the distribution of the main acoustic sardine backscatter suggesting main spawning grounds in the Eddystone Bay and west off Lands End (Fig 13). Eggs were also found north of the Cornish Peninsula corresponding spatially with the presence of sardine schools in this area (Fig. 13). A small number of eggs were also found at one isolated station in Cardigan Bay (same stations as in 2020). As expected, sardine larvae were more widespread in the survey area although they were absent from the offshore stations. Finally, zooplankton samples were also collected at the West Gabbard smartbuoy location during the return transit back to Lowestoft (objective 9).

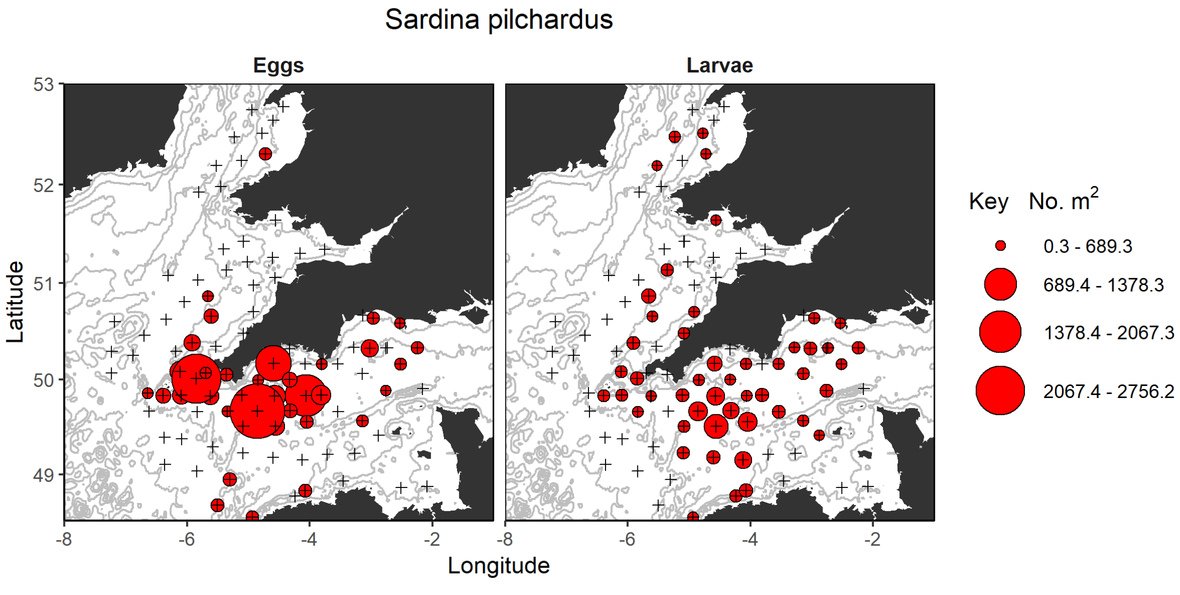

Figure 13 . Distribution of sardine eggs (left) and larvae (right) at the sampling stations derived from samples collected with the 270 µm ring net and analysed on board.

Oceanography

Vertical profiles of temperature and salinity of the water column were carried out at 95 plankton stations using a SAIV mini CTD, although no profiles are available at stations prime 61 and 97 due to failure of the mini CTD in recording environmental data. Furthermore, mini CTD profiles were carried out twice at each of prime stations 15, 32 and 63 (hence bringing the total of profiles carried out to 96; Table 3). At a subset of 36 of the sampling stations, additional data were collected (Table 3): a Rosette with SeaBird CTD and 10 Niskin bottles was deployed at 20 stations to collect information using temperature, salinity, PAR

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(Photosynthetic Active Radiation), dissolved oxygen, turbidity and fluorescence sensors and collect water samples for future analysis of phytoplankton (microscope) and microzooplankton (Flowcam) communities, dissolved oxygen, salinity, phytoplankton pigments (including chlorophyll-a) and dissolved inorganic nutrients (nitrate, nitrite, ammonium, phosphate, silicate). At 16 stations adverse weather conditions and damage to the lifting bar of the Rosette prevented the use of the Rosette. Instead, an ESM2 logger was deployed, and surface and bottom water samples were collected from the flow-through of the FerryBox and a single Niskin respectively (Table 3).

Subsurface (4 m) conditions were continuously monitored by the FerryBox, which recorded temperature, salinity, fluorescence, turbidity, and oxygen (Figure 14). No flow cytometer or Plankton Analyser, connected to the FerryBox, were available this year due to uses with these instruments and associated softwares.

At the end of the survey, during the journey back to Lowestoft, dissolved inorganic nutrients were collected hourly from the FerryBox flowthrough between 8 am – 8 pm, in the English Channel, for water quality assessment (winter nutrient concentration; Objective 15).

Table 3. Number of samples collected and number of profiles carried out during PELTIC 21.

	Total
Salinity	39
Dissolved oxygen (triplicates)	22
Chlorophyll/Pigments analysis (HPLC - duplicates)	36
Inorganic nutrients (36 x 2 methods)	72
Phytoplankton	36
Microzooplankton	36
Mesozooplankton (80 µm)	96
Mesozooplankton (270 µm)	96
eDNA samples	29
CTD profiles with Rosette	20
CTD profiles with ESM2	16
CTD profiles with SAIV MiniCTD	96

Dissolved oxygen samples from water near the bottom were analysed on board by the Winkler method using an auto-titrator; while salinity and inorganic nutrient samples were stored for analyses in the Laboratory. Duplicate inorganic nutrient samples were collected at all stations, to allow comparison between two different sample preservation methods (freezing vs. mercuric chloride). Chlorophyll and pigments samples were stored at -80 °C for subsequent HPLC (High Performance Liquid Chromatography) analysis at DHI (Denmark). Phytoplankton samples were fixed with Lugol for processing in the Lowestoft Laboratories using an inverted microscope, while microzooplankton samples (also fixed with Lugol) will be analysed with the FlowCam by Plymouth Marine Laboratory. Samples for dissolved oxygen, salinity and chlorophyll-a were collected to calibrate sensors on the FerryBox and on the SeaBird profiler.

Sea surface temperature was highest in the English Channel (the most easterly part sampled) and in the offshore stations in the Celtic Sea (Figure 14). Maximum temperature recorded by the FerryBox at the subsurface was 17.6 °C, higher than temperature recorded in 2020 (16.46 °C) and in 2019 (17.2 °C). Lowest surface temperatures were recorded offshore between the Celtic Sea and French side of the Channel and north of the Isles of Scilly (Figure 14). The lowest surface temperature recorded this year was 13.3 °C, warmer than the lowest surface temperature recorded in 2020 (12.7 °C) and 2018 (12.8 °C). Western offshore stations in the Bristol Channel, the Western approaches, Lizard Point and Eddystone Bay, were seasonally thermally stratified (Delta_T > 0.5 °C; Figure 14). The difference between surface and bottom temperatures was highest at offshore stations in the Celtic Sea, up to 4.5 °C (Table 4). The strength of stratification observed this year was comparable to that of previous years (typically between 4 and 5 °C).

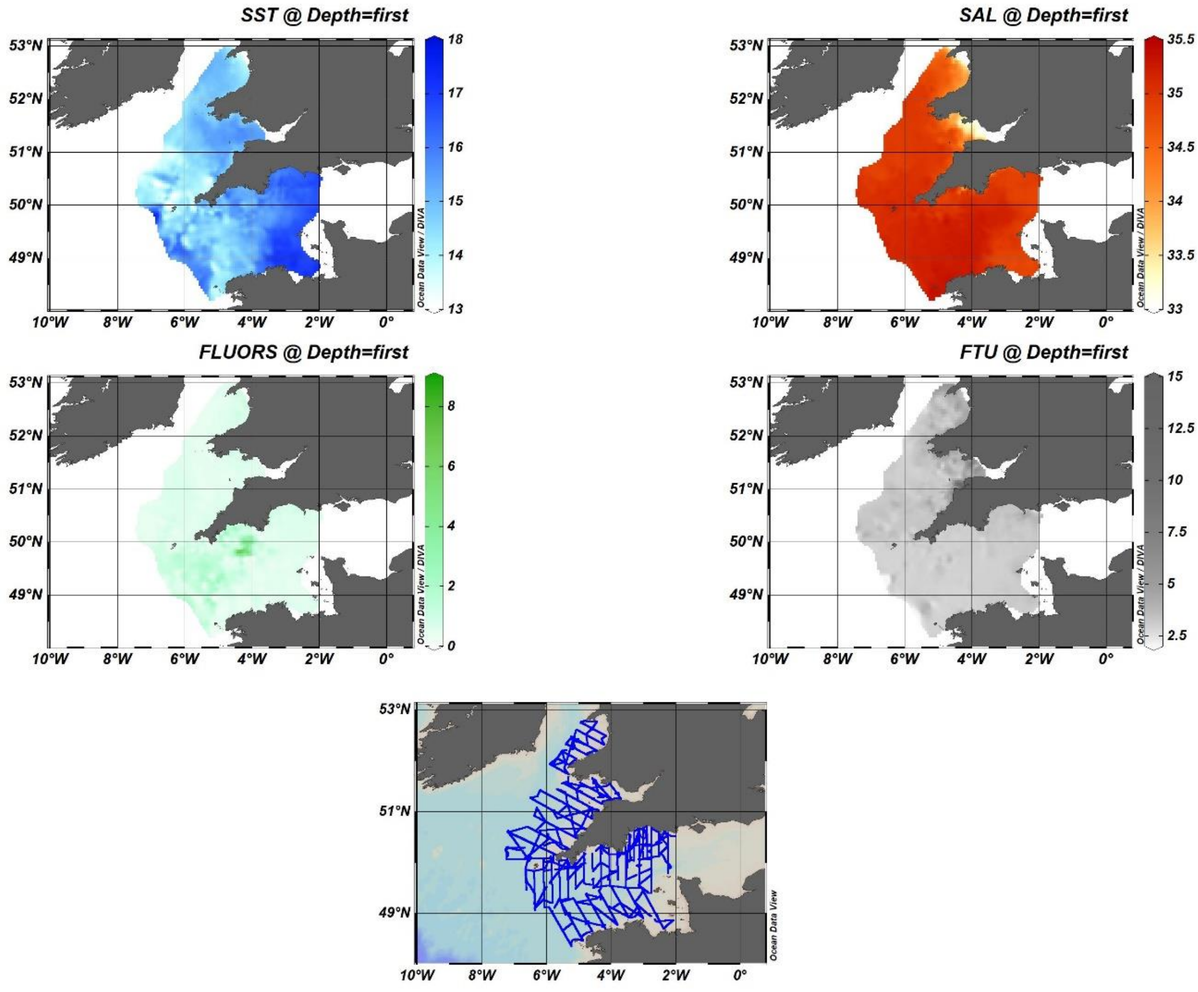

Figure 14. Sea surface temperature (SST), salinity (SAL), chlorophyll fluorescence (FLUORS), and turbidity (FTU) measurements (at 4 m depth) from the FerryBox underway system (track shown bottom), between 6/10 and 05/11/2021.

Offshore salinity showed little variation (Figure 14). Highest salinity (35.33) was recorded in the south-west corner of the Celtic Sea, and lowest (33.06) in the Bristol Channel and Cardigan Bay. Salinity stratification (Delta_S) was highest at the most westerly stations in the Celtic Sea, where the stratified water column presented a warmer and less salty, surface mixed layer separated by a thermocline from a saltier and cooler bottom mixed layer (Figure 15).

Table 4. Summary statistics (minimum, maximum, mean, standard deviation, and number of observations) of temperature measurements, recorded by the SAIV MiniCTD at the sampling stations.

	Temperature	Salinity	Fluorescence	Turbidity
Mean	13.33	33.06	0.31	2.86
Min	17.59	35.33	8.92	14.52
Max	15.19	34.94	0.74	3.49
Std Deviation	0.87	0.31	0.46	1.28
Number	41078	41078	41058	41098

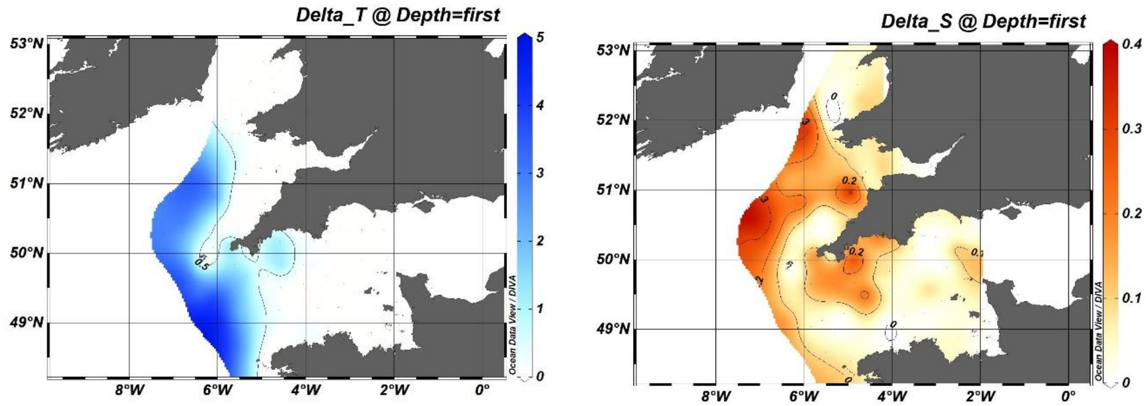

Figure 15. Delta_T (°C), difference in temperature between surface and bottom (left) and Delta_S, difference in salinity between surface and bottom (right) as recorded by the SAIV MiniCTD at the 96 sampling stations. The isotherm of Delta_T = 0.5 °C is highlighted to distinguish between mixed (Delta_T < 0.5 °C) and stratified waters (Delta_T > 0.5 °C).

Surface distribution of chlorophyll was estimated by fluorometer on the FerryBox. Fluorescence values (proxy for chlorophyll-a) were highest in the area south of Plymouth (Figure 14). This coincided with the easterly edge of the 0.5 °C isotherm, perhaps indicative of enhanced productivity in the frontal area between mixed and stratified waters. Images of surface chlorophyll distribution from satellite remote sensing (Figure 16) confirmed the presence of a bloom in the offshore area south of Plymouth, extending south along the Ushant Front. Although remote sensed images identified high chlorophyll concentration in the Bristol Channel, the fluorescence measurements from the FerryBox in this area were low. The inner Bristol Channel is an optically complex area with high levels of suspended sediments and coloured dissolved organic materials (CDOM) from the River Severn; therefore, it is possible that the algorithm used to estimate the chlorophyll map (OC4) is less suited for these optically complex areas. In fact, highest turbidity values were measured in the Bristol channel, causing some adaptations to be made to sample filtration, and zooplankton analysis (Figure 14).

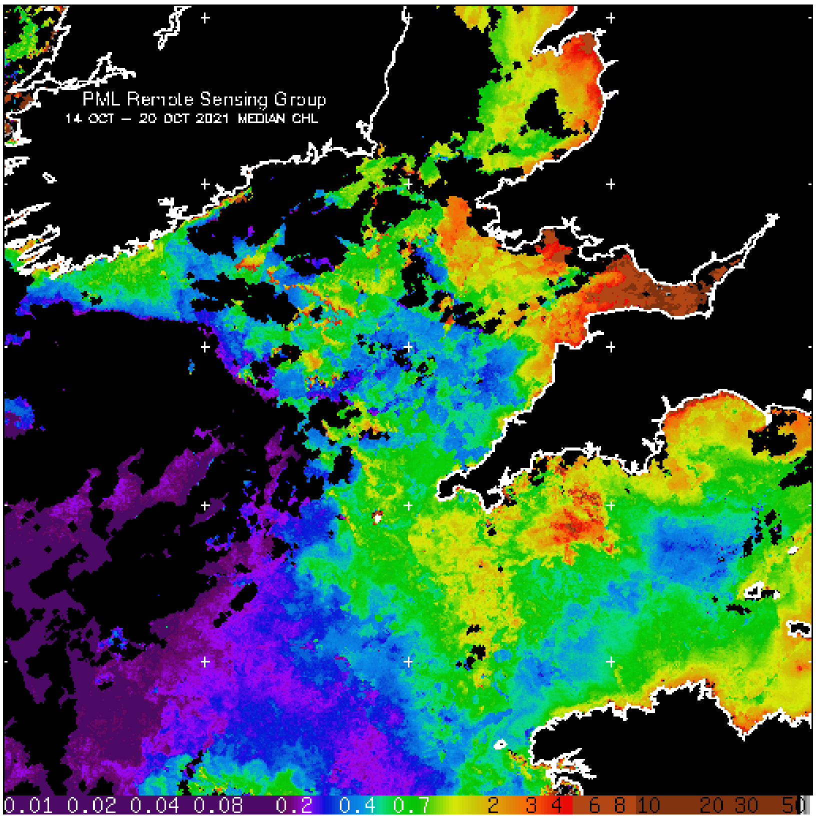

Figure 16 Surface chlorophyll distribution (OC4ME algorithm) between 14-20 October 2021, from https://data.neodaas.ac.uk/).

Observer data: apex predators

For the nineth year running, two volunteer MARINElife surveyors were stationed on the bridge in a central position, and employed an effort-based 300m box methodology for recording birds (an adapted version of ESAS methodology) with an additional 180° area scanned to survey each transect line. During transits between transects, the team recorded incidental observations when possible, logging significant species only. Furthermore, casual observations were recorded during the net-retrieval stage of trawls to identify species of birds associated with the fishing activity of the survey vessel but only where there was a significant gathering of birds. During survey transects, all species of birds (both seabirds and terrestrial migrants) were recorded, along with all sightings of marine mammals and pelagic fish such as tuna. The effort-based 300m box methodology employed was developed by the Cetacean Group of the Mammal Society for use from platforms of opportunity such as commercial ferries. The aim of this method is for the observer to record and identify as many seabirds and cetaceans as possible that pass through the 300m box and also record birds and marine mammals outside the box out to a distance of 1km. In 2021 both surveyors recorded cetaceans and seabirds.

Survey effort was made on 29 days from 6th October to 5th November, sampling approximately 4,039 km of transect line (the longest distance of any PELTIC surveys). The 2021 survey was very definitely a survey of two (almost equal) halves (Table 5). The period 6-17 October was characterised by light winds with a mean wind speed of force 2.2 and the sea state two or three for 73% of survey effort and only reaching five for just 4% of survey effort. The wind had an easterly component for 44%, westerly for 27%, due north or south for 20% and calm for 9% of survey effort. In stark contrast the period 18 October-5 November was characterised by strong westerly winds, with a mean wind speed of force 4.9 and with the wind between NW-SSW for 62% of survey effort and due north or south for the rest. Sea state was five or above for 70% of survey effort and a sea state two or less seen for just 3% of survey effort.

Table 5: Survey effort and sea state conditions from 2013-2021 by MARINElife team on the PELTIC Survey. *Only parts 1&2 of the 2017 survey during which both survey teams were present are included in this table.

	2013	2014	2015	2016	2017*	2018	2019	2020	2021
Transect length (km)	2092 (+278*)	3058	2447	2990	2644	3706	3025	3741	4039
No. survey days	16 (+2*)	20	18	16	24	32	26	30	29
Mean sea state	5.01	3.78	3.08	5.34	4.32	3.86	3.24	4.83	3.92
Modal sea state (% of total)	4	3	4	3	3	5	3	5	5
% Effort sea state 4 or less	37	67	92	45	53	63	81	39	56
Modal wind direction (% of effort)	SW (33)	SW (30)	NE (30)	ENE(24)	SW (40)	NE (28)	TBC	SW (15)	W (17)

*Southern North Sea

A total of 35 **bird** species were recorded on effort during the survey this year, slightly down on the 41 recorded in 2020. A total of 8,543 sightings of 24,107 birds were recorded throughout the survey (Table 6), exceeding the record set last year for the longer surveys undertaken since 2017. The additional transects in Cardigan Bay accounted for an additional 3,421 birds. Even if the Cardigan Bay transects are excluded from the total, the resulting 20,686 birds recorded is still higher than any 2017-2020 total. The Cardigan Bay transects accounted for about 14% of the total, comparable to the 12% last year.

As in all previous surveys, Gannet was the most commonly recorded species, although, once again, fewer were recorded than in 2017 & 2018. There seemed to be a lack of birds in the central English Channel, with no substantial numbers drawn to the vessel's trawling activity (despite the trawls being successful with decent amounts of fish) and few trawlers were encountered with large feeding flocks, unlike in previous years. This lack of trawler encounters may also be the reason Great Black-backed Gull and Great Skua numbers were low, although the latter has reportedly had successive poor breeding seasons.

The observed high abundance of small fish (0-group sprat, above) during the survey was a possible reason eight species – Balearic Shearwater, Black-headed-, Mediterranean- and Herring Gull, Kittiwake, Puffin, Guillemot, and Razorbill – were observed in record numbers. These species target prey fish in the 5-10cm range, which matches the size of year 0 Sprat. For the first time (since at least 2016) Razorbill numbers were close to those for Guillemot (normally half or less than Guillemot). The daily counts for Razorbill show good numbers on several days throughout the survey, with a peak day count of 337 on 24 October in Cardigan Bay, which suggests there were generally more birds present this year. Kittiwake

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are one of the easier birds to age during a survey and it was interesting to note that of the total of 1,690 birds observed, almost half (808) were juveniles, suggesting a decent breeding season in some parts of their range. The 229 Wigeon were all observed towards the north end of a transect in the western edge of Lyme Bay and they were likely there due to disturbance on the saltmarshes around Dawlish Warren and the Exe estuary.

Table 6: List of all bird species recorded on effort during Peltic survey 2021

Species	Scientific Name	No of sightings	No of birds
Dark-bellied Brent Goose	*Branta bernicla*	1	7
Wigeon	*Anas penelope*	4	229
Common Scoter	*Melanitta nigra*	9	36
Great Northern Diver	*Gavia immer*	3	5
Fulmar	*Fulmarus glacialis*	90	243
Manx Shearwater	*Puffinus puffinus*	42	54
Balearic Shearwater	*Puffinus mauretanicus*	73	346
Sooty Shearwater	*Puffinus griseus*	27	30
Shearwater sp.	*Puffinus sp.*	6	6
European Storm Petrel	*Hydrobates pelagicus*	50	159
Petrel sp.		4	6
Gannet	*Morus bassanus*	2990	7697
Cormorant	*Phalacrocorax carbo*	2	3
Shag	*Phalacrocorax aristotelis*	10	11
Little Egret	*Egretta garzetta*	1	1
Common Snipe	*Gallinago gallinago*	1	1
Great Skua	*Stercorarius skua*	122	135
Pomarine Skua	*Stercorarius pomarinus*	1	1
Arctic Skua	*Stercorarius parasiticus*	13	13
Skua sp.	*Stercorarius sp.*	4	4
Black-headed Gull	*Chroicocephalus ridibundus*	19	92
Common Gull	*Larus canus*	37	44
Mediterranean Gull	*Larus melanocephalus*	85	252
Herring Gull	*Larus argentatus*	169	512
Lesser Black-backed Gull	*Larus fuscus*	103	244
Yellow-legged Gull	*Larus michahelis*	1	1
Great Black-backed Gull	*Larus marinus*	193	380
Larus sp.	*Larus sp.*	68	601
Kittiwake	*Rissa tridactyla*	1195	4472
Little Gull	*Hydrocoloeus minutus*	8	31
Puffin	*Fratercula arctica*	262	512
Guillemot	*Uria aalge*	1437	2885
Razorbill	*Alca torda*	633	2101
Auk sp.		844	2858
Barn Swallow	*Hirundo rustica*	2	3
Meadow Pipit	*Anthus pratensis*	23	113
Pied Wagtail	*Motacilla alba yarrellii*	8	11
Starling	*Sturnus vulgaris*	1	5
Robin	*Erithacus rubecula*	1	1
Song Thrush	*Turdus philomelos*	1	2
Total		**8543**	**24107**

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Table 7: List of bird species recorded off-effort either at sea or onboard CEFAS Endeavour

Species	Scientific name	No of birds
Balearic Shearwater	*Puffinus mauretanicus*	45
Yellow-legged Gull	*Larus michahellis*	2
Chiffchaff	*Phylloscopus collybita*	8
Dusky Warbler	*Phylloscopus fuscatus*	1
Blackcap	*Sylvia atricapilla*	4
Song Thrush	*Turdus philomelos*	4
Robin	*Erithacus rubecula*	6
Grey Wagtail	*Motacilla cinerea*	3
Chaffinch	*Fringilla coelebs*	2
Snow Bunting	*Plectrophenax nivalis*	2

As Europe's only critically endangered seabird, **Balearic Shearwater** has been a target species of the PELTIC survey and additional data were recorded, including, where possible, 30 minutes effort after any off-transect sightings. This year a total of 387 birds were recorded, the highest total for the species in any of the Peltic surveys by some margin.. In total 346 specimens were recorded on transects (Table 6) and a further 41 while off-transect (in transit, during trawling, Table 7). In contrast to the early years of PELTIC no aggregations to the south-west of Lundy in the Bristol Channel were seen (Fig 16). This year nearly all the large numbers of birds were seen either shortly after dawn or near sunset and close to the French coast, the exception being the area to the southwest of Guernsey, an area known to be home to large numbers of Balearic Shearwater through July and August.

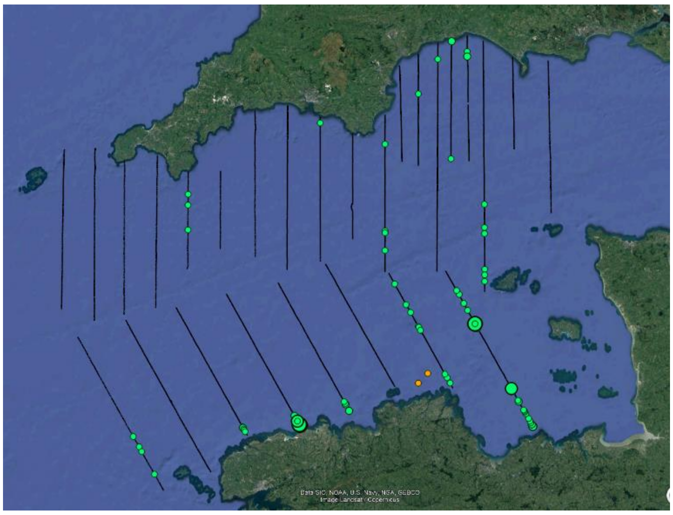

Figure 16: Distribution of all Balearic Shearwater sightings in 2021, scaled to abundance. Abundance categories (small to large circles): 1-5, 6-10, 11-20, 20+. Green dots were birds recorded on transect, orange dots off transect, black lines mark survey effort.

Cetaceans

A total of 293 cetacean encounters were made, totalling approximately 4,081 animals of eight species (Table 8). The total number of animals recorded is more than double that recorded in 2020 and is the best year for cetaceans so far. However, Harbour Porpoise observations totalled 32, which is low given the good surveying conditions while in their main habitat of the English Channel and particularly Lyme Bay.

Table 8. Cetacean species recorded by MARINElife surveyors on effort during Peltic survey 2021

Species	Scientific Name	No. sightings	No. animals
Fin Whale	*Balaenoptera physalus*	2	2
Fin Whale (probable)	*Balaenoptera physalus*	1	1
Minke Whale	*Balaenoptera acutorostrata*	3	3
Long-finned Pilot Whale	*Globicephala melas*	1	8
Risso's Dolphin	*Grampus griseus*	4	33
Common Bottlenose Dolphin	*Tursiops truncatus*	4	21
Common Dolphin	*Delphinus delphis*	246	3899
White-beaked Dolphin	*Lagenorhynchus albirostris*	1	3
Harbour Porpoise	*Phocoena phocoena*	17	32
Dolphin sp.		14	79
	Total:	293	4081

Common Dolphin was again by far the most frequently recorded species, with 246 sightings of 3,899 animals, the best year yet for the species on the PELTIC surveys (Table 8). The species is widely distributed throughout the survey area (Fig 16) with notable hotspots in Lyme Bay, mid-English Channel, around the Isles of Scilly and the Celtic Deep. Day totals exceeded 100 on 14 days with a maximum of 401 (30th October) and another four days with over 300 seen. The maximum count for a single pod was an estimated 300, followed by 200 and a further four in excess of 100.

A total of 10 Fin Whales were recorded plus a further five large rorquals – most likely Fin as well – of which only two (plus one probable) were seen on effort (Fig 16). In contrast to previous years, only one sighting was recorded near the Celtic Deep – the traditional area for fin whale sightings. Of note were three animals in the English Channel, especially the one about 30km south of Start Point, which may well be the animal seen feeding in Falmouth Bay a few days earlier.

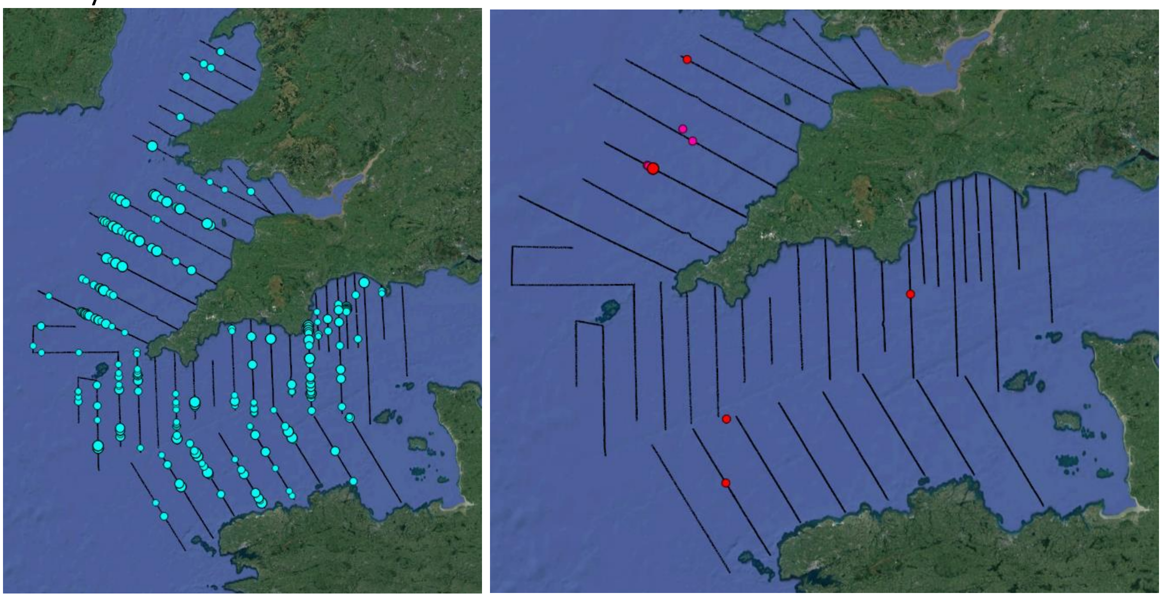

Figure 17: Distribution of Common Dolphin sightings (left, light blue circles), scaled to abundance. (small to large circles: 1-5, 6-10, 11-20, 20+) and Fin Whale/probable Fin Whale sightings (right) in 2021 (confirmed Fin red dot, probable pink dot), black lines mark survey effort.

Despite some calm conditions, Harbour Porpoise numbers were low with only 32 recorded, all bar one of which were in Lyme Bay (Fig 18). None were seen in typical habitats, such as Falmouth Bay, Mounts Bay and around the Isles of Scilly. Given that good numbers were recorded in Lyme Bay in the summer (Tom Brereton pers. comm.), it is possible that there was an autumnal distribution shift westwards where sea state was unfavourable for detection of Harbour Porpoise. A group of eight Long-finned Pilot Whale was observed just south of Eddystone light. It is a scarce species for the PELTIC surveys and has been recorded only a handful of times. One of the bulls had a hooked dorsal fin, similar to a Short-finned Pilot Whale, though it is extremely unlikely it was this species. A solitary group of three (probable) White-beaked Dolphin were once again seen in Lyme Bay. One appeared smaller so they may well have been the group, which included a calf, present in the Berryhead area for a week or two prior to the survey. Four groups of Risso's Dolphin, totalling 33 animals, and four small groups of Bottlenose Dolphin were recorded on widely scattered transects (Fig 18). Only three Minke Whales were recorded.

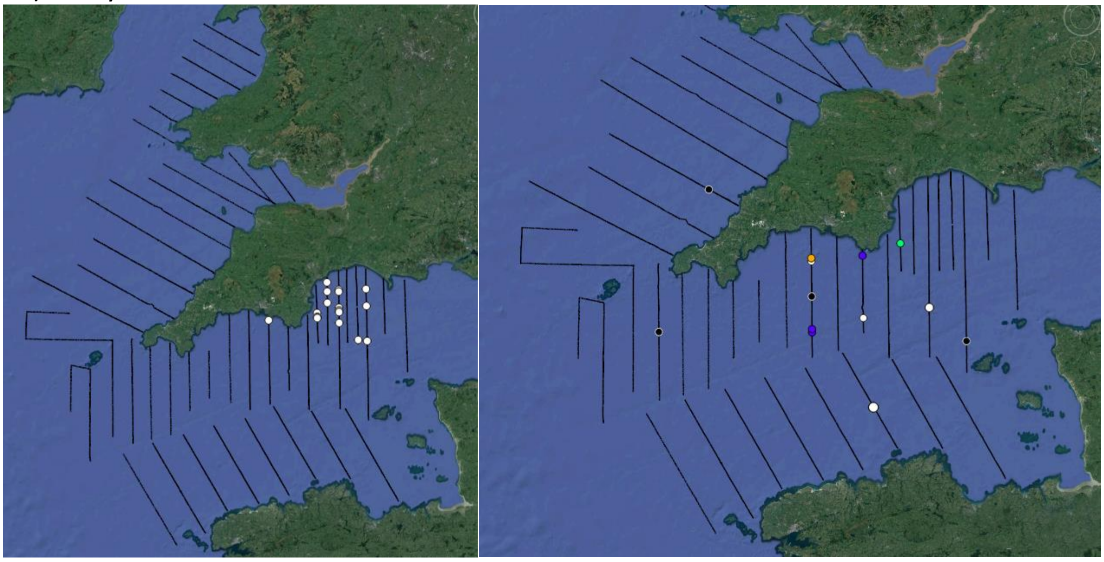

Figure 18: Distribution of Harbour Porpoise (left, white dots) and scarce cetacean species sightings (right). Black = Bottlenose Dolphin, green = White-beaked Dolphin, white = Risso's Dolphin, orange = Pilot Whale, purple = Minke Whale. Black lines mark survey effort.

Bluefin tuna

A total of 721 tuna were recorded in 88 encounters on the survey transects. Three categories of sighting are distinguished:

- possible – a single erratic splash is seen, nature of splash rules out a cetacean but not another large pelagic fish species
- probable – multiple erratic splashes with glimpses of animal but not enough to confirm identity as bluefin tuna
- definite – enough of the animal is seen to identify it as a bluefin tuna species

In contrast to last year all the sightings were in the eastern half of the survey area (Fig 19), although this is at least partly due to change in weather during the second half of the survey. Of particular note were the large numbers of tuna seen west of Guernsey on the French side of the Channel, this has traditionally been a poor area for sightings (cetacean, seabird and tuna and other fish) but the presence of sprat this year, likely accounted for the increased activity. This year saw more encounters with sizable feeding frenzies than 2020 but still fewer than were seen in 2017 and 2018.

In addition, there were two sightings of Atlantic Grey Seal *Halichoerus grypus* and three Basking Shark *Cetorhinus maximus*, the latter all seen in a 20-minute period on 13 October in Sea State 0 conditions in the middle of the Channel south off Plymouth.

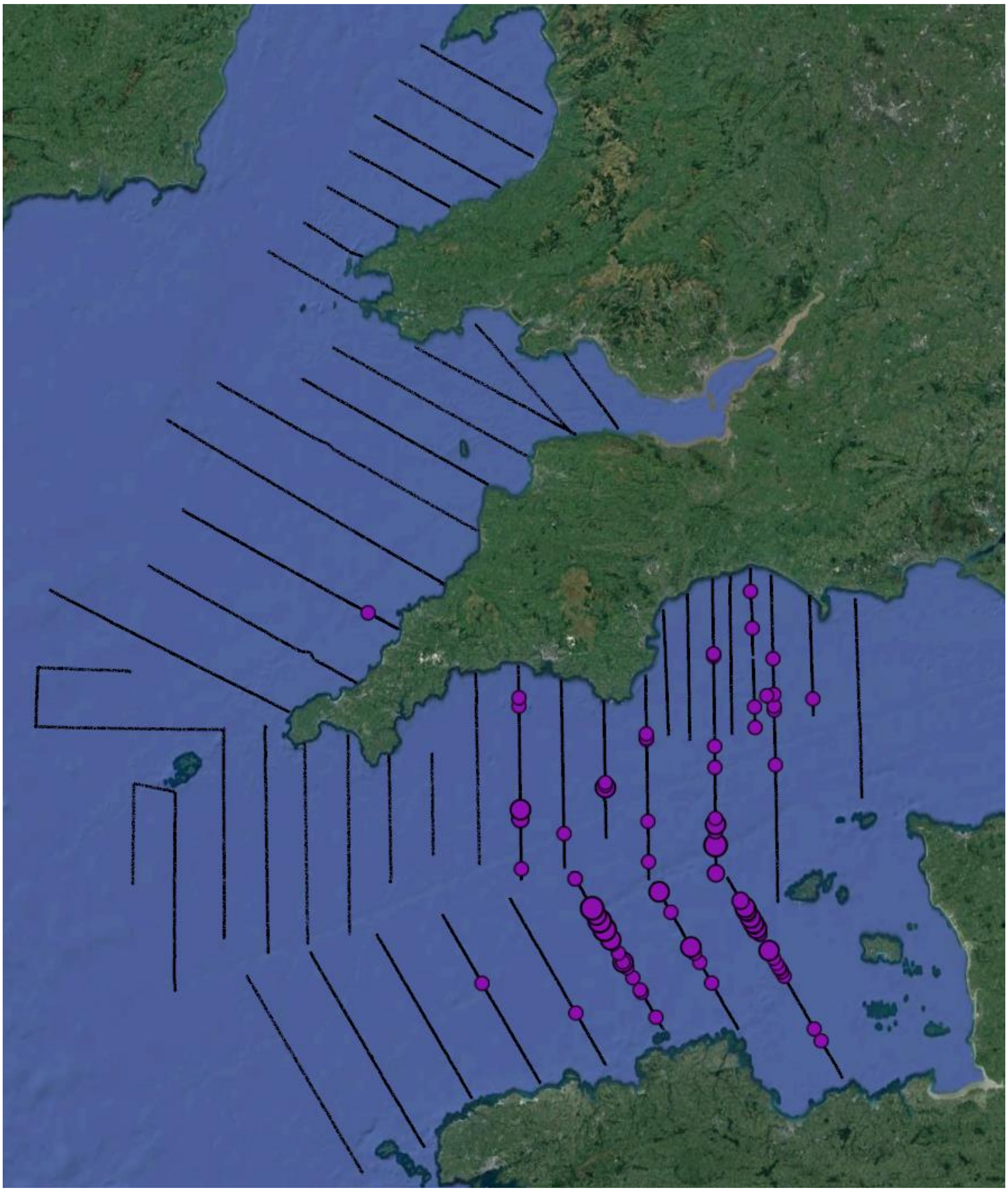

Figure 19: Distribution of all tuna sightings in 2021, scaled to abundance. Abundance categories (small to large purple dots): 1-5, 6-10, 10+. Black lines mark survey effort.

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Summary

The 2021 PELTIC survey was successfully completed despite delays due to COVID and inclement weather. The biomass estimates for key pelagic species was deemed of good quality: sprat in ICES area 7de and sardine in area 7ef for stock assessment. Sprat biomass in the core survey area used for the assessment was 107,355 t which was more than three times the 2020 estimate and the highest since the start of the PELTIC timeseries in 2013. This was comprised of 0-group fish, confirming a very strong recruitment. As in previous years, the highest quantities were found in Lyme Bay, showing a more offshore distribution than in 2020, although sprat was also found in the Eddystone Bay. Larger than usual numbers of sprat were also found along the northern French coast, although this areas is not considered in the assessment. Outside the western Channel, sprat was again also found north of the Cornish Peninsula: offshore in the deeper waters of the Celtic Sea, in the Inner Bristol Channel and, in very high numbers, in Cardigan Bay.

Sardine biomass for the survey areas included in the new assessment was 227,117 t. This represents a reduction by one third from peak values in 2020 (and 2019), although still higher than 2017 and 2018 and a close second most abundant small pelagic fish species after sprat. Anchovy biomass increase slightly from 2020 last year to 45,616t with again one year old fish dominating the population. There was sign of significant presence of post-larval Bay of Biscay anchovy, observed during PELTIC 2020 across all southern English Channel transects. Atlantic bluefin tuna were regularly observed particularly around the Channel Islands.

For the second time, PELTIC extended into Cardigan Bay to study its pelagic ichthyofauna and ecosystem. As was the case for the wider survey area, sprat was the most important small pelagic species with significant biomass observed (102,762 t). Horse mackerel, sardine, anchovy and herring were also found although in much lower numbers. A small number of sardine eggs were again found at one station (the same station as in 2020) confirming local spawning activity of this species, the northern-most location in the survey area to date.

Jeroen van der Kooij
Scientist in Charge
15/12/2021

Acknowledgement: This report was compiled by JvdK with contributions from FC, JS, EC and PH. We would like to thank all scientists, the officers and crew of the RV Cefas Endeavour for their help, support, advice, skill and cooperation, which were critical to the successful completion of the survey, particularly with the challenges of COVID-19.

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Annex 1: Metadata objectives 8, 10, 11, 14

Objective 8: To collect between 25-50 specimens per species (anchovy, boarfish, herring, horse mackerel, mackerel, sardine) and freeze for further analysis in the lab supporting a study on microplastics in fish stomachs (A. Bakir).

Trawl station	Survey stratum	Species code	Common name
18	western English Channel	HER/SPR	Herring and Sprat
28	western English Channel	MAC	Mackerel
38	western English Channel	ANE	Anchovy
48	western English Channel	HOM	Horse mackerel
55	western French Channel	SPR	Sprat
80	western English Channel	ANE	Anchovy
101	western French Channel	HOM	Horse mackerel
108	western French Channel	ANE	Anchovy
111	western French Channel	BOF	Boarfish
152	Scilly Isles	MAC	Mackerel
152	Scilly Isles	PIL	Sardine
152	Scilly Isles	ANE	Anchovy
166	Cardigan Bay	SPR	Sprat
166	Cardigan Bay	HER	Herring
184	Cardigan Bay	MAC	Mackerel
204	Bristol Channel	SPR	Sprat
210	Bristol Channel	MAC	Mackerel
250	Bristol Channel	ANE	Anchovy

Objective 10: To collect between 15-20 (similar sized) specimens per species (anchovy, boarfish, herring, horse mackerel, mackerel, sardine) and freeze (Stephen Smith, NMBAQC)

Trawl station	Survey stratum (label in bag)	Species code	Common name	ICES Rectangle	ICES Division
9	WEC (western English Channel)	MAC	Mackerel	30E7	7.e
48	WEC (western English Channel)	PIL	Sardine	28E6	7.e
		ANE	Anchovy		
		HOM	Horse mackerel		
101	WFC (western French Channel)	HOM	Horse mackerel	26E5	7.e
111	WFC (western French Channel)	BOF	Boarfish	26E4	7.h

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Objective 11. To collect 20 specimens each of anchovy and sardine at five different locations for a genetic study on both species (Naiara Rodriguez-Espeleta, AZTI, Spain)

Trawl station	Survey stratum	Species code	Common name
28	western English Channel	PIL	Sardine
48	western English Channel	ANE	Anchovy
108	western French Channel	ANE	Anchovy
152	Scilly Isles	ANE	Anchovy
152	Scilly Isles	PIL	Sardine
250	Bristol Channel	ANE	Anchovy

Objective 14. Collect ~25 sprat specimens from stations across the survey area for a genetic study on the stock structure of this species in the Celtic Sea ecoregion

Trawl station	Survey stratum	Species code	Common name
9	Western English Channel	SPR	Sprat
28	western English Channel	SPR	Sprat
55	western French Channel	SPR	Sprat
166	Cardigan Bay	SPR	Sprat
204	Bristol Channel	SPR	Sprat

Annex 13: 2021 6aSPAWN Survey Summary Table and Survey Report

Document 13a: 6aSPAWN 2021 survey summary table

*Please find survey on the next page.

Survey Summary table WGIPS 2022

Name of the survey (abbreviation):	6a/7b,c herring industry survey (6aSPAWN)
Target Species:	Herring
Survey dates:	6th-15th September (Chris Andra). 25-29th Sept (Afrika) (6aN) 2nd Dec (Ros Ard), 3rd Dec (Girl Kate), 16th Dec (K-Mar-K), 17th Dec (Rachel D) and 11th January 2022 (Crystal Dawn)

Summary:

6aS/7b,c Cruise Report Link: http://hdl.handle.net/10793/1742

2021 was the sixth industry-led survey of herring in 6a/7bc.

In 6aN, two vessels were deployed within 10days of one another. Each was equipped with hull mounted calibrated echosounder (s). FV Afrika used a Simrad EK80 with 3 frequencies and Chris Andra used a 38KhZ Furuno FCV-30. Both vessels were proven to be very stable platforms for acoustic surveys and the weather was good throughout the surveys. Following the guidance arising from WKHASS, the survey area in 6aN focussed again on two principal spawning areas, with timing planned to coincide with the known spawning period. Spawning ready fish were evident in strata 1 and spawning samples were taken for genetic analysis. As in previous recent years, the majority of herring were found in strata 1 running nort-south at a depth of 90-100m on flat ground, known to be suitable spawning habitat. Very few marks were recorded in strata 2 and only one small sample was obtained by Chris Andra. Chris Andra had sufficient time to make two passes of strata 1, which proved to be important because data from the first pass were corrupted and unrecoverable. A new feature of the 2021 survey was the occurrence of discrete 0-group mackerel schools that occurred off bottom, toward sloping ground and marked very hard on the 38khz. These marks were confirmed by several directed trawl samples. Discussion over concerns regarding the impact of limited samples from Afrika and unfamiliar data standards for the Furuno-FCV30 used on Chris Andra led to the decision to combine the biological samples from both vessels and apply them to acoustic data from Afrika to provide the final estimate of abundance and biomass to contribute to the time series. Accordingly, the total biomass estimates of herring recorded during the survey in 6aN was 7.01 t (CV= 0.40), comprising 98% matur fish. Despite concerted searching and several hauls, efforts to obtain a commercial catch as payment for the survey was limited by the lack of fish available.

6aS/7b,c - An acoustic survey of herring was conducted in 6aS/7b,c in December 2021 and January 2022. The 2021 survey was conducted using five vessels: MFVs Crystal Dawn WD201, Ros Ard SO745, K-Mar-K SO965, Rachel D SO976, and Girl Kate SO427. The survey design was similar to 2020 in that only core areas with prior knowledge of herring distribution from the monitoring fishery were targeted for surveying. Approximately 300nmi of transects were completed using 102 transects. This resulted in a total area coverage of approximately 65.04 nmi^2, similar to 2020 (66.26 nmi^2), but a significant reduction compared to previous survey (2016 – 2019). A pole-mounted system with a combi 38 kHz (split) 200 kHz (single) transducer was used successfully for the survey in 2021. 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 = 0.23). 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 strong herring marks in Bruckless Bay, Fintra Bay (Inishduff) and Inver Bay in discreet areas. A replicate survey was completed in Lough Foyle in January 2022, but herring had largely migrated out of the Foyle at this time, therefore this survey was not included. 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. The 2- and 3-wr age class of herring accounted for 74% of the overall numbers in 2020, but the 3-wr fish were dominant overall (56%). The total stock biomass (TSB) estimate of 35,944 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 2021, 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.	

	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 10 day lag in between. 6aS - Stratified systematic parallel design (~1 nmi spacing) with randomised start point. High intensity zig/zag transects in Lough Swilly and Lough Foyle
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- No issue for Chris Andra. Weather conditions excellent. Similarly, no issue for Afrika. 6aS – not an issue with the pole mounted system used in 2021
Extinction (shadowing)	6aN- No ocurrences recorded. Can occur with spawning aggregations, but no issues in 2021. Dense schools on rocky outcroppings can be subject to side lobes, but these were not classified as herring. 6aS – there was evidence of hyper-aggregating schools in all areas in 2021
Blind zone	6aN – Surface exclusion 6-8m 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 only one small biological sample obtained in strata 2 from on vessel, so acoustic analyses mainly inferred from samples in strata 1, where the size structure in the samples was very similar. 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 27/10/2021 at Black Head
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 combined estimate of abundance is considered to be a reliable estimate of the minimum abundance of herring present during spawning period. 6aS - The stock was not considered to be overall contained in 2021, particularly in the Donegal Bay area (Bruckless, Inver Bays, etc.) and more effort is required to contain the stock by targeting effort earlier and later than the survey timing in 2021. Herring appear to show up in these areas in large schools, are targeted by the monitoring fishery, and then leave these areas after spawning. There is anecdotal evidence that more herring also enter these bays prior to spawning later making containment difficult due to different waves of herring entering and leaving these inshore areas. However, the stock was most likely contained inshore on the days the core areas were covered by using smaller vessels in 2021. The surveys provide a snapshot of what is there at the time. Inshore areas were 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 earlier years. There is a concern regarding containment inshore in areas not covered by the survey and particularly the Malin Beg, and West Donegal areas. It would have been preferable if surveys were completed in these areas both before and after December in 2021. Ongoing COVID-19 restrictions made surveys difficult to complete in 2021.
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 for the combined survey analyses was 0.4. CV in strata 1 was 0.38 and higher in strata 2 (0.58) where very few herring marks were seen. 6aS – CV estimate on abundance estimate for the survey was 0.23, an improvement on the 2020 estimate of 0.34. Per strata, the CV estimate was relatively high for the Bruckless and Fintra/Teelin strata, and this had an adverse effect on the overall CV

	for the survey. These areas were dominated by large hyper-aggregating schools of herring. 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 2021.
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 2021 survey report

*Please find report on the next page.

The 2021 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], Katie Brigden[8], Shaun Fraser[8], Michael O'Malley[6], Ed Farrell[7]

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[7] EDF Scientific, Co. Cork, Ireland
[8] NAFC Marine Centre, Shetland

Chris Andra (Nicky Tait), Adenai (George Anderson), Afrika (skipper), MFVs Crystal Dawn WD201 (Liam O'Brien)), Ros Ard SO745 (Edward Gallagher), Girl Kate SO427 (Shaun McClenaghan and Paddy), South Eastern and K-Mar-K SO695 (John Menary and Kevin McCloskey) and Rachel D SO976 (Hughie Moore) were used in the Atlantic Herring in 6aS/7b Industry Acoustic Survey in 2021.

Contents

Executive summary

2021 was the sixth 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 3 751 t (2 958 t in 6aN and 793 t in 6aS/7bc) (EU 2021/703, Defra 2021), 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 vessels were deployed within 10days of one another. Each was equipped with hull mounted calibrated echosounder (s). FV Afrika used a Simrad EK80 with 3 frequencies and Chris Andra used a 38KhZ Furuno FCV-30. Both vessels were proven to be very stable platforms for acoustic surveys and the weather was good throughout the surveys.

Following the guidance arising from the ICES Workshop on Herring Acoustic Spawning Surveys (WKHASS, ICES 2020), the survey area in 6aN focussed again on two principal spawning areas, with timing planned to coincide with the known spawning period. Spawning ready fish were evident in strata 1 and spawning samples were taken for genetic analysis. As in previous recent years, the majority of herring were found in strata 1 running nort-south at a depth of 90-100m on flat ground, known to be suitable spawning habitat. Very few marks were recorded in strata 2 and only one small sample was obtained by Chris Andra. Chris Andra had sufficient time to make two passes of strata 1, which proved to be important because data from the first pass were corrupted and unrecoverable. A new feature of the 2021 survey was the occurrence of discrete 0-group mackerel schools that occurred off bottom, toward sloping ground and marked very hard on the 38khz. These marks were confirmed by several directed trawl samples. Discussion over concerns regarding the impact of limited samples from Afrika and unfamiliar data standards for the Furuno-FCV30 used on Chris Andra led to the decision to combine the biological samples from both vessels and apply them to acoustic data from Afrika to provide the final estimate of abundance and biomass to contribute to the time series. Accordingly, the total biomass estimates of herring recorded during the survey in 6aN was 7.01 t (CV= 0.40), comprising 98% mature fish. Despite concerted searching and several hauls, efforts to obtain a commercial catch as payment for the survey was limited by the lack of fish available.

In 2021 Scottish vessels used a new sampling bag attached to the end of the herring net. The purpose of the bag is to both to ensure that a representative sample of the catch can be retained, while at the same time allowing for release of fish in the event that the catch may be larger than required for a sample. Track record since 2016 shows that these events are very rare but may occur specifically when a very dense spawning mark is targeted for a sample. There are benefits and drawbacks to this approach but on balance, both the result that successful biological samples were retained and fish were observed to escape when the bag was full is considered that use of the sample bag was justified.

Coinciding with the 2021 International Herring Acoustic Survey, a 10-day acoustic survey was carried out by FV Adenia in July (Annex 2). 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. Out of 10 hauls, only 3 herring were caught, all in one haul. Scrutiny of the acoustically detected marks of fish schools resulted only 5 marks that were 'possibly' herring but they could not be verified by the sampling. Following a review of the acoustic and biological sampling results in consultation with lead scientists From the Marine Institute and Marine Scotland, the decision was made not to undertake any further analysis of the acoustic data, since doing so would require unjustifiable assumptions given the absence of biological sample data.

In 6aS/7b,c an acoustic survey of herring was conducted in December 2021 and January 2022. The 2021 survey was conducted using five vessels: MFVs Crystal Dawn WD201, Ros Ard SO745, K-Mar-K SO965, Rachel D SO976, and Girl Kate SO427. The survey design was similar to 2020 in that only core areas with prior knowledge of herring distribution from the monitoring fishery were targeted for surveying. Approximately 300nmi of transects were completed using 102 transects. This resulted in a total area coverage of approximately 65.04 nmi², similar to 2020 (66.26 nmi²), but a significant reduction compared to previous survey (2016 – 2019). A pole-mounted system with a combi 38 kHz (split) 200 kHz (single) transducer was used successfully for the survey in 2021. 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 = 0.23). 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 strong herring marks in Bruckless Bay, Fintra Bay (Inishduff) and Inver Bay in discreet areas. A replicate survey was completed in Lough Foyle in January 2022, but herring had largely migrated out of the Foyle at this time, therefore this survey was not included. 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. The 2- and 3-wr age class of herring accounted for 74% of the overall numbers in 2020, but the 3-wr fish were dominant overall (56%). The total stock biomass (TSB) estimate of 35,944 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 2021, 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.

Acoustic survey time series indices for 6aN (Mackinson and Berges 2022) and 6aS7b (O'Malley and Nolan 2022) were used during the 6a7bc herring benchmark workshop in February 2022 (ICES 2022).

Pending ICES recommendations for future monitoring requirements that arise from the ICES 6a7bc herring benchmark conducted in February 2022, tentative plans for surveys in 2022 are underway, based on provisions for monitoring TACs of 2 250 t (6aN) and TBC t 6aS7bc (Defra 2022, EU 2022/109).

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. The EU Council regulation (EU 2021/703) and UK Secretary of State (Defra 2021) enabled provision for a monitoring TAC of 3 751 t (2 958 t in 6aN and 793 t in 6aS/7bc) of 4 840 t, enabling the sixth survey to take place in 2021.

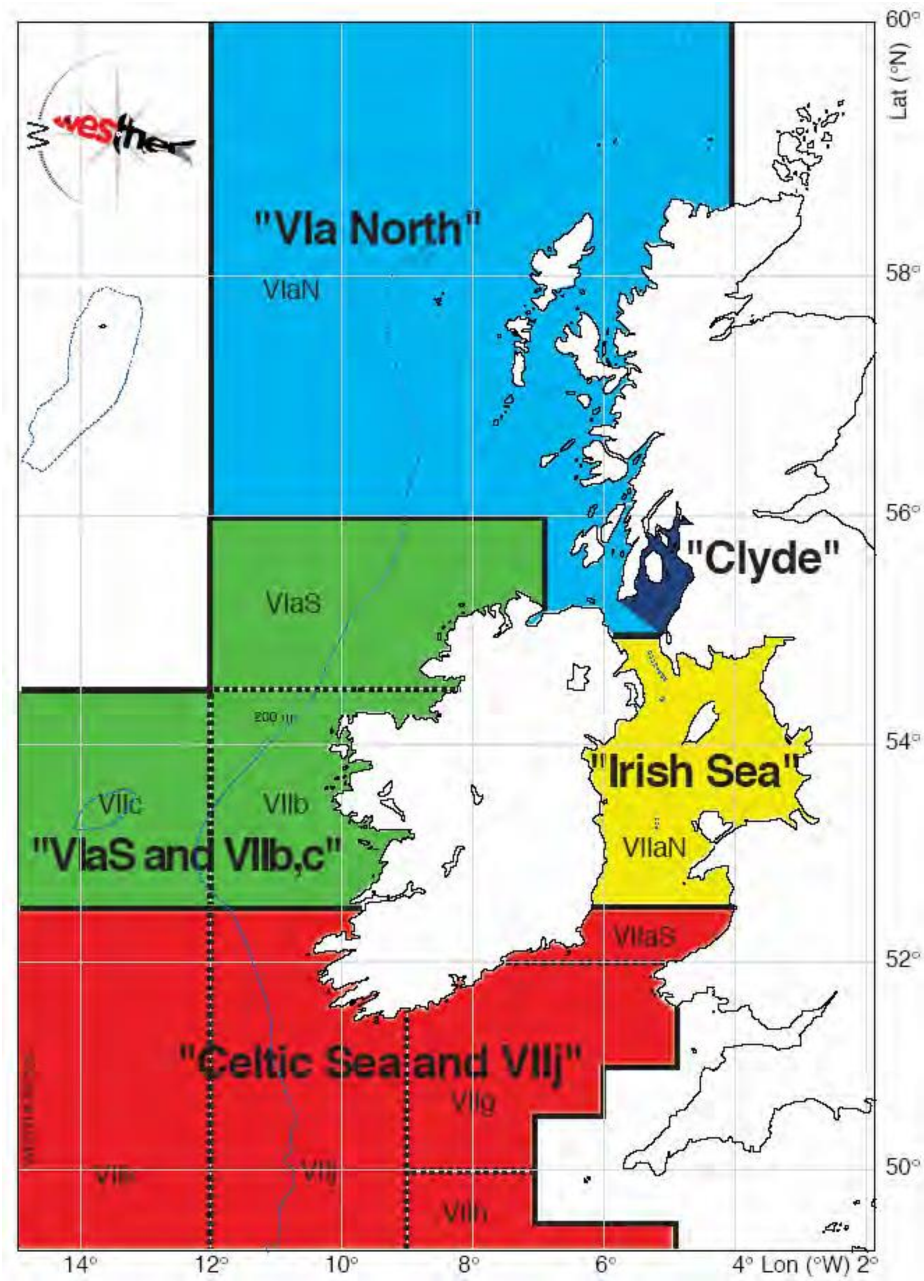


Figure 1.1. Herring stock assessment areas.

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.

Acoustic survey time series indices for 6aN (Mackinson and Berges 2022) and 6aS7b (O'Malley and Nolan 2022) were used during the 6a7bc herring benchmark workshop in February 2022 (ICES 2022).

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. Additional details of the 6aS7b acoustic survey are provided in a separate cruise report (O'Malley et al. 2022).

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.

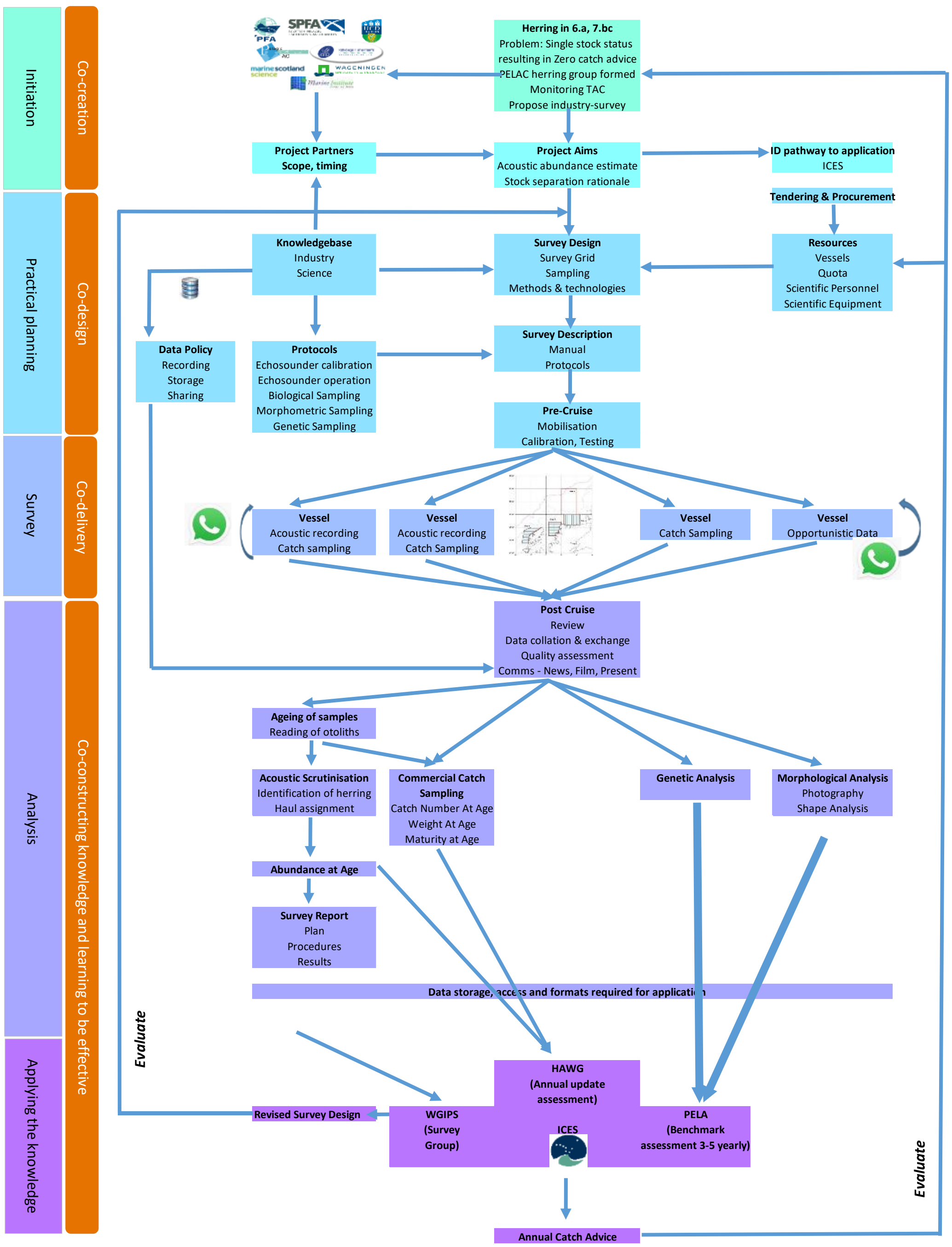


Figure 2.1. Overview of the planning, implementation and analysis stages in the Western herring surveys.

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, 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 guidance arising from the ICES Workshop on Herring Acoustic Spawning Surveys (WKHASS, ICES 2020), since 2020 the survey area in 6aN has 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 and re-analysis of surveys since 2016 has resulted in a consistency survey time series index (Mackinson and Berges 2022).

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 2021 survey was completed in 6aS/7b during December 2021 and January 2022 on the more dominant winter spawning herring in this area. Spawning is known to occur outside these times in 6aS/7b, however the timing was considered to be appropriate considering the resources available.

The timing of surveys in 6aN and 6aS/7b are shown in Table 2.2 and 2.3 respectively.

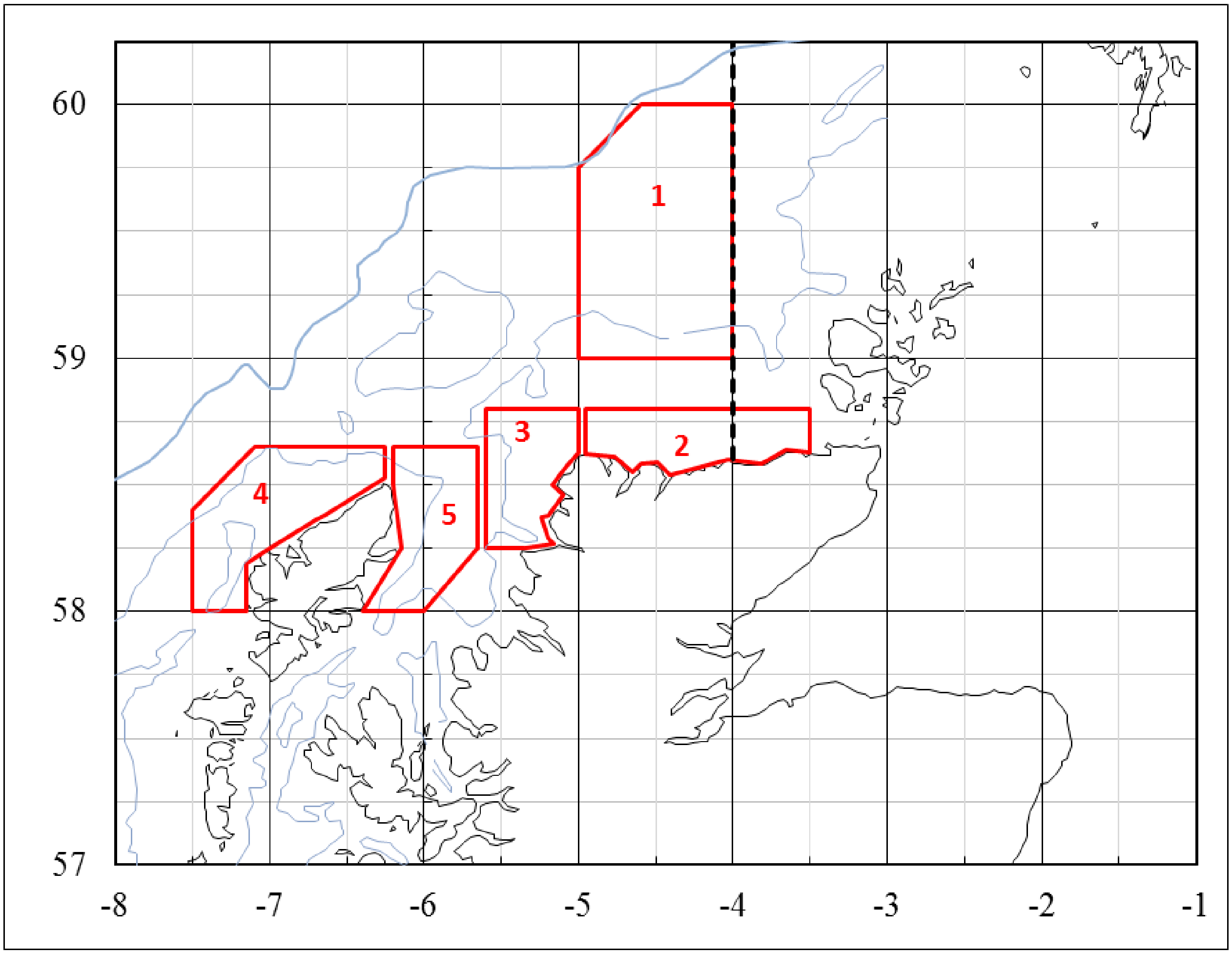


Figure 2.2. Planned survey areas used in the 6aNorth surveys prior to 2020. Area 1- North pre-spawning mixing area, Area 2 -East of cape Wrath, Area 3 – The Minch, Area 4 – Outer Hebrides, Area 5 – east Minch.

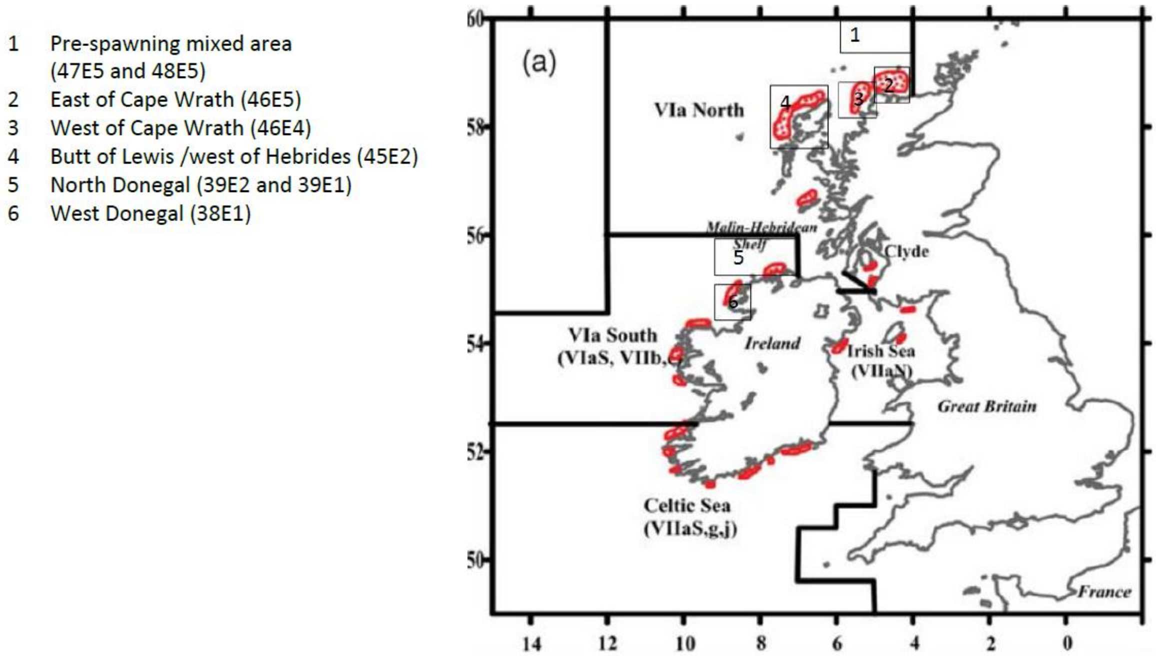


Figure 2.3. Spawning areas for herring in ICES subareas 6 and 7, with currently active spawning areas and pre-spawning aggregation areas for each stock indicated by black rectangles. Used in ICES 2016, redrawn from Geffen *et al.* (2011).

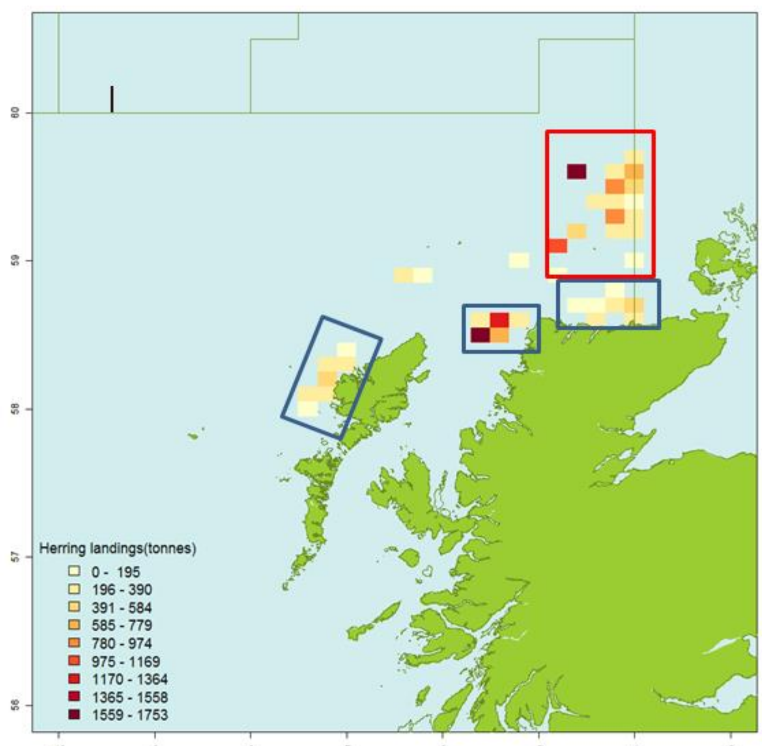


Figure 2.4. Distribution of commercial catches reported in 6aN in 2011.

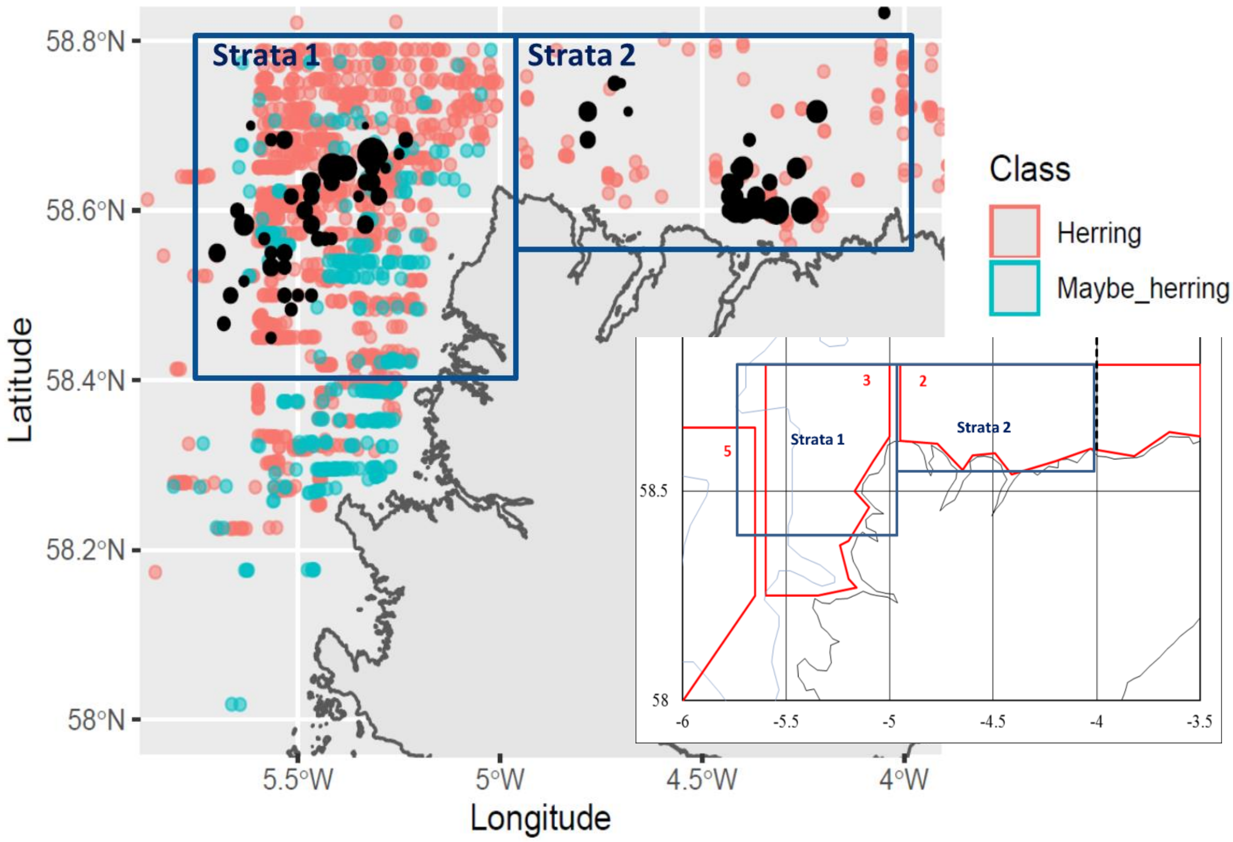


Figure 2.5. Acoustic survey recordings of herring and 'maybe herring' marks and locations of commercial catches 2016-2019 in the newly defined Strata 1 & 2, showing overlap with previous survey Areas 2,3,5 (inset) and noting that the distribution of catches reflect spawning grounds. Catches (black dots) scaled proportionally. Acoustic marks are not scaled and denote location only.

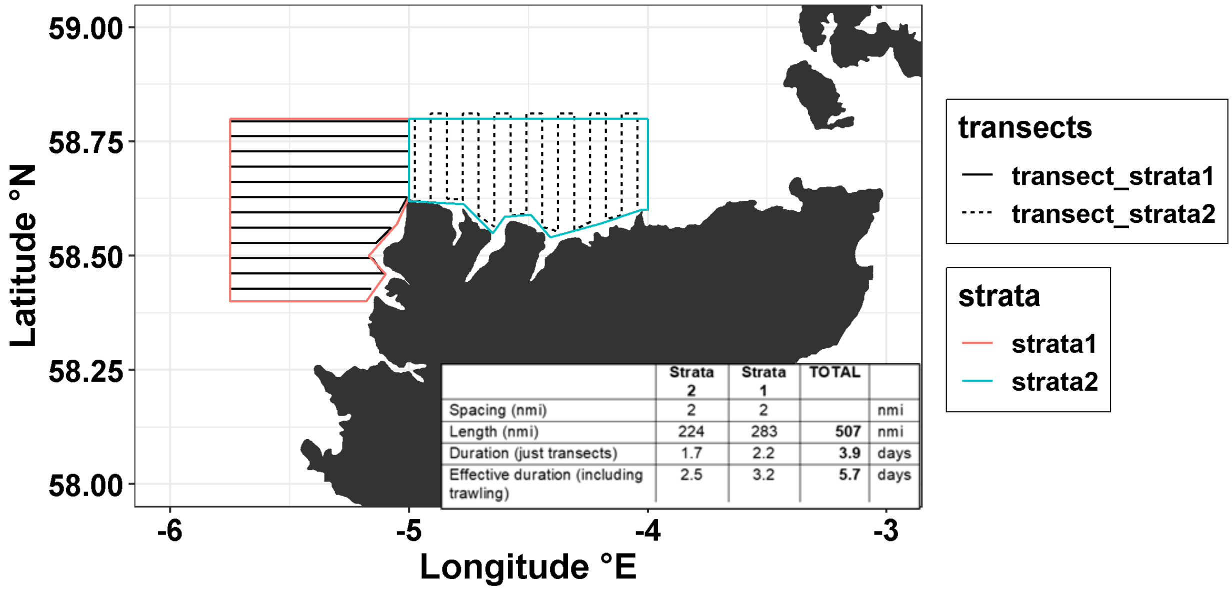
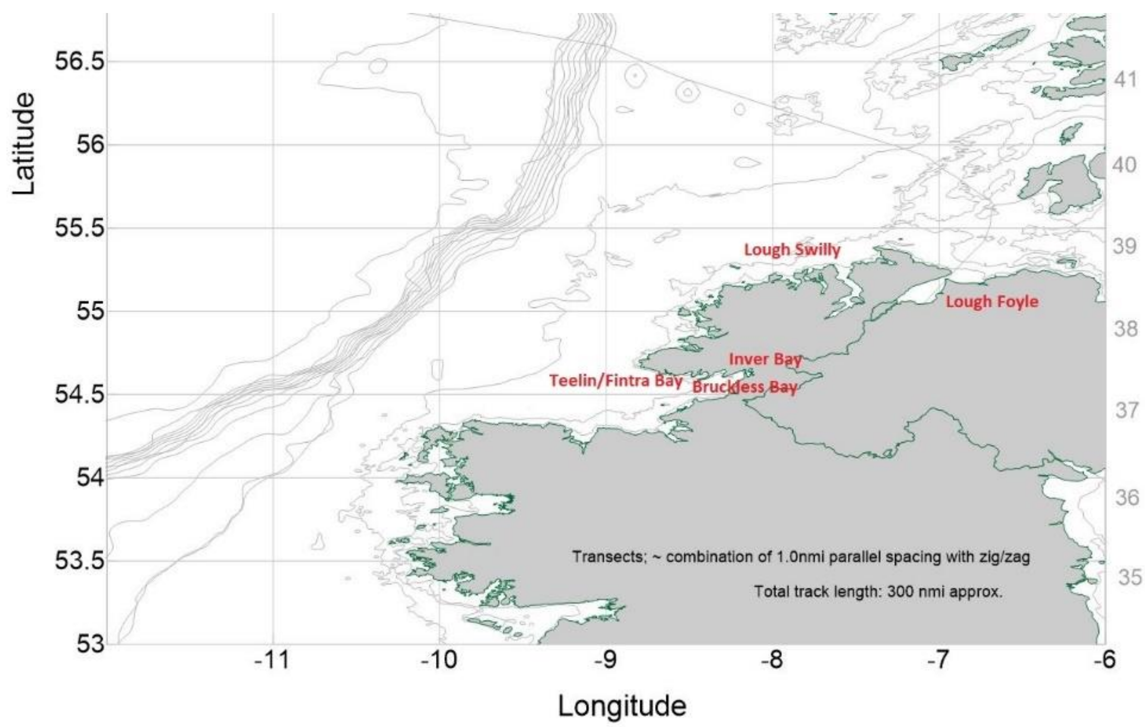


Figure 2.6. Planned survey areas used in the 2021 6aN surveys.



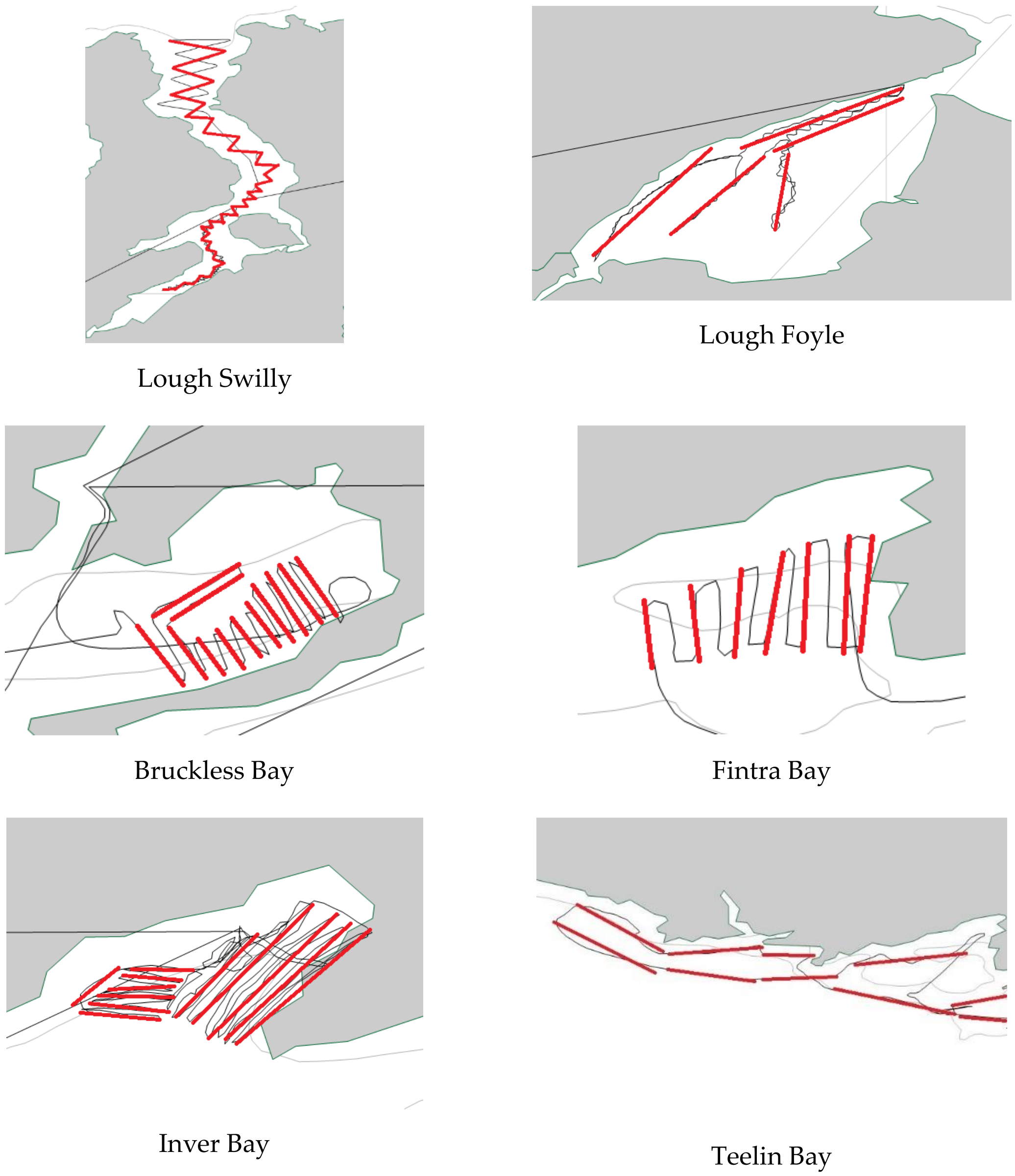


Figure 2.7. 6aS/7b industry acoustic survey in 2021: The 6 core areas were selected in 6aS/7b (top panel) based on information from the monitoring fishery and previous surveys (2016-2019). The 6 core areas in 2021 included: Lough Swilly, Lough Foyle, Bruckless Bay, Fintra Bay, Inver Bay and Teelin Bay. Red lines denote transects used in the final biomass estimates, grey lines were excluded from final analysis.

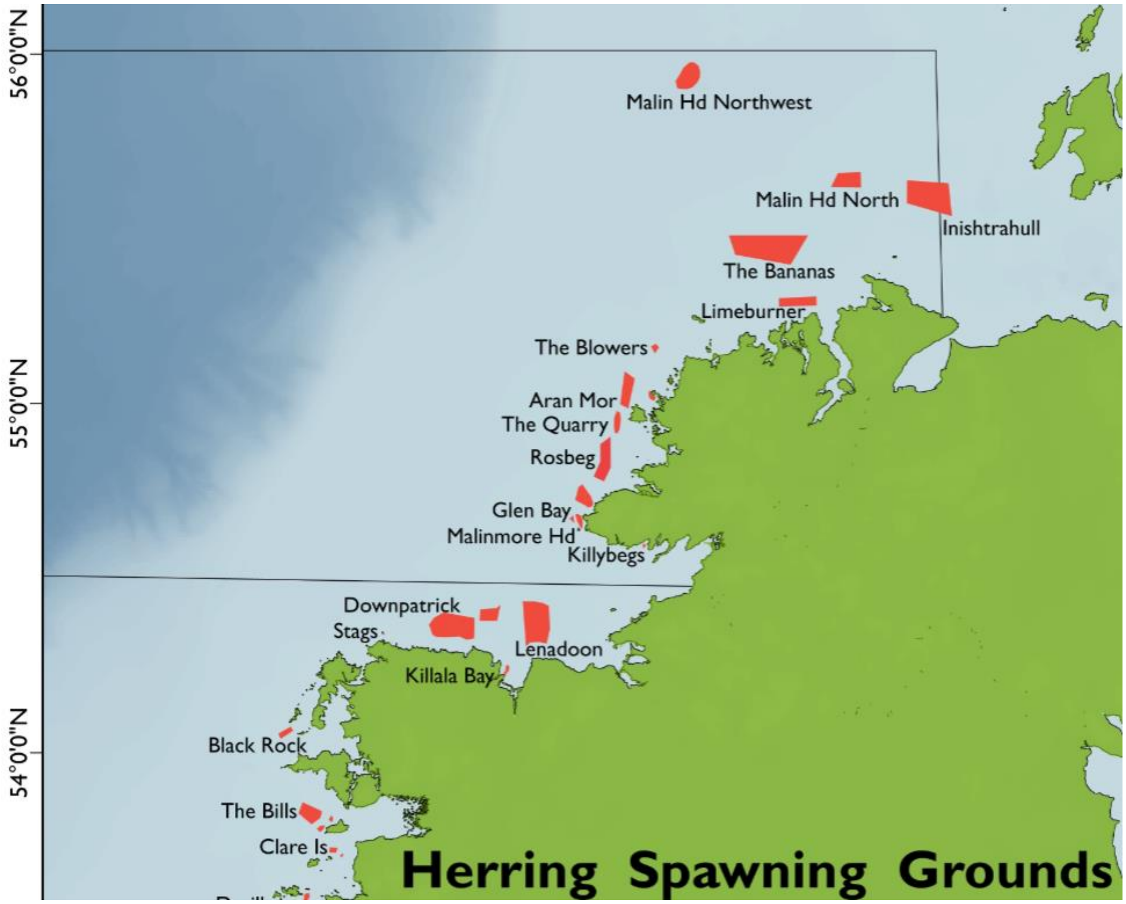


Figure 2.8. Herring Spawning grounds in 6aS/7b,c (extracted from O'Sullivan, 2013).

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 2021 surveys in 6aN.

Vessel	Start	End	Duration	Timing and area coverage	Fri 03-Sep	Sat 04-Sep	Sun 05-Sep	Mon 06-Sep	Tue 07-Sep	Wed 08-Sep	Thu 09-Sep	Fri 10-Sep	Sat 11-Sep	Sun 12-Sep	Mon 13-Sep	Tue 14-Sep	Wed 15-Sep	Thu 16-Sep	Fri 17-Sep	Sat 18-Sep	Sun 19-Sep	Mon 20-Sep	Tue 21-Sep	Wed 22-Sep	Thu 23-Sep	Fri 24-Sep	Sat 25-Sep	Sun 26-Sep	Mon 27-Sep	Tue 28-Sep	Wed 29-Sep
Chris Andra	**06-Sep**	**15-Sep**	**9**	**Strata 1 & 2 (acoustic)**	C			P																							
Afrika	**25-Sep**	**29-Sep**	**4**	**Strata 1 & 2 (acoustic)**																P	C										
C=Calibration																															
P=Passage to/from grounds																															

Table 2.3. Timing of 2021 surveys in 6aS/7b.

Area	Survey date	Survey distance	Vessel and type	Flag	Homeport	Vessel#	Role	Skipper
Loch Swilly	02 Dec 2021	~50nmi	MFV *Ros Ard* Trawler under 19.81m	IRL	Burtonport	SO745	Acoustic survey	Edward Gallagher
Lough Foyle	03 Dec 2021	~50nmi	MFV *Girl Kate* Half-decker trawler under 12m	IRL	Greencastle	SO427	Acoustic survey	Shaun McClenaghan
Inver Bay	16 Dec 2021	~50nmi	MFV K-Mar-K Potter under 12m	IRL	Killybegs	SO695	Acoustic survey	Kevin McCloskey
Bruckless, Teelin and Fintra Bays	17 Dec 2021	~50nmi	MFV Rachel D Trawler under 19.81m	IRL	Killybegs	SO976	Acoustic survey	Hughie Moore
Lough Foyle *(not used)*	11 Jan 2022	~50nmi	MFV Crystal Dawn Half-decker trawler under 12m	IRL	Greencastle	WD201	Acoustic survey	Liam O'Brien

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 (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.

The 2021 planned survey with parallel and zig/zag transect design 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 mixed parallel and zig/zag transect design. The straight line transects were completed at constant speed (or as close to as possible). 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.

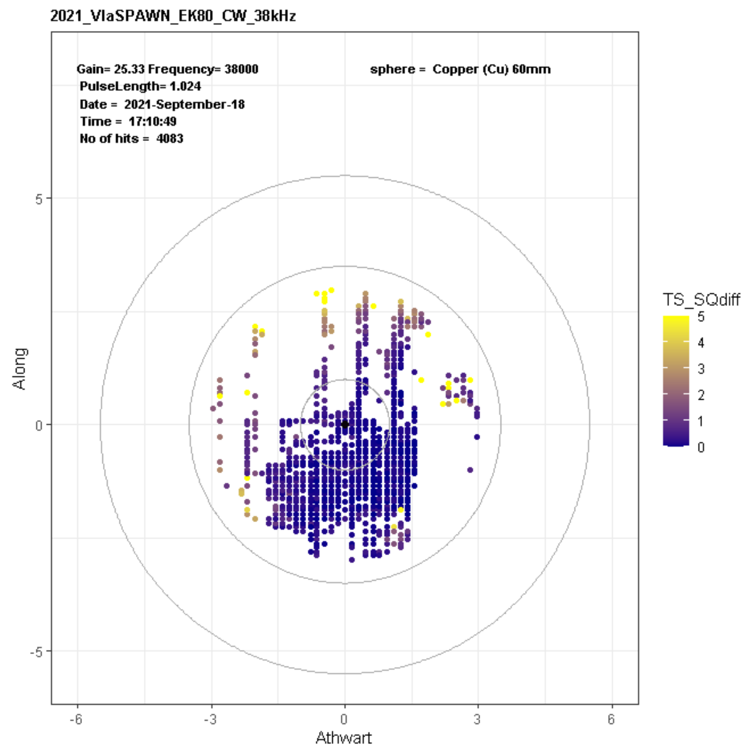
The standard calibration procedure described in Demer et al. (2015)[1] was used to calibrate each of the echosounders deployed on Chris Andra (see Annex 1), and Adenia (see Annex 2). Echomaster Marine successfully performed the calibration of stern on to the breakwater in Peterhead at the slack of a high tide (22m under transducer) in calm conditions.

[1] http://courses.washington.edu/fish538/resources/CRR326_Calibration.pdf

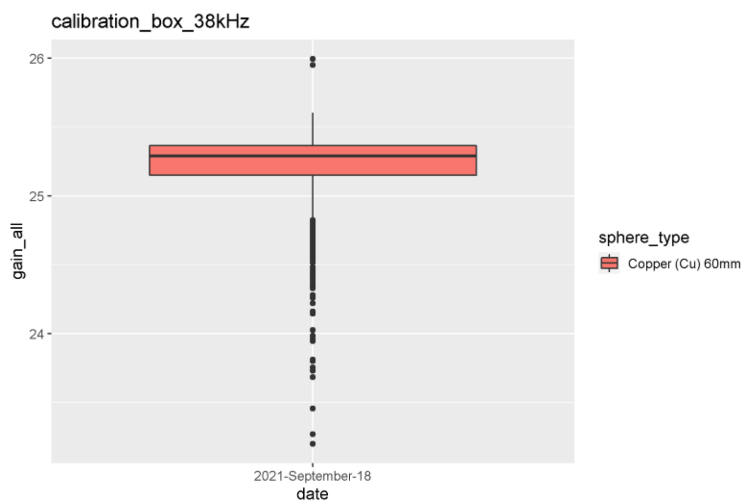
The 38kHz channel of the hull mounted echosounder onboard FV Afrika was calibrated in the port of Ijmuiden (The Netherlands) on 10th September under favourable weather conditions. The water column exemplified acceptable noise, suggesting an acceptable signal to noise ratio for calibration operations. This was confirmed by the low RMS error observed through the duration of the calibration trial (0.2 dB). (Figure 2.10)

Calibration of the pole-mounted EK80 38kHz echosounder was carried out at Black Head before the surveys began on 27/10/2021. Water depth was approximately 25m at the calibration site. The calibration was carried out using standard methodology as described by Foote et al (1987). The SIMRAD EK80 calibration software was used and the beam model was updated for the 38 kHz echosounder. The calibration was made possible by good conditions in a deep water area of the lough. There was minimal interference from biota in the water column during the calibration. Calibration settings are presented in Appendix 1 of O'Malley et al. (2022).

(a)



(b)



(c)

Frequency	SphereType	Gain (dB)	TSrms (dB)	sacorr
38000	Copper (Cu) 60mm	25.33	0.2058	0.0621

Figure 2.10. Results of the calibration performed on the Afrika (SCH24) on 18th September. (a) Calibration sphere detections and TS deviation within the acoustic beam. (b) Distribution of calibration gains. (c) Calibration result summary

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 and when weather was good. Survey speed was ~7 knots throughout, reduced as needed depending on weather conditation. 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. GPS feeds were 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. All other acoustic sounders that might cause interference with the EK80 were turned off. Survey log sheets were used to record all transect data, including transect position and other events taking place on and off transect.

2.2.4 Fishing operations for scientific samples

In 6aN, 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.

Scottish RSW vessels were granted a derogation to discard fish that were not required to be retained for biological sampling, subject to specific conditions.

In 6aS7b, rather than further impacting the stock by taking samples during the survey, it was decided that herring samples from the fishery would be adequate to work up an acoustic estimate. This was similar to the approach taken on the surveys in 2016 - 2020. Unlike the surveys in 2016 – 2019, no directed fishing took place during the acoustic survey in 2021. All biological sampling for the survey in 2021 came from the standard port sampling of herring conducted by the Marine Institute with samples from the monitoring fishery selected as close as possible in space and time to the surveys). (see O'Malley et al. 2022, Table 3 for details).

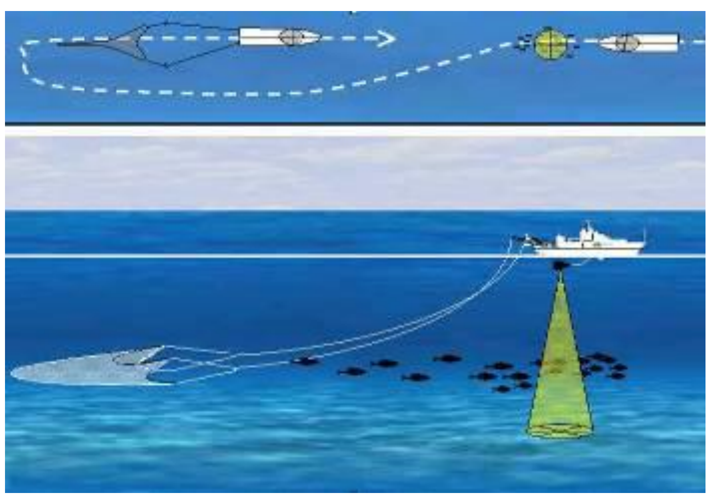


Figure 2.11. Schematic description of fishing operation to collect a biological catch sample during an acoustic survey.

In 2021 the Adenia and Chris Andra used a new sampling bag attached to the end of the herring net. The purpose of the bag is to both to ensure that a representative sample of the catch can be retained, while at the same time allowing for release of fish in the event that the catch may be larger than required for a sample. Track record since 2016 shows that these events are very rare but may occur specifically when a very dense spawning mark is targeted for a sample. There are benefits and drawbacks to this approach and the performance of the bag is very difficult to assess because it is not possible to control the many variables that may affect the catch. On balance, both the result that successful biological samples were retained and fish were observed to escape the bag when full it is considered that the use of the sample bag was justified.

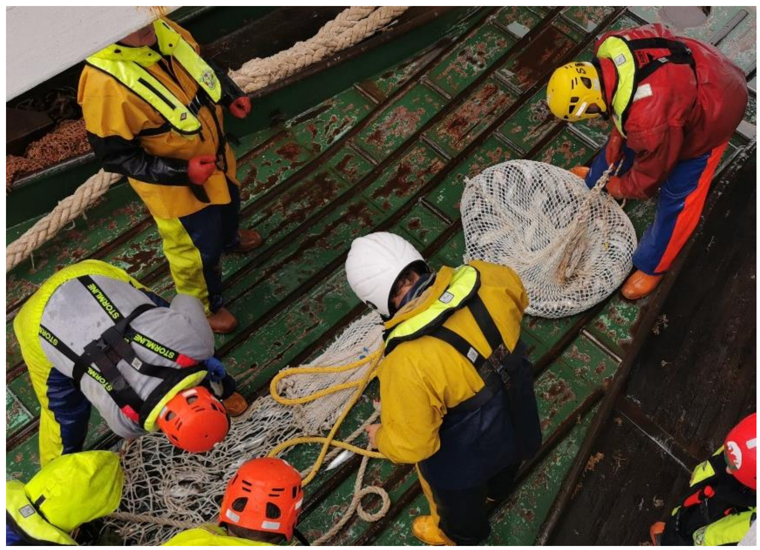



Table 2.4. Summary of equipment used for the 2021 acoustic surveys.

Area surveyed	Vessel	Transducer and Frequency	Echo-sounder	Power Pulse duration Ping interval	Environment	Calibration Location/ date, supplier	Survey area changes
Strata 1 & 2	Chris Andra (FR228)	Hull mounted split beam (38kHz), draft ~5m With heave compensation.	Furuno FCV-30	**@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 4 Sept, Echomaster Marine	
Strata 1 & and 2	Afrika (SCH24)	Hull mounted EK80 at 38 kHz.	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	Ijmuiden (The Netherlands) Benoit Berges (WMR)	
6aS and 7b	Six inshore vessels	Pole mounted EK80-18 C (38 kHz) ES38C	SIMRAD EK80 (38 kHz only used for estimates)	Power = 500W (38kHz); 100W (200kHz) Pulse duration = 1.024ms Ping interval = 750mS	Temp = 8 - 10.0˚C, Salinity = 35ppt, Sound speed = 1490.66 m/s	Black Head, Co. Clare 27th October 2021	

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).

As noted above, all biological sampling for the 6aS,7b survey in 2021 came from the standard port sampling of herring conducted by the Marine Institute.

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*

In 6aN, 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)

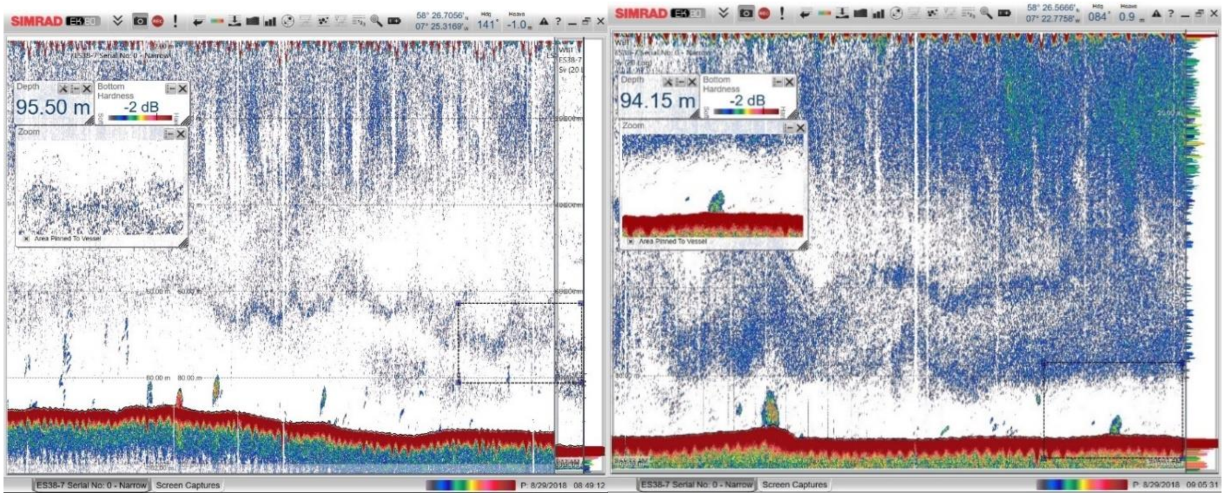


Figure 2.12. Example screen shots of targeted marks (first panel) and those trawled on.

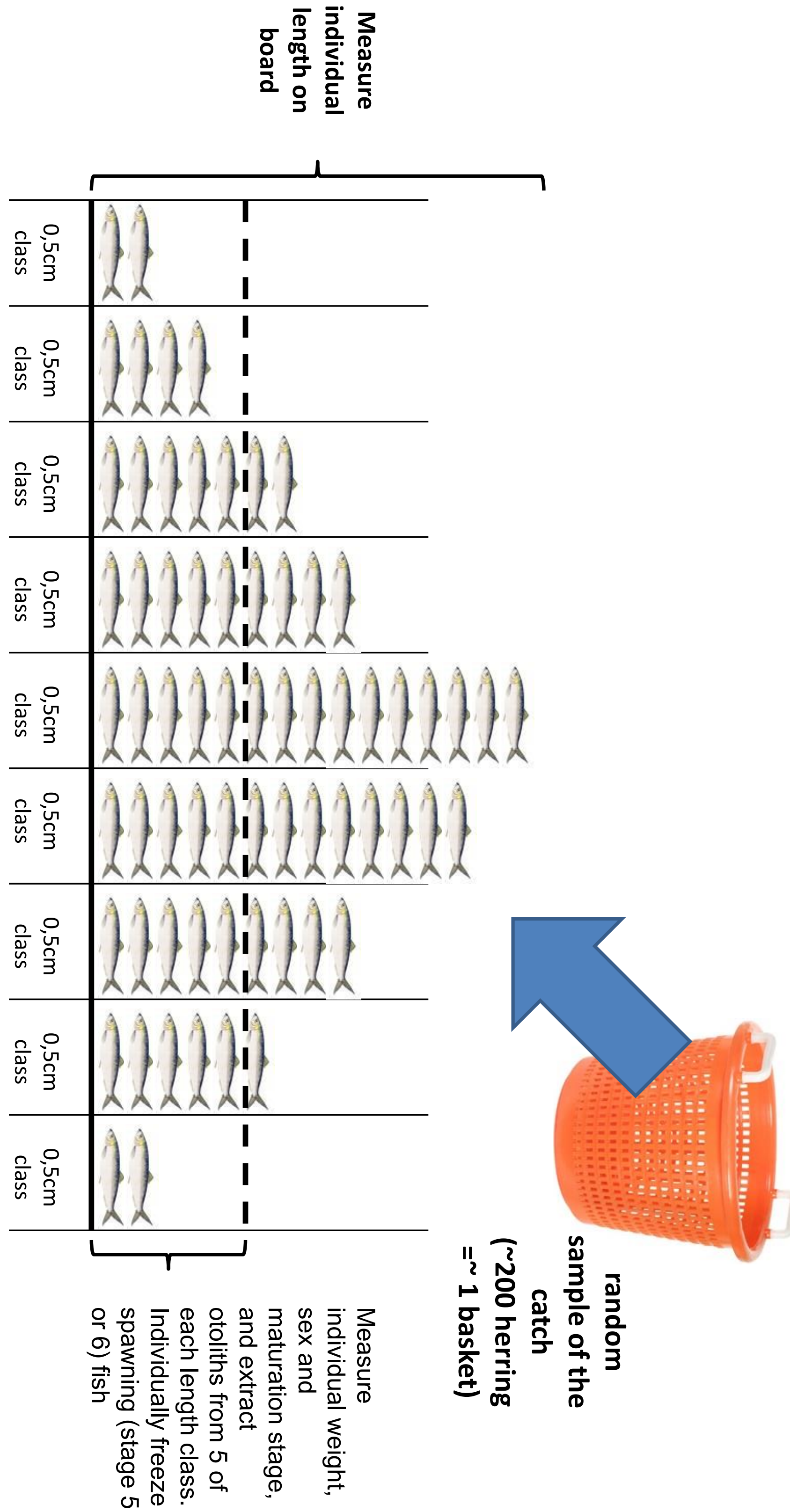


Figure 2.13. Illustration of the required catch sampling procedure.

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 tissue samples were collected following genetic sampling protocols.

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.
- **Probably 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 –** routinely found in the 6aN survey area. 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. The echograms were generally analysed at a threshold of -60 to70 dB. 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 and 2021 surveys on spawning grounds was an apparent 'cleanness' or separation of acoustic marks, compared to the mixed assemblages encountered in the 2018 and 2019.

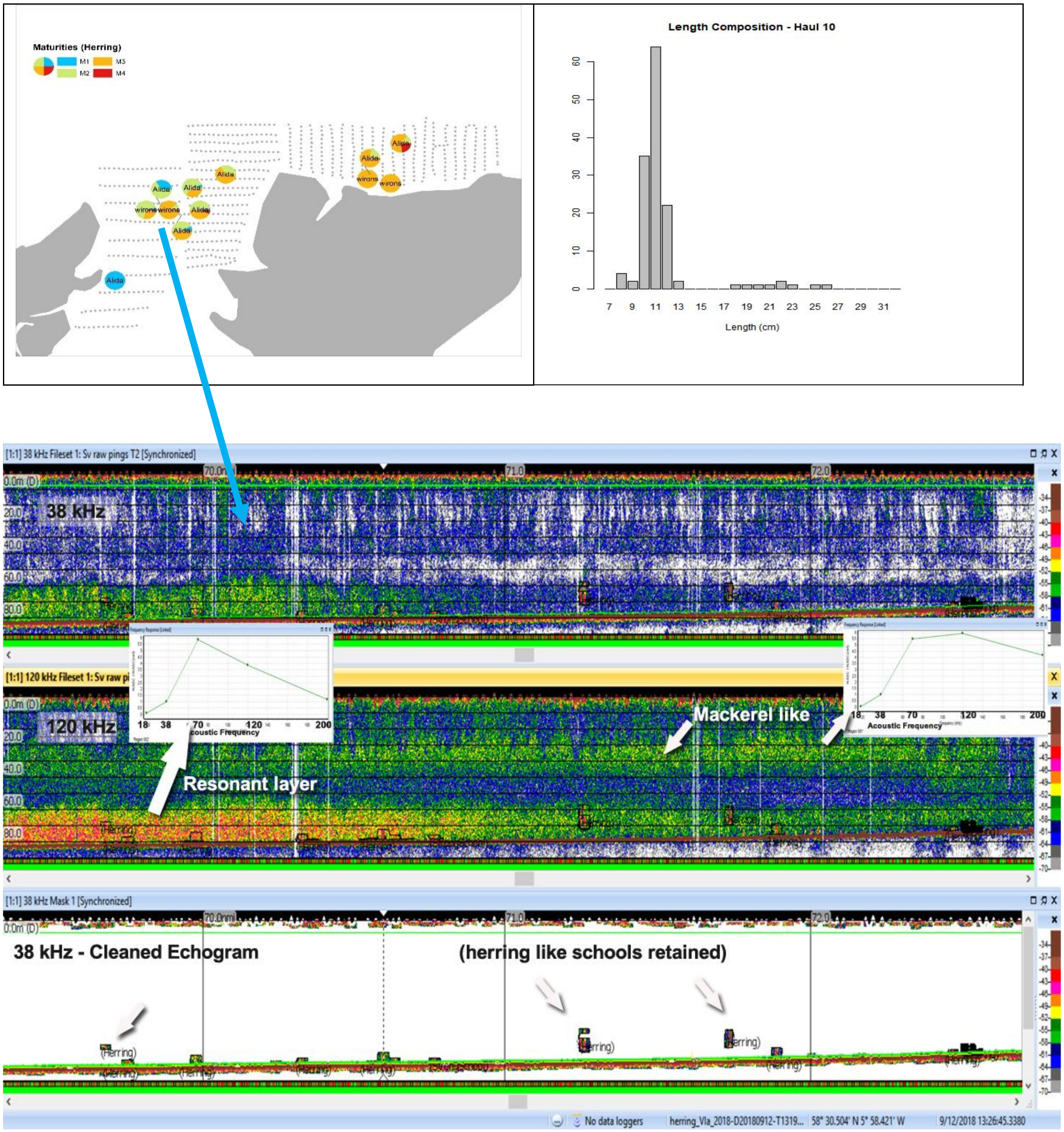
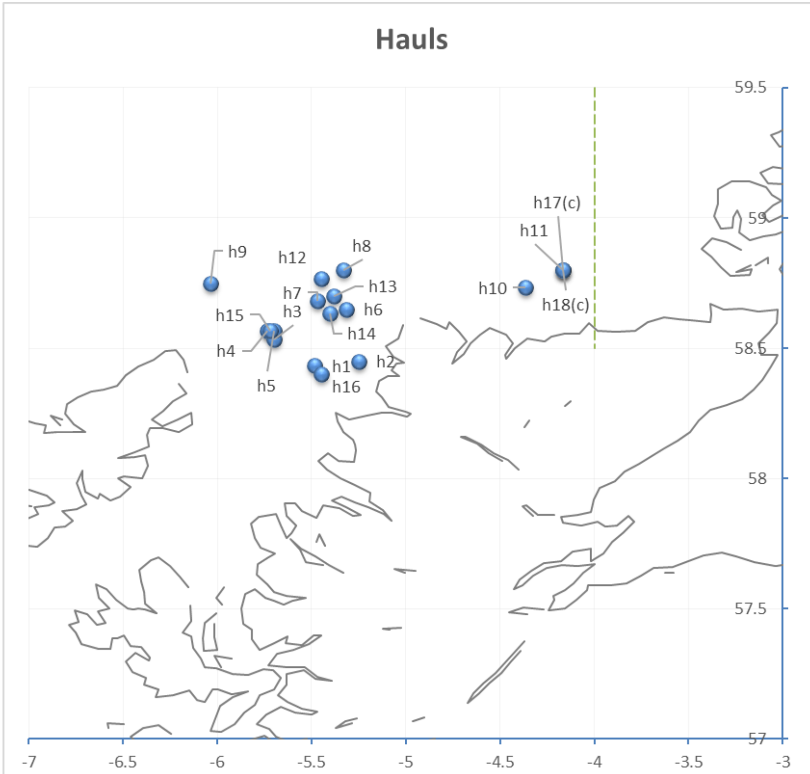


Figure 2.14. Example of analysis of acoustic properties to help classify schools in 6aN from Alida acoustic data in 2018.

6aN acoustic marks recorded by Chris Andra

(a)

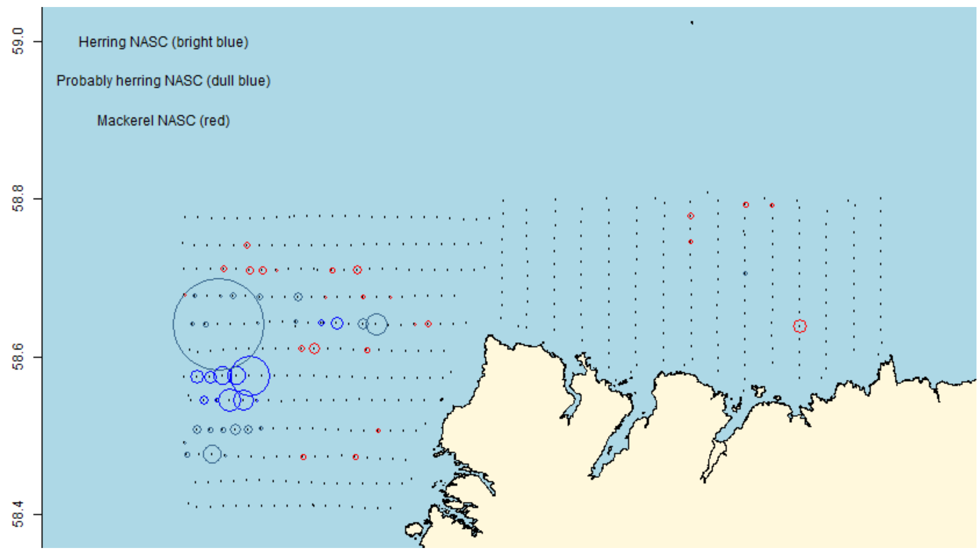


(b)

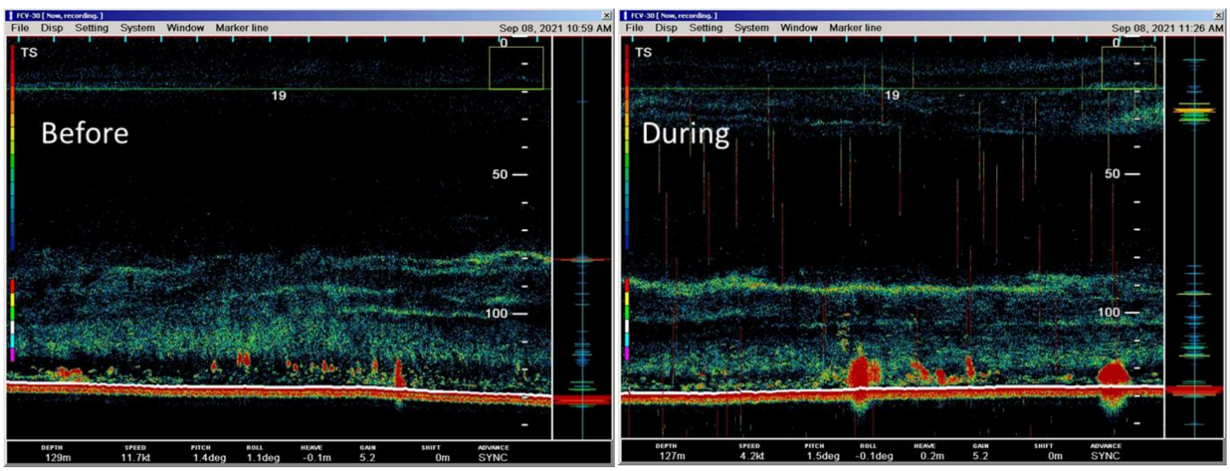
haul	date	HER	HOM	MAC	NOP	WHG	HAD	SPR	JELLY	WHB	Total Catch weight (t)
1	07/09/2021	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0
2	07/09/2021	0.0%	4.1%	32.7%	0.0%	0.0%	2.0%	0.0%	61.2%	0.0%	0.02
3	07/09/2021	0.0%	0.0%	64.0%	0.0%	0.0%	0.0%	0.1%	35.9%	0.0%	0.03
4	08/09/2021	86.0%	12.3%	1.2%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.04
5	08/09/2021	13.9%	85.5%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	2
6	08/09/2021	0.0%	0.0%	42.2%	1.6%	0.0%	0.0%	0.0%	56.3%	0.0%	0.1
7	09/09/2021	30.5%	15.1%	24.2%	0.0%	0.0%	0.0%	0.0%	30.2%	0.0%	0.02
8	09/09/2021	21.1%	0.0%	0.0%	0.0%	0.0%	28.3%	0.0%	50.6%	0.0%	0.05
9	09/09/2021	1.4%	0.0%	20.8%	15.6%	0.0%	0.0%	0.0%	62.3%	0.0%	0.02
10	11/09/2021	6.4%	0.0%	36.0%	0.0%	0.3%	56.7%	0.0%	0.5%	0.0%	0.09
11	12/09/2021	0.0%	4.9%	95.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.07

12	12/09/2021	0.0%	0.0%	91.9%	0.0%	0.0%	0.0%	0.0%	8.1%	0.0%	0.04
13	13/09/2021	0.0%	0.0%	98.9%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.09
14	13/09/2021	97.2%	0.0%	2.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3
15	14/09/2021	82.2%	0.0%	5.3%	0.0%	2.6%	9.9%	0.0%	0.0%	0.0%	0.07
16	15/09/2021	7.5%	11.3%	56.6%	1.9%	0.0%	22.6%	0.0%	0.0%	0.0%	0.03
17	19/09/2021	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	53.05
18	20/09/2021	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	17.68

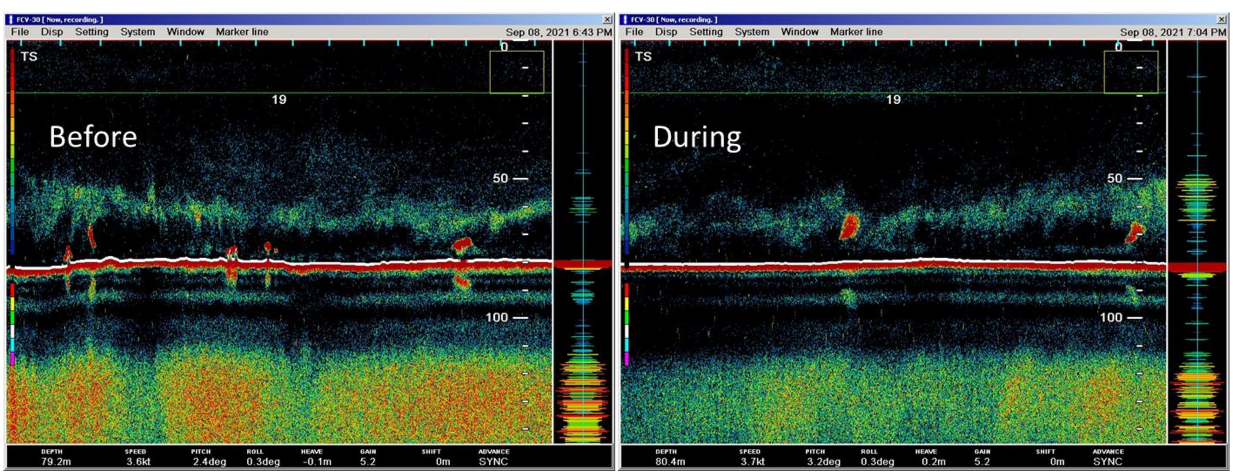
Figure 2.15. Biological sampling by Chris Andra. Sample haul locations and species composition of catches.


Herring NASC (bright blue)
Probably herring NASC (dull blue)
Mackerel NASC (red)
59.0
58.8
58.6
58.4

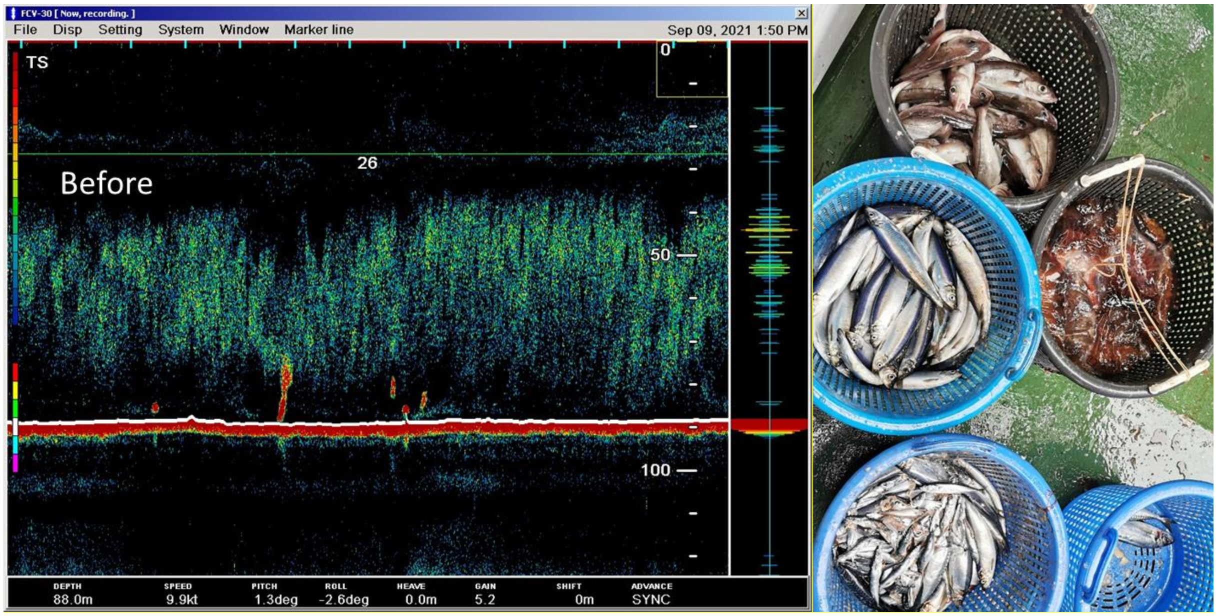
(b)


Before
Sep 08, 2021 10:59 AM
During
Sep 08, 2021 11:26 AM

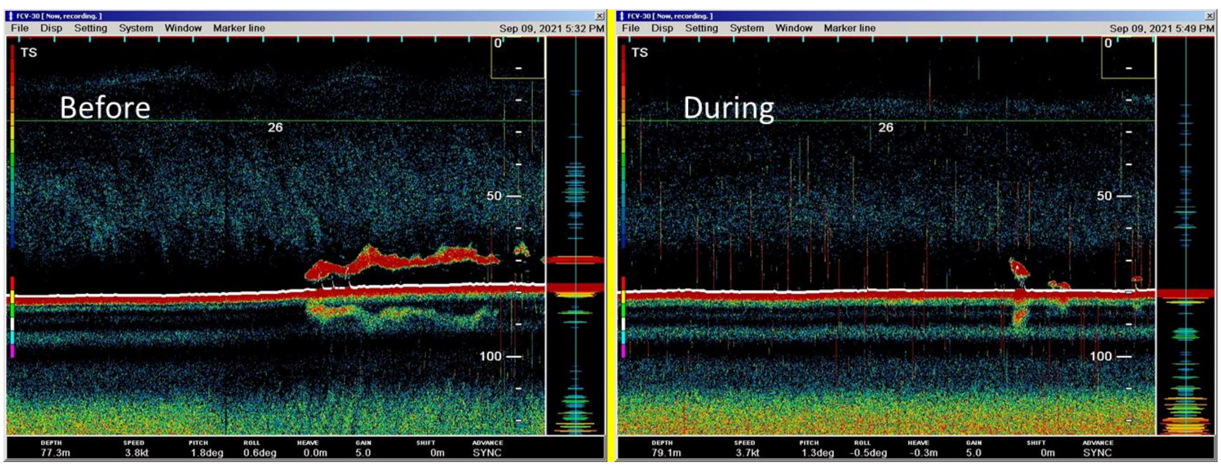
(c)


Before
Sep 08, 2021 6:43 PM
During
Sep 08, 2021 7:04 PM

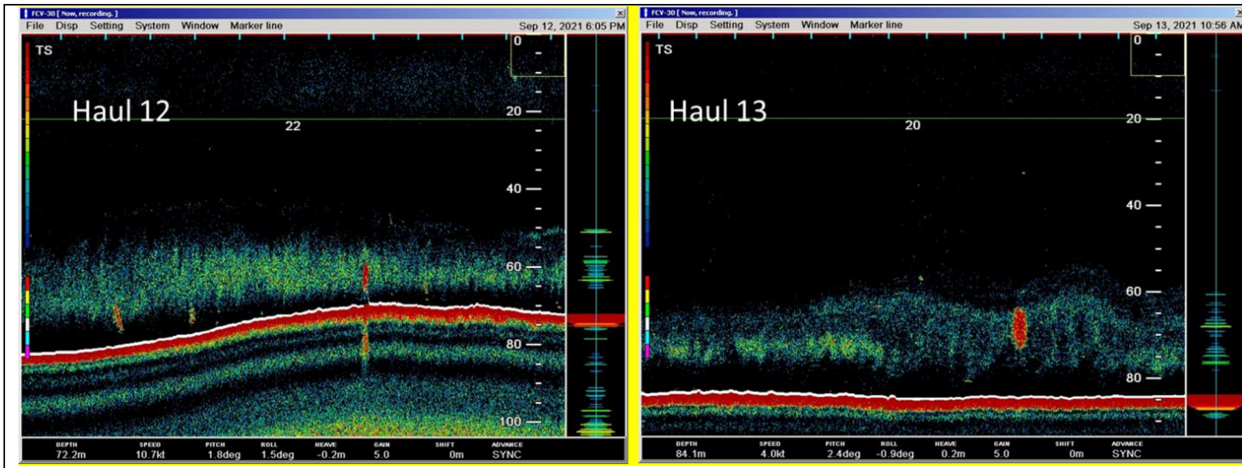
(d)


FCV-30 [Now, recording.]
File Disp Setting System Window Marker line
Sep 09, 2021 1:50 PM
TS
0
26
Before
50
100
DEPTH 88.0m
SPEED 9.9kt
PITCH 1.3deg
ROLL -2.6deg
HEAVE 0.0m
GAIN 5.2
SHIFT 0m
ADVANCE SYNC

(e)


File Disp Setting System Window Marker line
Sep 09, 2021 5:32 PM
TS
Before
26
50
100
DEPTH 77.3m
SPEED 3.8kt
PITCH 1.8deg
ROLL 0.6deg
HEAVE 0.0m
GAIN 5.0
SHIFT 0m
ADVANCE SYNC
File Disp Setting System Window Marker line
Sep 09, 2021 5:49 PM
TS
During
26
50
100
DEPTH 79.1m
SPEED 3.7kt
PITCH 1.3deg
ROLL -0.5deg
HEAVE -0.3m
GAIN 5.0
SHIFT 0m
ADVANCE SYNC

(f)



(g)

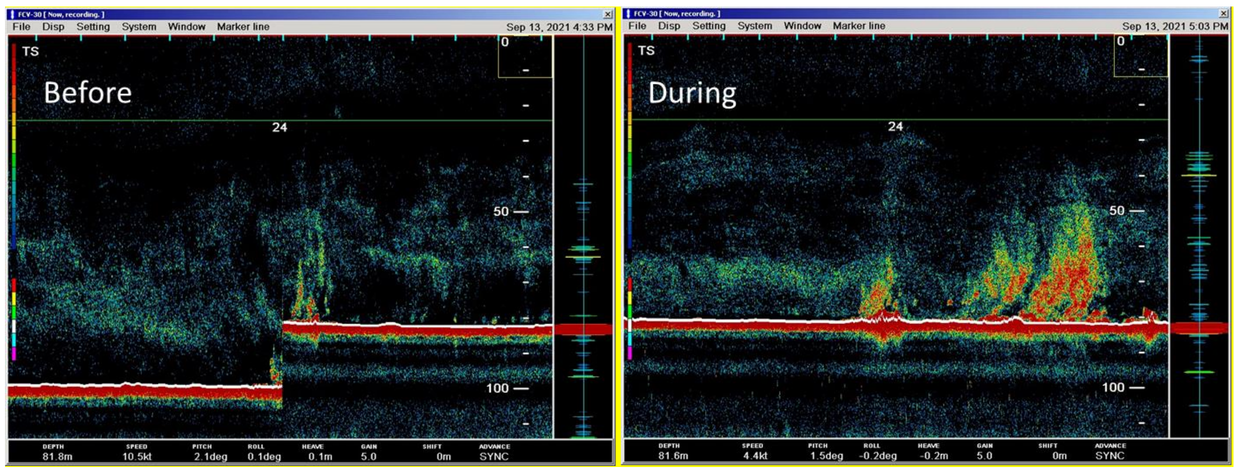
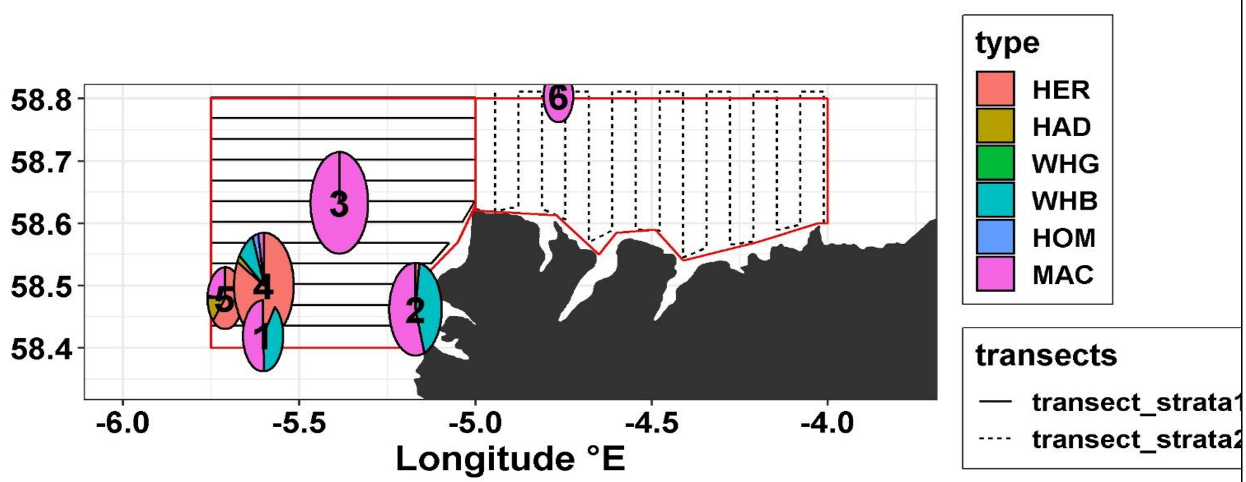


Figure 2.16. Echograms of sample hauls from Chris Andra. (a) Acoustic mark relative densities (b) haul 5 . (c) haul 6 (d) haul 8. (e) haul 9. (f) haul 12& 13 (g) haul 14

6aN acoustic marks recorded by Afrika

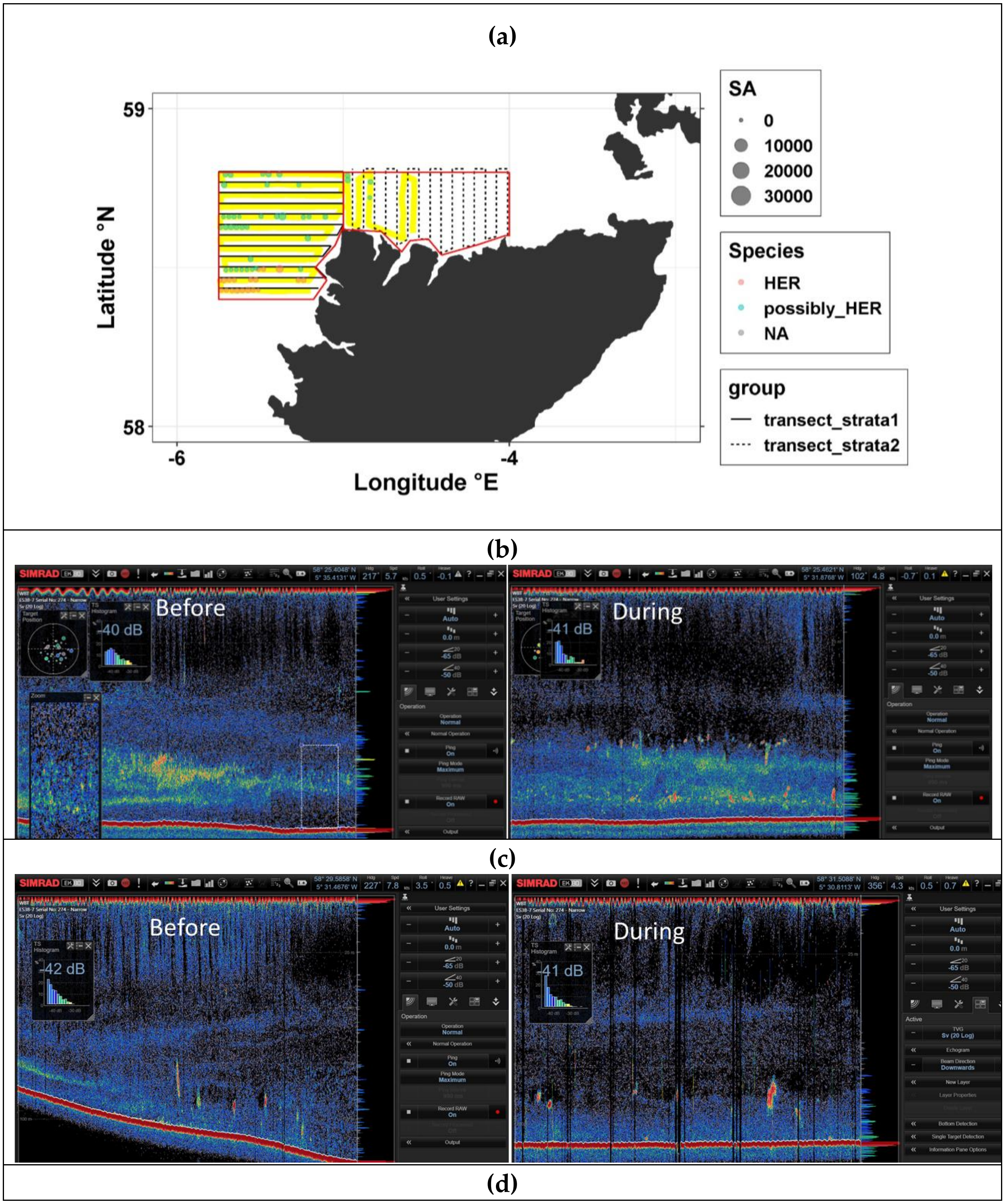
(a)

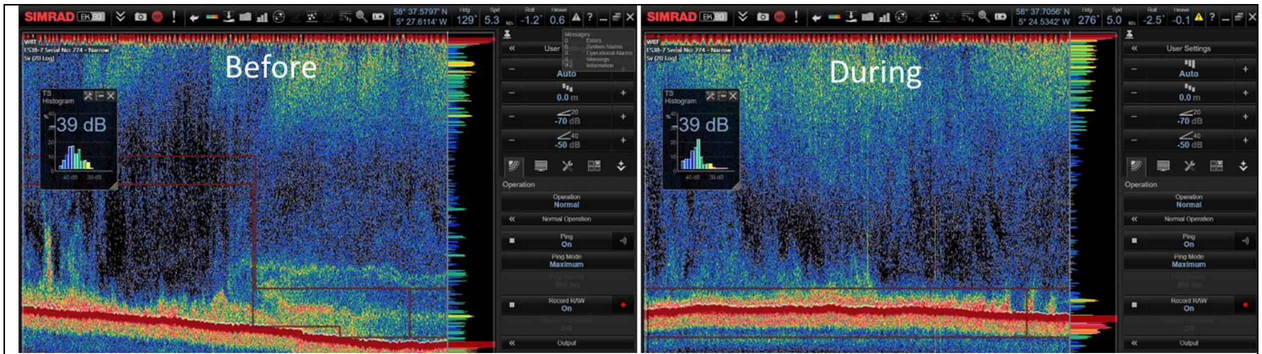


(b)

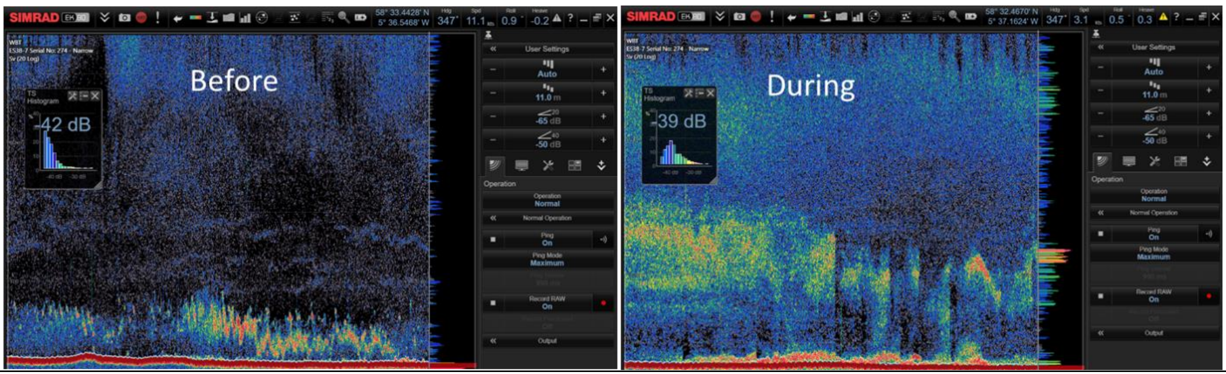
Haul	Date	HER	MAC	SPR	HOM	HAD	WHB	WHG	catch weight (t)
1	9/26/2021	10.0%	51.0%	0.0%	0.0%	0.0%	39.0%	0.0%	0.3
2	9/26/2021	2.1%	55.3%	0.0%	0.0%	0.0%	42.6%	0.0%	1.7
3	9/27/2021	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.476
4	9/29/2021	82.4%	3.2%	0.0%	3.2%	2.3%	9.0%	0.0%	4.8
5	9/30/2021	62.1%	23.7%	0.0%	0.0%	12.9%	0.0%	1.3%	0.144
6	9/30/2021	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.066

Figure 2.17. biological sampling by Afrika. Location and species composition of catches.


(a)
59
58
Latitude °N
-6
-4
Longitude °E
SA
0
10000
20000
30000
Species
HER
possibly_HER
NA
group
transect_strata1
transect_strata2
(b)
SIMRAD
Before
-40 dB
During
-41 dB
(c)
SIMRAD
Before
-42 dB
During
-41 dB
(d)



(e)



(f)

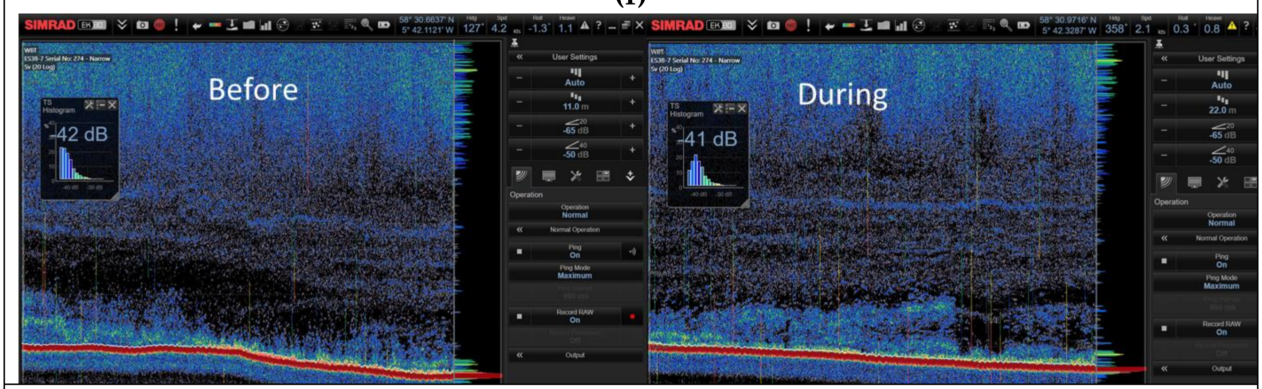
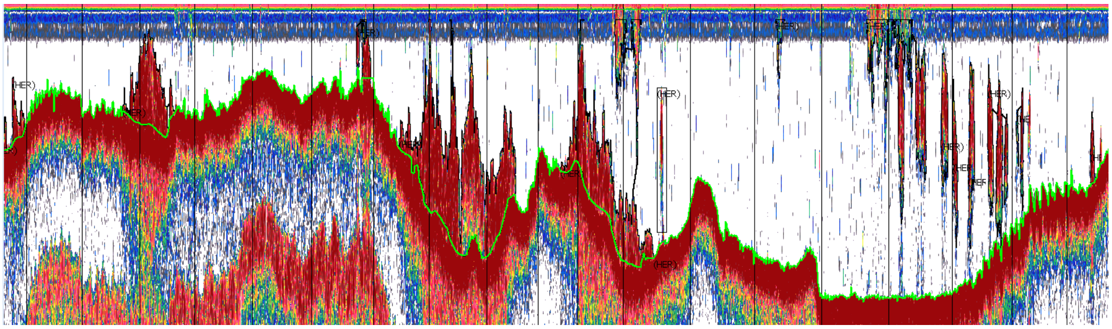


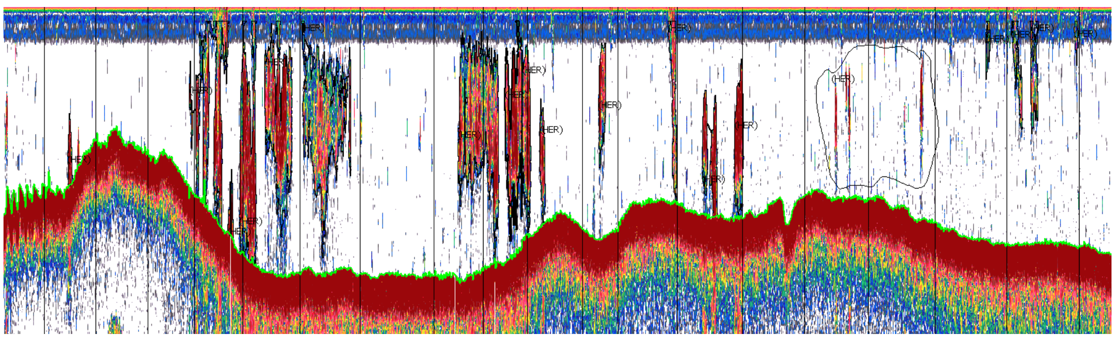
Figure 2.18. Echograms of sample hauls from Afrika. (a) Acoustic marks relative densities (b) haul 1 . (c) haul 2. (d) haul 3. (e) haul 4. (f) haul 5.

6aS/7b acoustic marks

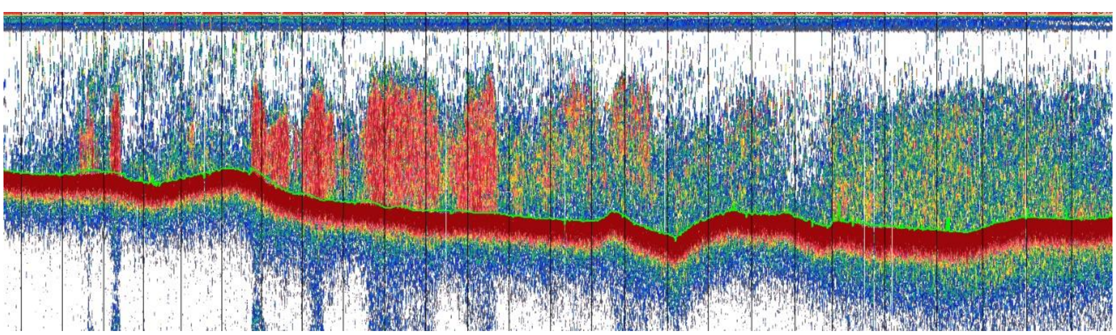
(a)



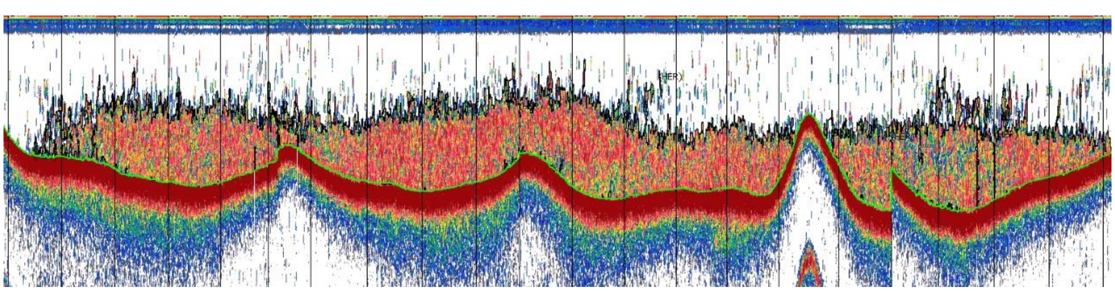
(b)



(c)



(d)



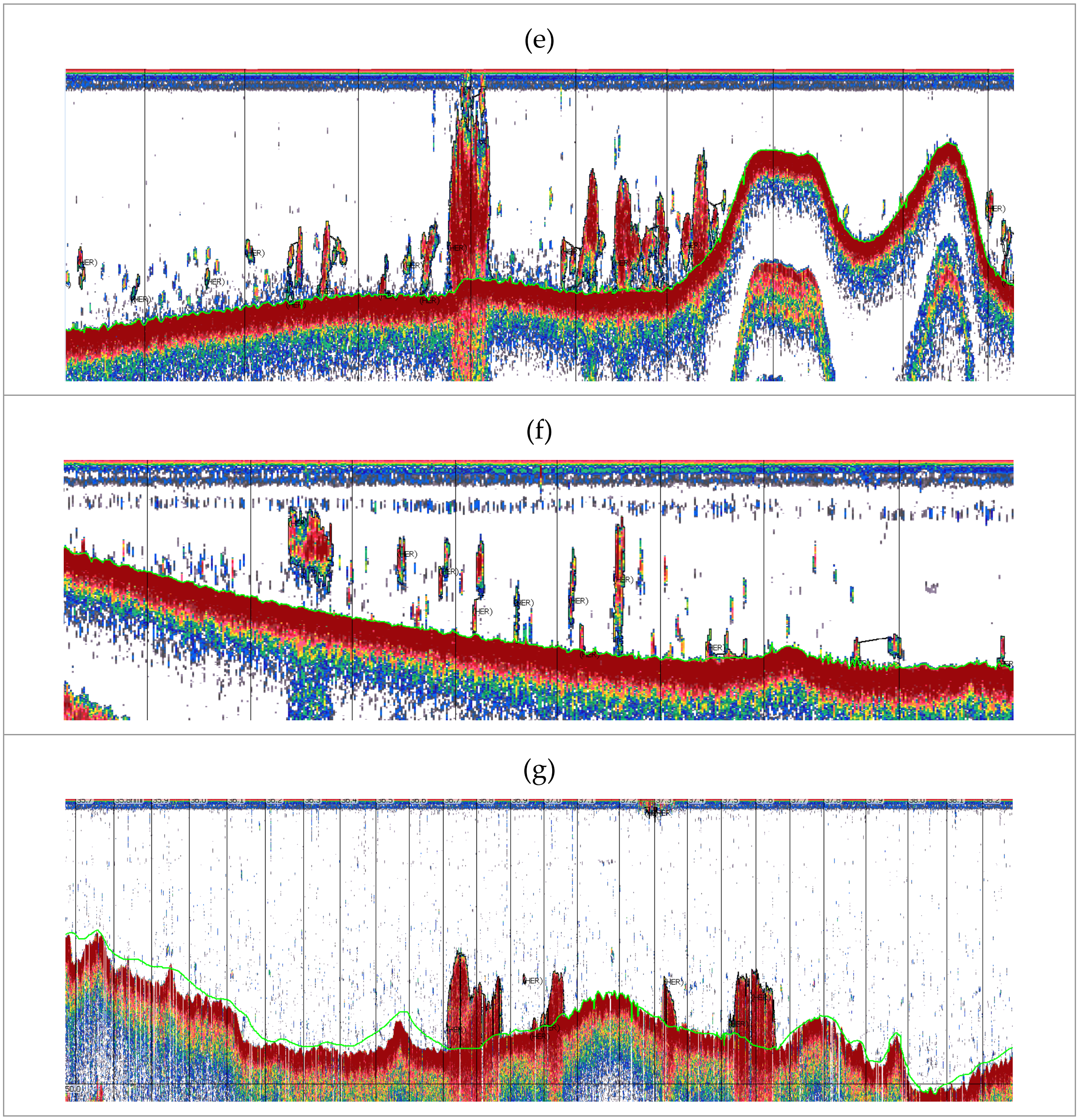


Figure 2.19. (a) 6aS/7b industry acoustic survey on 03/12/2021: A series of very strong herring marks (38 kHz) in Lough Foyle, Co. Donegal (ICES area 6aS). Water depth max ~ 15m approximately. (b) 6aS/7b industry acoustic survey on 03/12/2021: A series of very strong herring marks (38 kHz) midwater in Lough Foyle, Co. Donegal (ICES area 6aS). Water depth max ~ 15m approximately. (c) 6aS/7b industry acoustic survey on 02/12/2021: A series of strong herring marks (38 kHz) midwater in Lough Swilly, Co. Donegal (ICES area 6aS). Water depth max ~ 25m approximately. (d). 6aS/7b industry acoustic survey on 02/12/2021: A continuous strong herring aggregation (38 kHz) for miles in Lough Swilly, Co. Donegal (ICES area 6aS). Water depth max ~ 18m approximately. (e) 6aS/7b industry

acoustic survey on 17/12/2021: A series of strong herring marks (38 kHz) in Bruckless Bay, Co. Donegal (ICES area 6aS), close to a mussel farm. Water depth max ~ 20m approximately. (f) 6aS/7b industry acoustic survey on 16/12/2021: Herring marks (38 kHz) in midwater in Inver Bay, Co. Donegal (ICES area 6aS). Water depth max ~ 15m approximately. (g) 6aS/7b industry acoustic survey on 17/12/2021: A series of strong herring marks (38 kHz) tight to the bottom in Fintra/Teelin Bay strata (SE Inishduff and south of Drumanoo Head - ICES area 6aS). Water depth max ~ 45m 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.

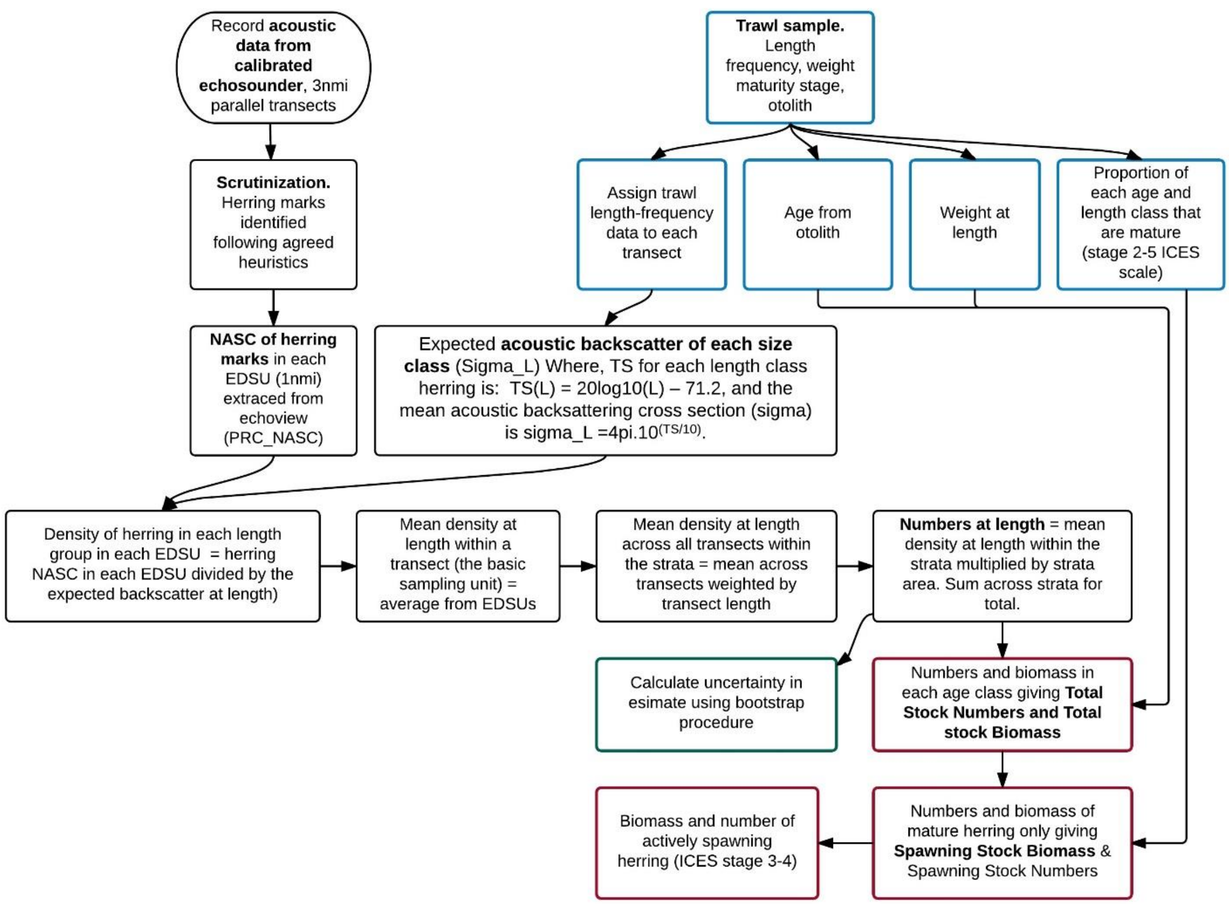


Figure 2.20. Flow diagram of the analysis methods to estimate abundance and biomass. Blue boxes – biological data; black boxes – treatment of acoustic data; red boxes- derived abundances indices; green box – uncertainty estimates

The StoX software (Johnsen et al, 2019)[2] (version 3.1.0 (http://www.imr.no/forskning/prosjekter/stox/nb-no) 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 carried out according to the stratified transect design model developed by Jolly and Hampton (1990). Coefficient of variance (CV) estimates of biomass and abundance for the survey strata and the overall strata areas combined were generated using the RStox framework package (version 3.1.0).

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 (Figure 2.6). In 6aS/7b, 6 core strata were defined in 2020 (Figure 2.7).
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. In 2021 the decision was made to use the Afrika acoustic data and a combination of Afrika and Chris Andra biological samples. This rationale for this was (i) to maintain consistency in acoustic data (following some concern over comparability between Chris Andra FCV-30 and Afrika EK80 acoustic data), (ii) to utilise the more extensive sampling from Chris Andra and avoid overinflation of young ages in S2 from applying poor samples from Afrika in S1 – noting that comparison of the good samples from both vessels showed very similar age distribution, (iii) the results that independent abundance estimates were very similar, so the final estimate would fall close anyway.
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)

[2] http://www.imr.no/forskning/prosjekter/stox/nb-no

relationship used to calculate the mean acoustic backscattering cross-sections for herring is:

$$TS = 20\log10\ (L) – 71.2 \quad [\text{at } 38 \text{ kHz}]\ \textit{for herring}$$

$$TS = 20\log10\ (L) – 67.5 \quad [\text{at } 38 \text{ kHz}]\ \textit{for horse mackerel}$$

$$TS = 20\log10\ (L) – 76 \text{ dB} \quad [\text{at } 120 \text{ kHz}]\ \textit{for herring}$$

and the mean acoustic backscattering cross section is:

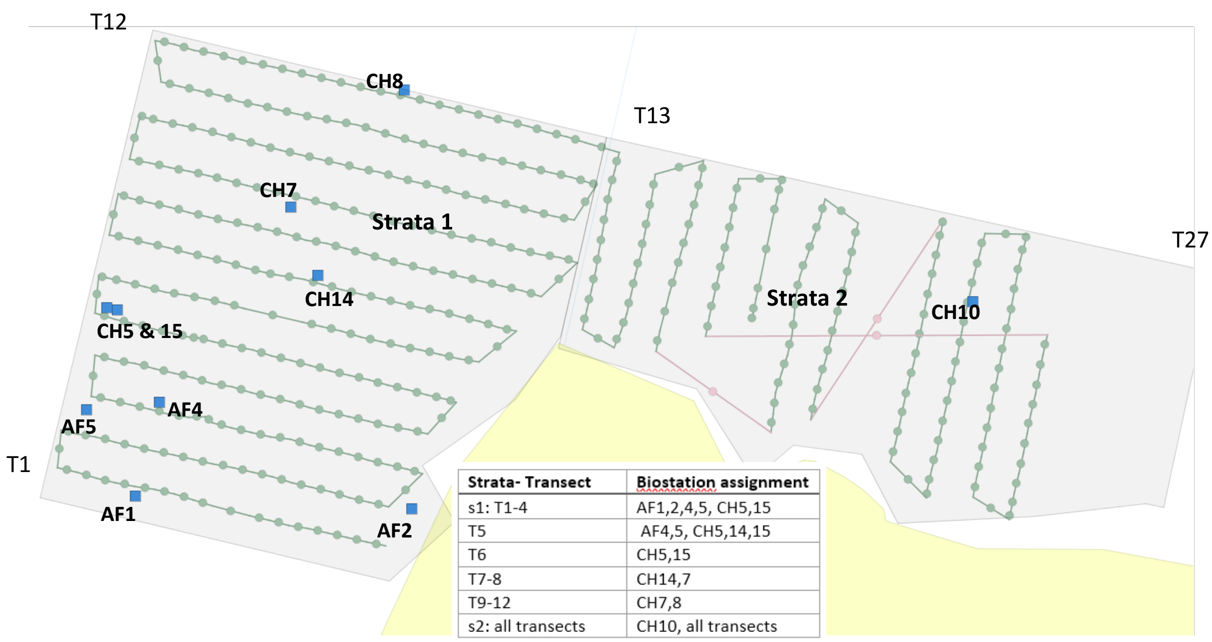
$$\sigma_{sp} = 4\pi.10^{(TS/10)}$$

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). 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).

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.



Strata- Transect	Biostation assignment
s1: T1-4	AF1,2,4,5, CH5,15
T5	AF4,5, CH5,14,15
T6	CH5,15
T7-8	CH14,7
T9-12	CH7,8
s2: all transects	CH10, all transects

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 6-29th September, making a total of 23 hauls (18 Chris Andra, 5 Afrika) for biological sampling resulting in biological information collected from a total of 525 herring.

Length distributions of herring from both vessels revealed similar size distributions found across all samples (Figure 3.1, 3.2), with a good spread of sizes and ages recorded (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. Spawning ready herring were recorded and genetic samples taken to inform the genetic baseline (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.

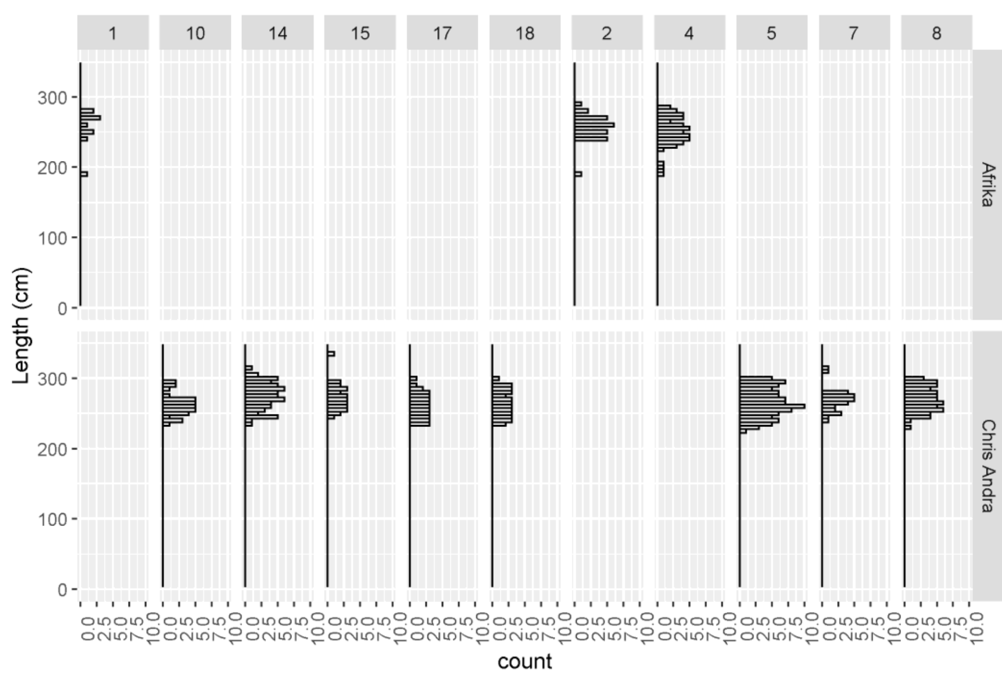


Figure 3.1. Herring length frequencies for the sample hauls taken by the Chris Andra and Afrika.

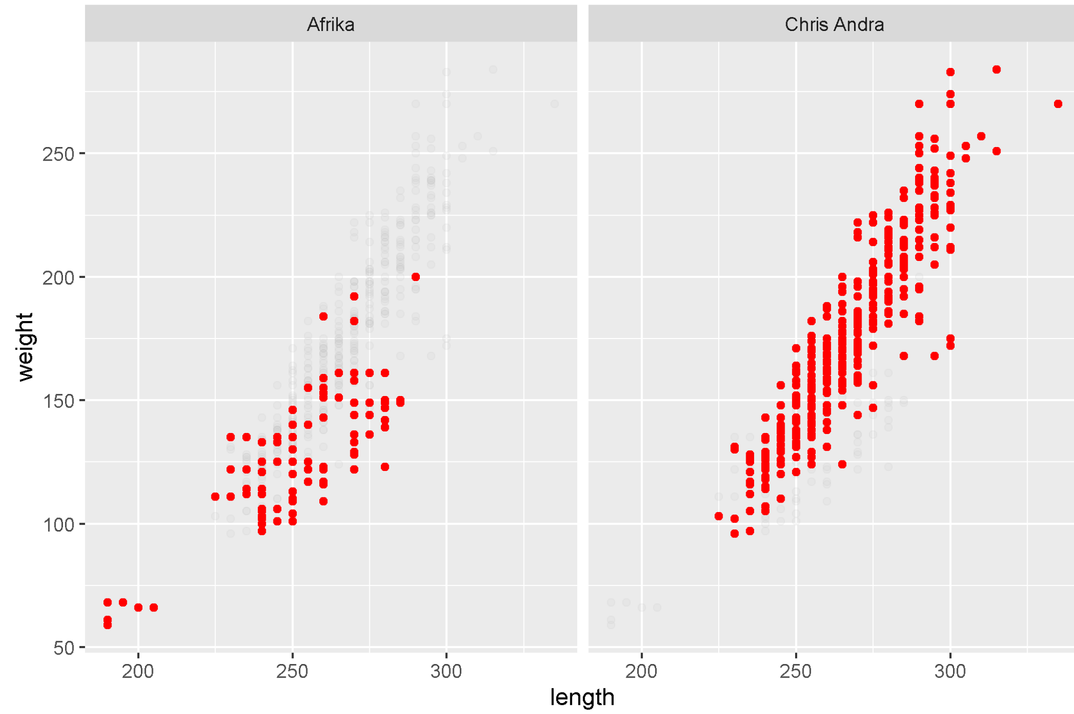


Figure 3.2. Herring weight length for the sample hauls taken by the Chris Andra and Afrika. Red circle markers are data from each individual surveys and grey circle markers are those combined for both surveys.

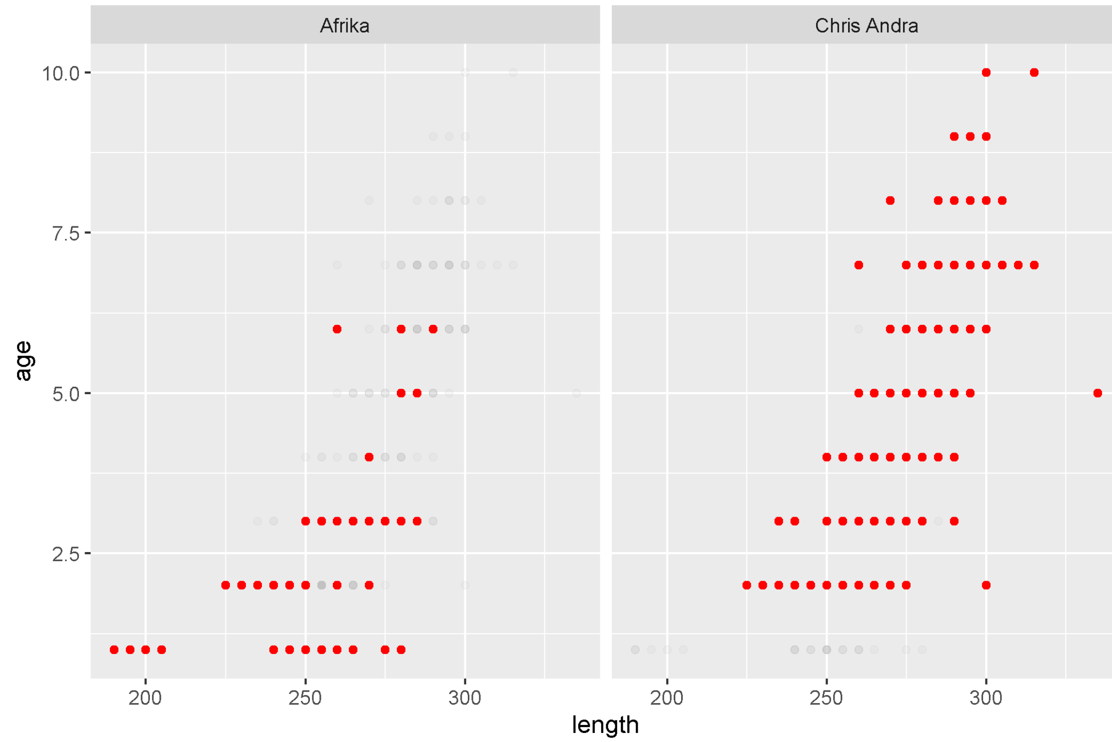


Figure 3.3. Herring age length keys for the sample hauls taken by the Chris Andra and Afrika. Red circle markers are data from each individual surveys and grey circle markers are those combined for both surveys

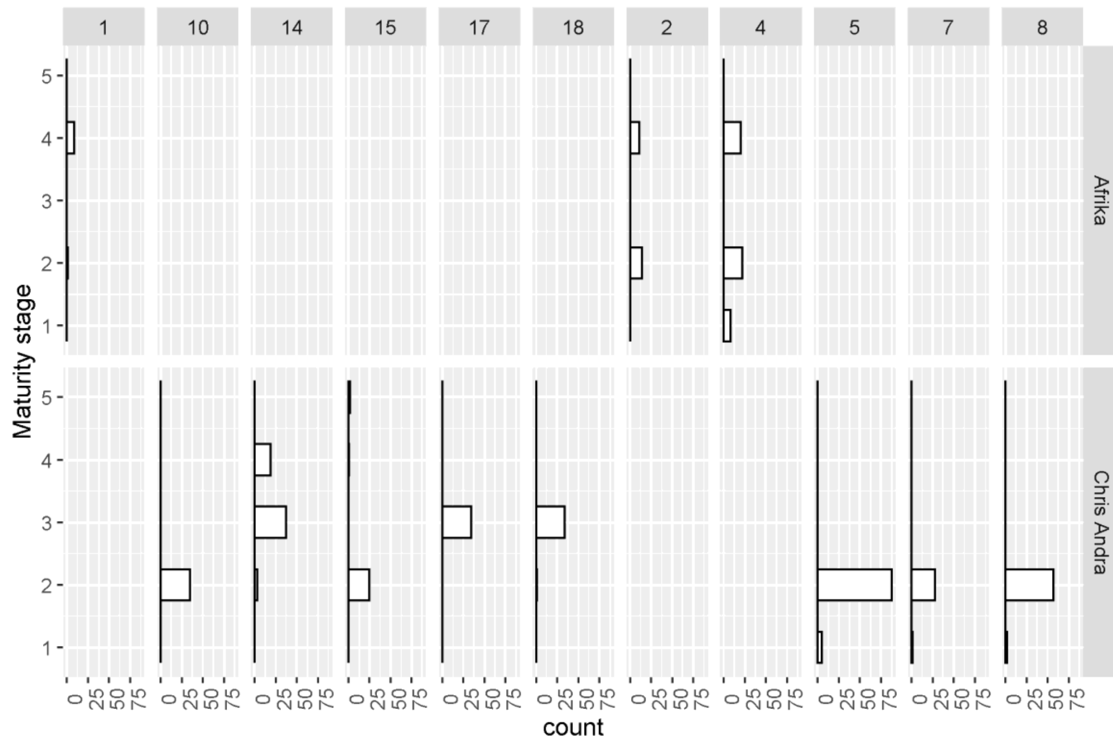


Figure 3.4. Herring maturity scales for the sample hauls taken by the Chris Andra and Afrika. Individuals with maturity stages 3 and 4 are considered spawners.

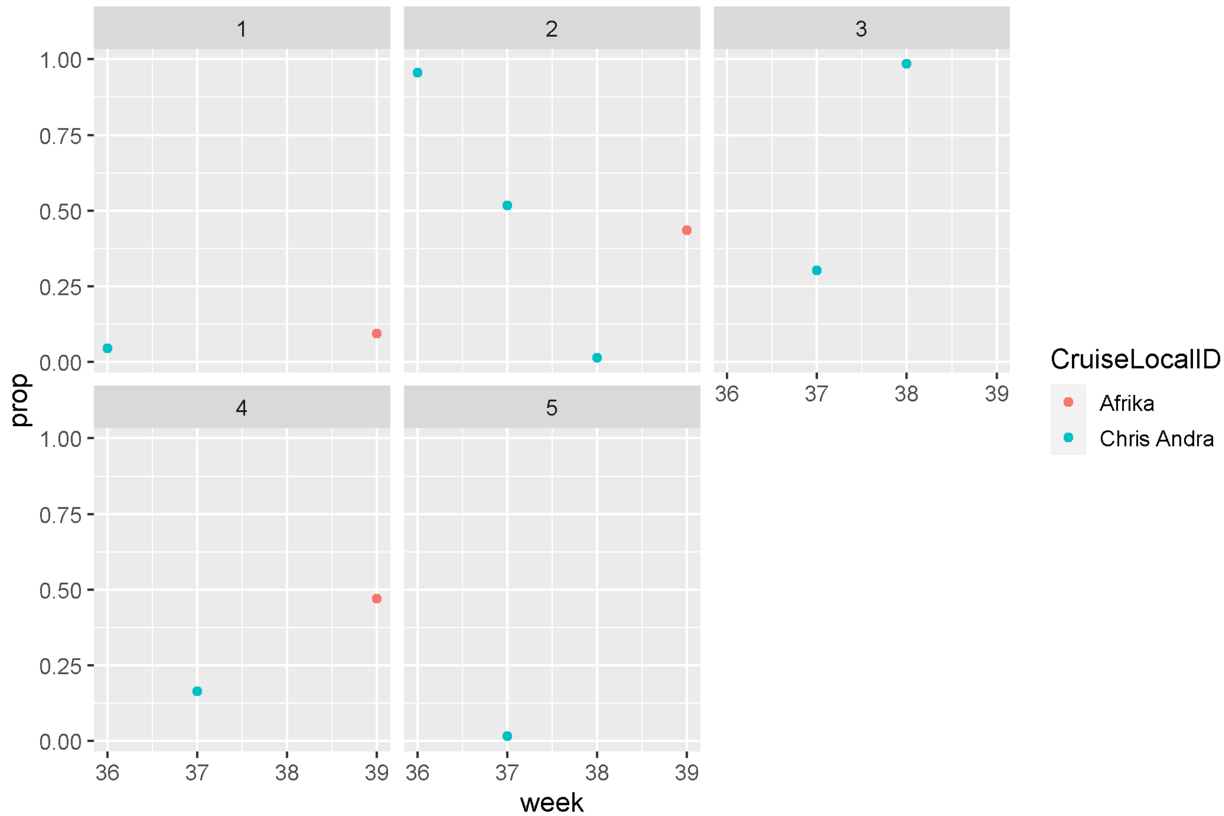


Figure 3.5. Proportion of maturity stage by date. Maturity stage 3 refers to spawning herring.

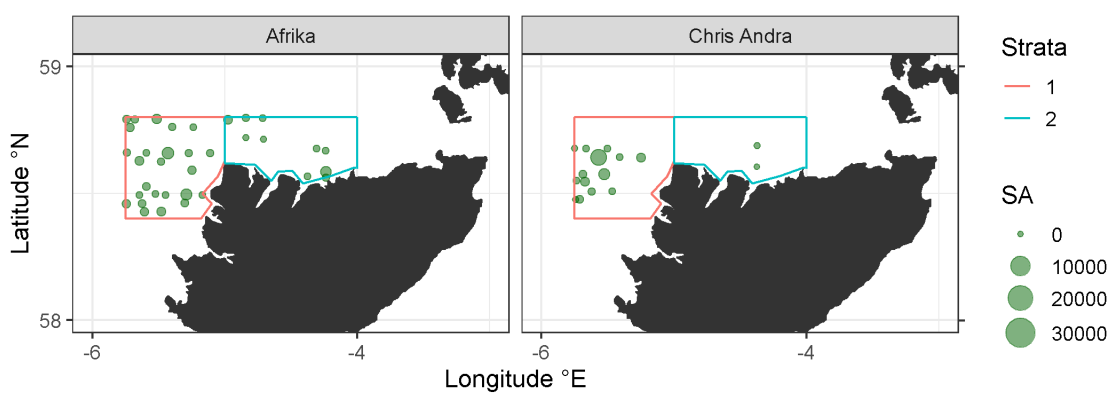


Figure 3.6. Maps of relative acoustic density in the two surveys.

Table 3.1. Haul information and catch composition for hauls relevant to the analysis of the acoustic surveys in 6aN.

				Position		**Catch (kg)**								
name	haul	date	haultype	plot_lon	plot_lat	HER	MAC	HOM	WHG	HAD	NOP	SPR	WHB	Jelly
Chris Andra	1	07/09/2021	S	-5.48	58.43									
	2	07/09/2021	S	-5.25	58.45		8	1		1				15
	3	07/09/2021	S	-5.70	58.53		18			0	0	0		10
	4	08/09/2021	S	-5.73	58.57	35	1	5		0				0
	5	08/09/2021	S	-5.70	58.57	277	12	1710					1	0
	6	08/09/2021	S	-5.32	58.65	0	41				2			54
	7	09/09/2021	S	-5.47	58.68	5	4	3						5
	8	09/09/2021	S	-5.33	58.80	10				14				25
	9	09/09/2021	S	-6.03	58.75	0	4				3			12
	10	11/09/2021	S	-4.37	58.73	6	33		0	52				1
	11	12/09/2021	S	-4.17	58.80		68	4						
	12	12/09/2021	S	-5.45	58.77		34							3
	13	13/09/2021	S	-5.38	58.70		90				1			
	14	13/09/2021	S	-5.40	58.63	2915	85							
	15	14/09/2021	S	-5.72	58.57	54	4		2	7				
	16	15/09/2021	S	-5.45	58.40	2	15	3	0	6	1			
	17	19/09/2021	C	-4.17	58.80	53051								
	18	20/09/2021	C	-4.17	58.80	17684								
Afrika	25	26/09/2021	S	-5.52	58.42	29	143						114	
	26	26/09/2021	S	-5.52	58.53	165	824						659	
	27	27/09/2021	S	-5.48	58.62		3472							
	28	29/09/2021	S	-5.62	58.55	4842	312	21	44	88			935	
	29	30/09/2021	S			120				22				

3.1.2 Sampling statistics 6aS/7bc

Approximately 300nmi of survey track were completed successfully over six surveys in the core areas. 161 nmi of survey tracks encompassing 102 individual transects were used in the analysis (Table 10). 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 (Figure 3). There were 6 strata areas selected for survey abundance estimation (Lough Swilly, Lough Foyle, Bruckless Bay, Inver Bay, Fintra Bay, and Teelin Bay). This resulted in a total area coverage of approximately 65.04 nmi² (2020 = 66.26 nmi²). A total of 16 biological samples were obtained from commercial tows on herring during the fishery).

Maps of the survey tracks, relative acoustic density, and locations of hauls that were used to determine biological parameters for the estimation of the biomass of herring in 6aS, 7b are shown in Figure 3.7-3.10, Table 3.2 & 3.3.

The location of hauls and samples from the fishery is shown in Figure 3.7. The monitoring fishery in 6aS/7b began in early November and continued throughout the survey period. Most of the fishing activity was inshore in shallow water. The samples from the fishery were deemed appropriate and were of sufficient quality to be used in the survey estimates

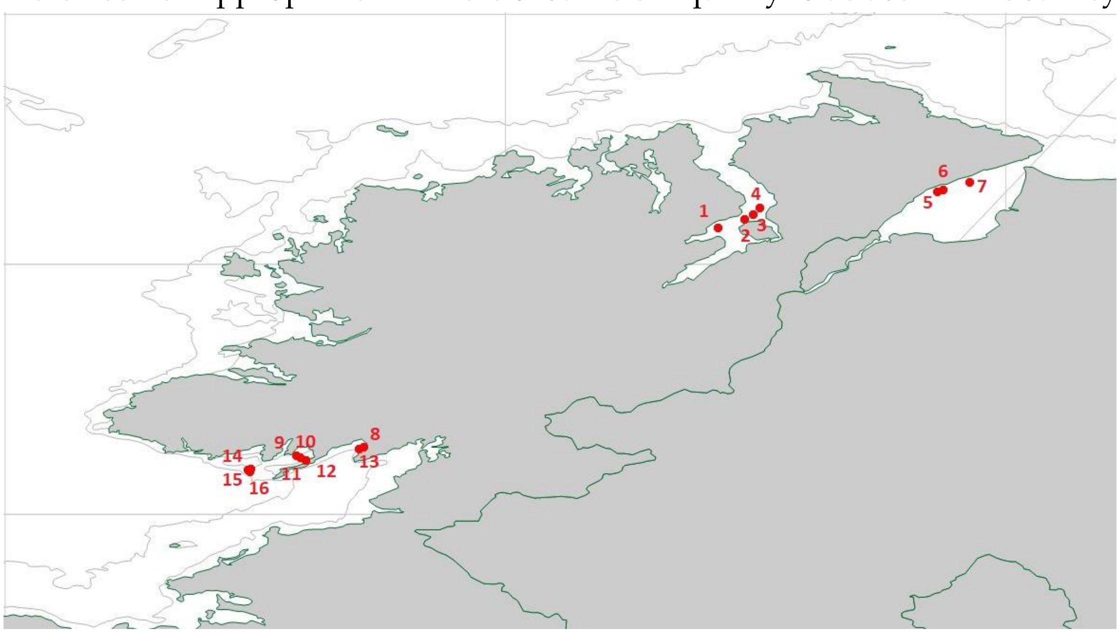
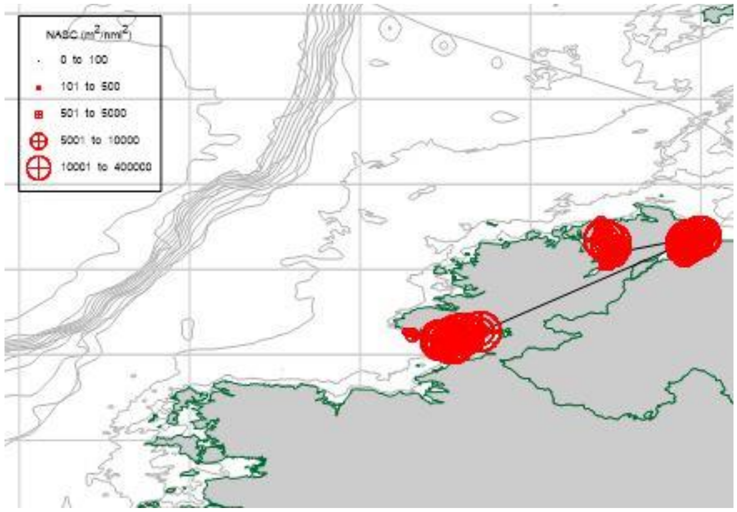
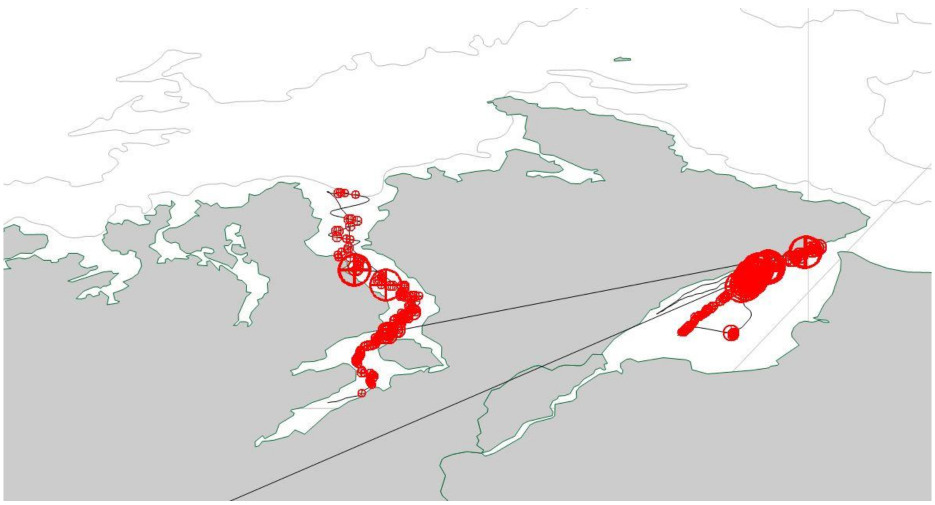
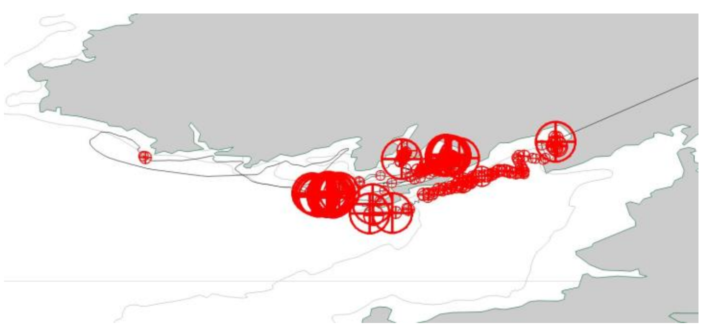


Figure 3.7. 6aS/7b industry acoustic survey in 2021: distribution of biological samples from the monitoring fishery (1-16).





Lough Swilly and Lough Foyle



Fintra Bay, Teelin Bay, Bruckless Bay and Inver Bay

Figure 3.8a. 6aS/7b industry acoustic survey in 2021: distribution of NASC (m^2/nmi^2) allocated to herring. The 6 core areas in 2020 included: Lough Swilly, Lough Foyle, Bruckless Bay, Fintra Bay, Inver Bay and Teelin Bay.

Table 3.2. 6aS/7b industry acoustic survey in 2021: details and number of biological samples from the hauls used in the survey estimates.

Haul no.	Date	ICES area	Ground	Measured	Otoliths	Gear
1	09/11/2021	6aS	Lough Swilly	322	58	Single trawl
2	09/11/2021	6aS	Lough Swilly	333	57	Pair trawl
3	09/11/2021	6aS	Lough Swilly	201	48	Pair trawl
4	23/11/2021	6aS	Lough Swilly	350	57	Single trawl
5	24/11/2021	6aS	Lough Foyle	328	193	Single trawl
6	29/11/2021	6aS	Lough Foyle	163	54	Single trawl
7	29/11/2021	6aS	Lough Foyle	334	70	Single trawl
8	05/12/2021	6aS	Inver Bay	283	51	Ring net
9	12/12/2021	6aS	Bruckless Bay	312	51	Pair trawl
10	13/12/2021	6aS	Bruckless Bay	294	60	Single trawl
11	13/12/2021	6aS	Bruckless Bay	306	52	Pair trawl
12	14/12/2021	6aS	Bruckless Bay	334	55	Single trawl
13	16/12/2021	6aS	Inver Bay	312	55	Pair trawl
14	20/12/2021	6aS	SE Inishduff	288	49	Pair trawl
15	20/12/2021	6aS	SE Inishduff	329	55	Pair trawl
16	20/12/2021	6aS	SE Inishduff	343	57	Pair trawl

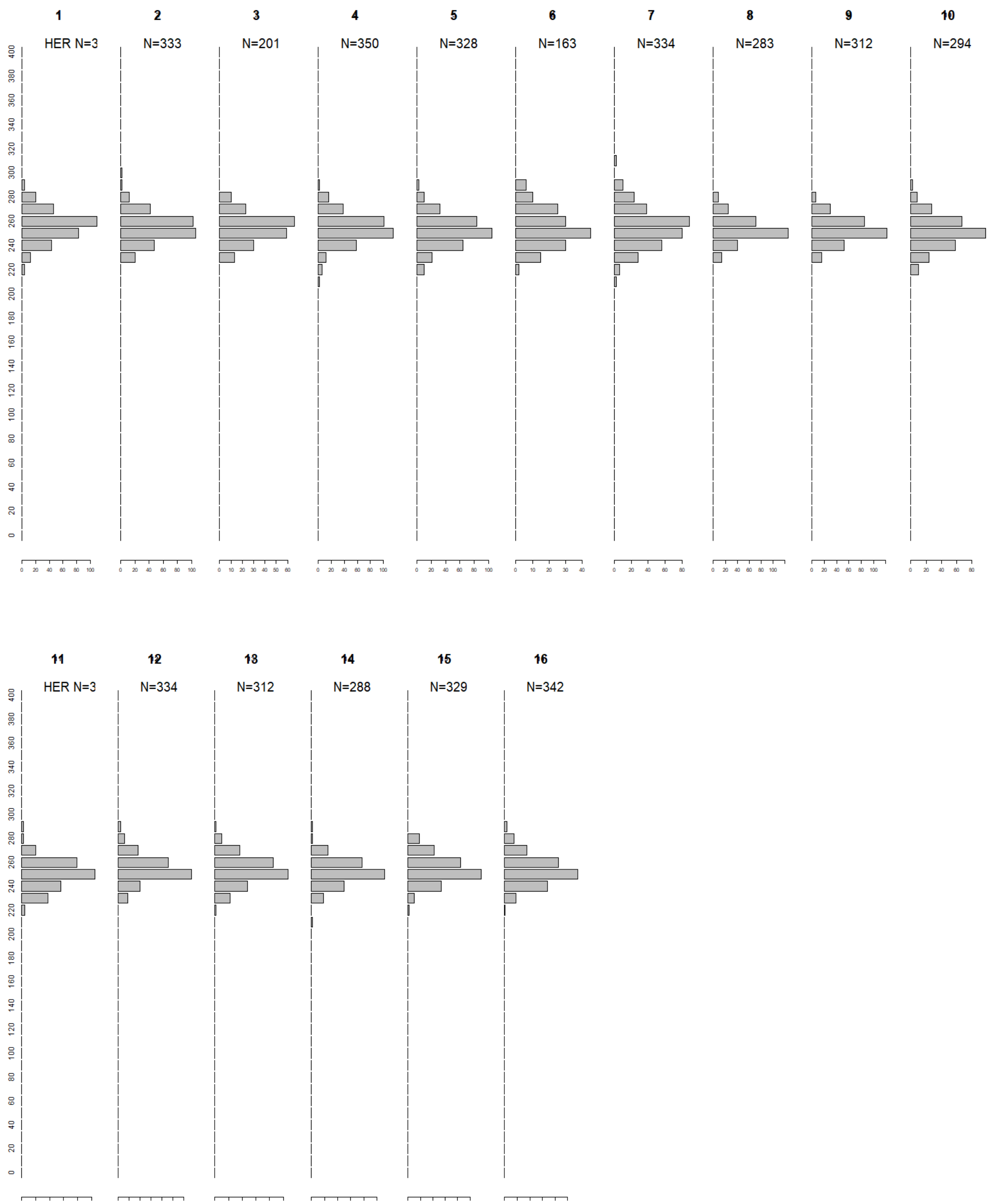


Figure 3.9a. 6aS/7b industry acoustic survey in 2021: relative length (cm) frequency distributions of herring in each haul that contained herring.

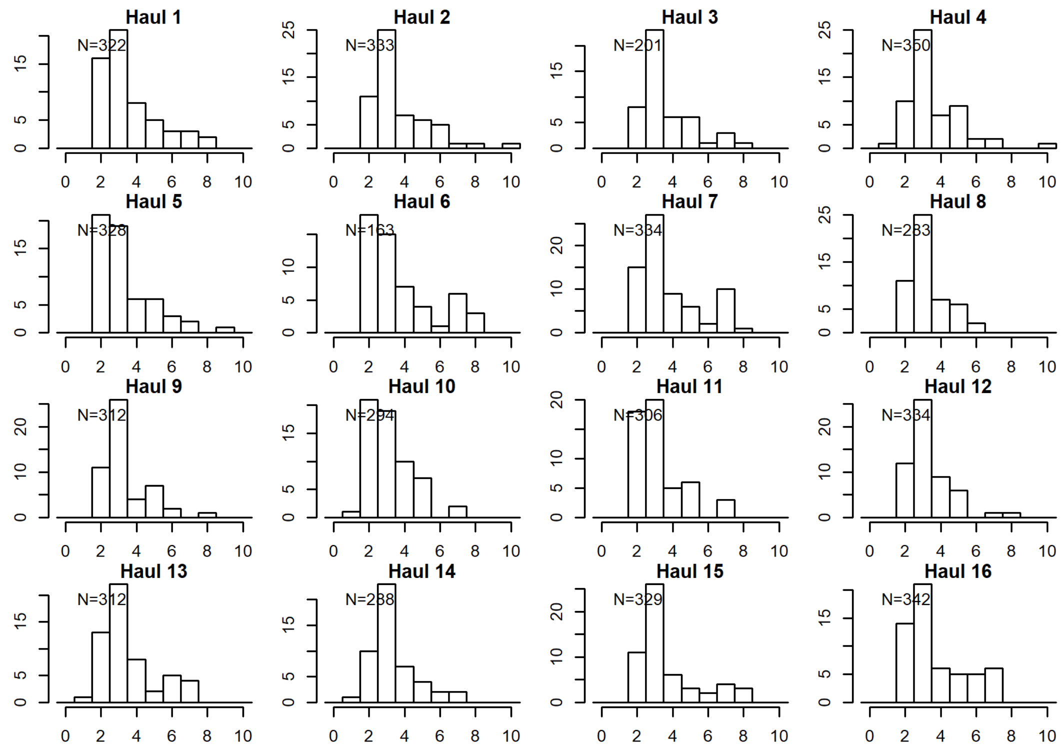


Figure 3.9b. 6aS/7b industry acoustic survey in 2021: relative age (-wr) frequency distributions of herring in each haul.

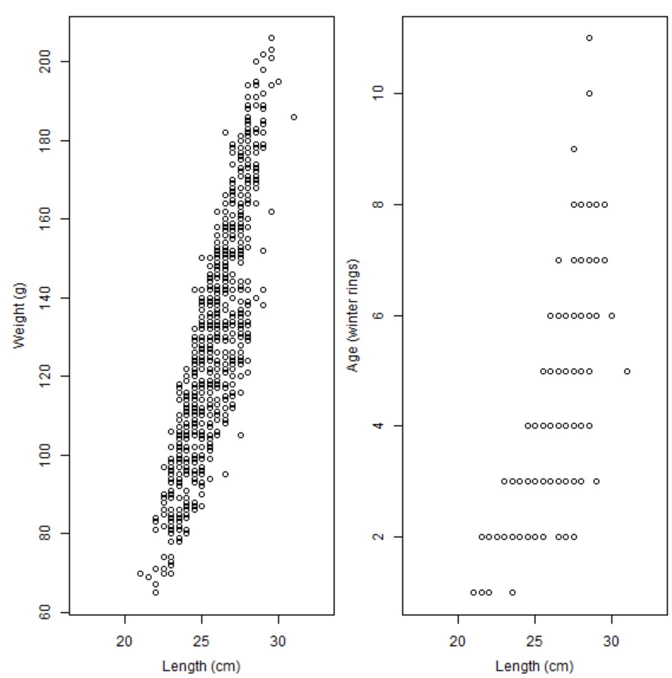


Figure 3.10. 6aS/7b industry acoustic survey in 2021: weight at length and age at length of herring.

The 2- and 3-winter ring (-wr) age class of herring accounted for 74% of the overall numbers (2-wr ~ 18% and 3-wr ~56%) in 2021 (Table 3.3a). This follows on from 2020 when 54% of the overall numbers were 2-wr (32%) and 3-wr (22%). The 1-wr age class of herring were found in very low numbers (< 1%). The 4-wr in 2021 made up 13% of the numbers, followed by 5-wr fish at 6%. The relatively strong 6-wr age class that showed in 2020 at 12%, is still showing a slight peak, but was only 3% in 2021. Maturity at age for 6aS/7b herring is shown in Table 3.3b. Approximately 81% of 1-wr herring were immature, but 1-wr herring were found in low numbers in 2021. 1.4% 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 2021: relative age (wr) distribution for 6aS/7b herring in 2020.

Age (winter rings)	*Relative age distribution (%)* *Herring*
0	**0.00**
1	**0.19**
2	**17.59**
3	**56.37**
4	**12.79**
5	**6.06**
6	**2.96**
7	**3.16**
8	**0.74**
9	**0.08**
10	**0.03**
11	**0.02**

Table 3.3b. 6aS/7b industry acoustic survey in 2021: maturity at age for 6aS/7b herring in 2020.

Age (winter rings)	*Immature (%)*	*Mature (%)*
0	100	0
1	81.2	18.8
2	1.4	98.6
3	0	100
4	0	100
5	0	100
6	0	100
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 2021 results

Results pertain to the combined analyses where Afrika and Chris Andra biological samples were applied to the analysis of acoustic data from Afrika (see section 2.2.6.2).

A summary table for the 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 were better than previous years indicating better sampling, particularly in Strata 1 (Figure 3.19).

Table 3.4. Combined results for all strata covered in 2021. (Figures in bold are weighted averages based on the numbers in each age group).

Results for all strata combined 2021					
Age (ring)	Numbers (mill)	Biomass (kt)	Maturity	Mean Weight (g)	Mean Length (cm)
0	0	0.0			
1	4	0.5	0.86	120.5	24.4
2	16	2.3	0.98	142.7	25.3
3	13	2.1	1.00	170.4	26.9
4	2	0.3	1.00	174.9	26.9
5	2	0.4	1.00	188.2	27.6
6	3	0.6	1.00	211.0	28.7
7	3	0.6	1.00	209.9	28.7
8	0	0.1	1.00	219.6	29.0
9+	0.5	0.1	1.00	240.8	30.2
Immature	1	0.092		94.2	22.0
Mature	42	7		164.0	26.5
Spawning	2	0			
unknown	0	0			
Total	43	**7.01**	0.98	**162.4**	26.4

Table 3.5. Strata summary 2021

	Strata summary 2021				
Strata	**Abundance (mill)**	**Biomass (kt)**	**Mean length (cm)**	**Mean weight (g)**	**% Mature**
Strata 1	30	4.8	26.5	161.8	0.97
Strata 2	13.3	2.2	26.1	163.8	1.00
TOTAL	43	7.01			

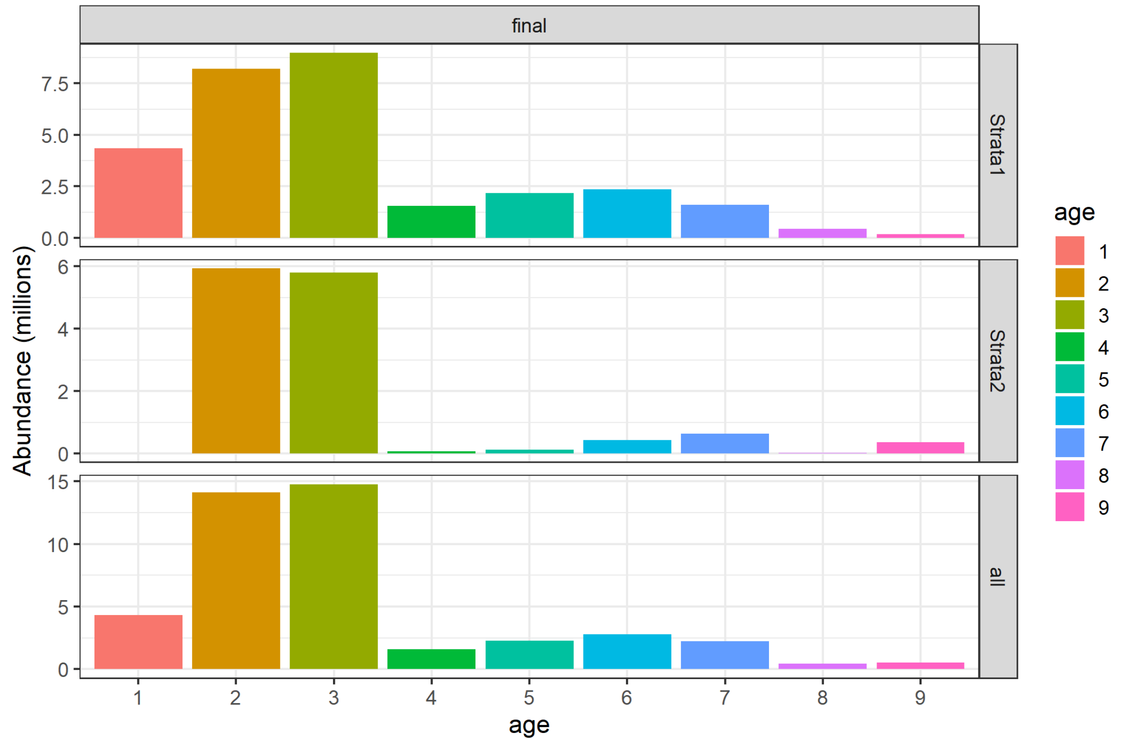


Figure 3.11. Combined abundance at age and per strata for 2021.

Table 3.6. Summary CV estimates for survey areas in 2021.

Ton by stratum	Ton.5%	Ton.50%	Ton.95%	Ton.mean	Ton.sd	Ton.cv
Strata1	2116	4551	6916	4534	1445	0.32
Strata2	505	2087	4590	2245	1305	0.58
Total number by stratum (mill)	**Ab.Sum.5%**	**Ab.Sum.50%**	**Ab.Sum.95%**	**Ab.Sum.mean**	**Ab.Sum.sd**	**Ab.Sum.cv**
Strata1	13381475	28051923	42505809	28099302	8722763	0.31
Strata2	3086283	12748278	28020869	13715250	7974065	0.58
Ton by survey	**Ton.5%**	**Ton.50%**	**Ton.95%**	**Ton.mean**	**Ton.sd**	**Ton.cv**
	2612	5923	10738	6189	2447	0.40
Total number by survey (mill)	**Ab.Sum.5%**	**Ab.Sum.50%**	**Ab.Sum.95%**	**Ab.Sum.mean**	**Ab.Sum.sd**	**Ab.Sum.cv**
	16623797	36552112	65509337	38207441	14856652	0.39

3.2.1.2 *Historical perspective on 6aN*

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 that was evaluated in the benchmark assessment in February 2022 (REF).

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).

All acoustic data from 2016-2021 pertaining to Strata 1 and 2 was analysed to provide acoustic indices for the 6a7bc herring benchmark (Mackinson and Berges 2022).

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)

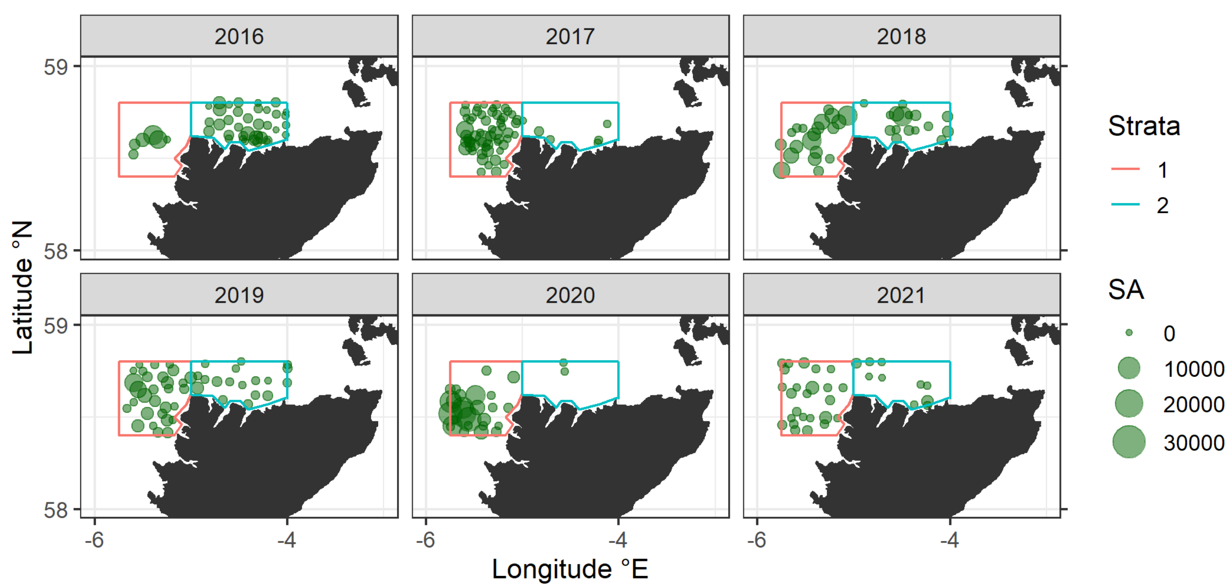


Figure 3.13. Herring acoustic density distribution (NASC) for the surveys in 6aN from 2016 to 2021.

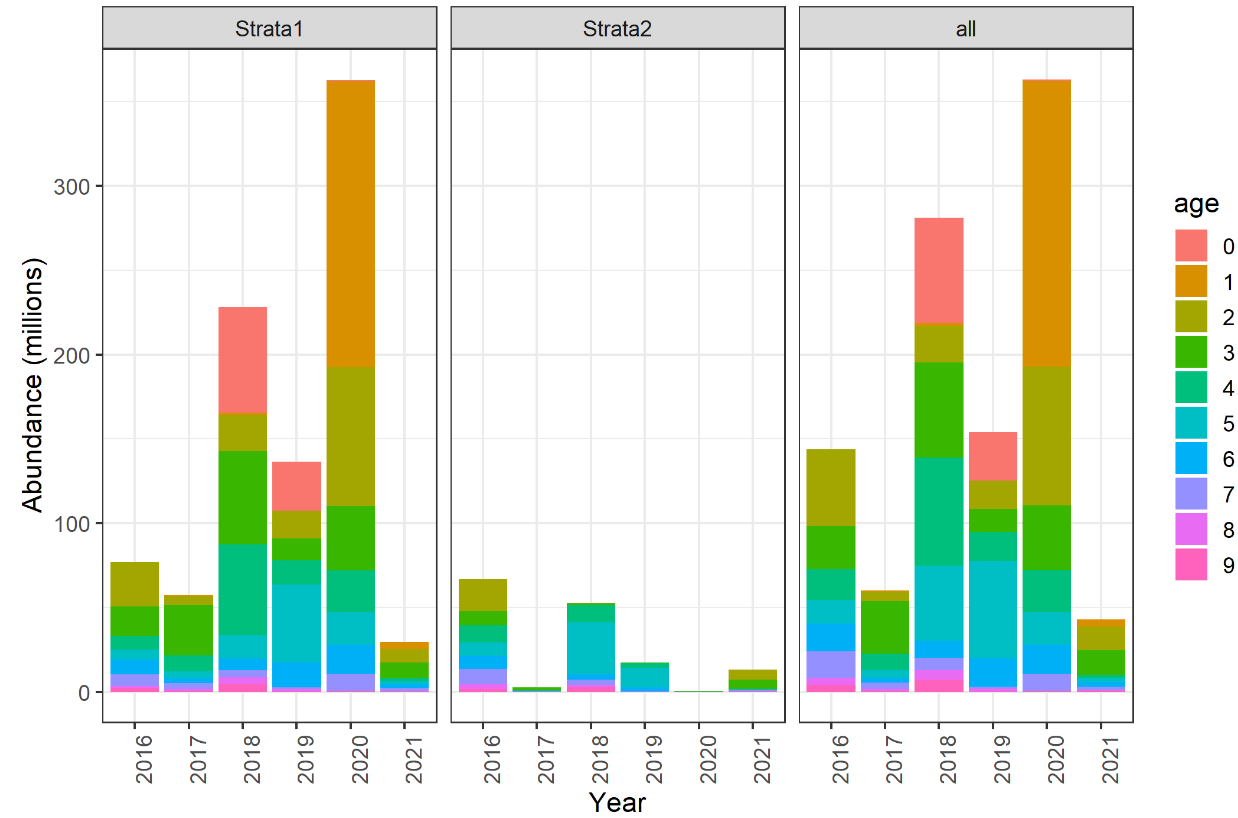


Figure 3.14. Historical abundance at age for 2016-2021.

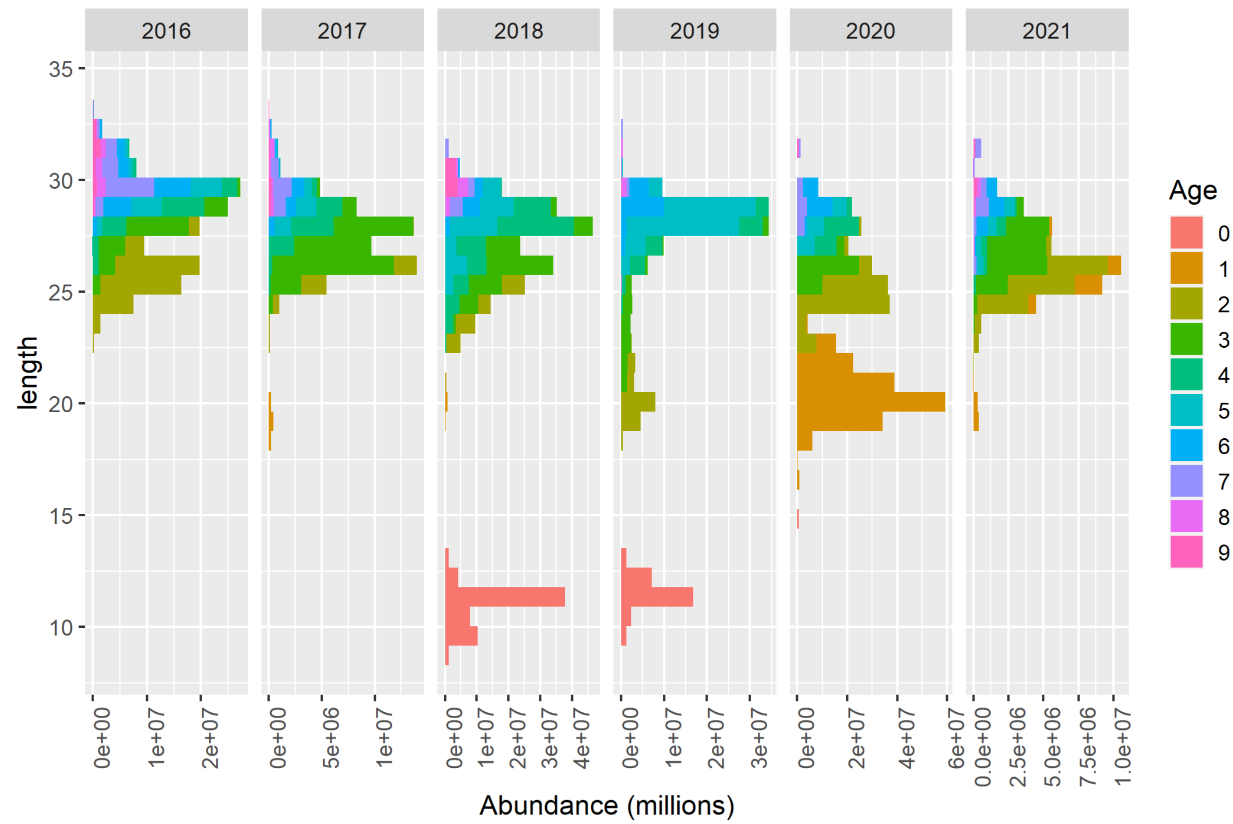


Figure 3.15. Abundance estimate by length group (1 cm bins) and age (winter rings) since 2016-2021.

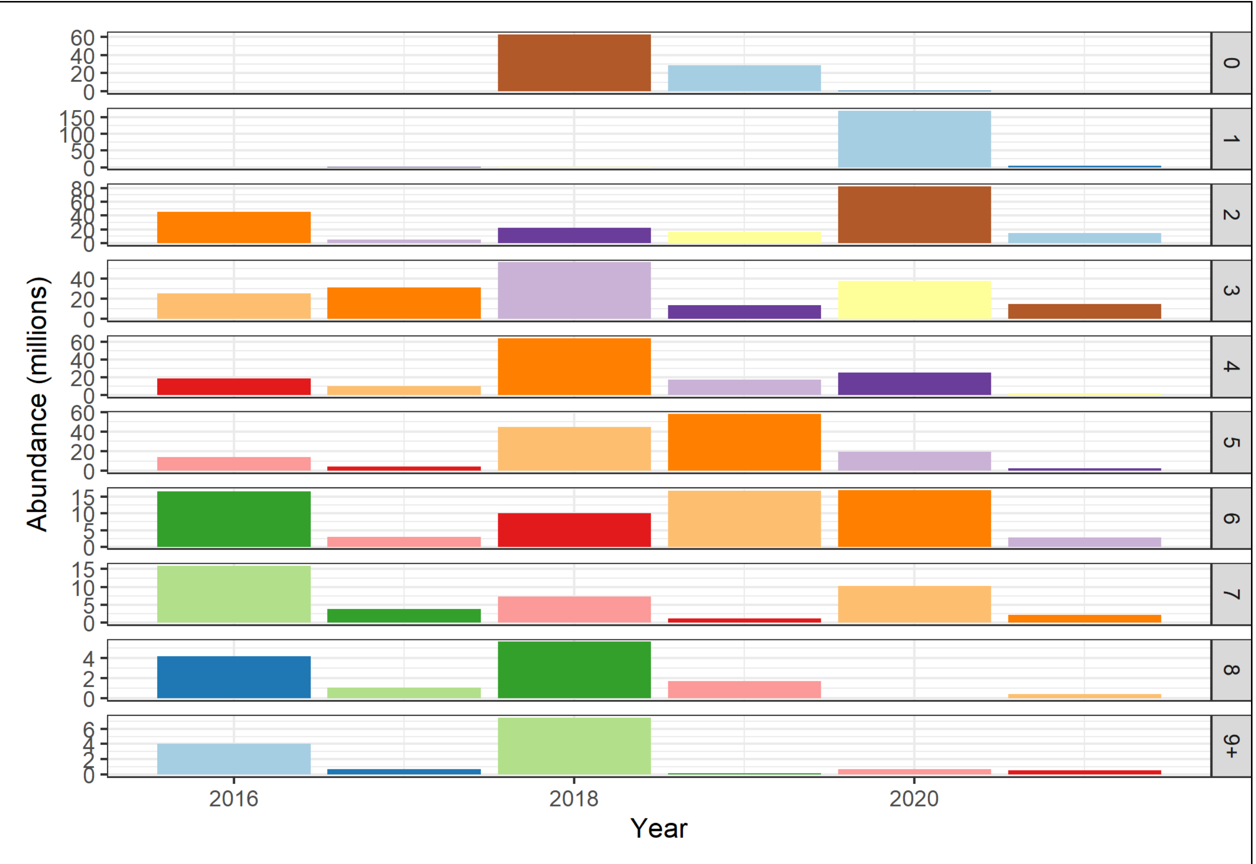


Figure 3.16. Indices at age (winter rings) and year from 2016 to 2021. Note diverging scales of abundance between ages.

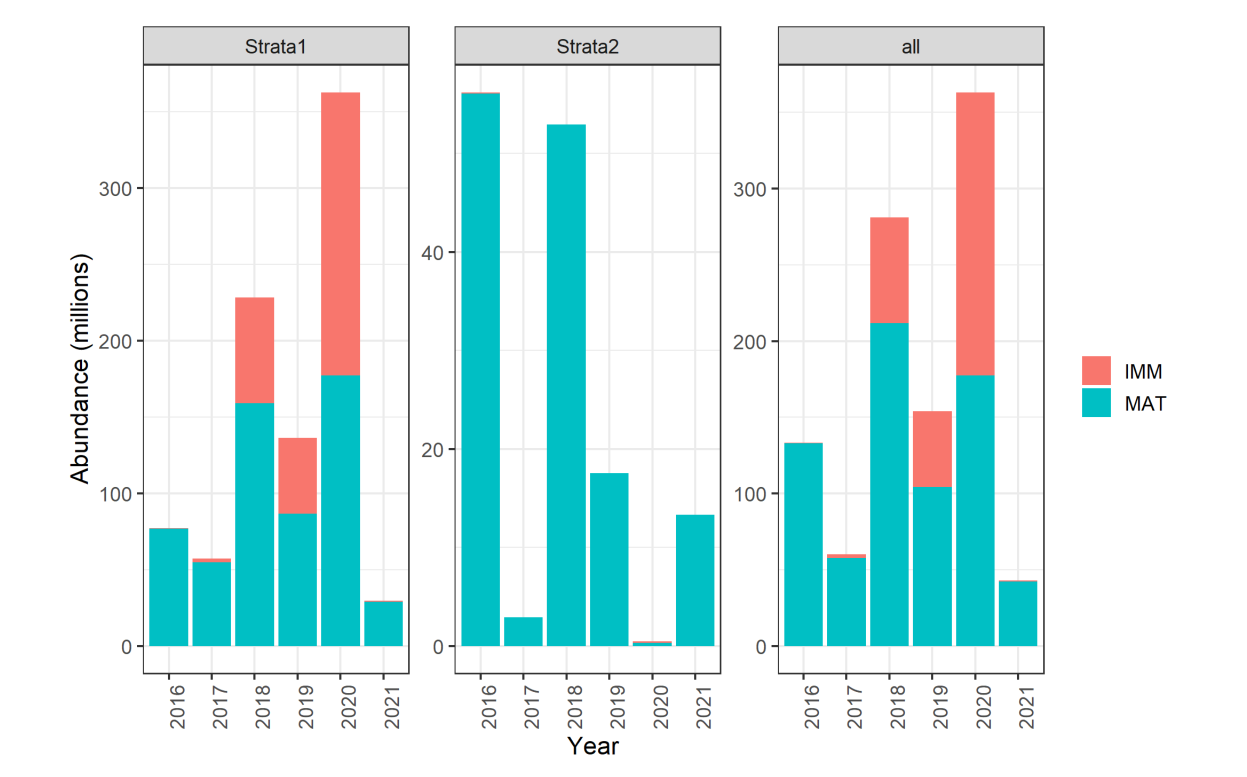


Figure 3.17. Historical abundance of mature and immature individuals.

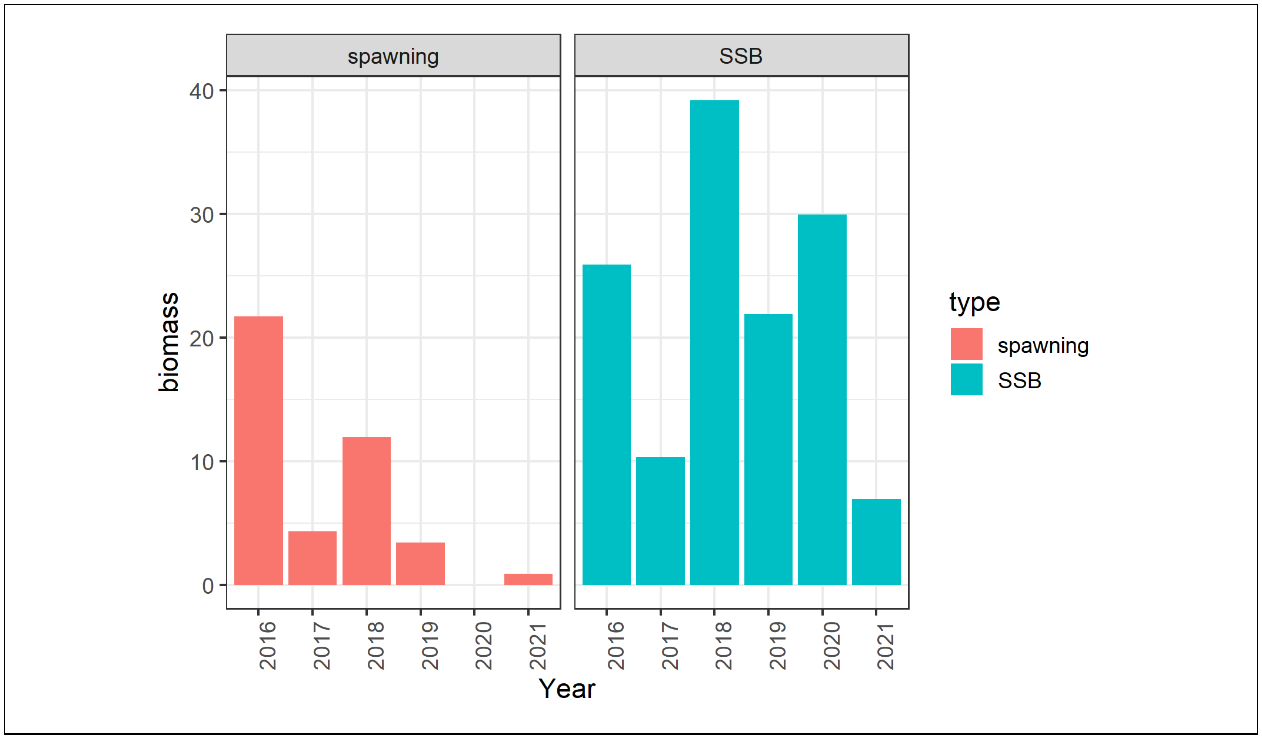


Figure 3.18. Historical SSB and biomass of spawners. Spawners are individuals at maturity stage 3 and 4.

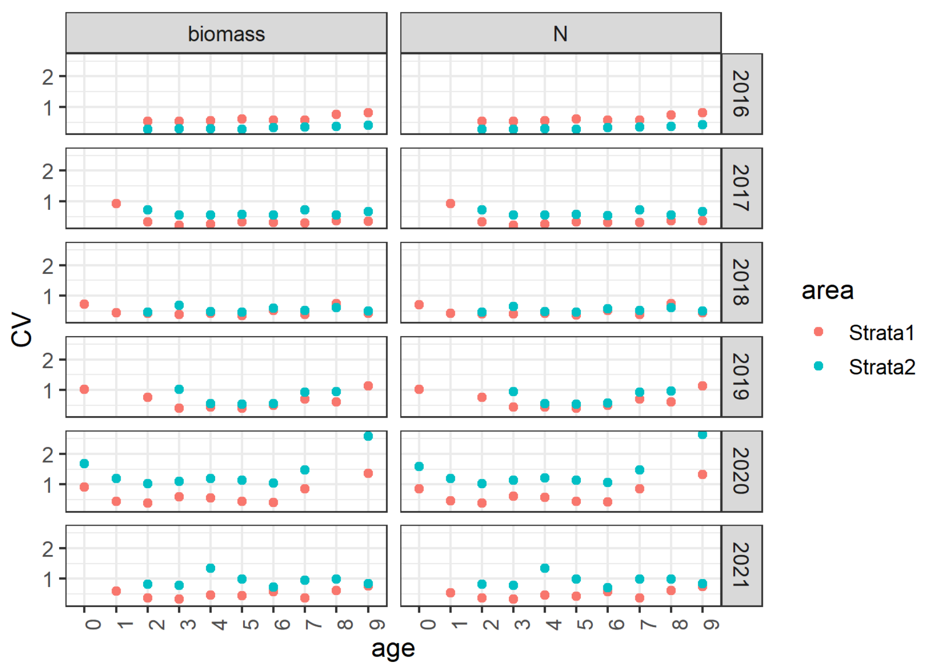


Figure 3.19. Historical CV per strata for abundance at age and biomass at age.

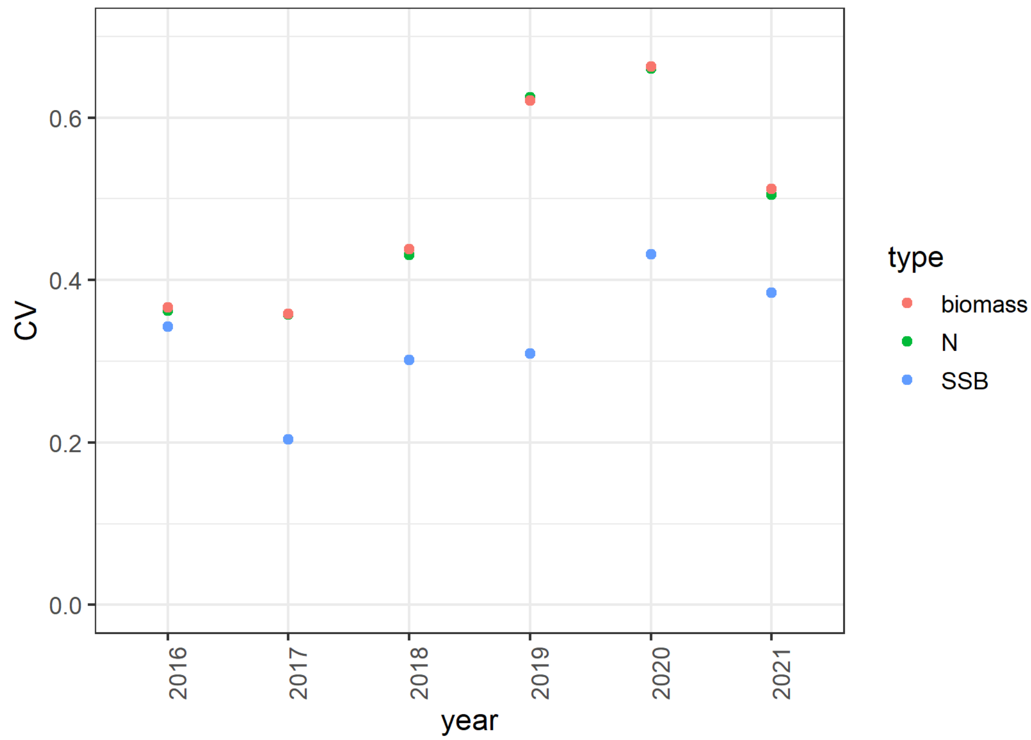


Figure 3.20. Historical CV in abundance at age, biomass and SSB. CV for the abundance at age and biomass is calculated as the mean across ages.

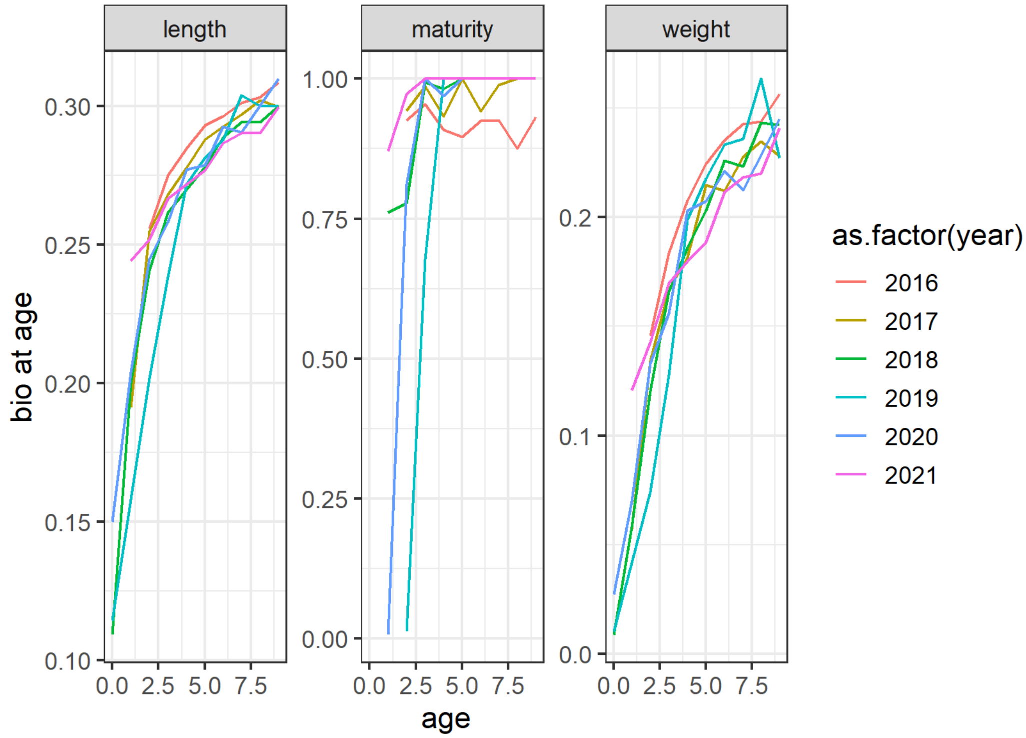
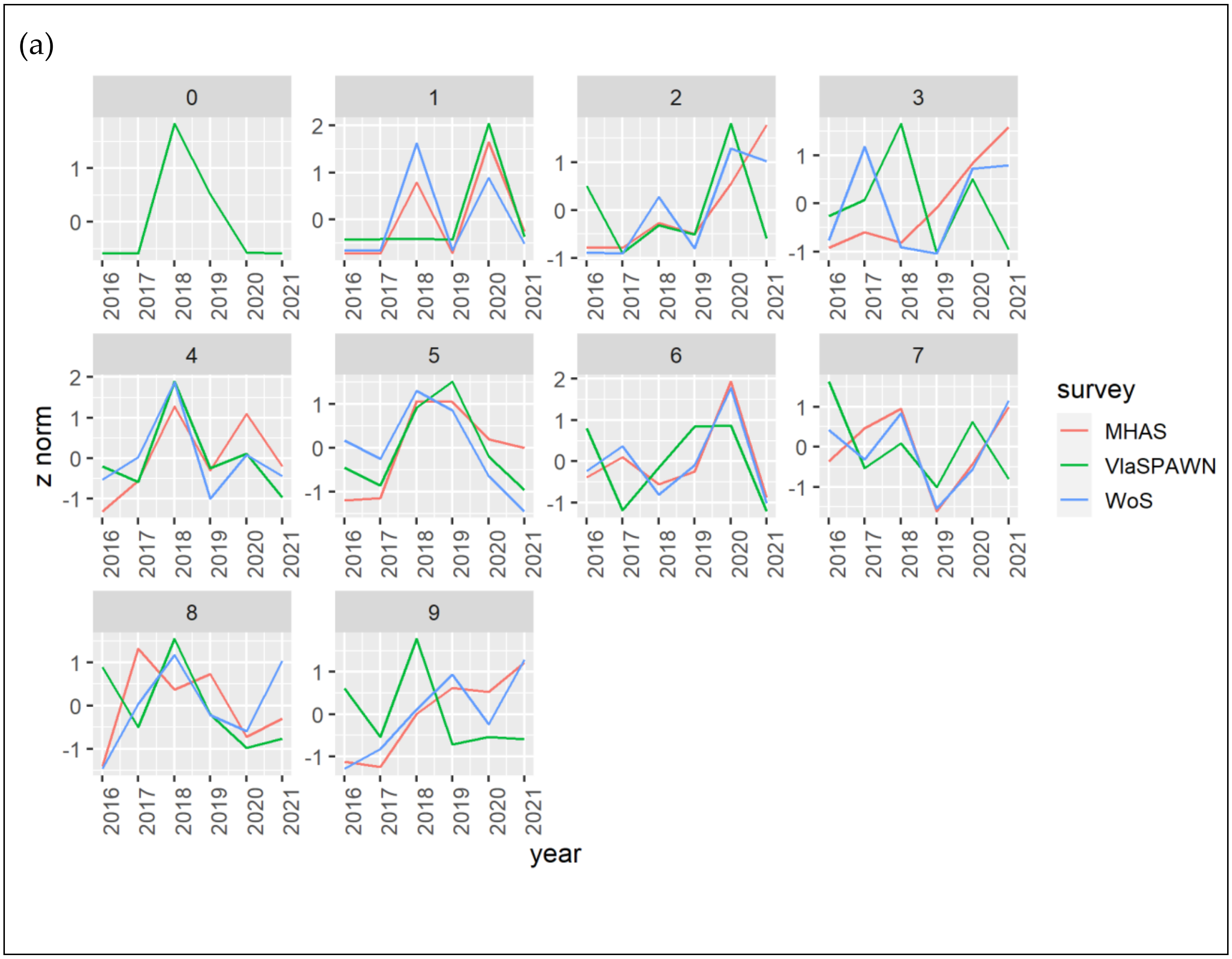


Figure 3.21. Historical biological parameters at age.


(a)
0
1
2
3
4
5
6
7
8
9
z norm
year
2016
2017
2018
2019
2020
2021
survey
MHAS
VlaSPAWN
WoS


0
1
2
3
4
5
6
7
8
9
z norm
year
survey
MHAS
VlaSPAWN
WoS

(b)

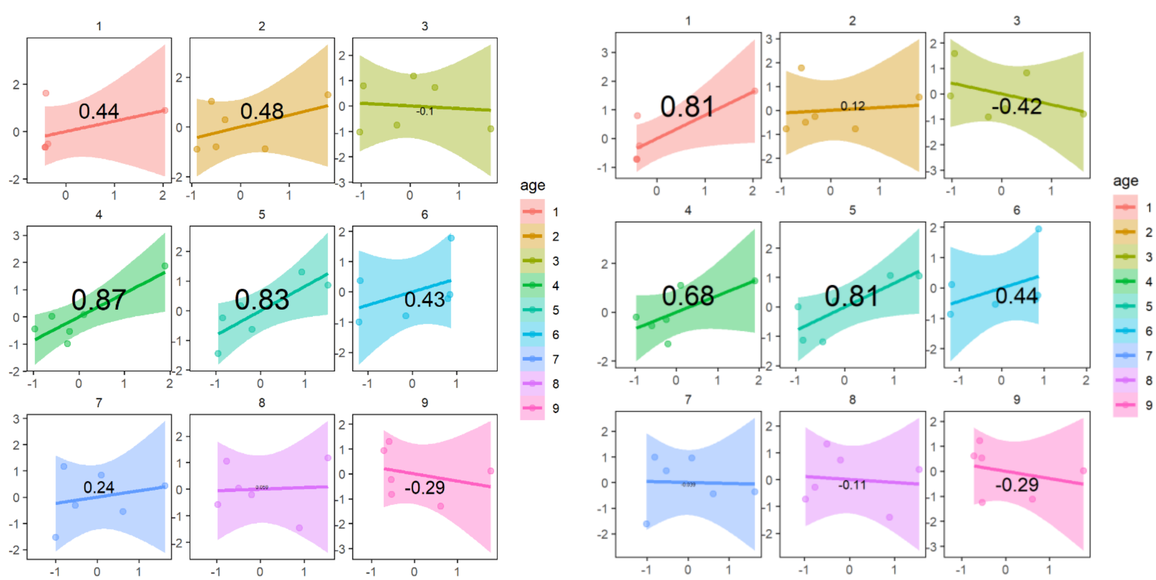

age
0.44
0.48
-0.1
0.87
0.83
0.43
0.24
-0.29
0.81
0.12
-0.42
0.68
0.81
0.44
-0.11
-0.29

Figure 3.22. Comparison of abundance at age for the 6aSPAWN and West of Scotland (WoS) and MSAS _vian split index surveys. (a) time series index, (b) correlations (6aSPAWN-WoS left) (6aSPAWN-MSAS_vian right)

3.2.2 6aS/7b herring

The survey in 2021 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 2021 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 all areas, 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. The marks in Bruckless and Fintra/Teelin (SE of Inishduff) were very strong and localised and therefore difficult to survey, leading to high CVs in these areas.

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 and CV estimates in Table 3.8.

The 6 core area surveys were treated as 5 separate strata within StoX (Lough Foyle, Lough Swilly, Bruckless Bay, Inver Bay and Fintra/Teelin Bay combined). The TSB estimate of herring for the combined 6aS/7b area was 35,944 tonnes (Lough Foyle = 8,255 tonnes, Lough Swilly = 5,792 tonnes, Bruckless Bay = 3,296 tonnes, Inver Bay = 1,191 tonnes and Fintra/Teelin Bay = 17,408 tonnes).

Table 3.7. 6aS/7b industry acoustic survey in 2021: age-disaggregated estimate of herring in the total survey area. The total estimated TSB for the combined survey areas = 35,944 tonnes

total length (cm)	1	2	3	4	5	6	7	8	9	10	11		abundance	biomass (t)	mean weight (g)
21	62048	0	0	0	0	0	0	0	0	0	0		62048	4	70
21.5	33317	111145	0	0	0	0	0	0	0	0	0		144462	10	69
22	85714	765914	0	0	0	0	0	0	0	0	0		659500	68	80
22.5	0	1799319	0	0	0	0	0	0	0	0	0		1683862	150	83
23	0	4870031	457897	0	0	0	0	0	0	0	0		5100874	473	89
23.5	327197	8860544	2105873	0	0	0	0	0	0	0	0		10722855	1124	100
24	0	11424416	5417058	0	0	0	0	0	0	0	0		16841474	1785	106
24.5	0	9506536	19975482	273566	0	0	0	0	0	0	0		29755584	3404	114
25	0	8760350	29372665	1866015	0	0	0	0	0	0	0		39999030	4873	122
25.5	0	779604	42482564	6576528	462475	0	0	0	0	0	0		50301172	6480	129
26	0	0	33596638	5715834	2382432	1388512	0	0	0	0	0		43083416	5955	138
26.5	0	787348	12589047	9605138	4022602	1283193	263103	0	0	0	0		28550431	4139	145
27	0	543555	6757728	6794307	4533647	857531	0	0	0	0	0		19486768	2953	152
27.5	0	84487	1405344	3155545	3039120	1747790	2076781	242086	221004	0	0		11972157	1884	157
28	0	0	299660	667361	1771841	2474187	2432350	396401	0	0	0		8041800	1369	170
28.5	0	0	0	454738	321502	185999	2235573	635092	0	71001	58359		3962264	708	179
29	0	0	285905	0	0	128879	1313158	489270	0	0	0		2217212	406	183
29.5	0	0	0	0	0	0	370105	278552	0	0	0		648657	127	196
30	0	0	0	0	0	62980	0	0	0	0	0		62980	12	195
31	0	0	0	0	111145	0	0	0	0	0	0		111145	21	186
TSN ('000)	95	47601	154746	35109	16645	8129	8691	2041	221	71	58		273408		
TSB (t)	38	5108	20043	4953	2558	1309	1520	356	36	12	10			35944	
SSB (t)	7	5055	20043	4953	2558	1309	1520	356	36	12	10			35859	
mean length (cm)	22.81	24.10	25.47	26.38	26.95	27.25	28.18	28.54	27.87	28.50	28.50				
mean weight (g)	75	106	130	141	154	161	175	175	163	171	164				

Table 3.8. 6aS/7b industry acoustic survey in 2021: Area coverage and number of transects per strata

Strata	Strata area (nmi²)	No. of transects	Transect length realised (nmi)	CV on abundance estimate
Lough Foyle	12.04	27	35.3	0.36
Lough Swilly	21.45	31	43.7	0.26
Bruckless Bay	5.95	12	10.6	0.70
Fintra/Teelin Bay	19.42	14	39.2	0.46
Inver Bay	6.17	18	22.6	0.33

3.2.2.1 *Historical perspective on 6aS7b*

The time series of age disaggregated herring data for the industry acoustic survey is shown in table 3.9 and 3.10, with CVs in Table 3.11.

Table 3.9. 6aS/7b industry acoustic survey in 2021: TSB and age-disaggregated (-wr) numbers at age of TSB herring ('000) from the industry acoustic survey 2016 – 2021. *Note: 2019 - 2021 survey area coverage significantly less than 2016 – 2018.*

Year	1	2	3	4	5	6	7	8	9	10	TSB
2016	7,284	34,055	71,229	15,781	46,066	31,877	14,956	2,244	0	0	35,475
2017	587	45,184	91,109	54,292	17,021	39,439	21,321	13,938	1,998	387	40,646
2018	655	59,268	66,776	101,824	67,951	20,334	23,443	4,336	931	672	50,145
2019*	54,629	56,772	31,590	17,911	24,616	14,358	10,123	2,162	2,907	347	25,289
2020**	8,259	115,831	79,244	54,039	34,449	44,226	19,789	3,953	2,745	350	45,046
2021**	508	48,293	154,745	35,109	16,644	8,129	8,691	2,041	221	129	35,944

*Reduced survey area in 2019 due to poor weather, only Lough Swilly and partial Donegal Bay covered

** Survey design changed significantly compared to other years, only 6 core areas covered

Table 3.10. 6aS/7b industry acoustic survey in 2021: SSB and age-disaggregated (-wr) numbers at age of SSB herring (‘000) from the industry acoustic survey 2016 – 2021. *Note: 2019 - 2021 survey area coverage significantly less than 2016 – 2018.*

Year	1	2	3	4	5	6	7	8	9	10	SSB
2016	1,894	34,048	71,229	15,781	46,066	31,877	14,956	2,244	0	0	35,038
2017	194	42,157	89,924	54,075	17,021	39,439	21,321	13,938	1,998	387	40,132
2018	328	56,127	66,242	101,500	67,951	20,334	23,443	4,336	931	672	49,523
2019*	14,438	50,961	30,869	17,911	24,616	14,358	9,972	2,162	2,907	347	22,386
2020**	694	109,856	79,184	54,039	34,449	44,225	19,789	3,953	2,745	350	44,107
2021**	95	47,600	154,745	35,109	16,644	8,129	8,691	2,041	221	129	35,859

*Reduced survey area in 2019 due to poor weather, only Lough Swilly and partial Donegal Bay covered

** Survey design changed significantly compared to other years, only 6 core areas covered

Table 3.11. 6aS/7b industry acoustic survey in 2021: CV estimates for the surveys 2016-2021. *Note: 2019 - 2021 survey area coverage significantly less than 2016 – 2018.*

Year	CV
2016	0.37
2017	0.51
2018	0.51
2019*	0.17
2020**	0.34
2021**	0.23

*Reduced survey area in 2019 due to poor weather, only Lough Swilly and partial Donegal Bay covered

** Survey design changed significantly compared to other years, only 6 core areas covered

4 Achievements and Recommendations

4.1 Abundance estimation –acoustics

4.1.1 Recommendations for data users

4.1.1.1 *6aN*

The 2021 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, it was not possible to maintain continuous observation over an extended period of time with a 10 day gap occurring between Chris Andra and Afrika.
- Provide a reliable estimate of
  - the minimum biomass of mature herring at age observed in survey areas during the survey period. The limited sampling by Afrika in 2021 and some uncertainty over the quality of acoustic data recorded using the Furuno FCV-30 on Chris Andra led to the decision to combine biological samples from both vessels in the acoustic analysis. While this practice is not uncommon, the temporal lag not optimal.
  - the minimum spawning biomass during the survey period.

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 Mackinson and Berges 2022, ICES 2022).
- 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 2021 TSB estimate of 35,944 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 2021, and therefore the stock was not overall contained in the survey area.
- The majority of herring marks were observed inshore in shallow areas. 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.
- 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 acceptable cohort tracking in the survey over the 6-year time-series.
- There was a tight distribution 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 74% of the overall numbers in 2021.
- The survey began after the fishery started in 2021. 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 before the surveys in 2021, but appeared to come into Bruckless Bay and SE of Inishduff in waves after the survey also; according to information coming from the monitoring fishery.

4.1.2 Recommendations for future surveys from WGIPS

4.1.2.1 *6aN*

- Seek to maintain the survey for a minimum of 10 years, following the outcomes of the benchmark (ICES 2022) that the index shows promise in tracking cohorts but is presently too short to fully assess it utility in an Category 1 stock assessment.

- 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 and 2021. Ideally 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. Plans for surveys in 2022 have been drafted to reflect this, seeking to .
- 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*

- There is a need to reduce uncertainty of estimate further through better survey design, particularly in the Bruckless and Fintra/Teelin Bays 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 appears to have helped overcome this issue in 2021. An improved survey design will be used again in 2022 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.

Acknowledgements

Skippers and crew of the Chris Andra, Afrika, Adenia arisma, Ocean Star, Alida, Crystal Dawn, Ros Ard, Girl Kate, G, South Eastern and K-Mar-K, Rachel D.

Echomaster Marine, MacDuff.

Killybegs Fishermen’s Organisation (KFO)

Irish South and West Fish Producers Organisation (IS&WFPO)

Barry’s Electronics, Killybegs, Donegal, Ireland

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Annex 1. Calibration and acoustic settings on Chris Andra

Calibration of the Furuno FCV-30 requires calculation of a Calibration offset from the reference sphere. The Calibration Sphere reference value was -34.4dB and the offset calculated during calibration was -2.6dB. This value is used the Calibration file (Table A1) applied in Echoview during post-processing.

Settings applied to the FCV-30 sought to ensure that raw unfiltered and untransformed acoustic data were recorded. The FCV-30 user guide was consulted to make decision on how the setting should be applied. The final setting resulted in the presentation of an echogram that closely matched that displayed on the Simrad EK80. Raw proprietary data were recorded and transferred into HAC format each day. This process took approximately 4 hours for every days-worth of acoustic recording. HAC files were read into Echoview for post-processing.

Table A1. Calibration file applied in Echoview

```
#==========================================================================================#
#              ECHOVIEW CALIBRATION SUPPLEMENT (.ECS) FILE (HAC v1.x)              #
#                        10/09/2021 20:27:55.2230                         #
#==========================================================================================#
#     +----------+  +-----------+  +----------+  +-----------+  +----------+     #
#     | Default  |-->| Data File |-->| Fileset  |-->| SourceCal |-->| LocalCal |      #
#     | Settings |   | Settings  |   | Settings |   | Settings  |   | Settings |      #
#     +----------+  +-----------+  +----------+  +-----------+  +----------+     #
# - Settings to the right override those to their left.                          #
# - See the Help file page "About calibration".                                  #
#==========================================================================================#
Version 1.00
#==========================================================================================#
#                          FILESET SETTINGS                          #
#==========================================================================================#

#==========================================================================================#
#                          SOURCECAL SETTINGS                          #
#==========================================================================================#
SourceCal T0
   # AbsorptionCoefficient = 0.0100000 # (decibels per meter) [0.0000000..100.0000000]
   # AbsorptionCoefficientLogging = 0.0100000 # (decibels per meter) [0.0000000..100.0000000]
   # CalibrationOffset=0
   # Frequency = 38.00 # (kilohertz) [0.01..10000.00]
   # MajorAxis3dbBeamAngle = 7.00 # (degrees) [0.00..359.99]
   # MinorAxis3dbBeamAngle = 7.00 # (degrees) [0.00..359.99]
   # SoundSpeed = 1500.00 # (meters per second) [1400.00..1700.00]
   # SoundSpeedLogging = 1500.00 # (meters per second) [1400.00..1700.00]
   # TransmittedPulseLength = 0.500 # (milliseconds) [0.001..50.000]

#==========================================================================================#
#                          LOCALCAL SETTINGS                          #
```

#==#

Chris Andra settings
LocalCal ChrisAndra
CalibrationOffset=-2.6

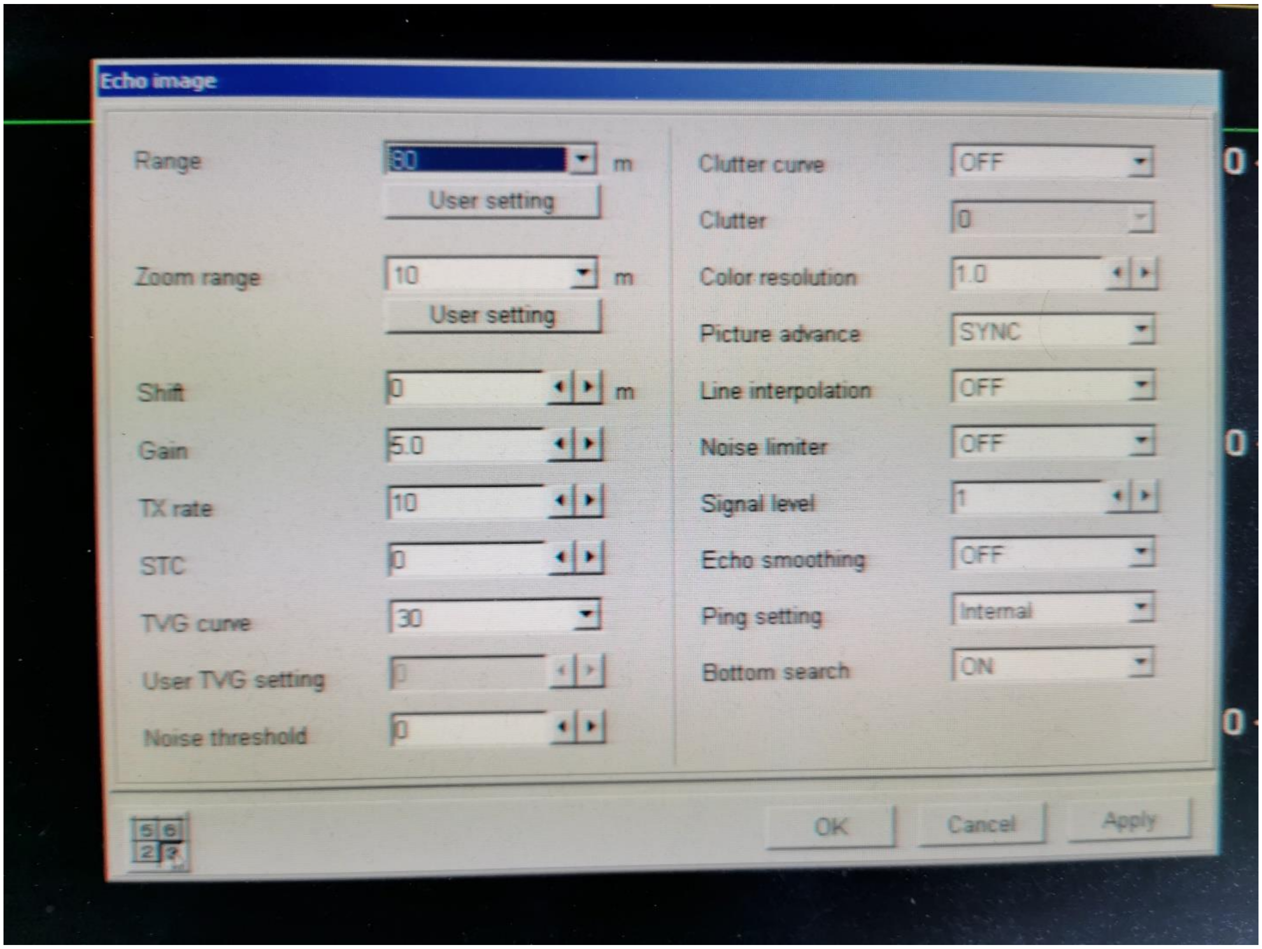


Figure A1. Setting applied to FCV-30 for acoustic recording.

Annex 2. FV Adenia – HERAS strata 1 and 3 survey – July 2021.

Coinciding with the 2021 International Herring Acoustic Survey, a 10-day acoustic survey was carried out by FV Adenia on 7-17 July 2021.

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 Adenia 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.**

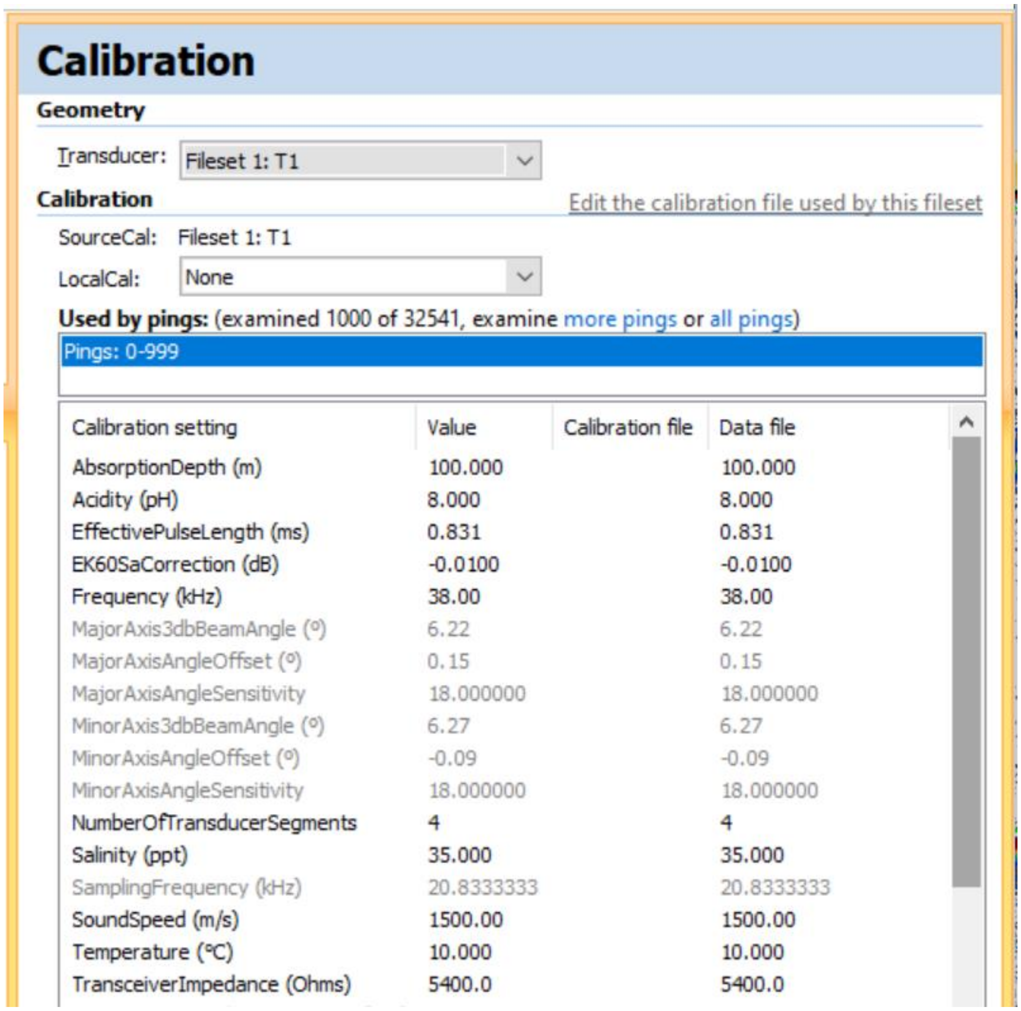
   The HERAS survey in the Malin shelf and 6a areas currently operates with a 15nmi transect spacing, which is based on previous statistical analysis of survey designs conducted when herring were more abundant in the area. During the current lower stock size, a test of the implications of transect spacing 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. Adenia calibration settings



Calibration

Geometry

Transducer: Fileset 1: T1

Calibration Edit the calibration file used by this fileset

SourceCal: Fileset 1: T1

LocalCal: None

Used by pings: (examined 1000 of 32541, examine more pings or all pings)

Pings: 0-999

Calibration setting	Value	Calibration file	Data file
AbsorptionDepth (m)	100.000		100.000
Acidity (pH)	8.000		8.000
EffectivePulseLength (ms)	0.831		0.831
EK60SaCorrection (dB)	-0.0100		-0.0100
Frequency (kHz)	38.00		38.00
MajorAxis3dbBeamAngle (º)	6.22		6.22
MajorAxisAngleOffset (º)	0.15		0.15
MajorAxisAngleSensitivity	18.000000		18.000000
MinorAxis3dbBeamAngle (º)	6.27		6.27
MinorAxisAngleOffset (º)	-0.09		-0.09
MinorAxisAngleSensitivity	18.000000		18.000000
NumberOfTransducerSegments	4		4
Salinity (ppt)	35.000		35.000
SamplingFrequency (kHz)	20.8333333		20.8333333
SoundSpeed (m/s)	1500.00		1500.00
Temperature (ºC)	10.000		10.000
TransceiverImpedance (Ohms)	5400.0		5400.0

Table A2.2. Summary of equipment used for the 2021 acoustic survey coinciding with HERAS.

Area surveyed	Vessel	Transducer and Frequency	Echo-sounder	Power Pulse duration Ping interval	Environment	Calibration Location/ date, supplier	Survey area changes
HERAS (7-17 July 2021)	Adenia	Hull mounted split beam ES38B (38kHhz), draft ~5.5m	SIMRAD EK80	**@38kHhz** Power: 2000W Pulse duration: 1.024ms Pulse form:	Temp = 10C, Salinity =35ppt, Sound speed 1491.5 m/s	Peterhead breakwater 7 Jul, Echomaster Marine	

		With heave compensation. ES200-7C (200kHz) split beam [not used]		Continuous wave Ping interval = 0.5 sec			

2.2 Survey design

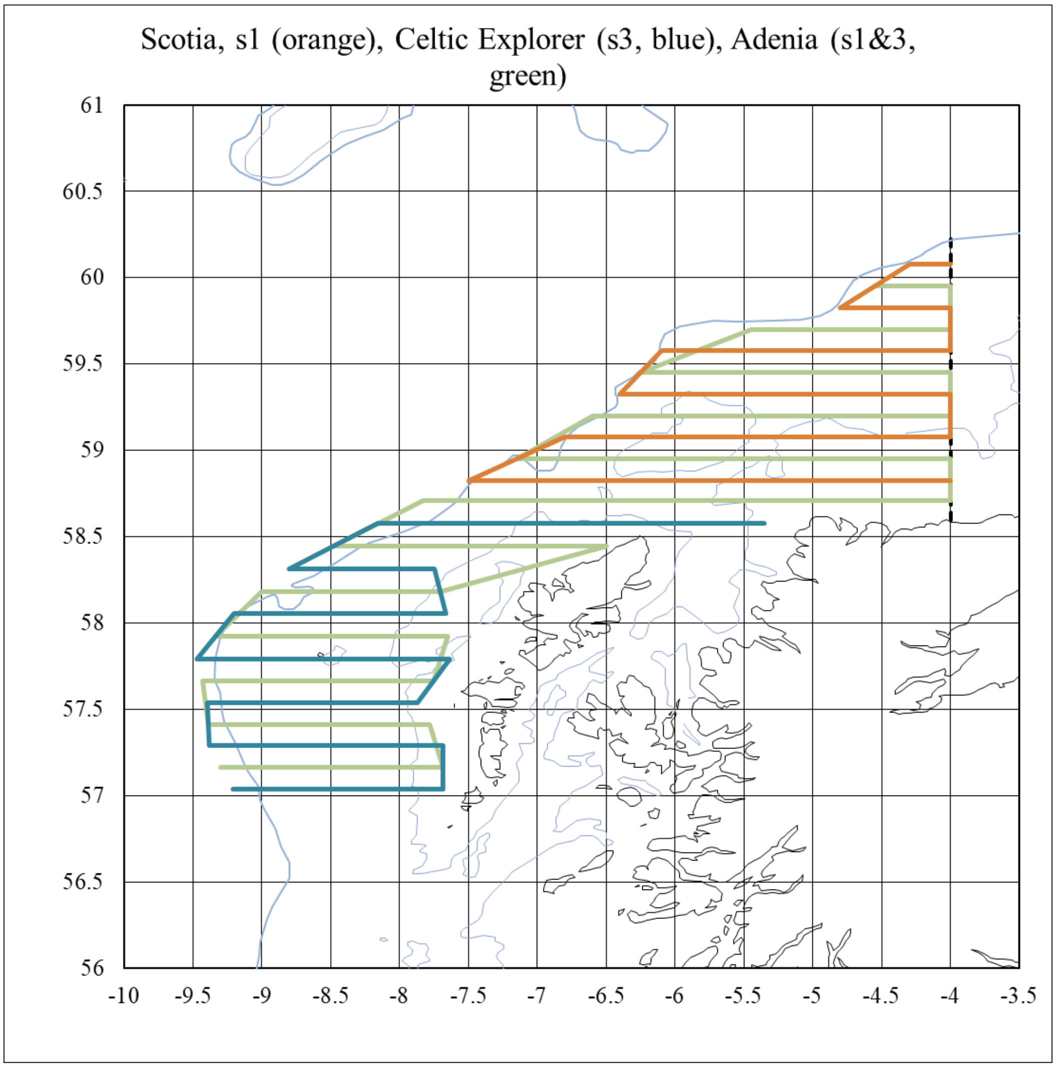


Figure A2.2. Adenia Survey plan. 15nmi spacing (green lines) covering HERAS strata 3 in the south and strata 1, North of the Butt of Lewis.

Surveys conducted in daylight hours only, 03:00 to 23:00 UTC/GMT.

2.3 Results

Haul locations are given in Figure A2.3 Only one contained any herring, 3 in number.

Scrutiny of the acoustically detected marks of fish schools resulted only 5 marks that were 'possibly' herring but could not be verified by the sampling (Figure A2.4, Table A2.3).

Following a review of the acoustic and biological sampling results in consultation with lead scientists From the Marine Institute and Marine Scotland, the decision was made not to undertake any further analysis of the acoustic data, since doing so would require unjustifiable assumptions given the absence of biological sample data.

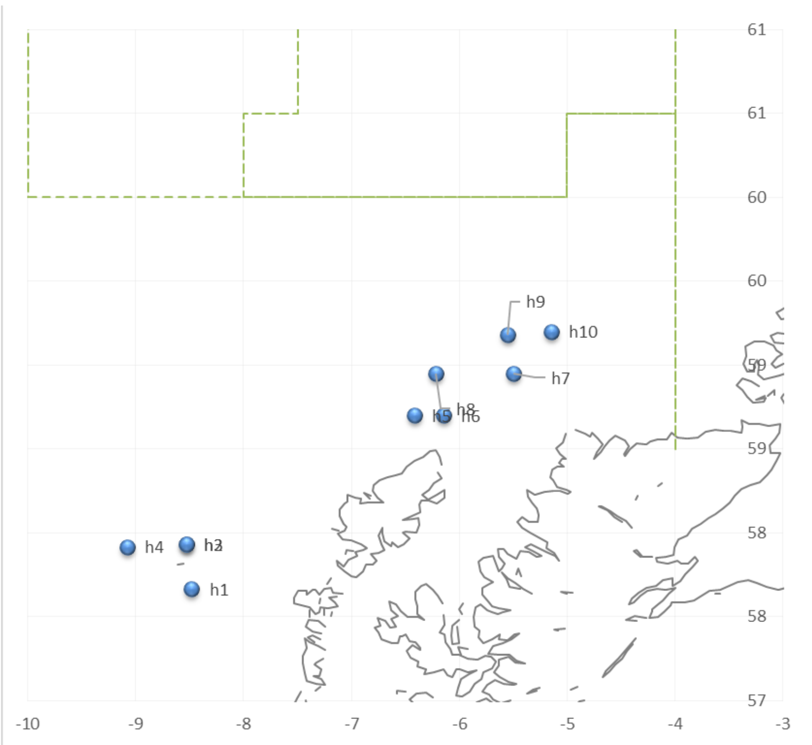


Figure A2.3. Haul locations

Table A2.1 Haul catch compostions

		Position			Catch composition (t)								
haul	date	lon	lat	Rect	HER	MAC	NOP	HAD	GGU	BOC	WHB	DGS	Total Catch weight (t)
1	10/07/21	-8.48	57.67	44E1		0.25		0.08			0.01		0.34
2	11/07/21	-8.53	57.93	44E1									
3	11/07/21	-8.53	57.93	44E1				0.01					0.01
4	11/07/21	-9.08	57.92	44E0		0.31		0.00	0.01	0.01	0.01		0.33

5	13/07/21	-6.42	58.70	46 E3	0.00	0.01	0.00	0.00	0.00			0.00	0.03
6	13/07/21	-6.15	58.70	46 E3				0.10	0.19			0.04	0.33
7	14/07/21	-5.50	58.95	46 E4		0.16		0.34	0.00				0.50
8	14/07/21	-6.22	58.95	46 E3									
9	14/07/21	-5.55	59.18	47 E4									
10	15/07/21	-5.15	59.20	47 E4		0.35				0.00			0.35

Table A2.3. Overview metrics of acoustic marks classified in analysis

Row Labels	mean Sv_mean	mean NASC	No. of Schools
Possibly herring	-52.05	2815	5
Unclassified regions	-52.17	1877	1728

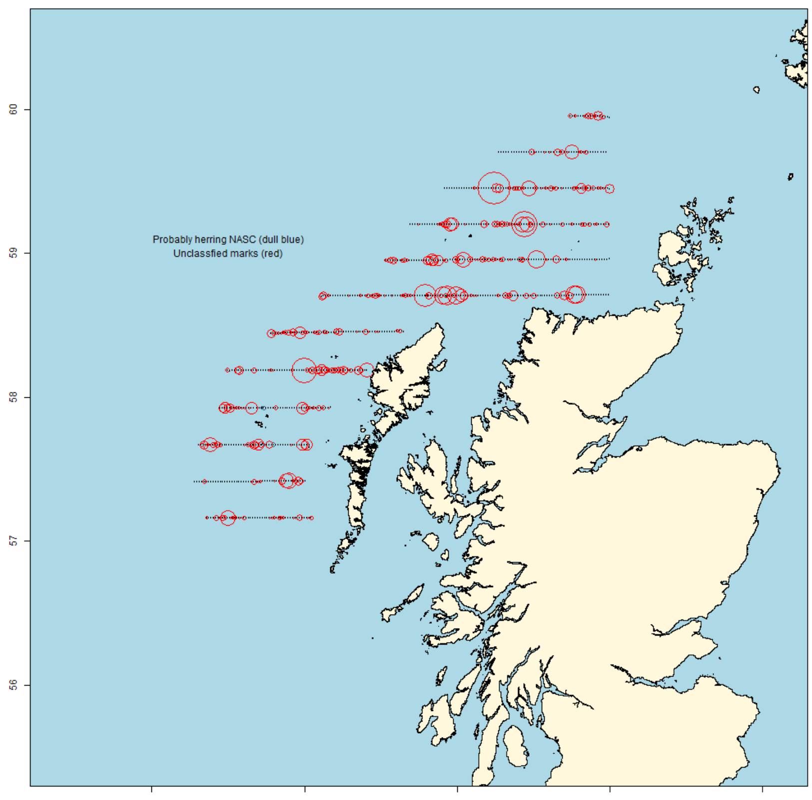


Figure A2.4. Acoustic survey recordings of herring and other marks.

Annex 14: 2021 PELACUS Survey Summary Table and Survey Report

*There is no survey summary table or report for the PELACUS (annex14) survey in 2021.

Annex 15: Ecosystem Index Overview Table

	IBWSS					IESNS					HERAS						IESSNS			GERAS	CSHAS	WESPAS	ISAS	PELTIC
Participating countries																								
✓																								
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	5			4	4	2		4	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		3			2	3	1		3	4	4			4	3	3	1	3

	IBWSS					IESNS					HERAS						IESSNS			Western Baltic	CSHAS	WESPAS	Irish Sea	Peltic
Participating countries	🇳🇴	🇫🇴	🇮🇪	🇳🇱	🇪🇸	🇳🇴	🇫🇴	🇮🇸	🇩🇰	🇷🇺	🇳🇴	🇮🇪	🇳🇱	🇩🇰	🏴󠁧󠁢󠁳󠁣󠁴󠁿	🇩🇪	🇳🇴	🇫🇴	🇮🇸	🇩🇪	🇮🇪	🇮🇪	🇬🇧	🏴󠁧󠁢󠁥󠁮󠁧󠁿
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																								
<u>*Environmental conditions*</u>																								
Weather condition/sea state	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓

Annex 16: WGIPS Survey Plans 2022

IBWSS

Five vessels representing the Faroe Islands, the Netherlands (EU), Ireland (EU) and Norway are scheduled to participate in the 2022 blue whiting spawning stock survey. In addition, Spain will participate with 5 days of survey time, 2.5 weeks before the start time of the core survey. The Spanish coverage will be in the southern part of the Porcupine Sea bight. This area will be covered again when the survey starts. The Spanish coverage will be used only to compare the blue whiting biomass with what is seen 2.5 weeks later. Only the main coverage will be used in the estimate.

Survey timing and design were discussed during the 2021 IBWSS post-cruise and 2022 WGIPS meetings. The group decided that in 2022, 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. In 2022 also UK plans to participate with a hired vessel in the survey. It is not clear whether UK manage to get all ready for this year's survey, so the coverage plan is without any participation from them. If UK can hire a vessel, they will participate in the core area (stratum 3) giving a good overlap with the other vessels and plan for this will be made during the survey.

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 day later and they will start in stratum 5 (Rockall). 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 28th of March 2022. 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 (not valid in stratum 3), 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 2022 survey are presented. Detailed cruise lines for each ship are uploaded on the WGIPS sharepoint (/2022 Meeting docs/Working documents/IBWSS 2022 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 A6.1. Individual vessel dates for the active surveying period in the 2022 International Blue Whiting Spawning Stock Survey (IBWSS).

SHIP	NATION	ACTIVE SURVEYING TIME (DAYS)	DEFINITIVE SURVEYING DATES
Celtic Explorer	Ireland (EU)	15	25.3.2022 – 9.4.2022
Vendla	Norway	13	25.3.2022 – 7.4.2022
Tridens	Netherlands (EU)	13	22.3.2022 – 4.4.2022
Jakup Sverri	Faroes	10	26.3.2022 – 5.4.2022
Vizconde	Spain	5	02.3.2022 – 7.3.2022
?	UK	?	?

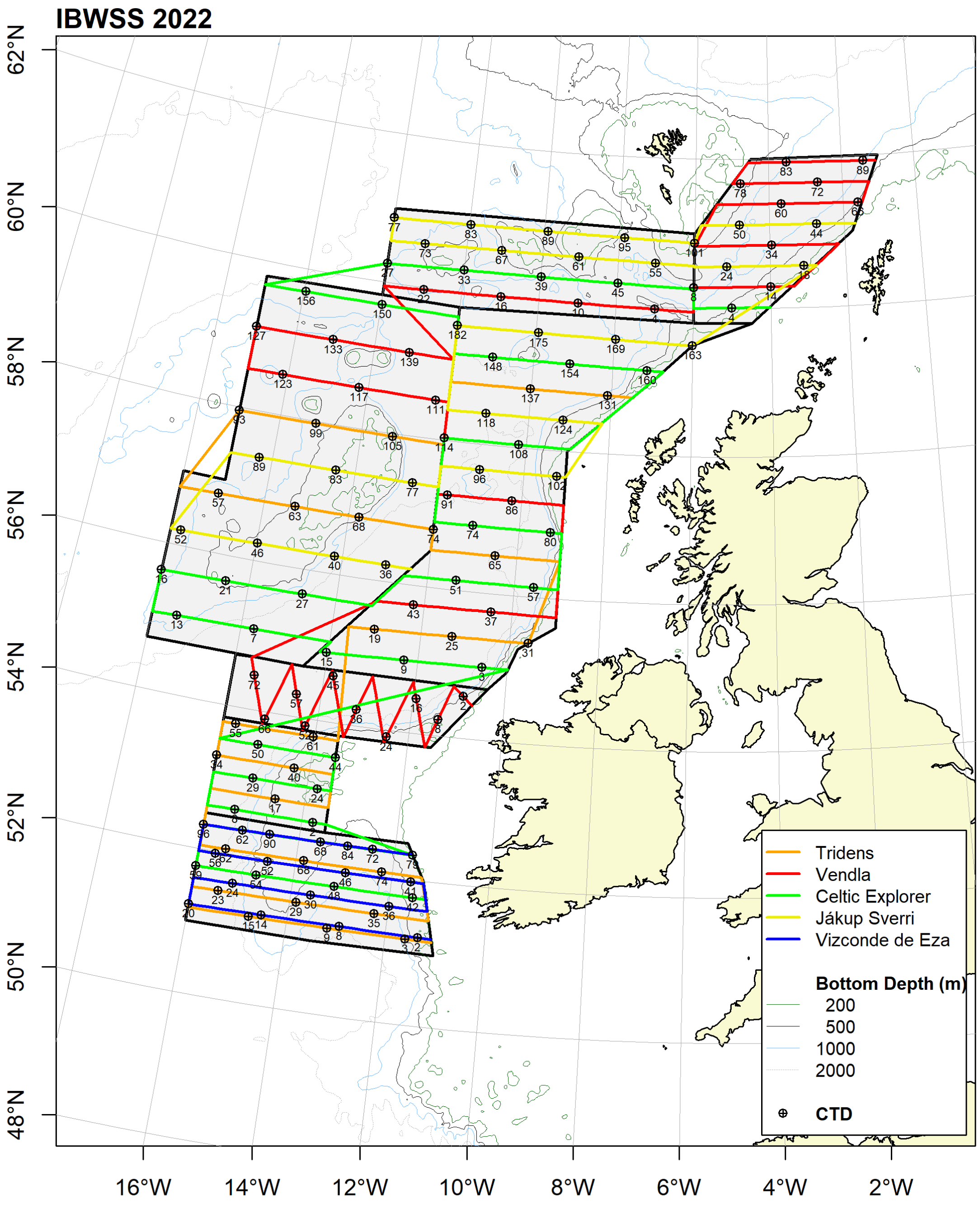


Figure A6.1. Planned survey tracks for the combined 2022 International Blue Whiting Spawning stock Survey (IBWSS).

IESNS

Denmark (EU-coordinator), Faroe Islands, Iceland and Norway will participate in the IESNS survey in April-May 2022. The Russian participation is uncertain and at this stage regarded as unlikely. The United Kingdom will perhaps participate and will, if this turns out to be the case, be incorporated in the plan at a later stage. Ships and preliminary dates are given in Table A16.9. Survey days exclude time for: hydrographic cross sections, coverage outside the IESNS area and crew change. As usual, the plan is based on 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 will be held 14-16 June 2022 as webex (Teams).

Table A16.9. 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)**	**25 Apr – 20 May**	**20**	**6-7 May in Bodø**
Jakup Sverri	**Faroe Islands**	**28 Apr – 8 May**	**10**	
Árni Friðriksson	**Iceland**	**4 May – 23 May**	**16**	
G.O. Sars	**Norway**	**26 Apr – 30 May**	**29**	**12 May in Tromsø, 23-24 May in Tromsø**
	Russia	**no participation**		
	United Kingdom	**Possible participation**		

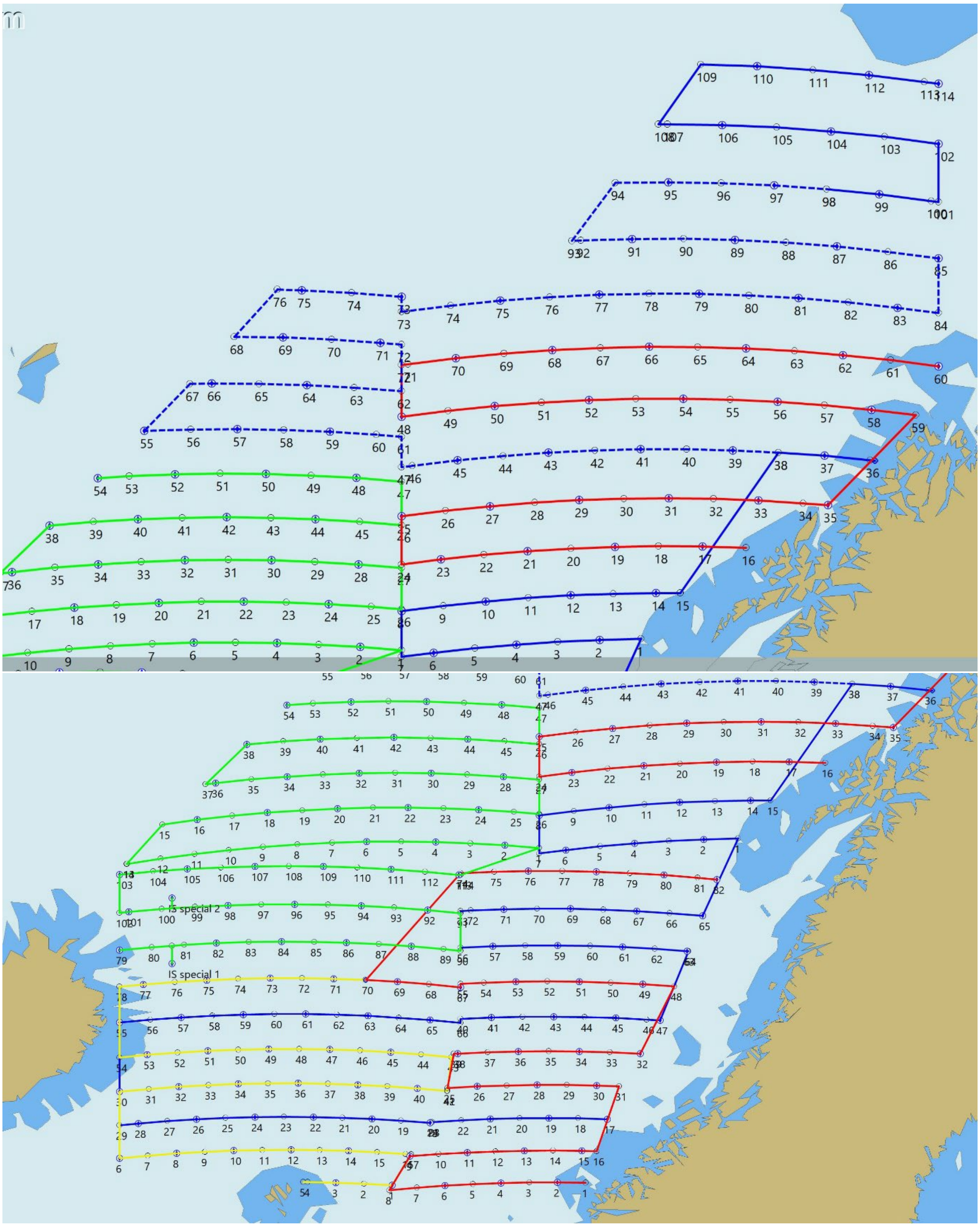


Figure A16.2. Planned cruise tracks and transects for the IESNS survey in 2022. Colors represent the different vessels/nations (yellow: FO, green: IS, dark blue: NO, red: EU,). Suggested CTD stations are shown as blue circles with a diamond inside (the numbered positions are transect points for each 30 nautical mile).

HERAS

Norway, Denmark, Germany, Netherlands, Scotland and Ireland will participate in the 2022 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 2022 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 in 2022, i.e. transect spacing, will be maintained at a similar level to that planned for 2021. 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. In 2021 genetic sampling for stock discrimination on individual fish level was conducted in both survey areas. 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 planned that genetic sampling of herring be carried out throughout the whole survey area including the areas where currently no stock splitting is carried out. Sampling methodology and level is recommended to be kept at the 2021 level. A dedicated workshop on sampling protocols and the identification of a common and definite sampling scheme is recommended.

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.

Table A16.3. Participating countries/vessels, time periods, areas and rectangles to be covered in the 2022 survey.

VESSEL	AVAILABLE DAYS FOR SURVEY	PERIOD AVAILABLE	STRATA TO COVER
Celtic Explorer (IRE)	20	4 July – 25 July	2, 3, 4, 5, 6
Scotia (GB-SCT)	18	29 June – 19 July	1, 91 (north of 58°30’N), 111, 121
Johan Hjort (NOR)	17	23 June – 15 July	11, 141
Dana (DEN)	13	22 June – 07 July	21, 31, 41, 42, 151, 152
Tridens (NED)	14	27 June – 22 July	81, 91 (south of 58°30’N), 101
Solea (GER)	19	1 July – 21 July	51, 61, 71, 131

Analysis and reporting

A post-cruise meeting will be held in Bergen, Norvey, November 21-25 (venue 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. Survey data for the 2022 survey is to be uploaded to the ICES Acoustic database in the agreed format no later than **31 October 2022.**

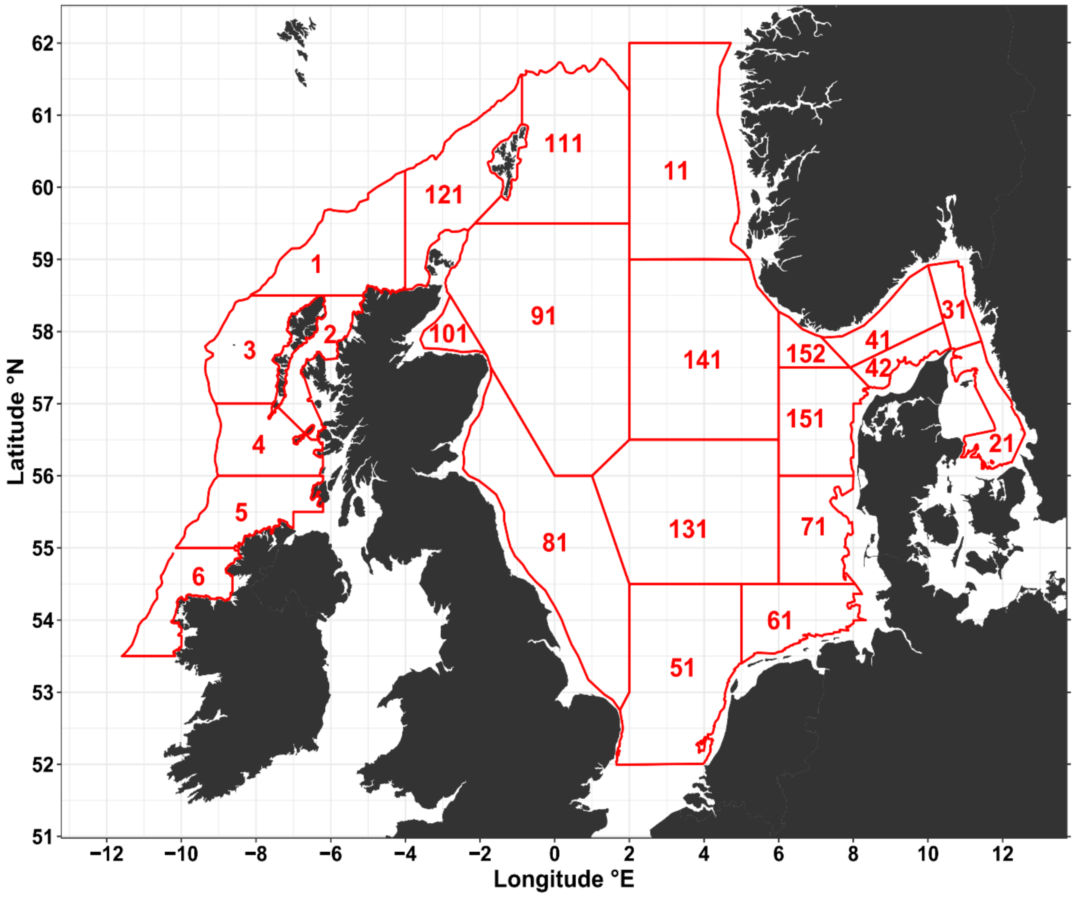


Figure A16.4. The 2022 ICES Coordinated Acoustic Survey in the Skagerrak and Kattegat, the North Sea, West of Scotland and the Malin Shelf area (HERAS): Strata.

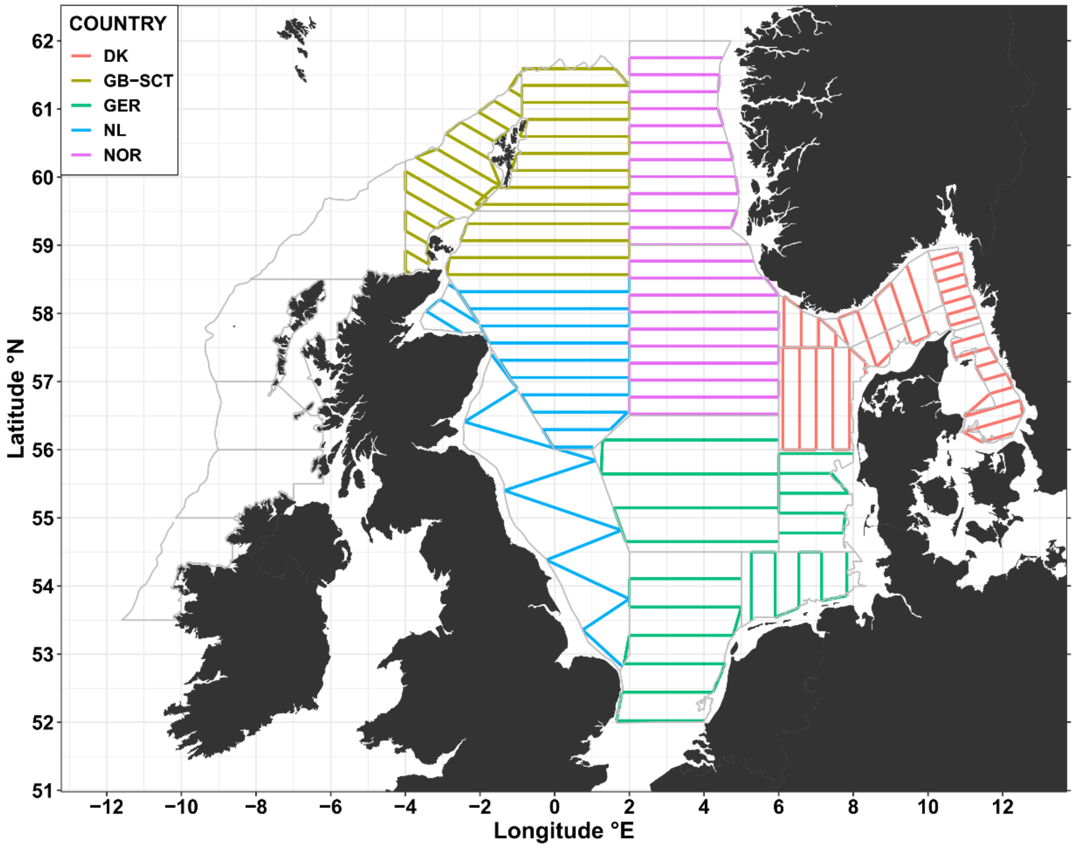


Figure A16.5. The 2022 ICES Coordinated Acoustic Survey in the Skagerrak and Kattegat, the North Sea, West of Scotland and the Malin Shelf area (HERAS): Strata and transects allocated to participants (excluding MSHAS transects West of 4°W)

IESSNS

Preliminary planning for the International Ecosystem Summer Survey in Nordic Seas (IESSNS) 2022 was presented in plenary. As in previous years six vessels from five nations will survey approximately 2.7 million km^2 in Nordic Seas and the North Sea during the period from June 30th to August 7, 2022. 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. Post-cruise meeting for IESSNS 2022 will be hosted in Bergen, Norway during the period August 15th – 19th 2022.

Some changes in operation of IESSNS 2022 compared to previous years are planned and they were mostly presented at WGIPS 2022. The changes are:

Concerning the plan for the IESSNS 2022 the biggest challenge is the reduced available total vessel time. Faroes have 18 days available (30.6-6.7, crew change 6.7, 6.7-19.7), and Norway 31 days for two vessels (4.7-21.7, crew change, 21.7-7.8). Given a daily average progression of 160 nmi per day, these three vessels can cover 12,900 nmi. The unrealistic option would be increase vessel time by 7 days (vessel independent).
Option 1: Keep the current plan and risk low/no coverage in the North
Option 2: Increase distance between transects to reduce number of transect per stratum

Option 1 will have large consequences for the estimates especially not being able to hit the 0 line. Option 2 might increase the variation/uncertainty within a stratum but will secure that IESSNS 2022 have covered the entire area. The IESSNS 2022 would need to increase the distance by 10 nmi for each stratum. This would reduce the number of transects per stratum by 1 but would reduce the total distance to 12,400 nmi. This would be within the possibilities given the current vessel time. The IESSNS group rapidly decided to move forward with option 2.

Stratum 11 (southern Irminger Sea, and 12 (Iceland basin) will not be surveyed 2022 since no mackerel nor herring was measured there during IESSNS 2018-2021. 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.

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).

With the previous plan presented at WGIPS 2022 it is lacking 1,000 nmi that cannot be covered with available survey time. The problems are in strata 1-3, 7 and 9. Greenland will cover stratum 10 as usual. Iceland will cover strata 4-6 but cannot cover additional transect in stratum 3 this year (4 days less as 2021). This means that Faroes and Norway must cover strata 1-3, 7 and 9. Following the previous plan presented during WGIPS 2022, this would be a total distance to cover all transect of 13,900 nmi (excluding ~1,000 nmi steaming distance). These three vessels can cover 12,900 nmi, with an average progression of 160 nmi per day. Increased distance between transects to reduce number of transect per stratum would be the only realistic operational option to move forward with during IESSNS 2022. This means that distance between predefined trawl stations will increase from 60 nmi to 70 nmi in the strata. This is not an optimal solution, but the only option possible in the real world to be able to maintain an acceptable overall spatial coverage og the mackerel during IESSNS 2022.

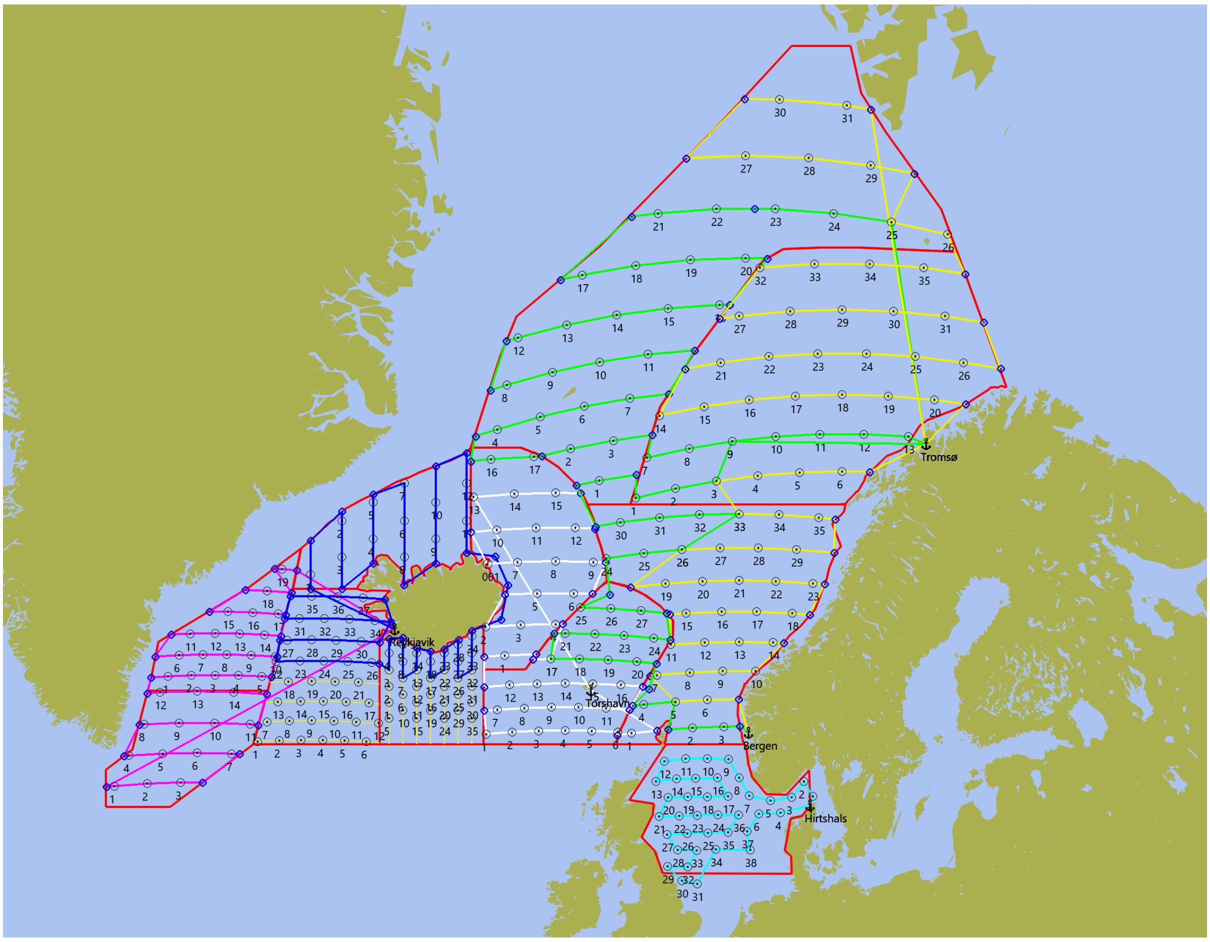


Figure A7. Updated survey plan for IESSNS 2022, including predetermined location of surface trawl stations (open circle with dot inside), survey tracks (different colours for the six different vessels from five different countries), stratum boundary (red line), as partly presented at the WGIPS 2022 meeting.

GERAS

The GERAS acoustic survey 2022 will be carried out on board FRV "*Solea*" from October 5th until October 25th. The plan for cruise SB812 and acoustic transects to be followed follow the design adopted for the previous years (figure A16.8) 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.

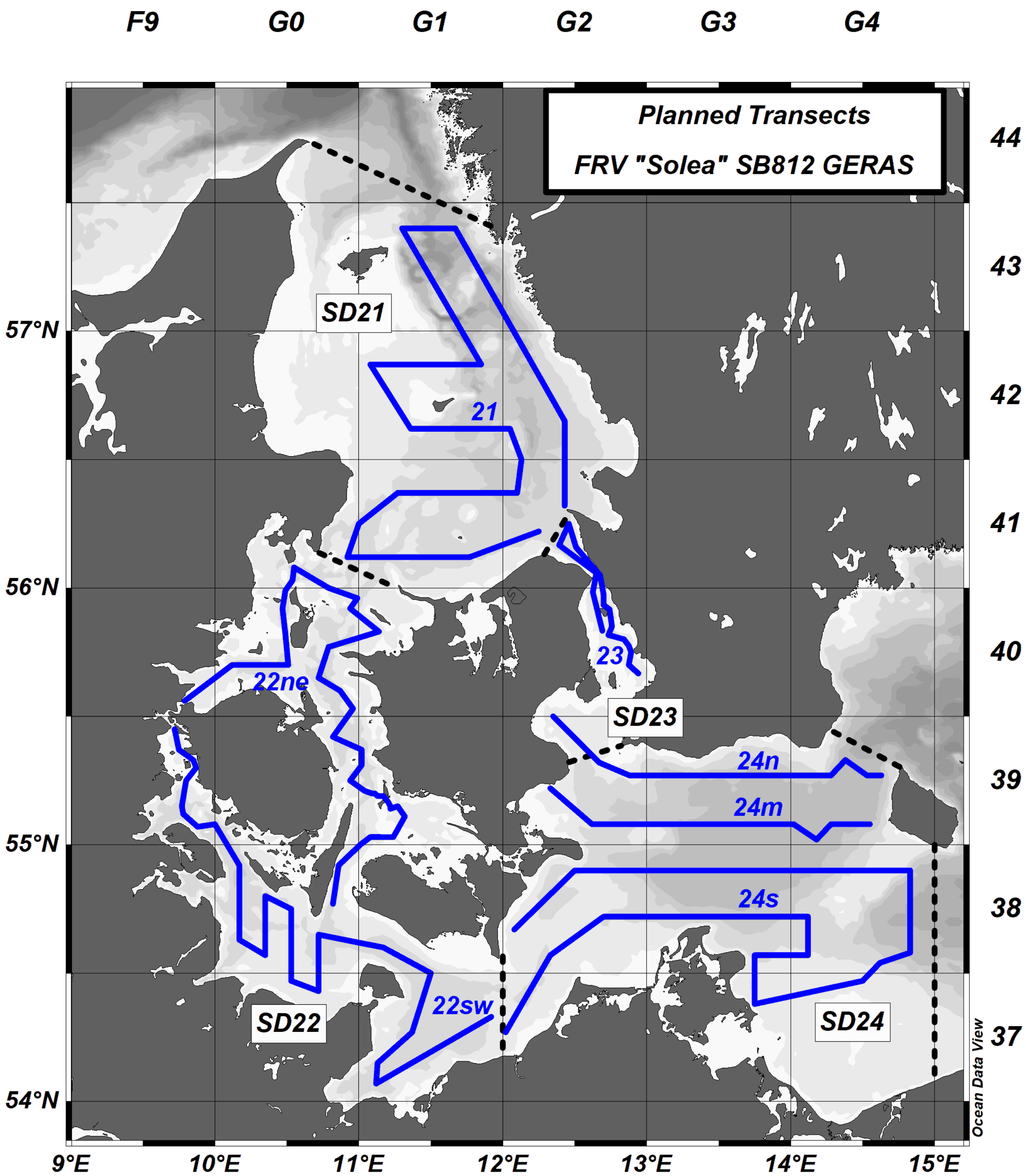


Figure A16.8. Map of the planned coverage in ICES Subdivisions (SD) 21-24 and acoustic transects (blue, transect ID indicated) for the German Acoustic Autumn Survey (GERAS) in 2022 (cruise SB812).

<u>ISAS</u>

The 2022 Irish Sea acoustic survey (ISAS) will be carried out onboard the RV *Corystes* between August 26th and September 14th. Figure A6.7 shows the plan and acoustic tracks for cruise C03522. 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.

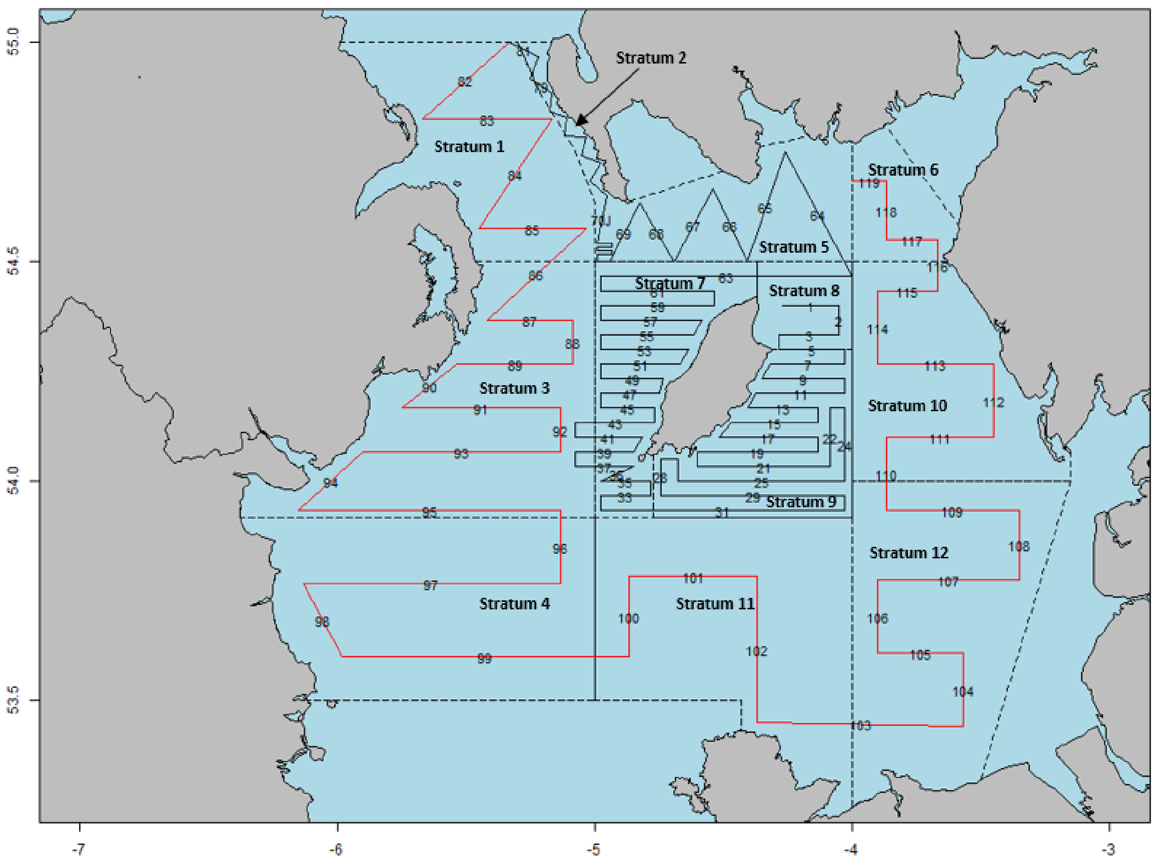


Figure A6.7. Map of Irish Sea and North Channel showing proposed coverage for the 2022 herring acoustic survey C03522.

ISSS

The 2022 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 A6.7 shows the plan and acoustic tracks for cruise HA3922. 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.

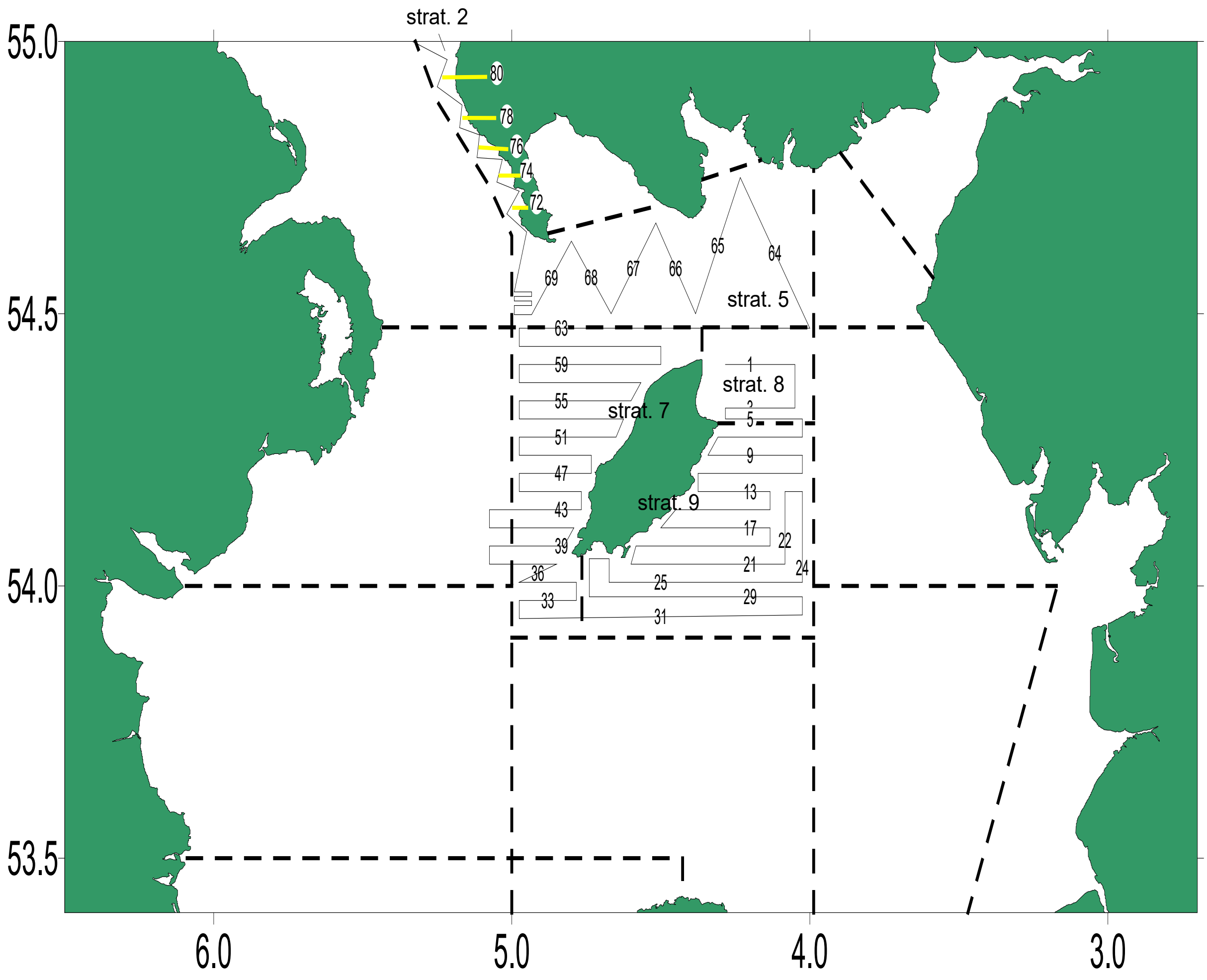


Figure A6.7. Map of Irish Sea and North Channel showing proposed coverage for the 2022 Irish Sea Acoustic Spawning Survey (ISSS) HA3922.

WESPAS

The 2022 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 14 June and work progressively northwards over 42 days ending on the 25 July to the north of Scotland. The survey will be broken into two 3-week legs, with a 1-day break to facilitate a crew change.

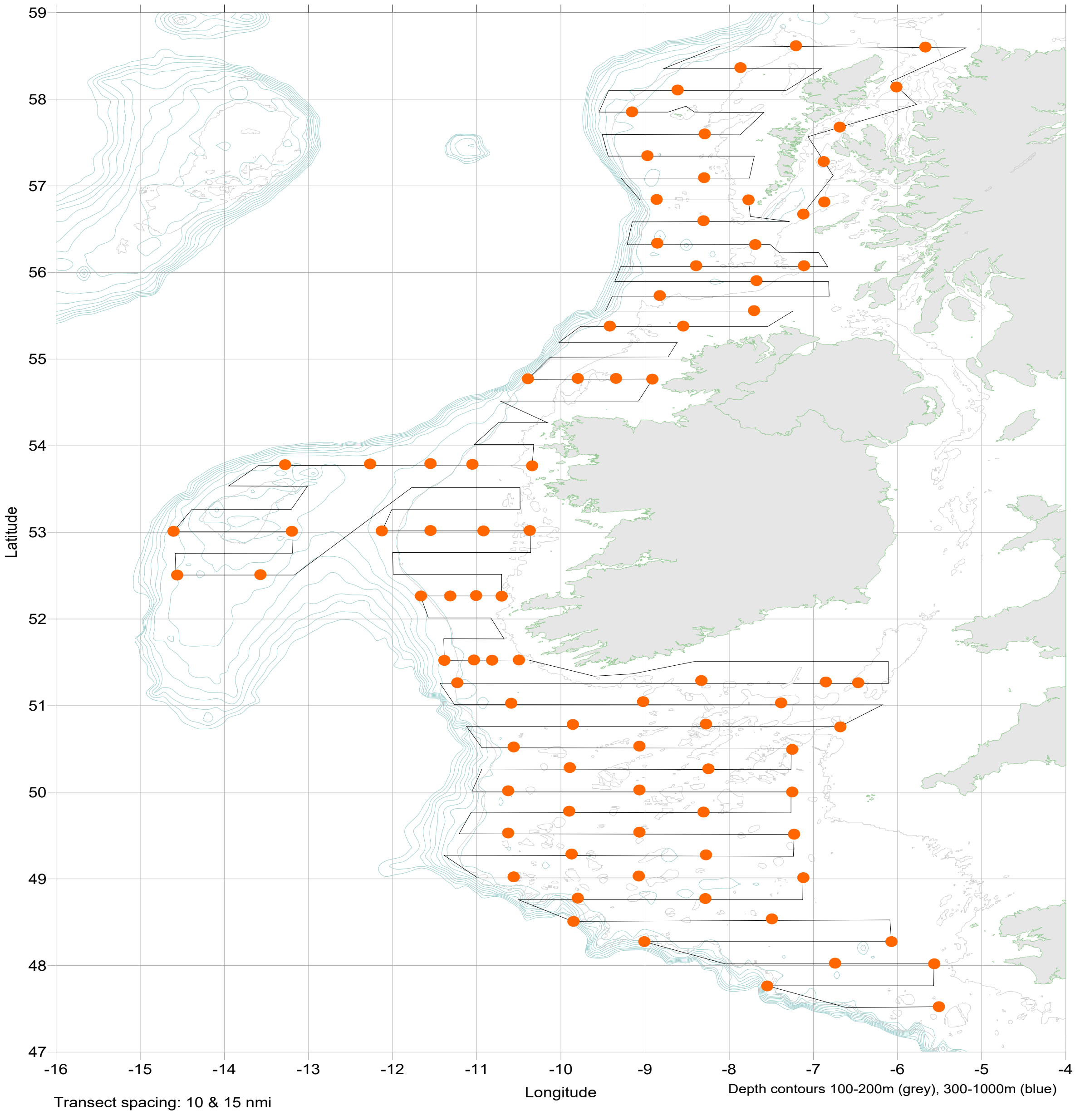


Figure A7.5. Proposed survey design and hydrographic station layout, WESPAS 2022.

CSHAS

The 2022 Celtic Sea acoustic survey will be carried out on board the RV *Tom Crean* (TBC) from the 08–28 October (21 days). Survey design utilises a laddered broad scale survey and focused adaptive high resolution site surveys.

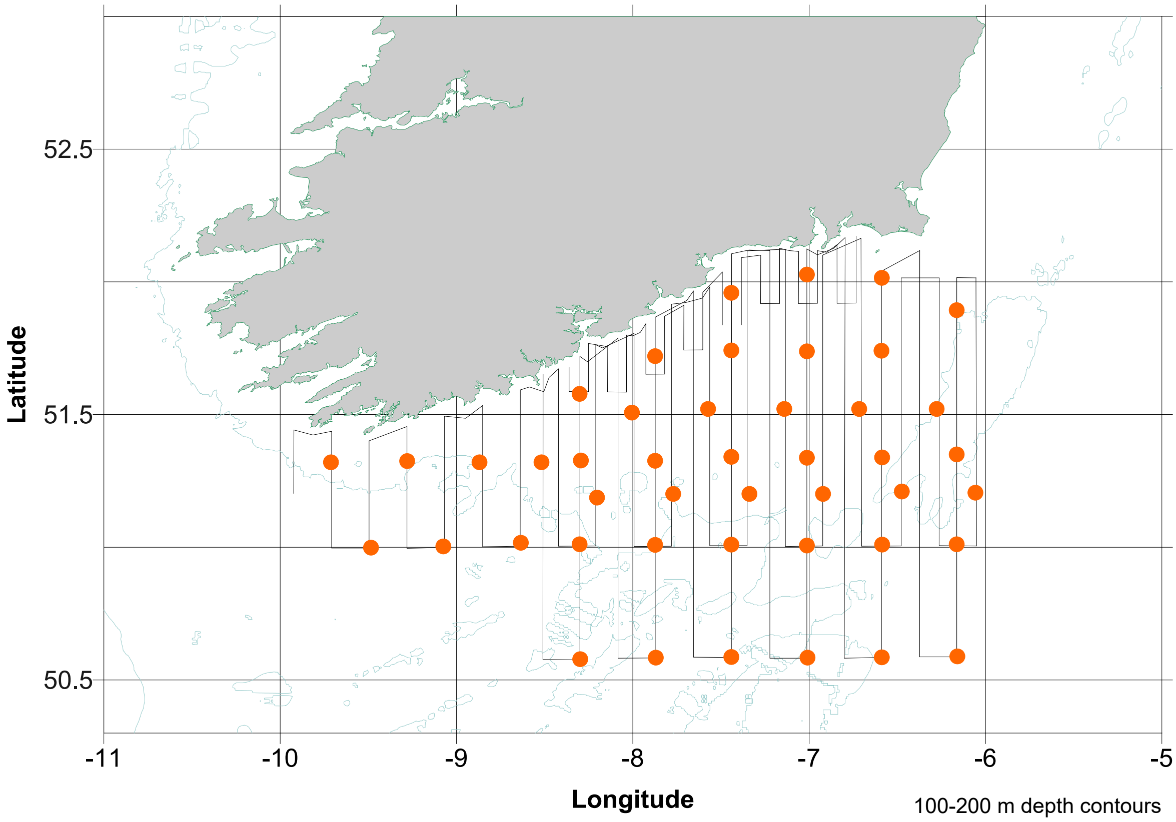


Figure A7.6. Proposed laddered survey design and hydrographic station layout, CSHAS 2022.

PELTIC

The 2022 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 24th of September to the 28th October (TBC). The depicted extension north into Cardigan Bay (transects 61-68) is not confirmed and would extend the survey by several days.

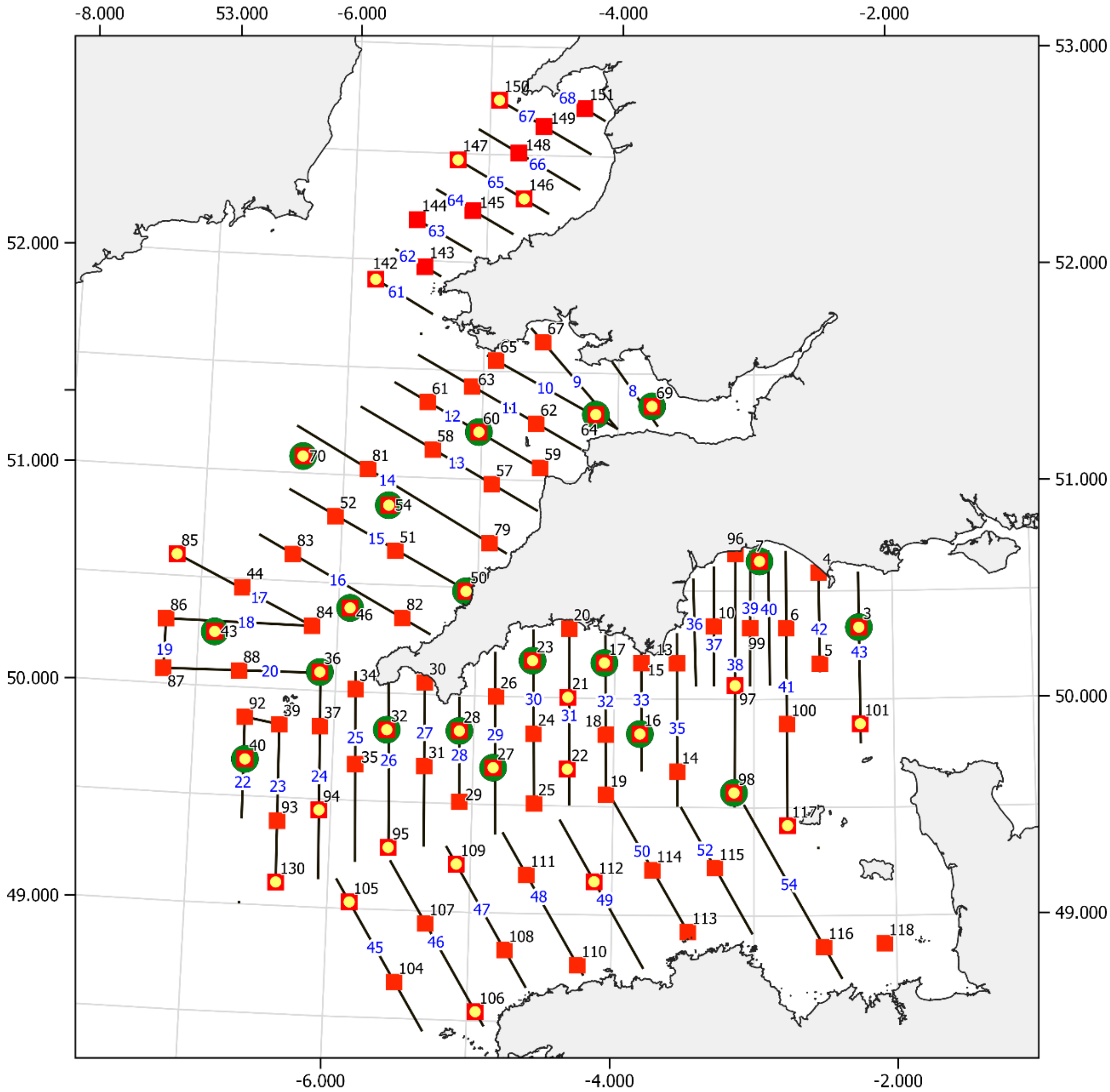


Figure A8XX Overview of the planned survey area, with the acoustic transect (black lines), plankton stations (red squares) and hydrographic stations (yellow circles)., PELTIC 2022.

Future survey plans 6aSPAWN

The 6a7bc herring Benchmark workshop in Feb 2022 will discuss requirements for future monitoring of stocks in 6aN and 6aS 7bc. Pending the outcomes of the advice from the benchmark, future surveys will be reported separately for each area to be consistent with the requirements of the assessments.

6aN

It is proposed to continue the acoustic-trawl monitoring survey of herring in 6aN for a minimum period of 10 years the following reasons:

- There is some evidence for cohort tracking and consistency with results from the WoS part of the HERAS survey, which is indicative of the potential utility of the index. But the time series is short and more time is needed to be able to effectively track the cohorts through their life. With the herring assessment combining ages 9 and above in a plus group, it would make sense for the survey to be run for 10 years.
- With the application of genetics analyses becoming the favoured method for stock splitting, it is very likely that there will be an ongoing need for the collection of baseline genetic samples to (i) maintain the baseline,(ii) resolve outstanding stock identity issues, (iii) inform future discussion on managing stocks 6aN - North Sea
- The survey has been a very important and successful application of a collaborative industry-science initiative that has provided: (i) the means to assess the capability of industry to contribute scientific data of sufficient quality to be useful in stock assessment and ecosystem research, (ii) to facilitate fishermen be able to better understand the scientific assessment process and to see the state of the stock with their own eyes, (iii) the Scottish government the opportunity to engage industry in a constructive way that has helped understanding of industry concerns related to science and management of pelagic fisheries, (iv) benefits to the pelagic industry's engagement in science extending into other initiatives such as self-sampling, support for academic research, support for research charters.
- Parallel work with the HERAS has had similar value – serving to provide understanding of and confidence in the HERAS results used in the North Sea herring assessment.

In 2020 and 2021 support was not forthcoming for conducting scouting searches before and after the acoustic surveys. We consider this to be a shortcoming in the survey design because it limits the opportunity to identify when and where the main spawning activities occur – and thus to adapt and evolve the survey to ensure it is fit-for-propose. It also limits the opportunity to contribute commercial catch samples necessary to support an analytical stock assessment. An element of adaptability is also important to be able to react appropriately to new information – such as recent reports of changes in spawning time and location that are the subject of a new research project led by Napier University.

An ongoing challenge for the planning of the 6aN survey centres on the process for agreeing how industry surveys will be paid in quota for their survey time. It would be beneficial to have a clear and agreed process for this so that the operation planning of the survey is efficient and thorough.

Outline for 2022 6aN herring industry surveys

(Pending outcomes of the benchmark)

Following the 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 acoustic survey would be coordinated with the HERAS survey in July, a second acoustic survey would focus on defined spawning grounds in September (as from 2016)m and the third would comprise a scouting and catch sampling exploration of 6aN. Detailed objectives are given below.

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 and extend the time series index used in assessment.	Building on the 6 year time series, an acoustic-trawl survey would be used to determine the age structure of the herring on the main spawning grounds and extend the time series needed to track the development of cohorts and used as an input to the stock assessment..
(4) Collect genetic samples from spawning fish	Contribute to the repository of baseline samples for genetic discrimination of stocks.
(5) 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.

(6) Carry out a limited commercial fishery to collect biological and genetic samples from areas where herring spawning and fishing have been reported.	A dedicated commercial fishery is proposed for the purpose of (i) providing commercial data needed for the stock assessment, and (ii) enhancing the chance of a successful acoustic survey on the spawning grounds in 6aN (4) by informing on the best timing for the acoustic survey. This scouting trip will collect biological and genetic samples from the reported spawning areas in 6aN that have been covered by the industry survey in previous years, including ‘area 1’ where commercial catches used in the stock assessment have been reported from in the past.

Survey Plans Outline

<u>SURVEY 1: JULY (IN TANDEM WITH HERAS SURVEY)</u>

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 1), in-between existing survey lines (Figure 1).

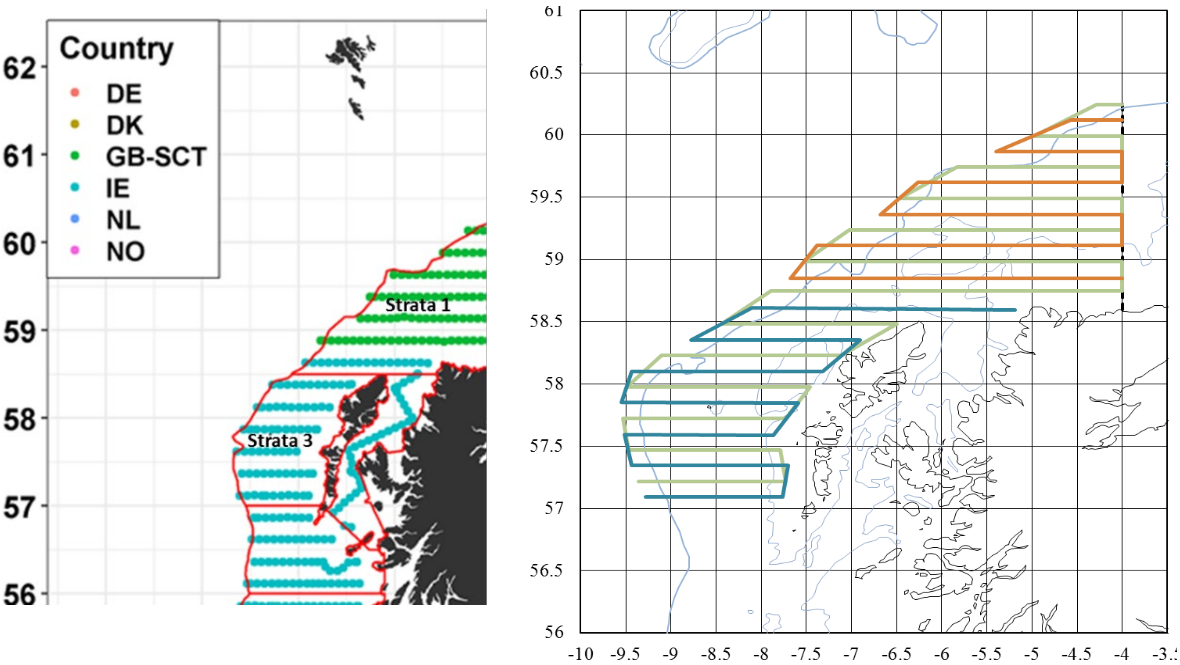


Figure 1. (a) left panel – HERAS survey strata, (b) right panel- Survey plan. 15nmi spacing (green lines) covering HERAS strata 3 in the south and strata 1, North of the Butt of Lewis. Blue lines are covered by Ireland (Celtic Explorer) and orange lines by Scotland (Scotia)

Survey 2: September (6aSPAWN survey)

Objectives 3, 4, 5. *Monitor the abundance-at-age of herring on the spawning grounds, collection genetic baseline samples and help resolve uncertainty in genetic discrimination of 6aN herring.*

As in 2022, 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 used in splitting stocks for assessment purposes. 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 1). 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 1. 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)

<u>Deployment</u>

Vessels: TBC (1 x Scottish vessel, 1x Dutch vessel)

Dates: 10 days between late Aug to end Sept

Staff: Steven Mackinson + 1

Survey design: 2nm spacing acoustic lines (Figure 2). Each vessel covers the survey area twice to provide extended temporal coverage

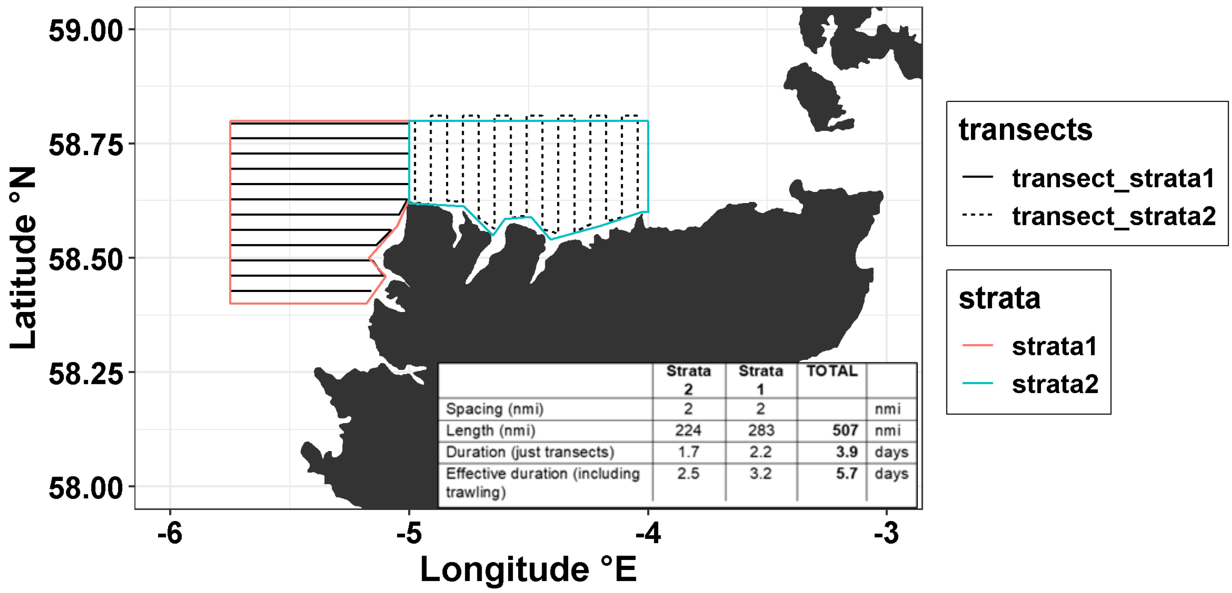


Figure 2. Survey areas for 2021 6aN surveys.

SURVEY 3: AUGUST-OCTOBER (6ASPAWN EXPLORATORY COMMERCIAL FISHING)

Objectives 4,5 & 6. *Carry out scouting activities of herring on the spawning grounds and other parts of 6aN during limited commercial fishery. Help resolve uncertainty in genetic discrimination of 6aN herring.*

Similar to 2019, scouting trips will be included in the overall approach to test whether spawning herring are present prior to or after the acoustic-trawl surveys. This flexibility is particularly important to be able to provide the best possible chance of obtaining baseline genetic samples from spawning fish, especially this year when the cold spring is anticipated to set back the timing of spawning. Scouting will be carried out in August and early October with a focus on the acoustic survey area (figure 2) and other parts of 6aN where spawning and commercial fishing have been reported in the past. In line with the recommendations from ICES, a limited commercial fishery will be carried out to provide for a continued time series of catch at age information to be used in the assessment.

This part of the survey will be carried out by vessel TBC. The vessels will undertake self-sampling within the survey period and will be required to :

- Notify the survey coordinator when commencing searching for herring in 6aN and when finishing the explorations.

- Record raw acoustic data from a calibrated 38khz echosounder during the search and fishing operations for the full duration of the trip in 6aN.
- During search and fishing explorations, record the location of all hauls directed at herring and undertake biological self-sampling of catches following defined protocols.
- Aim for relatively small catches (30-50 tonnes) to allow for multiple samples being taken across a wide area in 6aN. Avoid taking hauls within close vicinity.
- Send a daily update to the survey coordinator.
- If herring constitutes more than 75% of the sample, freeze a sample for later analysis at a scientific institute, labelling the carton clearly with the following information: vessel name, trip, date and Time, haul number, location (lat, long), total weight of herring caught in the haul, whether there was evidence of herring that were spawning at time of capture, such as milt or eggs on the deck. Just label as “Spawning” or “Not Spawning”
- Make the samples available for collection **as soon as possible** after end of fishery so that they can be processed in time for use in the assessment.

Deployment

Vessel: TBC

Dates: 8 days separated into a period in August 2022 and a period in early October 2022 (prior to and after the acoustic surveys).

Staff: self-sampling by vessel crew

Survey design: Scouting and collection of biological samples in combination with limited commercial fishery.

6aSPAWN (Industry Survey in 6.a.S/7.b, c)

An acoustic survey of Atlantic herring will be conducted in ICES areas 6aS/7b between October 2022 and March 2023. 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 2022/23 with the continued objective to capture the distribution of winter and spring spawning herring in the core inshore areas within the greater in the 6aS/7b area (Figure A16.1). 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 A16.2). 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.

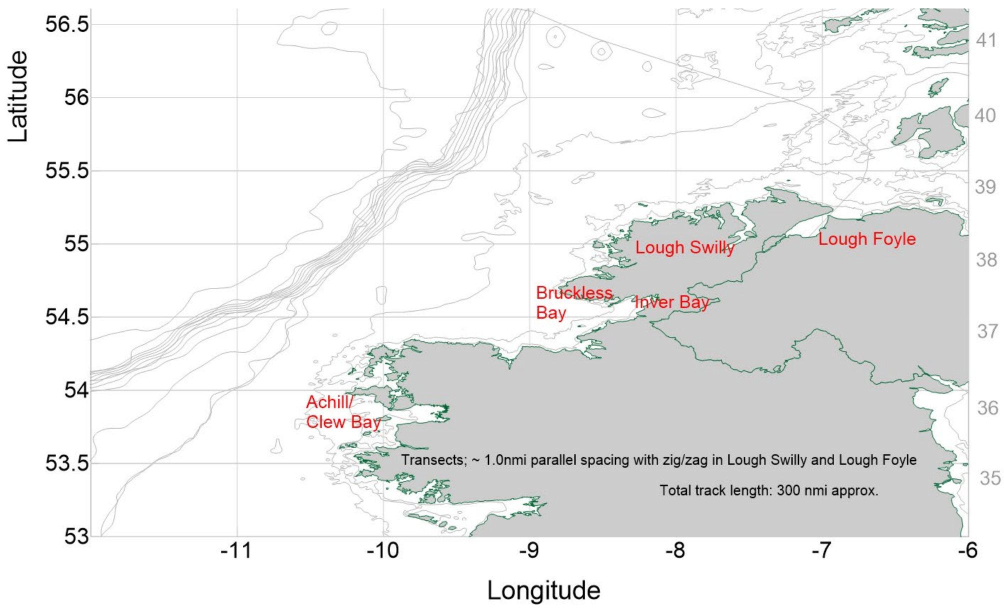


Figure A16.1. 6aS/7b industry acoustic survey in 2022/23: Core areas (5 – 6) will be selected for intense surveys based on information from the monitoring fishery and from previous surveys in 2016-2021. Estimates will be generated from these core areas and surveys will be replicated if possible.

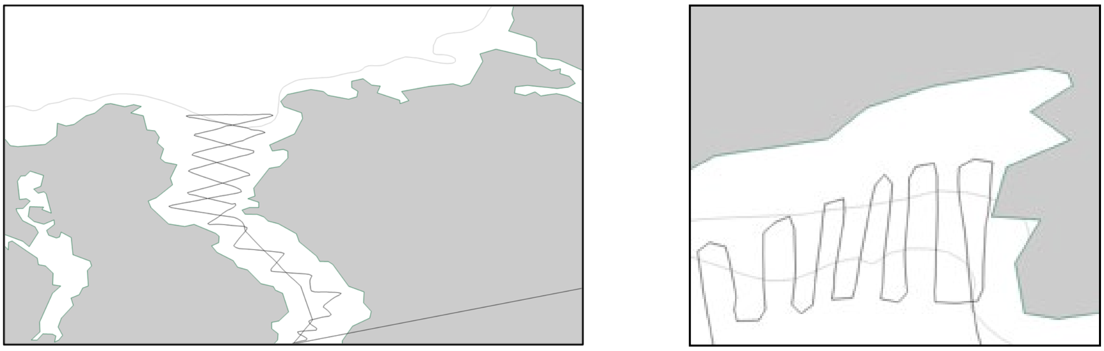


Figure A16.2. 6aS/7b industry acoustic survey in 2022/23: The total planned transect length is approximately 300 nmi in ~5 core areas. The survey design allows for intense surveys in areas where fish are observed and also in areas known to contain herring from information from the fleet (e.g. Lough Swilly (left) and Fintra Bay (right)).

Annex 17: Recommendation from WGAcousticGOV Sampling strategies

Recommendation to survey planning groups (WGBIFS, WGIPS and WGACEGG) from WGAcousticGov

Background

The collection of biological data from trawling sampling is an essential component of the process of estimating fish abundance from trawl acoustic surveys. The ICES Acoustic Trawl Survey database has a defined format and associated vocabularies for the submission of data. WGAcousticGov has started the process to establish a Biological metadata standard, to align with the existing Acoustic metadata standard, and will work with DATRAS via WGDG to develop this further.

Request for information

The input requirements for the submission of biological data to ICES Acoustic Trawl Survey database are defined (ICES data format). As part of this process, it is important to understand how these data are collected at source during national surveys and how data are handled up to the point of upload. Understanding the process of data collection and sampling decisions requires input from Survey Planning Groups.

To that end, WGAcousticGov requests input from the survey planning group (WGWIPS, WGBIFS and WGACEGG) members to provide information on sampling procedures from deck-to-database to feed into this process. This request is not restricted to ICES database users, and input from the those not using the database is encouraged to inform on the wider picture of how biological sampling is conducted during trawl acoustic surveys.

Please provide details (methodology, SOPs, schematics) of how biological sampling is carried out during your national and international coordinated survey programs, key points are highlighted below:

1. What is the biological sampling process on your survey? How is length sampling conducted (random, random stratified,…) and is this correlated to further biological sampling (age, weight, maturity).
2. Are biological sampling data stored separately in a local database, please provide details?
3. Is there currently a need to manipulate data to fit the ICES database and if so how is this carried out?

Feedback

Collated information from the group chairs can be sent directly to WGAcousticGov Chair: Ciaran.odonnell@marine.ie

Annex 18: Recommendation from WGAcousticGOV Standardised scripts

Request from WGAcousticGOV: Standardisation of survey outputs

Background

Reporting of survey derived biomass and abundance from survey data is the primary output from survey work and feeds directly into the stock assessment process. Ensuring consistent high quality and repeatable survey results are key to this process and reporting within TAF. Reporting of survey results has a number of commonalities across both national and internationally coordinated surveys in terms of structure and presentation. In a bid to provide consistency and to streamline the production of standard reporting outputs it has been proposed that code could be developed to query and compile outputs from StoX.

Given StoX has recently moved to an R based platform (from version 3.0) providing an opportunity to develop reporting scripts. StoX developers and the ICES Datacentre have indicated their support in this effort. The development of scripting routines for the production of output tables and figures would standardise the reporting of survey results while offering a time saving measure. For large multi-vessel surveys, a lot of time is taken to compile outputs for reports during the post cruise meetings, leaving less time for the discussion of the results.

Call for input

As WGIPS represent a large StoX user group we think this is the best starting point. Rather than bring this up for discussion cold at the next WGIPS meeting we thought we'd try and get a bit ahead by looking to the survey coordinators for contributions and feedback, the aim being that we would have something to present at our next meeting rather than just talking about it. It would also be good to schedule some time at the meeting in January to discuss this with the wider group if possible.

We have support for this within the ICES datacentre to get things moving on the scripting front. So to move this forward, we're requesting input from the survey coordinators. At this point we are looking for the standard tables and figures that people would like to see scripted. We know for some of the coordinated groups scripts likely already exist and they can feed into this process. Understandably a one-size-fits-all solution is unlikely due to differences in reporting and fish stock structures. That said, an opportunity exists to establish a baseline from which survey specific routines can be further developed.

Within WGIPS we have a GitHub site ready to go: WGIPS gitHub

If we could ask for feedback particularly from the survey co-ordinators, but anyone interested in contributing by Friday 17th September, that should allow time for people to consider what they would like from this product in the future.

Annex 19: WGFAST Response to WGIPS concerning acoustic shadowing

WGFAST Response to WGIPS concerning acoustic shadowing

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.

WGFAST Response

Rolf Korneliussen, Sven Gastauer, and Michael Jech provided a response to this request as follows.

Response from Rolf Korneliussen *(This is an excerpt of an e-mail from Rolf)*

Regarding the shadowing effect, I would claim that quite much is done there:

- *Foote (1983): Theory (after measuring)*
- *Toresen (1991) (some new measurements)*
- *Foote, Ona, Toresen (1992), Theory and measurements*
- *Zhao & Ona (2003) improvements in correction methods (with the help from Gorska).*
- *Utne & Ona (2006) ICES paper: Measurements with bottom fixed transducers: Same result at 2! On mean ext cross section, much meter data.*
- *Martha Uumati et al. (2010), on single schools from Marocco. Method development using BEI etc.*

Both Foote (1983) and Zhao & Ona (2003) methods were implemented in the Bergen Echo Integrator (BEI). These assumed a known, measured mean extinction cross section that was provided by R. Korneliussen. The Foote (1983) theory is approximate and potentially inaccurate depending on how measurements are made available. Implementation in LSSS would be easy. The problems are similar for sonar. I have myself collected data for this for MS70, and so have others at IMR.

The Foote (1983) theory resulted in a Taylor expansion. The expansion was an approximation that relied on high resolution in the data to be accurate. The Zhao & Ona (2003) theory was accurate and did not need high vertical resolution of the data. When herring data were stored at a vertical resolution of 1 m, the Zhao & One (2003) and Foote (1983) theories gave the same result. The extinction cross section was necessary for both theories for the estimation of extinction.

Background

The conversion of echo intensity to abundance estimates is a major goal of acoustic surveys of living marine and freshwater resources. Because these estimates are a (if not "the") fundamental product of acoustic surveys, considerable effort has been dedicated to quantifying the relationship between echo intensity and fish density when using echo integration (Foote, 1999). Ideally, that relationship is linear over the range of animal densities encountered during a survey, and indeed that relationship is indeed linear for most aggregations of animals. For example, Foote (1983) found a linear relationship for fish densities up to 40 pollack (*Pollachius pollachius*) and Atlantic herring (*Clupea harengus*) per m³. We take linearity for granted now, but in the course of determining that relationship, dense aggregations were found to have measured echo intensities that were not linearly proportional to their number densities. For example, early measurements of caged saithe (*Pollachius virens*) and sprat (*Sprattus sprattus*) by Røttingen (1976) suggested a linear relationship of echo intensity to fish density of up to 100 saithe m^{-3} and 2000 sprat m^{-3}, and up to 120 saithe m^{-3} and 2500 sprat m^{-3} at 38 and 120 kHz, respectively, but echo intensity deviated from linear at higher fish densities.

As the transmitted sound interacts with targets, a proportion of the acoustic energy is absorbed and scattered by each target. The combined effect of absorption and scattering by a target is called extinction and the extinction cross section of a target is denoted as σ_e (m^2). In addition, the scattered sound can interact with the other targets before it travels back to the receiver. This is called multiple scattering, and is often considered a second-order term because it has been shown to be of lesser magnitude than extinction (a first order term) under common survey conditions (Stanton, 1983), and is often assumed to be negligible when compared to the effects of extinction (Foote, 1983; Zhao and Ona, 2003). For the purposes of this response, we assume multiple scattering to be negligible.

When the relationship between echo intensity and fish density is linear, σ_e is negligible and the resulting estimates of fish density ($\rho, \# \, m^{-3}$) are calculated directly using echo integration. As fish density increases, more of the acoustic energy is scattered and absorbed, and increased levels of extinction will reduce the measured acoustic energy at proportionally greater magnitude. In this case, the measured acoustic energy is less than what it should be at the transducer. In terms of volume backscattering (s_v , $m^2 \, m^{-3}$), the measured volume backscatter ($\hat{s}_v$) is reduced by a factor of $exp(2\rho\sigma_e \Delta z)$, i.e., $\widehat{s_v} \sim s_v exp(2\rho\sigma_e \Delta z)$, where s_v is the true density, Δz is the vertical extent of the integration layer, and the factor 2 accounts for two-way travel (Foote, 1990). Excess extinction is often called acoustic shadowing (Zhao and Ona, 2003).

To estimate the level of acoustic shadowing, we need to know or estimate the density of scatterers and the extinction cross section of those scatterers. Unfortunately, these are not easy to obtain directly, so methods have been developed to estimate them. The next two sections review methods to identify and correct for acoustic shadowing when there is a reference target and when there is no reference target available.

Corrections for Acoustic Shadowing Using a Reference Target

The effect of acoustic shadowing in an aggregation can be estimated by comparing the echo intensities of a reference target with and without an intervening aggregation in the acoustic beam. A decline in the echo intensity of the reference target when an aggregation is present is proportional to the extinction cross section of that aggregation (Foote et al., 1992), and this information can be used to derive a ratio between the measured acoustic energy from an aggregation and what that energy would be without shadowing, such as the extinction coefficient $\left(\frac{\sigma_e}{\sigma_b}\right)$ where σ_b is the acoustic backscatter cross section $\left(TS = \frac{\sigma_b}{4\pi}, dB \; re \; m^2\right)$ (Foote et al., 1992), or the acoustic shadowing coefficient $\beta = \frac{(s_A - \widehat{s_A})}{s_A}$, where s_A is true areal backscatter $\left(s_A = 4\pi 1852^2 \int_{z1}^{z2} \; s_v dz, m^2 nmi^{-2}\right)$ without shadowing and $\widehat{s_A}$ is the measured areal backscatter, potentially with shadowing (Zhao and Ona, 2003). The seabed is most commonly used as the reference target (e.g., Toresen, 1991; Foote et al., 1992; Zhao and Ona, 2003; Uumati et al., 2010), but a calibration sphere could be used when stationary, or the sea surface (Utne and Ona, 2006) works for upward-looking transducers.

Zhao and Ona (2003) built on Foote et al. (1992) to provide methods to estimate the level of acoustic shadowing and subsequently correct for it. For this response, we assume an aggregation with homogeneous density and extinction cross sections. We leave the cases of inhomogeneous densities and extinction cross sections for the reader to pursue. The areal backscatter of a reference target without an intervening aggregation (s_{ARo}) and with an intervening aggregation $\left(s_{ARf}\right)$ are used to estimate the shadow coefficient $(\hat{\beta})$ by

$$\hat{\beta} = \frac{s_{ARo} - s_{ARf}}{s_{ARo}} = K\frac{\sigma_e}{\sigma_b}\widehat{s_A},$$

where the constant $K = \frac{2}{1852^2}$ accounts for 2-way travel and conversion from SI units to nautical mile squared $(1\ nmi = 1852\ m)$. This equation eliminates the need to estimate ρ within the aggregation, but still requires estimates of σ_e and σ_b. Foote et al. (1992) derived a method to estimate the ratio of σ_e and σ_b ($\gamma = \frac{\sigma_e}{\sigma_b}$ using Zhao and Ona (2003) notation) by using the coefficients of the regression between s_{ARo} and s_{ARf}

$$s_{ARo} = \alpha' + \beta' s_{ARf.}$$

α' and β' are used to define γ as

$$\gamma = \frac{\sigma_e}{\sigma_b} = \frac{-1852^2\widehat{\beta\prime}}{2\widehat{\alpha\prime}},$$

where $\widehat{\beta}'$ and $\widehat{\alpha}'$ are the estimated regression coefficients derived from survey data. Higher values of γ indicate greater acoustic shadowing. Zhao and Ona (2003) provide a correction factor (CF) for acoustic shadowing:

$$CF = \frac{1}{K\gamma\widehat{s_A}} \cdot ln\left(\frac{1}{1 - K\gamma\widehat{s_A}}\right)$$

Table 1 and Figure 1 show that at γ values less than 3, $\widehat{s_A}$ values need to be greater than 100,000 m^2 nmi^{-2} to have correction factors greater than 10%. The R-code to generate Table 1 and Figure 1 is provided at the end of the response.

Table 1. Measured s_A (x1000 m2 nmi-2) ($\widehat{s_A}$), and correction factors (CF) at γ = 1, 2, and 3. The bold and underlined values represent the 10% correction factor where $\widehat{s_A}$ values less than that require less than 10% correction and $\widehat{s_A}$ values above that require greater than 10% correction. NAN represents CF values that are invalid (see Foote (1990) and Zhao and Ona (2003) for causes). The R-code to generate this table is provided at the end of this document.

$\widehat{s_A}$	CF:γ=1	CF:γ=2	CF: γ=2
1	1.000	1.001	1.001
5	1.001	1.003	1.004
10	1.003	1.006	1.009
15	1.004	1.009	1.013
20	1.006	1.012	1.018
25	1.007	1.015	1.023
30	1.009	1.018	1.027
35	1.010	1.021	1.032

40	1.012	1.024	1.037
45	1.013	1.027	1.042
50	1.015	1.030	1.046
55	1.016	1.034	1.051
60	1.018	1.037	1.056
65	1.019	1.040	1.062
70	1.021	1.043	1.067
75	1.023	1.046	1.072
80	1.024	1.050	1.077
85	1.026	1.053	1.083
90	1.027	1.056	1.088
95	1.029	1.060	1.094
100	1.030	1.063	**1.099**
150	1.046	**1.099**	1.160
200	1.063	1.139	1.231
250	1.081	1.182	1.315
300	**1.099**	1.231	1.418
350	1.118	1.285	1.547
400	1.139	1.347	1.719
450	1.160	1.418	1.966
500	1.182	1.500	2.374
550	1.206	1.599	3.402
600	1.231	1.719	NaN
650	1.257	1.872	NaN
700	1.285	2.076	NaN
750	1.315	2.374	NaN
800	1.347	2.897	NaN
850	1.381	4.784	NaN
900	1.418	NaN	NaN
950	1.457	NaN	NaN
1000	1.500	NaN	NaN

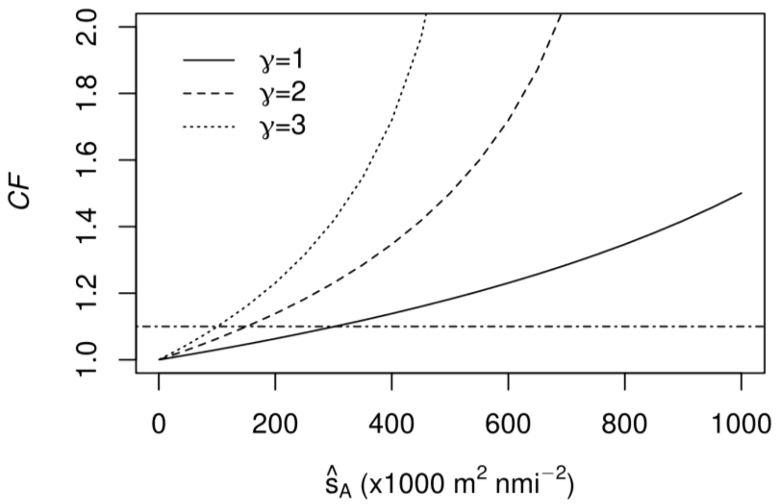


Figure 1. Correction factor (CF) as a function of $\widehat{s_A}$ for three different γ values. The horizontal dash-dot is at the 10% correction level. The R-code to generate this figure is provided at the end of this document.

A limitation to using a reference target, such as the seabed echo, is that measurements of that seabed echo must be obtained without the intervening aggregations. This may be difficult under survey conditions, so additional resources may be required to survey the seabed.

Corrections for Acoustic Shadowing Without a Reference Target

In instances where the seabed echo is not recorded, e.g., when the target species is located where the water depth is much deeper than the depth of the target species, using the seabed as a reference target is not possible.

In the absence of a reference target, the correction factor developed by Zhao and Ona (2003) uses γ as a proxy for animal density and extinction coefficient, thus estimates of γ may be used to indicate the magnitude of correction. Foote et al. (1992) provide ranges of γ for measurements of Atlantic herring at 38 kHz found in their study as well as from the literature from 1.17 to 3.3 (Foote et al., 1992). For these γ values, correction factors can range from approximately 3 to 10% for aggregations with $\widehat{s_A}$ of 100,000 m^2 nmi^{-2} or from about 14 to 70% for aggregations with $\widehat{s_A}$ of 400,000 m^2 nmi^{-2} (Table 1). Thus, it is up to the analyst to decide what level of estimation they are comfortable with.

Software

Echoview currently does not have a dedicated module/virtual variable to identify and correct acoustic extinction by fish schools, but the user can build their own process using their virtual variables to do this.

BEI (Bergen Echo Integrator) that is not used anymore did have a processing module to correct for extinction of herring. There is no similar implementation for LSSS, although the code for BEI is available so that implementing correction for extinction would be relatively easy.

Recommendations

1. Inspect historical data for the prevalence of aggregations that may be affected by acoustic shadowing (e.g., $\widehat{s_A}$ values greater than 100,000 m^2 nmi^{-2}), and develop metrics to estimate the magnitude of the effects. Metrics include percentage of aggregations with acoustic shadowing, magnitude of acoustic shadowing, and effects on abundance estimates.

2. If acoustic shadowing is determined to be significant, devote resources to develop survey protocols and collecting additional data.

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R-Code

```
############################
# Acoustic-Shadow.R
# calculate acoustic shadow correction factors using Zhao and Ona (2003)
# "Estimation and compensation models for the shadowing effect in dense fish
# aggregations", ICES JMS, 60:155-163.
#
# jech
# source('Acoustic-Shadow.R')

# start with clean slate
rm(list=ls(all=TRUE))

# generate areal backscatter values. These simulate those used in Fig. 2 of
# Zhao and Ona
sA = c(seq(0, 100, by=5), seq(150, 1000, by=50))
sA[1] = 1
# scale to typical NASC values of aggregations
sA = sA*1000
# the K constant
K = 2/1852^2

# output plot to a .png file with 300 dpi resolution
png('test.png', bg='white', res=300, width=5, height=4, units='in')
# gamma value, ratio of sigma-e and sigma-b, sigma-e/sigma-b
d = 1
# the correction factor (C), equation 27
cf = (1/(K*d*sA))*log(1/(1-K*d*sA))
plot(sA/1000, cf, pch=20, ylim=c(1,2), lty=1, type='l',
            xlab=expression(paste(hat(s)[A], ' (x1000 ', m^2,' ',nmi^-2,')')),
            ylab=expression(italic('CF')))
abline(h=1.1, lty=4)

# calculate and plot C for gamma values 2 & 3
for (d in 2:3) {
  tmp = (1/(K*d*sA))*log(1/(1-K*d*sA))
```

```
  lines(sA/1000, tmp, pch=20, lty=d)
  cf = cbind(cf, tmp)
}

legend(0, 2, lty=c(1,2,3), box.col='white',
             legend=c(expression(paste(gamma,'=1')),
             expression(paste(gamma,'=2')),
             expression(paste(gamma,'=3'))))
dev.off()

# print the values
cat('Measured sA', '\t\t', ' CF:d=1', '\t\t', ' CF:d=2', '\t\t',
             ' CF:d=3', '\n')
for (i in 1:length(sA)) {
  cat(sprintf('%.0f', sA[i]/1000), '\t\t',
             sprintf('%.3f', cf[i,1]), '\t\t',
             sprintf('%.3f', cf[i,2]), '\t\t',
             sprintf('%.3f', cf[i,3]), '\t\t',
             '\n')
}
```

Annex 20: Splitting the Malin Shelf Herring Acoustic Survey estimates (2014 – 2021) using genetic results from the EASME project

Michael O'Malley, Steven O'Connell, Cormac Nolan, Ed Farrell, Emma White, Afra Egan, Neil Campbell, Ellie MacLeod, Campbell Pert, Steve Mackinson, Richard Nash, Benoit Berges, Andrew Campbell

Background

The Herring Assessment Working Group (HAWG) recommended to the Working Group on International Pelagic Surveys (WGIPS) in 2021 that the results of the EASME project (Farrell et al., 2021) on stock splitting be considered in future analysis and planning of the summer survey in 6.a.N and 6.a.S (also known as the Malin Shelf Herring Acoustic Survey, or MSHAS). WGIPS considered the recommendation and suggested that a Working Document (WD) be produced that gives worked examples of ways that the EASME results can be interpreted and used to split the Malin Shelf herring index. WGIPS suggested that the work should be completed in 2021 before the MSHAS post-cruise meeting, primarily by members of WGIPS but also scientists at the Marine Institute in Ireland (MI) and Marine Scotland Science (MSS) in Aberdeen. The primary task was that separate indices be delivered for the herring stocks surveyed on the MSHAS, using results from the EASME project. A sub-group of scientists from the MI, MSS, IMARES, CEFAS, industry and WGIPS met on numerous occasions on-line during 2021 to discuss the most appropriate splitting methods and to interpret the results. This WD outlines the results of this benchmark sub-group's work.

Introduction

The MSHAS is part of a wider effort to survey herring and sprat in the Northeast Atlantic. The survey comes under the umbrella of the Herring Acoustic Survey (HERAS) for planning and data analysis purposes within WGIPS. The data analysis for MSHAS is largely done during annual post-cruise meetings held in conjunction with other HERAS surveys, e.g. the North Sea Autumn Spawning Herring Acoustic Survey. The survey is presented along with other HERAS surveys at WGIPS annually and results are published in the WGIPS report. Currently, two indices from the MSHAS area are produced for WGIPS: (1) the Malin Shelf Herring (6.a and 7.b, c) index (Table 1) and (2) the West of Scotland herring (6.a.N) index (Table 2). The Malin Shelf index 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 1). The survey targets herring of 6.a.N and 6.a.S spawning origin in mixed feeding aggregations on the Malin Shelf in the summer. The differentiation between 6.a herring and North Sea herring across the 4°W line of longitude is purely based on geography (see review in Farrell et al, 2021). The West of Scotland herring (6.a.N) index is a subset of the MSHAS herring abundance\biomass estimates based purely on geographical location (strata 1 - 4 in Figure 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 (e.g. Table 2). 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 (Table 1).

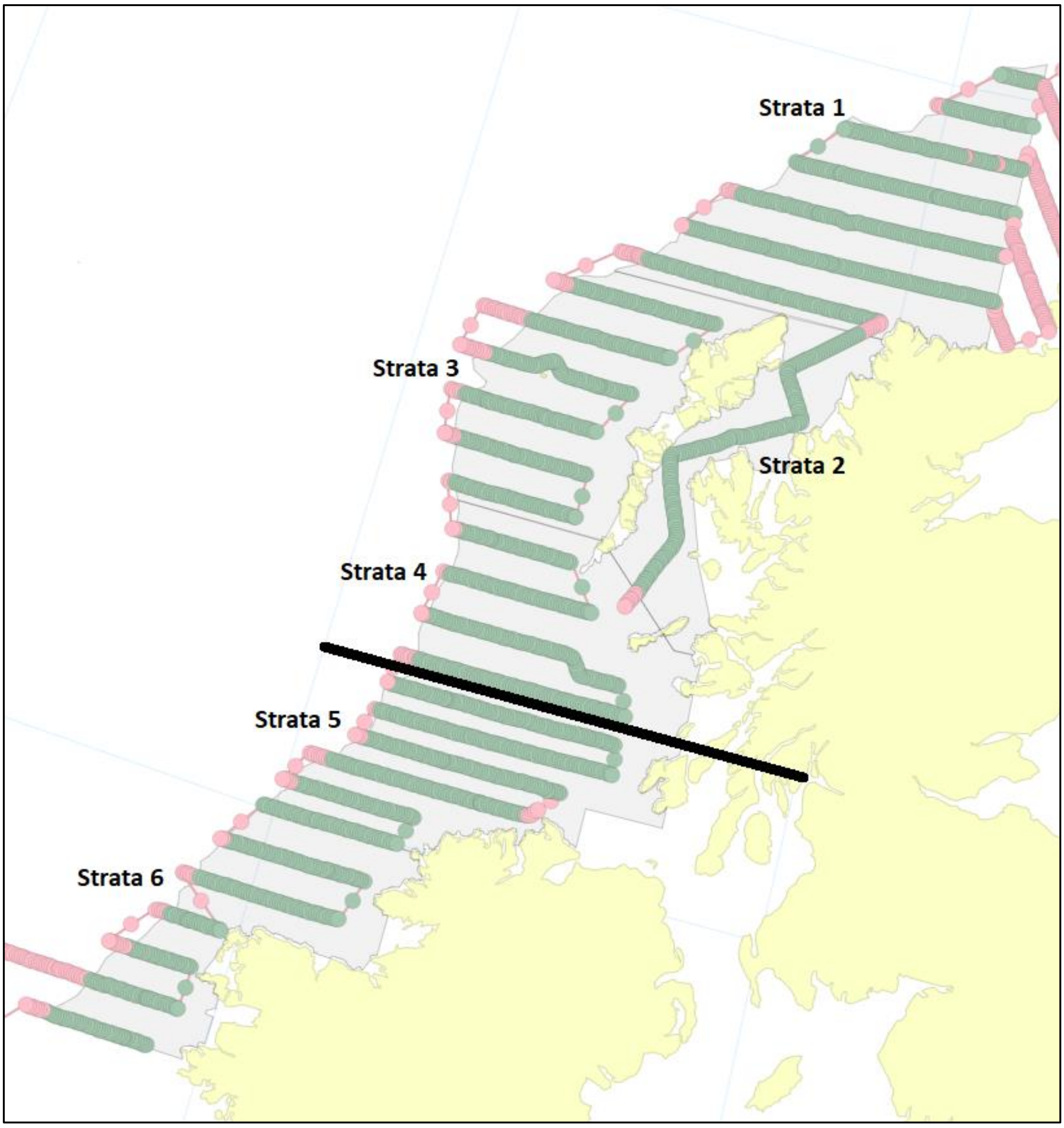

Figure 1: Strata delineations for the MSHAS survey. Transect lines are shown in green. Strata 1 – 6 are the boundaries used to estimate the MSHAS abundance and biomass of herring (Malin Shelf herring). Strata 1-4 was used in the past to generate the 6aN estimates of herring and Strata 5 -6 was used to generate estimates for 6aS/7b,c herring. The heavy black line delineated between the geographical split used historically. These strata are not currently considered to be appropriate for these stocks. Strata 1 is usually completed by MRV *Scotia*, and Strata 2-6 are usually completed by MRV *Celtic Explorer*. In 2015, MRV *Celtic Explorer* completed all Strata 1-6.

Table 1. Numbers at age (winter rings, millions) and SSB (thousands of tonnes) of the Malin Shelf acoustic survey (6.a/7.b,c) time series from 2008 to 2020.

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 2. Numbers at age (millions) and SSB (thousands of tonnes) of West of Scotland herring (6aN) at age (winter rings) from acoustic surveys 1993 to 2020.

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

MSHAS survey design

The recommendation from HAWG to WGIPS was to interpret the EASME project results from 2014 – 2020, therefore we will only deal with the MSHAS index during that time frame here. The MSHAS (2014- 2020) was carried out and analysed in accordance with the ICES survey manual for International Pelagic Surveys (ICES 2015a) using SIMRAD EK60 echosounders with transducers mounted on the drop keel of the MRV *Celtic Explorer* and MRV *Scotia*. Echo integration and further data analyses were carried out using Echoview (Echoview Software Pty Ltd, Hobart, Australia).

The MSHAS survey is designed to be analysed using StoX (Johnsen et al 2019) with a set of 6 strata surveyed annually (Figure 1). The survey area has remained largely the same for the period 2014 – 2020, however, the 2014 and 2015 survey originally used ICES rectangles as the base strata for abundance and biomass estimation rather than the currently delineated larger strata (e.g. 2016 -2020 surveys). This has been updated and made consistent to allow for the splitting work; the strata delineations for 2014 and 2015 surveys were reconfigured within StoX to match 2016 – 2020 surveys.

Genetic sampling on MSHAS (2014 – 2020)

The number of genetic samples obtained in the years 2014 – 2020 averaged about 6 samples per year, but varied between 3 samples in 2019 and 10 samples in 2020 (Annex 1). The target for an individual sample was 120 fish per haul, with most sampling events reaching that target (Annex 1). In the early years of the EASME project, sampling effort was targeted only at fish > 23cm, this was to align with a corresponding effort that was underway looking into stock splitting using morphometric methods; a continuation of the SGHERWAY project methods (ICES SGHERWAY, 2010). Hauls comprising mostly < 23 cm fish were not sampled. The initial plan was to test whether it was possible to align the ongoing morphometric splitting methods with the genetic methods being developed in the EASME project. Unfortunately, stock assignments based on morphometric vs. genetic methods did not have sufficient agreement to warrant the continuation of morphometric data collection (EASME 2020). This period coincided with low sampling numbers overall on the survey. The stock has also been at a low level during these years, some of the lowest in the time-series, meaning that obtaining samples on the MSHAS survey was generally very difficult during this time (Table 1).

Interpreting the EASME results

<u>Genetic Analyses:</u> Baseline spawning samples and putatively mixed MSHAS samples were analysed with a panel of 45 informative genetic markers (45 SNPs) derived from whole genome sequencing analyses undertaken as part of a Norwegian/Swedish/Danish funded project entitled '*GENetic adaptations underlying population Structure IN herring*' (GENSINC) (Han et al., 2020). The baseline genetic analyses indicated that herring in ICES Division 6.a comprise at least three distinct populations; 6.a.S herring, 6.a.N autumn spawning herring and 6.a.N spring spawning herring. The 6.a.S herring are a primarily a winter spawning population though there is a later spawning component present in the area also. These components are currently inseparable and for the purposes of stock assessment should be combined as 6.a.S herring. The Celtic Sea herring and Irish Sea herring are distinct from each other and from the populations in ICES Divisions 6.a however the current genetic marker panel is not optimised for their inclusion in the baseline assignment dataset. This is not considered to be a significant issue as there is no robust evidence that Irish Sea herring are found in large abundance west of the Hebrides during summer. Subsequent to the completion of the EASME project further analyses were undertaken and additional baseline samples added to the 6.a.S herring and 6.a.N autumn spawning herring baselines. The revised baseline was used for the final assignment of the MSHAS 2014-2020 samples.

Genetic Assignment method: A Support Vector Machine learning (SVM) algorithm was used for classification of fish from mixed MSHAS samples to baselines, based on (Approach 1) prior knowledge of baseline sample origin and (Approach 2) genetic clustering of baseline samples. Approach 2 is more precautionary but neither approach would artificially inflate either stock in the resulting split as each approach allows for 'mixed' and 'unknown' categories that would not be included in either 6aN or 6aS indices. Both approaches resulted in self-assignment rates of >90% indicating a high level of assignment accuracy and both were endorsed in an independent review by the ICES Stock Identification Methods Working Group (ICES 2021). The more objective classification method of approach 2, genetic clustering, was therefore chosen by the sub-group. All further reference to genetic assignment in this WD refers to approach 2.

Successful Assignment Threshold (0.67): A probability of classification of 0.67 was used in the EASME project as the threshold for successful stock assignment of an individual herring. This threshold indicated that an individual was twice as likely to be from one baseline group than the alternate group. The effects of different assignment thresholds were investigated by the sub-group. The results of this work are presented in Annex 8. Most resulting probabilities for approach 2 were in the region of 0.95 and the sub-group decided that a threshold probability of 0.67 struck an appropriate balance between certainty of stock assignment and retaining as many fish as possible in the analysis.

Genotyping fails vs. threshold fails: It was decided by the sub-group that genotyping fails were to be disregarded from the analysis (e.g. samples that could not be genetically analysed due to DNA degradation or did not pass genotyping quality control etc. See section 4.8 page 81 of the EASME report for details). Such samples were NOT included as 'unknown' her-27.6a7bc when proportioning biomass. Threshold failures however WERE included in the analysis and will therefore count towards 'unknown' her-27.6a7bc in the table below.

StoX survey analysis software: The group decided that using StoX (Johnsen *et al.* 2019) would be the preferred method to split the MSHAS index. StoX is the accepted survey analysis software tool used by MSHAS and the wider WGIPS group dealing with acoustic surveys for herring in the Northeast Atlantic. StoX programmers (IMR, Norway) designed the StoX project and functions to suit the MSHAS split work. This helps ensure that the project is easily implemented in the Transparent Assessment Framework (ICES TAF) and that the survey projects can be re-run by any StoX user by downloading files from the ICES DB. The StoX project is designed to include bootstrapping of results to generate associated CVs.

Data processing to include the EASME results

The scrutiny of hydroacoustic data in the MSHAS area is done to individual species level. Nautical Area Scatter Coefficient (NASC m^2/nmi^2) values of herring are generated per nautical mile (nmi) along the transects of the survey and the MSHAS is divided up into 6 strata (Figure 1). Abundance and biomass at age (-wr) is estimated per strata and for the entire survey area, The following target strength are used for Malin Shelf herring (ICES, 2015a):

Herring **TS = 20 log L - 71.2 dB**

The disaggregated biological and acoustic data are uploaded annually to the acoustic survey database held on the ICES database (ICES DB) by the ICES data centre. https://www.ices.dk/data/data-portals/Pages/acoustic.aspx

The ICES DB uploaded files are in 2 types:

1. Acoustic .csv files include all the NASC values per species per nautical mile on the survey transects
2. Biotic .csv files include all the biological data from hauls/samples obtained on the survey. Individual information from fish samples include length, weight, sex, age maturity and stock code.

All biotic files from the Irish and Scottish MSHAS surveys in the ICES DB (2014 – 2020) were updated and re-uploaded to include the results of the EASME project. Essentially this involved populating the stock code column for the individual fish that had been genetically sampled. Fish that had achieved a probability threshold of (0.67) using Approach 2 were given a stock code in the ICES DB. In the ICES DB, the column heading is *BiologyStockCode*. The *BiologyStockCode* names are shown in Table 3. It was decided by the group that the names currently in the ICES DB were to be used as temporary proxies for this work until a naming convention is agreed by ICES in the future.

Table 3. *BiologyStockCode* names used in the ICES DB. The stock codes in the right hand column (in red) were nominally given to the stocks for the purposes of this benchmark. It is expected that these would change to meet the most up-to-date ICES naming conventions (example suggested names in the left-hand column).

Biology-StockCode **ICES DB name (proposed – naming convention needs to be agreed)**	**Stock description**	**EASME Approach 1 category in final assignment**	**EASME Approach 2 category in final assignment**	***Temporary Biology-StockCode*** **Already in ICES DB (when using Approach 2 – until decision on naming is made)**
her.27.6aN_aut	autumn spawning 6.a.N herring	6aN_Aut	Group135	her-vian
her.27.6aN_sp	spring spawning 6.a.N herring	6aN_Sp		
her.27.6aS7bc	6.a.S/7.b,c herring	6aS	Group46	her-irlw
her.27.6a7bc	mix of herring from 6.a and 7.b,c; *i.e. unknown or below threshold fish*	NA	NA	her.27.6a7bc
her.27.6a7bc_sp	spring spawning herring of uncertain origin, could be 6.a.N or 6a.S/7.b,c	6aS/6aN_SP	Group2 and Group 462	her-67bc

Using StoX to re-analyse the MSHAS survey (2014 – 2020)

The data was re-analysed using the newest StoX version (3.1.0) software (Johnsen et al 2019). Older versions of StoX (e.g. StoX 2.7) did not have the functionality to split the survey estimates using *BiologyStockCode*, however this is now possible with the latest StoX version 3.1.0. The new StoX 3.1.0 projects were set up for the years (2014 – 2020) to match as close as possible the StoX projects from previous runs. This involved MI and MSS scientists going through each project and matching up transects and haul allocations to what had been done previously. Acoustic and biological data for both surveys were combined within the same StoX project to provide an overall global estimate for the Malin Shelf area for each year 2014 – 2020 and for each biology stock code. Estimates of numbers-at-age, spawning stock biomass, uncertainty (CV), maturity stage and mean weights-at-age were calculated by individual survey stratum. The results provide estimates per survey of:

- autumn spawning 6.a.N herring: *BiologyStockCode* = *her-vian*
- 6.a.S,7b, c herring: *BiologyStockCode* = *her-irlw*
- mix of herring from 6.a. and 7b, c; i.e. unknown or below threshold fish: *BiologyStockCode* = *her.27.6a7bc*
- spring spawning herring of uncertain origin, could be 6.a.N or 6.a.S/7.b, c: *BiologyStockCode* = *her-67bc*

StoX imputing procedures

StoX 3.1.0 has implemented methods to split length group structured abundance estimates by biological variables such as length groups, age, special stages, maturity, sex, stock code etc. As these variables typically are measured on a small number of the length measured individuals, a large proportion of the length group structured abundance estimates (super-individuals) have missing values for the biological variables. However, an imputation functionality in StoX make it possible to fill in missing ages for all length groups. The imputation of missing age is principally carried out at the station level, randomly selecting the value from aged super-individuals within the same length group. If no aged super-individual is available at station level, the imputation is attempted at strata level, or lastly on survey level. In instances, where no age information is available at any level for a specific length group, the abundance estimate is presented with unknown age (StoX imputation methods in annex 9).

Results

Overall the sum of the combined split SSB are very close to the original SSB for the Malin Shelf area for the years 2014 -2020 considered here (Figure 2 and Table 4). The slight differences are due to the change in length frequencies applied to transects according to the differences in the length frequencies of the stocks as the split is applied. The new StoX projects that were set up to match the original are considered to be very close to the original.

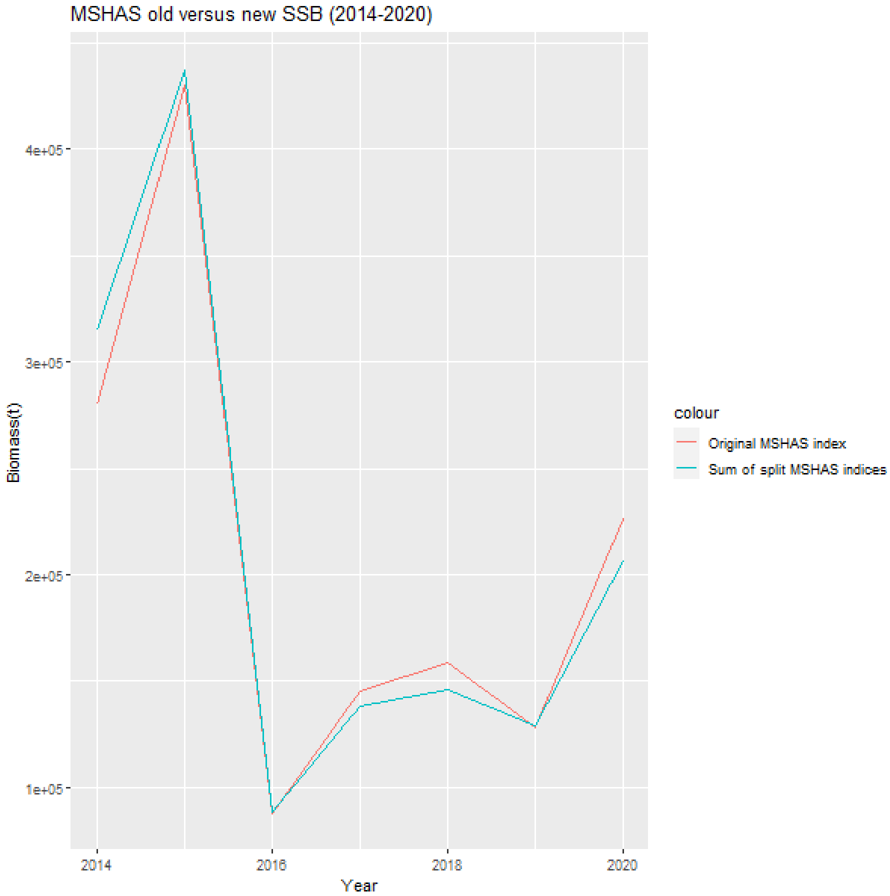

Figure 2. SSB (t) comparison between the original MSHAS index and the sum of the combined split indices.

	Abundance at age (TSN x 10^6)												
Age(-wr)	1	2	3	4	5	6	7	8	9+			SSB (t)	
2014 (WGIPS)	1012	278	242	502	534	148	33	19	13			280000	original SSB
										blank			
her.27.6a7bc	0	5	16	16	20	2	0	0	0	0		8855	
her-67bc	0	28	99	174	182	69	9	15	6	1		108367	
her-irlw	0	30	119	271	252	99	31	10	5	0		149270	
her-vian	0	3	13	21	85	20	5	2	7	0		32460	
(blank)	80	25	5	0	1	2	2	1	2	811		15687	
TOTAL	80	91	252	482	541	193	48	29	19	812		314638	split SSB (total)
											% difference	12	

	Abundance at age (TSN x 10^6)												
Age(-wr)	1	2	3	4	5	6	7	8	9+			SSB (t)	
2015 (WGIPS)	0	212	397	747	423	476	90	24	2			430000	original SSB
										blank			
her.27.6a7bc	0	22	52	23	21	27	2	3	0	0		27610	
her-67bc	0	32	58	150	60	99	13	1	0	0		76009	
her-irlw	0	123	256	395	255	225	59	9	0	0		226293	
her-vian	0	36	139	127	97	106	25	4	6	0		107113	
(blank)	0	0	0	0	0	0	0	0	0	2		26	
TOTAL	0	212	505	695	433	458	98	17	6	2		437050	split SSB (total)
											% difference	2	

	Abundance at age (TSN x 10^6)												
Age(-wr)	1	2	3	4	5	6	7	8	9+			SSB (t)	
2016 (WGIPS)	0	30	108	88	112	79	62	6	1			88000	original SSB
										blank			
her.27.6a7bc	0	2	4	1	2	2	2	2	0	0		2848	
her-67bc	0	1	37	31	67	31	32	1	0	0		37809	
her-irlw	0	8	45	42	38	42	26	2	1	0		36707	
her-vian	0	6	16	14	11	9	5	0	1	0		10870	
(blank)	0	1	0	0	0	0	0	0	0	3		181	
TOTAL	0	18	102	88	118	84	66	4	2	4		88414	split SSB (total)
											% difference	0	

	Abundance at age (TSN x 10^6)												
Age(-wr)	1	2	3	4	5	6	7	8	9+			SSB (t)	
2017 (WGIPS)	0	25	339	155	106	110	47	13	5			145000	original SSB
										blank			
her.27.6a7bc	0	0	9	3	4	4	2	0	0	2		4392	
her-67bc	0	0	110	36	20	44	8	4	1	11		43478	
her-irlw	0	7	113	88	39	59	39	22	0	9		66342	
her-vian	0	1	36	25	26	11	10	2	2	1		21863	
(blank)	0	2	1	0	0	1	2	1	1	66		2210	
TOTAL	0	9	269	153	90	119	62	29	4	89		138285	split SSB (total)
											% difference	-5	

	Abundance at age (TSN x 10^6)												
Age(-wr)	1	2	3	4	5	6	7	8	9+			SSB (t)	
2018 (WGIPS)	1289	447	106	343	153	52	72	27	13			159000	original SSB
										blank			
her.27.6a7bc	51	11	4	3	6	0	2	0	2	0		4213	
her-67bc	51	49	17	50	26	14	7	7	1	1		24426	
her-irlw	573	304	68	199	92	37	47	15	6	1		96138	
her-vian	93	41	14	48	17	3	10	5	2	0		20663	
(blank)	141	3	0	0	0	0	0	0	0	260		564	
TOTAL	910	408	104	301	141	55	67	27	11	262		146004	split SSB (total)
											% difference	-8	

Table 4. TSN (x 10^6) and SSB (t) comparison between the original MSHAS index and the split indices. The blank row and column are fish that are not assigned to any stock code.

	Abundance at age (TSN x 10^6)												
Age(-wr)	1	2	3	4	5	6	7	8	9+			SSB (t)	
2019 (WGIPS)	24	231	225	123	169	95	14	17	21			128000	original SSB
										blank			
her.27.6a7bc	0	5	2	2	10	5	0	2	0	0		4222	
her-67bc	3	33	4	24	27	12	4	11	1	0		17370	
her-irlw	4	171	214	103	92	47	6	17	9	0		92364	
her-vian	0	17	17	16	20	5	0	0	1	0		10508	
(blank)	0	0	0	0	4	6	2	1	3	41		4814	
TOTAL	7	226	237	145	153	75	12	32	14	41		129278	split SSB (total)
											% difference	1	

	Abundance at age (TSN x 10^6)												
Age(-wr)	1	2	3	4	5	6	7	8	9+			SSB (t)	
2020 (WGIPS)	1175	1226	609	235	110	209	42	18	10			226000	original SSB
										blank			
her.27.6a7bc	55	46	42	5	0	9	0	4	0	0		10387	
her-67bc	238	193	98	21	22	38	5	5	0	0		33987	
her-irlw	895	776	402	188	71	120	25	7	9	0		135335	
her-vian	59	104	50	15	12	28	11	0	0	0		26070	
(blank)	2	0	0	0	0	0	0	0	0	6		260	
TOTAL	1248	1119	591	229	107	195	40	16	9	6		206038	split SSB (total)
											% difference	-9	

Table 4 continued. TSN (x 10⁶) and SSB (t) comparison between the original MSHAS index and the split indices. The blank row and column are fish that are not assigned to any stock code.

In all years apart from 2014, the difference between the original MSHAS index SSB and the sum of the combined split SSB is < 10% (Table 4). For the 2014 StoX project, it was difficult to match exactly what was done in the original estimate because there was a change in the strata design from 2015 onwards (ICES 2015b). The survey moved from an ICES rectangle based extrapolation to a strata based approach during this time. However, the new StoX project with split indices is still considered to be a good representation of the 2014 survey.

The TSN numbers in the new combined split projects match well with the originals also similar trends in numbers persist in all years. There are some years where there appears to be a slight discrepancy in the 1-wr fish, these appear in the "blank" row and column. This happened in years when the < 23cm fish were not targeted for sampling. If there is a paucity of sampling for a particular length class, then StoX is unable to assign a *BiologyStockCode*.

CVs on the split survey estimates are within expected values for acoustic surveys for herring in this area (Annex 3).

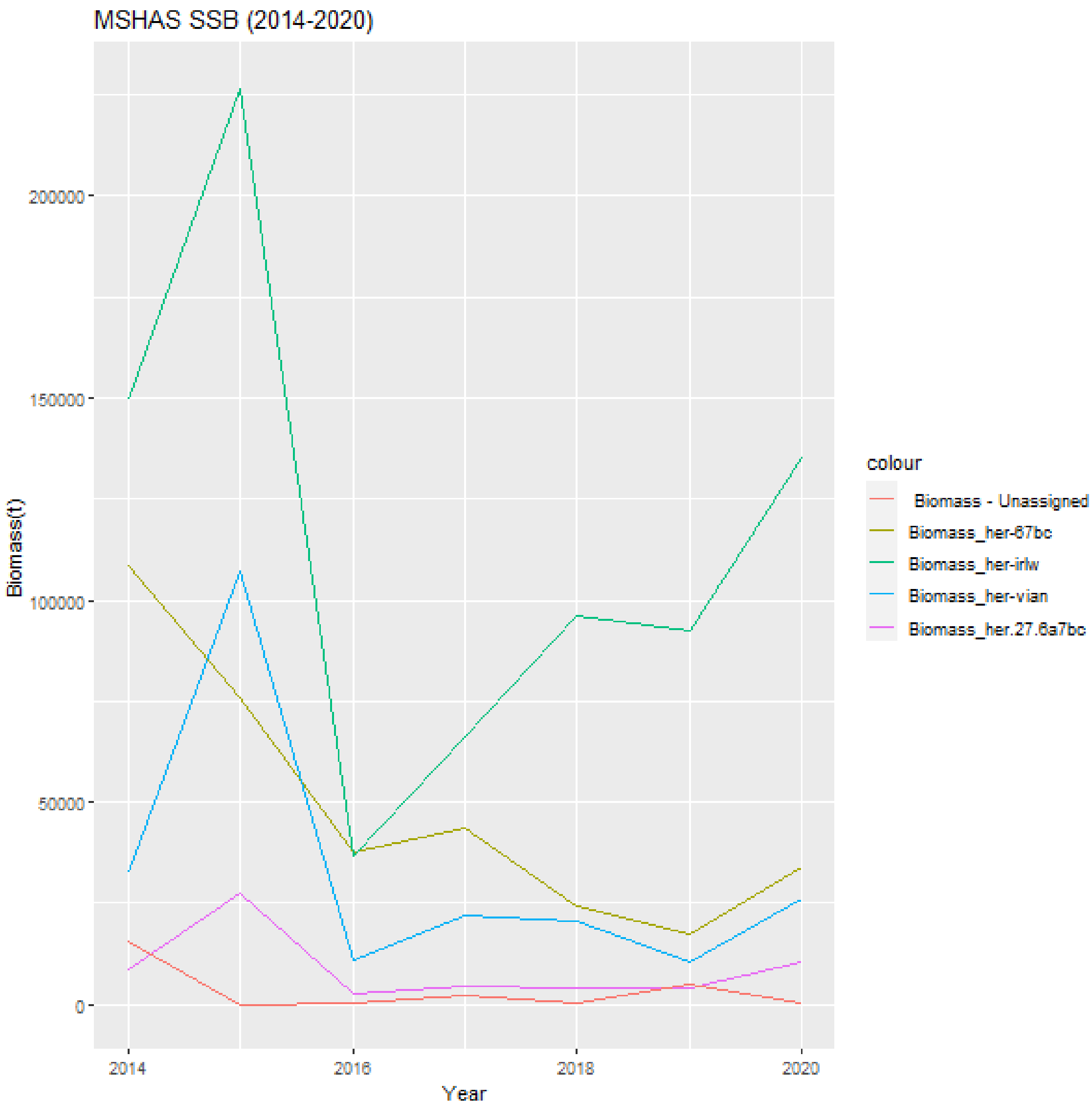

Figure 3. SSB (t) time-series for the individual split indices (2014 – 2020).

Cohort Tracking of Split Indices

The cohort tracking of the catch numbers at age of the split indices are shown in figures 5 – 8. There appears to be reasonably good cohort tracking for some of the individual split surveys, particularly the her-67bc (spring spawning herring of uncertain origin – Figure 5) and her-irlw (6aS and 7.b c herring – Figure 6). The her-vian (6aN autumn spawning herring – Figure 7) numbers at age appears variable but there are some signs of cohort tracking, the variability may be linked to the low numbers of these fish in the genetic samples in some years. The her.27.6a7bc (unknown or below threshold fish – Figure 4) cohort tracking also appears to be variable, however, this is not unexpected considering that there are very low samples of these fish in the genetic samples in most years.

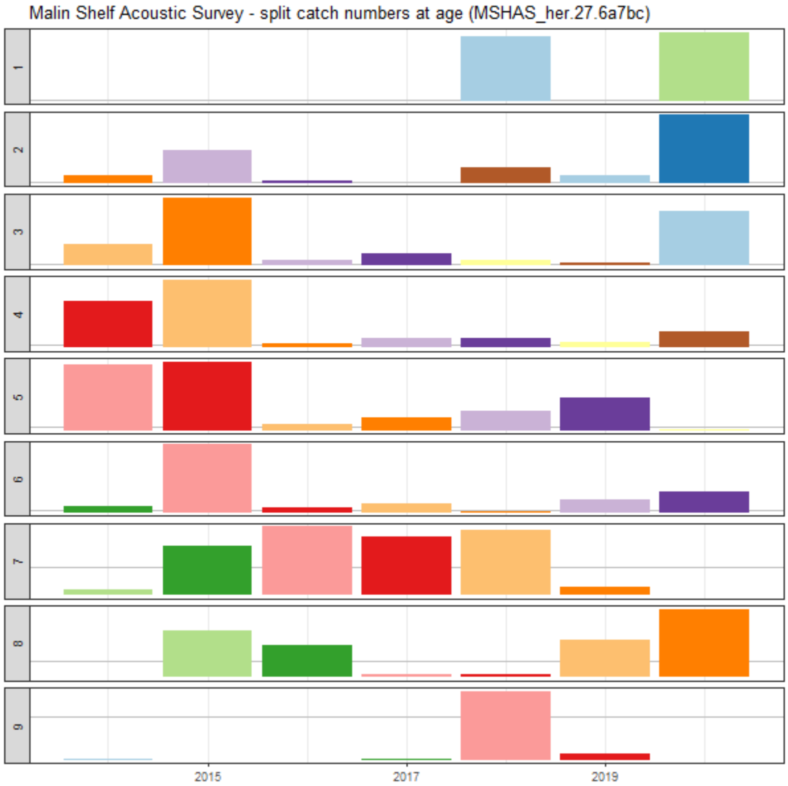

Figure 4. Malin Shelf Acoustic Survey - split catch numbers at age (MSHAS her.27.6a7bc)

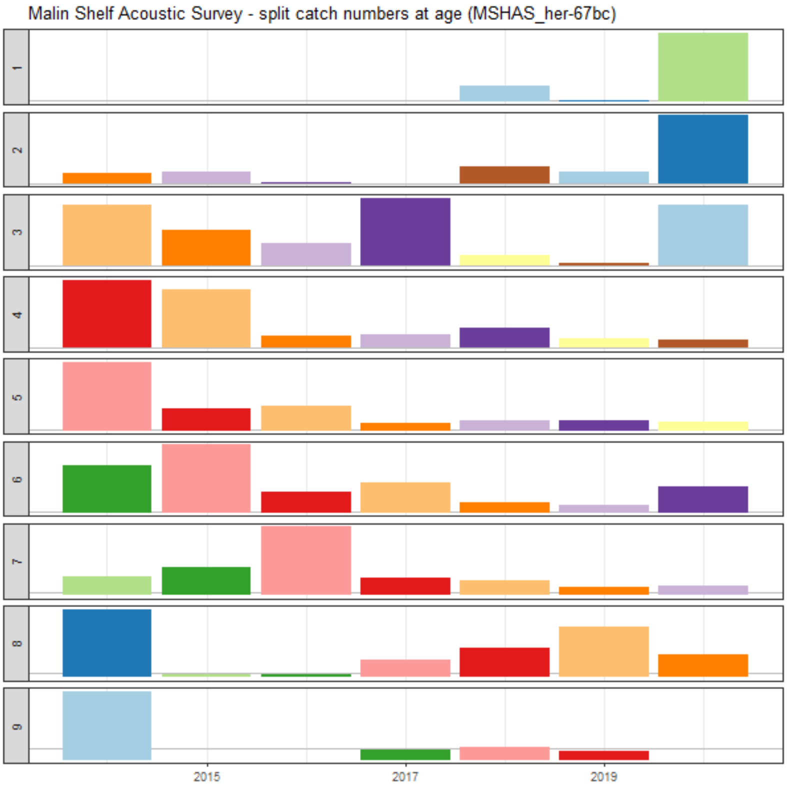

Figure 5. Malin Shelf Acoustic Survey - split catch numbers at age (MSHAS her-67bc)

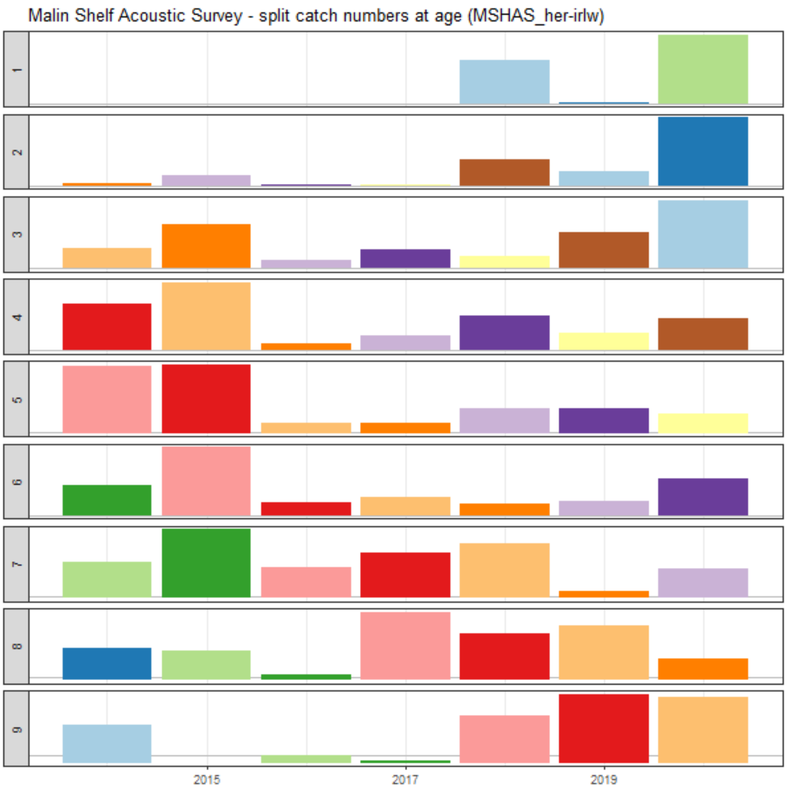

Figure 6. Malin Shelf Acoustic Survey - split catch numbers at age (MSHAS her-irlw)

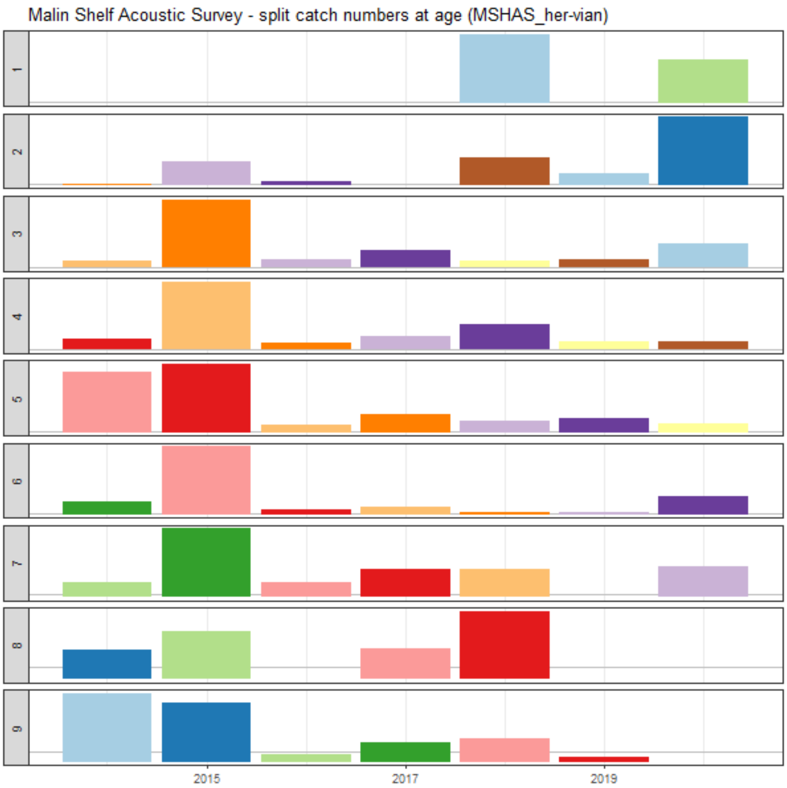

Figure 7. Malin Shelf Acoustic Survey - split catch numbers at age (MSHAS her-vian)

Length Frequency of herring abundance

Length frequency density plots of the split Malin Shelf index are shown in figures 8 – 11. Similar to the cohort tracking of age, there appears to be some evidence of length frequency tracking for the individual split surveys, particularly the her-67bc (spring spawning herring of uncertain origin – Figure 9) and her-irlw (6aS and 7.b c herring – Figure 10). Smaller and younger fish, particularly 1-wr fish are caught sporadically on this survey, and in some years don't appear in the samples on the survey. Younger immature fish may be outside of the survey area during the survey, and can be difficult to sample in some years.

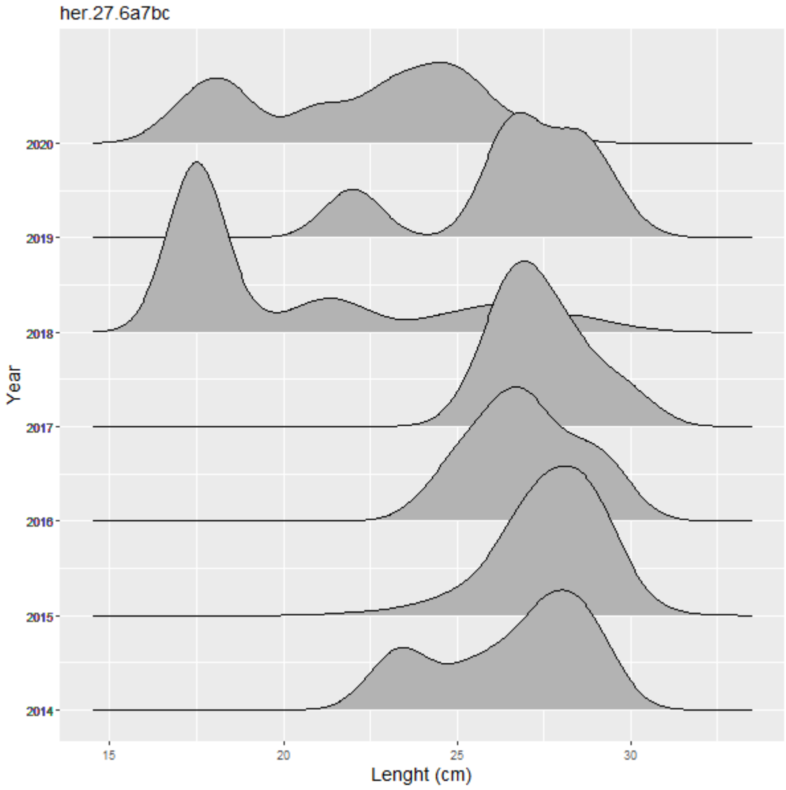

Figure 8. Malin Shelf Acoustic Survey - split index length frequency density plot (MSHAS her.27.6a7bc)

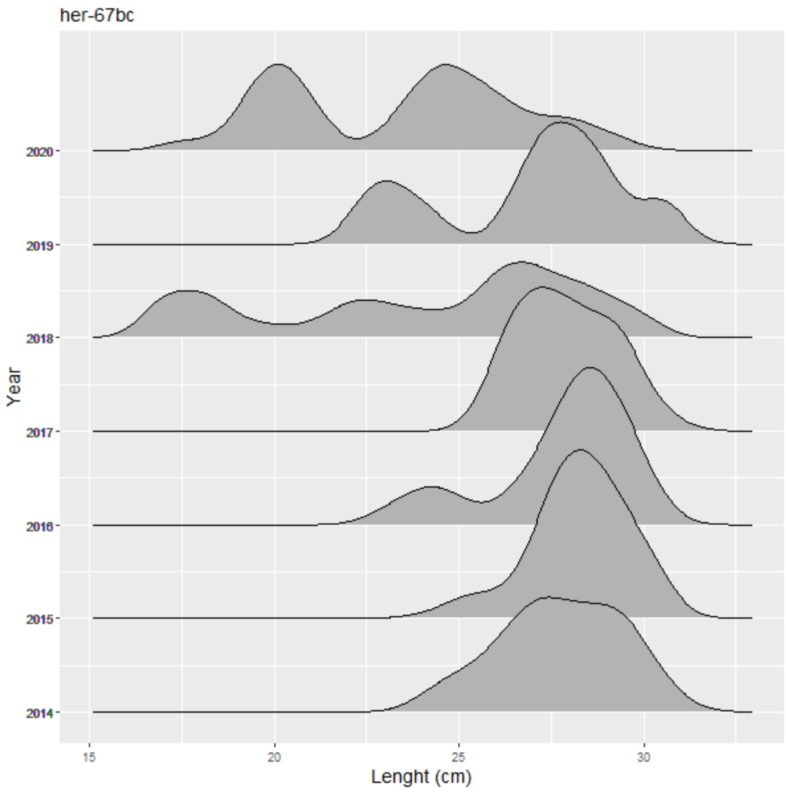

Figure 9. Malin Shelf Acoustic Survey - split index length frequency density plot (MSHAS her-67bc)

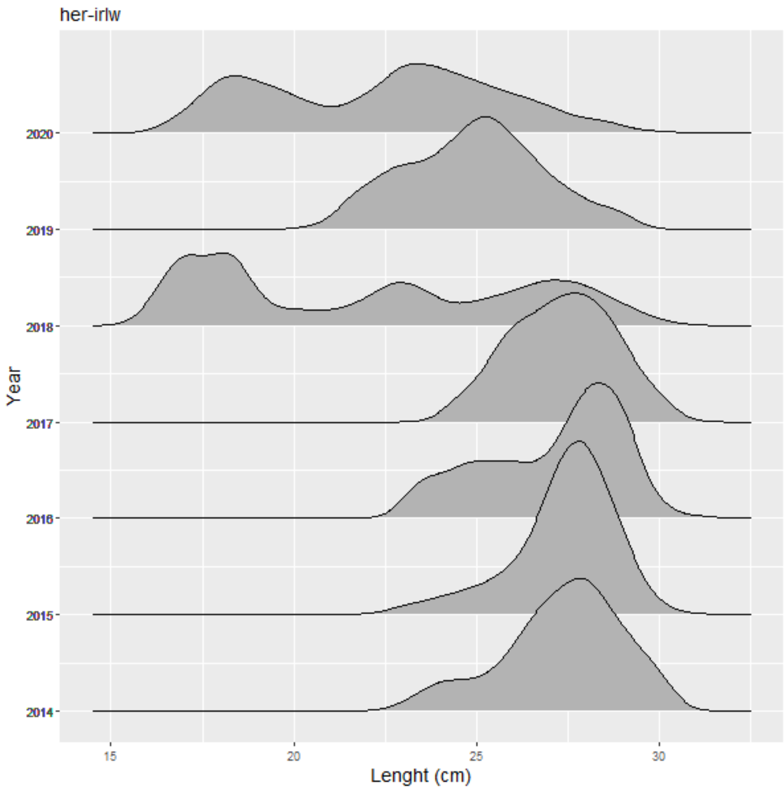

Figure 10. Malin Shelf Acoustic Survey - split index length frequency density plot (MSHAS her-irlw)

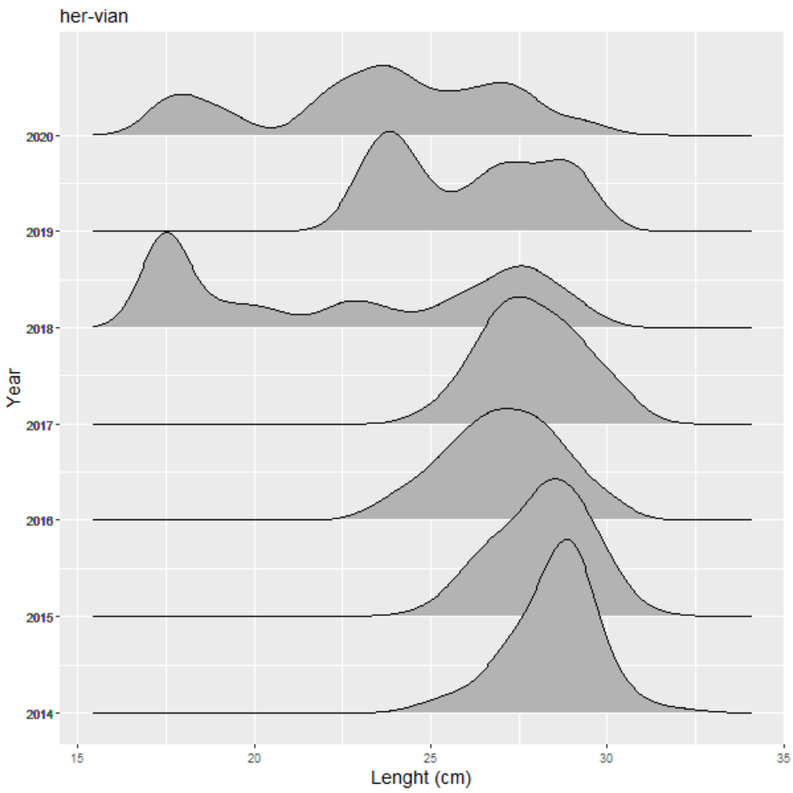

Figure 11. Malin Shelf Acoustic Survey - split index length frequency density plot (MSHAS her-vian)

Conclusions

- The 0.67 threshold for successful genetic assignment at the individual herring level is deemed appropriate.
- The new StoX projects that were set up to match the original projects are considered to sufficiently match the original estimates for the intents and purposes of the splitting work.
- The 1-wr fish estimates are unreliable due to under sampling in some years. The majority of the fish that were unassigned were length classes under sampled (e.g. < 23cm fish in early years) or fish length classes that were in the haul samples at very low levels
- CVs on the split survey estimates are within expected values for acoustic surveys for herring in this area.
- There appears to be reasonably good age and length cohort tracking for some of the individual split surveys, particularly the her-67bc (spring spawning herring of uncertain origin) and her-irlw (6aS and 7.b c herring).
- The her-vian (6aN autumn spawning herring) cohort tracking appears to be variable, which may be linked to the low numbers of these fish in the genetic samples in some years.
- The her.27.6a7bc (unknown or below threshold fish) cohort tracking appears to be variable, however, there are very low samples of these fish in the genetic samples in most years.
- The stocks have been at low levels during these years, making obtaining samples difficult on the MSHAS survey generally during this time.
- In future surveys, all fish sampled for ageing should also be sampled for genetic stock identification. This will reduce the number of un-assigned fish in the estimates.
- More appropriate *BiologyStockCode* names should be agreed and the ICES DB for 2014 – 2020 MSHAS surveys should be updated to reflect this.

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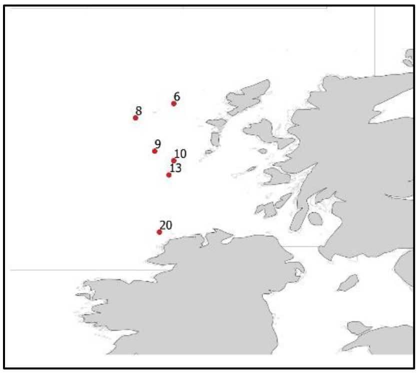
Annex 1 Sample numbers, source and location for genetics samples collected (2014 – 2020)

2014

Source	Haul	# Fish	Lat	Lon
MI	6	120	58.00	-8.20
MI	8	120	57.70	-9.00
MI	9	120	57.00	-8.60
MI	10	120	56.80	-8.20
MI	13	120	56.50	-8.30
MI	20	120	55.30	-8.50

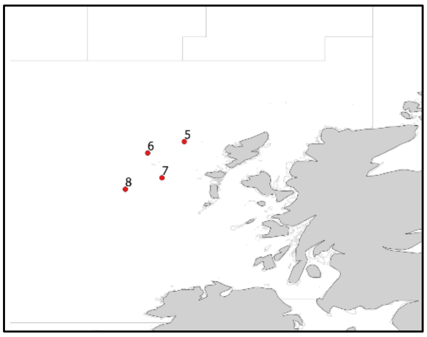


2015

Source	Haul	# Fish	Lat	Lon
MI	2	120	59.9	-4.3
MI	3	120	58.9	-5.9
MI	5	120	57.7	-8.5
MI	8	120	56.7	-8.5
MI	10	120	56.4	-8.5
MI	11	120	56.1	-8.3
MI	16	102	55.5	-9
MI	17	119	55.4	-8.8

2016

Source	Haul	# Fish	Lat	Lon
MI	5	100	58.3	-7.96
MI	6	100	58.06	-8.73
MI	7	100	57.54	-8.43
MI	8	100	57.3	-9.2



2017

Source	Haul	# Fish	Lat	Lon
MI	36	100	56.96	-8.59
MI	37	100	57.71	-8.77
MI	39	100	58.21	-8.07
MSS	172	120	59.622	-5.97
MSS	174	70	59.1205	-6.73

2018

Source	haul	#Fish	Lat	Lon
MI	32	100	55.54	-7.77
MI	35	120	56.52	-8.66
MI	37	120	57.27	-8.52
MI	39	120	57.77	-8.89
MI	40	120	58.54	-7.25
MSS	181	121	58.64	-6.67
MSS	182	119	58.64	-7.21

2019

Source	Haul	# Fish	Lat	Lon
MI	32	125	55.86	-8.46
MI	35	29	55.86	-9.25
MI	37	122	58.25	-8.52

2020

Source	Haul	# Fish	Lat	Lon
MI	22	13	55.01	-9.42
MI	23	120	55.23	-8.06
MI	25	120	55.33	-8.23
MI	26	120	55.44	-8.27
MI	27	100	55.54	-7.07

MI	28	120	56.04	-9.03
MI	31	120	57.36	-8.31
MI	32	120	58.21	-8.03
MI	34	100	58.36	-7.06
MSS	169	100	59.362	-4.132

Annex 2 Raw results of splitting MSHAS samples (2014 – 2020) using approach 2 from EASME results. *Group 135 = her-vian, group 46 = her-irlw, group 2 plus group 462 = her-67bc, NA = her.27.6a7bc and Fail = not assigned*

2014

Area	Lon	Lat	Group135	Group46	Group2	Group462	NA	Fail
2014_H6	-8.20	58.00	26	33	53	1	7	0
2014_H8	-9.00	57.70	11	56	46	0	6	1
2014_H9	-8.60	57.00	5	72	42	0	1	0
2014_H10	-8.20	56.80	6	68	40	1	4	1
2014_H13	-8.30	56.50	7	75	33	0	5	0
2014_H20	-8.50	55.30	5	84	14	0	6	11

2015

Area	Lon	Lat	Group135	Group46	Group2	Group462	NA	Fail
2015_H2	-4.30	59.90	62	37	9	0	11	1
2015_H3	-5.90	58.90	46	47	15	0	12	0
2015_H5	-8.50	57.70	20	49	47	1	3	0
2015_H8	-8.50	56.70	9	83	20	3	4	1
2015_H10	-8.50	56.40	9	94	15	1	1	0
2015_H11	-8.30	56.10	5	99	13	0	3	0
2015_H16	-9.00	55.50	9	87	4	0	2	0
2015_H17	-8.80	55.40	14	90	6	1	8	0

2016

Area	Lon	Lat	Group135	Group46	Group2	Group462	NA	Fail
2016_H5	-7.96	58.30	20	31	44	1	4	0
2016_H6	-8.73	58.06	12	30	52	3	3	0
2016_H7	-8.43	57.54	15	50	30	4	1	0
2016_H8	-9.20	57.30	2	45	50	2	1	0

2017

Area	Lon	Lat	Group135	Group46	Group2	Group462	NA	Fail
2017_H36	-8.59	56.96	9	65	21	1	4	0
2017_H37	-8.77	57.71	18	53	24	2	3	0
2017_H39	-8.07	58.21	12	51	32	1	3	1
2017_MSH172	-5.97	59.62	32	33	46	2	6	0
2017_MSH174	-6.73	59.12	12	30	23	3	2	0

2018

Area	Lon	Lat	Group135	Group46	Group2	Group462	NA	Fail
2018_H32	-7.77	55.54	9	80	7	0	4	0
2017_H35	-8.66	56.52	10	95	11	0	4	0
2018_H37	-8.52	57.27	21	65	29	0	4	1
2018_H39	-8.89	57.77	25	62	32	0	1	0
2018_H40	-7.25	58.54	7	94	17	1	1	0
2018_MSH181	-6.67	58.64	20	82	12	1	5	1
2018_MSH182	-7.21	58.64	13	73	28	1	4	1

2019

Area	Lon	Lat	Group135	Group46	Group2	Group462	NA	Fail
2019_H35	-8.46	55.86	9	106	8	0	2	0
2019_H36	-9.52	55.86	4	23	2	0	0	0
2019_H42	-8.52	58.25	14	68	30	2	7	1

2020

Area	Lon	Lat	Group135	Group46	Group2	Group462	NA	Fail
2020_H22	-9.42	55.01	1	12	0	0	0	0
2020_H23	-8.06	55.23	7	102	4	0	6	1
2020_H25	-8.23	55.33	4	98	10	0	8	0
2020_H26	-8.27	55.44	11	93	10	0	6	0

2020_H27	-7.07	55.54	7	79	7	0	7	0
2020_H28	-9.03	56.04	12	95	6	0	7	0
2020_H31	-8.31	57.36	13	77	26	0	4	0
2020_H32	-8.03	58.21	19	52	49	0	0	0
2020_H34	-7.06	58.36	4	54	38	1	3	0
2020_MSH169	-4.13	59.36	43	42	5	0	10	0

Annex 3 Time series of TSN, SSB and survey CV for MSHAS split areas (2014 – 2020)

	Abundance at age (TSN x 10^6)												
Year	**Age(-wr)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9+**		**CV**	**SSB (t)**
2014	**her.27.6a7bc**	0.0000	5.1140	16.2665	15.5935	20.0628	2.3020	0.1891	0.0000	0.0162		0.334341	**8855**
2015	**her.27.6a7bc**	0.0000	21.8304	52.1914	23.0523	21.0353	27.3221	1.7464	2.8243	0.0000		0.293081	**27610**
2016	**her.27.6a7bc**	0.0000	1.6619	4.4056	1.3158	1.9470	2.1060	2.4606	1.9547	0.0000		0.288907	**2848**
2017	**her.27.6a7bc**	0.0000	0.0167	9.1408	3.3376	4.0927	3.7480	2.0888	0.1647	0.0009		0.3577	**4392**
2018	**her.27.6a7bc**	51.3347	10.8785	4.0430	3.2545	6.0172	0.3408	2.3150	0.1770	1.6072		0.911825	**4213**
2019	**her.27.6a7bc**	0.0000	5.3533	1.8944	1.7188	9.8303	5.2613	0.2943	2.2994	0.1535		0.305855	**4222**
2020	**her.27.6a7bc**	54.8934	46.2086	41.9605	5.4038	0.1218	8.6076	0.0000	4.1808	0.0000		0.298906	**10387**
	Abundance at age (TSN x 10^6)												
Year	**Age(-wr)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9+**		**CV**	**SSB (t)**
2014	**her-67bc**	0.0000	28.4089	98.5127	174.0238	182.4457	68.9525	8.9542	15.0414	5.7864		0.26896	**108367**
2015	**her-67bc**	0.0000	32.0537	58.1348	149.7840	59.9639	98.6108	13.0696	0.7936	0.0000		0.345617	**76009**
2016	**her-67bc**	0.0000	1.3783	36.8888	30.6506	67.0304	30.8061	32.1406	0.7548	0.0000		0.23502	**37809**
2017	**her-67bc**	0.0000	0.0761	110.4795	35.9469	19.9498	43.8870	8.4338	3.9577	0.8885		0.336334	**43478**
2018	**her-67bc**	51.4733	49.4533	17.3836	50.4940	26.0562	14.2776	7.1821	6.5782	1.0489		0.475703	**24426**
2019	**her-67bc**	3.1602	32.9129	3.6783	24.3829	27.1210	11.8836	3.8007	11.0859	0.7716		0.33305	**17370**
2020	**her-67bc**	237.7280	192.5793	98.0860	20.7453	22.2304	37.7383	4.5880	5.0520	0.0000		0.310676	**33987**
	Abundance at age (TSN x 10^6)												
Year	**Age(-wr)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9+**		**CV**	**SSB (t)**
2014	**her-irlw**	0.0000	30.0215	118.6330	271.0141	252.2080	99.3417	31.3819	10.3914	4.8973		0.263919	**149270**
2015	**her-irlw**	0.0000	122.5152	255.6748	395.2611	254.8183	225.2797	58.9608	9.3817	0.0000		0.237824	**226293**
2016	**her-irlw**	0.0000	8.0892	45.2178	42.1824	38.0626	42.3432	26.0502	1.7079	0.9087		0.225782	**36707**
2017	**her-irlw**	0.0000	6.5547	112.5661	87.6862	39.2217	58.6593	39.2075	21.6470	0.3307		0.328388	**66342**
2018	**her-irlw**	572.9450	303.5882	68.3010	199.1444	92.3418	36.8026	47.0780	14.6288	6.1442		0.573993	**96138**
2019	**her-irlw**	3.8002	170.6983	213.9642	103.4593	91.9746	47.1626	5.9276	17.2714	8.9242		0.264386	**92364**
2020	**her-irlw**	895.1145	776.2013	401.7521	188.2019	71.4467	120.2135	24.7746	6.6401	8.5084		0.242645	**135335**
	Abundance at age (TSN x 10^6)												
Year	**Age(-wr)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9+**		**CV**	**SSB (t)**
2014	**her-vian**	0.0000	2.7492	13.4998	21.3605	85.1344	20.3935	5.3508	2.4059	6.6465		0.353272	**32460**
2015	**her-vian**	0.0000	35.5612	139.0257	127.4016	97.3653	106.3794	24.6814	3.8126	5.7576		0.297154	**107113**
2016	**her-vian**	0.0000	5.8118	15.5022	13.6230	11.1487	8.8312	5.2186	0.0593	0.7259		0.260274	**10870**
2017	**her-vian**	0.0000	0.7119	35.7483	25.3994	26.4408	11.4064	9.9308	2.4848	1.8554		0.370461	**21863**
2018	**her-vian**	92.9576	41.0736	14.2680	48.3073	16.6657	3.3408	10.0539	5.4897	2.2750		0.591464	**20663**
2019	**her-vian**	0.0000	17.1654	17.3175	15.7957	20.1719	4.6363	0.1622	0.0000	0.5106		0.279563	**10508**
2020	**her-vian**	59.0456	103.8148	49.5056	14.9640	12.4394	28.2074	11.0095	0.0000	0.0000		0.25838	**26070**

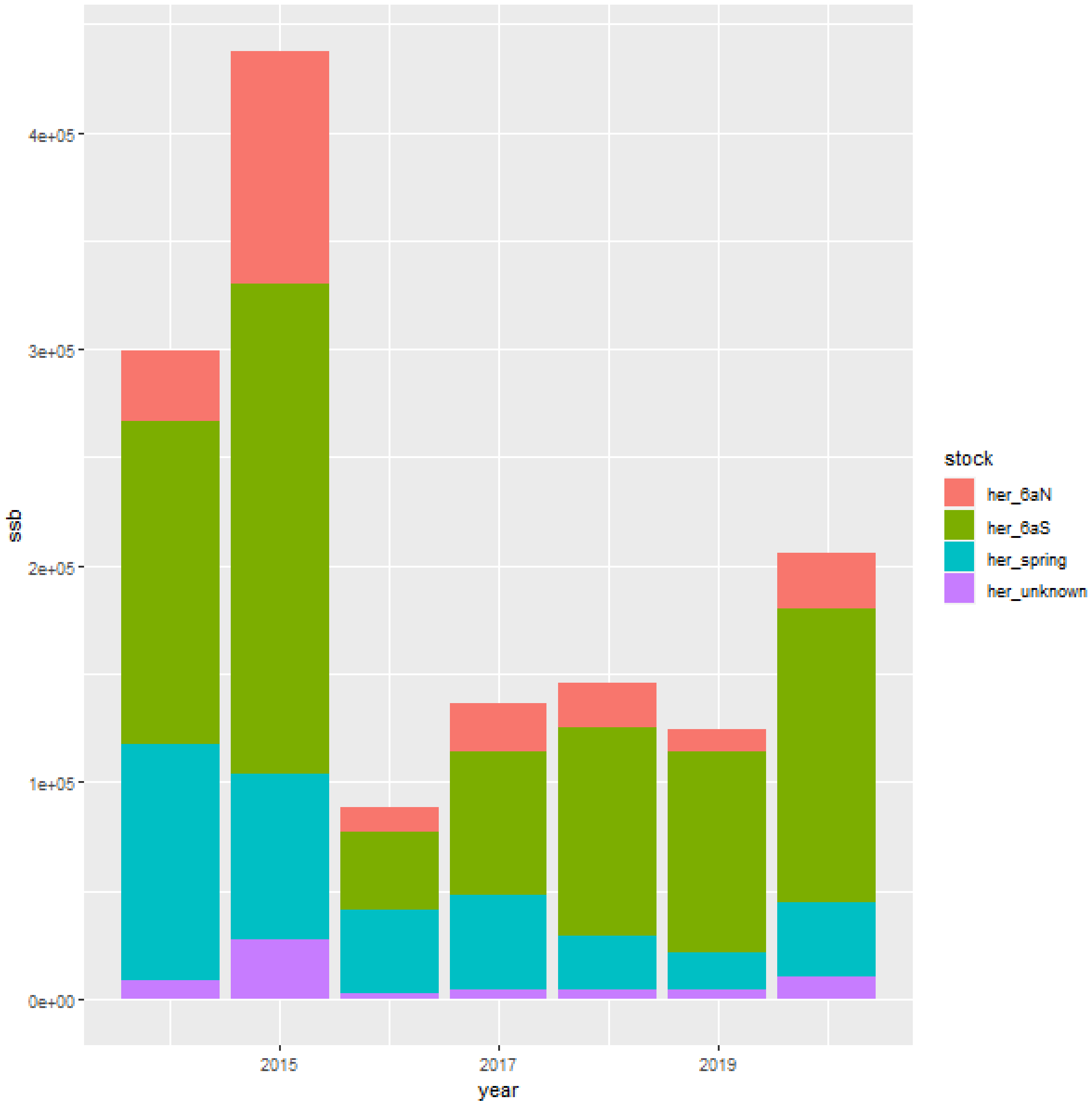
Annex 4 Time series of mean weight at age for MSHAS split areas (2014 – 2020)

	Mean weight at age									
Year	**Age(-wr)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9+**
2014	**her.27.6a7bc**		122.9825	130.6064	179.8284	200.6152	212.94	218.3725		232
2015	**her.27.6a7bc**		154.0363	183.7427	189.8158	206.671	221.4653	263.0269	198.361	
2016	**her.27.6a7bc**		156.4904	166.3064	161.0061	173.7055	200.0521	195.9477	205.3825	
2017	**her.27.6a7bc**		132.6078	166.687	162.5354	207.8346	178.5137	209.8339	220	177
2018	**her.27.6a7bc**	49.47859	108.8506	155.6181	168.5843	190.887	187.8703	218.4548	199.6489	225.1648
2019	**her.27.6a7bc**		104.0189	185.6468	181.0859	188.7432	189.4391	214.2352	222.8159	193
2020	**her.27.6a7bc**	50.94005	104.5871	133.6736	163.4042	137.7655	172.6148		219.1324	
	Mean weight at age									
Year	**Age(-wr)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9+**
2014	**her-67bc**		142.0722	163.0748	177.587	212.9472	220.3746	241.6186	238.3617	256.6118
2015	**her-67bc**		147.5711	177.8919	197.0718	203.4167	220.0865	228.7766	188.1514	
2016	**her-67bc**		157.4122	128.9066	179.379	203.5024	214.3747	215.6688	214.299	
2017	**her-67bc**		137.3883	170.0981	186.8572	199.9737	205.0361	221.0792	224.9963	231.727
2018	**her-67bc**	48.45867	104.2273	155.6269	174.4415	192.7117	213.8978	216.4694	215.2	229.0954
2019	**her-67bc**	103.6805	127.7042	133.1482	180.433	202.2747	223.0303	219.9833	220.7396	209.7838
2020	**her-67bc**	68.65212	129.7619	154.0843	180.952	200.997	215.6574	223.2169	207.5902	
	Mean weight at age									
Year	**Age(-wr)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9+**
2014	**her-irlw**		134.7419	159.1868	177.4914	201.0586	211.0369	213.0334	224.1584	231.1702
2015	**her-irlw**		134.4724	173.8059	187.9741	194.6582	201.2022	205.5488	206.981	
2016	**her-irlw**		130.7165	133.8378	168.5184	204.3267	204.855	206.5822	210.5212	274.309
2017	**her-irlw**		133.4608	161.4263	172.2934	185.2353	196.3584	194.5574	202.9834	177
2018	**her-irlw**	48.6744	107.9185	149.1652	172.5105	183.8389	206.1402	208.644	210.2436	218.7353
2019	**her-irlw**	86.41714	116.5599	153.1985	167.467	190.9549	182.6826	189.5388	220.5046	218.9408
2020	**her-irlw**	54.98346	110.0068	136.8355	157.7479	171.3946	190.9157	203.7815	201.0988	233.2594
	Mean weight at age									
Year	**Age(-wr)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9+**
2014	**her-vian**		141.8435	178.5389	181.6016	212.3945	215.8146	229.1525	226.4082	254.749
2015	**her-vian**		158.6943	183.9732	197.7302	214.1418	220.4562	218.9908	198.3834	219.8243
2016	**her-vian**		147.093	153.9886	174.4342	194.5898	208.8167	201.4107	219	224.8967
2017	**her-vian**		130.1647	174.8259	184.158	197.4164	206.6286	211.2038	238.4029	220.5536
2018	**her-vian**	50.85257	102.7295	164.1505	181.1838	203.4421	206.4526	200.4279	232.4458	216.8551
2019	**her-vian**		121.3027	140.2027	174.6277	207.6356	214.3556	204		211.8074
2020	**her-vian**	49.9913	112.1839	148.7456	168.0059	198.0407	198.5637	220.2673		

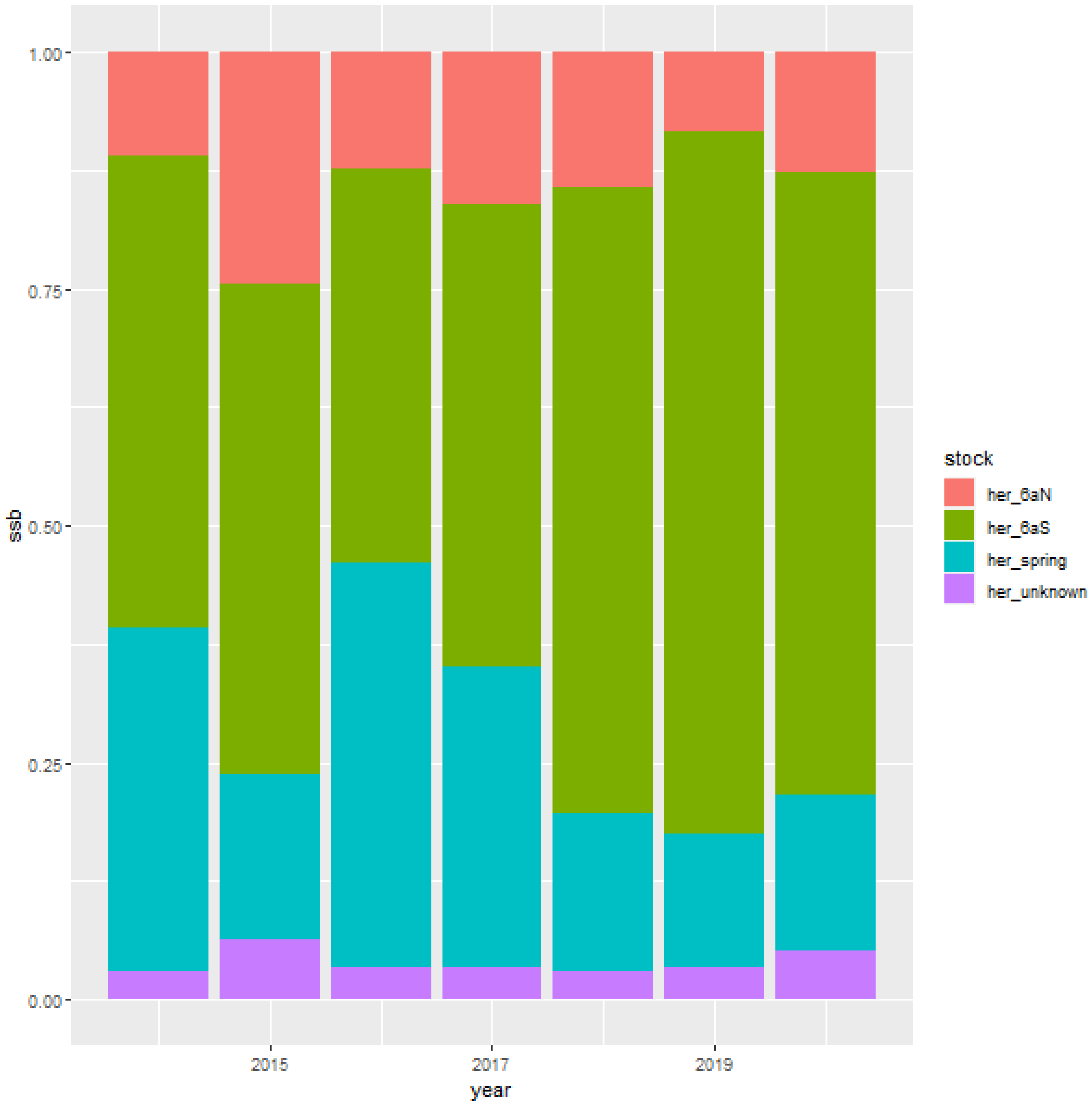
Annex 5 Time series of Maturity Ogive for MSHAS split areas (2014 – 2020)

	Maturity ogive									
Year	**Age(-wr)**	**1**	2	3	4	5	6	7	8	9+
2014	**her.27.6a7bc**		0.52	0.51	0.92	1.00	1.00	1.00		1.00
2015	**her.27.6a7bc**		0.65	0.98	1.00	1.00	1.00	1.00	1.00	
2016	**her.27.6a7bc**		1.00	1.00	1.00	1.00	1.00	1.00	1.00	
2017	**her.27.6a7bc**		1.00	1.00	0.82	1.00	1.00	1.00	1.00	1.00
2018	**her.27.6a7bc**	0.00	0.77	0.96	0.95	1.00	1.00	1.00	1.00	1.00
2019	**her.27.6a7bc**		0.16	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2020	**her.27.6a7bc**	0.00	0.32	0.93	1.00	1.00	1.00		1.00	
	Maturity ogive									
Year	**Age(-wr)**	**1**	2	3	4	5	6	7	8	9+
2014	**her-67bc**		0.74	0.79	0.99	1.00	1.00	1.00	1.00	1.00
2015	**her-67bc**		0.18	0.81	0.99	1.00	1.00	1.00	1.00	
2016	**her-67bc**		1.00	1.00	1.00	1.00	1.00	1.00	1.00	
2017	**her-67bc**		1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00
2018	**her-67bc**	0.00	0.27	0.96	0.98	1.00	1.00	1.00	1.00	1.00
2019	**her-67bc**	0.00	0.20	0.45	1.00	1.00	1.00	1.00	1.00	1.00
2020	**her-67bc**	0.00	0.29	0.53	1.00	1.00	1.00	1.00	1.00	
	Maturity ogive									
Year	**Age(-wr)**	**1**	2	3	4	5	6	7	8	9+
2014	**her-irlw**		0.85	0.81	0.99	1.00	1.00	1.00	1.00	1.00
2015	**her-irlw**		0.41	0.84	0.98	0.94	0.99	0.98	1.00	
2016	**her-irlw**		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2017	**her-irlw**		1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00
2018	**her-irlw**	0.01	0.42	0.82	0.97	0.98	1.00	1.00	1.00	1.00
2019	**her-irlw**	0.00	0.51	0.94	1.00	1.00	1.00	1.00	1.00	1.00
2020	**her-irlw**	0.00	0.25	0.64	1.00	1.00	1.00	1.00	1.00	1.00
	Maturity ogive									
Year	**Age(-wr)**	**1**	2	3	4	5	6	7	8	9+
2014	**her-vian**		0.98	1.00	0.95	1.00	1.00	1.00	1.00	1.00
2015	**her-vian**		0.88	0.99	0.99	1.00	1.00	1.00	1.00	1.00
2016	**her-vian**		1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00
2017	**her-vian**		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2018	**her-vian**	0.00	0.37	0.97	1.00	1.00	1.00	1.00	1.00	1.00
2019	**her-vian**		0.51	0.48	1.00	1.00	1.00	1.00		1.00
2020	**her-vian**	0.00	0.47	0.97	1.00	1.00	1.00	1.00		

Annex 6 Stacked bar chart of the time series of SSB for MSHAS split areas (2014 – 2020)



Annex 7 Percent stacked bar chart of the time series of SSB for MSHAS split areas (2014 – 2020)



Annex 8 Thresholding for Genetic Assignments – the following tables show the number (No.) and proportion (Prop.) of herring falling below various assignment thresholds for both genetic approaches. Levels (Lvl1 and Lvl2) refer to the two stages of the assignment process (see Farrell et al., 2021 for further details). Approach 2, genetic clustering, using a threshold of 0.67 was deemed appropriate by the sub-group.

Approach 1

Threshold->		0.6				0.67				0.7				0.8				0.9			
		Lvl1		Lvl2		Lvl1		Lvl2		Lvl1		Lvl2		Lvl1		Lvl2		Lvl1		Lvl2	
Year	No. fish	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.
2014	694	17	0.02	61	0.09	**29**	**0.04**	**105**	**0.15**	33	0.05	128	0.18	51	0.07	174	0.25	105	0.15	204	0.29
2015	911	31	0.03	33	0.04	**46**	**0.05**	**53**	**0.06**	56	0.06	71	0.08	90	0.10	104	0.11	185	0.20	118	0.13
2016	500	10	0.02	39	0.08	**24**	**0.05**	**78**	**0.16**	30	0.06	107	0.21	41	0.08	145	0.29	112	0.22	175	0.35
2017	283	12	0.04	20	0.07	**13**	**0.05**	**41**	**0.14**	19	0.07	53	0.19	26	0.09	75	0.27	58	0.20	93	0.33
2018	797	18	0.02	23	0.03	**37**	**0.05**	**44**	**0.06**	41	0.05	56	0.07	65	0.08	90	0.11	138	0.17	111	0.14
2019	272	3	0.01	8	0.03	**5**	**0.02**	**13**	**0.05**	9	0.03	15	0.06	17	0.06	26	0.10	49	0.18	31	0.11

Approach 2

Threshold->		0.6				0.67				0.7				0.8				0.9			
		Lvl1		Lvl2		Lvl1		Lvl2		Lvl1		Lvl2		Lvl1		Lvl2		Lvl1		Lvl2	
Year	No. fish	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.	No.	Prop.
2014	694	1	0.00	1	0.00	**5**	**0.01**	**1**	**0.00**	5	0.01	2	0.00	8	0.01	3	0.00	20	0.03	12	0.02
2015	911	15	0.02	3	0.00	**24**	**0.03**	**7**	**0.01**	27	0.03	7	0.01	48	0.05	11	0.01	70	0.08	14	0.02
2016	500	9	0.02	1	0.00	**16**	**0.03**	**7**	**0.01**	18	0.04	9	0.02	29	0.06	14	0.03	40	0.08	26	0.05
2017	480	4	0.01	1	0.00	**10**	**0.02**	**4**	**0.01**	16	0.03	6	0.01	26	0.05	10	0.02	33	0.07	21	0.04
2018	797	6	0.01	3	0.00	**10**	**0.01**	**3**	**0.00**	13	0.02	5	0.01	22	0.03	11	0.01	39	0.05	15	0.02
2019	272	1	0.00	1	0.00	**1**	**0.00**	**1**	**0.00**	1	0.00	2	0.01	3	0.01	2	0.01	7	0.03	3	0.01

Annex 9. StoX Imputing procedures

- *For a given length of fish with no BiologyStockCode, there are 4 possible outcomes from imputing with varying probabilities*
    - *her-vian (6.a.N)*
    - *her-irlw (6.a.S)*
    - *her.27.6a7bc (mix of herring from 6.a and 7.b, c; i.e. unknown or below threshold fish)*
    - *her-67bc (spring spawning herring of uncertain origin)*
- *When StoX finds a fish with no BiologyStockCode, a fish of the same total length (TL) is randomly selected first within haul, then within strata, then from survey*
- *Only fish with no BiologyStockCode are imputed*
- *All biological information is copied with imputed BiologyStockCode (e.g. age, sex, maturity, etc.)*
- *The same procedure is then repeated to fill in any remaining missing age, sex, maturity*
- *Followed by a bootstrap procedure (1,000 times in this instance)*
- *There are some fish that will be unassigned, these are fish that fall into a length class where there is no BiologyStockCode in any of the survey samples for that year. These are generally fish length classes that occur at very low levels or fish that were under-sampled for some reason and as a result just so happened to not have a genetic sample taken.*

Annex 21: Tests of Deep Vision in-trawl stereo camera system during 2021 IESSNS, Norway

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During the 2021 *IESSNS* (cruise number 2021816), the Institute of Marine Research tested the Deep Vision in-trawl stereo camera system (Rosen and Holst, 2013) mounted in the Multpelt 832 trawl at a subset of stations. The motivation was to see if fish could be counted and identified from images, reducing the need for physical samples and thus the ecological footprint and cost of the survey. In addition, the image data should provide increased spatial resolution over aggregate catch in the codend and information on how much is captured during setting out and retrieving the trawl compared with active trawling. Five sets of comparative hauls were carried out at surface trawling stations and the Deep Vision was used on five "deep" hauls targeting blue whiting (no paired non- Deep Vision hauls).

No statistically significant differences were measured in either the trawl's opening height or doorspread between trawling with or without the Deep Vision system attached, but this is based upon a rather small dataset and results should be treated as preliminary. Catches of mackerel were in all instances greater with the Deep Vision attached than without, but this result was just statistically significant ($t(4) = 2.9$, $p = 0.04$). Given the high variation seen historically in catches between stations, it will take a much larger dataset to detect an effect on catch rate. The percentage of each species identified using the RetinaNet neural network object detector previously developed for Deep Vision images (Allken et al., 2021) corresponded to catch measurements (Figure 1), but the network's raw counts by species were unreliable due to counting the same fish multiple times over consecutive images and undercounting in high density images where not all fish were detected as unique individuals.

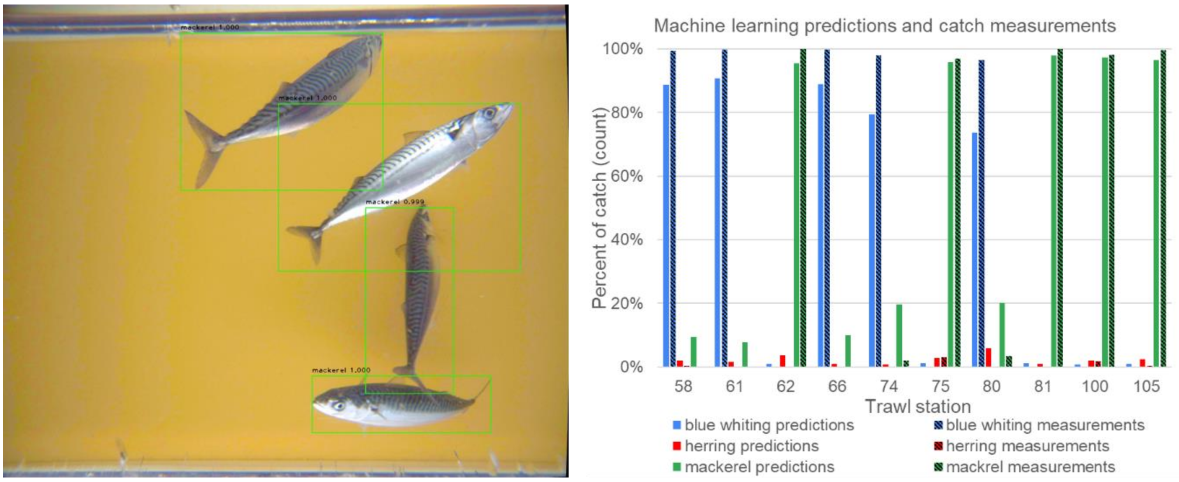

Figure 1. Example result from RetinaNet which detects and draws bounding boxes around four Atlantic mackerel in the Deep Vision image (left). Right panel shows overall species composition at the 10 stations using the Deep Vision system. Solid bars are predictions from RetinaNet analyses, bars with diagonal stripes are measurements from trawl catches.

The network's performance in counting individuals will likely be improved by training with more high-density images, and tracking can reduce the likelihood of counting an individual multiple times. Routines for estimating fish length are in the very early stages of development. Further work is planned to review historic trawl geometry data from both the 2021 and previous years' IESSNS in order to determine whether the values observed with the Deep Vision system fall within the normally observed variation. For 2022, Deep Vision will not be used on the IESSNS, but will be used on the IESNS.

References

Rosen, S. and Holst, J.C., 2013. DeepVision in-trawl imaging: Sampling the water column in four dimensions. Fisheries Research, 148, pp.64-73.

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