WORKING GROUP OF INTERNATIONAL PELAGIC SURVEYS (WGIPS)

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Contents

i Executive summary

The Working Group of International Pelagic Surveys (WGIPS) met in Santa Cruz, Tenerife, Spain on 14–18 January 2019, under the chairmanship of Bram Couperus, Nether-lands and Michael O'Malley, Ireland. This was the first meeting in the multi-annual ToR term. The core objectives of the Expert Group are to combine and review results of annual pelagic ecosystem surveys to provide indices for the stocks of herring, sprat, mackerel, boarfish, and blue whiting in the North-east Atlantic, Norwegian Sea, North Sea, and Western Baltic; and to coordinate timing, coverage and methodologies for the upcoming 2019 surveys.

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

Additionally, progress, developments and experiences with the survey analysis software StoX as well as with the ICES acoustic database repository were analysed and discussed amongst users and developers during the meeting and the intention to further consolidate both the software and the database as common tools to be utilized among all surveys coordinated within WGIPS was stated. Further work progressed on editing the current version of the SISP 9 Manual for International Pelagic Surveys and will continue intersessionally.

WGIPS requests a workshop to establish and agree on survey design and protocols for coordinating and conducting acoustic surveys on herring spawning aggregations. The workshop will focus on industry acoustic surveys on herring spawning aggregations in 6.a and in the Irish Sea. WGIPS also requests a workshop on scrutinising procedures of acoustic data from surveys participating in the IESSNS survey. Scrutinisation procedures, including using biological samples and allocation of species to echotraces need to be scientifically reviewed periodically for all acoustic surveys and a set of technical procedures agreed for each survey.

A new Term of Reference (ToR) was added to the Working Group ToRs. The purpose of the ToR is to review the work, and report of workshops organized by WGIPS and develop formal ICES recommendations. This should include SISP updates and adopting changes to survey coordination where deemed appropriate.

Results from the WGIPS surveys in 2018 as well as coordination plans for the 2019 individual and multinational pelagic acoustic surveys in Northeast Atlantic waters (Multinational surveys: IBWSS, IESNS, IESSNS, HERAS, and individual surveys: CSHAS, WESPAS, ISAS, PELTIC, GERAS, PELACUS, Irish Sea spawning survey and industry acoustic surveys in 6.a/7.b/c) are given in Annexes 3 -14 of this report.

ii Expert group information

Expert group name	Working Group of International Pelagic Surveys (WGIPS)
Expert group cycle	Multiannual fixed term
Year cycle started	2019
Reporting year in cycle	1/3
Chair(s)	Michael O'Malley, Ireland
	Bram Couperus, Netherlands
Meeting venue(s) and dates	14-18 January 2019, Santa Cruz, Tenerife, 20 participants

1 Terms of Reference

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

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, PELTIC, GERAS, WESPAS, industry coordinated surveys, CAPS)

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

d) Periodically review and update the WGIPS acoustic survey manual to address and maintain monitoring requirements for pelagic ecosystem surveys

e) Review and evaluate survey designs across all WGIPS coordinated surveys to ensure the integrity of survey deliverables, including acoustic surveys on spawning aggregations

f) Assess and compare scrutinisation procedures employed for the analysis of raw acoustic data from WGIPS coordinated surveys

g) Collaborate with groups wishing to utilize available time-series from WGIPS coordinated surveys

h) 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.

2 Summary of work plan

Year 1:

General meeting, preceded by 3 post-cruise meetings which collate data of multinational surveys.

Session to review and evaluate survey designs across all WGIPS coordinated surveys done in Year 1; and coordinate planning and discuss designs for surveys taking place in Year 2.

Session to standardize scrutinisation procedures for the International Ecosystem Summer Survey in the Norwegian Sea (IESSNS) covered by the WG (WKSCRUT).

Intersessional work on the review and updates for the WGIPS acoustic manual, followed by a session during the annual meeting to review and provide possible updates for the WGIPS acoustic survey manual. Harmonize changes among the different surveys. Develop survey design protocols for acoustic surveys on spawning aggregations for inclusion in the survey manual.

Session (mini symposium) to assess auxiliary pelagic ecosystem surveying technology focusing on methods currently used to monitor different ecosystem components across WGIPS coordinated surveys.

Session on the future and development of databases (more specifically the ICES acoustic database and the PGNAPES database)

Year 2:

General meeting, preceded by 3 post-cruise meetings which collate data of multinational surveys.

Session to review and evaluate survey designs across all WGIPS coordinated surveys done in Year 2, and coordinate planning and discuss designs for surveys taking place in Year 3.

Intersessional work on the review and updates for the WGIPS acoustic manual, followed by a session during the annual meeting to review and provide possible updates for the WGIPS acoustic survey manual. Harmonize changes among the different surveys. Develop survey design protocols for acoustic surveys on spawning aggregations for inclusion in the survey manual.

Session to assess progress in the implementation of auxiliary pelagic ecosystem surveying technology and methodology (e.g. optical technology, multibeam and wideband acoustics) for monitoring components of the wider ecosystem in surveys covered by WGIPS.

Session on the future and development of databases (more specifically the ICES acoustic database and the PGNAPES database).

Year 3:

General meeting, preceded by 3 post-cruise meetings which collate data of multinational surveys.

Session to review and evaluate survey designs across all WGIPS coordinated surveys done in Year 3.

Intersessional work on the review and updates for the WGIPS acoustic manual, followed by a session during the annual meeting to review and provide possible updates for the WGIPS acoustic survey manual. Harmonize changes among the different surveys. Develop survey design protocols for acoustic surveys on spawning aggregations for inclusion in the survey manual.

Session to assess progress in the implementation of auxiliary pelagic ecosystem surveying technology and methodology (e.g. optical technology, multibeam and wideband acoustics) for monitoring components of the wider ecosystem in surveys covered by WGIPS.

Session on the future and development of databases (more specifically the ICES acoustic database and the PGNAPES database).

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

3 List of outcomes and achievements of the WG in this delivery period

Indices for the stocks of herring, sprat, 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 HAWG and WGWIDE. The following outcomes and achievements were obtained during this delivery period:

- North Sea autumn spawning herring numbers, biomass, maturity proportion, mean weight, and length-at-age, from the ICES Coordinated Acoustic Survey in the Skagerrak and Kattegat, the North Sea, West of Scotland, and the Malin Shelf area (HERAS);
- Western Baltic spring-spawning herring numbers, biomass, maturity pro-portion, mean weight, and length-at-age, from the HERAS;
- West of Scotland autumn spawning herring numbers, biomass, maturity proportion, mean weight, and length-at-age, from the HERAS;
- Malin Shelf herring (areas 6.a, 7b/c) numbers, biomass, maturity proportion, mean weight, and length-at-age, from the HERAS;
- Sprat in the North Sea (Subarea 4) numbers, biomass, mean weight, and length-at-age, from the HERAS;
- Sprat in Division 3.a numbers, biomass, mean weight, and length-at-age, from the HERAS;
- Norwegian spring-spawning herring numbers, biomass, mean weight, and length-at-age, from the International Ecosystem Survey in the Nordic Sea (IESNS);
- Blue whiting numbers, biomass, mean weight, and length-at-age, from the International Ecosystem Survey in the Nordic Sea (IESNS);
- Mackerel numbers, biomass, mean weight, and length-at-age, from the International Ecosystem Summer Survey in the Nordic Sea (IESSNS);
- Norwegian spring-spawning herring numbers, biomass, mean weight, and length-at-age, from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS);
- Blue Whiting numbers, biomass, maturity proportion, mean weight, and length-at-age, from the ICES International Blue Whiting Spawning stock Survey (IBWSS);
- Irish Sea and North Channel (area 7.a), autumn spawning herring, numbers, biomass, distribution maturity proportion, mean weight, and length-at-age from the Irish Sea Acoustic Survey (ISAS);
- Western Baltic Spring-spawning Herring (including and excluding Central Baltic Herring) as well as sprat numbers, biomass, and mean weight-at-age by area for the Western Baltic (ICES Subdivisions 21, 22, 23, and 24) from the German Acoustic Autumn Survey (GERAS) of the Baltic International Acoustic Survey (BIAS);
- Boarfish numbers, biomass, maturity proportion, mean weight, and length-at-age, from the Western European Shelf Pelagic Acoustic Survey (WESPAS);
- Celtic Sea herring numbers, biomass, maturity proportion, mean weight, and length-at-age, from the Celtic Sea herring Acoustic Survey (CSHAS);
- 6.a herring numbers, biomass, maturity proportion, mean weight, and length-at-age, from the industry surveys in 6.a.N and 6.a.S:

- Blue whiting numbers, biomass, maturity proportion, mean weight, and length-at-age, from PELACUS.

Other ecosystem survey-derived operational products:

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

Other outcomes and achievements:

- Comments and input to development of the ICES Acoustic database;
- Overview of currently applied auxiliary pelagic ecosystem sampling technology;
- Investigation of possibilities to improve stock and spawning component splitting methods;
- 2019 survey plans (see Annex 16 for 2019 survey plans);
- Contribution to ICES Annual Science Conference;
- Contribution to the Topic Group on Collecting Quality Underwater Acoustic Data in Inclement Weather (TGQUAD);
- 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;
- Continued development of common code to aid survey planning, and to format, quality check, and plot data from acoustic surveys and WGIPS GitHub repository initiated (https://github.com/ices-eg/WGIPS).

4 Progress report on ToRs and work plan

Progress by ToR:

a) Results of different ecosystem surveys conducted in 2018 and disseminated during preceding post-cruise meetings were shown. The combined results provided indices of abundance and distribution for stocks of herring, sprat, mackerel, boarfish, and blue whiting in Northeast Atlantic waters (ToR a).
b) Timing, planning, and methods applied for individual (CSHAS, BFAS, ISAS, PELTIC, GERAS) and multinational (IBWSS, IESNS, IESSNS, HERAS, IHLS) surveys were discussed and evaluated (ToR b).
c) A number of WGIPS coordinated acoustic surveys have already made it into ICES Acoustic Trawl survey database e.g. HERAS, CSHAS, WESPAS, PELTIC, 6.aN Industry survey (6.aSPAWN) and CLYDAS (see table 1). Under this TOR, the group will keep following the progress for the rest of the surveys coordinated by WGIPS.

Table 1. Progress of adopting the ICES DB and StoX for the individual surveys with the following columns:

Survey	Database (ICES or other)	Abundance estimation software (StoX or other)
Herring Acoustic Survey (HERAS)	Biological and acoustic files in ICES DB	StoX
Malin Shelf Acoustic Survey (MSAS)	Biological and acoustic files in ICES DB	StoX
West of Scotland acoustic survey (WoS)	Biological and acoustic files in ICES DB	StoX
6.a/7.b/c Industry herring acoustic survey(6.aSPAWN)	6.a.N biological and acoustic files in ICES DB from 2018. 6.aS data stored locally in Institute	StoX
GERAS	Access database/Preparation of uploading files to ICES DB	GERIBAS II
ISAS	National SQL database	R-scripts
WESPAS	Biological and acoustic files in ICES DB	StoX
PELTIC	National Database	EchoR
IBWSS	PGNAPES & ICES Database	StoX
IESSNS	PGNAPES	StoX
IESNS	PGNAPES & ICES Database	StoX
CSHAS	Biological and acoustic files in ICES DB	StoX

a) The SISP manual will be updated intersessionally. Outstanding tasks have been allocated to relevant WGIPS members.
b) A workshop on herring acoustic spawning surveys is requested by WGIPS. The review will look at survey design and acoustic data collection methods of ongoing surveys not previously reviewed by WGIPS (Irish Sea Spawning

Survey and 6.a Herring Industry Acoustic Spawning Surveys). The review should address survey design, timing, stock identification, containment, biological sampling and acoustic data collection methods. The workshop should preferably take place in 2019

c) A workshop on scrutinising of acoustic data from the IESSNS survey is requested by WGIPS. Scrutinisation procedures may differ slightly between coordinated surveys, however, it is very important that all scientists responsible for the scrutinisation are following the same general procedure. The workshop should preferably take place prior to the survey in 2019. Uncertainty regarding the scrutinising procedure, i.e. categorization and allocation into species or species groups, emphasizes the need for a workshop which involves scientists responsible for the scrutinizing in the survey (e.g. from Iceland, Norway, Faroes, Greenland and EU).

d) The collaboration with HAWG and WGWIDE takes mainly place by (responses to) recommendations. The group got two recommendations from HAWG (7 and 8) and two from WGWIDE (188 and 189). The responses have been uploaded to the ICES Recommendation Database. The workshop WKHASS is one of the actions in response to recommendation 7. In response to recommendation 8, updated the Stock Summary Table to include all the suggested inclusions. In addition a column for response from the assessment WG's has been included.

e) The core work of WGIPS coordinated surveys is to provide annual age stratified abundance estimates for target species to the assessment working groups. 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. Currently such additional data sources are collected in a somewhat ad hoc fashion by national institutes. To provide meaningful ongoing 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?
- prioritize 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 recognizes 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.

Changes/ Edits/ Additions to ToR

Acoustic surveys are generally dedicated to one or a few commercial species with the objective to provide biomass and abundance estimates for inclusion as indices in assessments. Many WGIPS surveys are developing towards multidisciplinary surveys that cover a broader range of ecosystem components (see paragraph on progress on TOR h). As a result, WGIPS's task to review surveys (TOR a) has therefore expanded. The auxiliary ecosystem techniques are very diverse and vary between national surveys and between years. In order to structure the effort dedicated to the review of surveys, the group decided to split the session of survey presentations into two sessions that (1) covers the traditional acoustic biomass estimation and (2) covers auxiliary ecosystem survey techniques. In practice this means that the session planned under TOR h for 2019 will be repeated in 2020 and 2021.

There are two workshops proposed for 2019 (a workshop on herring acoustic spawning surveys, WKHASS; and a workshop on scrutinisation procedures in the IESSNS survey, WKSCRUT2). These workshops will provide recommendations to improve survey design and procedures. This will invariably require an update to the SISP 9 manual for International Pelagic Surveys. The Ecosystem Observation Steering Group (EOSG) therefore suggested an additional ToR as follows:

Proposed new ToR: Review the work, and report of workshops organized by WGIPS and develop formal ICES recommendations. This should include SISP updates and adopting changes to survey coordination where deemed appropriate.

Recommendations issued to WGIPS from other working groups in 2018

RECOMMENDATION	ADRESSED TO
ID 7 All acoustic surveys used in herring and sprat stock assessments carried out in HAWG should be evaluated annually by WGIPS and the most recent year's survey should be reviewed prior to inclusion in assessments. Background: WGIPS annually evaluates acoustic surveys for herring and sprat stocks assessed by HAWG. This provides a common standard for quality assurance of the survey data used in the assessments and ensures that issues with individual surveys or individual years in surveys are evaluated in a forum with the appropriate expertise maintaining historic survey index quality. It ensures that survey methodology follows best practice and that these are reviewed and updated as new technologies and analysis methods are developed. It also provides stock assessors with a peer review of the suitability of including or excluding the most recent survey year in the assessment. HAWG therefore recommends that all acoustic surveys used in herring and sprat stock assessments carried out in HAWG should be reviewed by WGIPS and the most recent survey year evaluated annually in WGIPS prior to inclusion in assessments.	WGIPS; EOSG

ID 7 Reply: WGIPS will continue to review all internationally coordinated and individual national surveys as they are presented. If the most recent survey does not have all the data ready in time for the WGIPS meeting in January, the survey can only be reviewed by WGIPS up to that point (for example, Irish Sea Acoustic Survey, Irish Sea Spawning Survey and 6.a Industry Surveys). The Irish Sea spawning survey or the 6.a Industry Surveys have never been thoroughly reviewed by WGIPS. WGIPS is requesting a workshop to establish and agree on survey design and protocols for conducting these surveys. The Manual for International Pelagic Surveys will be updated to include these surveys also during this workshop. It is hoped that this workshop will take place towards the end of 2019.

RECOMMENDATION	ADRESSED TO
ID 8 HAWG recommends that the survey summary table for acoustic surveys under WGIPS is amended to include Comments on Stock ID and mixing issues, stock containment, availability of measures of uncertainty and a summary of the number of biological samples used in the index calculations. Background: The Survey Summary Table provided annually for each survey reviewed in WGIPS is a valuable guide to the quality of the survey. HAWG recommends this table to be augmented to include the following additional information: Stock containment - e.g. did the survey contain the stock? Stock ID/mixing - is there evidence of mixing of stocks within the survey area? Uncertainty - Is there a measure of uncertainty available associated to the indices of abundance calculated from the survey (e.g. CV)? Number of biological samples used to work up acoustic estimate for the survey area - xx hauls containing target species, xx aged of target species.	WGIPS; EOSG

ID 8 Reply: WGIPS have updated the Stock Summary Table to include all the suggested inclusions. Each Stock Summary Table is presented in plenary at the WGIPS meeting and included in the report. WGIPS requests feedback on the usefulness of the new Stock Summary Tables.

RECOMMENDATION	ADRESSED TO
ID 61 WGFAST recommends that acoustic survey groups adopt the ICES metadata convention for processed acoustic data and the ICES data portal for acoustic trawl surveys.	WGIPS; WGBIFS; WGACEGG

ID 61 Reply: WGIPS have adopted the recommendation from WGFAST. So far, a number of WGIPS coordinated surveys have already made it into ICES Acoustic Trawl Survey database e.g. HERAS, CSHAS, WESPAS, PELTIC, 6.aSPAWN and CLYDAS. In addition, a ToR C have been created to follow the progress for the rest of the surveys coordinated by WGIPS.

RECOMMENDATION	ADRESSED TO
ID 71 WKASMSF recommends to adopt the 'WKMATCH 2012 maturity scale revised' and approve the implementation plan (presented in chapter 7). Approval should be sent to WGBIOP. (Note that all requests with regards to maturity scales or stages in the ICES, RCG and GFCM databases should be directed, in the form of a recommendation, to WGBIOP for approval.	WGBIFS; WGMEGS; WKNEPS; PGDATA; WGBIOP; WGIDEEPS; WGNEACS; WGBEAM; WGCATCH; WGALES; IBTSWG; WGIPS; ICES Data Centre

ID 71 Reply: The National laboratories each have their own methods to determine maturity, being it a 6 or 8 point scale (or other versions). ICES do not force the laboratories to change their scale, although the WKASMSF in 2018 recommended that 6 point scale should be used as default. Acknowledging that national or international surveys might have adopted other maturity scales than the 6 point scale, WGIPS will not try to influence the national procedures on maturity readings. When it comes to reporting the maturity data to the ICES database, it was recommended to use the scale that the data originally was produced by, to minimize the risk of conversion errors, and to provide the maturity scales used to ICES. It is possible with little or no hassle to convert from

e.g. the 8 to the 6 point scale if needed. Further the national laboratories would have to adhere to the format demands from common databases when asked to, in order to conform to the recipient database standard. However, the ICES databases will output only the 6 point maturity scale, regardless of the original input maturity scale used when supplying data to ICES.

RECOMMENDATION	ADRESSED TO
ID 72 All survey groups should update their manuals with the correct references (see chapter 4 in this report) and include or update the conversion table for the national maturity scales.	WGBIFS; WGMEGS; WGACEGG; WKNEPS; PGDATA; WGBIOP; WGIDEEPS; WGNEACS; WGBEAM; WGCATCH; WGALES; IBTSWG; WGIPS; ICES Data Centre

ID 72 Reply: WGIPS is currently reviewing the manual and this review will include the updating of references and will include the conversion table for the national maturity scales. Workshops planned in 2019 on survey design of the individual surveys will also require the updating of the manual for these surveys.

RECOMMENDATION	ADRESSED TO
ID 128 Recommend that relevant ICES expert groups review plans for data collection and coordination of US/Canadian surveys in NW Atlantic, and give advice on survey design, and data requirements for ecosystem monitoring and modelling.	WGNARS; WGIPS; WGINOR; WGZE

ID 128 Reply: WGIPS acknowledges the request to review and provide advice on US/Canadian ecosystem surveys insofar as it relates the skill and expertise of WGIPS members. There was however, insufficient information or background documentation for WGIPS to make any informed input at this time. If appropriate and still relevant, WGIPS suggests that the originators of the request identify the specific aspects of acoustic survey design that are within reasonable scope to make it feasible for WGIPS to provide meaningful comments on intersessionally.

RECOMMENDATION	ADRESSED TO
ID 188 WGWIDE recommends that IBWSS explores methods/approaches to survey division 8abd in order to understand the dynamics and connectivity between blue whiting spawning components.	WGIPS

ID 188 Reply: WGIPS has reviewed the blue whiting distribution in 8abd from the Spanish surveys conducted in this area. However, there is not enough survey time for covering the whole 8abd area together with the adjacent area of the core blue whiting spawning area located in 7j-k (e.g. Porcupine Sea bight). Instead, WGIPS recommend IBWSS will maintain the coverage in Porcupine Sea bight and to conduct acoustic survey in specific boxes along the 8abd aiming at to get insights on blue whiting stock structure and dynamics in this area. Moreover, this task will complement the systematic coverage IEO is doing in spring time off North Spanish coast (8c and 9aN) during PELACUS acoustic-trawl survey targeting also in blue whiting.

RECOMMENDATION	ADRESSED TO
ID 189 It is recommended that work is initiated on how to separate among different stock components of herring in internationally coordinated surveys.	WGIPS; WGBIOP

ID 189 Reply: The separation of different herring stock components is an issue in several of the surveys coordinated in WGIPS. In 2016 WGIPS recommended HAWG and WGBIOP to develop operational methods to be deployed on WGIPS coordinated surveys with particular reference to standardizing stock splitting methods for Western Baltic Spring Spawning herring and North Sea Autumn Spawning herring in the HERAS survey. As it was recognized that this was a wider issue in surveys and catches of many herring stocks assessed in HAWG and also WGWIDE, this recommendation lead to the workshop WKSIDAC which was held in November 2017. The workshop carried out a review of information on stock identification methods being pursued for many of the herring stocks in questions. It was clear that a lot of effort is ongoing in this area but also that there is still work to be done to validate or in some cases update validation of methods used before protocols for separation of herring stocks can be developed and implemented on the surveys coordinated by WGIPS.

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 and North Sea type autumn-spawning herring) might have occurred in some of the fringe regions in the Norwegian Sea. Up to date fixed cut lines have been used 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.

Given the importance of this issue to the assessments of most herring stocks, WGIPS suggests that HAWG, WGIPS, WGBFAS and WGWIDE all encourages researchers involved in projects to further this cause are invited to present progress at their meetings to foster collaboration towards this common goal and that ICES carry out a WKSIDAC 2 workshop in a few years when these efforts have matured further to put the methods into operation.

RECOMMENDATION	ADRESSED TO
ID 241 WGBIOP recommends the collection of gonad samples (images of gonads and gonads for histology) during regular sampling to ensure a basic set of samples is available for maturity exchanges and workshops. This will be followed up with an e-mail with a protocol with instructions on how to collect the samples.	WGBIFS; WGMEGS; WGACEGG; PGDATA; WGIDEEPS; WGNEACS; WGBEAM; WGCATCH; WGALES; IBTSWG; WGIPS

ID 241 Reply WGIPS recognizes the potential importance of the collection of such samples and the benefits the availability of such a library of samples would have for maturity exchanges and workshops and therefore possible improvement of the assessments of stocks surveyed by WGIPS coordinated surveys.

In addition to a detailed protocol with instructions on how to collect the samples, WGIPS considers it necessary that detailed instructions on number of gonad samples required for combinations of surveys, areas, species, maturity levels, seasons and number of years this is anticipated to run over is provided. Furthermore WGIPS would welcome clarification of who will be responsible for coordinating this sampling effort

and also how the samples will be curated before taking this further. If it is the intention that the responsibility for curating the samples is intended to be with the institutes participating in the surveys then this recommendation is probably better directed to the national institutes at a higher level to ensure resources such as long term storage space for both images and physical samples are made available.

RECOMMENDATION	ADRESSED TO
ID 262 WGS2D requests feedback from WGIPS regarding the value, or lack thereof, of the Blue Whiting Spawning Habitat forecast product (see e.g. http://www.fishforecasts.dtu.dk/forecasts/blue-whiting-spawning-habitat for the most recent version). In particular, we would welcome comments on the perceived accuracy and precision of the forecast, timeliness, understandability, presentation format and suggestions for improvement. WGS2D welcomes all critiques of this work (both positive and negative) and would like to encourage the group to actively collaborate to help improve this forecast system.	WGIPS

ID 262 Reply: WGIPS follows the Blue Whiting Spawning Habitat forecast with great interest and values the effort taken to present results to the group each year. The forecast appears to predict the distribution of blue whiting spawning habitat well and as the forecast continues and has more data points, it will become more useful. The forecast was presented very clearly and was understood by the group. WGIPS wishes to continue to collaborate with WGS2D and will cooperate in the future where reasonable. Areas where the forecast could be improved include predicting the timing of peak spawning.

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

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

ICES Database

Since 2015 the ICES Data Centre has been developing a new 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, among 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 came from the yearly WGIPS and survey post-cruise meetings.

Science Highlights

Miesner, A.K., and Payne, M.R. (2018) Oceanographic variability shapes the spawning distribution of blue whiting (Micromesistius poutassou). Fisheries Oceanography, 27(6), 623–638. doi:10.1111/fog.12382

5 Revision to the work plan and justification

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

6 Next meetings

The Working Group of International Pelagic Surveys (WGIPS), chaired by Bram Couperus, the Netherlands, and Michael O´Malley, Ireland, 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 2020	13–17 January	Bergen, Norway	Final report by 2 March 2020 to SSGIEOM, SCICOM & ACOM	Year 2
Year 2021	18–22 January	Belfast, Northern Ireland	Final report by 8 March 2021 to EOSG, SCICOM	Year 3

Annex 1: List of participants

Name	Institute	Country (of institute)	E-mail
Bram Couperus (Chair)	Wageningen Marine Research	Netherlands	bram.couperus@wur.nl
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Åge Høines	Institute of Marine Research	Norway	aageh@hi.no
Cecilie Kvamme	Institute of Marine Research	Norway	cecilie.kvamme@hi.no
Ciaran O´Donnell	Marine Institute	Ireland	Ciaran.odonnell@marine.ie
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Hjálmar Hátún	Faroe Marine Research Institute	Faroe Islands	hjalmarh@hav.fo
Hjalte Parner	ICES	Denmark	hjalte.parner@ices.dk
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Mathieu Lundy	Agri-food and Biosciences Institute	Northern Ireland	Mathieu.Lundy@afbini.gov.uk
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Pablo Carrera	IEO (Spanish Institute of Oceanography)	Spain	pablo.carrera@ieo.es
Serdar Sakinan	Wageningen Marine Research	Netherlands	serdar.sakinan@wur.nl
Steven Mackinson	Scottish Pelagic Fishermen's Association	Scotland	steve.mackinson@scottishpelagic.co.uk
Steven O'Connell	Marine Scotland	Scotland	Steven.O'connell@gov.scot
Susan Mærsk Lusseau	Marine Scotland Science	Scotland	S.Lusseau@marlab.ac.uk
Urbano Autón	IEO (Spanish Institute of Oceanography)	Spain	urbano.auton@ieo.es

Annex 2: Resolutions

WGIPS – Working Group of International Pelagic Surveys

2017/MA2/EOSG23 The **Working Group of International Pelagic Surveys** (WGIPS), chaired by Bram Couperus, The Netherlands, and Michael O´Malley*, Ireland, 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 2019	14–18 January	Santa Cruz, Spain	Interim report by 3 March 2019 to EOSG, SCICOM & ACOM	Incoming chair Michael O´Malley
Year 2020	13–17 January	Bergen, Norway	Interim report by 2 March 2020 to EOSG, SCICOM & ACOM	
Year 2021	18–22 January	Belfast, Northern Ireland	Final report by 8 March 2021 to EOSG, SCICOM & ACOM	

ToR descriptors

ToR	Description	Background	Science plan codes	Duration	Expected Deliverables
a (ACOM)	Combine and review annual ecosystem survey data to provide: indices of abundance and spatial distribution for the stocks of herring, sprat, mackerel, boarfish and blue whiting in Northeast Atlantic waters.	a) Advisory Requirements b) Requirements from other EGs	3.2, 5.2	years 1–3	Survey reports containing indices of stock biomass and abundance at age, spatial distributions of stocks and hydrographic conditions. HAWG WGWIDE
b(ACOM)	Coordinate the timing, area and effort allocation and methodologies for individual and multinational acoustic surveys on pelagic resources in the Northeast Atlantic waters	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs	3.1	years 1–3	Cruise plans for international and individual surveys. HAWG WGWIDE

	covered (Multinational surveys: IBWSS, IESNS, IESSNS, HERAS, and individual surveys: CSHAS, ISAS, PELTIC, GERAS, WESPAS, industry coordinated surveys, CAPS).				
c (SCICOM)	Adopt standardized analysis methodology and data storage format utilizing the ICES acoustic database repository for all acoustically derived abundance estimates of WGIPS coordinated surveys	a) Science Requirements b) Advisory Requirements	3.2	years 1–3	Progress on the adaption of standardized analysis methodology and data storage format utilizing the ICES pelagic acoustic database repository for WGIPS coordinated surveys.
d (ACOM)	Periodically review and update the WGIPS acoustic survey manual to address and maintain monitoring requirements for pelagic ecosystem surveys	a) Science requirements b) Advisory requirements	3.1	years 1–3	Updated WGIPS survey manual.
e (ACOM)	Review the work, and report of workshops organized by WGIPS and develop formal ICES recommendations. This should include SISP updates and adopting changes to survey coordination where deemed appropriate.	a) Science requirements b) Advisory requirements	3.1	years 1–3	

f (ACOM)	Review and evaluate survey designs across all WGIPS coordinated surveys to ensure the integrity of survey deliverables, including acoustic surveys on spawning aggregations.	a) Science requirements b) Advisory Requirements c) Requirements from other EGs	3.1, 3.3	years 1–3	Optimize and harmonize sampling designs and precision estimates for the different surveys to ensure survey quality. HAWG WGWIDE
g(ACOM)	Assess and compare scrutinisation procedures employed for the analysis of raw acoustic data from WGIPS coordinated surveys	a) Science requirements b) Advisory requirements	3.2, 3.3, 4.2	year 1	Documented standardized scrutinisation recommendations; Update of survey manual to address and maintain monitoring requirements for pelagic ecosystem surveys.
h (SCICOM)	Collaborate with groups wishing to utilize available time-series from WGIPS coordinated surveys.	a) Science requirements	3.2	Years 1-3	Facilitate testing and developing forecast models provided by WGS2D and other groups.
i (SCICOM)	Assess developing pelagic ecosystem surveying technology (e.g. optical technology, 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.

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

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

Annex 3: 2018 Survey Summary Tables and Cruise Reports

Document 3a: IBWSS 2018 survey summary table

Survey Summary table WGIPS 2019	
Name of the survey (abbreviation):	International blue whiting spawning stock survey (IBWSS)
Target Species:	Blue whiting
Survey dates:	20 March – 6 April
Summary:	
The International Blue Whiting Spawning stock survey was carried out over 20 days and thus within the recommended 21 day time window agreed by the group. Weather conditions were mixed with both good and bad periods. All vessels experienced some weather induced downtime ranging from 24 hrs to 48 hrs. The total area surveyed was slightly lower than in 2017 and this can be accounted for in the western periphery of Rockall. Overall, acoustic sampling effort (track miles), trawling effort and biological metrics were comparable, if not higher, than in 2017. The survey in 2018 shows an increase in total-stock biomass of 29% with a corresponding increase in total abundance of 15% when compared to the 2017 estimate. The estimated uncertainty around the total-stock biomass remains low, just above CV=0.12 which is lower than previous year (around 0.16). The stock biomass within the survey area was dominated by 3, 4 and 5 year old fish contributing 86% of total-stock biomass. The proportion of immature fish (1 year old) in the 2018 estimate is three times higher than in 2017 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 the same vessel and sampling equipment (transducers and trawl) were used.	
	Description
Survey design	Stratified systematic parallel design (15 - 35 nmi spacing) with randomized 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 PGNAPES database)
Random/systematic error issues	NA, outside of those already described in literature for standardized 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 2018 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, just above CV=0.12 which is lower than previous year (around 0.16).
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 time-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*

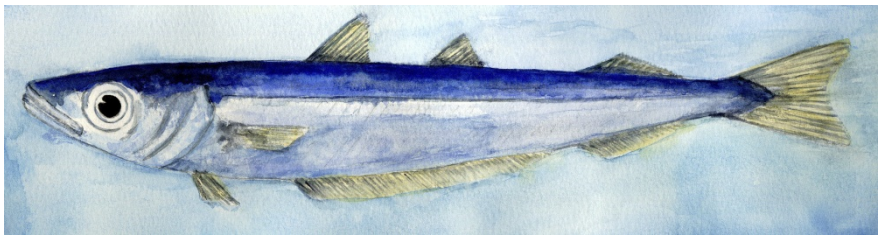
Document 3b: IBWSS 2018 survey report

Please see the report on the next page.

Working Document

Working Group on International Pelagic Surveys
Tenerife, Spain, January 2019

Working Group on Widely Distributed Stocks
Copenhagen, Denmark, September 2018



INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY (IBWSS) SPRING 2018

Jan Arge Jacobsen[4*], Leon Smith[4*], Jens Arni Thomassen[4], Mourits Mohr Joensen[4]
R/V Magnus Heinason

Thomas Pasterkamp[1], Dirk Burggraaf[1], Dirk Tijssen[8], Eric Armstrong[6*], Felix Muller[7], Bram Couperus[1]
R/V Tridens

Ciaran O'Donnel[5*], Graham Johnston[5], Eugene Mullins[5], Niall Keogh[9], John Power[10]
R/V Celtic Explorer

Åge Høines[2^*], Valantine Anthonypillai[2], Ørjan Sørensen[2], Ståle Kolbeinson[2], Justine Diaz[2]
M/S Kings Bay

1 Wageningen Marine Research, IJmuiden, The Netherlands
2 Institute of Marine Research, Bergen, Norway
3 PINRO, Murmansk, Russia
4 Faroe Marine Research Institute, Tórshavn, Faroe Islands
5 Marine Institute, Galway, Ireland
6 Marine Scotland Marine Laboratory, Aberdeen, Scotland, United Kingdom
7 Johann Heinrich von Thünen-Institut, Hamburg, Germany
8 Danish Institute for Fisheries Research, Denmark
9 Galway, Mayo Institute of Technology
10 National Parks and Wildlife Service, Ireland
* Participated in post cruise meeting,
^ Survey coordinator

Material and methods

Survey planning and Coordination

Coordination of the survey was initiated in the meeting of the Working Group on International Pelagic Surveys (WGIPS) 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	20/3 – 06/4
Magnus Heinason	Faroe Marine Research Institute, Faroe Islands	28/3 – 11/4
Tridens	Wageningen Marine Research, the Netherlands	20/3 – 4/4
Kings Bay	Institute of Marine Research, Norway	23/3 – 4/4

The survey design was based on methods described in ICES Survey design Manual (2015). Overall weather conditions were mixed with periods of poor and good weather. All vessels experienced some downtime due to poor weather conditions. The entire survey was completed within 20 days, below the 21 day target threshold.

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. All vessels worked in a northerly direction (Figure 4). Communication between vessels occurred daily via email to the coordinator exchanging up to date information on blue whiting distribution, echograms, fleet activity and biological information.

Sampling equipment

Vessels employed a 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. The level of biological sampling by vessel is shown 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 a dedicated hydrographic transect where full depth was achieved. 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 Kings Bay (NO) and Magnus Heinason (FO) to depths of 400m and 200m respectively (Table 3).

Acoustic data processing

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

On Celtic Explorer, acoustic data were backed up every 24 hrs and scrutinised using EchoView (V.8) post-processing software for the previous days work. Data was partitioned into the

following categories: plankton (<120 m depth layer), mesopelagic species (daylight only) and blue whiting.

On Magnus Heinason, acoustic data were scrutinised every 24 hrs on board using EchoView (V 8) post processing software. Data were partitioned into the following categories: plankton (<200 m depth layer), pearlside and mesopelagic species, blue whiting and krill (krill/mesopelagics). Partitioning of data into the above categories was based on trawl samples and acoustic characteristics on the echograms.

On Tridens, acoustic data were backed up continuously and scrutinised every 24 hrs using the Large Scale Survey System LSSS (2.0) post-processing software. Blue whiting were identified and separated from other recordings based on trawl catch information and characteristics of the recordings.

On Kings Bay, the acoustic recordings were scrutinized using LSSS (V. 2. 0.0) once or twice per day. Data was partitioned into the following categories: plankton (<120 m depth layer), mesopelagic species and blue whiting.

Acoustic data analysis

Acoustic data were analysed using the StoX software package (V 2.6), as the standard adopted for WGIPS coordinated surveys. A description of StoX can be found here: http://www.imr.no/forskning /prosjekter/stox/nb-no. 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 2018 (Figure 1). The strata and transects used 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) used is:

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

In StoX a super-individual table is produced where abundance is linked to population parameters like 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 2018 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 (RStoX V1.9) randomly replaces transects and trawl stations within a stratum on each successive run. The output of all the runs is stored in a RData-file, which is used to calculate the relative sampling error.

Results

Distribution of blue whiting

In total 7,296 nmi (nautical miles) of survey transects were completed across six strata, relating to an overall geographical coverage of 128,030 nmi² (Figure 1, Tables 3). Acoustic sampling effort and area coverage were comparable to 2017 (Table 7). 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 was located in the 3 strata bordering the shelf edge (Strata 1, 2 and 3) accounting for 88% of total biomass (Table 4). The Rockall Bank (strata 5) accounted for only 4% of the biomass in 2018 (Table 4). The two northernmost strata (South Faroes strata 4 and Shetland Channel strata 6) accounted for the remaining 8% of the biomass (Table 4). In 2018, the north Porcupine Bank strata (strata 2) increased by nearly 130% and contained 13% of the stock as compared to 6% in 2017 (Table 4).

The two highest s_A values observed in the survey were recorded by the Celtic Explorer in the southern Rockall Trough, strata 3 (Figure 8c) and the western Porcupine Bank (strata 1) accounting for 41,974 m²/nmi² and 36,693 m²/nmi² (sampling unit: one nautical mile and 50 m vertical depth channel) respectively. The third highest value was recorded by Tridens in the southern Rockall Trough, strata 3 in close proximity to that recorded by the Celtic Explorer and accounted for 34,547 m²/nmi² (Figure 8d).

The vertical distribution of blue whiting extended to deeper than has been previously observed during the survey time series. In the northern and western Porcupine Bank (strata 1&2) aggregations of blue whiting were observed to extend below the current acquisition floor of 750m (Figure 8a). These aggregations were positively identified as blue whiting by trawling. Although important, the acoustic density of blue whiting below 750 m was not considered as significant or widespread, and was restricted to a localised area.

Stock size

The estimated total biomass of blue whiting for the 2018 international survey was 4.04 million tonnes, representing an abundance of 40.6×10^9 individuals (Table 4). Spawning stock was estimated at 3.99 million tonnes and 40.0×10^9 individuals (Table 5).

Stock composition

Individuals of ages 1 to 18 years were observed during the survey.

The main contribution (86%) to the spawning stock biomass were the age groups 3, 4 and 5 with the four year olds (2014 year-class) being most abundant (50%), followed by the 2013 year-class (21%) and 2015 year-class (15%), (Table 5).

The Rockall Trough, historically the most productive stratum, accounted for upwards of 50% of the SBB in previous years, with the exception of 2013-2014 (48% and 44% respectively). In 2018, as in 2017, this stratum accounted for approximately 60% of SSB (Table 4). The highest mean weights of blue whiting were caught in the Rockall Trough stratum 3 (Figures 9 and 10).

In the northern area stratum 4 (South Faroes) reported an increase in abundance of 58% compared to 2017, while stratum 6 (Faroes/Shetland) saw a decrease in abundance of 31% (Table 4). When combined, both strata accounted for a comparable contribution to the total stock biomass as reported in 2017 (Table 4). Age group 1 (the 2017 year-class) dominated in the area south of the Faroes, followed by four year olds (Figure 12). Age groups 3-5 dominated in the Faroe-Shetland Channel, with one year olds present in smaller proportions (Figure12). The proportion of 2-year olds (2016 year-class) was low in this area in 2018 compared to 2017.

The bulk of the blue whiting observed in the 3 strata bordering the shelf edge (strata 1, 2 and 3) was dominated by 3 to 5 year olds, representing the bulk of biomass observed during the survey (Figures 12 and 13).

The proportion of blue whiting by number on the Rockall and Hatton Banks (strata 5) decreased from 6.6% in 2017 to 4.5% in 2018 following a similar pattern observed during 2016-2017 (Table 4). A decrease in salinity and temperature observed in 2017 persists in 2018 (see next section).

Four year olds (the 2014 year-class) were dominant in all strata with the exception of strata 4 (south Faroes), where 1 year olds ranked highest (Figure 12). The proportion of 1 and 2 year old fish was low in the total estimate in 2018 (Figure 13).

An uncertainty estimate based on a comparison of the abundance estimates by age was calculated for IBWSS for years 2016, 2017 and 2018 using StoX (Figure 11). It was possible to compare the progress of individual year classes, and by comparing the estimates of young year classes from 2016 to 2017 it appears evident that consistency from one year to the next is acceptable for some year classes. For example the two year olds in 2016 (2014 year class) was high and also as three year olds in 2017 and four year olds in 2018. It seems as the CV of the abundant age groups 3 to 5 was acceptable, below 0.2, in 2018 (Figure 11).

The survey time series (2004-2018) of TSN and TSB are presented in Figures 14 and 15 respectively and Table 6.

Hydrography

A combined total of 101 CTD casts were undertaken over the course of the survey (Table 1). Horizontal plots of temperature and salinity at depths of 50m, 100m, 200m and 500m as derived from vertical CTD casts are displayed in Figures 16-19 respectively. In 2018, temperature and salinity for the combined area was comparable to observations in 2017. Indications of a small increase in salinity were observed in the deeper layers in 2018 (Figures 18-19).

Concluding remarks

Main results

- Weather conditions were mixed with both good and bad periods. All vessels experienced some weather induced downtime ranging from 24 hrs to 48 hrs.
- The total area surveyed was slightly lower than in 2017 and this can be accounted for in the western periphery of Rockall. Overall, acoustic sampling effort (track miles), trawling effort and biological metrics were comparable, if not higher, than in 2017.
- The International Blue Whiting Spawning stock Survey 2018 shows an increase in total stock biomass of 29% with a corresponding increase in total abundance of 15% when compared to the 2017 estimate.
- The survey was carried out over 20 days and thus within the recommended 21 day time window agreed by the group.
- Estimated uncertainty around the total stock biomass remains low, just above CV=0.12 which is lower than previous year (around 0.16).
- The stock biomass within the survey area was dominated by 3, 4 and 5 year old fish contributing 86% of total stock biomass.
- The presence of blue whiting below 750 m was not considered significant or widespread and is therefore considered to have had little impact on the overall estimate of abundance.

- The proportion of immature fish (1 year old) in the 2018 estimate is three times higher than in 2017 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.

Interpretation of the results

- The group considers the 2018 estimate of abundance as robust. Good stock containment was achieved for both core and peripheral strata. Sampling effort (biological and acoustic), was comparable to the previous year.
- Total stock biomass observed in 2018 is the highest in the overall time series (2004-present). Representing an increase in TSB of 29% compared to 2017 (3.1 mt and 4.0 mt respectively). The 2014 year class (4 year old fish) accounts for approximately 50% of the TSB and over 2 mt. This year class is the largest observed in the survey time series.
- The bulk of SSB was distributed from the northern edge of the Porcupine Bank and continued northwards through the Rockall Trough and up to the Hebrides.
- Although not considered a reliable indicator of emerging year class strength this survey has in the past foreseen strong or weak signals from observations in the northern strata, as in 2016. The lack of abundance of two year olds in 2018, although not definitive, may indicate a poor emerging 2016 year class.

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. We propose that western extension of transects is 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.
- In order to ensure vertical containment of aggregations, participants are asked to be aware when surveying strata 1 & 2 in 2019 and adjust data acquisition depth where applicable.
- The group recommends that standardised reporting tables, including maturity proportions by length and age, be discussed and agreed upon within internationally coordinated surveys (IBWSS, IESNS, IESSNS & HERAS) at WGIPS in January 2019 and put forward to StoX developers as routine output formats.
- 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.
- The group recommends that vessels report trawl positions in the daily report and that these are plotted along with cruise track progression by the coordinator.
- Survey participants are encouraged to attend the workshop on mesopelagic methods (WKMESOMeth) in Galway 2019 in order to harmonise the categorisation criteria for the collection of meaningful acoustic data on mesopelagic fish aggregations during the IBWSS survey.

Achievements

- The entire survey area (128,030 nmi^2) was covered in 20 days in line with the group recommendation of 21 days.
- Acoustic sampling effort (track miles), trawling effort and biological metrics of blue whiting were comparable, if not higher, than in 2017.

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Table 1. Country and vessel specific details, IBWSS March-April 2018.

	Celtic Explorer	Magnus Heinason	Tridens	Kings Bay
Trawl dimensions				

Circumference (m)	768	640	860	832
Vertical opening (m)	50	40-45	30-70	45
Mesh size in codend (mm)	20	40	40	40
Typical towing speed (kn)	3.5-4.0	2.9-3.1	3.5-4.0	3.5-4.0
Plankton sampling	-	16	0	22
Sampling net	-	WP2 plankton net	-	WP2 plankton net
Standard sampling depth (m)	-	200	-	400
Hydrographic sampling				
CTD Unit	SBE911	SBE911	SBE911	SBE25/SAI V SD208
Standard sampling depth (m)	1000	1000	1000	1000

Table 2. Acoustic instruments and settings for the primary frequency, IBWSS March-April 2018.

	Celtic Explorer	Magnus Heinason	Tridens	Kings Bay
Echo sounder	Simrad EK 60	Simrad EK60	Simrad EK 60	Simrad EK 80
Frequency (kHz)	**38**, 18, 120, 200	**38**, 200	18, **38**, 70, 120, 200, 333	18, **38**, 120, 200
Primary transducer	ES 38B	ES 38B	ES 38B	ES 38B
Transducer installation	Drop keel	Hull	Drop keel	Drop keel
Transducer depth (m)	8.7	3	8	8.5
Upper integration limit (m)	15	7	15	15
Absorption coeff. (dB/km)	9.4	10.1	10	9.59
Pulse length (ms)	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.43	2.43	2.43
Transmitter power (W)	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	21.9	23
2-way beam angle (dB)	-20.6	-20.8	-20.6	-20.7
Sv Transducer gain (dB)				
Ts Transducer gain (dB)	25.65	25.67	26.49	24.06
s_A correction (dB)	-0.58	-0.73	-0.64	0.008
3 dB beam width (dg)				
alongship:	7.03	7.15	6.97	7.0
athw. ship:	7.09	7.08	6.96	7.0
Maximum range (m)	750	750	750	750
Post processing software	Echoview	Echoview	LSSS	LSSS

Table 3. Survey effort by vessel, IBWSS March-April 2018.

Vessel	Effective survey period	Length of cruise track (nmi)	Trawl stations	CTD stations	Plankton sampling WP2-net	Aged fish	Length-measured fish

Celtic Explorer	21/3-4/4	2442	14	35	-	600	1700
Magnus Heinason	30/3-8/4	1232	11	16	16	592	1415
Kings Bay	23/3- 4/4	1667	11	29	29	330	1,100
Tridens	20/3-4/4	1955	13	21	-	1097	1100
Total	21/3-8/4	7296	49	101	45	2619	5315

Table 4. Abundance and biomass estimates of blue whiting by strata in 2018 and 2017. IBWSS March-April 2018.

		2018				2017				Difference 2018-2017	
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	534	5 519	13.2	13.6	616	7 367	19.6	20.9	-33%	-35%
2	N Porcupine Bank	521	5 599	12.9	13.8	177	2 084	5.6	5.9	128%	133%
3	Rockall Trough	2 475	24 708	61.4	60.9	1 871	20 855	59.7	59.3	3%	3%
4	South Faroes	164	1 604	4.1	4.0	102	881	3.2	2.5	25%	58%
5	Rockall Bank	179	1 835	4.4	4.5	215	2 321	6.9	6.6	-36%	-31%
6	Faroe/Shetland Ch.	162	1 336	4.0	3.3	154	1 670	4.9	4.7	-18%	-31%
	Total	4 035	40 602	100	100	3 135	35 178	100	100	29%	15%

Table 5. Survey stock estimate of blue whiting, IBWSS March-April 2018.

					Age in years (year class)						Number	Biomass	Mean	Prop
Length	1	2	3	4	5	6	7	8	9	10+			weight	Mature
(cm)	2017	2016	2015	2014	2013	2012	2011	2010	2009		(10^6)	(10^6 kg)	(g)	
17-18	7										7	0.2	31	0
18-19	30										30	1.0	33	0
19-20	73	1									74	2.9	39	8
20-21	153										153	7.1	47	3
21-22	259	5									264	14.3	54	25
22-23	196	3			4						203	12.8	63	30
23-24	112	130	55	50							348	23.8	69	93
24-25	6	135	630	762	363						1 895	137.1	72	100
25-26		169	1 631	3 449	950	137					6 336	503.4	79	100
26-27		138	1 764	6 000	1 365	204	74				9 544	825.7	87	100
27-28		48	1 541	5 301	1 356	323	46	7			8 620	829.2	96	100
28-29			587	3 420	1 018	319	72				5 416	578.3	107	100
29-30			187	1 501	1 154	387	145		9		3 383	407.5	120	100
30-31			143	631	536	298	116	33	20		1 777	235.1	132	100
31-32			21	277	410	242	59	21	6		1 036	148.7	143	100
32-33			56	55	246	104	56	21	10	6	554	90.7	164	100
33-34				34	171	98	89		12	4	407	75.1	184	100
34-35				11	42	48	34	41		11	186	38.1	204	100
35-36					36		24	24	15	29	128	29.1	228	100
36-37					32		11	21		2	66	16.9	256	100
37-38						14	21			11	46	11.7	256	100
38-39						14				40	54	15.2	280	100
39-40								10		10	21	6.9	337	100
40-41					10		10	10		3	32	11.2	348	100
41-42											0	0.0	-	100
42-43											0	0.0	-	100
43-44										12	12	7.8	633	100
44-45										8	8	4.7	574	100
TSN(mill)	836	628	6 615	21 490	7 692	2 187	755	188	72	144	40 602			
TSB(1000 t)	46.4	50.6	591.4	2 024.2	836.3	274.2	118.4	36.7	12.9	38.2	4 034.5			
Mean length(cm	21.3	25.0	26.5	27.0	27.9	29.2	30.6	33.5	32.0					
Mean weight(g)	55	81	89	94	109	125	157	195	178					
% Mature	23	99	100	100	100	100	100	100	100	100				
SSB (1000 t)	10.8	50.1	591.2	2024.2	836.0	274.2	118.4	36.7	12.9	38.2	3 993			
SSN (mill)	194	622	6613	21490	7689	2187	755	188	72	144	39 954			

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
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

*Survey discarded.

Table 7. Survey effort in the IBWSS.

Survey effort	Survey area (nmi²)	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

* No Russian vessel in 2016, 2017, 2018.

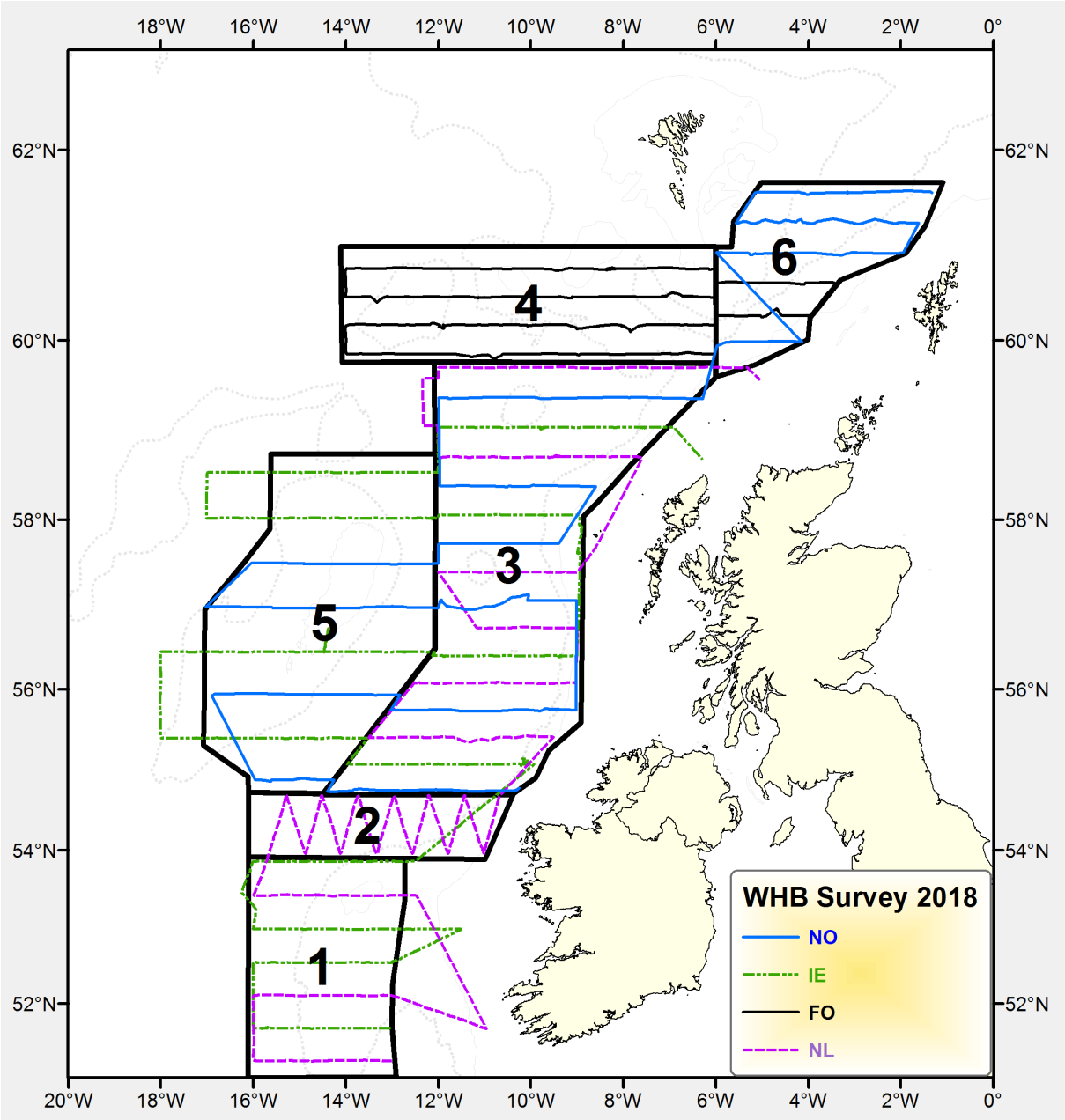


Figure 1. Strata and cruise tracks for the individual vessels (country) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2018.

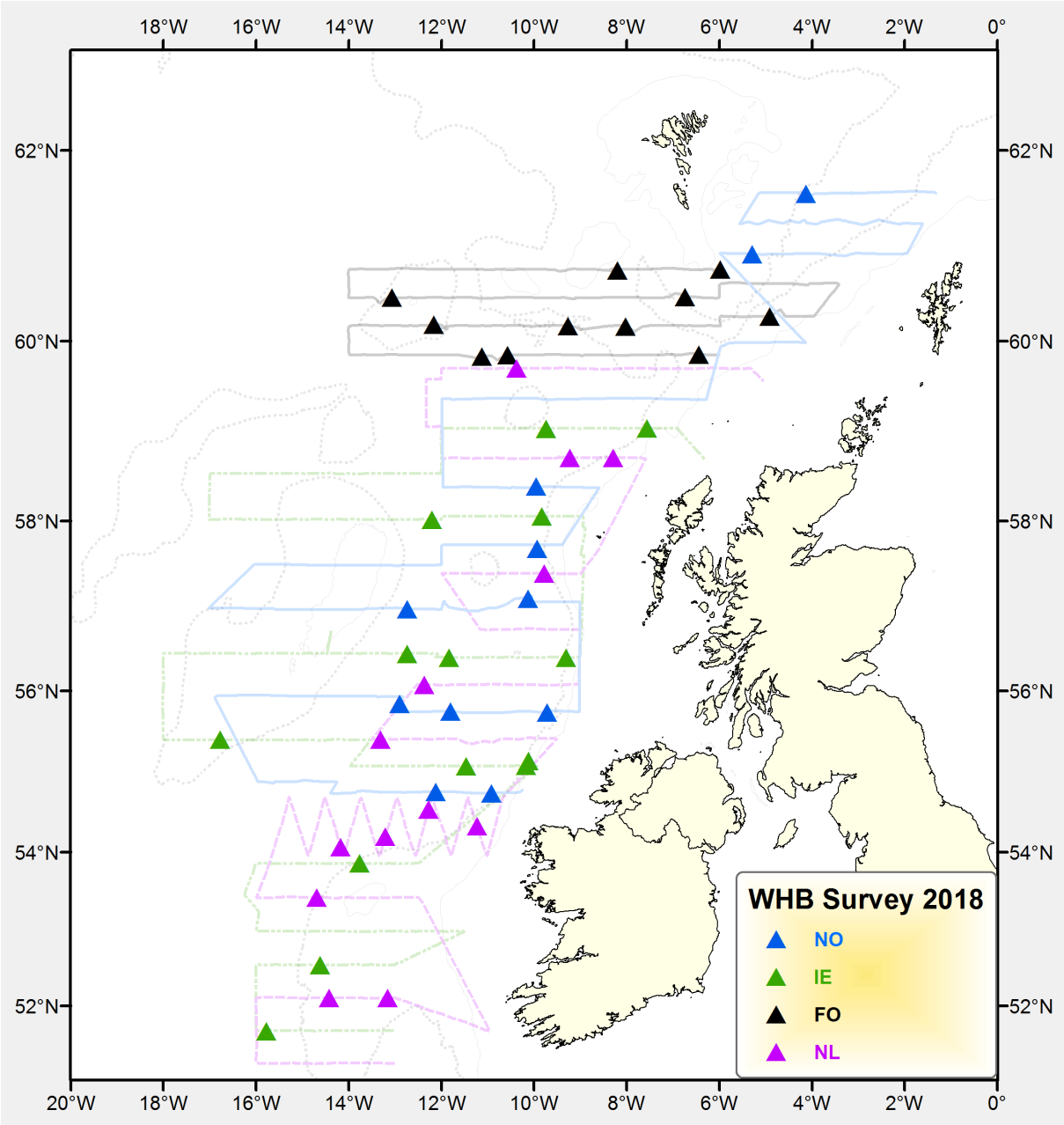


Figure 2. Vessel cruise tracks and trawl stations of the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2018. IE: Ireland (Celtic Explorer); FO: Faroe Islands (Magnus Heinason); NL: Netherlands (Tridens); NO: Norway (Kings Bay).

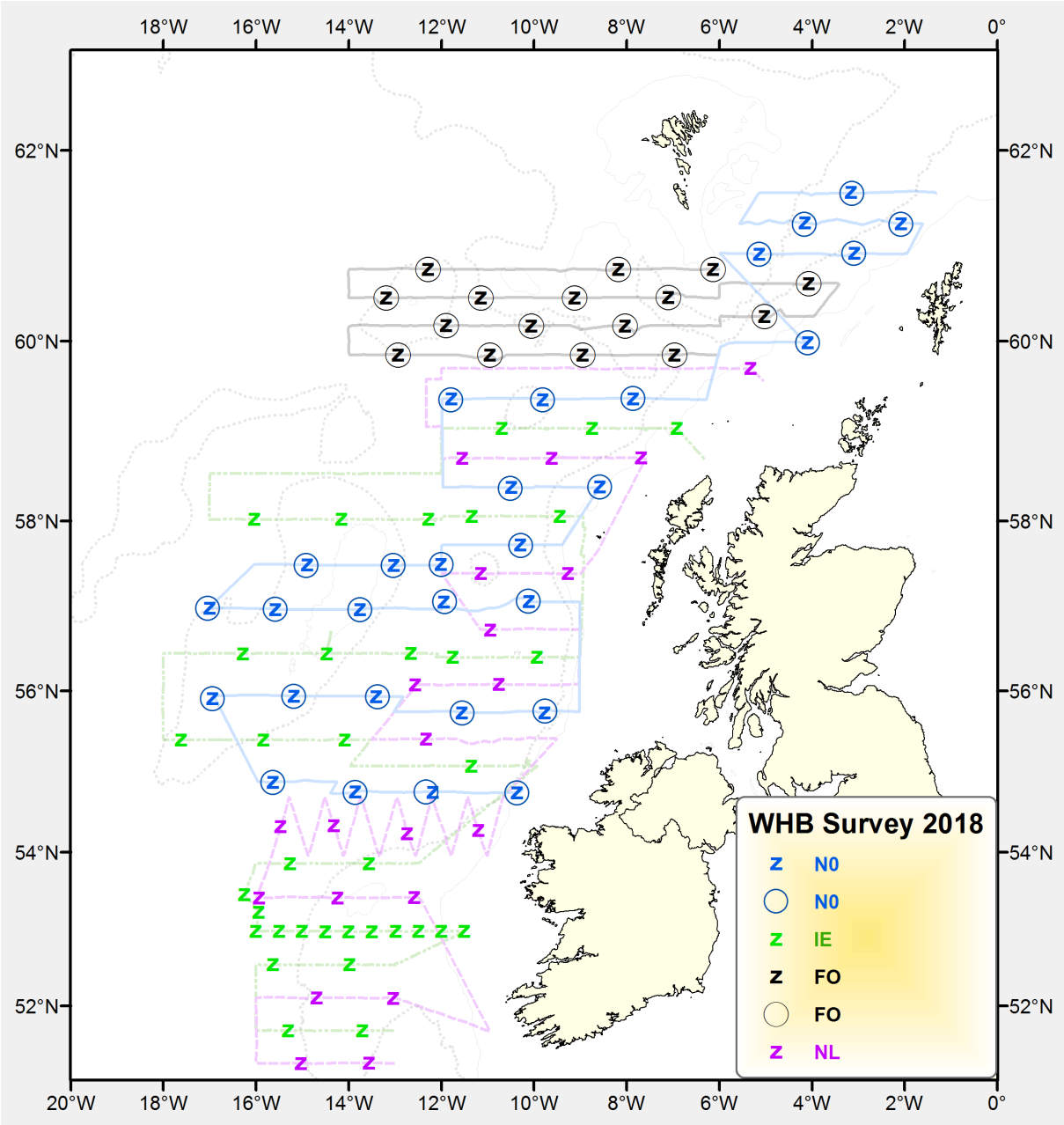


Figure 3. Vessel cruise tracks with hydrographic CTD stations (z) and WP2 plankton net samples (citrcles) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2018. Colour coded by vessel.

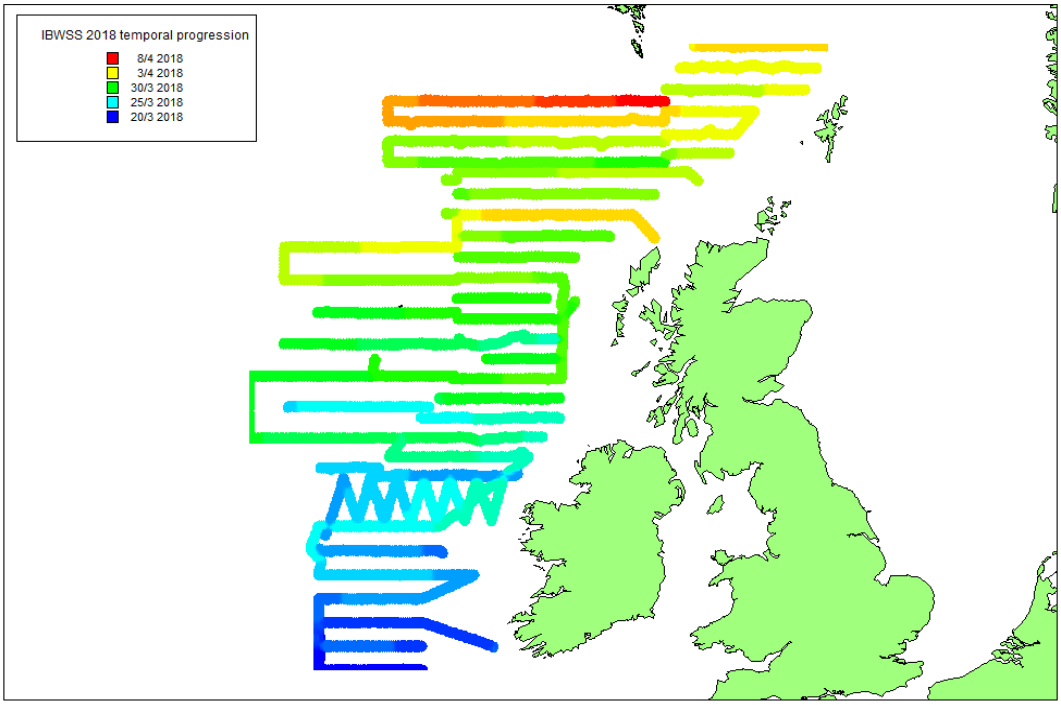


Figure 4. Temporal progression for the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2018.

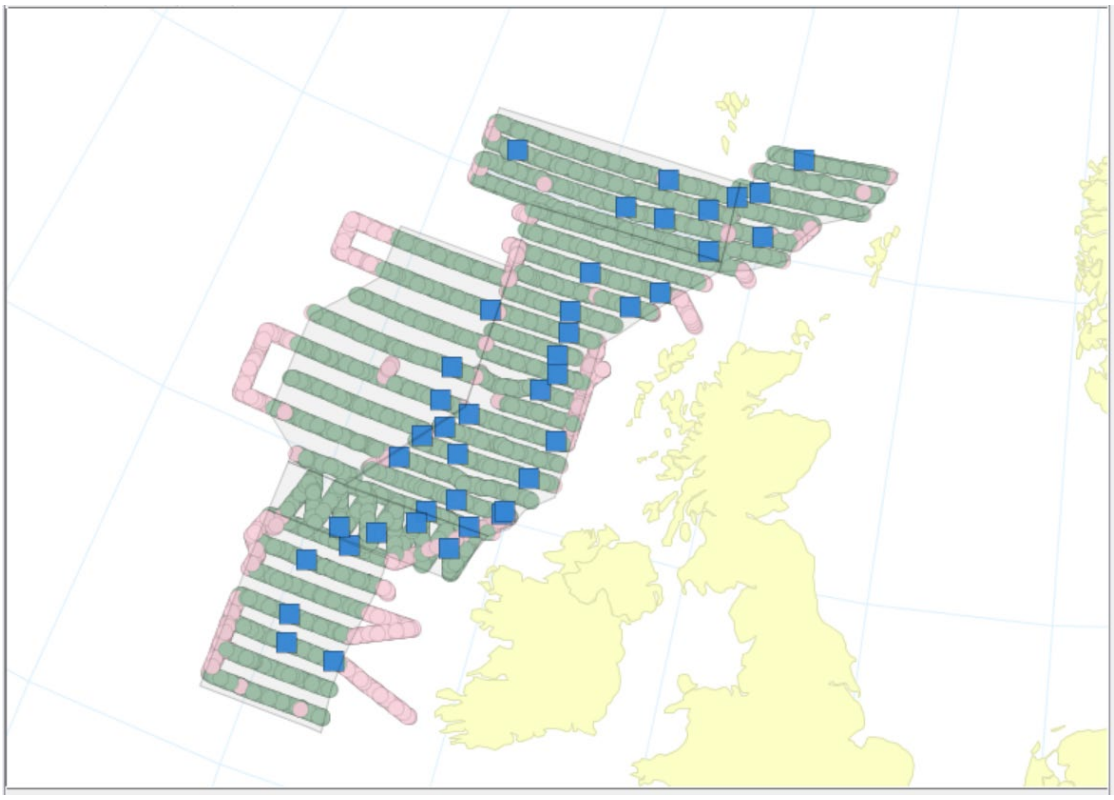


Figure 5. Tagged acoustic transects (green circles) with associated trawl stations containing blue whiting (blue squares) used in the StoX abundance estimation. IBWSS March-April 2018.

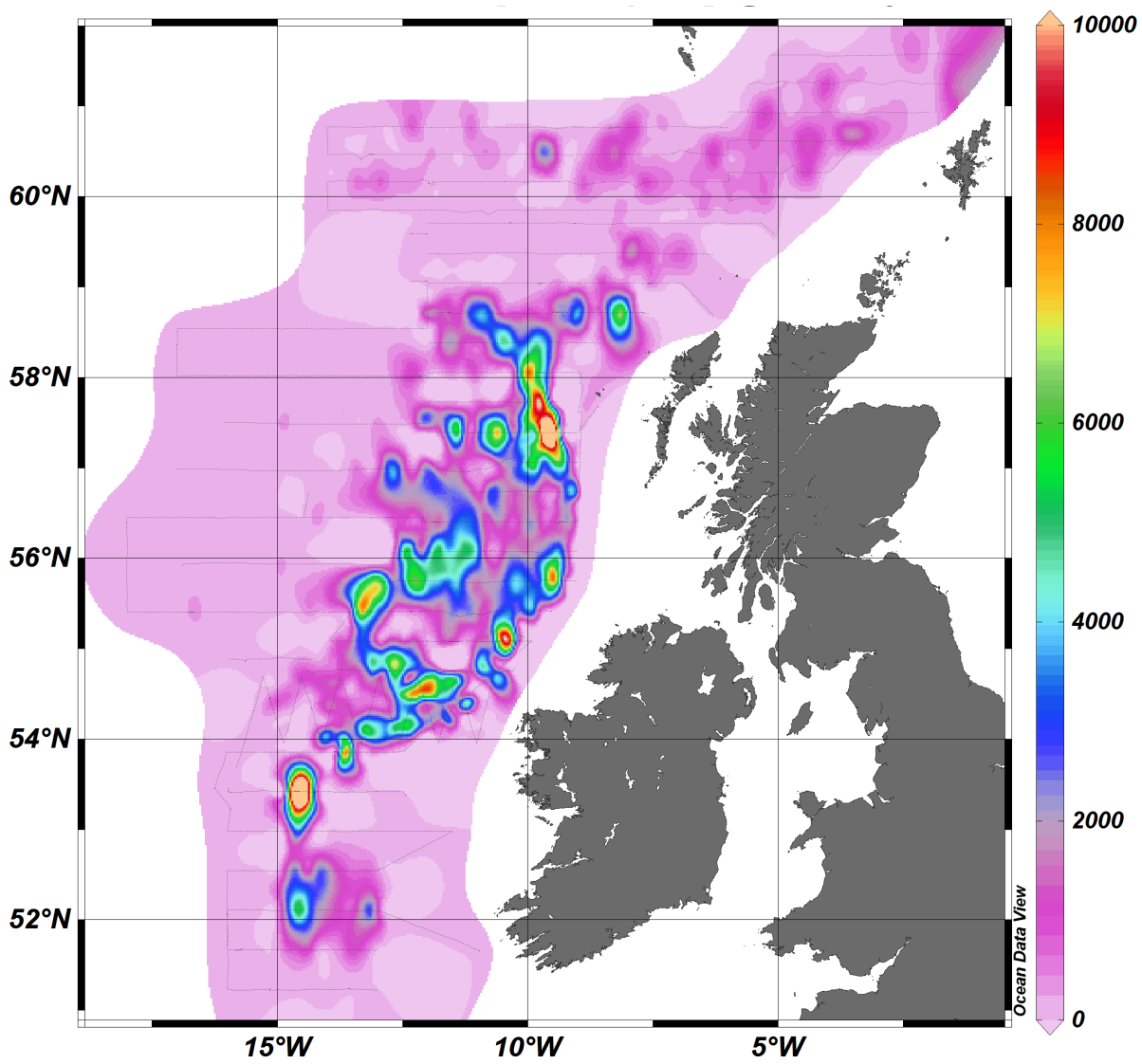


Figure 6. Map of acoustic density (s_A m^2/nmi^2) of blue whiting during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2018.

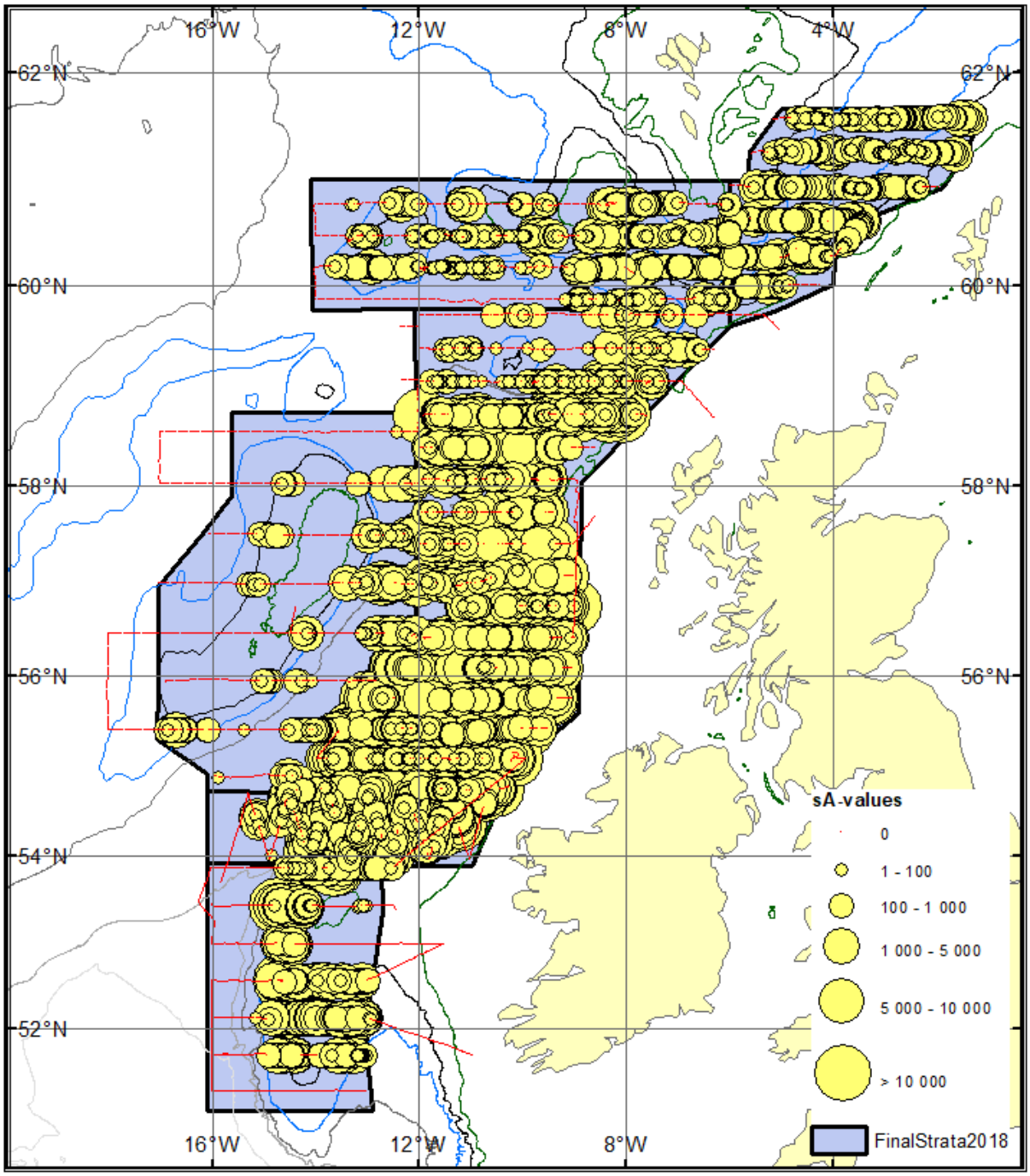
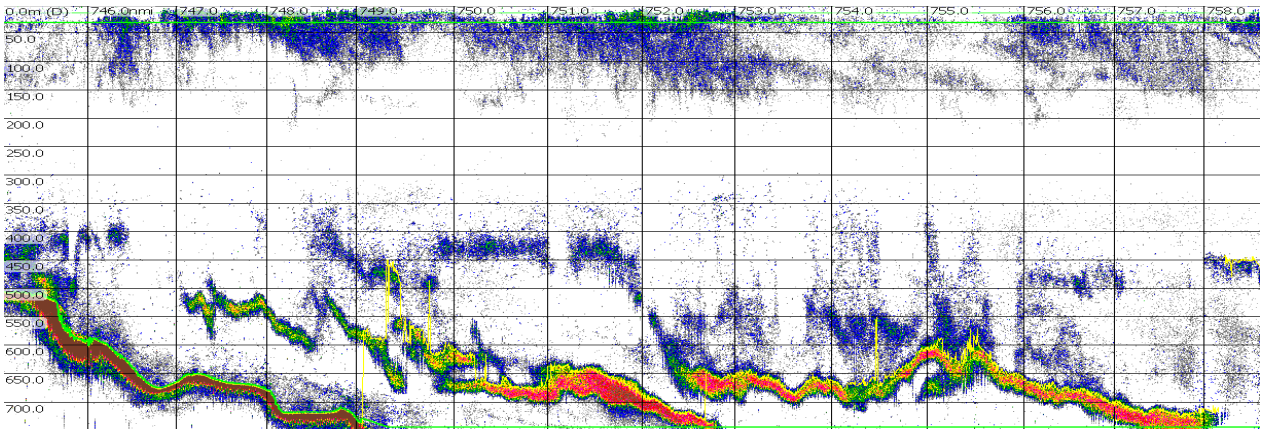
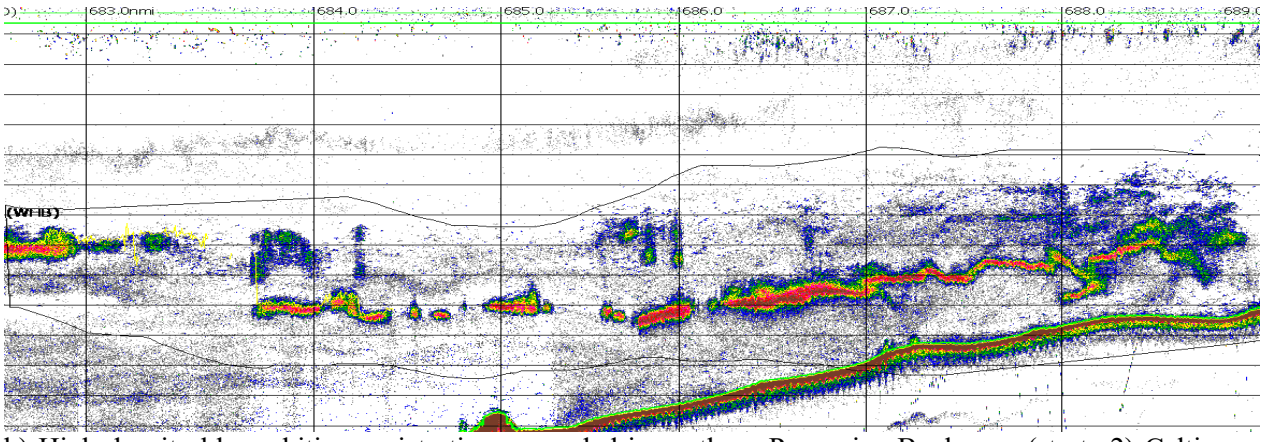


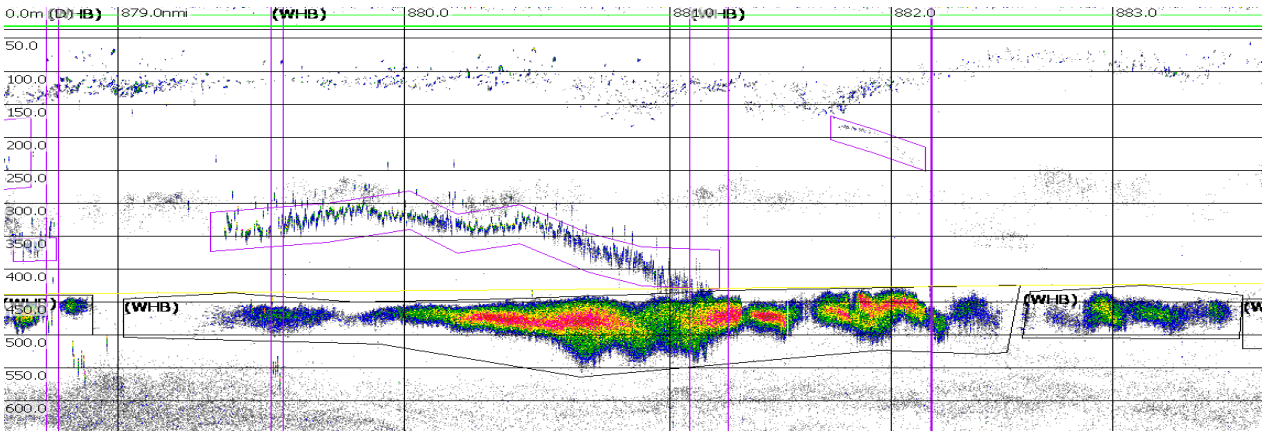
Figure 7. Map of acoustic density (s_A m^2/nmi^2) of blue whiting by 1 nmi (circle scaled by acoustic density). IBWSS March-April 2018.



a) Deep and high density schools of blue whiting as observed by Celtic Explorer in the western Porcupine Bank area, strata 2. Note schools extende below the current 750m data acquisition floor.



b) High density blue whiting registrations recorded in northern Porcupine Bank area (strata 2) Celtic Explorer.



c) Single high density blue whiting aggregation per 1 nmi log interval recorded by the Celtic Explorer in the Rockall Trough Bank area (strata 3).

Figure 8. Echograms of interest encountered during the IBWSS, March-April 2018.

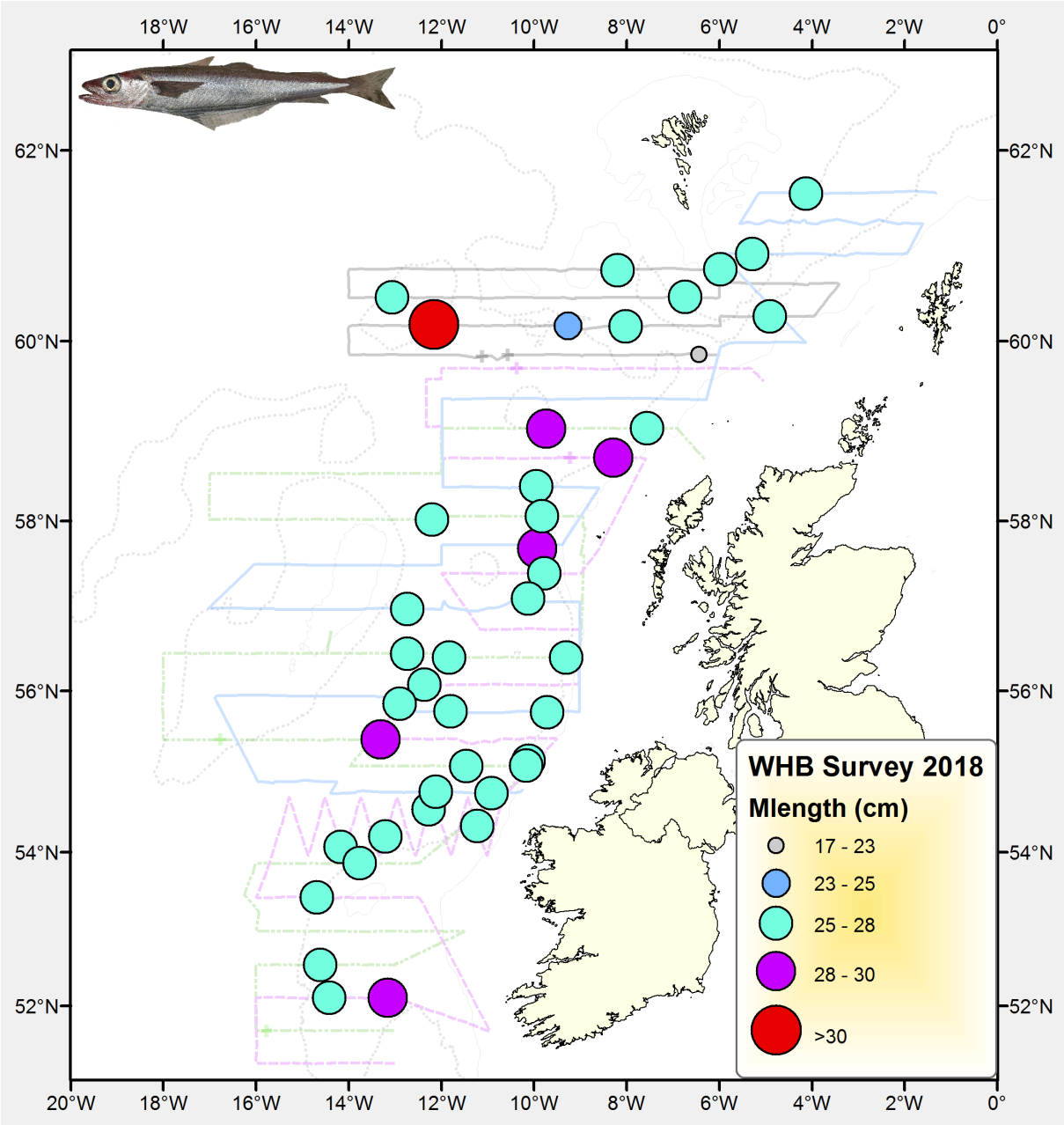


Figure 9. Combined mean length of blue whiting from trawl catches by vessel, IBWSS in March- April 2018. Crosses indicate hauls with zero blue whiting catches.

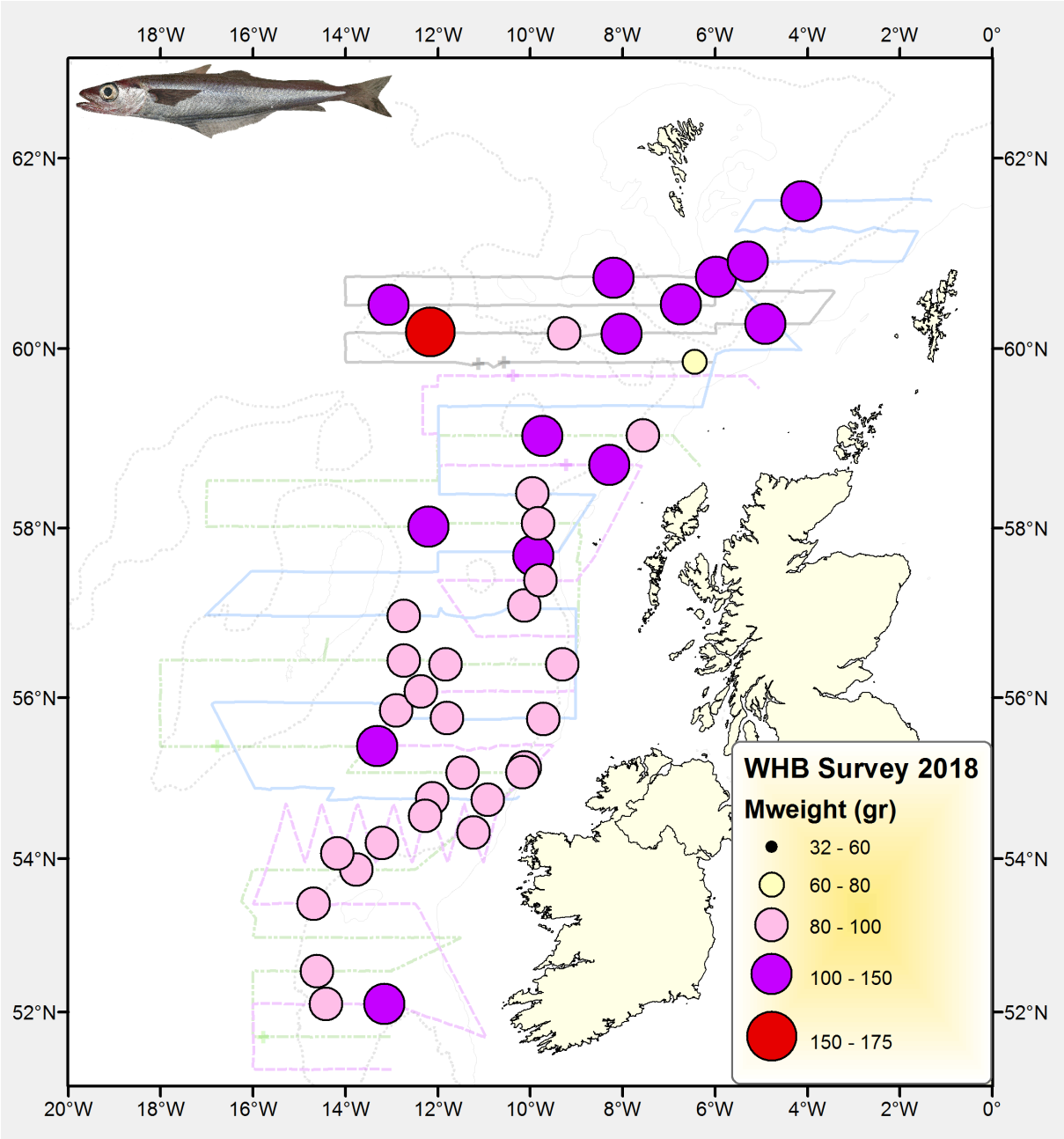


Figure 10. Combined mean weight of blue whiting from trawl catches, IBWSS March- April 2018. Crosses indicate hauls with zero blue whiting catches.

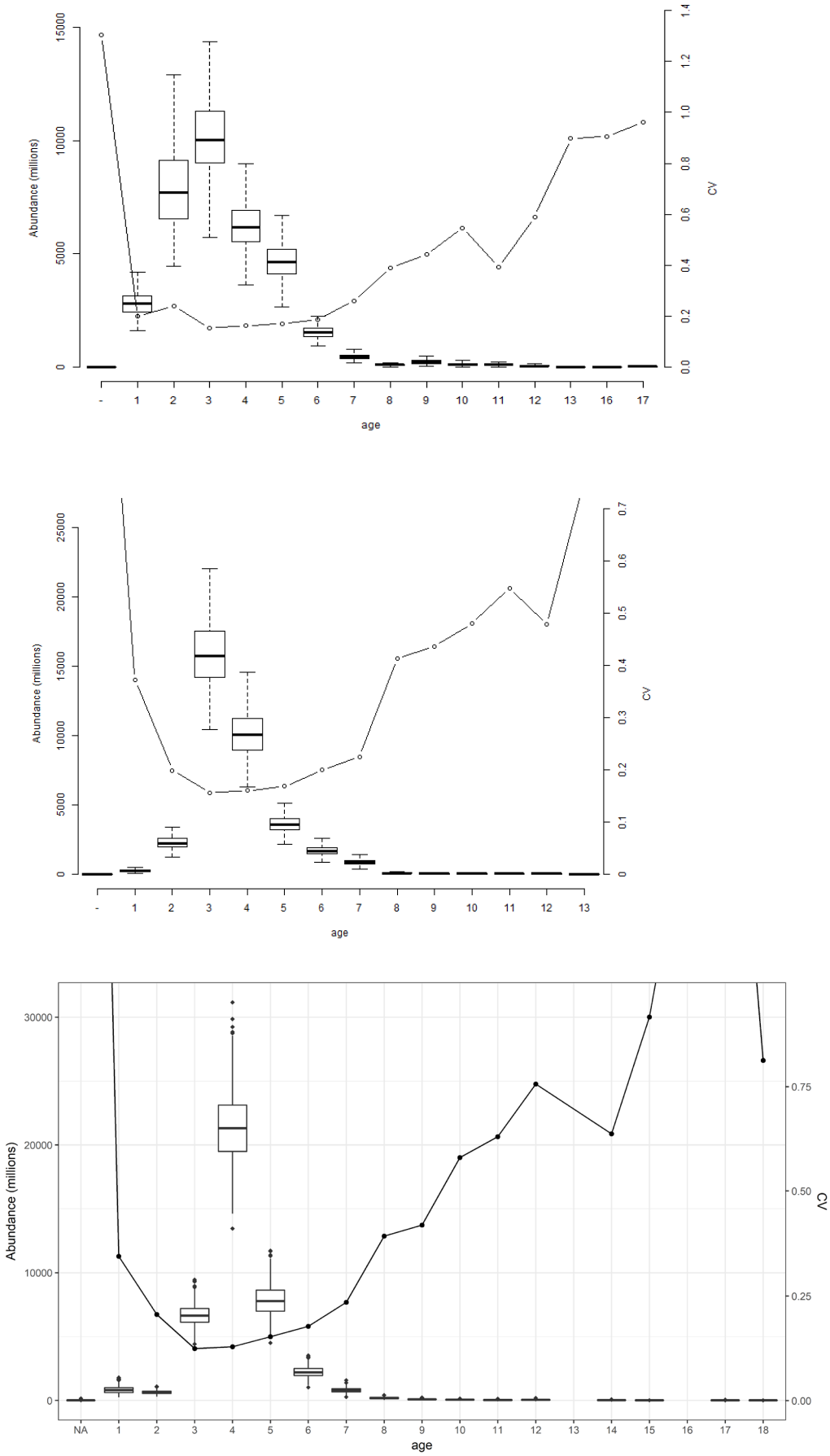


Figure 11. Blue whiting bootstrap abundance (millions) by age (left axis) and associated CVs (right axis) in 2016 (top panel), 2017 (middle panel) and 2018 (lower panel). From StoX.

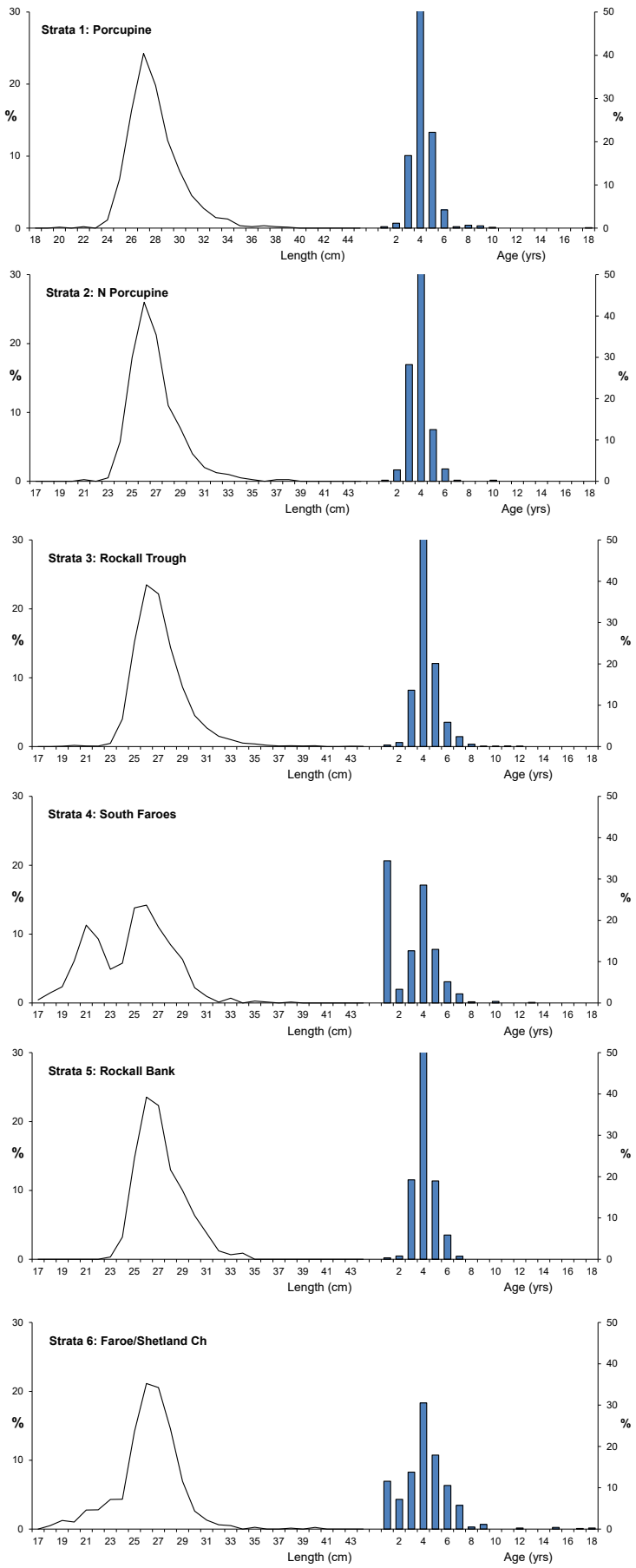


Figure 12. Length and age distribution (numbers) of blue whiting by survey strata. March-April 2019.

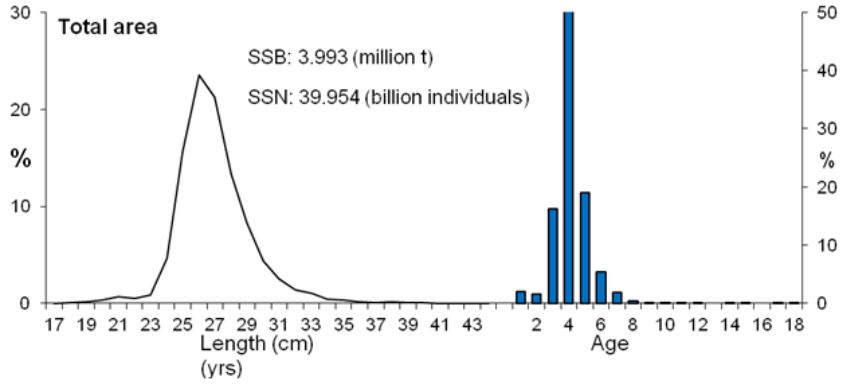


Figure 13. Length and age distribution (numbers) of total stock of blue whiting. March-April 2018.

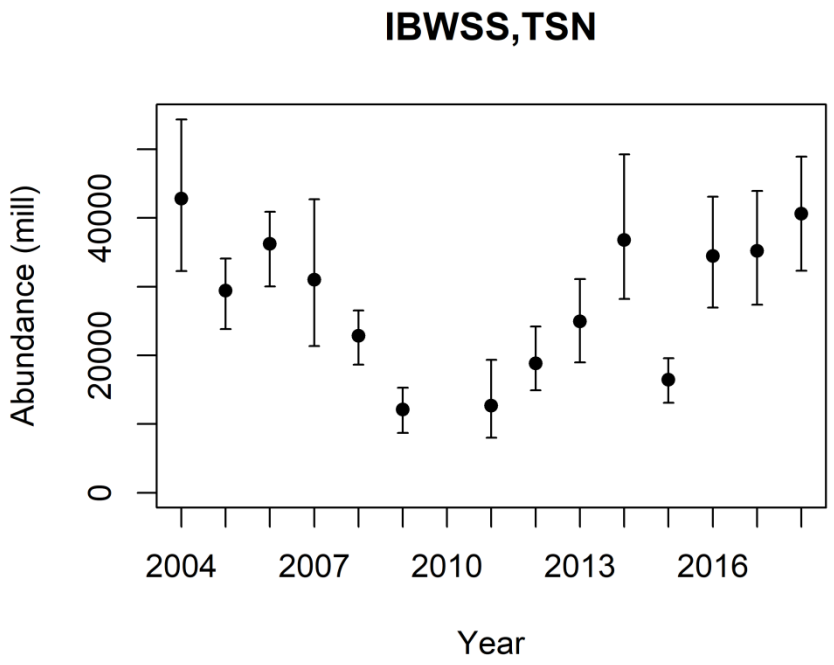


Figure 14. Time series of StoX survey indices of blue whiting abundance, 2004-2018, excluding 2010 due to data problems.

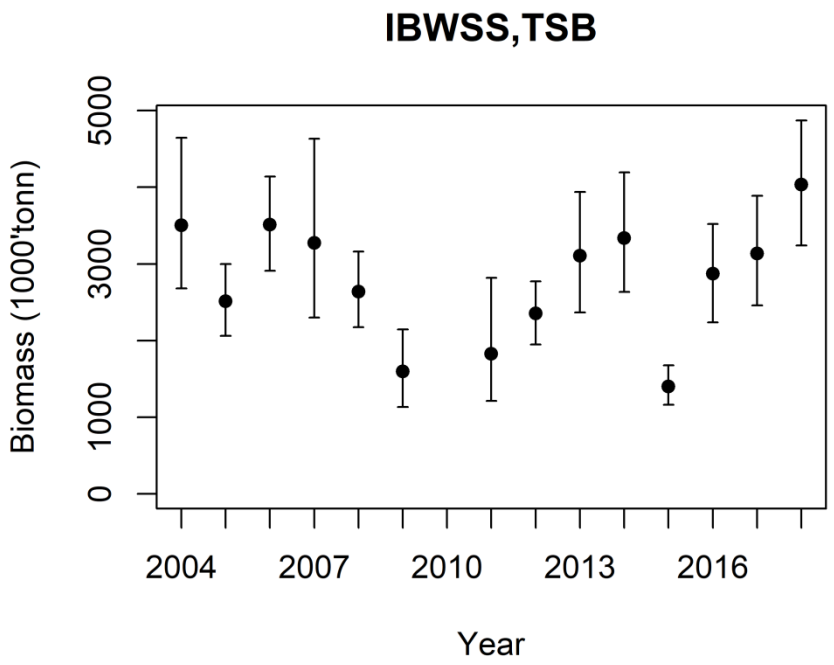


Figure 15. Time series of StoX survey indices of blue whiting biomass, 2004-2018, excluding 2010 due to data problems.

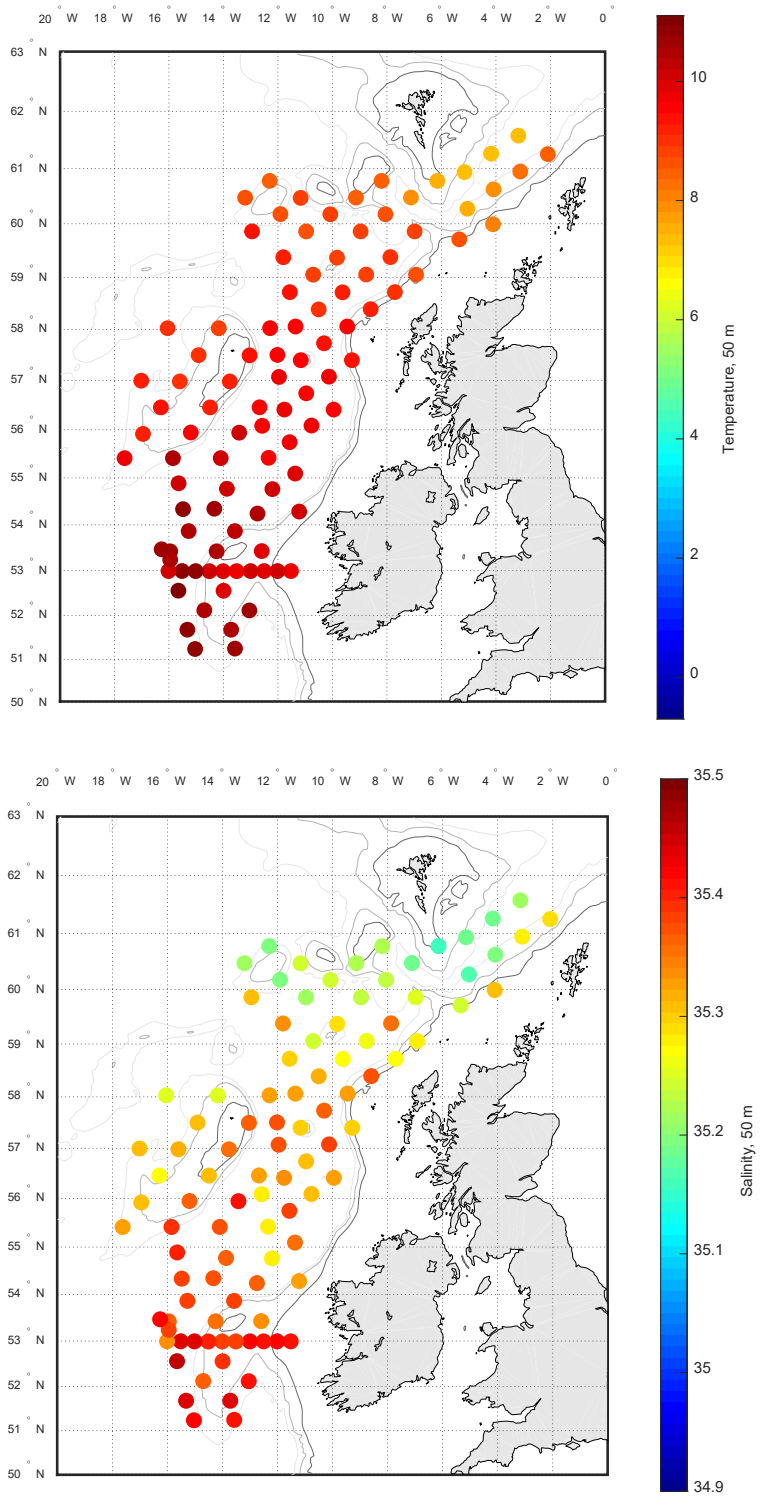


Figure 16. Horizontal temperature (top panel) and salinity (bottom panel) at 50 m subsurface as derived from vertical CTD casts. IBWSS March-April 2018.

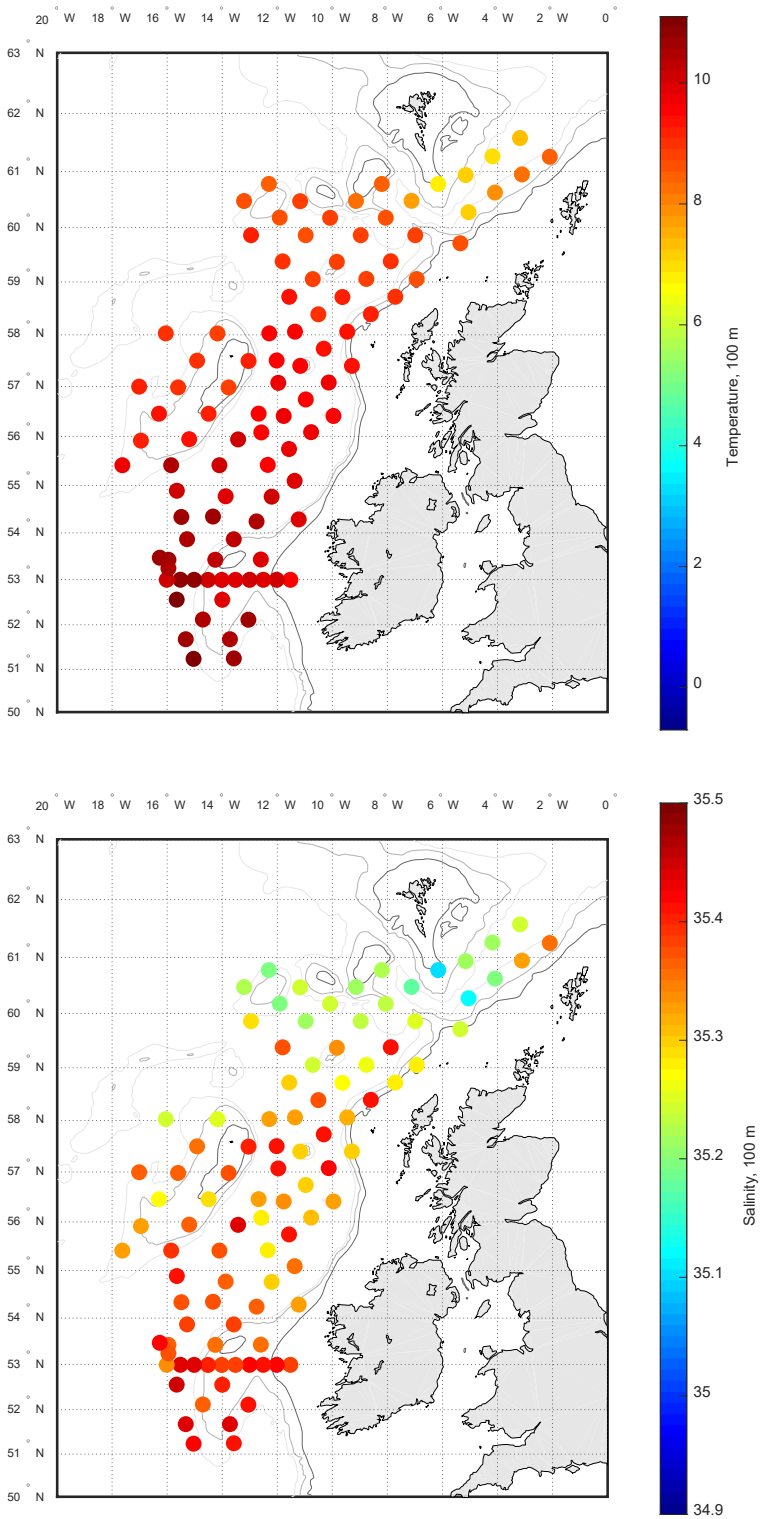


Figure 17. Horizontal temperature (top panel) and salinity (bottom panel) at 100 m subsurface as derived from vertical CTD casts. IBWSS March-April 2018.

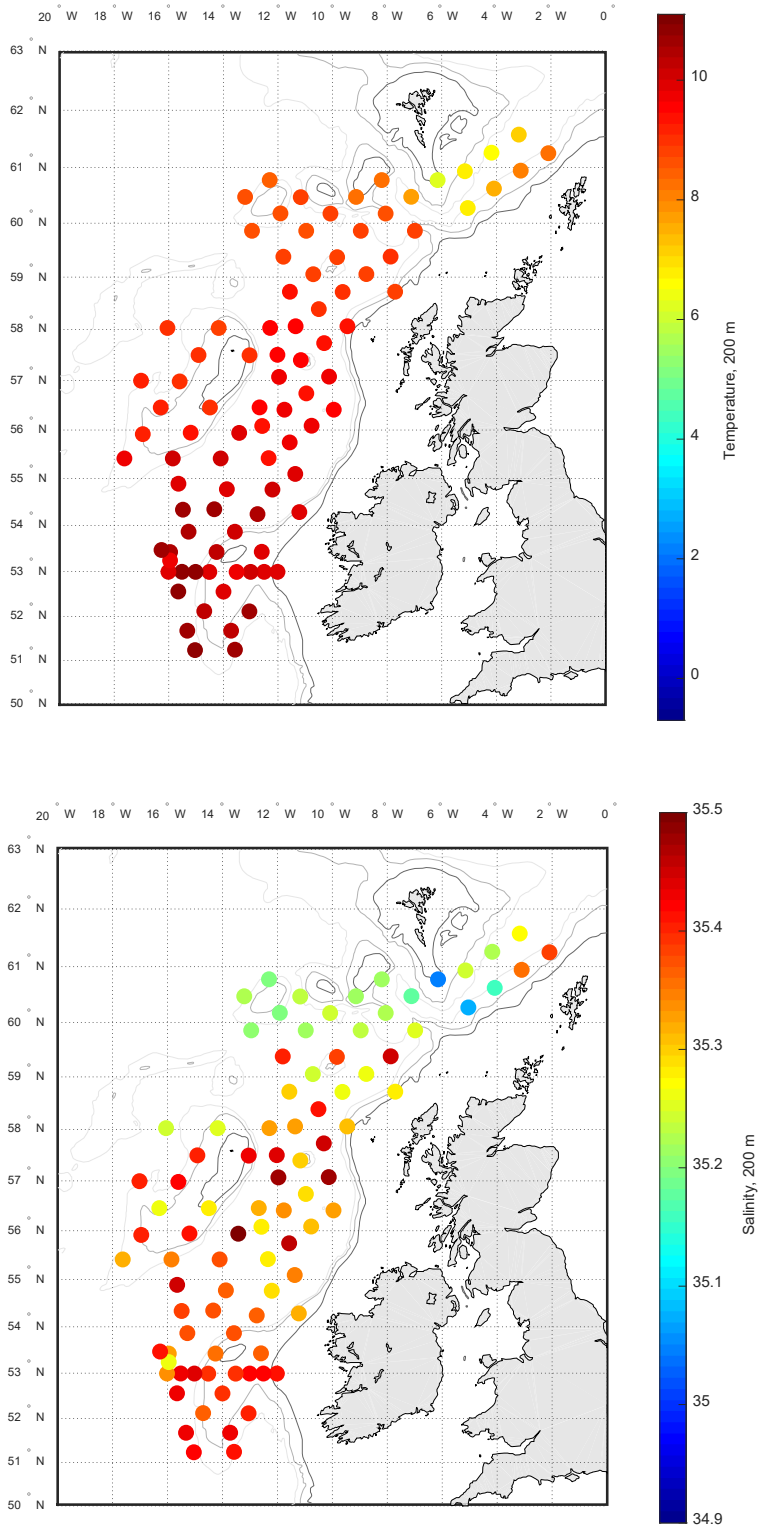


Figure 18. Horizontal temperature (top panel) and salinity (bottom panel) at 200 m subsurface as derived from vertical CTD casts. IBWSS March-April 2018.

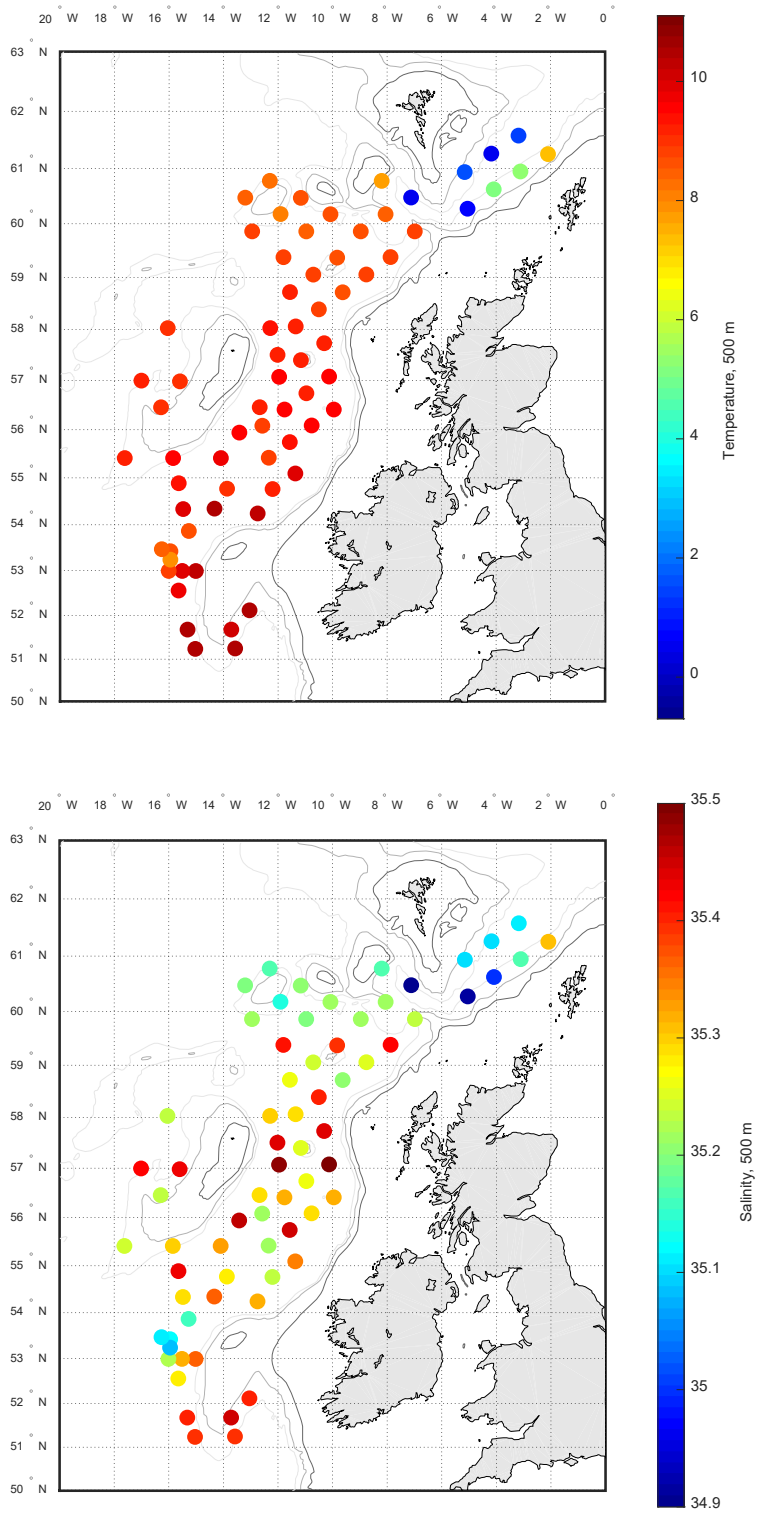


Figure 19. Horizontal temperature (top panel) and salinity (bottom panel) at 500 m subsurface as derived from vertical CTD casts. IBWSS March-April 2018.

Document 4a: IESNS 2018 survey summary table

Survey Summary table WGIPS 2019	
Name of the survey (abbreviation):	International Ecosystem Survey in the Nordic Seas (IESNS)
Target Species:	Norwegian spring-spawning herring
Survey dates:	30 April – 16 June

Summary:

Survey coverage in the Norwegian Sea was considered adequate in 2018 and in line with previous years. The zero-line was believed to be reached for adult NSS herring throughout the area. It is therefore recommended that the results can be used for assessment purpose. The herring was primarily distributed in the southwestern Norwegian Sea. In the Barents Sea the main aggregations of young herring were observed in the eastern part. Registrations of NSS herring were low in the eastern part of the Norwegian Sea. In the southernmost part of the survey area herring was also observed, but based on the otolith structure a significant part of this herring was of autumn spawning type and was excluded fom the index calculation.

The total biomass estimate of herring in the Norwegian Sea was 5.04 million tonnes. This estimate is 0.84 million tonnes (20 %) increase from the 2017 survey estimate. 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 2013) dominated in the survey stock biomass estimate (25%). Each of three older age groups (age 12-14), which have dominated in the stock in previous years, contributed equally to the stock estimate of around 10% each.

The abundance estimates of herring in the Barents Sea indicated a relatively strong 2016 year-class, being the fifth highest in the time-series (at age 2). However, the zeroline of juvenile herring distributions towards north was apparently not reached in Barents Sea in 2018.

Survey effort, timing and area coverage were comparable to previous years.

	Description
Survey design	Stratified systematic parallel transects design with randomized starting point of the southernmost transect within each strata.
Index Calculation method	StoX (via the PGNAPES database)
Random/systematic error issues	N/A
Specific survey error issues (acoustic)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Bubble sweep down	No problems due to bad weather for a coustic 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 The target strength for blue whiting was first applied in 2012
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 adeqately 2018 survey: the entire stock during its migration on the feeding grounds, the adults in the Norwegian Sea and adjacent waters
Stock ID and mixing issues	Yes, some mixing of herring might have occurred in some of the fringe regions: Southeastern Icelandic zone all herring west of 14 W were excluded from the index calculations (being Icelandic sumer-spawners). In the Faroe zone all herring north of 62 N was allocated to NSSH. In the EU zone/NO zone in the southeast the herring of autumn-spawning type was excluded fom the stock index calculations (south of 62 N).
Measures of uncertainty (CV)	The estimated survey uncertainty for the main age groups in the sestimate was around 0.25
Biological sampling	Sampling levels was considered representative. In the recent four 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 has been ongoing for some period, where scales and otoliths for the same fish have been sampled. On basis of that work, a workshop was planned in the spring 2018 to discuss the results. This workshop was postponed and has not yet been undertaken.
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole time-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 4b: IESNS 2018 survey report

Please see the report on the next page.

Working Document

Post-cruise meeting of the Working Group on International Pelagic Surveys (WGIPS)
Copenhagen, Denmark, 19 – 21 June 2018

Working Group on Widely distributed Stocks
Tórshavn, Faroe Islands, 28 August - 3 September 2018

INTERNATIONAL ECOSYSTEM SURVEY IN NORDIC SEA (IESNS) in May – June 2018

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Introduction

In May-June 2018, five research vessels; R/V Dana, Denmark (joined survey by Denmark, Germany, Ireland, The Netherland, Sweden and UK), R/V Magnus Heinason, Faroe Islands, R/V Árni Friðriksson, Iceland, R/V G.O. Sars 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 biomass of the herring stock, in addition to collect data on plankton and hydrographical conditions in the area. The survey was initiated by the Faroes, Iceland, Norway and Russia in 1995. Since 1997 also the EU participated (except 2002 and 2003) and from 2004 onwards it was more integrated into an ecosystem survey. This report is compilation of data from this International survey stored in the PGNAPES database and supported by national survey reports from each survey (Dana: Staehr, Bergès, Kloppmann, Kupschus 2018, Magnus Heinason: Homrum, Eliasen, FAMRI 1820-2018, Árni Friðriksson: Óskarsson et al. 2018, Vilnyus: Rybakov PINRO 2018).

Material and methods

Coordination of the survey was done during the WGIPS meeting in January 2018. The participating vessels together with their effective survey periods are listed in the table below:

Vessel	Institute	Survey period
Dana	Danish Institute for Fisheries Research, Denmark	1/5-30/05
G.O. Sars	Institute of Marine Research, Bergen, Norway	30/4-2/6
Vilnyus	PINRO, Russia	23/5–16/6
Magnus Heinason	Faroe Marine Research Institute, Faroe Islands	03/5-15/5
Árni Friðriksson	Marine and Freshwater Research Institute, Iceland	05/5-19/5

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

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

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

	Dana	G.O. Sars	Arni Friðriksson	Magnus Heinason	Vilnyus
Echo sounder	Simrad EK 60	Simrad EK 80	Simrad EK60	Simrad EK60	Simrad EK60
Frequency (kHz)	**38**	**38**, 18, 70, 120, 200, 333	**38**, 18, 120, 200	**38**,200	**38**, 120
Primary transducer	ES38BP	ES 38B	ES38B	ES38B	ES38B
Transducer installation	Towed body	Drop keel	Drop keel	Hull	Hull
Transducer depth (m)	5	8.5	8	3	4.5
Upper integration limit (m)	5	15	15	7	10
Absorption coeff. (dB/km)	10	9.8	10	10.1	10
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	1.573	2.43	2.425	2425	2.425
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)	-20.5	-20.7	-20.81	-20.8	-20.6
Sv Transducer gain (dB)					
Ts Transducer gain (dB)	25.32	26.25	24.34	25.67	25.76
s_A correction (dB)	-0.56	-0.13	-0.61	-0.73	-0.64
3 dB beam width (dg)					
alongship:	6.8	6.4	7.28	7.15	7.09
athw. ship:	6.8	6.35	7.23	7.08	7.01
Maximum range (m)	500	500	500	500	500
Post processing software	LSSS	LSSS	LSSS	Sonardata Echoview 8.1	LSSS

Post-processing software differed among the vessels but all participants used the same post-processing procedure, which is according to an agreement at a PGNAPES scrutinizing workshop in Bergen in February 2009 (ICES 2009), and "Notes from acoustic Scrutinizing workshop in relation to the IESNS", Reykjavík 3.-5. March 2015 (Annex 4 in ICES 2015).
Generally, acoustic recordings were scrutinized on daily basis and species identified and partitioned using catch information, characteristic of the recordings, and frequency between integration on 38 kHz and on other frequencies by a scientist experienced in viewing echograms. All vessels used a large or medium-sized pelagic trawl as the main tool for biological sampling. The salient properties of the trawls are as follows:

	Dana	G.O. Sars	Arni Friðriksson	Magnus Heinason	Vilnyus
Circumference (m)		832	832	640	500
Vertical opening (m)	25-35	30–50	30–35	45–55	50
Mesh size in codend (mm)		40	40	40	16
Typical towing speed (kn)	3.5-4.0	3.0–4.5	3.1–5.0	3.0–4.0	3.3–4.5

Catches from trawl hauls were sorted and weighed; fish were identified to species level, when possible, and other taxa to higher taxonomic levels. Normally, a subsample of 30–100 herring, blue whiting and mackerel were sexed, aged, and measured for length and weight, and their maturity status was estimated using established methods. For the Norwegian, Icelandic and Faroese vessel, a smaller subsample of stomachs was sampled for further analyses on land. An additional sample of 70–300 fish was measured for length.

Acoustic data were analysed using the StoX software package recently adopted for WGIPS coordinated surveys. A description of StoX can be found here: http://www.imr.no/forskning/prosjekter/stox/nb-no. 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 as agreed during the WGIPS in January 2017. 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 3. All trawl stations within a given stratum with catches of the target species (either blue whiting or herring) were assigned to all transects within the stratum, and the length distributions were weighted equally within the stratum. The following target strength (TS)-to-fish length (L) relationships were used:

Blue whiting: $TS = 20 \log(L) - 65.2$ dB (ICES 2012)

Herring: $TS = 20.0 \log(L) - 71.9$ dB

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

In StoX a superindividual table is produced where abundance is linked to population parameters like age, length, weight, sex, maturity etc. (exact name: 1_FillMissingData_SuperIndividuals.txt). This table can be used to split the total abundance estimate by any combination of population parameters.

The hydrographical and plankton stations by survey are shown in Figure 1. 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. On the Danish, the Icelandic, the Faroese and the Norwegian vessels the samples for dry weight were size fractionated before drying. Data are presented as g 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 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.

Some preliminary results from ongoing work with sonar and the deep vision system are presented as appendices to this report (Appendix 2-4), but they were not discussed at the post-cruise meeting. In addition, corrected IESNS estimates for 2017 (blue whiting and herring in the Norwegian Sea; ICES 2018) are shown in Appendix 1.

Results and Discussion

Hydrography

The temperature for selected depths in the Norwegian Sea is shown in Figure 5. The temperature distributions in the ocean, averaged over selected depth intervals; 0-50 m, 50-200 m, and 200-500 m, are then shown in Figures 6-8. The temperatures in the surface layer (0-50 m) ranged from 0°C in the Iceland and Greenland Sea to 9°C in the southern part of the Norwegian Sea (Fig. 6). The Iceland-Faroe Front was encountered slightly south of 65°N east of Iceland extending eastwards towards about 0° west where it turned almost straight northwards. This front was well-defined at 200-500 m depth while shallower it was more diffuse. Further to west at about 8°W, the Jan Mayen Front runs northwards towards Jan Mayen, this front was distinct throughout the observed water column. The warmer North Atlantic water formed a broad tongue that stretched far northwards along the Norwegian coast with temperatures > 7 °C to 70° N in the surface layer.

Relative to a 23 years long-term mean, from 1995 to 2017, the temperatures at 0-50 m and 50-200 m over the western and central Norwegian Sea, roughly west of the 0 meridian, were higher in 2018 compared to the long-term mean (Figures 6 and 7). Relative warmest water was in the western Norwegian Sea where the temperatures in some regions were 1.5 °C higher than the mean. In the eastern area of the Norwegian Sea, along the continental shelf, the temperatures were instead lower than normal, particular in the south where temperatures in some areas were 0.5 °C lower than the mean. At 200-500 m depth no clear regional deviances from the long-term means could be observed (Figure 8). It should also be noted that the temperature in the southwestern region, i.e. south of the Iceland-Faroe Ridge, were lower that the long-term mean.

The temperature, salinity and potential density in the upper 800 m at the Svinøy section in May 2018 is shown in Figure 9. Atlantic water is lying over the colder and fresher intermediate layer and reach down to 500 m at the shelf edge and shallower westward. The warmest water 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. Relative to a long-term mean, from 1978 to 2007, the temperatures were higher in 2018 on the shelf and at the shelf edge where the main northward transport of Atlantic Water is located. Further west the temperatures in the upper layer were in general lower than long-term mean.

The Norwegian Atlantic Current (NWAC) and the East Icelandic Current are the two main features of the circulation in the Norwegian Sea where the herring stock is grazing. The NWAC with its offshoots forms the northern limb of the North Atlantic current system and carries relatively warm and salty water from the North Atlantic into the Nordic Seas. The EIC, on the other hand, carries Arctic waters. To a large extent this water derives from the East

Greenland Current, but to a varying extent, some of its waters may also have been formed in the Iceland and Greenland Seas. The EIC flows into the southwestern Norwegian Sea where its waters subduct under the Atlantic waters to form an intermediate Arctic layer. While such a layer has long been known in the area north of the Faroes and in the Faroe-Shetland Channel, it is only in the last three decades that a similar layer has been observed all over the Norwegian Sea.

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

Zooplankton

The zooplankton biomass (g dry weight m^{-2}) in the upper 200 m is shown in Figure 10. Sampling stations were evenly spread over the area, and most oceanographic regions were covered. The Svinøy transect is also shown in the figure. The high zooplankton biomasses were spread over several locations covering the entire sampling area, maybe except from the most north-eastern area which contained intermediate biomasses. High biomasses were found southwest of Lofoten, in the southern Norwegian Sea, south in the Lofoten Basin, and in western and north western areas towards the Jan Mayen and Mohn ridge.

Figure 11 shows the zooplankton index given for the sampling area (delimited to east of 14°W and west of 20°E), and for four sub-areas. The zooplankton biomass index for the Norwegian Sea and nearby areas in 2018 was 8.8 g dry weight m^{-2}, which is a small decrease from last year (Figure 11). A similar decrease was observed in all sub-areas, except from East of Iceland.

The zooplankton biomass index for the Norwegian Sea in May has been estimated since 1995. For the period 1995-2002 the plankton index was relatively high (mean 11.2 g) even if varying between years. From 2003-2006, the index decreased continuously and has been at lower levels since then (mean 7.7 g for the period 2003-2018). However, an increase can be noted in the last part of the low-biomass period. This general pattern applies more or less to all the different sub-areas within the Norwegian Sea. The zooplankton biomass east of Iceland was, however, in general higher compared with the other sub-areas until 2015.

The reason for this fluctuation in the zooplankton biomass is not obvious to us. The unusually high biomass of pelagic fish feeding on zooplankton has been suggested to be one of the main causes for the reduction in zooplankton biomass. However, carnivorous zooplankton and not

pelagic fish are the main predators of zooplankton in the Norwegian Sea (Skjoldal *et al.,* 2004), and we do not have good data on the development of the carnivorous zooplankton stocks. Timing effects, as match/mismatch with the phytoplankton bloom, can also affect the zooplankton abundance. Also the time of entry of fish into the area, i.e. the residence of forage fish in the area, in relation to the sampling period might complicate inferences from such data. More ecological and environmental research to reveal inter-annual variations and long-term trends in zooplankton abundance are recommended. Quantitative research on carnivorous zooplankton stocks (such as krill and amphipods) across the whole survey area is an important step in that direction and needs a further effort by all participating countries.

Norwegian spring-spawning herring

Survey coverage in the Norwegian Sea was considered adequate in 2018 and in line with previous years. The zero-line was believed to be reached for adult NSS herring throughout the area. It is therefore recommended that the results can be used for assessment purpose. The herring was primarily distributed in the southwestern Norwegian Sea (Figure 12). In the Barents Sea the main aggregations were observed in the eastern part. Registrations of NSS herring were low in the eastern part of the Norwegian Sea. In the southernmost part of the survey area herring was also observed (Figure 12a), but based on the otolith structure a significant part of this herring was of autumn spawning type.

As in previous years the size and age of herring were found to increase towards west and south in the Norwegian Sea (Figure 13). Correspondingly, it was mainly older herring that appeared in the southwestern areas. The 2013 year class (age 5) was observed across most of the survey area, but in low quantity in the western most areas.

Five year old herring (year class 2013) dominated both in terms of number (29 %) and biomass (25 %) on basis of the StoX estimations for Norwegian Sea (Table 2). Its number at age 5 (Table 2) is two times higher than for the 2009 year class at same age, but only half the size of the large 2004 year class (Figure 14), which puts the size of the 2013 year class into a perspective. Each of three older age groups (age 12-14), which have dominated in the stock in previous years, contributed to ~8 % in number and 10 % in biomass, respectively. Thus, they are still contributing to 30 % of the total biomass. Uncertainty estimates for number at age based on bootstrapping within StoX are shown in Figure 15.

The total estimate of herring in the Norwegian Sea from the 2018 survey was 19.7 billions in number and the biomass 5.04 million tonnes. This estimate is 0.84 million tonnes (20 %) increase from the 2017 survey estimate (Annex 1; corrected estimates). The biomass estimate decreased 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 increase in total biomass estimate of herring between 2017 and 2018 is largely driven by the 2013 year class, which constituted to 17 % of the biomass in 2017 while 25 % in 2018. The 2014 year class contributed also to the increase in the biomass estimations between these two years.

The abundance estimates of herring by age and length in the Barents Sea (Stratum 6) are shown in Table 3. The herring at age 2 was in the highest number (17 billions, mean length 17.2 cm and mean weight 33.4 g), but age 1 was also in significant amount (6.8 billions, mean length 10.5 cm and mean weight 7.0 g). The survey estimates of age 1 and 2 from the period 1991-2018 are shown in Figure 17. It indicates that the number of age 2 in 2018 is the fifth highest in the time series. This year class from 2016 was also relatively numerous at age 1 in 2017. However, the uncertainty around these estimates are large, and larger than indicated on Figure 17 as it only accounts for the sampling variability but not for the uncertainty related to spatial restriction and number of biological samples behind the estimates. Moreover, the zero-line of juvenile herring distributions towards north was apparently not reached in Barents Sea as indicated on Figure 12 where herring was registered on the inter-transects.

In the recent four years there have been concerns regarding age reading of herring, because the age distributions from the different participants have showed differences. A scale and otolith exchange has been ongoing for some period, where scales and otoliths for the same fish have been sampled. On basis of that work, a workshop was planned in the spring 2018 to discuss the results. This workshop was postponed until the autumn 2018. 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 showed a similar difference as observed in recent years (Figure 23). For example, the 2004 year class was in higher proportion by the Norwegian readers than the Faroese and the Icelandic readers in Stratum 3 and 4, which had higher proportion the 2005 and 2006 year classes. These three year classes are combined as plus group in the analytical assessment (age 12+).

In the 2018 IESNS there were no big discrepancies in the acoustic scrutinizing results between any neighboring vessels. An observed difference in acoustic registrations between RV Dana and neighboring vessels west of Jan Mayen (~70°N and 4°E) was related to a bad weather experienced by RV Dana there. In the western part of the survey area, where the highest concentrations of herring were observed, there was a good agreement between any neighboring vessels.

Blue whiting

The spatial distribution of blue whiting in 2018 was similar to the years before, with the highest abundance estimates in the southern and eastern part of the Norwegian Sea, along the Norwegian continental slope. The main concentrations were observed in connections with the continental slopes of Norway and along the Scotland – Iceland ridge (Figure 18). Blue whiting was not distributed as far west into the Norwegian Sea as in the last ~five years and there was less overlap in distribution of herring and blue whiting this 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 2018 was 0.50 million tonnes, which is a 46 % decrease from the biomass estimate in 2017 (0.93). The abundance index for 2018 was 4.4 billion, which is about 54 % lower than in 2017. Ages 2-4 are dominating the biomass (79 % of the biomass and 78% by number). Uncertainty estimates for numbers at age based on bootstrapping with StoX are shown in Figure 20.

In this year's IESNS survey, two year old blue whiting was more numerous as compared to IESNS 2017 and IBWSS 2018 (International Blue Whiting Spawning Survey). The survey group compared age and length distributions by vessel and strata and found some differences in length distributions (Figure 24) by vessel within strata but significant differences in age distribution by vessel within strata (Figure 25) particularly in strata 1 and 2. The survey group could not conclude if the changes in length distribution were enough to explain the difference in age distributions. This is a concern particularly for the high number of 2-year olds (the 2016 year-class) observed in May as this year-class has not been observed in any quantities in earlier cruises. It is recommended that this issue is further investigated and resolved before IESNS 2019 and also in relation to the use of these data at WGWIDE as young-fish indices.

Vertical profile across the Norwegian Sea

Two transects were taken by G.O. Sars across the whole Norwegian Sea (Figure 21). There was apparently no clear pattern in the relation between temperature and herring distribution, neither vertically nor horizontally. The herring was mainly in the western part in the temperature range of 0-6°C. Distribution of blue whiting was limited to Atlantic waters warmer than around 1.5°C (Figure 21) as also represented by its spatial distribution where it was observed across the whole Norwegian Sea except for the cold and fresh East Iceland Current (Figures 4, 5 and 18).

Mackerel

During the last decade an increasing amount of mackerel has been observed in the catches during the May survey (see last year's survey report). This pattern continued in 2018 where mackerel was caught in the central and eastern part of the Norwegian Sea (Figure 22). No quantitative information can be drawn from these data as this survey is not designed to monitor mackerel. Mackerel at age 2 (mean length 26.4 cm) was most numerous in the combined samples (not weighed by catch size), and amounted to 26 %, followed by age 1 (17 %) and age 5 (13 %).

General recommendations and comments

RECOMMENDATION	ADRESSED TO
1. Continue the methodological research in distinguishing between Herring and blue whiting in the interpretation of echograms.	WGIPS
2. It is recommended that a workshop based on the ongoing otolith and scale exchange will take place before next year's IESNS survey.	WGBIOP, WGWIDE
3. It is recommended that the WGIPS meeting in 2019 includes a workshop on how to deal with stock components of herring in the IESNS-survey.	WGIPS
4. It is recommended that the next blue whiting otolith exchange and workshop is informed about the different age distributions observed in IESNS 2018.	WGBIOP, WGWIDE

Next year's post-cruise meeting

We will aim for next meeting in Reykjavik 18-20 June 2019. The final decision will be made at the next WGIPS meeting.

Concluding remarks

- The sea temperature in 2018 at 0-200 m depth was above long-term mean (1995-2017) in the western and central Norwegian Sea but below the mean in the eastern and southern areas of the Norwegian Sea.
- The 2018 index of meso-zooplankton biomass in the Norwegian Sea and adjoining waters decreased a bit from last year and is still comparable to the mean of the earlier high-biomass period, but is still relatively low in the westernmost areas.
- The total biomass estimate of NSSH in herring in the Norwegian Sea was 5.04 million tonnes, which is a 20 % increase from the 2017 survey estimate. The survey followed the pre-planned protocol and the survey group recommends using the abundance estimates in the analytical assessment.
- The 2013 year class dominated in the survey indices both in numbers (29 %) and biomass (25 %). Despite relatively high number at age 5 of this year class, it is half the size of the large 2004 year class at the same age.
- The estimated number at age 2 (2016 year class) of NSSH in the Barents Sea was higher in 2018 than in recent years and the fifth highest in the time series since 1991. It might indicate improved recruitment, but the uncertainty around the estimate is high.
- The biomass of blue whiting measured in the 2017 survey decreased by 46 % from last year's survey and by 54 % in number.
- Ages 2-4 (2014-2016 year classes) of blue whiting are dominating the acoustic estimate (79 % of the biomass and 78 % by numbers).

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Tables

Table 1. Survey effort by vessel for the International ecosystem survey in the Nordic Seas in May - June 2018.

Vessel	Effective survey period	Effective acoustic cruise track (nm)	Trawl stations	Ctd stations	Aged fish (HER)	Length fish (HER)	Plankton stations
Dana	05/05-25/05	1874	29	33	552	2276	32
Magnus heinason	3/5-15/5	1078	13	21	371	636	21
Árni Fridriksson	5/5-19/5	1936	22	34	1440	5502	30
G.O.Sars	03/5-1/6	3105	64	69	711	2269	76
Vilnyus	23/5-16/6	2872	28	38	314	1770	38
Total		**10865**	**156**	**195**	**3388**	**12453**	**197**

Table 2. IESNS 2018 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring.

LenGrp	age 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Number (1E3)	Biomass (1E3kg)	Mean W (g)
18-19	4901	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4901	235.3	48.00
19-20	85695	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	85695	4833.2	56.40
20-21	158130	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	158130	10565.5	66.82
21-22	146523	3484	-	-	-	-	-	-	-	-	-	-	-	-	-	-	150007	11500.0	76.66
22-23	85952	83460	-	-	-	-	-	-	-	-	-	-	-	-	-	-	169413	14587.2	86.10
23-24	13243	114929	4014	-	-	-	-	-	-	-	-	-	-	-	-	-	132187	14423.5	109.12
24-25	3300	264754	-	-	-	-	-	-	-	-	-	-	-	-	-	-	268054	31519.6	117.59
25-26	1253	340495	15075	15075	-	-	-	-	-	-	-	-	-	-	-	-	371899	48523.7	130.48
26-27	-	134630	151649	5856	26710	-	-	-	-	-	-	-	-	-	-	-	318845	45809.4	143.67
27-28	-	57909	363460	92838	3951	-	-	-	-	-	-	-	-	-	-	-	518158	82561.3	159.34
28-29	-	45391	639581	219603	19358	-	1075	-	-	-	-	-	-	-	-	-	925010	160033.7	173.01
29-30	-	7173	576303	617954	27638	27418	22286	11730	4912	-	-	-	-	-	-	-	1295414	249161.7	192.34
30-31	-	-	163368	1418819	75990	36510	13054	31414	4896	-	-	-	-	-	-	-	1744050	370990.0	212.72
31-32	-	-	110460	1874863	193919	55780	34270	17217	21021	-	-	19152	-	-	-	-	2326682	540355.0	232.24
32-33	-	-	23223	1079384	248665	304970	22869	39538	7994	4958	7994	-	4958	-	-	-	1744554	435552.7	249.66
33-34	1236	-	11589	290327	195445	370623	35949	114753	-	-	14213	-	-	-	-	-	1034135	277748.2	268.58
34-35	-	-	4491	65698	132898	406123	122429	197401	22242	40719	105839	43229	49154	-	7983	-	1198205	351759.3	293.57
35-36	-	-	-	5969	48754	182479	231490	441721	93455	240023	434621	334872	221419	18106	14485	-	2267395	707529.2	312.04
36-37	-	-	-	-	-	48699	76399	312391	65597	262479	585867	594494	601101	83594	19622	-	2650243	868235.6	327.61
37-38	-	-	-	-	-	985	-	130688	117576	119672	366092	437464	429959	124381	59389	16747	1802952	622166.4	345.08
38-39	-	-	-	-	-	-	1128	31348	-	20976	39777	36864	206505	25287	54441	11123	427448	157798.9	369.16
39-40	-	-	-	-	-	-	-	-	-	-	5487	11761	15571	6415	37895	8553	85681	33928.4	395.98
40-41	-	-	-	-	-	-	-	-	-	-	4799	-	-	-	-	-	4799	1842.7	384.00
TSN(1000)	500232	1052226	2063214	5686387	973329	1433588	560950	1328201	337692	688827	1564688	1477836	1528668	257783	193815	36423	19683857	-	-
TSB(1000 kg)	36405.6	133291.7	374152.3	1275393.0	240593.2	393848.5	163141.4	405473.4	108056.1	223975.1	506171.3	490108.9	518277.3	89915.9	69296.3	13560.6	-	5041660.7	-
Mean length (cm)	20.86	24.90	28.54	30.83	32.09	33.38	34.25	35.01	35.49	35.82	35.96	36.06	36.44	36.70	37.40	37.78	-	-	-
Mean weight (g)	72.78	126.68	181.34	224.29	247.19	274.73	290.83	305.28	319.98	325.15	323.50	331.64	339.04	348.80	357.54	372.31	-	-	256.13

Table 3. IESNS 2018 in the Barents Sea. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring.

LenGrp	age 1	2	3	4	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
8-9	-	-	-	-	520041	520041	-	-
9-10	1387351	-	-	-	-	1387351	6705.5	4.83
10-11	3454174	-	-	-	-	3454174	23047.7	6.67
11-12	1729698	-	-	-	-	1729698	14235.4	8.23
12-13	87114	580761	-	-	-	667875	7482.1	11.20
13-14	55348	525809	-	-	-	581157	8302.2	14.29
14-15	152238	418656	-	-	-	570894	9971.6	17.47
15-16	-	2482188	-	-	-	2482188	55037.4	22.17
16-17	-	4567488	-	-	-	4567488	118814.1	26.01
17-18	-	3502545	-	-	-	3502545	108991.0	31.12
18-19	-	752673	-	-	-	752673	27545.4	36.60
19-20	-	1795332	96523	-	-	1891855	90606.3	47.89
20-21	-	1583094	98943	-	-	1682038	89929.6	53.46
21-22	-	1003720	54748	-	-	1058468	66592.3	62.91
22-23	-	118952	288884	-	-	407836	32057.6	78.60
23-24	-	72411	90513	-	-	162924	14029.6	86.11
24-25	-	-	78268	-	-	78268	8609.4	110.00
25-26	-	-	235335	-	-	235335	25886.9	110.00
27-28	-	-	-	9227	-	9227	1324.0	143.50
TSN(1000)	6865924	17403628	943215	9227	520041	25742035	-	-
TSB(1000 kg)	48040.8	581618.4	78185.0	1324.0	-	-	709168.2	-
Mean length (cm)	10.47	17.15	22.56	27.50	8.50	-	-	-
Mean weight (g)	7.00	33.42	82.89	143.50	-	-	-	28.12

Table 4. IESNS 2018 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of blue whiting.

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	13	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
18-19	13911	-	-	-	-	-	-	-	-	-	-	-	-	-	13911	514.7	37.00
19-20	26636	-	-	-	-	-	-	-	-	-	-	-	-	-	26636	1017.3	38.19
20-21	85769	-	-	-	-	-	-	-	-	-	-	-	-	-	85769	3861.8	45.03
21-22	86969	21591	317	-	-	-	-	-	-	-	-	-	-	-	108877	5699.8	52.35
22-23	163191	12543	1775	-	-	-	-	-	-	-	-	-	-	-	177509	10463.4	58.95
23-24	35165	74535	11626	4550	-	-	-	-	-	-	-	-	-	-	125877	8951.7	71.11
24-25	23535	244175	56159	28210	2135	-	-	-	-	-	-	-	-	-	354214	29602.1	83.57
25-26	4253	402575	145174	92393	10188	-	-	-	-	-	-	-	-	-	654582	62861.3	96.03
26-27	-	377994	190087	290411	31258	5288	-	-	-	-	-	-	-	-	895039	96981.5	108.35
27-28	1523	246510	144361	374003	97499	9521	536	473	-	-	-	-	-	-	874427	105639.2	120.81
28-29	-	76062	113124	222973	98111	17506	6333	-	-	-	-	-	-	-	534109	72406.0	135.56
29-30	-	28914	66980	119522	70636	16462	786	-	-	-	-	-	-	-	303301	45879.0	151.27
30-31	-	1601	37824	40757	35577	19888	2152	-	-	-	-	4802	-	-	142601	23623.1	165.66
31-32	-	3092	19574	8698	11874	10844	8952	-	6162	-	-	-	-	-	69196	12883.5	186.19
32-33	-	1593	15935	517	4413	4449	2979	-	-	-	-	-	-	-	29887	5881.4	196.79
33-34	-	-	-	-	8513	1860	18361	1240	1240	-	-	-	-	-	31215	6365.6	203.93
34-35	-	-	-	1614	-	2599	1818	3898	-	-	-	-	-	-	9929	2453.5	247.11
35-36	-	-	-	1370	-	-	4316	1439	1023	1439	-	-	-	-	9585	2615.7	272.89
36-37	-	-	-	-	-	574	287	-	559	-	1119	-	-	-	2539	668.5	263.25
37-38	-	-	-	-	-	-	-	-	-	-	-	-	-	849	849	274.9	323.70
38-39	-	-	-	-	-	-	-	-	763	-	-	-	763	-	1526	498.1	326.50
39-40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41-42	-	-	-	4605	-	-	-	-	-	-	-	-	-	-	4605	1510.4	328.00
TSN(1000)	440951	1491186	802935	1189624	370205	88991	46520	7050	9747	1439	1119	4802	763	849	4456182	-	-
TSB(1000 kg)	24407.6	152104.0	96146.8	146812.4	51564.3	14525.5	9174.7	1659.5	2167.6	388.4	298.2	858.0	270.8	274.9	-	500652.6	-
Mean length (cm)	21.45	25.53	26.92	27.29	28.28	29.50	31.98	33.70	32.68	35.00	36.00	30.17	38.00	37.38	-	-	-
Mean weight (g)	55.35	102.00	119.74	123.41	139.29	163.22	197.22	235.40	222.38	270.00	266.50	178.67	355.00	323.70	-	-	112.35

Figures

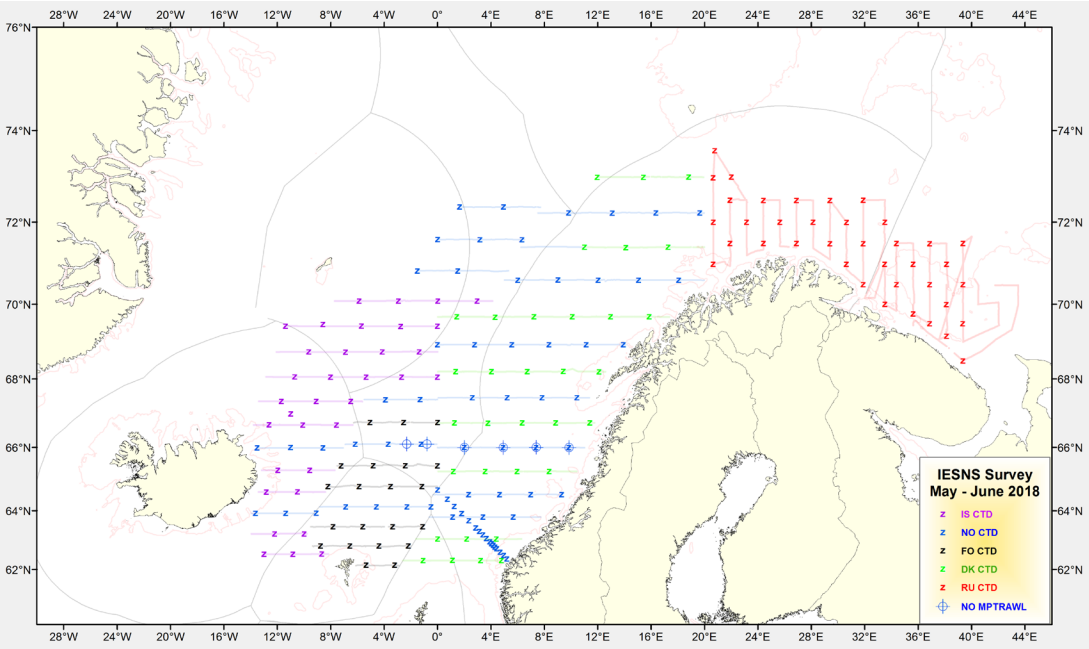


Figure 1. Cruise tracks and CTD stations by country for the IESNS survey in May-June 2018. Manta trawl hauls for sampling of micro plastics in the surface are also shown.

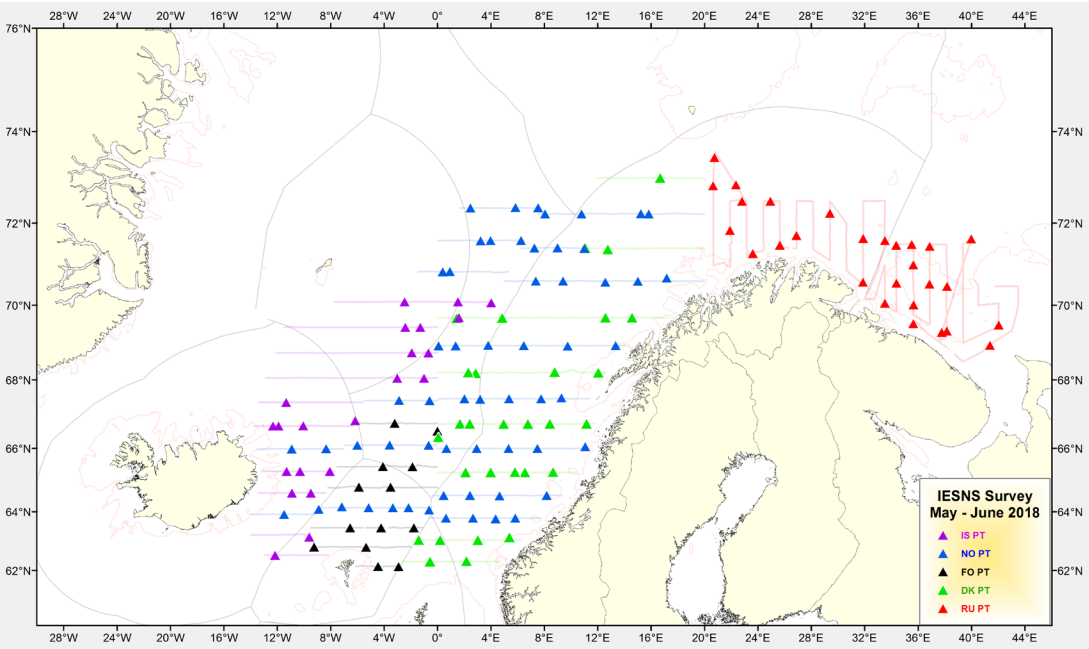


Figure 2. Cruise tracks during the IESNS survey in May-June 2018 and location of trawl stations.

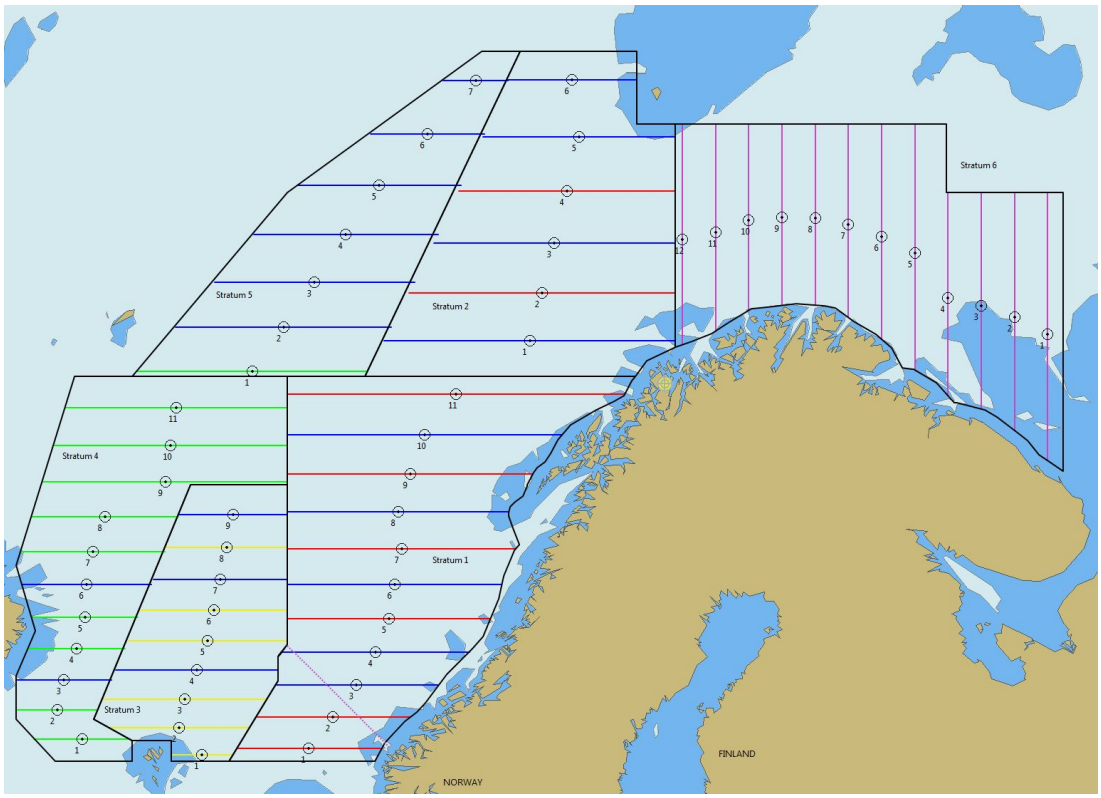


Figure 3. The pre-planned strata and transects for the IESNS survey in 2018 (red: EU, dark blue: Norway, yellow: Faroes Islands, violet: Russia, green: Iceland).

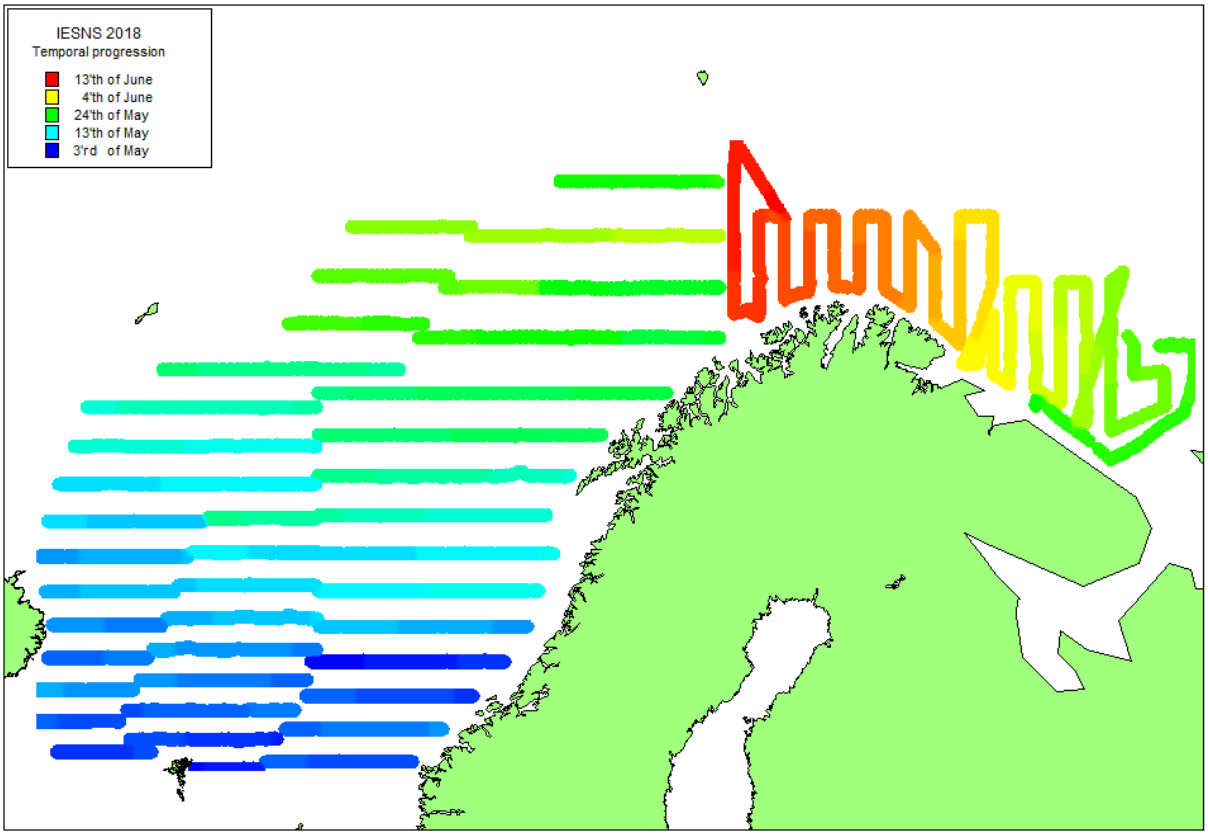


Figure 4. Temporal progression IESNS in May-June 2018.

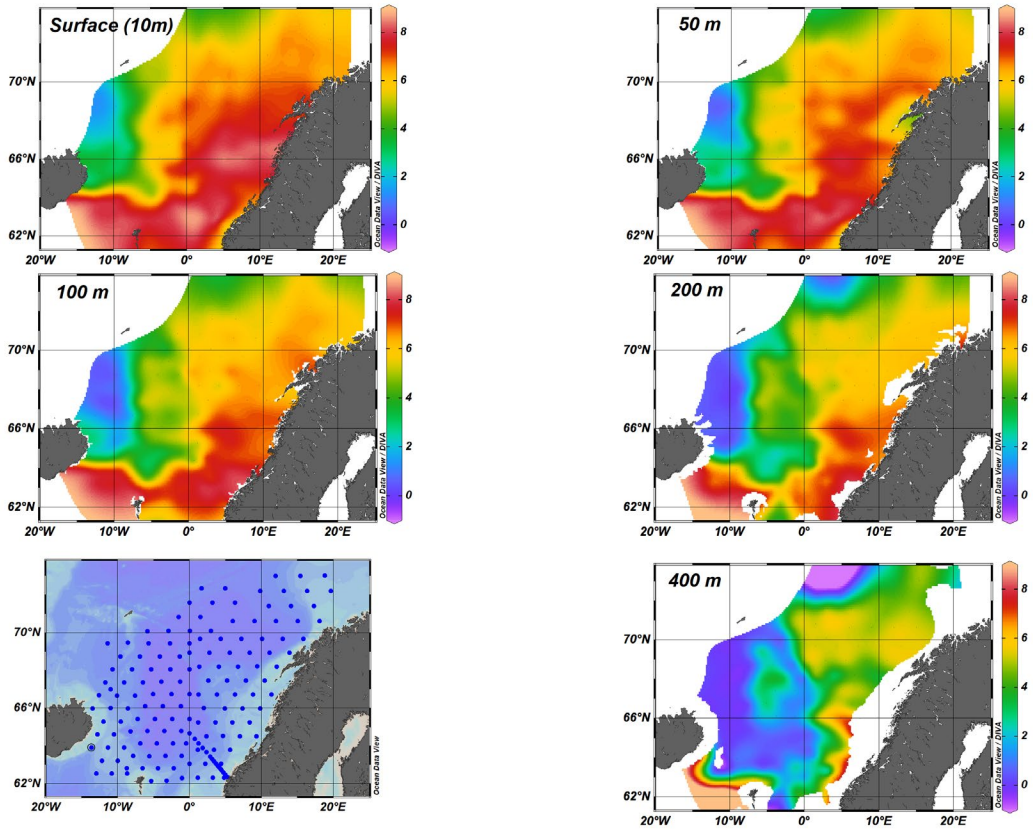


Figure 5. The horizontal distribution of temperatures (°C) at 10 m (surface), 50m, 100m, 200m and 400m depth in IESNS in May-June 2018.

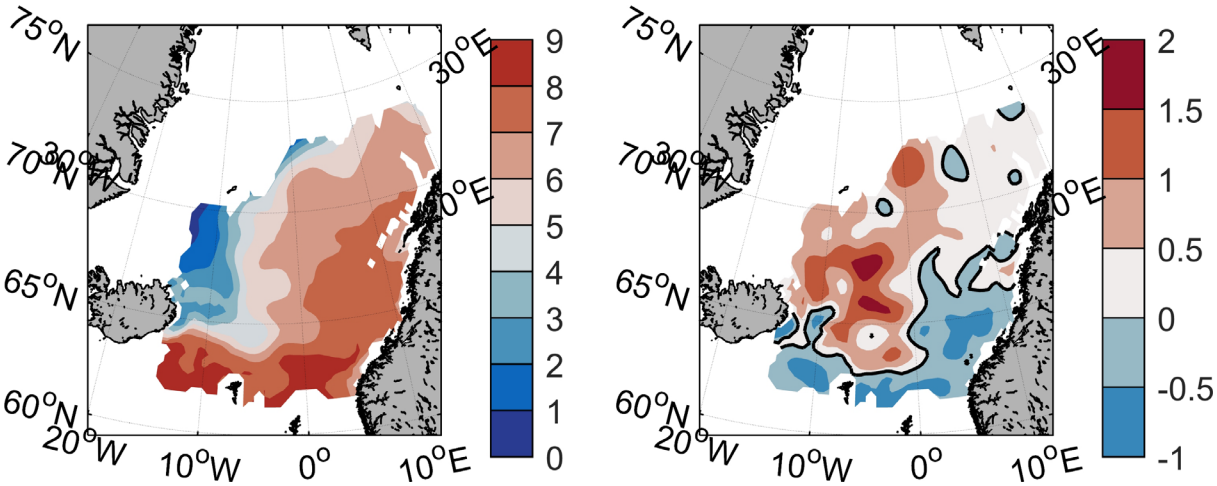


Figure 6. Temperature (left) and temperature anomaly (right) averaged over 0-50 m depth in May 2018. Anomaly is relative to the 1995-2017 mean.

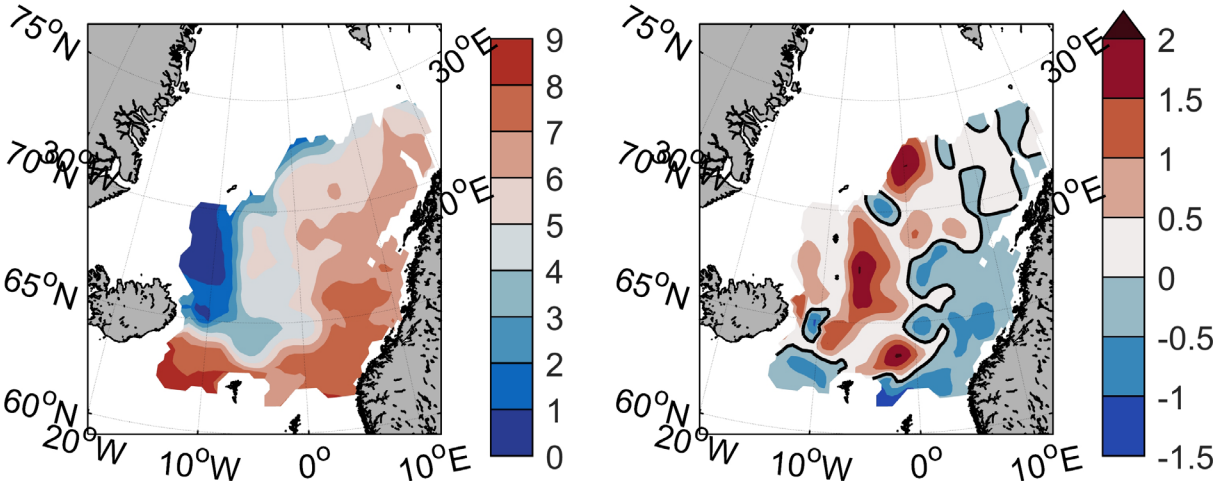


Figure 7. Temperature (left) and temperature anomaly (right) averaged over 50-200 m depth in May 2018. Anomaly is relative to the 1995-2017 mean.

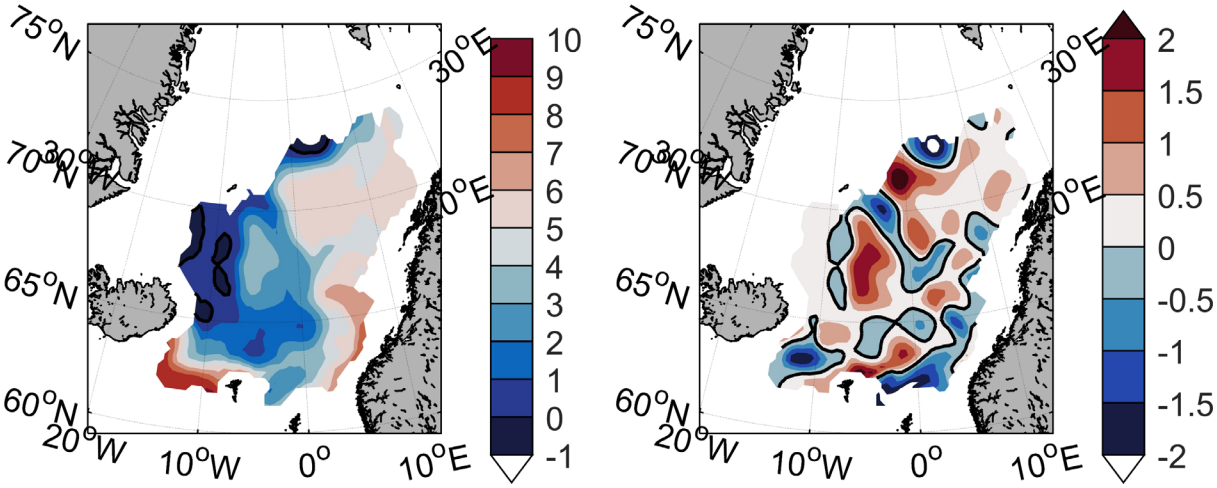


Figure 8. Temperature (left) and temperature anomaly (right) averaged over 200-500 m depth in May 2018. Anomaly is relative to the 1995-2017 mean.

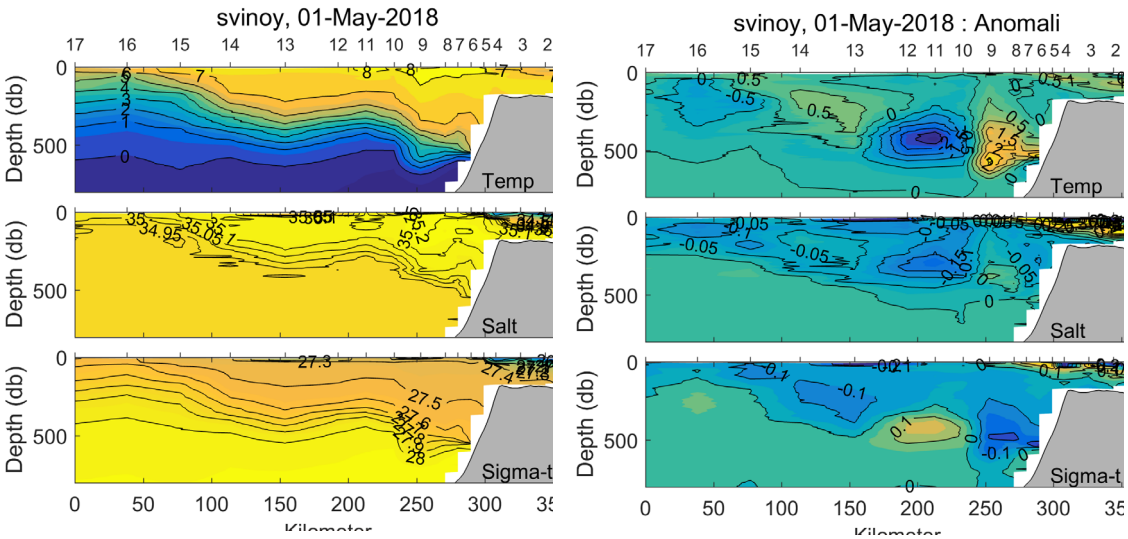


Figure 9. Temperature, salinity and potential density (sigma-t) (left hand panel) and anomalies (right hand panel) at the Svinøy section, May 2018. Anomalies are relative to a 30 years long-term mean (1978-2007).

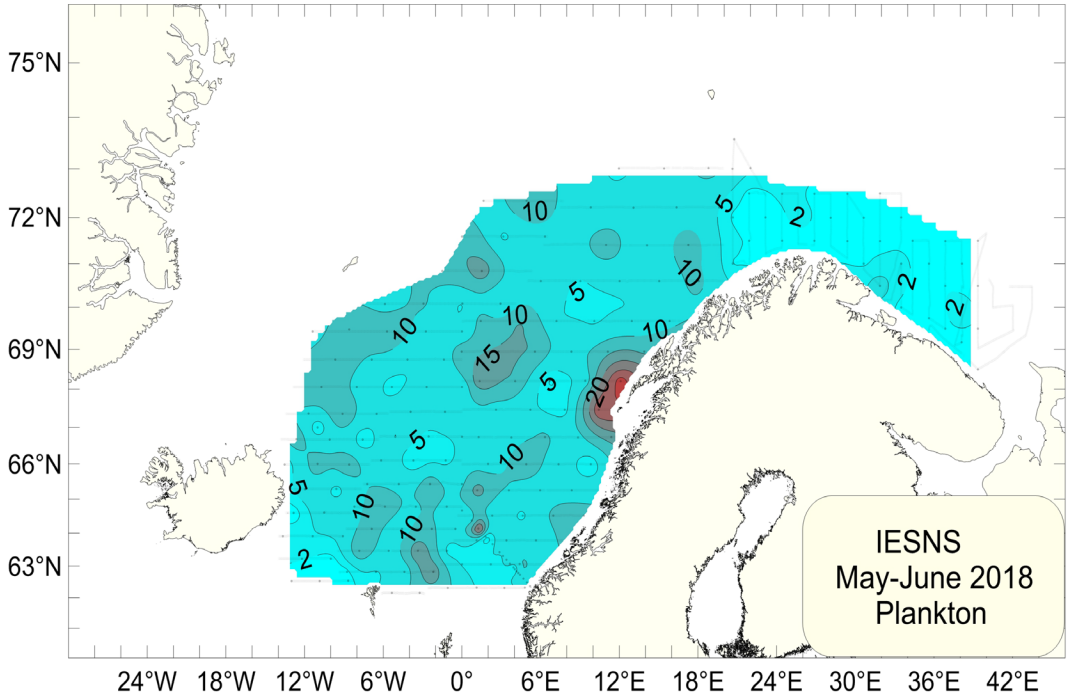


Figure 10. Representation of zooplankton biomass (g dry weight m^{-2}; at 0-200 m depth) in May-June 2018.

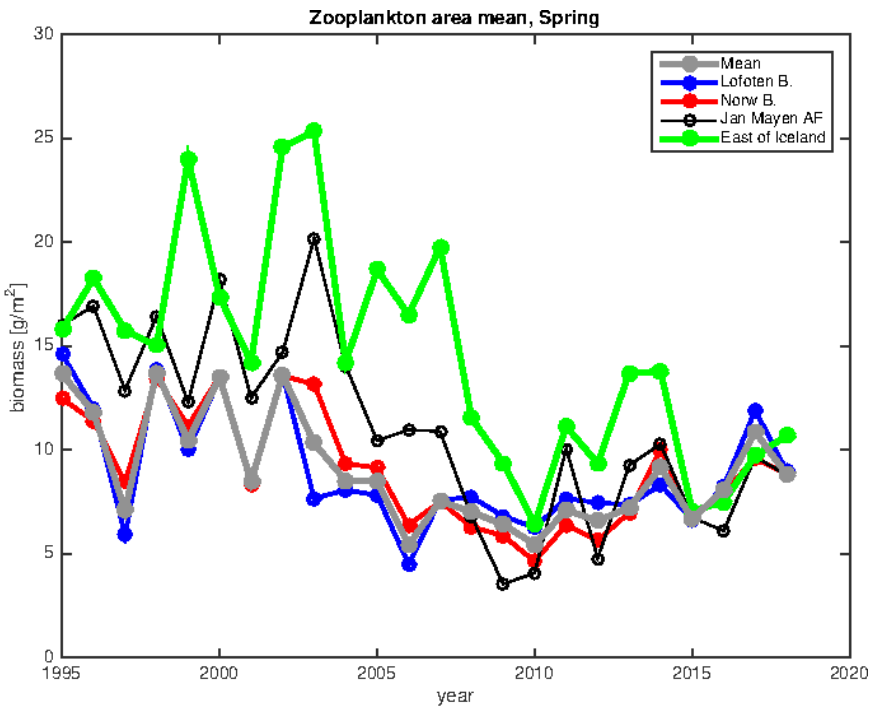
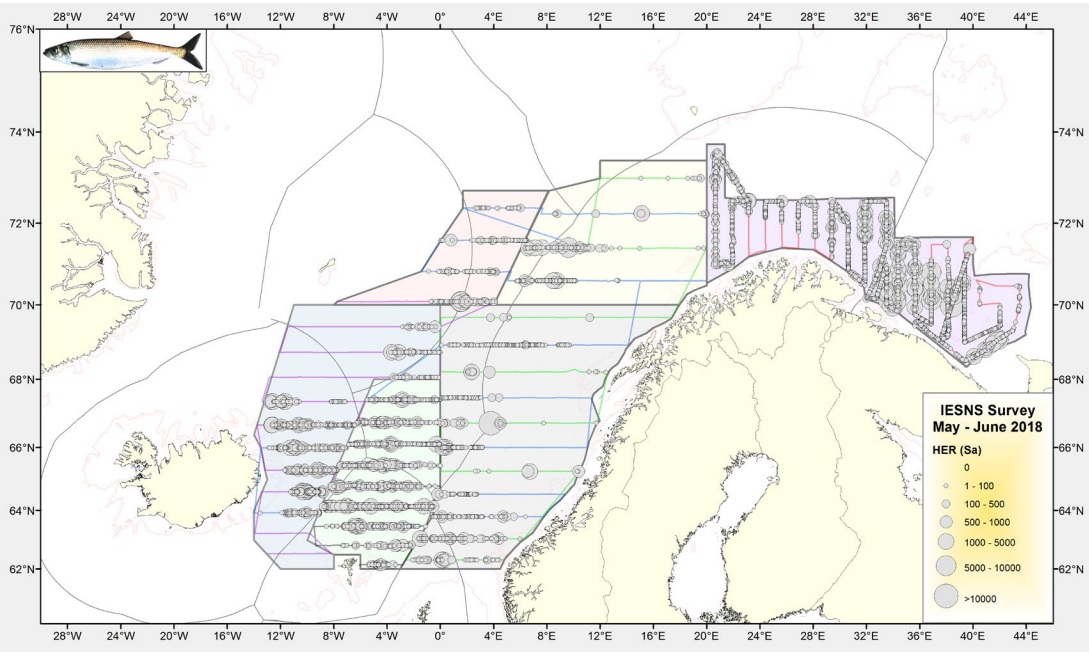


Figure 11. Indices of zooplankton dry weight (g m^{-2}) sampled by WP2 in May in (a) the different areas in and near Norwegian Sea from 1997 to 2018 as derived from interpolation using objective analysis utilizing a Gaussian correlation function (see details on methods and areas in ICES 2016).

(a)



(b)

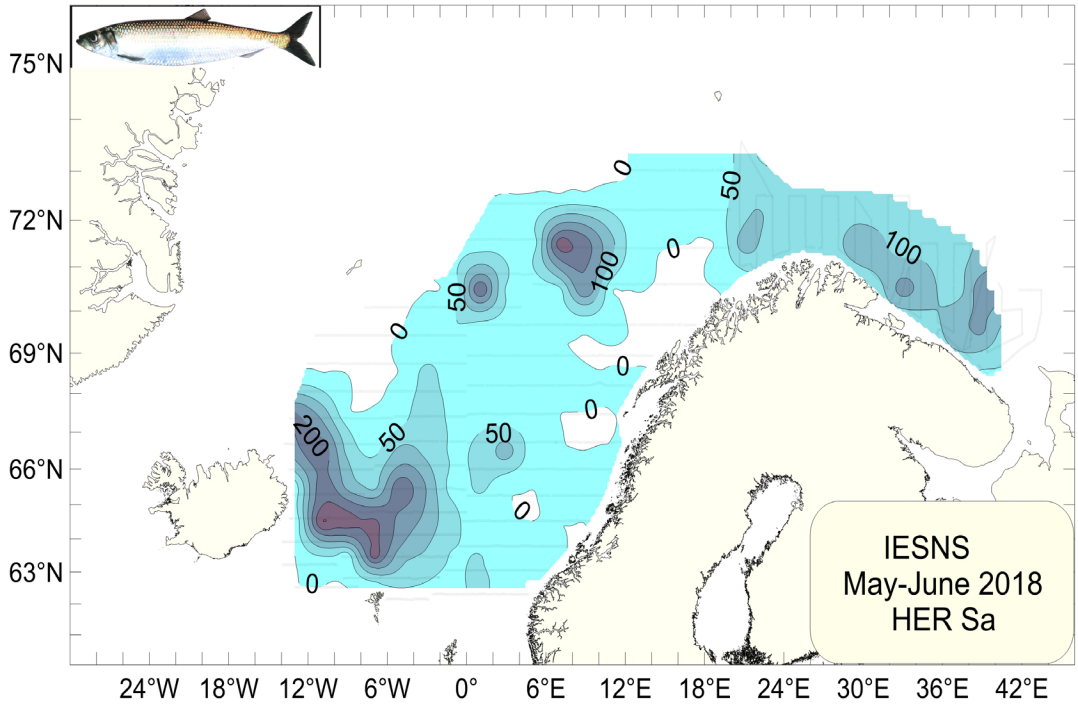


Figure 12. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in April-June 2018 in terms of NASC values (m²/nm²) (a) averaged for every 1 nautical mile and (b) represented by a contour plot. The stratification of the survey area is shown on the upper map.

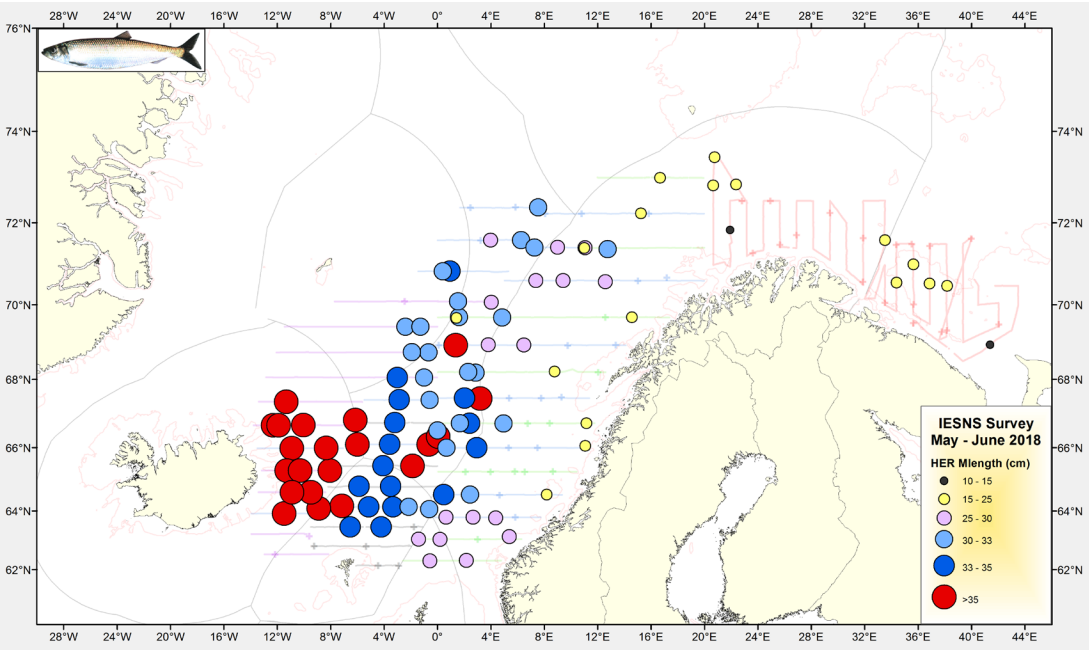


Figure 13. Mean length of Norwegian spring-spawning herring in all hauls in April-June 2018.

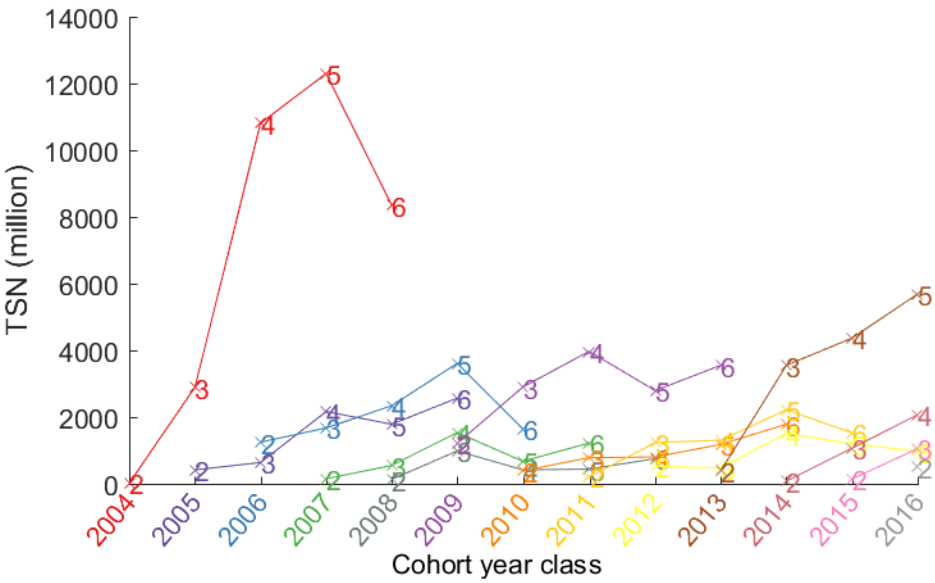


Figure 14. Tracking of the Total Stock Number (TSN, in millions) of Norwegian spring-spawning herring for each cohort since 2004 from age 2 to age 6. From 2008, stock is estimated using the StoX software. Prior to 2008, stock was estimated using BEAM.

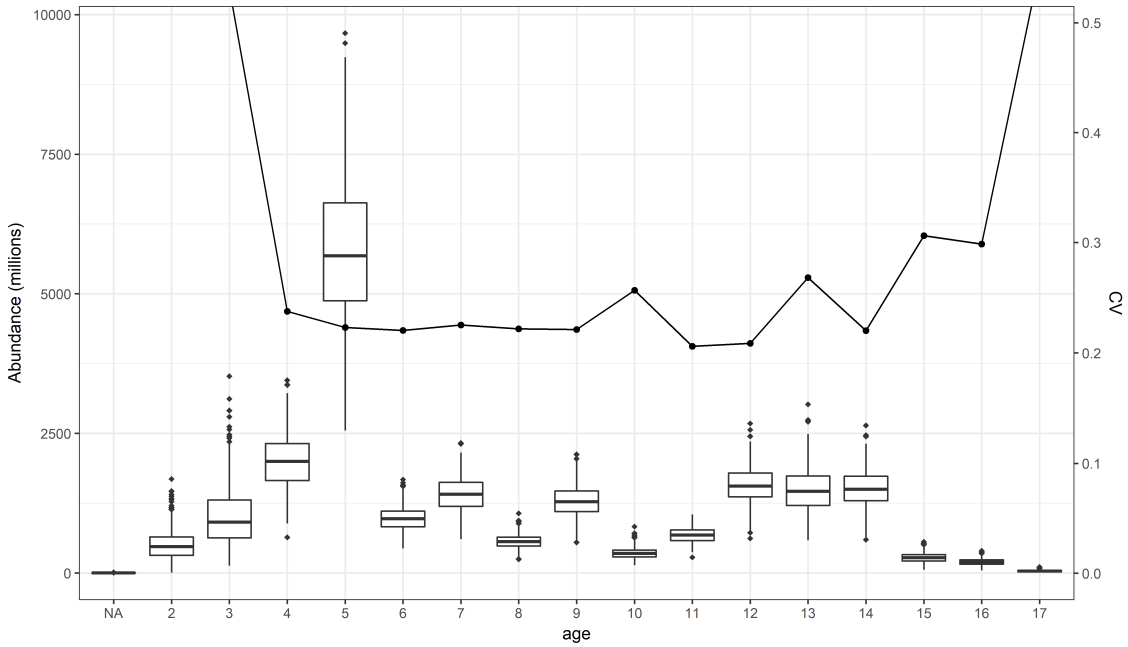


Figure 15. Norwegian spring-spawning herring in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

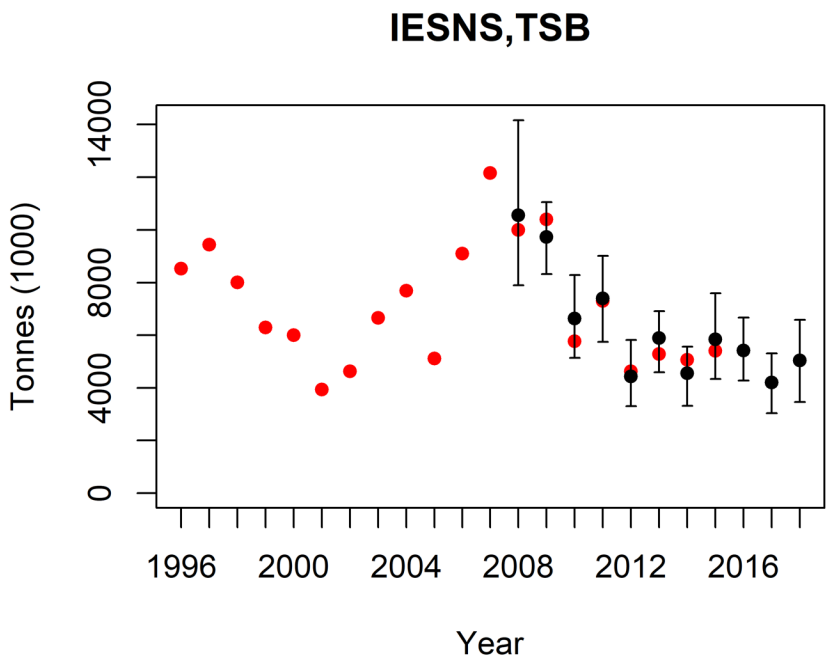


Figure 16. The annual biomass index of Norwegian-spring spawning herring in the IESNS survey (Barents Sea, east of 20°E, is excluded) from 1996 to 2018 as estimated using BEAM (red dots; calculated on basis of rectangles) and as estimated with the software StoX (black dots with 90% confidence interval; calculated on basis of standard stratified transect design).

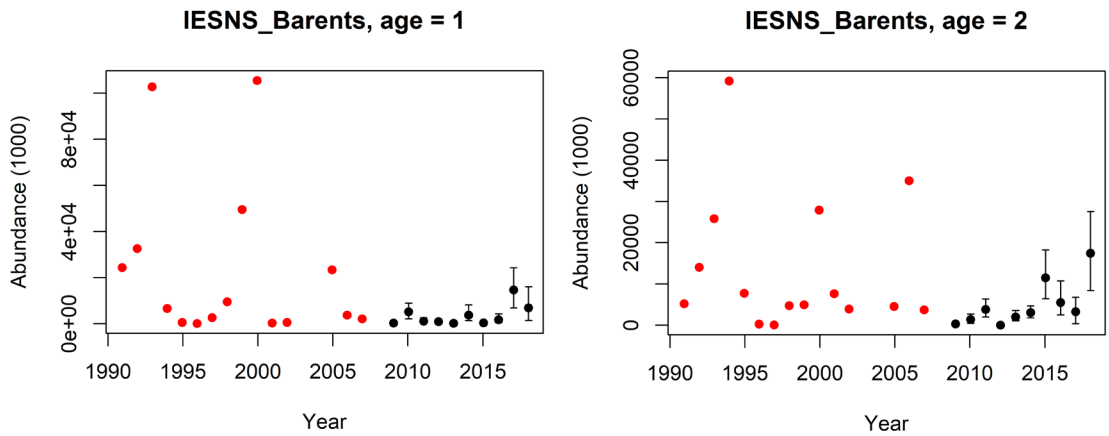
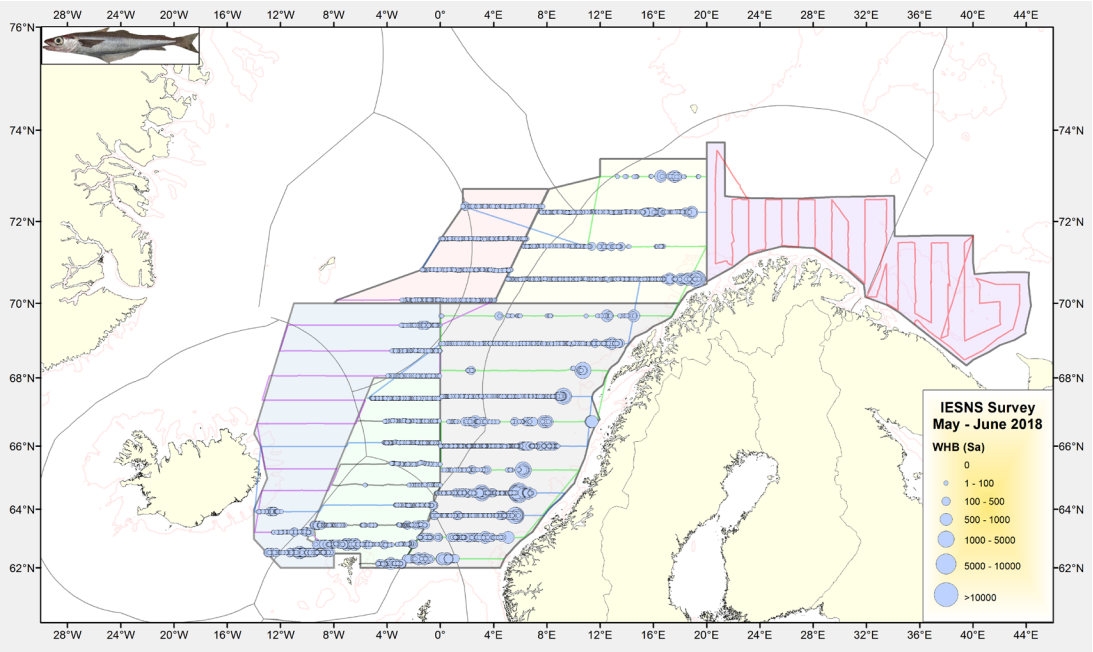


Figure 17. Numbers at age 1 (to left) and age 2 (right) herring in the Barents Sea in April-June as estimated using BEAM (red dots; calculated on basis of rectangles) and the software StoX (black dots with 90% confidence interval; calculated on basis of standard stratified transect design).

(a)



(b)

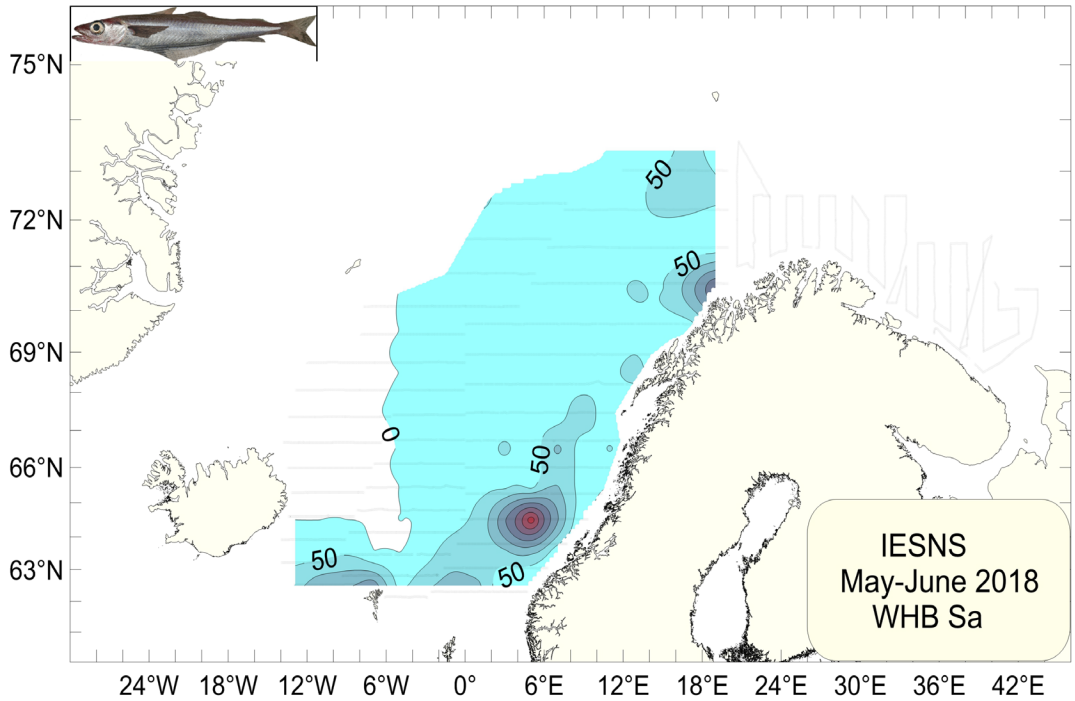


Figure 18. Distribution of blue whiting as measured during the IESNS survey in April-June 2018 in terms of NASC values (m²/nm²) (a) averaged for every 1 nautical mile and (b) represented by a contour plot. The stratification of the survey area is shown on the upper map.

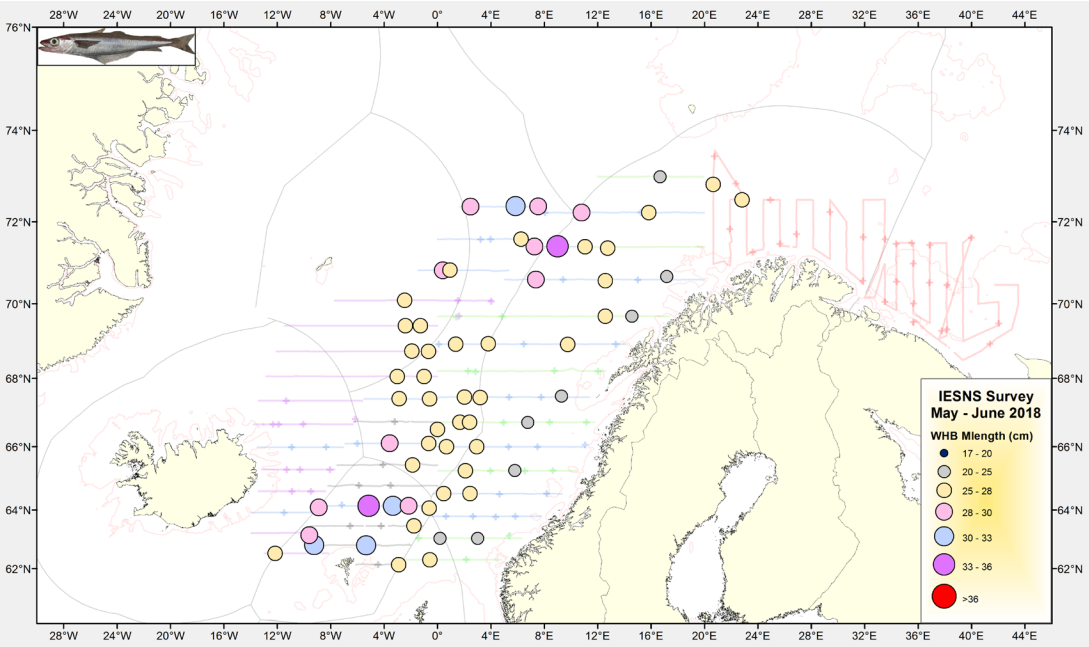


Figure 19. Mean length of blue whiting in all hauls in IESNS 2018.

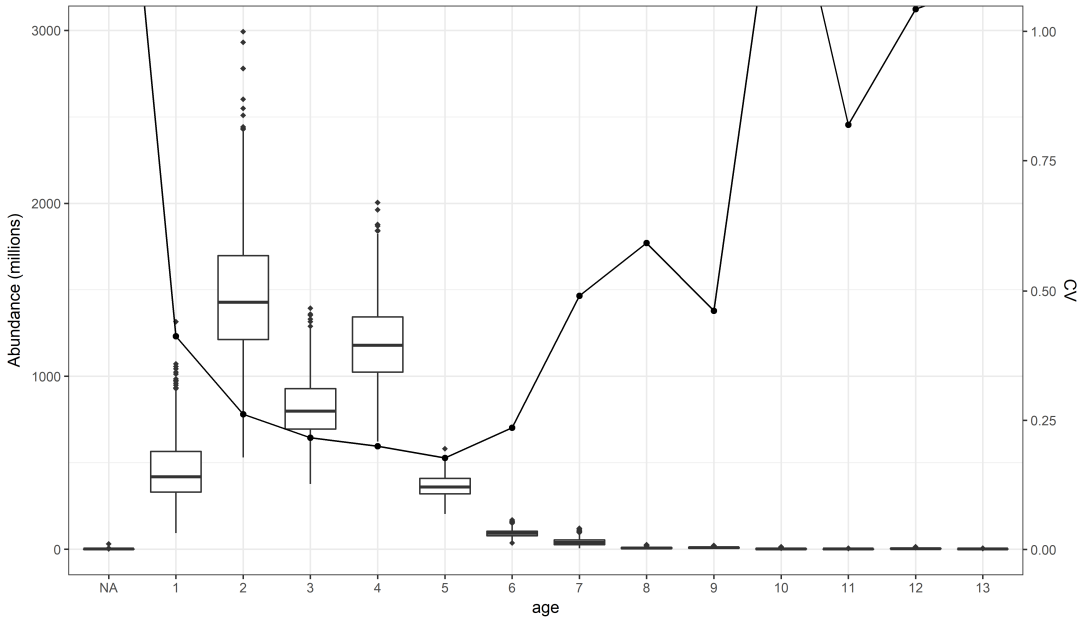


Figure 20. Blue whiting in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

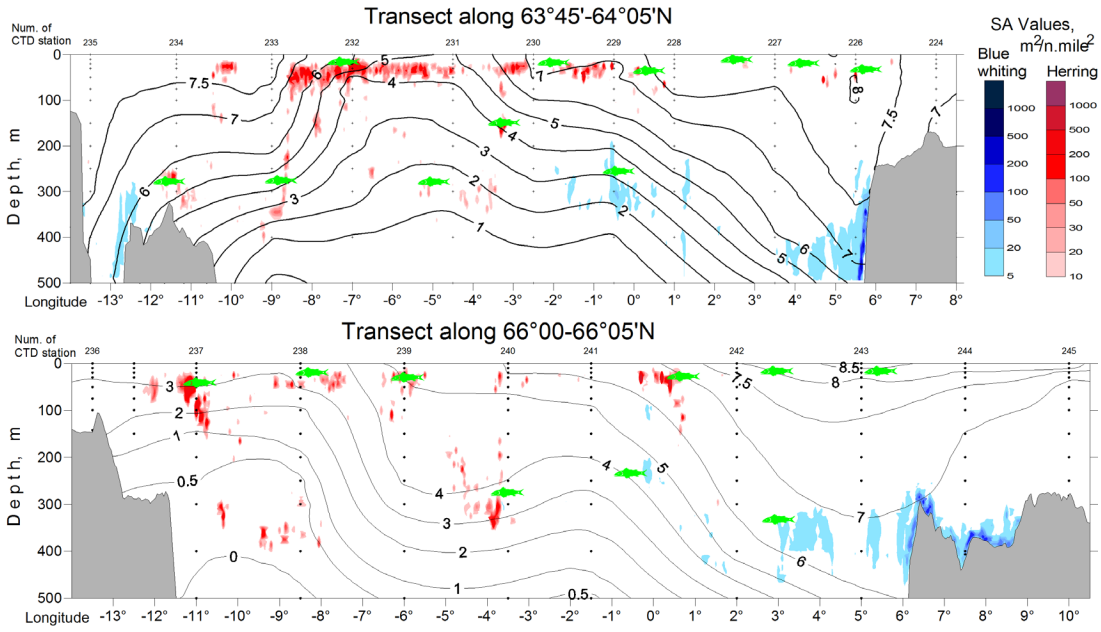


Figure 21. Acoustic values of NSS-herring (red) and blue whiting (blue), location of trawl stations (green fish) and temperature profile (black lines) along two transects across the whole Norwegian Sea in May 2018, covered by "G.O. Sars".

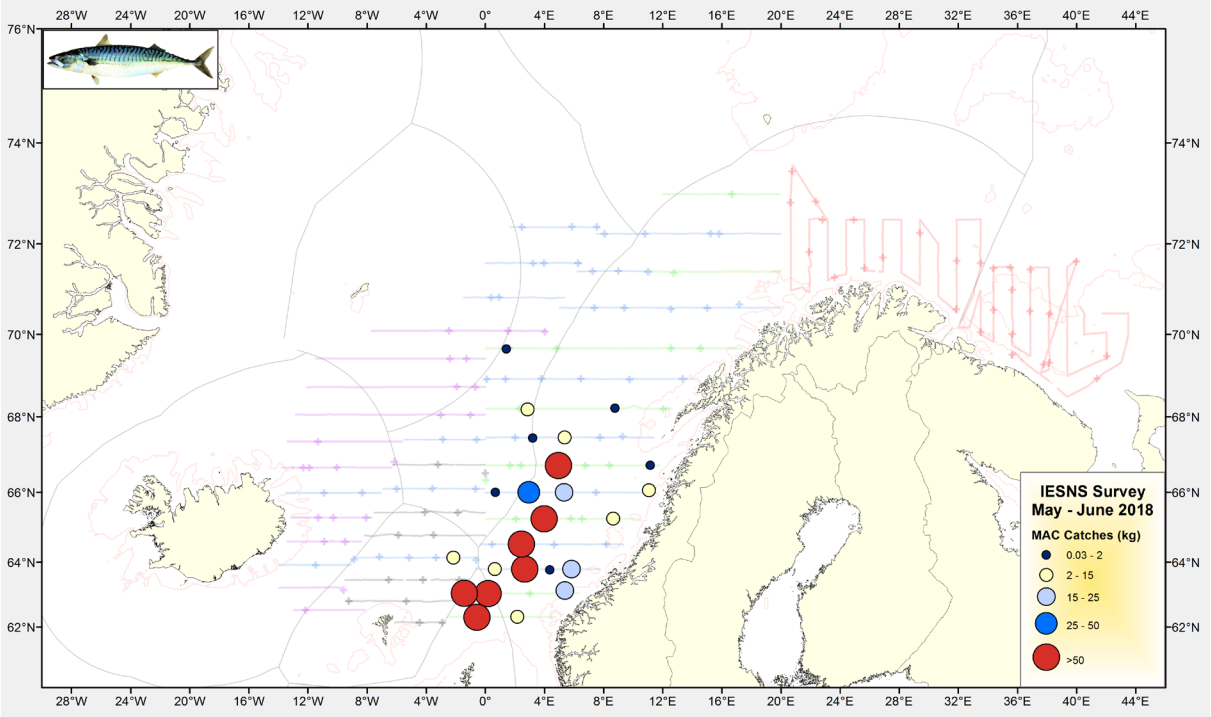


Figure 22. Distribution of hauls containing mackerel and the catch size in the 2018 IESNS.

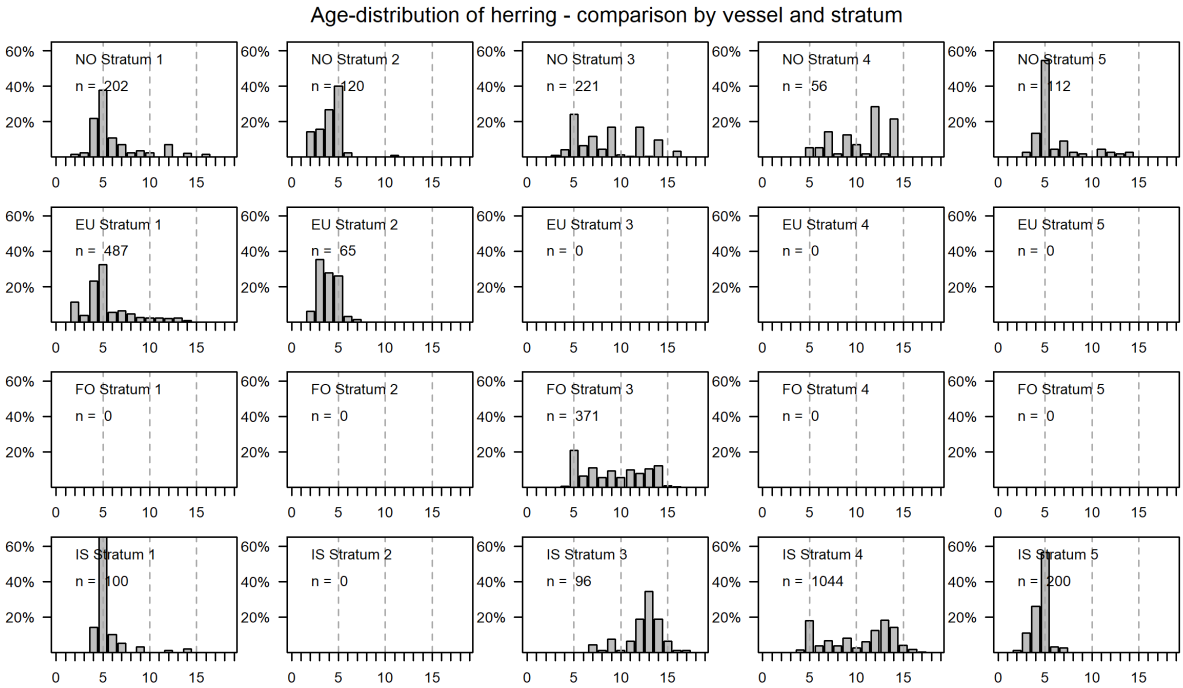


Figure 23. Comparison of the age distributions of NSS-herring by stratum and country in IESNS 2018. The strata are shown in Figure 3.

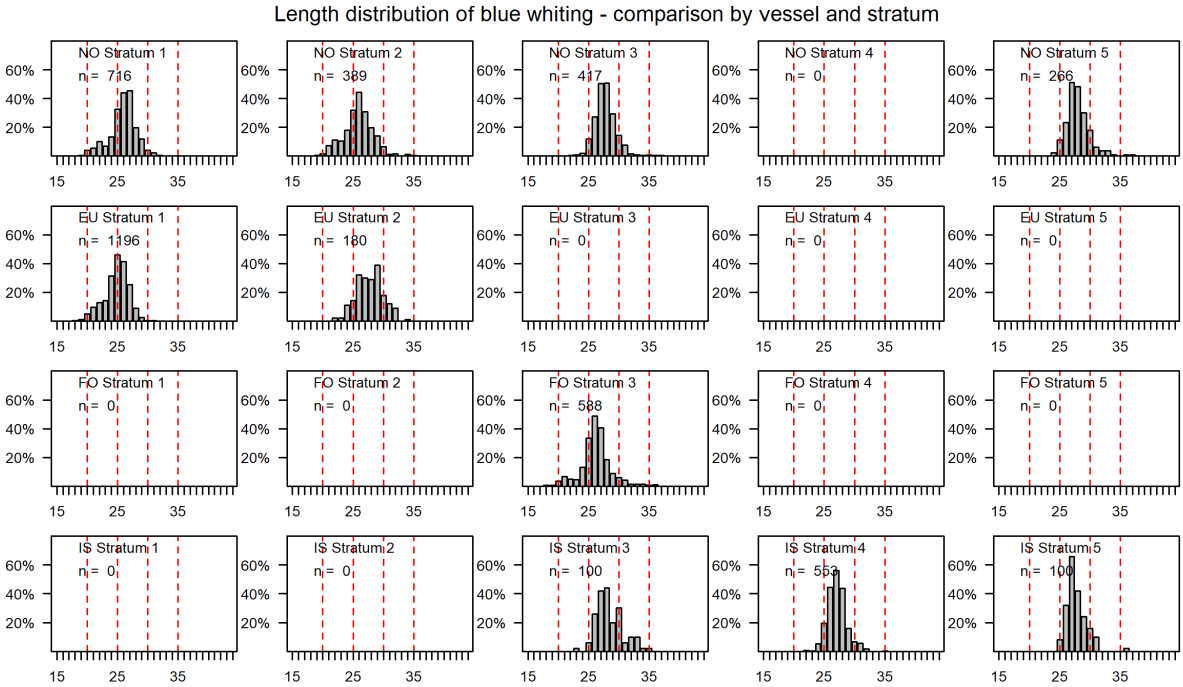


Figure 24. Comparison of the length distributions of blue whiting by stratum and country in IESNS 2018. The strata are shown in Figure 3.

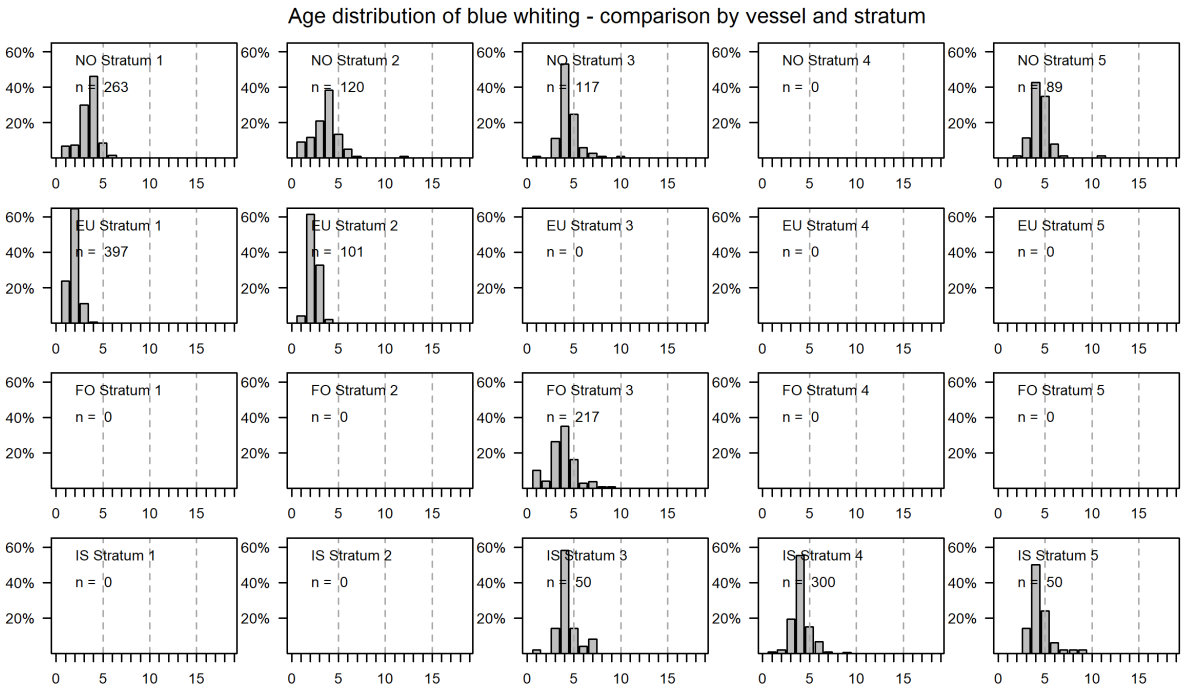


Figure 25. Comparison of the age distributions of blue whiting by stratum and country in IESNS 2018. The strata are shown in Figure 3.

Appendix 1

Corrected estimates for IESNS 2017

When the stox estimates for 2017 was obtained at the post-cruise meeting in Bergen in june 2017 an error was made: the biological data from the Norwegian vessel was omitted. This error was discovered recently, and at the IESNS post-cruise meeting in June 2018 it was decided to present the corrected estimates (i.e. with the Norwegian biological data included in the stox estimate) as an appendix to the IESNS 2018 cruise report. The corrected point estimates for Norwegian spring-spawning herring are shown in table A1 and figure A1. The corrected estimates are quite similar to the original estimates, the most notable difference is higher corrected estimate of the abundance of 13 year old herring (2004 year class). The corrected point estimates for blue whiting are shown in table A2 and Figure A2. The differences between the original and corrected estimates are very small. Based on the confidence intervals obtained from boostrap runs in Stox the corrected and original herring and blue whiting estimates of abundance at age are not significantly different from the original estimates (results not shown here).

Table A1. IESNS 2017 in the Norwegian Sea. Corrected estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring.

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
11-12	5622	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5622	45.0	8.00
12-13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5622	5622	50.4	9.00
13-14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5622	5622	78.7	14.00
14-15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15-16	5116	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5116	133.0	26.00
16-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1843	1843	88.5	48.00
19-20	-	8334	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8334	432.4	51.88
20-21	-	25615	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25615	1440.9	56.25
21-22	-	31343	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	31343	2169.7	69.22
22-23	-	23895	48155	6338	-	-	-	-	-	-	-	-	-	-	-	-	-	-	78389	6372.9	81.30
23-24	-	15794	128944	15794	3949	-	-	-	-	-	-	-	-	-	-	-	-	-	164481	14930.2	90.77
24-25	-	-	275215	10219	-	3172	-	-	-	-	-	-	-	-	-	-	-	-	288607	29974.9	103.86
25-26	-	-	250725	57680	-	-	-	-	-	-	-	-	-	-	-	-	-	-	308405	35731.5	115.76
26-27	-	-	95647	361602	-	-	-	-	-	-	-	-	-	-	-	-	-	-	457248	59474.1	130.07
27-28	-	3452	36491	715828	94399	3452	-	-	9530	-	-	-	-	-	-	-	-	-	863152	130151.1	150.79
28-29	-	-	101646	1255870	241522	61454	30773	9991	4996	-	18805	-	-	-	-	-	-	-	1724657	288039.2	167.01
29-30	-	23649	69301	1172540	309389	102945	100807	38678	55000	4298	8595	-	-	-	-	-	-	-	1885240	342156.3	181.49
30-31	-	-	15983	523572	249850	327652	213289	157134	23963	9585	4793	1739	-	-	-	-	-	-	1533582	304540.9	198.58
31-32	-	-	40409	140523	200254	300957	116275	148850	7410	55313	18393	15785	-	-	-	-	-	-	1044371	226533.2	216.93
32-33	-	-	-	44168	44097	225825	92930	50064	28724	19502	-	4828	14485	-	-	-	-	-	544623	129560.2	237.89
33-34	-	-	-	48406	26546	257034	64379	84912	-	42729	28354	-	5462	7280	-	-	-	-	565121	149174.5	263.97
34-35	-	-	-	3397	2265	178940	135498	317893	39745	48848	101095	112420	53887	-	-	-	-	-	1013989	291284.0	287.27
35-36	-	-	-	-	-	54636	88250	524634	69648	261730	321495	449952	392923	34834	8385	-	-	-	2204486	667182.3	302.37
36-37	-	-	-	574	-	5783	32451	118594	55438	213444	352450	732214	991171	189498	83353	-	-	-	2767282	875952.2	316.54
37-38	-	-	-	-	-	-	-	10063	31856	48554	108562	386499	546003	225151	76428	9206	-	-	1442722	481643.0	333.84
38-39	-	-	-	-	-	-	-	-	-	2948	12382	46867	208394	81170	24945	17885	9630	-	404221	143821.5	355.80
39-40	-	-	-	-	-	-	-	-	-	-	-	34141	14744	-	7759	-	-	-	56645	21826.4	372.18
40-41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1005	1005	-	-
TSN(1000)	10739	132104	1062516	4362511	1192292	1521880	874451	1452815	326509	726950	974924	1784745	2229068	537932	201072	27091	9630	14093	17441322	-	-
TSB(1000 kg)	178.0	12195.0	134102.1	740852.4	224865.9	349122.3	205269.0	396325.3	87616.0	215760.4	295730.6	563097.7	716332.0	177948.6	67738.6	9706.0	3719.2	217.8	-	4202777.1	-
Mean length (cm)	13.41	22.92	25.40	28.55	29.47	31.69	31.92	33.45	31.35	34.87	35.27	35.95	36.29	36.45	36.82	37.66	38.00	15.38	-	-	-
Mean weight (g)	16.58	92.31	126.21	169.82	190.28	229.40	234.74	272.80	268.34	296.80	303.34	315.51	321.36	330.80	336.89	358.28	386.20	16.64	-	-	240.98

Table A2. IESNS 2017 in the Norwegian Sea. Corrected estimates of abundance, mean weight and mean length of blue whiting.

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Number (1E3)	Biomass (1E3kg)	Mean W (g)
17-18	888	-	-	-	-	-	-	-	-	-	-	-	-	-	888	24.9	28.00
18-19	10398	-	-	-	-	-	-	-	-	-	-	-	-	-	10398	363.0	34.91
19-20	149759	-	-	-	-	-	-	-	-	-	-	-	-	-	149759	5968.3	39.85
20-21	477802	10505	1050	2101	-	-	-	-	-	-	-	-	-	-	491458	22488.8	45.76
21-22	441561	120703	17223	-	-	-	-	-	-	-	-	-	-	-	579487	30680.8	52.94
22-23	150338	301374	164217	29957	-	-	-	-	-	-	-	-	-	-	645886	40393.5	62.54
23-24	1416	570459	392353	39080	-	-	-	-	-	-	-	-	-	-	1003308	73677.1	73.43
24-25	-	559031	810208	113490	13412	-	-	-	-	-	-	-	-	-	1496140	124233.8	83.04
25-26	-	365348	1170907	194005	24131	-	-	-	-	-	-	-	-	-	1754392	164146.7	93.56
26-27	-	116902	1027315	307565	24622	-	889	-	-	-	-	-	-	-	1477294	153361.9	103.81
27-28	-	30825	450062	319144	50148	12904	969	-	-	-	-	-	-	-	864051	99827.3	115.53
28-29	4172	11918	119831	169348	77800	23608	8781	-	-	-	-	-	-	-	415459	54422.9	130.99
29-30	-	-	29875	73561	50703	36938	9994	-	-	1110	-	-	-	-	202181	29735.8	147.07
30-31	-	-	16984	10735	36996	42736	40811	-	-	-	-	-	-	-	148262	23816.4	160.64
31-32	-	-	2783	-	85013	15291	6254	1251	-	-	-	-	-	-	110593	19528.3	176.58
32-33	-	-	-	2772	7718	18121	8316	11352	-	5544	9805	-	-	5544	69172	14629.9	211.50
33-34	-	-	-	2350	10246	17297	12596	9402	-	11752	4701	4701	2350	2350	77746	16124.1	207.39
34-35	-	-	-	1891	5622	5622	5622	7713	2811	8433	2811	14825	-	2811	58163	14214.3	244.39
35-36	-	-	-	-	-	-	19464	13917	9278	18557	4639	-	-	-	65856	17901.5	271.83
36-37	-	-	-	-	2897	-	2897	2897	5793	5793	5793	-	-	-	26070	8003.5	307.00
37-38	-	-	-	-	-	-	-	-	4549	4549	-	-	-	-	9098	2563.4	281.75
38-39	-	-	-	-	-	-	-	-	-	-	-	2187	14825	-	17012	5163.2	303.50
39-40	-	-	-	-	-	-	3645	-	-	-	-	-	14825	-	18470	6003.4	325.03
40-41	-	-	-	-	-	-	-	-	-	-	-	1094	-	-	1094	371.8	340.00
TSN(1000)	1236334	2087065	4202809	1266000	389308	172518	120238	46531	22432	55739	27750	22807	32000	10706	9692236	-	-
TSB(1000 kg)	60658.2	163393.9	398269.8	139271.3	56926.9	29458.0	22886.0	11258.6	5967.1	14316.2	7039.6	5945.3	9774.4	2479.1	-	927644.5	-
Mean length (cm)	20.54	23.68	25.21	26.43	28.95	30.22	31.82	33.89	35.77	34.47	33.81	34.51	38.13	32.87	-	-	-
Mean weight (g)	49.06	78.29	94.76	110.01	146.23	170.75	190.34	241.96	266.01	256.84	253.68	260.68	305.45	231.57	-	-	95.71

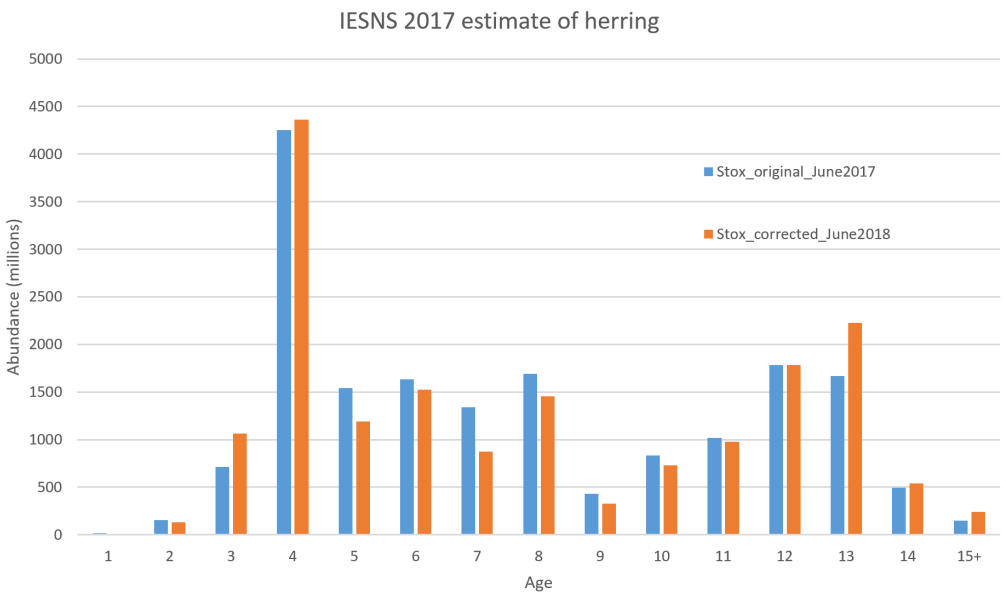


Figure A1. IESNS 2017 in the Norwegian Sea. Original and corrected abundance estimates of Norwegian spring-spawning herring.

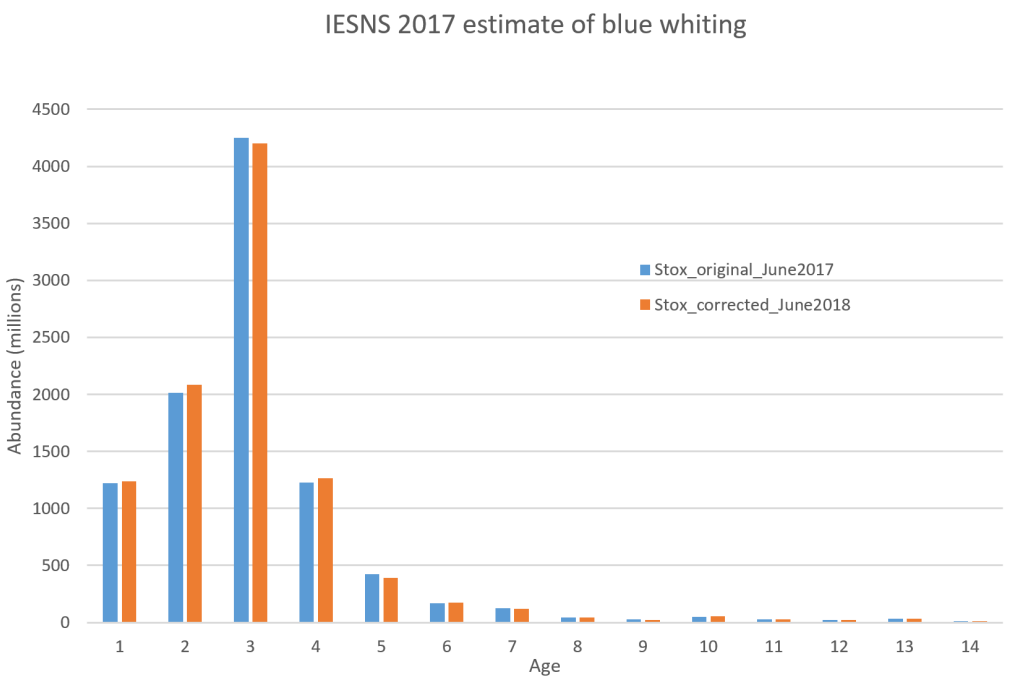


Figure A2. IESNS 2017 in the Norwegian Sea. Original and corrected abundance estimates of blue whiting.

Appendix 2

Observations of Norwegian spring spawning herring (NSSH) using fisheries sonar during international ecosystem survey in Nordic SEA (IESNS) in May – June 2018

Authors: Sindre Vatnehol and Héctor Peña

Contents

1. Introduction:

In acoustic trawl surveys on pelagic schooling species, the down-looking narrow-beam echo sounder is the standard tool used for estimating fish abundance. Bias in the estimate may occur when fish are distributed in the acoustic blind zone of the echo sounder, i.e. between the sea surface and the acoustic far-field distance of the transducer. When transducers are mounted on a drop keel below the vessels hull, this blind zone can extend up to 15 m below the sea surface. Another source of bias may occur when fish avoids the surveying vessel, either due to an horizontal movement or an vertical movement, i.e. diving (De Robertis and Handegard, 2013).

The fisheries sonar is multibeam acoustic systems using horizontal beams in a 360 deg fan around the vessel alternated with vertical beams in a 180 deg fan. The horizontal beams can be electronically steered, being able to measure the fish aggregations in the upper layers up to the sea surface, at long distances (i.e. kilometers) from the vessel. Similarly, the vertical beams can be steered to form a vertical fan that is perpendicular to the vessel track, sampling the entire water column, at both sides of the vessel. These technical

characteristics, together with the high availability of these instruments in most research and commercial fishing vessels, makes sonars into a tool capable of investigating the blind zone and avoidance bias of the echo sounder sampling. Disadvantages of this type of sonar when compared with scientific sonars are a wider beam width (i.e. 5 deg in Simrad SU90) in comparison with scientific sonars (i.e. 4 deg in Simrad MS70), and a reduced dynamic range.

Efforts from the Norwegian Institute of Marine Research, over the last 10 years, includes calibration procedure (Macaulay et al., 2016; Ona et al., 2009) and post-processing system for sonar data, to be used for either single school investigations or for systematic surveys for abundance estimation. Interpretation of sonar data is not part of the routine activity during the IESNS survey, and one objective for this cruise was to do establish a daily routine for interpretation sonar data the first 21 days of the survey. In this report, we present the progress for using sonar as a tool to identify and quantify the bias of the echo sounder estimates.

2. Preparation

2.1 Calibration

The sonar was calibrated in Sandviksflaket on 30th of April, 2018. Weather conditions were good, with low wind speed and low sea height. The procedure for calibration of the fisheries sonar was conducted according to Macaulay et al. (2016), where totally 9 beams were calibrated (3 port, 3 bow and 3 starboard side). 64 mm tungsten carbide was used as a calibration target. The following configuration was used; signal frequency of 26 kHz, FM normal transmission mode, narrow vertical beam and tilt angle of 7 deg. below horizontal. The calibration procedure took 3 hours, including rig mounting, calibrating and demount of the rig. The processing of the calibration data was not made when the results in the present report were made; hence, any values presented in this report are uncalibrated ones.

2.2 Operational settings and procedures

The sonar has two beam configuration modes, the horizontal and the vertical, where alternates between the two configurations for each successive ping. The horizontal mode was configured to sample the echo sounder blind zone, i.e. from surface up to 10-12 m; thus, a beam tilt angle of 5 degrees below horizontal was used. For the vertical mode, a 180° vertical beam fan was set perpendicular to the vessel. The detection range of the sonar was set to 600 m for both beam configurations. The sonar was synchronized in time with the EK80 echo sounder and MS70 scientific sonar to avoid acoustic interference in either equipment. The resulting ping rate of the sonar was between 4 to 5 seconds between measurement of either beam configuration mode. For practical usage, this is too slow ping rate. All the sonar filters (AGC, RCG, Ping to ping) were set to default values, except for the "Noise filter" which was disabled as this corrupts the data. Data in the '.raw' format was collected continuously during the survey and stored in an external 2 TB hard drive and into tape backup system. The '.raw' data was converted to the ICES recommended '.nc' (NetCDF) format.

2.3 Common output file

A similar file to the echo sounder's output file List User File 20 (coined EK80-LUF20) was made for the sonar output. The sonar output files are henceforth coined sonar-LUF20. Using a common output file structure enables direct comparison between the echo sounder and the sonar; and, the sonar output file can be uploaded and used on several processing software, such as Stox. Since the fisheries sonar has two beams' configurations, two sonar-LUF20 files were made for each configuration. The procedure for making the sonar-LUF20 are further described.

2.4 Post-processing of vertical sonar beams (Automatic)

An automatic algorithm was made in PYTHON language to automatically process the sonar data, and convert the data to NASC values,

$$s_A = 4\pi\,(1852)^2\, s_a.$$

Here, s_a is the area backscatter coefficient. For the sonar data, a similar approach as shown in Patel and Ona (2009) was used, where only data within a specified range interval (horizontal distance from the vessel) between w_1 and w_2 are used, see figure 2. Consequently,

$$s_a = \int_{w_1}^{w_2}\int_{z_1}^{z_2} s_v\, dz\, dw.$$

At this point, all the s_v values are integrated, even those with background noise and other biological targets. Additional filters are needed to increase the signal-to-noise ratio.

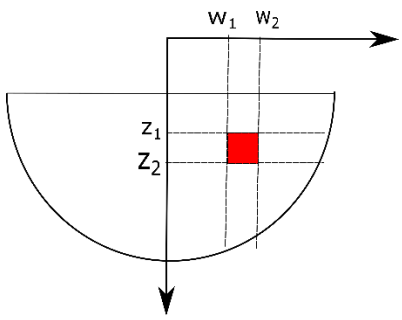


Figure 1Illustration of the echo integration of the vertical beams. All data between the depth interval z_1 and z_2, as well as the distance interval w_1 and w_2, are integrated. One integration bin is identified as the red square.

Background noise filter

The background noise within a time interval can be removed via

$$s_v = \begin{cases} s_v & if \quad s_v \geq \dfrac{\kappa}{t_2 - t_1}\displaystyle\int_{t_1}^{t_2} s_v(r,m,t)\,dt \\ 0 & else \end{cases},$$

where κ is a threshold coefficient. This filter was included for each log distance.

Threshold filter

Targets with low s_v values, hence fish without swim bladder, can be removed via

$$s_v = \begin{cases} s_v & if \quad s_v \geq s_v^{min} \\ 0 & else \end{cases}$$

Here, s_v^{min} is the minimal s_v value for acceptance where $10 \log_{10} s_v^{min} = -65\ dB$.

2.5 Post-processing of horizontal sonar beams (PROFOS)

The Processing system for omni directional fisheries sonar (PROFOS) module of the LSSS (Large Scale Survey System, Korneliussen et al., 2016) software was used to process the data. The software has an automatic school detection functionality that was used, and, sequentially, manual quality control and correction of the segmented schools was done. The criteria for school detection was continuously adapted by the user to enable fish schools of different size and shape to be detected. In general, the most common settings were: 10 dB above the background level, minimum surface of 100 m^2, maximum surface of 7000 m^2, two missing pings, at least 10 pings schools, and a ratio of 10 between length and school width.

The output from the PROFOS are s_v values for each data pixel on each school. These values were integrated into 10m x 1nmi bins and converted into NASC values, a similar approach as done for the vertical beams. The conversion from the PROFOS output files to sonar-LUF20 was done using a dedicated R-script.

3. Preliminary result

3.1 Making the common data output

The sonar data collected in vertical mode was integrated into 10 meters depth bins for each 1 nmi distance (vertical, Figure 3 lower panel), In the horizontal mode, acoustic backscattering data from schools detected in the horizontal beams was integrated in one channel where the size was defined by the volume sampled by the sonar (i.e. 10 and 80 m depth). To simplify the comparison, start and stop of each distant channel was identical to that of the EK80-LUF20. Fisheries sonar emits sound with only one signal frequency; hence, a species discrimination using multi-frequency analysis (Fässler et al., 2007; Korneliussen et al., 2016) is not possible. Therefore, the sonar-LUF20 for the vertical beams includes all species, i.e NSSH, mesopelagic fish and blue whiting; however, fish aggregated into schools was labeled as herring for the horizontal beam data. Visual interpretation of the sonar-LUF20 report, Figure 3, identifies the first two depth channels, i.e. 0-20 m, as noisy, largely influenced by near-surface bobbles and waves. Also, specifically for the vertical beams, the seabed was included in the integration. A future development of a bottom filter is needed; however, in the comparison with the echo sounder, this proportion of the data was ignored.

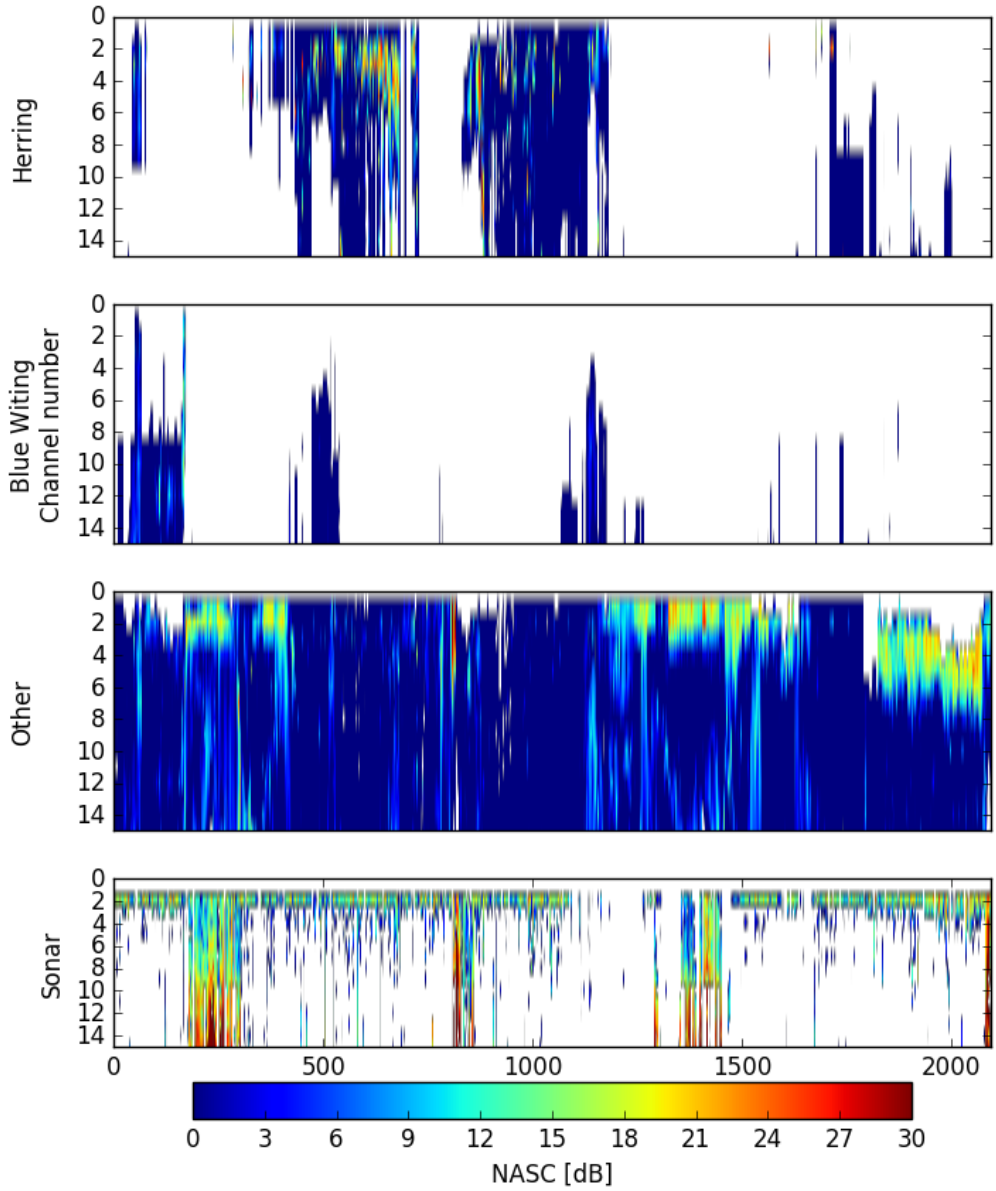


Figure 2. Visualization of EK80-LUF20 file for herring (first upper panel), blue whiting (second upper panel) and other species (third upper panel) and of the sonar-LUF20 (lower panel) using data from Simrad SU90 collected in the vertical mode. The size of the depth channels is 10 m, and the size of the distance channels is 1 nmi. In the lower panel, the data with a NASC value larger than 21 dB is from the seabed, and must be removed in a future development. Higher noise levels are seen in depth channel 1 and 2 in the sonar-LUF20, where this noise origins from air-bobbles and surface waves.

3.2 Comparison with echosounder output

In a preliminary comparison with the echosounder, the NASC information of all species in the EK80-LUF20 were used (Figure 3, three top panel) as the sonar-LUF20 for the vertical beams does not divide the NASC values between species. The vertical distribution, figure 4,

show the sonar record more acoustic energy at 20 m depth than what was recorded of herring by the echosounder; but, the sonar integrates all acoustic energy, also the ones originated from blue whiting, plankton and mesopelagic fish. Also, because the unsuccessful calibration, the values from the sonar must be treated as relative. In the next step for using sonar on routine surveys is to develop statistical models that combines the LUF20 files from several sources, i.e. sonar and echosounder, in order to make a bias-correction LUF20.

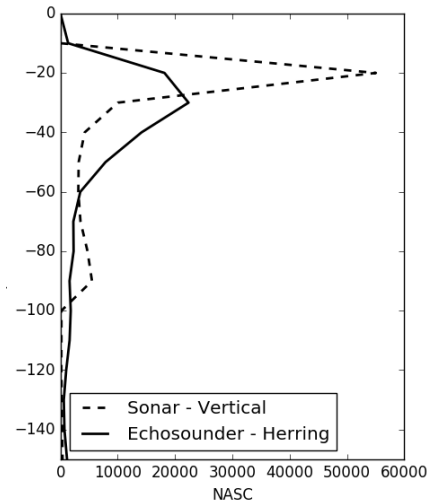


Figure 4. Vertical distribution of herring as recorded by the echosounder (whole line), and the vertical distribution of all scatterers as recorded by the sonar (dotted line)

The analysis of interpreted schools detected within the sonar's horizontal beams, and the acoustics scatters assigned to herring with the echo sounder, are show in Figure 5. Here, it is possible to identify two periods (4.05 to 6.05 and first hours of 10.05) where no herring was allocated in the echo sounder data, and school were detected by the sonar in the same depth layer. Further analysis is needed to identify if this is caused by one of the bias sources, i.e. avoidance or fish in blind zone; and, if so, if these represent a significant contribution of the stock. Analysis of the remaining data from the survey will be analyzed in a later stage.

Figure 5. Distribution of schools observed with the sonar (green dots) and herring allocated in the echo sounder (red dots) between 3rd to 12th May. Sa values from sonar and echo sounder are scaled so can be displayed in same level. During a period on May 8th sonar data was not interpreted and indicated in the figure.

3.3 Other sonar results

Implementation

An implicit objective during the survey, was to interpret the horizontal beams the sonar in a daily basis. The interpretation of 24 hours took 4 hours; however, more time was needed when several fish schools were present in the data. The automatic school detection feature in PROFOS performed very good when sea state was calm, and wind speed below 20 knots. When wind increases, noise level increased at ranges around the vessel. A criterion was established to define the sonar exclusion zone around the vessel, and the size of the exclusion zone was optimised to exclude the noisy data (Figure 6). E.g. with noise levels about 20-30 knots the exclusion zone was set up to 300 m; but, with even higher wind speed, the interpretation of the sonar data was not possible, and this proportion of the data was ignored.

Another challenge was to identify when clouds of air-bubbles were interpreted by the automatic detection algorithm as small schools. These features fulfil all the criteria (strength, size, persistence, etc.) used for school detection. The approach to avoid these data to be included was to continuous observe the sonar screen. Candidates that had a strong and well-defined echo in the vertical fan was labelled as herring, while the other was ignored.

In summary, the scrutinizing of the SU90 data during a systematic acoustic survey is doable activity, that requires a dedicated monitoring of the sonar display, frequently record the events in a separate log-book or screen-dumps.

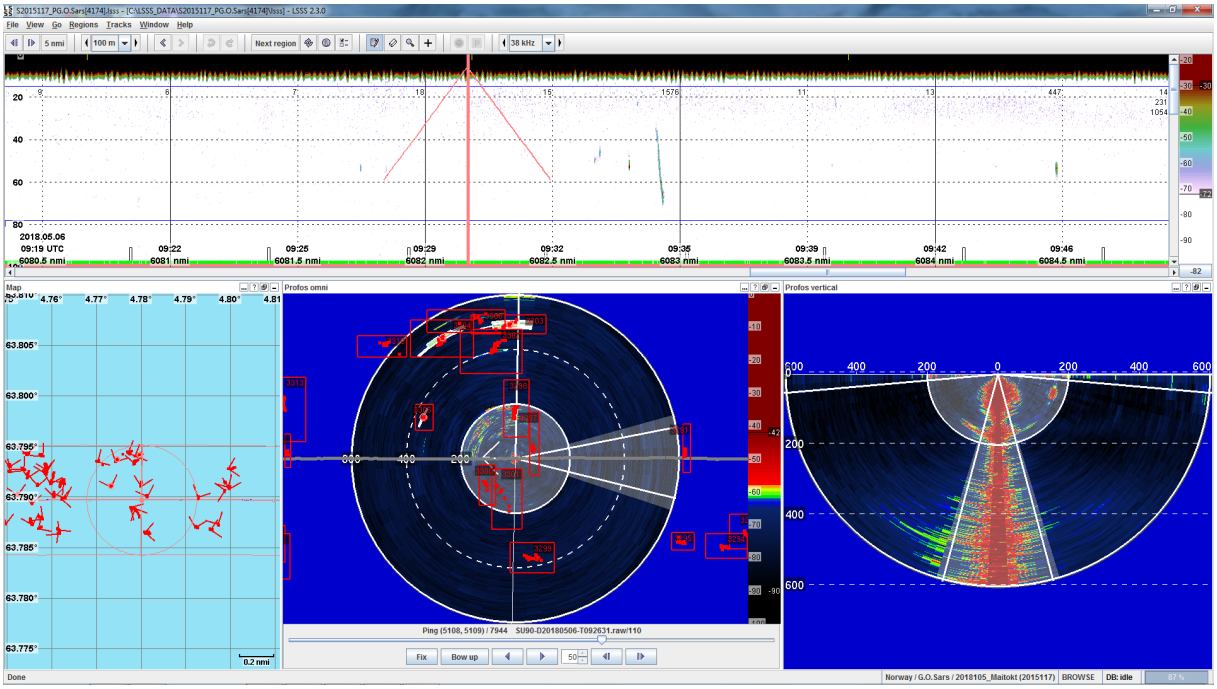


Figure 6. Screen shot of LSSS program showing the EK80 data (upper panel), map with school's detections in the sonar along the track (left bottom), sonar horizontal beams with red dots representing each school detection (centre bottom) and vertical sonar beams (right bottom panel).

Single school biomass estimates from echosounder

The biomass of three schools observed with both the sonar and the echo sounder were made, Table 1, using school parameters derived from the echo sounder measurements. The computed school biomass confirm that the targets observed in the sonar horizontal beams correspond to herring schools, and provides an idea of individual school biomass, which ranges between hundreds of kilos to few tonnes.

	School 1	School 2	School 3

Fish length (cm)	31	35	29
Fish weight (g)	212	340	171
s_A (m^2 nmi^{-2})	7870	69	41697
s_L (m)	115	1	656
Length (nmi)	0.01	0.01	0.02
Length (m)	27.1	26.8	29.1
Mean SV (dB)	-46.0	-64.2	-40.8
Mean TS (dB)	-42.1	-41.0	-42.7
SV-TS (dB)	-3.9	-23.2	1.9
RHO (fish m^{-3})	0.40	0.005	1.53
Radius (m)	13.5	13.4	15
Height (m)	6.0	4.3	10.0
Section area (m^2)	575	566	666
Volume (m^3)	3449	2432	6664
Fish number	1396	12	10208
School biomass (ton)	0.30	3.97E-03	1.75

Table 1. School parameters obtained from EK80 echo sounder measurements. The same schools were previously sampled with the horizontal beams of the fisheries sonar. Fish length and weight were obtained from pelagic trawling. Target strength was computed using equation 20 Log (fish length) -71.9.

Fish school distribution

A general overview of the sonar data shows the presence of rather small fish aggregations in most of the survey track, with more schools observed from the centre of the Norwegian sea to the west (Figure 7). The absence of fish in a few regions correspond to periods of adverse weather conditions (wind speed above 25 knots), in which it was not possible to interpret the data because of the increased noise level.

Based in the school and vessel geographical position, the distance of each school to the vessel track on each ping was computed (Figure 8, left panel). Most of the school detections occurred 100 m from the vessel track, with a decrease of schools' detection at closer distances, a consequence of a reduced sampling volume. The centre depth of the schools detected by the sonar had a normal distribution with a maximum of schools at about 30 m depth (Figure 8, right panel). The minimum central school depth was 11 m, and a maximum of 62 m. The depth distribution of the schools depends on the tilt angle of the horizontal fan and the vertical beam opening and the operational sonar range. Therefore, there is a detection probability of the schools at different depth, i.e. at shallower depths the sampling surface of the horizontal fan is reduced in comparison with mid and large ranges. It is required to estimate the theoretical detection to obtain a realistic vertical school distribution.

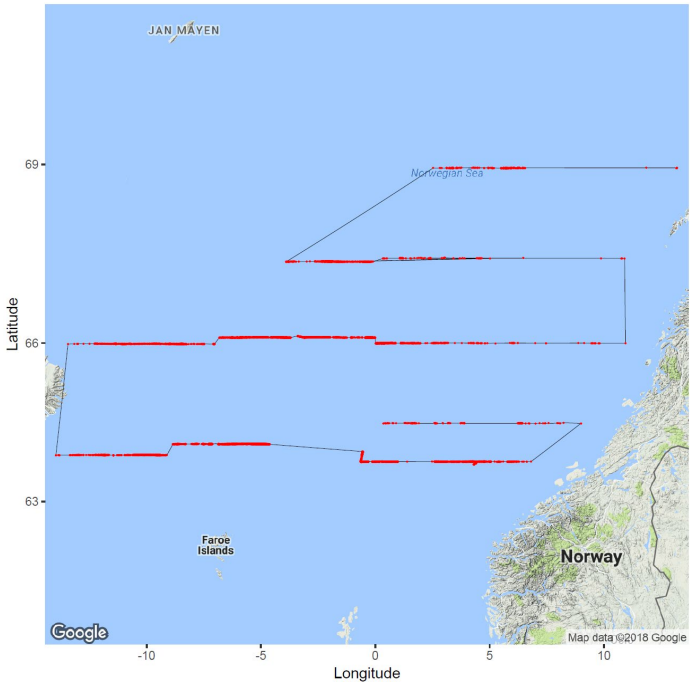


Figure 7. Map showing the survey track from R/V G.O. Sars between 30 April to 21 June. Red dots represent fish aggregations detected within SU90 fisheries sonar's horizontal beams.

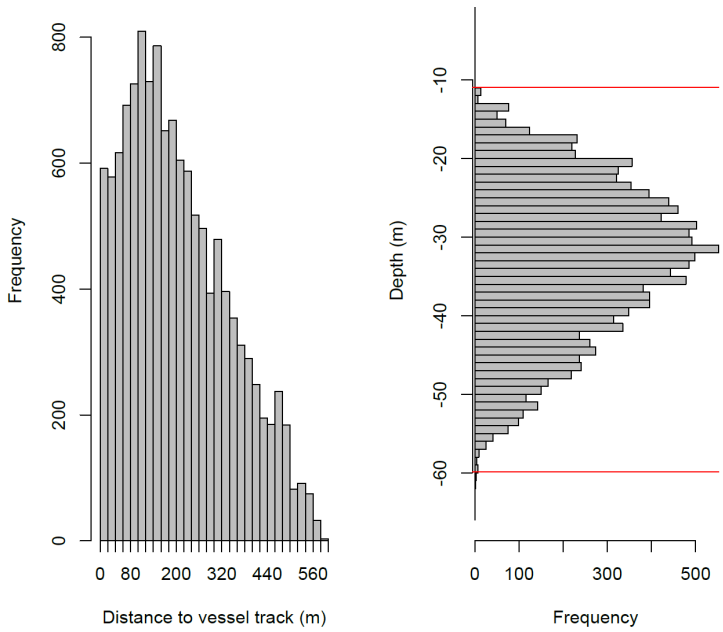


Figure 8. School distance to the vessel track (left panel) and centre depth of schools (right panel).

Fish migration

The mean swimming speed of the schools aggregated by 1 nmi was below 1 knot (Figure 8, left panel). There is not a clear predominant swimming direction. In the northerly transect more schools are swimming north and in transect centred in 66° N a general west direction is observed. When accumulate the migration data of all schools, the polar histogram confirms the absence of a general migration direction during the survey period (Figure 9, right panel).

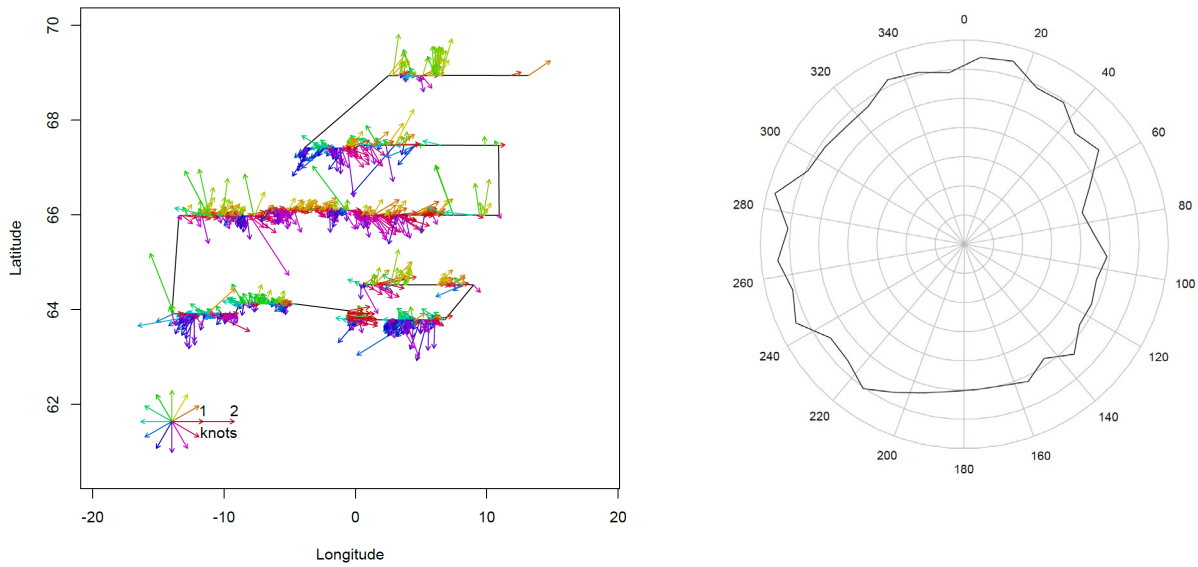


Figure 9. Mean school speed and direction aggregated by 1 nmi along the cruise track (left panel) and polar histogram of school direction (right panel).

4. References:

5. Fässler, S. M. M., Santos, R., García-Núñez, N., and Fernandes, P. G. (2007). "Multifrequency backscattering properties of Atlantic herring (Clupea harengus) and Norway pout (Trisopterus esmarkii),” Can. J. Fish. Aquat. Sci., 64, 362–374. doi:10.1139/f07-013

6. Korneliussen, R. J., Heggelund, Y., Macaulay, G. J., Patel, D., Johnsen, E., and Eliassen, I. K. (2016). "Acoustic identification of marine species using a feature library,” Methods Oceanogr., 17, 187–205. doi:10.1016/j.mio.2016.09.002

7. Macaulay, G. J., Vatnehol, S., Gammelsæter, O. B., Ona, E., and Pena, H. (2016). "Practical calibration of ship-mounted omni-directional fisheries sonars,” Methods Oceanogr., 17, 206--220.

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10. De Robertis, A., and Handegard, N. O. (2013). "Fish avoidance of research vessels and the efficacy of noise-reduced vessels: A review,” ICES J. Mar. Sci., 70, 34–45. doi:10.1093/icesjms/fss155

Appendix 3

Observations of Norwegian spring spawning herring (NSSH) using scientific and fisheries sonar during international ecosystem survey in Nordic SEA (IESNS) in May – June 2018

Author:Rolf Korneliussen

4. Scientific sonar – Simrad MS70

4.1 Calibration

The sonar MS70 was calibrated in Sandviksflaket on 30th of April 2018. Weather conditions were good, with low wind speed and low sea height. The calibration of the scientific sonar was conducted according to procedures described in Ona et a. (2009). The 500 port oriented beams of MS70 covers 60˚ horizontally x 45 ˚ vertically from a transducer with center at 7.5 m depth when operated. MS70 transmits 20 vertical fans, with the highest frequency (112 kHz) aiming 45˚ downwards relative to the surface and the lowest frequency (75 kHz) aiming horizontally, i.e. at 0˚. Due to the span of the frequencies, there was a need to use two calibration spheres: a 75-mm diameter and 84-mm tungsten-carbide with 6% cobalt binder.

4.2 Data collection

The sonar was operated in continuous-wave mode, with pulse duration of 2 ms and a data collection range of 350 m. Four fan beams transmitted simultaneously (i.e. 112 kHz at 45 ˚, 113.9 kHz at 47.5 ˚, 115.7 kHz at 50 ˚, and 117.6 kHz at 52.5 ˚ transmitted concurrently, followed by the next four, etc.). Therefore, all pulses with 2 ms duration were transmitted during 10 ms. The beam widths were between 3˚ and 4 ˚ varying vertically with the frequency. The first side lobe was -35 dB relative to the main lobe vertically, and -25 dB horizontally. Using data from the MRU, the sonar automatically compensated for roll of up to 10˚. The sonar pings were synchronized with those of the echosounder, typically at a frequency of 1.2 Hz. The relatively short range of MS70 was used to be able to maintain the same ping-rate as for the echo sounder EK80.

The MS70 sonar had increasingly technical problems during the survey, with increasing number of bad samples in the pings. From May 15 MS70 was only sporadically functioning, and at the beginning of May 17 it was turned off for good.

4.3 Preprocessing

The sonar was operated in continuous-wave mode, with pulse duration of 2 ms and a data collection range of 350 m. Four fan beams transmitted simultaneously (i.e. 112 kHz at 45 ˚, 113.9 kHz at 47.5 ˚, 115.7 kHz at 50 ˚, and 117.6 kHz at 52.5 ˚ transmitted concurrently, followed by the next four, etc.). Therefore, all pulses with 2 ms duration were transmitted during 10 ms. The beam widths were between 3˚ and 4 ˚ varying vertically with the frequency. The first side lobe was -35 dB relative to the main lobe vertically, and -25 dB horizontally. Using data from the MRU, the sonar automatically compensated for roll of up to 10˚. The sonar pings were synchronized with those of the echosounder, typically at a

frequency of 1.2 Hz. The relatively short range of MS70 was used to be able to maintain the same ping-rate as for the echo sounder EK80.

The MS70 data were processed with the PROMUS (Processing system for advanced multibeam sonar) module (Korneliussen et al., 2009) of LSSS (Korneliussen et al., 2016). The data were pre-processed with KORONA by means of processing modules dedicated for MS70 data. Pre-processing means that the processing was done automatically without interference from the operator. The modules were used to: (1) Remove of spatial and temporal spikes; (2) Reduce data; (3) Detect schools automatically; (4) Detect bad data; The results from the pre-processing were made available to the operator for use during scrutiny, and the operator than decided which parts of the information should be used. Some modules were run sequentially with different settings, to perform different tasks. The detailed KORONA-PROMUS setup may not be of interest, but they are listed below for reference. The setup for pre-processing MS70 data were:

1) *Reduce data:*
   - *remove all data with a horizontal distance to the ship less than 30 m.*
   - *Remove outer parts of beam at ranges where the upper edge hits surface*
2) *Spike-filter: remove wall-shaped spatial spikes > -45 dB and 15 dB stronger than surroundings*
3) *Spike-filter: remove pencil-beam-shaped spatial spikes > -45 dB and 15 dB stronger than surroundings*
4) *Spike-filter: remove temporal spikes > -45 dB and 15 dB stronger than surroundings*
5) *Smooth along beam with an 8 m Gaussian kernel*
6) *Quantify ambient noise: use the 175 outermost meters of each beam to estimate noise. The slowly varying ambient noise is used further, i.e. a noise-estimate for the ambient noise of each beam based on data from the whole survey.*
7) *Reduce data (Not done previously to make spike-removal and estimation of ambient noise better)*
   - *Remove all data at more than 250 horizontal distance from the ship*
   - *Remove the outmost part of beams where uppermost edge is closer to surface than 4 m*
8) *Correct data for ambient noise*
9) *Spike-filter: remove spikes > -70 dB (of corrected data) shaped as vertical fans and 20 dB stronger than surroundings*
10) *Spike-filter: remove spikes > -70 dB (of corrected data) shaped as pencil-beams and 20 dB stronger than surroundings*
11) *Remove all samples stronger than -25 dB and weaker than -70 dB*
12) *Detect schools using K-means clustering*
13) *Compress data*
14) *Detect bad pings*

4.4 MS70 data interpretation

The preprocessing removed most spike-noise and corrected for ambient noise. During the manual scrutiny, some pings were manually marked for exclusion and not used further. The scrutiny of the echosounder data is done by a team consisting of ***at least*** the instrument chief and the cruise leader. The result of the discussion during the scrutiny is essential for the quality of the scrutinized data. Ideally, the MS70 data should have been scrutinized together with EK80 data. As the expected processing-speed of the MS70 data were expected to be too slow for co-scrutinize simultaneous with the EK80 data, those data were intended to be scrutinized during the survey closely after the scrutiny of the echosounder. Unlike the EK80 data scrutinized by a team of two, the MS70 data were scrutinized by one scientist only. The processing was not much faster than real-time during the first days of the survey, which made it challenging to keep up with survey activities in the same manner as during the 2017 survey. The MS70 processing eventually became slower than real-time, which made it impossible to keep up with the survey activities. Most of the time after the survey has been used to improve speed of the both the pre-processing, the semi-automatic processing, and to automate some of the manual work. The speed is currently 60 times faster than during the survey. Analysis of 24 hours of MS70 data typically took 45 – 60

minutes in front of the screen on a laptop after the survey, with the potential of reducing that to 25 minutes (on a laptop).

2D data based on the 4D MS70 data were used to extract 2D-phantom echograms. These echograms were used to get an overview and identify locations of schools in addition to the automatic detection from step 12 above. After the improvement of speed and functionality, the following procedure was used: (1) Data were pre-processed as described above. (2) Chunks of typically 12 hours were loaded into the PC. Bad pings were automatically detected during pre-processing, and were marked as excluded during scrutiny. Schools candidates were automatically detected and grown in 4 dimensions (3 spatial + time). A set of requirements were used to start growing: In most cases, the samples were required to be above 150 m stronger than -58 dB, and weaker than -35 dB. Depending on weather, the schools were in most cases required to not be shallower than 10 – 18 m, but on some occasions, they could be as shallow as 4 m or as deep as 35 m. When grown, a set of criteria were used for automatically rejecting the school-candidate. These were: (A) Minimum (uncorrected) volume 225 m^3; (B) Minimum (uncorrected) height: 90 m; (C) Maximum aspect ratio (uncorrected data): 4; (D) Minimum number of pings: 2; Minimum s_V x Volume: 500; (E) Maximum s_V x Volume: 5 x 10^8. Note that $s_V \equiv 4\pi 1852^2 s_v$. This detection of school candidates typically took 5 minutes for 12 hours of data. The school-candidates were sorted on Volume, upper depth of school and average s_V in addition to the variables listed above, and inspected and potentially removed. There were on average 3500 school candidates in 12 hours of data, of which typically 5-10% were rejected. This process of removing bad school-candidates typically took 15 minutes for 12 hours of data.

The scrutiny itself were usually quite fast as there were mostly two candidate species: herring and blue whiting. Blue whiting was commonly deeper than herring, and for MS70 no schools were considered below 150 m, that is 150 m for the MS70 beam centers: the lower edge of beam could be deeper. The scrutiny for the data May 9-10 were challenging as much backscatter close to the surface due to bubbles and mesopelagic fish. Figure 4.1 shows a screen-grab of LSSS-PROMUS, and the 2m x 2m x 2m grid for representing two different schools close to the surface.

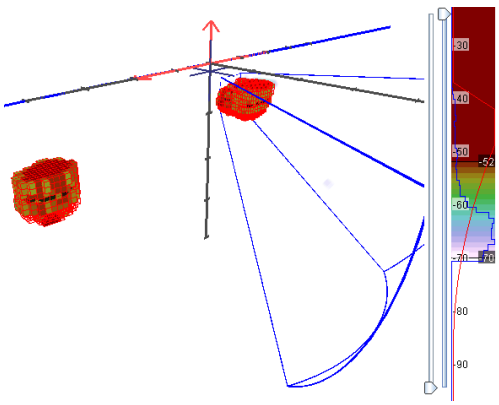

Figure 4.1. LSSS-PROMUS and grid representing two grown schools.

4.5 Results

The results of the data scrutiny were grouped into 5 segments based on its location in two stratas along the cruise-line. Data from (1) May 3, 11:30 – May 5, 02:30 (UTC); (2) May 5

20:15 – May 7, 12:00 (UTC); (5) May 13, 00:00 – May 14, 17:00 (UTC) were in the eastern strata closest to Norway. Data from (3) May 7, 12:00 – May 10, 05:15 (UTC); (4) May 10 19:30 – May 12, 24:00 (UTC); **Figure 4.1** below shows the vertical distribution of herring backscatter for those 5 different regions.

Figure 4.3 shows the vertical distribution of backscatter of the vertical oriented echo sounder EK80 and the sonar MS70 covering horizontal to 45 degrees down of all scrutinized data from May 3, 11:40 – May 14, 17:00 (UTC). The EK80 and MS70 data are not directly comparable, since EK80 stores data as s_A (NASC, i.e. s_V × depth_range), while the MS70 data are stored as s_V (i.e. density). Furthermore, based on simulations the TS-relation of grazing incidence is 3 – 6 dB lower than dorsal side depending on frequency and grazing angle. Previous research has indicated that avoidance reaction is weak below 80 m depth, and therefore the MS70 and EK80 data are normalized so that they are approximately similar in the depth range below 80 m. The frequency and gracing angle dependency on the TS relation Figure 4.2 makes the comparison at e.g. 40-50 m depth between EK80 and MS70 uncertain. Further, notice that the functionality of PROMUS was updated until this report was made, so there may be some miscalculations.

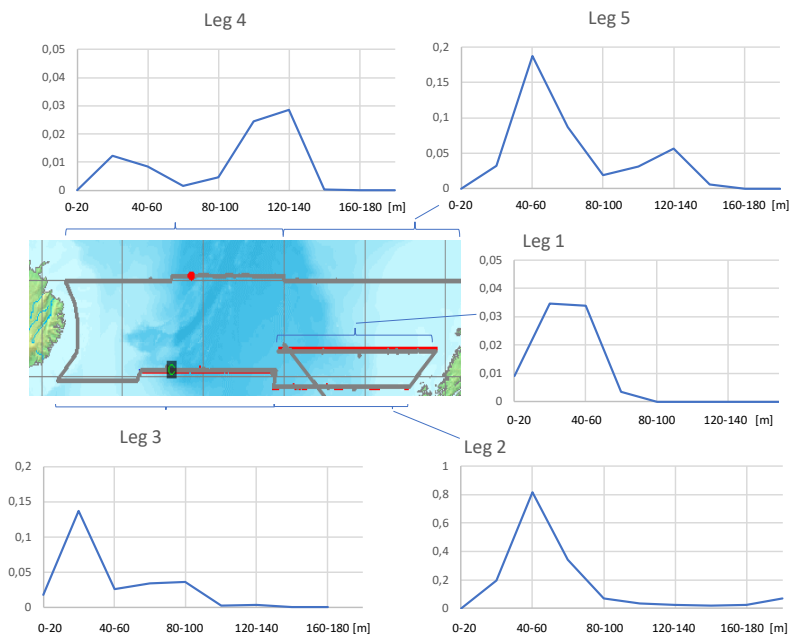

Figure 4.2. Vertical distribution of acoustic backscatter from herring as measured by MS70 onboard FRV "G.O. Sars".

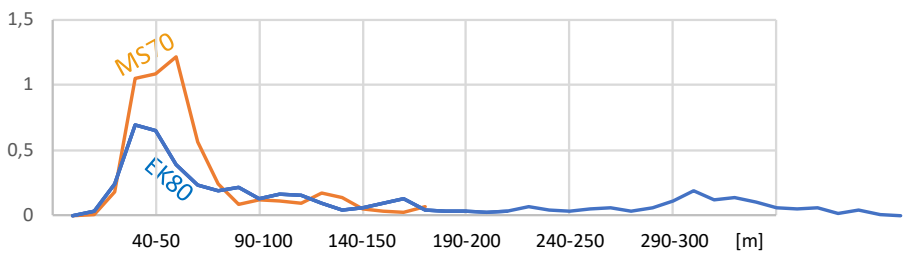

Figure 4.3. Vertical distribution of herring backscatter: EK80, MS70

Although Figures 4.2 and 4.3 are quite simple, they show essentially that there is no need for correcting the acoustic abundance that was measured EK80, at least not in this region.

References:

Korneliussen, R. J., Heggelund, Y., Eliassen, I. K., Øye, O. K., Knutsen, T., and Dalen, J. (**2009**). Combining multibeam-sonar and multifrequency echosounder data: examples of the analysis and imaging of large euphausiid schools," ICES J. Mar. Sci., **66**: 991–997. doi: 10.1093/icesjms/fsp092

Korneliussen, R. J., Heggelund, Y., Macaulay, G. J., Patel, D., Johnsen, E., and Eliassen. (**2016**). Acoustic identification of marine species using a feature library. Methods in Oceanography, **17**, 187–205. doi: 10.1016/j.mio.2016.09.002

Appendix 4

First trial of Deep Vision

Authors: Sindre Vatnehol and Vaneeda Allken.

The Deep Vision is a box-unit mounted between the trawl and the cod-end (Rosen et al., 2013). The unit includes a depth sensor, a computer, lights and a stereo-camera system; and recorded 5 frames/seconds (on each camera). This system was used on all trawl hauls but the last, on the first leg on G. O. Sars; and consequently, more than 2 million pictures were taken. The system can estimate the size of the species by manually identifying the snout and the tail of each fish; but this feature was not used.

This was the first time this system was implemented on a routine survey using personnel without detailed knowledge of the system. The equipment was experienced as easy to operate, but transferring data between unit and a topside computer was slow. Handling the large quantity of files proved to be an issue, i.e. loading the files into the LSSS frequently failed. Suggestions to optimize the operation and data handling were frequently forwarded to the equipment's manufacturer. Also, the issues regarding the Deep Vision unit were characterized as minor.

The picture files and the depth sensor log were loaded into the LSSS system. The information was used to identify the depth at which the fish were caught and whether there were some species too small to be caught by the trawl. We regard this as valuable information when interpreting the echosounder data. Future development, such as identification of empty pictures, automatic target and species detections algorithms and automatic length estimation are appreciated as part of the routine survey.

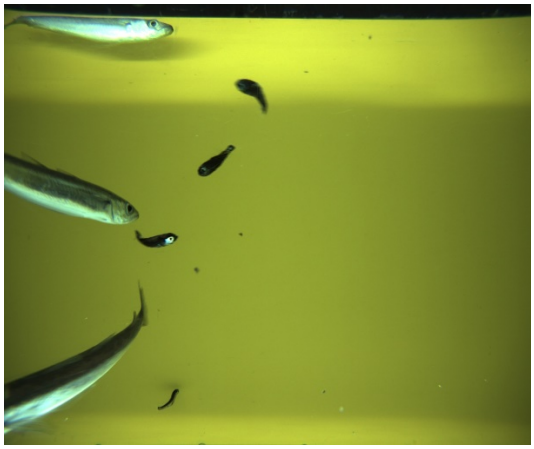

Figure 3 One picture collected from the right-side camera on the Deep-Vision unit.

Rosen, S., Jörgensen, T., Hammersland-White, D., Holst, J. C., and Grant, J. (**2013**). "DeepVision: a stereo camera system provides highly accurate counts and lengths of fish passing inside a trawl," Can. J. Fish. Aquat. Sci., **70**, 1456–1467.

Document 5: HERAS 2018 survey summary table and report

Please see the report on the next page.

Survey Summary table WGIPS 2019

Name of the survey (abbreviation):	HERAS
Target Species:	Herring and sprat
Survey dates:	25 June – 21 July 2018

Summary:

The 2018 survey covered all planned strata and survey effort, timing and coverage were mainly comparable to previous years and all main aggregations of sprat and herring are considered to have been sampled sufficiently. The transect spacing within the two Norwegian strata had to be increased during the survey due to time constraints, and thus varied within the strata. This was handled by using substrata in the StoX analysis.

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 all strata.

Distribution of herring in the North Sea area was similar to recent surveys although both in 2017 and 2018 they did not extend as far south as in previous years. Maturity levels of age 2 herring was very low again this year. This could potentially be due to slightly delayed migration compared to the survey timing as also indicated by the less southerly distribution. Abundance of NSAS herring was largely comparable to recent surveys in the North Sea area.

The WBSS herring abundance estimate was half of last year's estimate, and the abundance estimates of the youngest ages are well below the long-term average.

In the Malin Shelf area herring was found in all but the most southern strata with the majority in the northern part of the area (north of 56°N). In the Malin Shelf area abundance was at the same level as last year but still at one of the lowest levels in the timeseries.

Sprat was also encountered within the expected areas. Abundance estimates in the North Sea and Div. 3.a were both high above the long-term average.

The estimates derived from the 2018 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 (via ICES database) is used to provide indices of abundance. StoX calculated abundances in strata covered by Norway (strata11 and 141) are split by proportion WBSS and NSAS following the Norwegian national method that has been used for the whole time series before being combined with StoX calculated abundances from all other strata.
Random/systematic error issues	No specific issues for this survey outside of those described for standardised acoustic surveys.
Specific survey error issues (acoustic)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*

Bubble sweep down	2018: OK Not generally an issue. During severe weather survey effort was paused in most strata until conditions improved.
Extinction (shadowing)	2018: OK Target species not thought to aggregate in dense enough schools to produce extinction effects.
Blind zone	2018: OK Target species typically not found in large quantities near 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	2018: OK Target species (herring and sprat) typically not distributed tight to seabed, and thus not a problem.
Allocation of backscatter to species	2018: OK Species composition verified by directed trawling. Allocation of backscatter to species mainly using multifrequency algorithms in LSSS and Echoview.
Target strength	2018: OK Standard agreed (TS = 20 log L - 71.2 dB herring and sprat)
Calibration	2018: 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	2018: OK Other surveys often see NSAS herring slightly north of our survey area, but only small amounts assumed not to influence our indices significantly. This is evaluated annually by data from the other surveys.
Stock ID and mixing issues	2018: OK WBSS and NSAS herring mix in the North Sea and Skagerrak-Kattegat, and the stocks are split east of 2°E and north of 56°N. Some WoS and Norwegian spring spawning herring might also be found the North Sea. Work is done to find a common and fast method for assigning each individual to the correct stock.
Measures of uncertainty (CV)	
Biological sampling	2018: OK

	The number of trawl stations, and herring and sprat measured and aged are considered sufficient and at a similar level as earlier 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 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*

The 2018 ICES Coordinated Acoustic Survey in the Skagerrak and Kattegat, the North Sea, West of Scotland and the Malin Shelf area

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

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[2] Wageningen Marine Research, IJmuiden, The Netherlands
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[4] Thünen Institute of Sea Fisheries, Hamburg, Germany
[5] Institute of Marine Research, Bergen, Norway
[6] DTU-Aqua, Hirtshals, Denmark

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

The estimate of North Sea autumn spawning herring spawning stock biomass is higher than previous year at 2.3 million tonnes (2017: 1.9) due to an increase in the number of fish (2017: 11,621 mill. fish, 2018: 12,315) and an increase in weight-at-age for mature herring. The spawning stock is dominated by young fish of age 4 and 5 wr, which is in accordance with the strongest year classes in the 2017 survey.

The 2018 estimate of Western Baltic spring-spawning herring 3+ group is 107,000 tonnes and 745 million. This is a decrease of 52 and 45%, respectively, compared to the 2017 estimates of 221,000 tonnes and 1 353 million fish.

The West of Scotland estimate (6.a.N) of SSB is 152 000 tonnes and 875 million individuals, a small increase compared to the 139 000 tonnes and 765 million herring estimate in 2017.

The 2018 SSB estimate for the Malin Shelf area (6.a and 7.b,c) is 159,000 tonnes and 925 million individuals. This is a about the same level as the 2017 estimates (145,000 tonnes and 798 million herring). There was some herring distribution south of 56°N in 2017-2018; this resulted in a slightly higher estimate for the Malin Shelf compared to the West of Scotland.

There was a sprat benchmark in November 2018 (ICES 2018), resulting in the two sprat stocks in the North Sea and Skagerrak-Kattegat being merged into one. For consistency, the survey results are presented separately in this report for these two areas.

The total abundance of North Sea sprat (Subarea 4) in 2018 was estimated at 120,141 million individuals and the biomass at 834,000 tonnes (Table 5.10). This is nearly 3 times as many sprat as last year, the second highest in the time series and high above the long-term average of the time series, in terms of both abundance (137% above) and biomass (88%). The stock is dominated by 1-year-old sprat (89% in numbers). The estimate also included 0-gr sprat (3% in numbers, and 0.1% in biomass), which only occasionally is observed in the HERAS survey.

In Div. 3.a, the sprat abundance in 2018 is estimated at 3,438 million individuals and the biomass at 33,400 tonnes; the second highest estimate of the time series as for the North Sea. This is well above the long-term

average both in terms of abundance (86%) and biomass (38%). The stock is dominated by 1- and 2-year-old sprat.

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 2018 herring acoustic surveys.

VESSEL	PERIOD	CONTRIBUTING TO STOCKS	STRATA
Celtic Explorer (IRL) EIGB	3 – 21 July	MSHAS, WoS	2, 3, 4, 5, 6
Scotia (SCO) MXHR6	29 June – 19 July	MSHAS,WoS, NSAS, Sprat NS	1, 91 (north of 58°30'N), 111, 121
Johan Hjort (NOR) LDGJ	2 – 17 July	NSAS, WBSS	11, 141
Tridens (NED) PBVO	2 – 20 July	NSAS, Sprat NS	81, 91 (south of 58°30'N), 101
Solea (GER) DBFH	29 June – 19 July	NSAS, Sprat NS	51, 61, 71, 131
Dana (DEN) OXBH	25 June – 10 July	NSAS, WBSS, Sprat NS, Sprat 3.a	21, 31, 41, 42, 151, 152

Methods

Survey design and acoustic data collection

The acoustic surveys were carried out and analysed in accordance with the ICES survey manual for International Pelagic Surveys (ICES 2015) using Simrad EK60 and EK80 echosounders with transducers mounted either on the hull, drop keel or in towed bodies. Only data gathered at 38kHz was used for the analysis. Data collected at other frequencies was used for target discrimination. Echo integration and further data analyses were carried out using either LSSS (Large Scale Survey System), Myriax Echoview or Ev2Akubio software. The survey tracks were selected to cover the whole area with sampling intensities based on the herring densities of previous years. Transect spacing between 10 and 30 nautical miles were used in various parts of the area according to perceived abundance and variance from previous years' surveys (Table 5.18). The survey was designed to be analysed using StoX (StoX 2015) with an internal agreed strata system (Figure 5.1-5.2).

A total of 9617 n.mi of track covered during the survey was used in the acoustic analysis, achieving good coverage of the entire survey area. The transect distance had to be increased slightly from the planned 15 nm due to time constraints in the two Norwegian strata (11, 141). Trawling effort was adequate to achieve good resolution of length distribution and biological parameters in all strata.

The following target strength to fish length relationships were used to analyse the data:

herring TS = 20 log L - 71.2 dB
sprat TS = 20 log L - 71.2 dB

Data analysis

The 2018 disaggregated biological and acoustic data were delivered to the new acoustic survey database held at the ICES data centre and the data was analysed using StoX analysis software.

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 strata (Figure 5.1). The data were combined to provide estimates of the North Sea autumn spawning herring, Western Baltic spring-spawning herring, West of Scotland (6.a.N) herring and Malin Shelf herring stocks (6.a.N-S and 7.b-c) as well as sprat in the North Sea and 3.a.

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 81, 91, 101, 111, 121 in Figure 5.1). East of 2°E and north of 56°N [56.5°N between 2-6°E], in strata 11, 141, 151, 152, 41, 42, 31 and 21, herring is split into North Sea autumn spawners and Western Baltic spring spawners (Figure 5.1). In strata 11 and 141 this is based on analysis of number of vertebrae and in strata 21, 31, 41, 42, 151 and 152 is based on otolith shape analysis.

Western Baltic spring spawning herring (WBSS)

The allocation to the Western Baltic spring spawning stock is partly a geographical assignment and partly a biological assignment based on the vertebrae and otolith shape analysis mentioned above. The stock splitting methodologies are only applied within strata 11, 21, 31, 41, 42, 141, 151 and 152 (Figure 5.1).

Malin Shelf Herring (MSHAS)

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

West of Scotland herring (6.a.N)

This is a subset of the Malin Shelf herring abundance\biomass estimate based purely on geographical location (strata 1 - 4 in Figure 5.1). All herring recorded north of the 56°N line of latitude are reported as West of Scotland (6.a.N). This distinction is kept to maintain a comparable time series of herring abundance to the

West of Scotland. The area North of the 56°N line of latitude has been covered annually since 1991 whereas the extended area (MSHAS index) has only been covered since 2008.

North Sea and Div. 3a sprat

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

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

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

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

Acoustic Survey Results for 2018

The survey strata used for the analysis are shown in Figure 5.1. The area covered during the national acoustic surveys is given in Figure 5.2, and magnitudes of acoustic herring and sprat detections (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-spawners, Western Baltic spring-spawners, West of Scotland, Malin Shelf herring, sprat in the North Sea and Div. 3.a) and the time series of these are given in Figures 5.5-5.10. The time series of abundance for the four herring stocks (North Sea autumn-spawners, Western Baltic spring-spawners, West of Scotland and Malin Shelf herring) are given in Tables 5.6 – 5.9 and illustrated in Figures 5.11 - 5.14, respectively. In each of them, a 3-year running mean is included to show the general trend more clearly.

Herring

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

The estimate of **North Sea** autumn spawning herring spawning stock biomass has increased from 1.9 million tonnes in 2017 to 2.3 million tonnes this year (Table 5.6, Figure 5.11).

The abundance of mature fish has increased slightly from 11 621 million in 2017 to 12 315 this year (Table 5.2). The mean weight of mature fish has increased again from 167.2 g last year to 189.7g. The increased weight combined with the higher number of fish accounts for the increased biomass. The 2012- and 2013- year classes (age 4 and 5 winter ring now) continues to be stronger than the long-term average and accounts for 50% of the stock in this year's survey. The 2014-year class (3 wr in 2018) continues to be below average.

The abundance of immature fish in the stock has increased from 18 434 million in 2017 to 20 290 million this year. This is mainly due to the high number of 1 wr fish this year and partly due to the exceptionally low maturity level of the 2 wr fish this year (Table 5.6, Figure 5.5).

Maturity of 2 winter ringers was at an all-time low at 37%. Maturities for ages 3 and above were comparable to the long-term average, with 91% of 3 winter ringers and 98% or higher maturity for all ages 4 and above. 100% maturity was achieved by age 5 (Table 5.2). The presence of immature fish above age 4 indicates a shift in reporting by the group in 2015. Previously all fish above age 4 have been assumed to be mature. In 2015

however it was agreed that observed maturities would be reported, and it would be left to the assessment working group to decide whether to assume 100% maturity above a certain age.

The distribution of adult herring in the North Sea is still concentrated in the areas east and north of Scotland (Figure 5.3). This year the distribution is slightly further north compared to the previous two years. Substantial aggregations of juvenile herring were encountered around the Dogger Bank area in addition to the usual distribution in the south eastern parts of the North Sea and in Kattegat.

The 2018 estimate of Western Baltic spring-spawning herring 3+ group is 107 000 tonnes and 745 million herring (Table 5.3). This is close to the average since 2008 (730 million herring) after last year's high estimate. The 2017 estimate was the highest level observed since 2008 and comparable to the stock size prior to the low levels observed after 2009. The stock is dominated by 2 and 3 winter ring fish (Table 5.7, Figure 5.6). The numbers of older herring (3+ group) in the stock is on the recent average level but comprise a large proportion of the total stock compared to recent period (69% as compared to an average of 33% for 2009 to 2017). In 2017, mean weights at age were significantly increased for ages 1-3 winter ringers (up by an average of 20%) but returned to old levels in 2018.

The Malin Shelf herring estimate of SSB is 159 000 tonnes and 925 million individuals (Table 5.4), a slight increase compared to the 145 000 tonnes and 798 million herring estimate in 2017. The estimate is still however very low in the time series (Table 5.9, Figure 5.14). In 2018, 96% of the biomass was observed north of 56°N (the geographic area included in the West of Scotland (6.a.N) index) in line with observations through the time series. The West of Scotland (6.a.N) estimate of SSB is 152 000 tonnes and 875 million individuals (Table 5.4), an increase compared to the 139 000 tonnes and 765 million herring estimate in 2017. Long-term indices of abundance per age class for West of Scotland herring are provided in Table 5.8 and Figure 5.7. In 2018, the biomass of herring in 6.a.S and 7.b,c was 7 000 tonnes.

Although there was a slight increase in the 2018 estimates for the Malin Shelf and West of Scotland (6.a.N) compared to 2017, the estimates since 2016 are the lowest in the time series. The distribution of herring schools was similar to 2017 with some herring distributed south of 56°N line of latitude (Figure 5.3a). There were some strong herring marks found to the west and northwest of the Outer Hebrides and around St. Kilda in 2018 again. This year larger aggregations of herring were observed around the Northern end of the Hebrides, around the Butt of Lewis and the North Minch and on Stanton banks. These were predominantly juvenile herring (Figures 5.3 and 5.17). Herring has in the past been found in high densities to the east of the 4°W line 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 no evidence in 2018 that herring distributions in this area influenced the Malin Shelf/West of Scotland estimates. It appears that the increase in the 2017 and 2018 estimates compared to 2016 were a result of a greater spread in the distribution of herring rather than distributions occurring around the 4°W line.

In 2017, 3 to 6 winter ringed fish dominated the index representing 89% of both biomass and total abundance. This year, the 2012- and 2013-year classes (age 4 and 5 winter rings in 2018) are still strong in the stock and comprised 20% of total abundance and 35% of the biomass. In contrast to recent years, a large proportion of the stock was made up of 1 and 2 winter ring fish this year (69% of the total abundance and 44% of total biomass). As 1 winter ring fish are only sporadically picked up in the survey due to their distribution typically being in the more inshore areas it cannot be confirmed yet whether 2016 is a strong year class, but it looks like the 2015-year class (2 winter ringers in 2018) is above average. Age disaggregated survey abundance indices for Malin Shelf herring since 2008 are given in Table 5.9 and Figure 5.8.

Sprat in the North Sea and Div. 3.a

In the North Sea, sprat data were available from strata 51, 61, 71, 81, 91, 101, 131 and 151 (Table 5.17). As in 2015-2016, no sprat were observed in the northern part of the North Sea in strata 11, 111, 121, 141 and 152. Sprat were found in the entire stratum 101 in 2018, whereas in 2015-2017 they were mostly found in coastal

areas. In 2014, no sprat were found in this part of the survey, and the coastal distribution of sprat probably explains some of the high variability in abundances between years. In strata 51, 61, 71 and 21, sprat as in previous years were distributed throughout the whole survey area. Highest sprat densities were measured in the southern part of the survey area (strata 51 and 61). Sprat concentrated in the southern part of the North Sea, with the highest abundances and biomass in an area below 55° N. The southern limit of the surveyed area is at 52° N. There is no indication that the southern limit of the sprat stock distribution has been reached; it is likely that sprat can be found even further south in the English Channel. The sprat distribution in the North Sea and Div. 3.a in terms of abundance and biomass per stratum is shown in Table 5.17. The NASC values attributed to sprat in the survey are shown in Figure 5.4.

The total abundance of North Sea sprat (Subarea 4) in 2018 was estimated at 120 141 million individuals and the biomass at 834 000 tonnes (Table 5.10). This is the second highest in the time series both in terms of abundance and biomass. Compared to the historic high of the time series (the 2016 estimate), abundance and biomass is 4 and 25% lower, respectively (Table 5.11, Figure 5.9). The stock was dominated by 1-year-old sprat (86% of biomass), and most of the sprat were found to be mature (62%) (Table 5.10). The 2018, as the 2014-2016, sprat biomass estimates are all well above the long-term average for the survey time series, whereas the 2017 estimate is 20% lower (Table 5.11).

An age-disaggregated time-series of North Sea sprat abundance and biomass (ICES Subarea 4), as obtained from the acoustic survey, is given in Table 5.11. Note that for 2003, information on the sprat distribution in the North Sea is available from one nation only.

In Div. 3.a, sprat were only found in the Kattegat (stratum 21), as in 2013. In 2014-2017, sprat in stratum 21 dominated the estimate, but very small amounts were also found in the Skagerrak area (stratum 151). The abundance is estimated at 3 438 million individuals, nearly 14 times as many as the 248 million individuals in 2017 (Tables 5.12-5.13). The biomass was about 8 times as high, at 33 400 tonnes. 1-year-old sprat dominate the stock (61% in numbers and 53% in biomass), while also the 2-group was a large proportion of the stock. The age-disaggregated time-series of sprat abundance and biomass in Div. 3.a are given in Table 5.13 and Figure 5.10. The sprat distribution in the North Sea and Div. 3.a in terms of abundance and biomass per stratum is shown in Table 5.17. The NASC values attributed to sprat in the survey are shown in Figure 5.4.

Quality considerations

The 2018 HERAS global survey estimates of abundance were calculated using StoX, with input files (XML) mostly generated via the ICES Acoustic database. 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. At the present Norwegian data is missing in the database, but it is expected that the Norwegian data from 2016 onwards will be uploaded in 2019.

Scrutiny of Danish acoustic data

In the Danish survey scrutiny is only taken to the level of distinguishing between fish or not fish, and the echo traces are then partitioned based entirely on composition of trawl catches. This approach is not compatible with best practice anymore and it should be possible to use modern acoustics species discrimination techniques to apply a more specific allocation. At WGIPS 2017 a scrutiny exercise with all participants was carried out for Danish data, and there was general agreement that it is possible to standardise Danish scrutiny methods to align with those used by other participants in most of the area. However, in the deepest part of the area covered by Denmark (strata 41 and 152) fish does not tend to school even in daytime and herring is found mixed with other species in layers. The group notices that issues such as different catchability of species, height

of trawl compared to thickness of the water column sampled and the validity of the TS values for some of the less studied species all add to the uncertainty in partitioning the echoes and this method should only be used when there is no other alternative, i.e. when species level scrutiny is not possible due to herring an sprat occurring in truly inseparable mixed aggregations.

Stock splitting methods

At present two different methods are used within the survey to assign herring in the splitting area (otolith microstructure: strata 21, 31, 41, 42, 151, 152, vertebrae count: 11, 141) to the North Sea autumn spawning stock or the Western Baltic spring spawning stock. These methods have been developed independently within national laboratories but have not been calibrated against each other so far. To ensure resilience in the consistency over the time series, the two methods should be calibrated against each other. Ideally, the method should be standardised across the surveys to use one common method for all splitting between the two stocks.

Recently Germany has also conducted analysis of otoliths to deduct stock membership of herring in the southern area. Only very small amounts of spring spawners have been found during this exercise (2 in 2015, 1 in 2016, 3 in 2017, 1 in 2018).

The method used by Norway does not provide stock information at the individual fish level and it is therefore not possible at the present, to analyse the Norwegian component of the survey within an overall StoX project for the two herring stocks. This means that at the present time it is still not possible to routinely produce uncertainty estimates for the herring stocks.

An ICES workshop to address this issue and to provide guidance on data collection and analysis of this survey was carried out in November 2017 (WKSIDAC: ICES 2017b). Although progress was made towards unifying the methods in this workshop the practical guidance aspect was deferred to recommending a further workshop on this topic.

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

It should also be mentioned that Norwegian spring spawning herring is occasionally encountered in very small quantities in the most northern part of the survey area and this should be considered in a future splitting scenario.

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.

Survey uncertainty

The use of the StoX software for survey abundance estimation, concurrent availability of disaggregated survey data, and application of a transect-based approach allows for an estimate of survey uncertainty. However, until such time as issues with the stock splitting methodology mentioned above is fully addressed, the StoX software cannot be used to fully complete the estimation of abundance of each stock and therefore uncertainty estimation is not possible at the present.

Stock containment

The last few years, herring has been observed in the most northern HERAS transects, indicating that North Sea herring is now distributed further north than the area covered by the HERAS survey. Other surveys covering the area north of the HERAS area have also detected small amounts of herring in recent years. To ensure containment of North Sea herring in the northern part of the HERAS survey we suggest to use data from summer surveys covering the most northern part of the North Sea and areas further north. In particular, the Norwegian acoustic saithe survey (NORACCU) 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. NORACCU allocate herring for the acoustics, but since herring is not the target species there are no targeted hauls. The trawl hauls targeting saithe though occasionally have good samples of herring, and this survey thus can be used to add an exploratory stratum North of the northern boundary of if the HERAS to monitor the containments (or lack thereof) of North Sea herring.

EK80 vs EK60

During this survey, two vessels used the EK80 system in Continuous Wave mode (CW, i.e. narrow band): RV Solea from Germany and RV Johan Hjort from Norway. Because the EK80 CW is relatively new, the performance of this system is currently under scrutiny. Previous research showed that the results from the EK60 and the EK80 CW are comparable (Demer et al. 2017, ICES 2017a); however, it is important to monitor the quality of the results produced by the EK80 system while the system is being used by more countries as the successor to the EK60. Performance was evaluated by considering the consistency of the calibration using the standard spheres method (Demer et al. 2015, Foote et al. 2007). Results for both vessels are presented in Table 5.19 and Figure 5.18. It was observed that the rms error in this experiment is small (< 1dB) and that the S_a correction is minor. Macaulay et al. (2018) recently investigated in depth the performances of the EK60 and the EK80 CW. This was done using ping to ping data collected in 2016 by FRV Tridens II and FRV G.O. SARS (Norway) during the IBWSS survey (Blue Whiting). This work shows that the magnitude of variability between the two systems are smaller than the stochastic variation expected from echosounders. Further investigations have been carried out from the data collected by FRV Tridens II during the HERAS 2017 and 2018 surveys in a similar fashion to Macaulay et al. (2018) and resulted similarly without significant differences. WMR (Netherlands) has also decided to switch to EK80 after addressing some vessel-specific electronic issues.

Recommendations:

1) Efforts to further standardise the HERAS survey should continue. Scrutinization in the Danish survey should be reviewed and where possible brought into line with the procedures used by the rest of the survey group.

2) Include an exploratory stratum covered by NORACCU to the North of stratum 111 to monitor stock containment to the north and investigate whether it is necessary to expand the survey area further north.

3) Norwegian data from 2016 onwards will be uploaded to the ICES database in 2019.

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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 2018. Mean weights, mean length and fraction mature by age winter ring.

Age (ring)	Numbers	Biomass	Maturity	Weight(g)	Length (cm)
0	7,480	39	0.00	5.2	8.9
1	9,938	401	0.01	40.3	17.2
2	4,254	392	0.37	92.3	22.0
3	1,692	246	0.91	145.4	25.2
4	5,150	991	0.98	192.4	27.2
5	2,440	546	1.00	223.8	28.5
6	719	164	1.00	228.0	28.8
7	529	127	1.00	240.1	29.3
8	293	80	1.00	272.1	30.3
9+	111	30	1.00	272.9	30.4
Immature	20,290	679		33.5	14.7
Mature	12,315	2,337		189.7	27.0
Total	32,606	3,016	0.38	92.5	19.4

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 2018. Numbers, biomass, mean weights and mean length and by winter ring.

Age (ring)	Numbers	Biomass	Weight (g)	Length (cm)
0	0	0		
1	106	4	42.0	17.4
2	224	19	82.9	21.6
3	271	28	104.6	23.5
4	175	25	145.4	25.6
5	169	28	164.9	26.5
6	50	9	172.6	27.3
7	35	7	187.3	27.9
8+	44	10	236.4	29.6
3+	745	107	144.1	25.5
Total	1,075	130	121.3	23.9

Table 5.4. Total numbers (millions) and biomass (thousands of tonnes) of autumn spawning West of Scotland herring in the area surveyed in the acoustic surveys July 2018. Mean weights, mean lengths and fraction mature by winter ring.

Age (ring)	Numbers	Biomass	Maturity	Weight (g)	Length (cm)
0	294	0.7	0.00	2.5	6.6
1	964	46.1	0.00	47.8	17.5
2	323	35.5	0.48	110.0	22.9
3	92	14.3	0.91	155.0	25.6
4	331	58.2	0.98	176.1	26.8
5	153	29.0	0.98	190.1	27.5
6	51	10.6	1.00	209.7	28.7
7	72	15.1	1.00	209.4	28.8
8	27	5.8	1.00	218.0	29.1
9+	13	2.8	1.00	222.2	29.3
Immature	1443	67		46.1	16.0
Mature	875	152		173.2	26.6
Total	2318	218	0.38	94.1	20.0

Table 5.5. Total numbers (millions) and biomass (thousands of tonnes) of Malin Shelf herring (6.a.N-S, 7.b,c) June-July 2018. Mean weights, mean lengths and fraction mature by winter ring.

Age (ring)	Numbers	Biomass	Maturity	Weight (g)	Length (cm)
0	294	0.7	0.00	2.5	6.6
1	1289	64.2	0.00	49.8	17.7
2	447	47.9	0.40	107.0	22.7
3	106	16.2	0.85	152.1	25.4
4	343	60.2	0.98	175.8	26.8
5	153	29.1	0.98	190.0	27.5
6	52	10.8	1.00	208.8	28.6
7	72	15.1	1.00	209.4	28.8
8	27	5.8	1.00	218.0	29.1
9+	13	3.0	1.00	224.4	29.4
Immature	**1872**	**95**		**50.5**	**16.7**
Mature	**925**	**159**		**171.4**	**26.5**
Total	**2797**	**253**	**0.33**	**90.5**	**19.9**

Table 5.6. Estimates of North Sea autumn spawners (millions) at age and SSB from acoustic surveys, 1986–2018. 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 2018 estimates are from summer surveys in Div. 4.a-c and 3.a excluding estimates of Western Baltic spring spawners. 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

Table 5.7. Numbers at age (millions) of Western Baltic spring spawning herring at age (winter rings) from acoustic surveys 1992 to 2018. 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

Table 5.8. Numbers at age (millions) and SSB (thousands of tonnes) of West of Scotland autumn spawning herring at age (winter rings) from acoustic surveys 1993 to 2018. 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	1031	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

Table 5.9. Numbers at age (winter rings, millions) and SSB (thousands of tonnes) of the Malin Shelf acoustic survey (6.a.N-S, 7.b,c) time series from 2008 to 2018. This table was 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

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 2018 North Sea acoustic survey (HERAS).

Age	Abundance (million)	Biomass (1000 t)	Mean weight (g)	Mean length (cm)
0i	3 409	1.2	0.3	3.9
1i	37 938	189.0	5.0	8.6
1m	69 145	528.0	7.6	9.9
2i	27	0.2	5.8	9.0
2m	9 034	106.3	11.8	11.5
3i				
3m	447	7.2	16.1	13.0
4m	122	2.2	17.8	13.3
5m	19	0.3	17.0	13.0
6m				
Immature	**41 374**	**190.3**	**4.6**	**8.2**
Mature	**78 767**	**644.0**	**8.2**	**10.1**
Total	**120 141**	**834.3**	**6.9**	**9.5**

Table 5.11. Sprat in the North Sea (ICES Subarea 4): Time-series of abundance and biomass as obtained from the summer North Sea acoustic survey (HERAS) time series 2000-2018. 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
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 2018 North Sea acoustic survey (HERAS).

Age	Abundance (million)	Biomass (tonnes)	Mean weight (g)	Mean length (cm)
0i	81	229	2.8	7.5
0m	17	57	3.4	8.0
1i	154	543	3.5	7.9
1m	1943	17 171	8.8	10.3
2i				
2m	1052	11 713	11.1	11.2
3m+	191	3 697	19.4	13.9
Immature	236	772	3.3	7.7
Mature	3202	32 637	10.2	10.8
Total	3438	33 409	9.7	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 2006-2018.

	Abundance (million)					Biomass (1000 t)				
Year/Age	0	1	2	3+	Sum	0	1	2	3+	Sum
2018	98	2 097	1 052	191	3 438	0.3	17.7	11.7	3.7	33.4
2017	0	11	146	91	248	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 by stratum, last year and present survey. Stratum numbers correspond to numbering in Figure 5.1.

	2017				2018			
Strat.	Abundance (mill)	Biomass (kt)	Mean weight (g)	% Mature	Abundance (mill)	Biomass (kt)	Mean weight (g)	% Mature
11	1 186	194	163.2	76	327	69	211.2	96
21	125	4	31.9	0	841	6.9	8.2	0.5
31	110	6	57.0	2	193	8.7	45.1	2.9
41	142	9	64.1	2	60	5.6	92.9	5.3
42	50	3	51.7	1	84	6.2	73.8	2.8
51	3 325	10	3.1	0	4158	23.7	5.7	0.0
61	10 603	37	3.5	0	2326	17.7	7.6	0.0
71	285	5	18.2	0	395	4.7	11.9	0.0
81	715	54	75.5	48	4475	197.7	44.2	0.3
91	6 871	950	138.2	85	7850	864.1	110.1	53
101	155	9	57.5	6	337	7.9	23.4	0.0
111	3 093	602	194.6	98	6546	1373.9	209.9	97
121	1 301	250	192.5	99	1279	268.0	209.6	99
131	1 289	32	25.1	0	3080	106.8	34.7	0.0
141	586	64	108.7	39	229	34	147.5	60
151	135	4	30	0	319	11.6	36.3	0.3
152	82	5	62.2	4	108	9.7	89.9	13

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.

	2017			2018		
Stratum	Abundance (mill)	Biomass (kt)	Mean weight (g)	Abundance (mill)	Biomass (kt)	Mean weight (g)
11	265	46	174.8	16	2	204.4
21	98	4	37.4	67	4.4	64.8
31	100	6	63.6	211	18.0	85.3
41	135	9	70.1	102	10.6	104.4
42	46	2	52.8	63	5.2	81.3
141	251	38	150.0	67	8	154.5
151	213	6	30.2	92	3.9	42.3
152	112	8	74.9	129	15.1	116.3

Table 5.16. Malin shelf and 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 *.

	2017					2018				
Stratum	Abundance (mill)	Biomass (kt)	CV	Mean weight (g)	% Mature	Abundance (mill)	Biomass (kt)	CV	Mean weight (g)	% Mature
1*	304	57	-	188.6	100	1218	82.8		68.0	0.16
2*	0	0	-	-	-	332	2.5		7.5	0.00
3*	293	54	-	185.6	100	522	96.8		185.5	0.98
4*	168	28	-	165.0	100	247	36.1		146.3	0.71
5	36	6	-	165.0	100	478	34.9		73.0	0.10
6	0	0	-	-	-	0	0.0		-	-

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.

		2017				2018			
ICES area	Stratum	Abundance (mill)	Biomass (t)	Mean Weight (g)	% Mature	Abundance (mill)	Biomass (t)	Mean Weight (g)	% Mature
Div. 3.a	21	256	4 223	16.5	100%	3 438	33 409	9.7	93%
	31	0	0	-	-	0	0	-	-
	41	0	0	-	-	0	0	-	-
	42*	0	0	-	-	0	0	-	-
North Sea	11	0	0	-	-	0	0	-	-
	51	27 874	191 881	6.9	51%	62 624	457 761	7.3	65%
	61	9 540	65 232	6.8	65%	41 663	272 339	6.5	64%
	71	1 583	15 234	9.6	88%	3 441	32 623	9.5	89%
	81	768	11 492	15.0	100%	1 821	13 430	7.4	80%
	91	0	0	-	-	3 885	2 276	4.5	9
	101	113	1 206	10.6	85%	5 669	42 816	7.6	100%
	111	0	0	-	-	0	0	-	-
	121	0	0	-	-	0	0	-	-
	131	6 025	68 315	11.3	98%	1 022	11 650	11.4	100%
	141	0	0	-	-	0	0	-	-
	151	52	706	13.5	100%	16	235	14.3	99%
	152*	0	0	-	-	0	0	-	-

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

Table 5.18. Length of track used in analysis, number of fish ages used in estimates and transect spacing for each stratum in the 2017 and 2018 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.

	2017				2018			
Stratum	Total transect length (nmi.)	Herring ages	Sprat ages	Transect spacing (nmi.)	Total transect length (nmi.)	Herring ages	Sprat ages	Transect spacing (nmi.)
1	518	297	-	15	589	723	-	15
2	90	0	-	-	184	33	-	-
3	167	150	-	15	292	778	-	15
4	125	100	-	15	265	170	-	15
5	153	100	-	15	256	150	-	15
6	124	100	-	15	188	0	-	15
11	907	1026	-	15	715	500	0	15-18.75
51	595	393	676	25	600	603	676	25
61	248	239	338	23	243	327	338	23
71	328	421	343	17.5	303	184	343	17.5
81	575	125	88	30	477	239	88	30
91	1532	1367	22	15	1609	1195	22	15
101	96	45	21	15	95	40	21	15
111	1042	1196	-	10	701	965	0	15
121	413	344	-	15	431	578	0	15
131	614	415	345	30	610	276	345	30
141	1243	497	0	15	1106	450	0	15-24
21	190	635	391	13	151	481	391	13
31	138	357	-	10	147	355	-	10
41	141	697	-	17.5	155	826	-	17.5
42	70	355	-	17.5	85	489	-	17.5
151	328	720	71	15	341	956	71	15
152	80	362	0	15	73	550	0	15

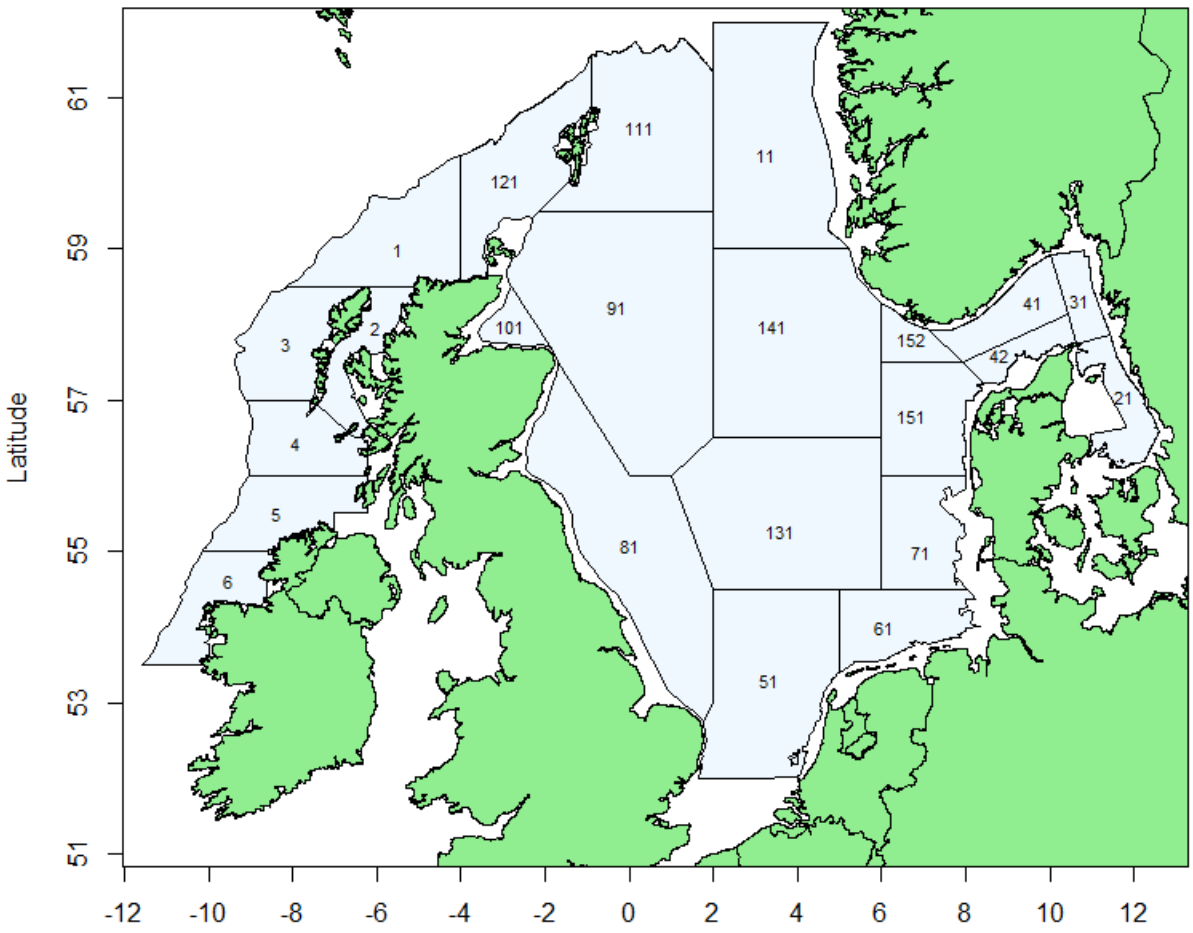

Figure 5.1. Strata used in the HERAS survey 2018.

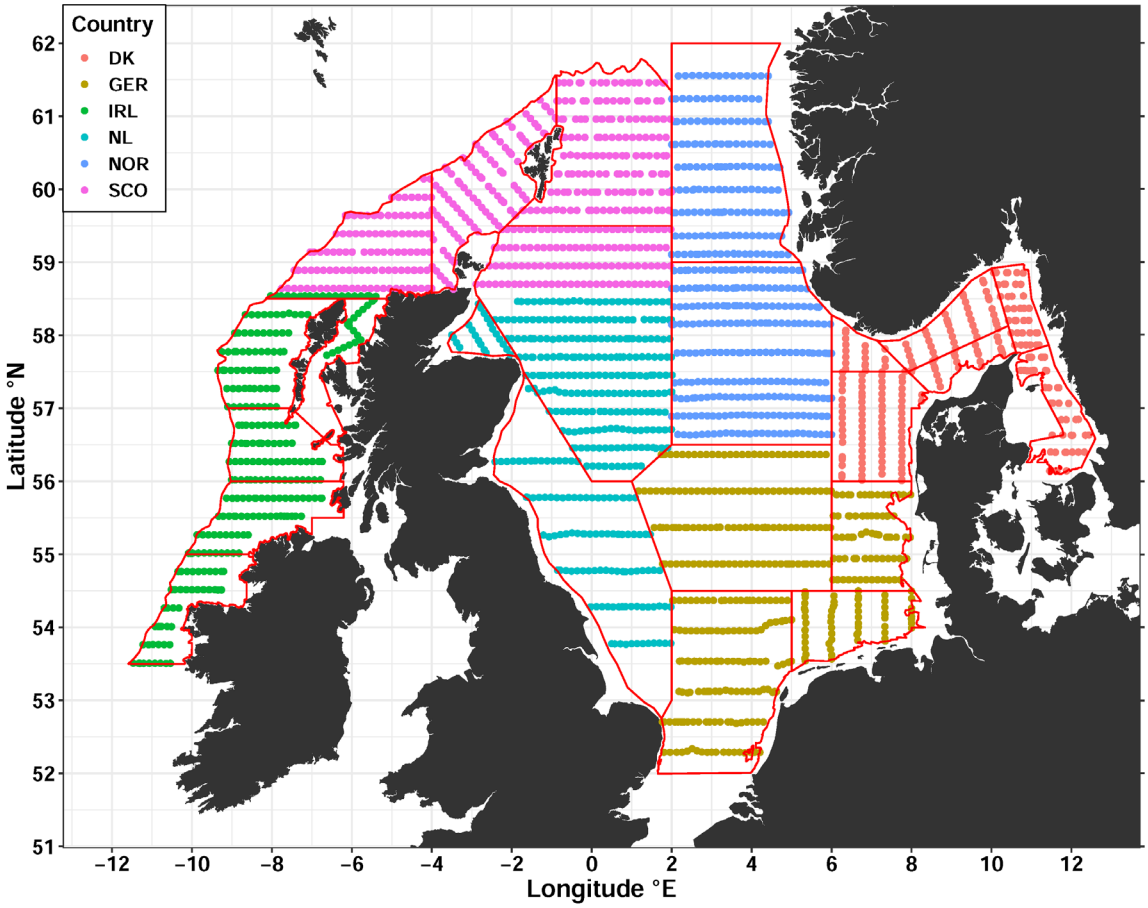

Figure 5.2. Survey area coverage in the HERAS survey in 2018 and individual vessel tracks by nation.

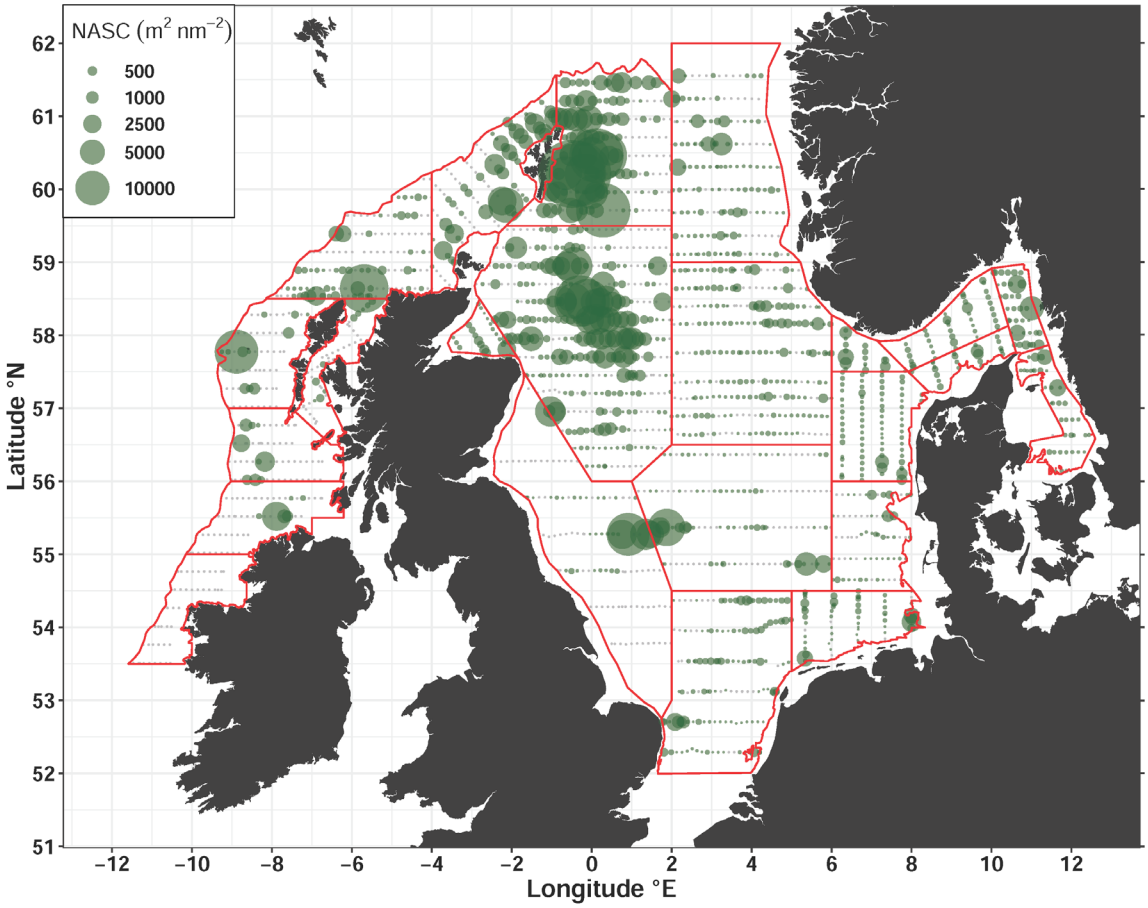

Figure 5.3. Distribution of NASC attributed to herring in HERAS in 2018. Acoustic intervals represented by light grey dot with green circles representing size and location of herring aggregations. NASC values are resampled at 5 nmi. intervals along the cruise track. The red lines show the strata system.

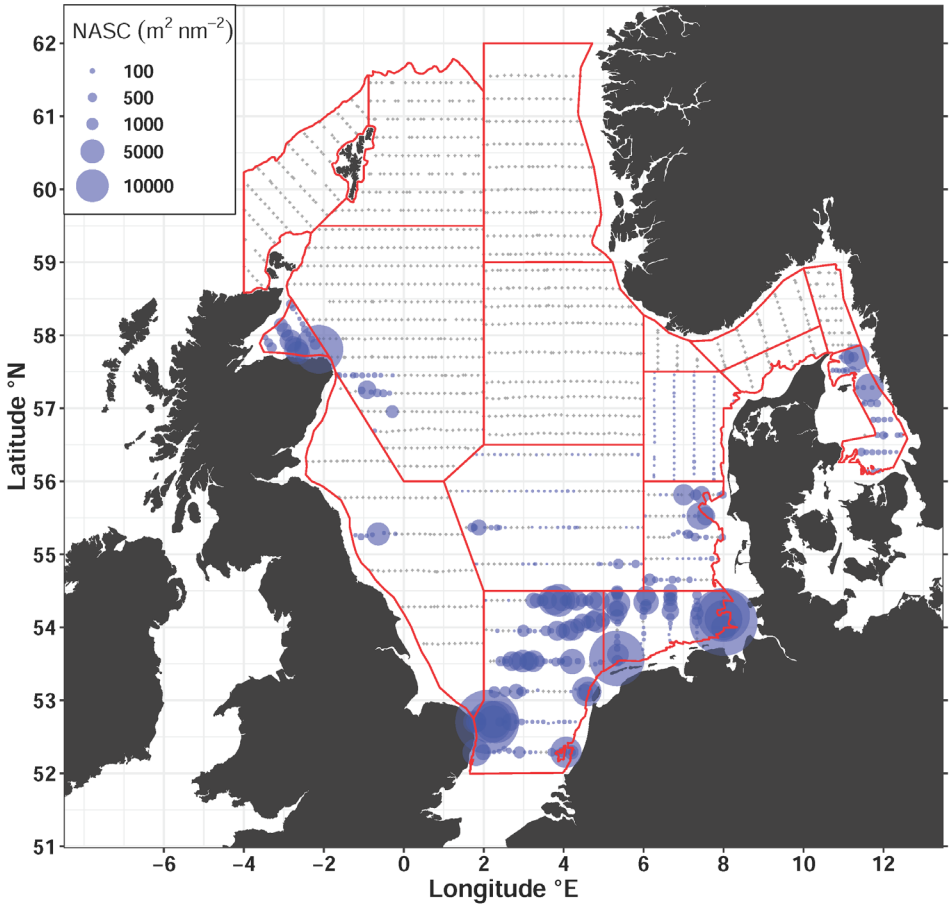

Figure 5.4. Distribution of NASC attributed to sprat in HERAS in 2018. Acoustic intervals represented by light grey dot with blue circles representing size and location of sprat aggregations. NASC values are resampled at 5 nmi. intervals along the cruise track. The red lines show the strata system.

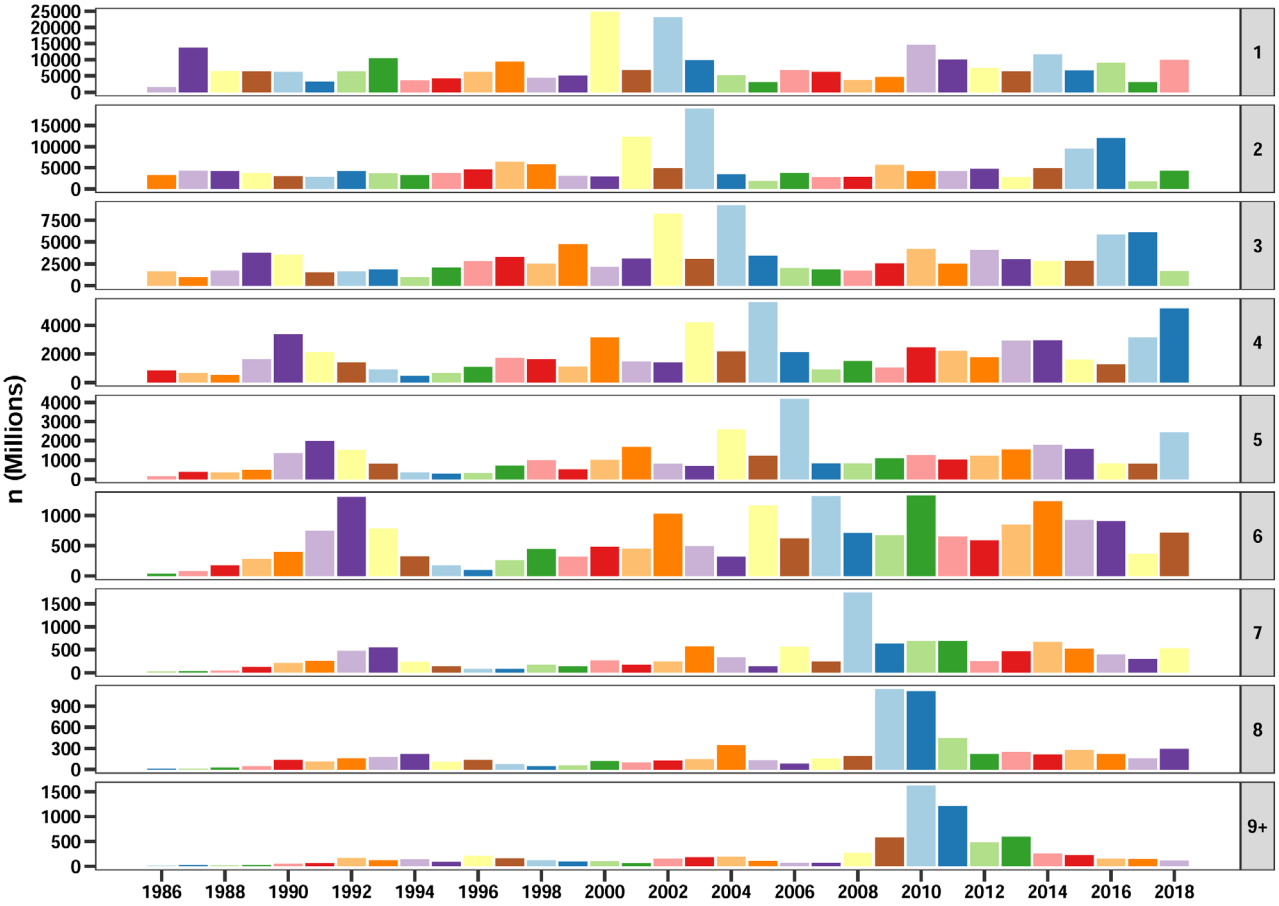

Figure 5.5. North Sea autumn spawning Herring: HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 1986-2018. Note diverging scales of abundance between ages.

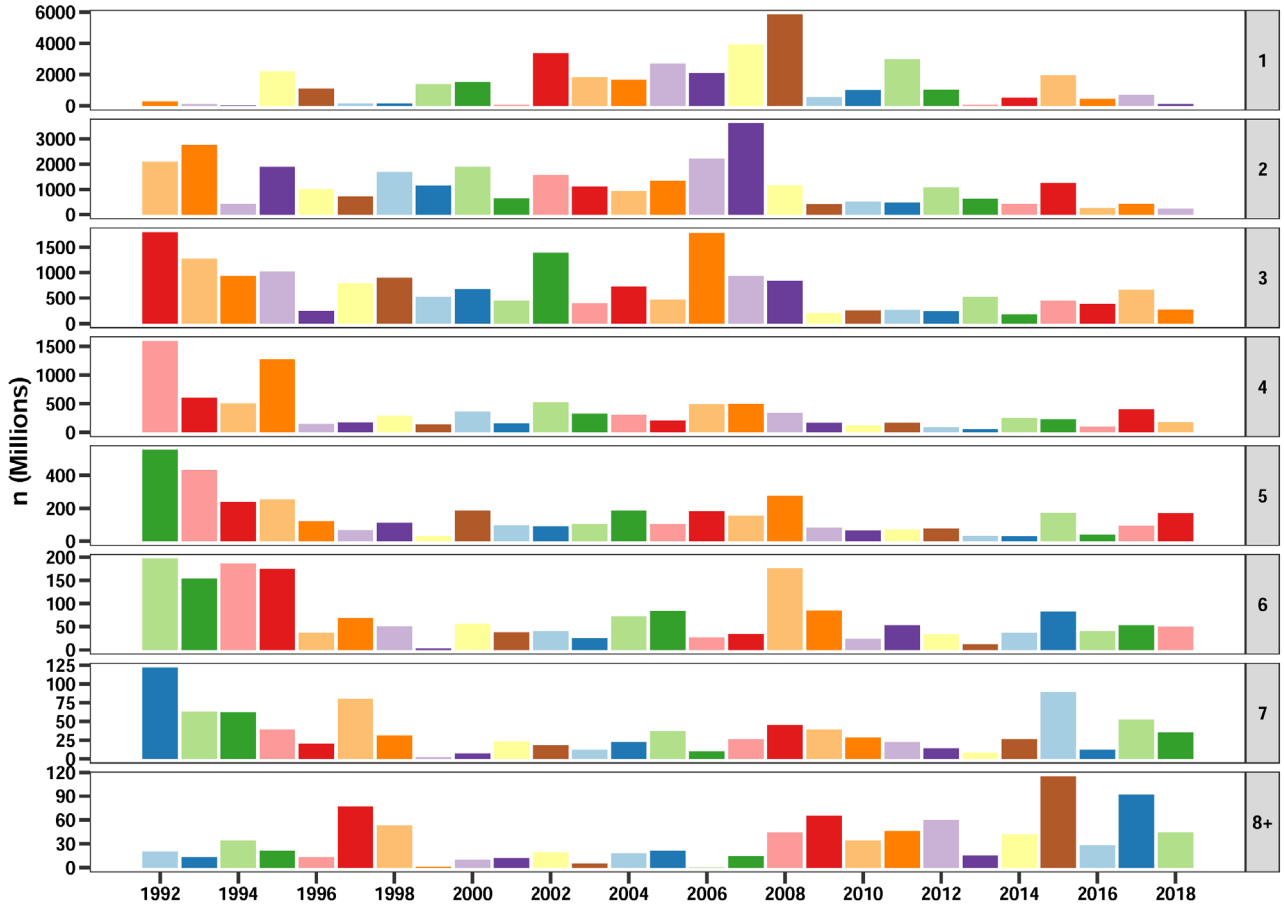

Figure 5.6. Western Baltic spring spawning Herring: HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 1992-2018. Note diverging scales of abundance between ages.

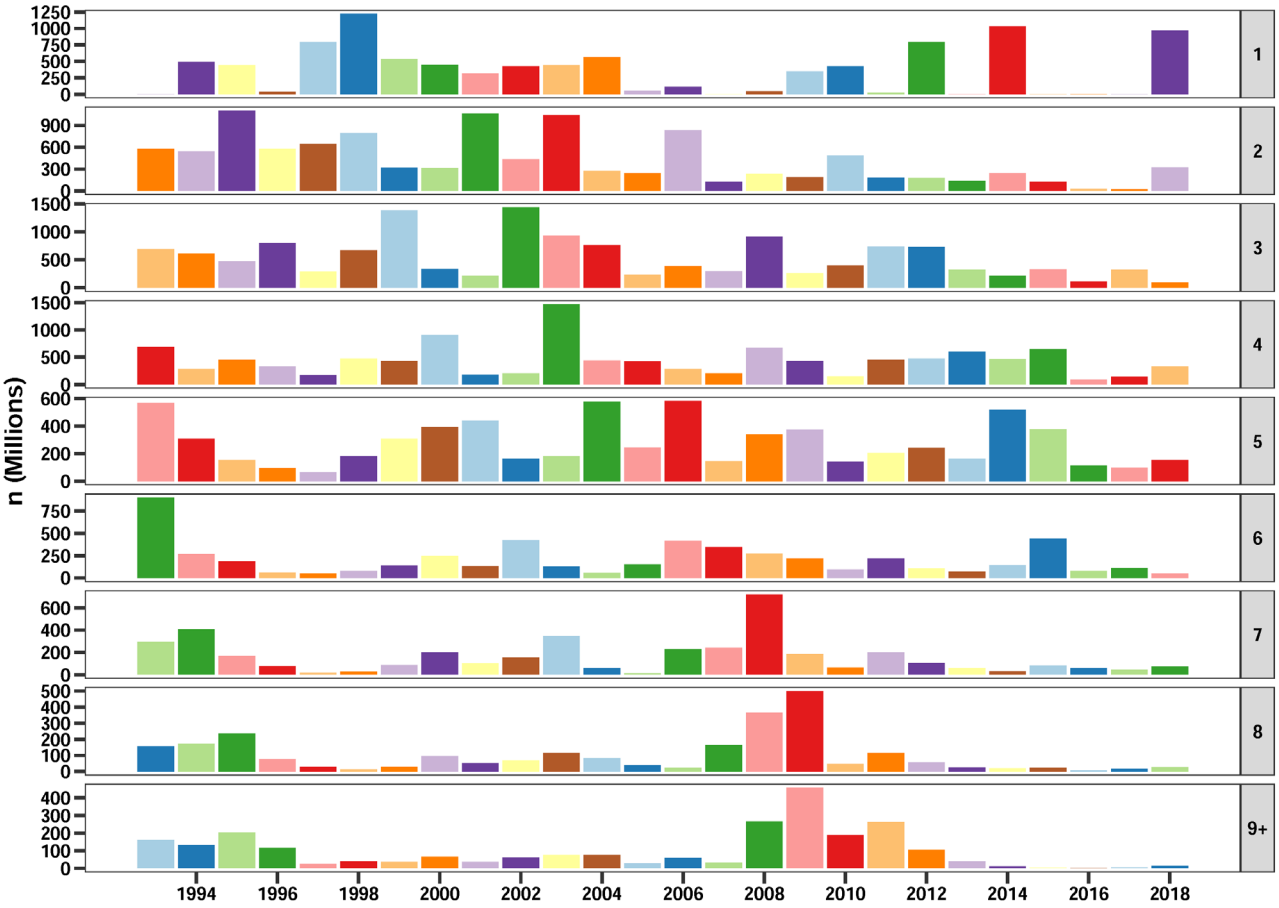

Figure 5.7. West of Scotland (6.a.N) autumn spawning herring: HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 1993-2018.

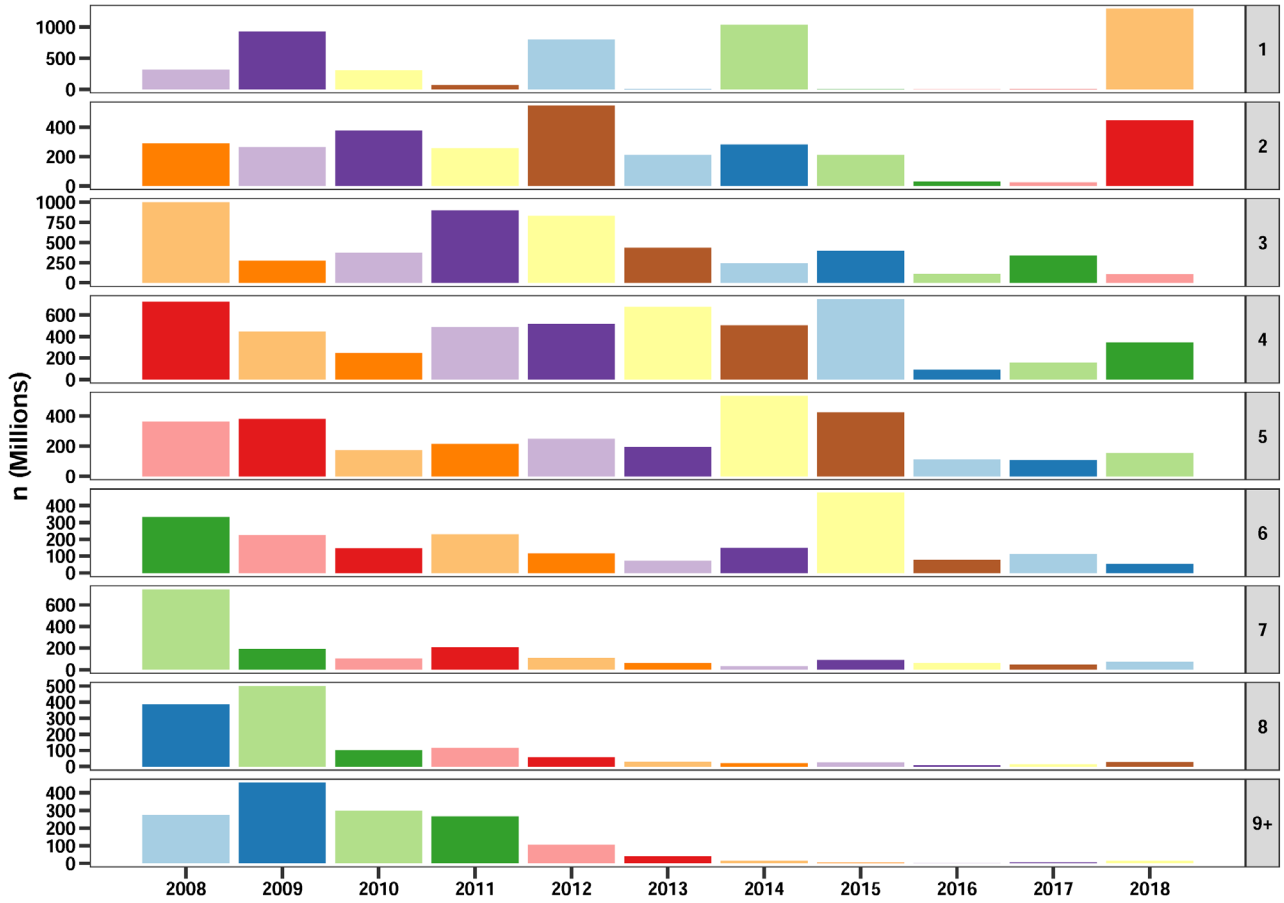

Figure 5.8. Malin Shelf Herring (6.a.N-S, 7.b,c): HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 2008-2018.

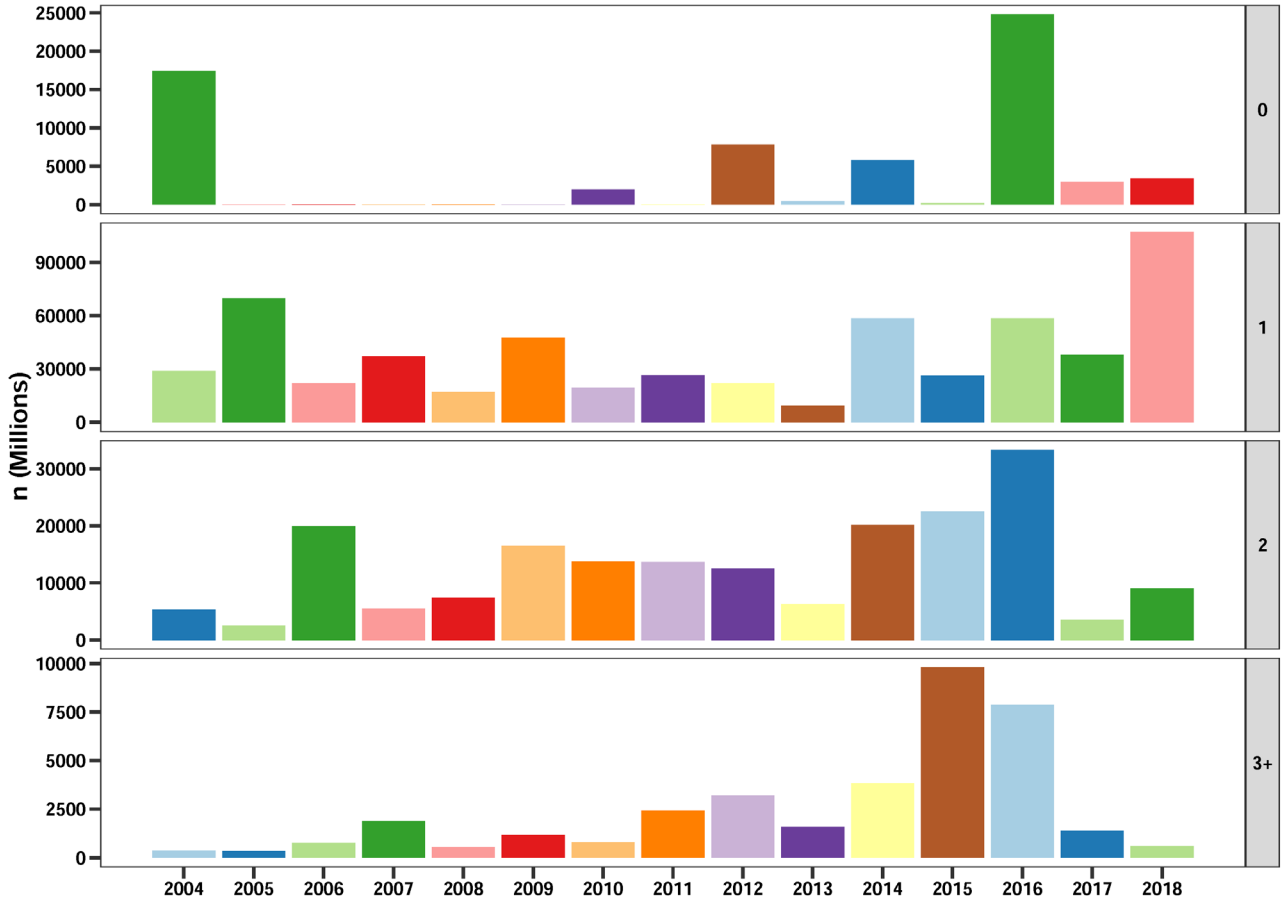

Figure 5.9. North Sea Sprat: HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 2004-2018. Note diverging scales of abundance between ages.

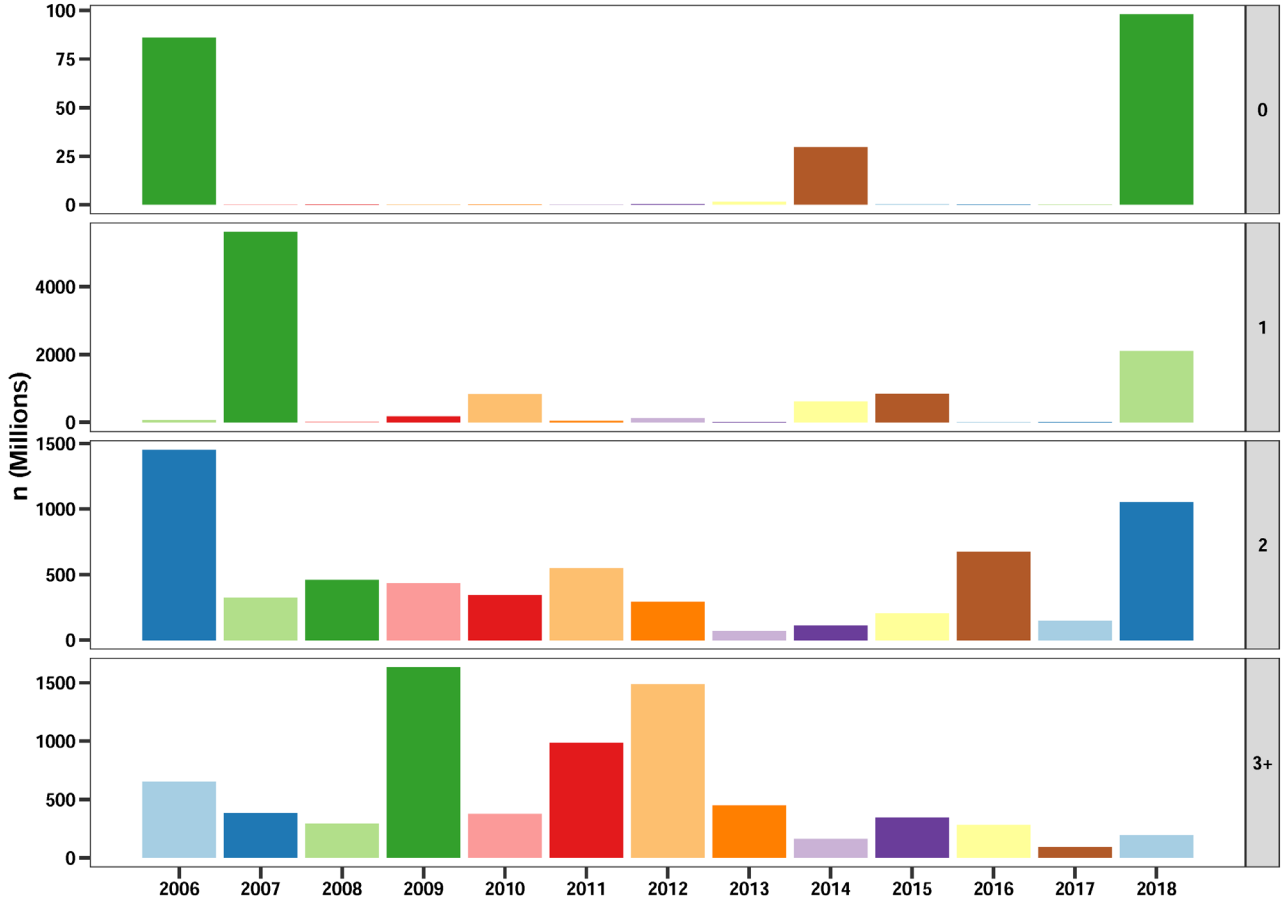

Figure 5.10. Sprat in Div. 3.a: HERAS indices (millions) by age (winter rings, panels) and year from the acoustic surveys 2006-2018. Note diverging scales of abundance between ages.

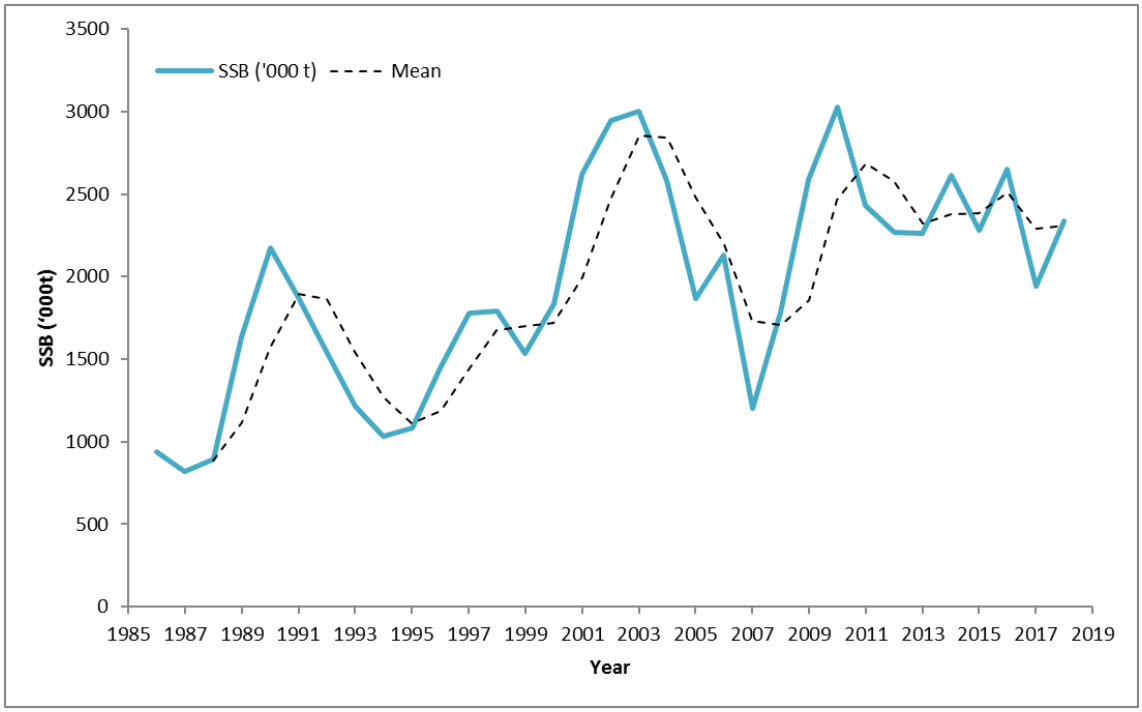

Figure 5.11. Time series of SSB of North Sea autumn spawning herring with three year running mean.

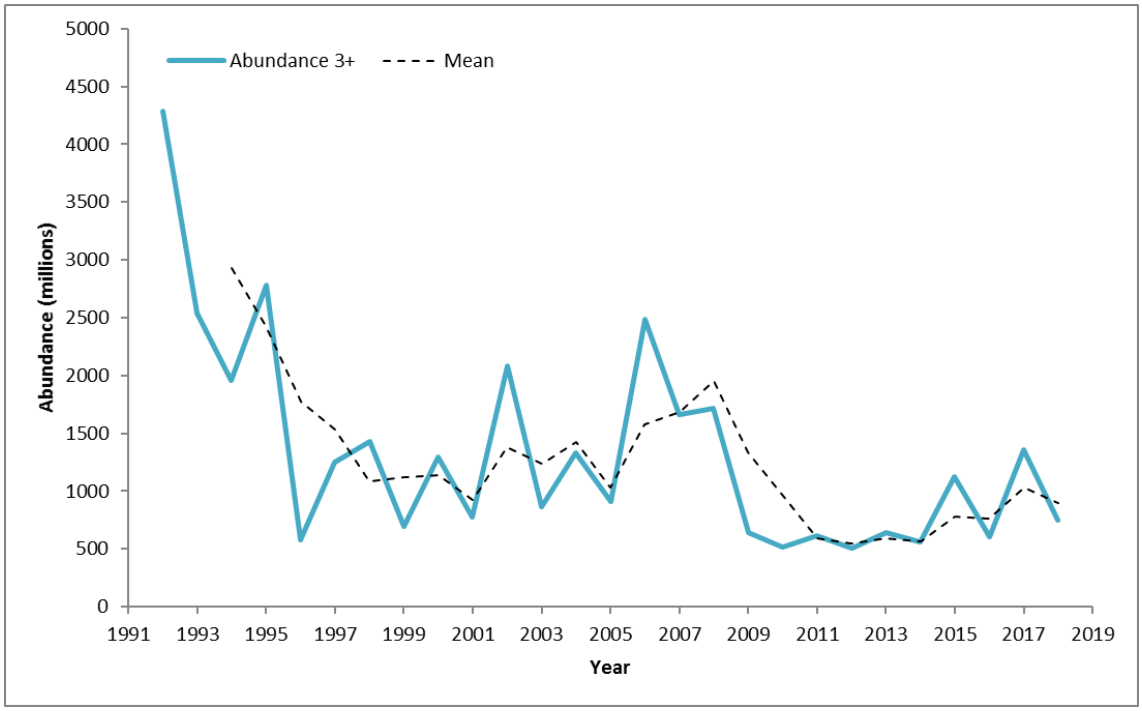

Figure 5.12. Time series of 3+ abundance of Western Baltic spring-spawning herring with three year running mean.

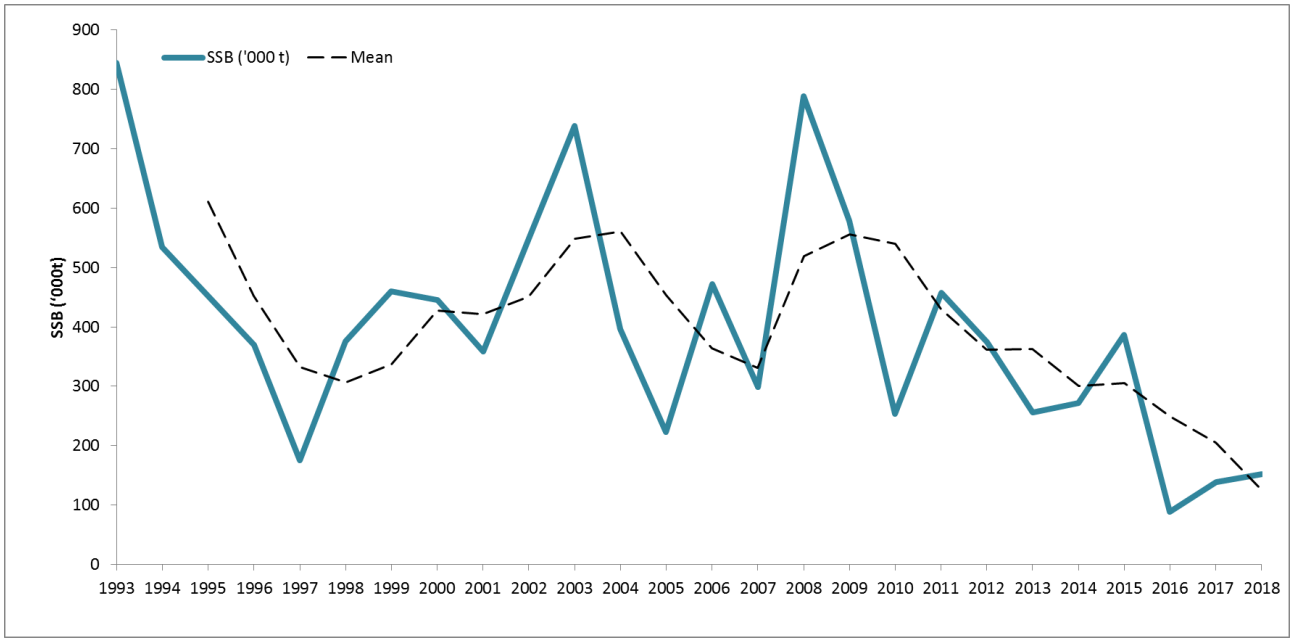

Figure 5.13. Time series of SSB of West of Scotland herring (geographical subset of Malin Shelf herring) with three year running mean.

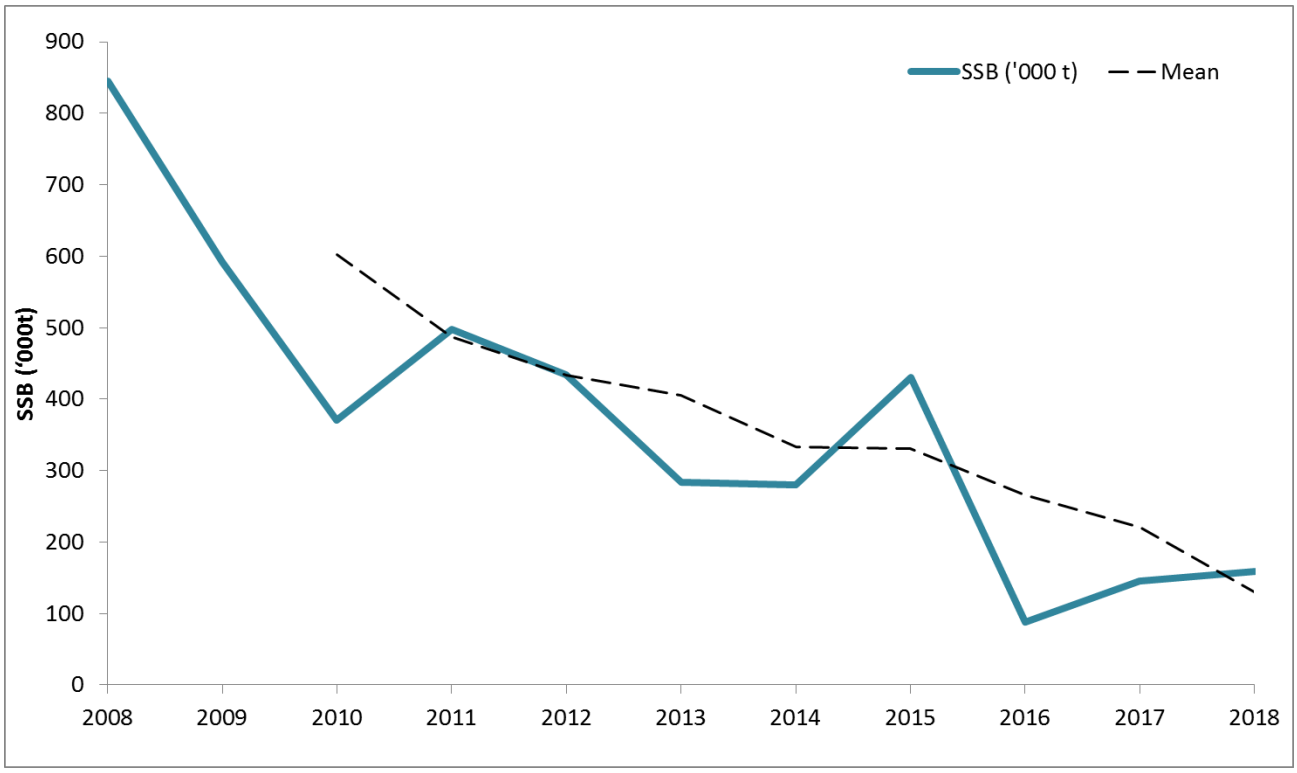

Figure 5.14. Time series of SSB of Malin Shelf herring with three year running mean.

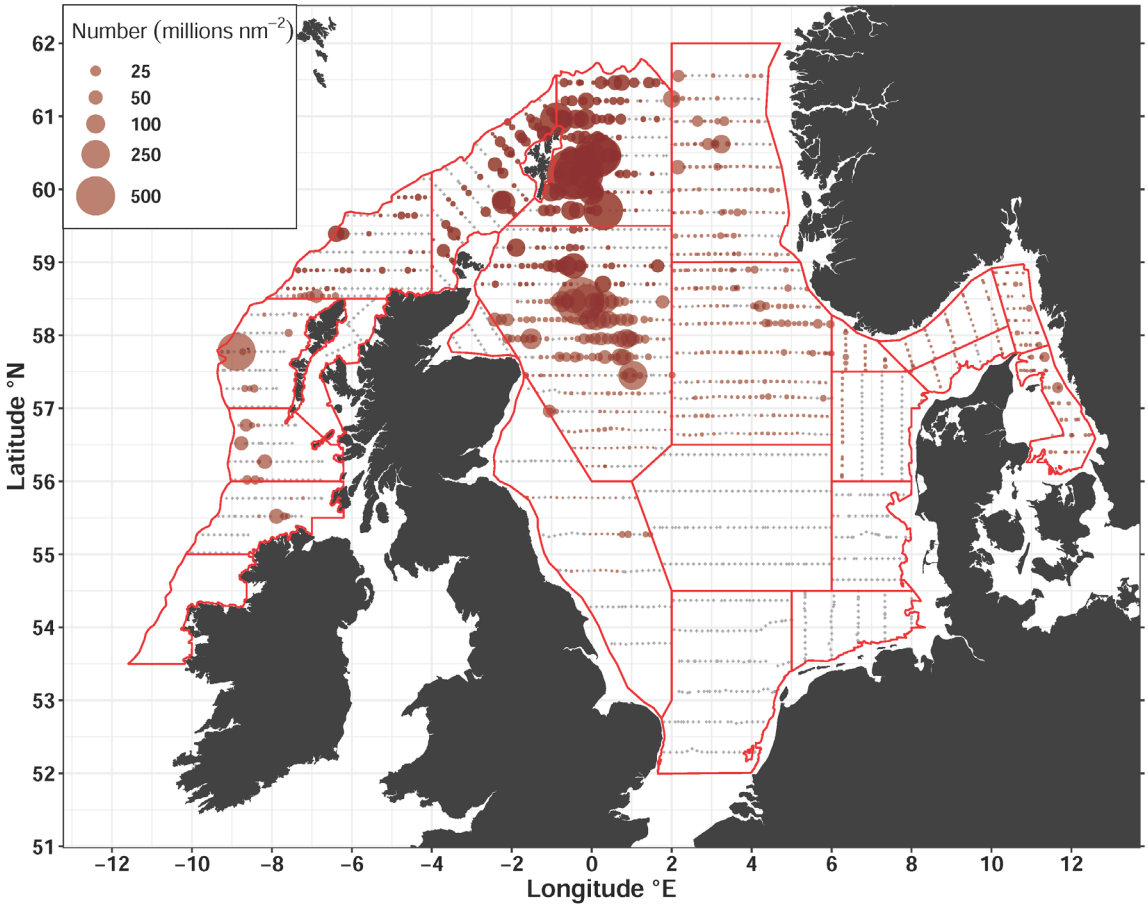

Figure 5.16. Distribution of mature herring in 2018 (n in millions). The NASC values per interval within each stratum were split into mature and immature following the proportion mature for the stratum.

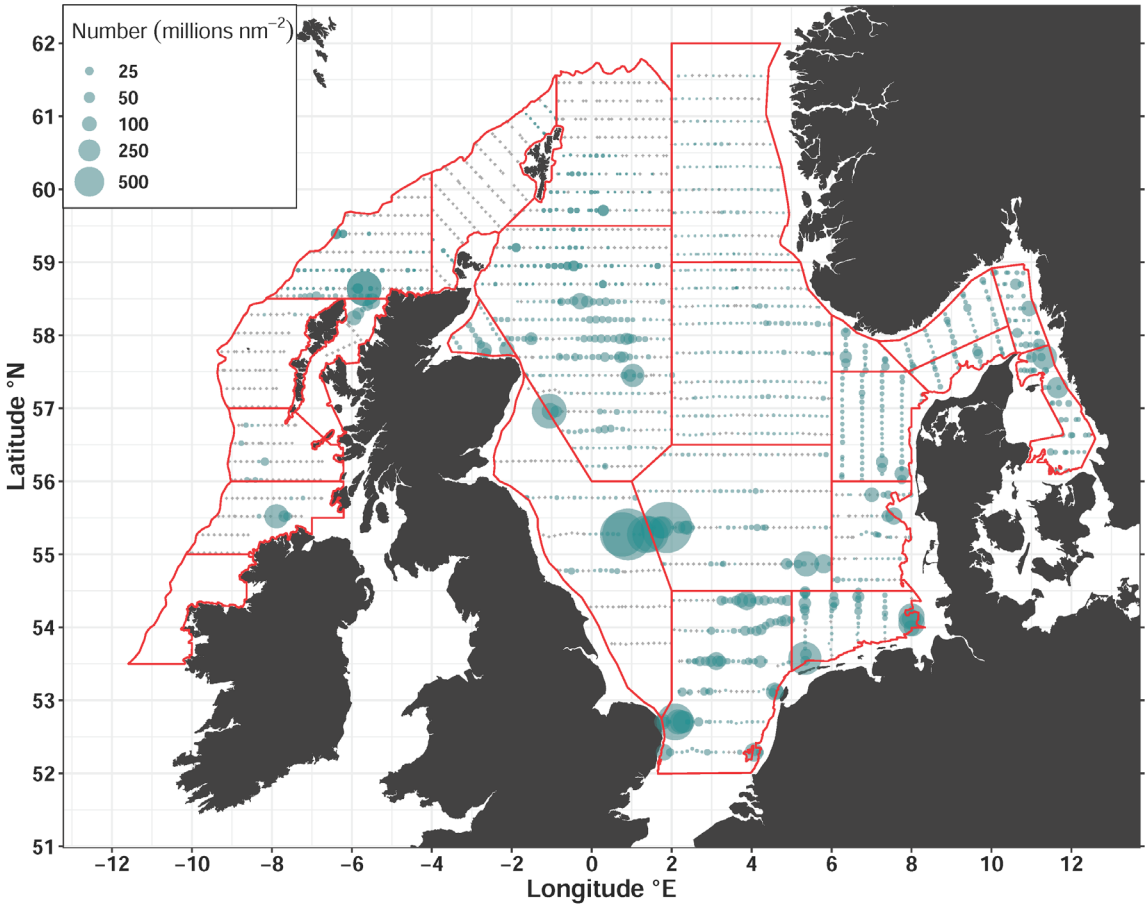

Figure 5.17. Distribution of immature herring in 2018 (n in millions). The NASC values per interval within each stratum were split into mature and immature following the calculated proportion mature for the stratum.

Document 6a: IESSNS 2018 survey summary table

Survey Summary table WGIPS 2019	
Name of the survey (abbreviation):	International Ecosystem Summer Survey in the Nordic Seas (IESSNS)
Target Species:	NEA mackerel
Survey dates:	30 June – 6 August
Summary:	
In 2018, the survey included six vessels (including coverage on the North Sea) from five nations with similar coverage as last year (2.8 mill km). The mackerel stock index decreased 40% for biomass and decreased 30 % for abundance compared to the 2017 index. The incoming 2017-year class has the largest age-1 index value recorded in IESSNS and is 150 % larger than the incoming age-1 cohort in 2017. There was a significant eastwards shift in the mackerel summer feeding distribution in 2018 compared to 2017. This difference in distribution primarily consists of a marked biomass decline in the west (76 % decrease in biomass west of stratum 3 (Eastgreenland/Iceland). In the central and eastern areas, the decline was less (21 %). Furthermore, there was also an eastward shift of distribution within the Norwegian Sea. Distribution zero boundaries were found in majority of survey area with a few exceptions of low mackerel abundance at the survey boundaries south of Faroe Island. The acoustic abundance index of Norwegian spring-spawning herring was 13.6 billion corresponding to 4.46 million tonnes. The abundance estimate of herring from the 2017 survey was 20.6 billion corresponding to 5.88 million tonnes, i.e. a reduction of approx. 24.2% in terms of biomass this year. This drop cannot be easily explained but migration of NSSH south of 62 ^{0}N, where it would mix with other stocks, might influence the result The acoustic abundance index of blue whiting was 16.3 billion corresponding to 2.0 million tonnes. The abundance estimate of blue whiting from the 2017 survey was 22.3 billion corresponding to 2.3 million tonnes, corresponding to decrease in 2018 of approximately 11% in terms of biomass and 27% in terms of abundance of age 1+ fish. It should be noted that in 2017, there were some strong registrations of 0-group blue whiting south of the Faroe Islands which accounted for 15% of the abundance that year. However, in 2018, no 0-group was registered in the survey. As in previous years, the spatio-temporal overlap between NEA mackerel and NSSH was highest in the southern and south-western parts of the Norwegian Sea. There was practically no overlap between NEA mackerel and NSSH in the central and northern 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. 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 (via the PGNAPES database)
Random/systematic error issues	N/A
Specific survey error issues (acoustic)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Bubble sweep down	No problems due to bad weather for a acoustic recordings
Extinction (shadowing)	N/A
Blind zone	Upper 8-15 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
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 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
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 time-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 2018 survey report

Please see the report on the next page.

Working Document to

ICES Working Group on Widely Distributed Stocks (WGWIDE, No. 05), Havstovan, Tórshavn, Faroe Islands, 28. August – 3. September 2018

Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) 30th of June – 6th of August 2018

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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 6th in 2018 using six vessels from Norway (2), Iceland (1), Faroe Islands (1), Greenland (1) and Denmark (1). The main objective is to provide annual age-segregated abundance index, with an uncertainty estimate, for northeast Atlantic mackerel (*Scomber scombrus*). The index is used as a tuning series in stock assessment according to conclusions from the 2017 ICES mackerel benchmark. 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 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 2018 index decreased 40% for biomass and decreased 30 % for abundance (numbers of individuals) compared to the 2017 index. In 2018, the most abundant year classes were 2010, 2011, 2014, 2016 and 2017 with 11 %, 14 %, 14 %, 15 % and 13 % (in numbers). The incoming 2017-year class has the largest age-1 index value recorded in IESSNS and is 150 % larger than the incoming age-1 cohort in 2017. Mackerel cohort internal consistency remained relatively high. Internal consistency is strong for ages 1 to 5 years ($r > 0.8$) and a fair/good internal consistency for ages 5 to 11 years ($r > 0.5$), except for 7-8 year old mackerel. The survey coverage area was 2.8 million square kilometres in 2018 which is the same as in 2017. Furthermore, 0.25 million km^2 was surveyed in the North Sea. Mackerel was observed in most of the survey area. Distribution zero boundaries were found in majority of survey area with a few exceptions of low mackerel abundance at the survey boundaries south of Faroe Island, and north and south of the strata adjacent to Greenland.

The mackerel appeared more evenly distributed within the survey area and more easterly distributed than in 2017. This difference in distribution primarily consists of a marked biomass decline in the west (76 % decrease in biomass west of stratum 3, see StoX results). In the eastern areas, the decline was less (21 %). Furthermore, there was also an eastward shift of distribution within the Norwegian Sea.

The acoustic abundance index of Norwegian spring-spawning herring was 13.6 billion corresponding to 4.46 million tonnes (Table 8). The abundance estimate of herring from the 2017 survey was 20.6 billion corresponding to 5.88 million tonnes, i.e. a reduction of approx. 24.2% in terms of biomass this year. This drop cannot be easily explained but migration of NSSH south of 62 ^{0}N, where it would mix with other stocks, might influence the result. Older fish dominated in the western and southwestern part and a range of year classes are present in this area. In the north-eastern part of the Norwegian Sea, at the entrance to the Barents Sea, mainly juvenile fish age 4-5 years and younger were present.

The acoustic abundance index of blue whiting was 16.3 billion corresponding to 2.0 million tonnes (Table 9). The abundance estimate of blue whiting from the 2017 survey was 22.3 billion corresponding to 2.3 million tonnes, corresponding to decrease in 2018 of approximately 11% in terms of biomass and 27% in terms of abundance of age 1+ fish. It should be noted that in 2017, there were some strong registrations of 0-group blue whiting south of the Faroe Islands which accounted for 15% of the abundance that year. However, in 2018, no 0-group was registered in the survey. The blue whiting was distributed in the entire survey area with exception of the area north of Iceland influenced by the cold East Icelandic Current and in the East Greenland area.

As in previous years, the spatio-temporal overlap between NEA mackerel and NSSH was highest in the southern and south-western parts of the Norwegian Sea. There was practically no overlap between NEA mackerel and NSSH in the central and northern part of the Norwegian Sea. Herring distribution was limited to the area east and north of Iceland and the southern Norwegian Sea. Mackerel, on the other hand, was distributed in most of the surveyed area.

Other fish species also monitored are lumpfish (*Cyclopterus lumpus*) and Atlantic salmon (*Salmo salar*). Lumpfish was caught at 65% of surface trawl stations distributed across the surveyed area from Cape Farwell, Greenland, to western part of the Barents Sea. Abundance was greater north of latitude 66 °N compared to southern areas. A total of 80 North Atlantic salmon were caught, mainly in central northern and north-western part of the Norwegian Sea.

Environmental conditions were different in 2018 compared to 2017. Temperature in the surface layer was 0.5-2°C colder in most of the surveyed area. The 2018, sea surface temperature (SST) was 1-2 °C lower than the long-term average (20-year mean) south and west of Iceland, but similar to the long-term mean in central and northern part of the Norwegian Sea, and warmer on the east Greenland shelf and north of Iceland. The average zooplankton index declined 18% compared to 2017. It was slightly lower in Greenlandic waters (15.8 g m^{-2}; n=27) and in the Norwegian Sea (7.2 g m^{-2}; n=167), while it was 18% higher in Icelandic waters (9.9 g m^{-2}; n=64).

1 Introduction

During approximately five weeks of survey in 2018 (30th of June to 6th of August), six vessels; the M/V "Kings Bay" and M/V "Vendla" from Norway, and M/V "Tróndur í Gøtu" from Faroe Islands, the R/V "Árni Friðriksson" from Iceland, the M/V "Finnur Fridi" operating in Greenland waters and M/V "Ceton" operating in the North Sea by Danish scientists, participated in the International Ecosystem Summer Survey in the Nordic Seas (IESSNS).

The main aim of the coordinated IESSNS have been to collect data on abundance, distribution, migration and ecology of Northeast Atlantic mackerel (*Scomber scombrus*) during its summer feeding migration phase in the Nordic Seas, used as tuning series in stock assessment of mackerel at the annual meeting of ICES working group of widely distributed stocks (WGWIDE). Since 2016, systematic acoustic abundance estimation of both Norwegian spring-spawning herring (*Clupea harengus*) and blue whiting (*Micromesistius poutassou*) have also been conducted. This objective was initiated to provide an additional abundance index for these two stocks because the current indices used in the stock assessments by ICES have shown some unexplained fluctuations (ICES 2016). It was considered that a relatively small increase in survey effort would accommodate a full acoustic coverage of the adult fraction (spawning stock biomass (SSB)) of both species during their summer feeding distribution in the Nordic Seas (Utne et al. 2012; Trenkel et al. 2014; Pampoulie et al. 2015). The pelagic trawl survey was initiated by Norway in the Norwegian Sea in the beginning of the 1990s. Faroe Islands and Iceland have participated in the joint mackerel-ecosystem survey since 2009, Greenland since 2013 and Denmark for the first time in 2018.

Opportunistic whale observations were conducted onboard the Norwegian vessels Kings Bay and Vendla, and the Icelandic R/V Arni Fridriksson to collect data on distribution, aggregation and behaviour of marine mammals in relation to potential prey species and the physical environment.

Swept-area abundance indices of mackerel from IESSNS have been used for tuning in the analytical assessment by ICES WGWIDE, since the benchmark assessment in 2014. A new benchmark assessment on NEA mackerel was performed in January 2017 (ICES 2017). Methodological and statistical changes and improvements have been done in the survey design; inclusion of uncertainty estimates on the age-disaggregated abundance estimations using the StoX have improved the quality and consistency of the NEA mackerel abundance estimates (Olafsdottir et al. 2017, Salthaug et al 2017). Details on the survey methods are published in Nøttestad et al. (2016). The benchmark assessment accepted several changes and improvements from the IESSNS related to abundance of NEA mackerel based on the swept area analyses including using StoX (ICES 2017). The changes involving IESSNS included the following issues (see Olafsdottir et al. 2017):

a) Implement a new stratified approach using the StoX software to calculate mackerel age-segregated index and coefficient of variation (Salthaug *et al.*, 2017),
b) Introduce an annual swept-area age-structured abundance index,
c) Include age-groups 3+ (3-11 years old),
d) Include years 2010 and 2012 onwards (2012-2017),
e) Expand the spatial coverage to include the area from 60 °N northwards (east of longitude -2 W) in the stratified approach (see Nøttestad *et al.*, 2016).

The North Sea was included in the survey area in 2018, following the recommendations of WGWIDE. This was done by scientists from DTU Aqua, Copenhagen, Denmark. The commercial fishing vessels "Ceton S205" was used, and in total 39 stations (CTD and fishing with the pelagic Multipelt 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.

3 Material and methods

Coordination of the IESSNS was done during WGWIDE 2017 meeting in August-September 2017 in Copenhagen, Denmark, and at the WGIPS meeting in January 2018 in Den Helden, Nederlands, and by correspondence in spring and summer 2018. The participating vessels together with their effective survey periods are listed in Table 1.

Overall, the weather conditions were calm with good survey conditions for all six vessels for oceanographic monitoring, plankton sampling, acoustic registrations and pelagic trawling. There were sporadic windy periods in Greenland and Faroese waters. The weather was good and calm for the two Norwegian vessels and the Icelandic vessel operating in the central and northern part of the Norwegian Sea and in Icelandic waters.

During the IESSNS, the special designed pelagic trawl, Multpelt 832, has now been applied by all participating vessels since 2012. This trawl is a product of cooperation between participating institutes in designing and constructing a standardized sampling trawl for the IESSNS. The work was lead by trawl gear scientist John Willy Valdemarsen, Institute of Marine Research (IMR), Bergen, Norway (Valdemarsen et al. 2014). The design of the trawl was finalized during meetings of fishing gear experts and skippers at meetings in January and May 2011. Further discussions on modifications in standardization between the rigging and operation of Multpelt 832 was done during a trawl expert meeting in Copenhagen 17-18 August 2012, in parallel with the post-cruise meeting for the joint ecosystem survey, and then at the WKNAMMM workshop and tank experiments on a prototype (1:32) of the Multpelt 832 pelagic trawl, conducted as a sequence of trials in Hirtshals, Denmark from 26 to 28 February 2013 (ICES 2013a). The swept area methodology was also presented and discussed during the WGISDAA workshop in Dublin, Ireland in May 2013 (ICES 2013b). The standardization and quantification of catchability from the Multpelt 832 pelagic trawl was further discussed during the mackerel benchmark in Copenhagen in February 2014. Recommendations and requests coming out of the mackerel benchmark in February 2014, were considered and implemented during the IESSNS survey in July-August 2014 and in the surveys thereafter. Furthermore, recommendations and requests resulting from of the mackerel benchmark in January-February 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 2018. 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	2/7-2/8	6300	91/71	71	70
Tróndur í Gøtu	30/6- 21/7	3350	54/48	48	48
Finnur Fríði	18/7-6/8	2900	37/31	32	31
Ceton	2/7-13/7	1600	39/39	39	-
Vendla	4/7-5/8	5275	100/74	74	74
Kings Bay	4/7-5/8	5205	87/66	68	66
Total	30/6-6/8	24230	408/329	332	289

3.1 Hydrography and Zooplankton

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

Zooplankton was sampled with a WP2-net on 5 of 6 vessels, Ceton did not take any plankton samples. Mesh sizes were 180 µm (Kings Bay and Vendla) and 200 µm (Árni Friðriksson, Tróndur í Gøtu and Finnur Fridi). 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). Effective trawl width (actually door spread) and trawl depth was monitored live by scientific personnel and/or the captain and stored on various sensors on the trawl doors, headrope and groundrope of the Multpelt 832 trawl. The properties of the Multpelt 832 trawl and rigging on each vessel is reported in Table 2.

Trawl catch was sorted to the highest taxonomical level possible, usually to species for fish, and total weight per species recorded. The processing of trawl catch varied between nations as the Norwegian, Icelandic and Greenlandic vessels sorted the whole catch to species but the Faroese vessel sub-sampled the catch before sorting. Sub-sample size ranged from 60 kg (if it was clean catch of either herring or mackerel) to 100 kg (if it was a mixture of herring and mackerel). The biological sampling protocol for trawl catch varied between nations in number of specimen sampled per station (Table 3).

Table 2. Trawl settings and operation details during the international mackerel survey in the Nordic Seas from 30th June to 6th August 2018. The column for influence indicates observed differences between vessels likely to influence performance. Influence is categorized as 0 (no influence) and + (some influence).

Properties	**Kings Bay**	**Árni Friðriksson**	**Vendla**	**Ceton**	**Tróndur í Gøtu**	**Finnur Fríði**	**Influ-ence**
Trawl producer	Egersund Trawl AS	Hampiðjan new 2017 trawl	Egersund Trawl AS	Egersund Trawl AS	Vónin	Hampiðjan	0
Warp in front of doors	Dynex–34 mm	Dynex-34 mm	Dynex -34 mm	Dynex	Dynema – 32mm	Dynex-38 mm	+
Warp length during towing	350	350	350	350	350-370	350	0
Difference in warp length port/starb. (m)	2-10	16m	2-10	10	5-20	10-20	0
Weight at the lower wing ends (kg)	2×400	2×400 kg	2×400	2×400	2×400	2×500	0
Setback (m)	0	14m	0	6	6	6	+
Type of trawl door	Seaflex 7.5 m² adjustable hatches	Jupiter	Seaflex 7.5 m² adjustable hatches	Thybron type 15	Injector F-15	T-20vf Flipper	0
Weight of trawl door (kg)	1700	2200	1700	1970	2000	2000	+
Area trawl door (m²)	7.5 with 25% hatches (effective 6.5)	6	7.5 with 25% hatches (effective 6.5)	7	6	7 with 50% hatches (effective 6.5)	+
Towing speed (knots)	4.8 (4.2-5.8)	4.9 (4.5-5.8)	4.5 (3.3-5.3)	5.1 (4.6-5.4	4.7 (4.4-5.0)	4.6 (4.1-5.0)	+
Trawl height (m)	28-40	34.1 (28.5-39.3)	28-37	31 (24-35)	44.1	-	+
Door distance (m)	115-132	117 (106 - 127)	115-128	122 (116-127)	109.2	105 (85-112)	+
Trawl width (m)*	68.2	66.1	66.5	68 (66-70)	62	60.3	+
Turn radius (degrees)	5-10	5	5-10	5-10	5-10 BB turn	5-10	+
Fish lock front of cod-end	Yes	Yes	Yes	Yes	Yes	Yes	+
Trawl door depth (port, starboard, m)	5-15, 7-18	4-17, 8-20	6-18, 7-19	3-12, 4-14	11.2, 13.4	-	+
Headline depth	0-1 m	0	0-1 m	-	0 m	0-1 m	+
Float arrangements on the headline	Kite with fender buoy +2 buoys on each wingtip	Kite + 2 buoys on wings	Kite with fender buoy + 2 buoys on each wingtip	Kite with fender buoy + 2 buoys on each wingtip	Kite + 2 buoys on wingtips	Kite + 2 buoys on wingtips	+
Weighing of catch	All weighted	All weighted	All weighted	-	All weighed	All weighted	+

* calculated from door distance

Table 3. Protocol of biological sampling during the IESSNS 2018. Numbers denote the maximum number of individuals sampled for each species for the different determinations.

	Species	Faroes	Greenland	Iceland	Norway	Denmark ***
Length measurements	Mackerel	100	100/50*	150	100	
	Herring	100	100/50*	200	100	
	Blue whiting	100	100/50*	50	100	
	Other fish sp.	0	25/25*	50	25	
Weighed, sexed and maturity determination	Mackerel	20	25	50	25	
	Herring	25	25	50	25	
	Blue whiting	25	25	50	25	
	Other fish sp.	0	0	10	0	
Otoliths/scales collected	Mackerel	25	25	25	25	
	Herring	25	25	50	25	
	Blue whiting	25	25	50	25	
	Other fish sp.	0	0	0	0	
Fat content	Mackerel	0	50	0	10	
	Blue whiting	0	50			
	Herring	0	0	0		
Stomach sampling	Mackerel	5	20	10**		
	Herring	5	20	10**	10	
	Blue whiting	5	20	10	10	
	Other fish sp.	0	0	0	10	
Tissue for genotyping	Mackerel	0	0	0	0	
	Herring	0	0	0	30	

*Length measurements / weighed individuals
**Stomachs sampled at every third station
*** One fish per cm-group from each station was weighed, aged and the stomach was sampled.

Underwater camera observations during trawling

M/V "Kings Bay" and M/V "Vendla" employed an underwater video camera (GoPro HD Hero 4 Black Edition, www.gopro.com) to observe mackerel aggregation, swimming behaviour and 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 83 trawl stations. The camera was attached on the trawl in the transition between 200 mm and 400 mm meshes

3.3 Marine mammals

Opportunistic observations of marine mammals were conducted by trained scientific personnel and crew members from the bridge between 3rd July and 4th August 2018 onboard M/V "Kings Bay" and M/V "Vendla", respectively. Opportunistic marine mammal observations were also done on R/V Árni Friðriksson by crew members without any dedicated whale observers.

3.4 Lumpfish tagging

Lumpfish caught during the survey by vessels R/V "Árni Friðriksson" and M/V "Finnur Fridi" 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 estimate the latitude and longitude of the release location.

3.5 Acoustics

Multifrequency echosounder

The acoustic equipment onboard Kings Bay and Vendla were calibrated 2nd July 2018 for 18, 38 and 200 kHz. Árni Friðriksson was calibrated in April 2018 for the frequencies 18, 38, 120 and 200 kHz. Tróndur í Gøtu was calibrated on 27th June 2018 for 38 and 200 kHz. Calibration of the acoustic equipment onboard Finnur Fríði was done after the cruise on the 5th of August. 120 and 200 kHz were calibrated, but the calibration of 38 kHz failed. Ceton did not use acoustic recording equipment. All 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 or Echoview, see Table 4 for details of the acoustic settings by vessel). Species were identified and partitioned using catch information, characteristic of the recordings, and frequency between integration on 38 kHz and on other frequencies by a scientist experienced in viewing echograms.

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

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

Table 4. Acoustic instruments and settings for the primary frequency (38 kHz) during IESSNS 2018.

	M/V Kings Bay	R/V Árni Friðriksson	M/V Vendla	M/V Tróndur í Gøtu	M/V Finnur Fríði	M/V Ceton *
Echo sounder	Simrad EK80	Simrad EK 60	Simrad EK 60	Simrad EK 60	Simrad EK 60	
Frequency (kHz)	18, 38, 70, 120, 200	18, 38, 120, 200	18, 38, 70, 120, 200	38,120, 200	38,120, 200	
Primary transducer	ES38B	ES38B	ES38B	ES38B	ES38B	
Transducer installation	Drop keel	Drop keel	Drop keel	Hull	Hull	
Transducer depth (m)	9	10	9	6	8	
Upper integration limit (m)	15	15	15	7	Not used	
Absorption coeff. (dB/km)	9.6	10.6	9.1	9.7	9.7	
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024	
Band width (kHz)	2.43	2.43	2.43	2.43	2.43	
Transmitter power (W)	2000	2000	2000	2000	2000	
Angle sensitivity (dB)	21.90	21.9	21.90	21.9	21.9	
2-way beam angle (dB)	-20.7	-20.81	-20.6	-20.6	-20.7	
TS Transducer gain (dB)	24.33	24.34	25.56	24.04	23.75	
s_A correction (dB)	0.01	-0.61	-0.69	-0.64	-0.59	
alongship:	7.01	7.28	7.03	7.07	7.17	
athw. ship:	7.00	7.23	7.09	7.09	7.01	
Maximum range (m)	500	500	500	500	500 (750 in part of the survey)	
Post processing software	LSSS	LSSS v.2.3.0	LSSS	Sonardata Echoview 9.x	Sonardata Echoview 8.x	

* No acoustic data collection

Multibeam sonar

M/V Kings Bay was 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. M/V Vendla was equipped with the Simrad fisheries sonar SX93 (frequency range: 20-30 kHz). Acoustic multibeam sonar data was stored continuously onboard Kings Bay and Vendla for the entire survey.

Cruise tracks

The six participating vessels followed predetermined survey lines with predetermined surface trawl stations (Figure 1). Calculations of the mackerel index are based on swept area approach with the survey area split into 13 strata, permanent and dynamic strata (Figure 2). Distance between predetermined surface trawl stations is constant within stratum but variable between stratum 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). In addition, the Norwegian vessel Vendla had four stations in the Barents Sea as there was some available time at the end of the survey. Temporal survey progression by vessel along the cruise tracks in July-August 2018 is shown in Figure 3. The cruising speed was between 10-13 knots if the weather permitted otherwise the cruising speed was adapted to the weather situation.

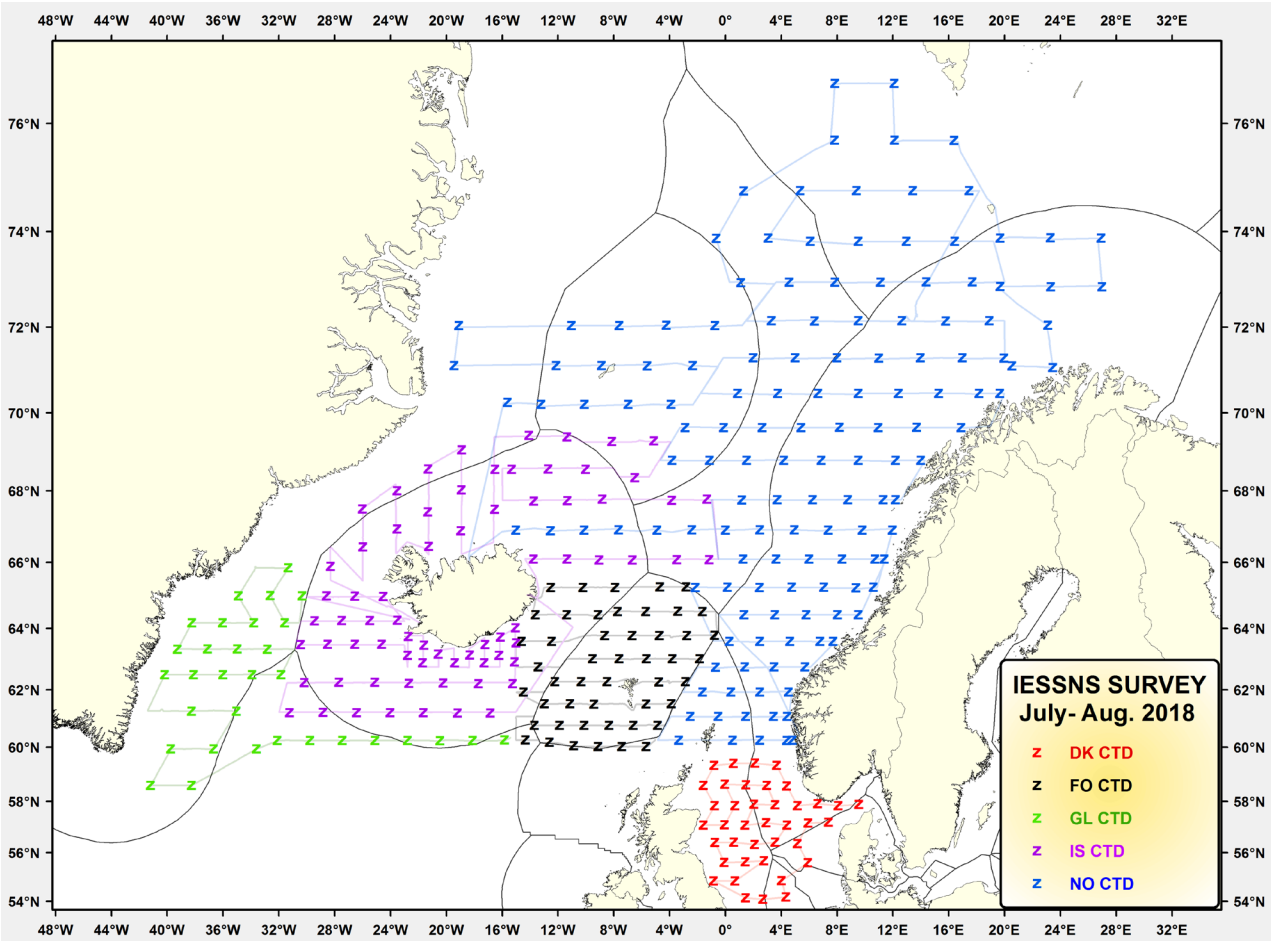

Figure 1. Fixed predetermined trawl stations included in the IESSNS 30th June – 5th August 2018. At each station a 30 min surface trawl haul, a CTD station (0-500 m) and WP2 plankton net samples (0-200 m depth) was performed. The colour codes, Árni Friðriksson (purple), Tróndur í Gøtu (black), Kings Bay and Vendla (blue), Finnur Fríði (green) and Ceton (red).

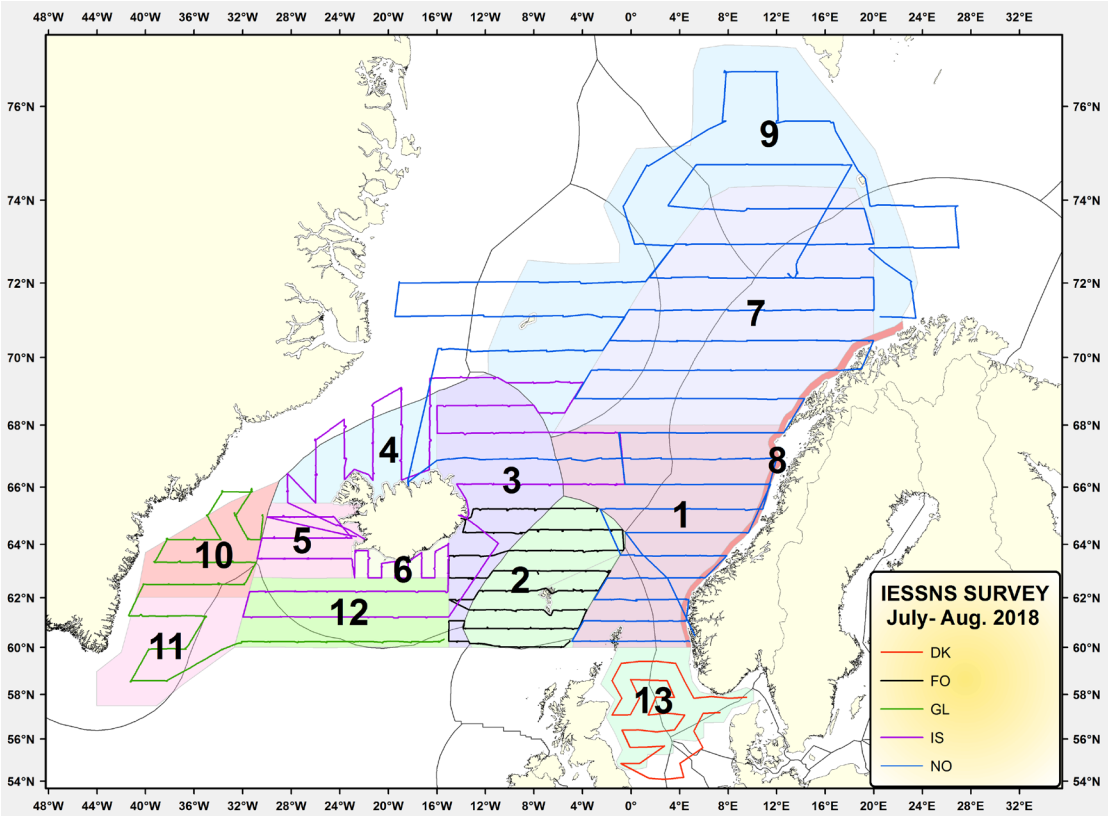

Figure 2. Permanent and dynamic strata used in StoX for IESSNS 2018. The dynamic strata are: 4, 9 and 11.

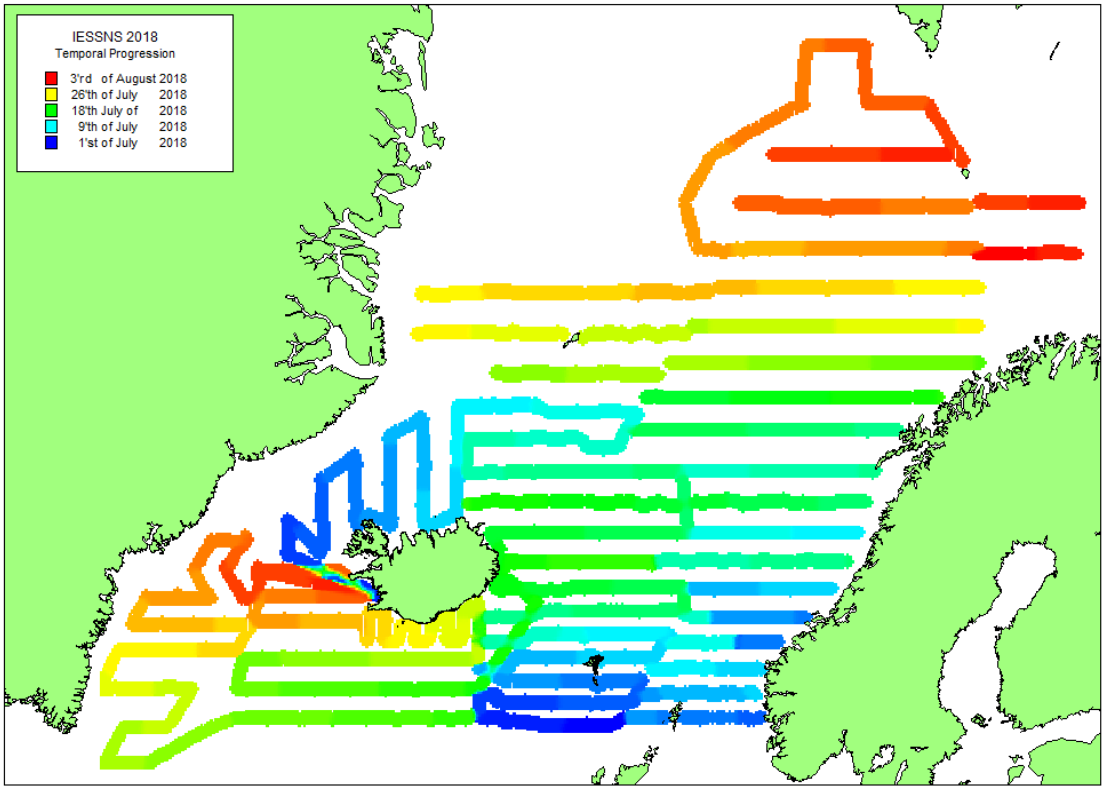

Figure 3. Temporal survey progression by vessel along the cruise tracks during IESSNS 2018: blue represents effective survey start (1st July) progressing to red representing the effective end of the survey (3rd August).

3.6 StoX

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

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 57°N and 76°N and 44°W and 22°E.

Average density (Mac_D; kg km^{-2}) is calculated for each trawl haul with the following formula;

$$Mac\_D = h * d * c$$

where h (km) is the horizontal opening of the trawl, d is distance trawled (km) and c is the total mackerel catch (kg). 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).

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

	Tróndur í Gøtu	RV Árni Friðriksson	Kings Bay	Vendla	Finnur Fríði	Ceton
Trawl doors horizontal spread (m)						
Number of stations	48	54	66	74	31	39
Mean	109.2	117	125	121	105	122
max	116.8	127	132	128	112	127
min	98.9	106	115	115	85	116
st. dev.	6.1	3.9	3.8	1.8	4.9	2.5
Vertical trawl opening (m)						
Number of stations	48	49	66	74	-	39
Mean	44.1	34.1	31.7	31	-	31
max	51.2	39.3	40	37	-	35
min	39.9	28.5	28	28	-	24
st. dev.	7.7	2.3	3.1	1.3	-	2.5
Horizontal trawl opening (m)						
mean	62	66.1	68.2	66.1	60.3	68
Speed (over ground, nmi)						
Number of stations	48	54	66	74	31	39
mean	4.7	4.9	4.8	4.5	4.6	5.1
max	5.0	5.8	5.8	5.3	5.0	5.4
min	4.4	4.5	4.2	3.3	4.1	4.6
st. dev.	0.11	0.2	0.3	0.4	0.2	0.2

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

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

Towing speed 5.0 knots: Horizontal opening (m) = 0.3959 * Doorspread (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.

	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

4 Results

4.1 Hydrography

Surface temperature in the Norwegian Sea was similar to the average for 1990-2009 based on Sea Surface Temperature (SST) anomaly plot (Figure 4). On the other hand, south and west of Iceland SST was 1-2°C colder than the average, but 1-2°C warmer on the east Greenland shelf and north of Iceland. Surface temperature in 2018 was similar to 2015 although this year was warmer on the east Greenland shelf and

north of Iceland. SST was noticeably lower in 2018 compared to 2017 for majority of the survey area, excluding the east Greenland shelf.

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

The upper layer (< 20 m depth) was 0.5-2.0°C colder in 2018 compared to 2017 in most of the surveyed area (Figures 5). The temperature in the upper layer was higher than 7°C in most of the surveyed area, except along the north-western fringes of the surveyed areas north of Iceland, west of Jan Mayen and north of Bear Island where it was slightly lower. In the deeper layers (50 m and deeper; Figure 6-8), the hydrographical features in the area were similar to the last three years. At all depths there were a clear signal from the cold East Icelandic Current, which originates from the East Greenland Current.

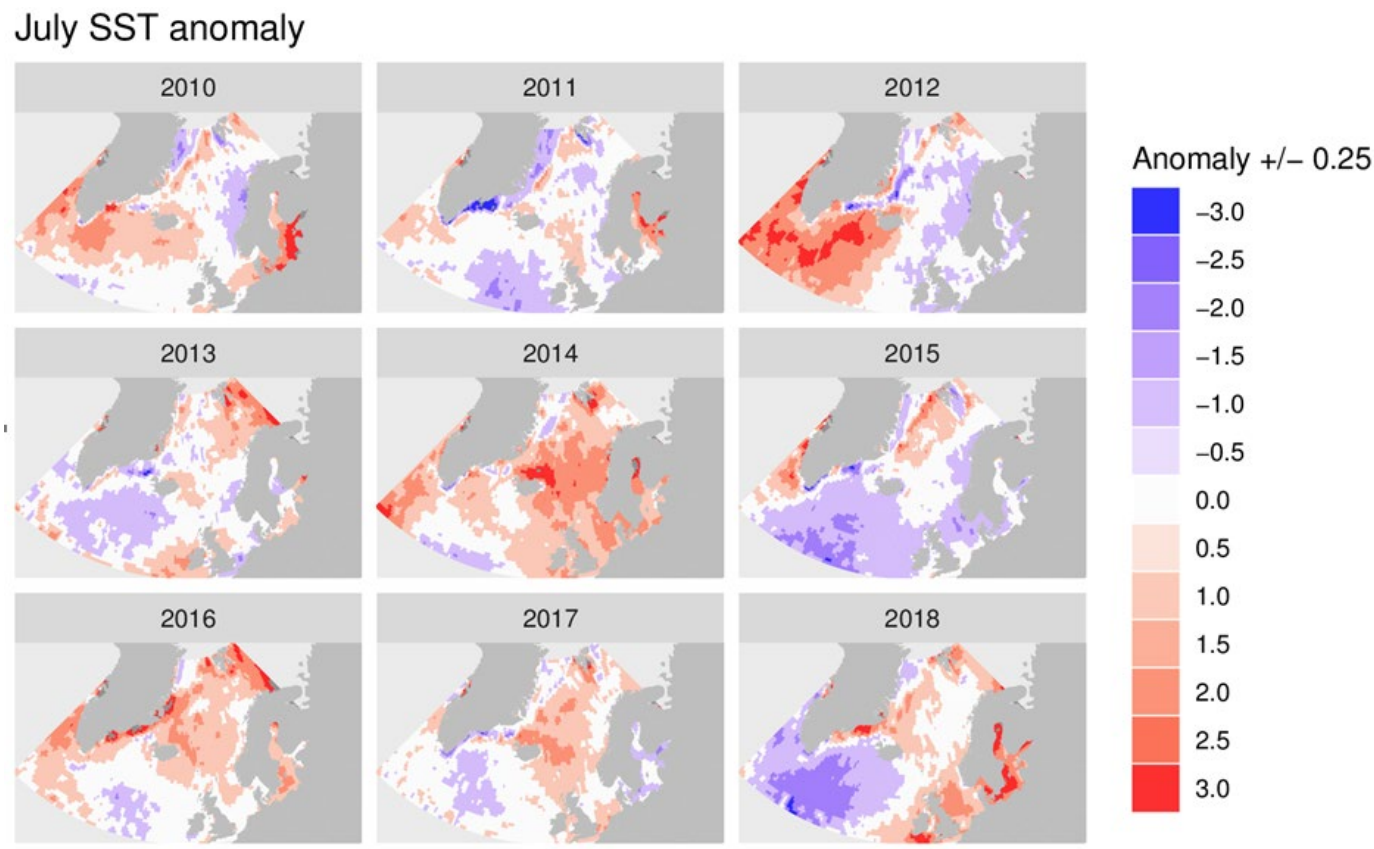

Figure 4. Annual sea surface temperature anomaly (°C) in Northeast Atlantic for the month of July from 2010 to 2018 showing warm and cold conditions in comparison to the average for July 1990-2009. Based on monthly averages of daily Optimum Interpolation Sea Surface Temperature (OISST, AVHRR-only, Banzon et al. 2016, https://www.ncdc.noaa.gov/oisst).

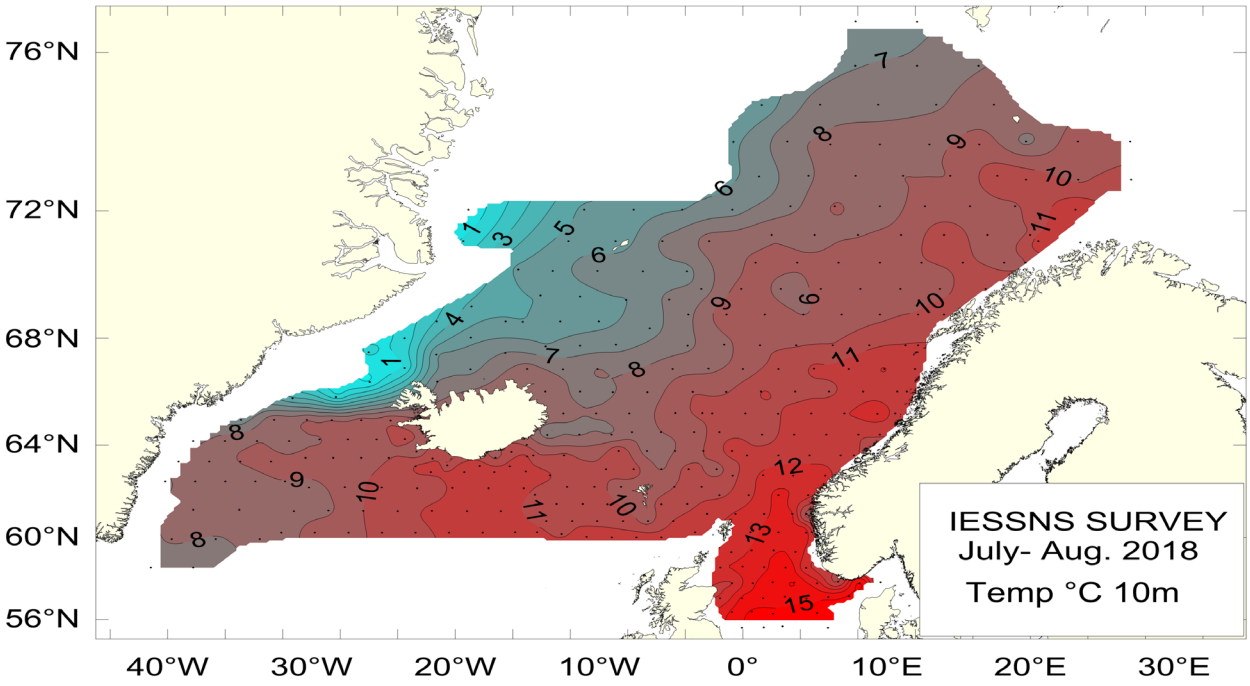

Figure 5. Temperature (°C) at 10 m depth in Nordic Seas and the North Sea in July-August 2018.

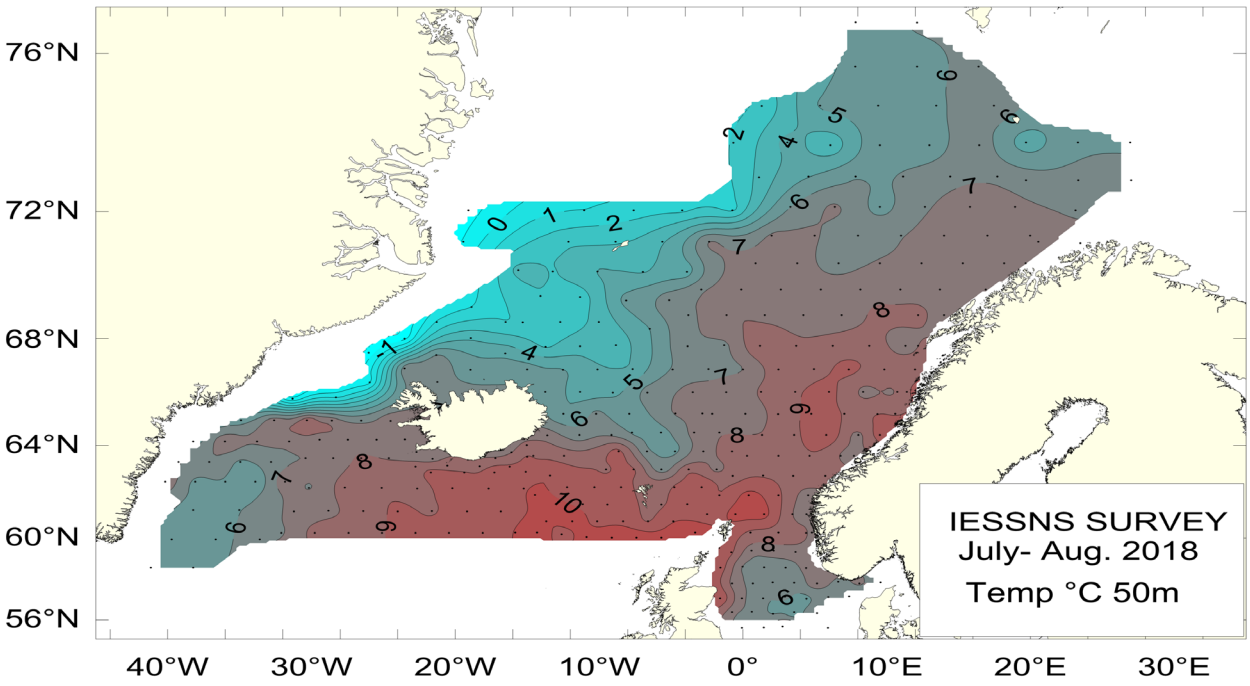

Figure 6. Temperature (°C) at 50 m depth Nordic Seas and the North Sea in July-August 2018.

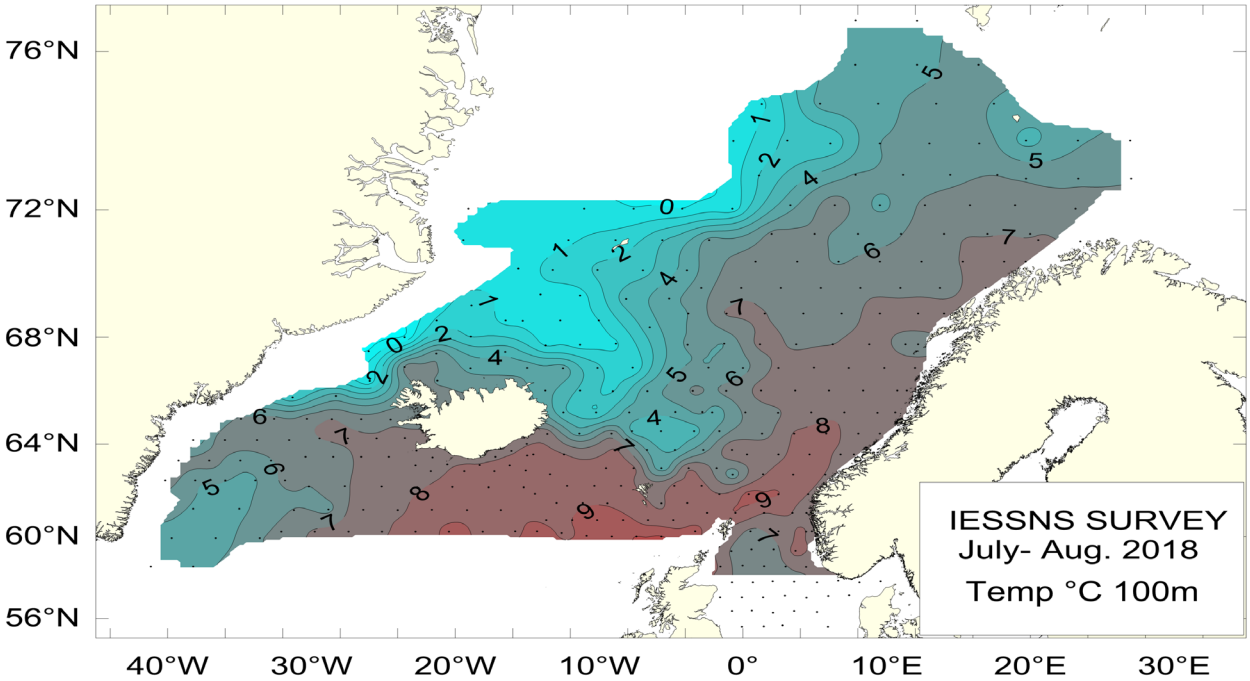

Figure 7. Temperature (°C) at 100 m depth in Nordic Seas and the North Sea in July-August 2018.

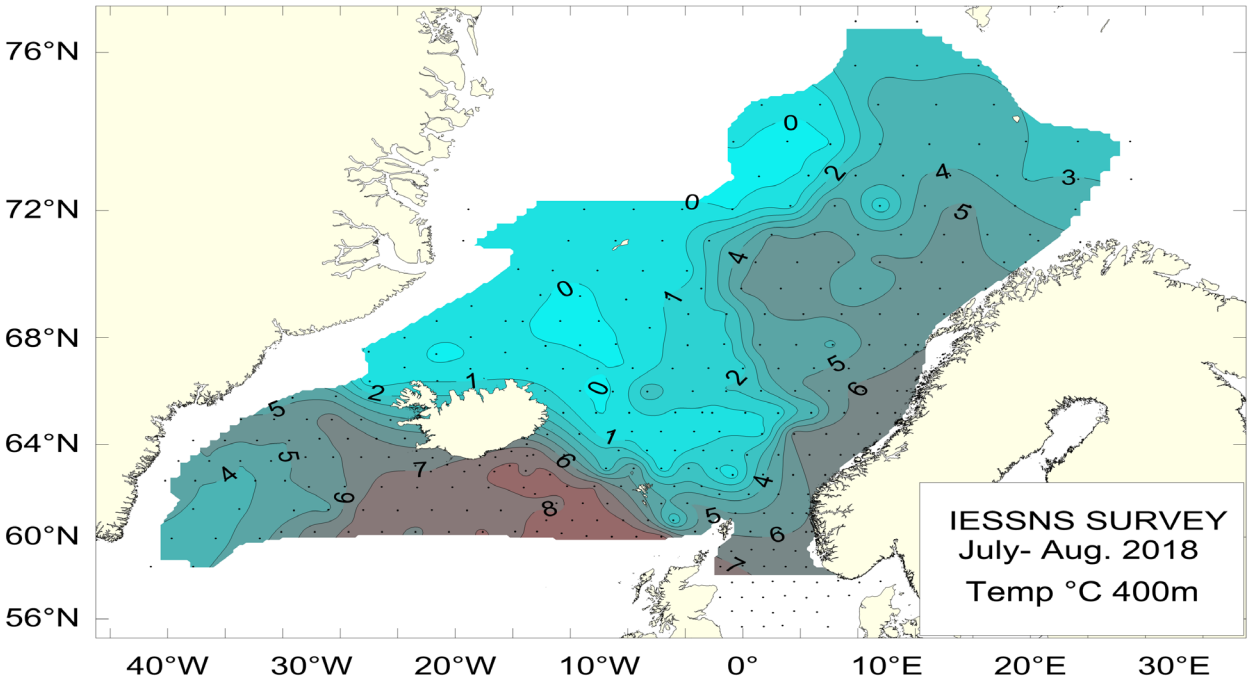

Figure 8. Temperature (°C) at 400 m depth in Nordic Seas and the North Sea in July-August 2018.

4.2 Zooplankton

Zooplankton biomass varied between areas and was highest in Greenland waters where it ranged from 10-20 g m^{-2} for most of the area compared to 5-10 g m^{-2} in the Norwegian Sea and in Icelandic waters (Figure 9a). Mean zooplankton biomass for the survey area was 6.9 g m^{-2} (n=287) which is an 18 % decline compared to 2017. In 2018, the average index was slightly lower in Greenland waters (15.6 g m^{-2}; n=27) and in the Norwegian Sea (7.2 g m^{-2}; n=167) compared to 2017 while 18% higher in Icelandic waters (9.9 g m^{-2}; n=64; Figure 9b). This relatively short time-series show much more pronounced fluctuations and year-to-year variability (cyclical patterns) in Icelandic and Greenlandic waters compared to the Norwegian Sea. This might in part be explained by both more homogeneous oceanographic conditions in the area defined as Norwegian Sea. Iceland and Greenland waters fluctuate a lot, however, they fluctuate in the same way from one year to the next.

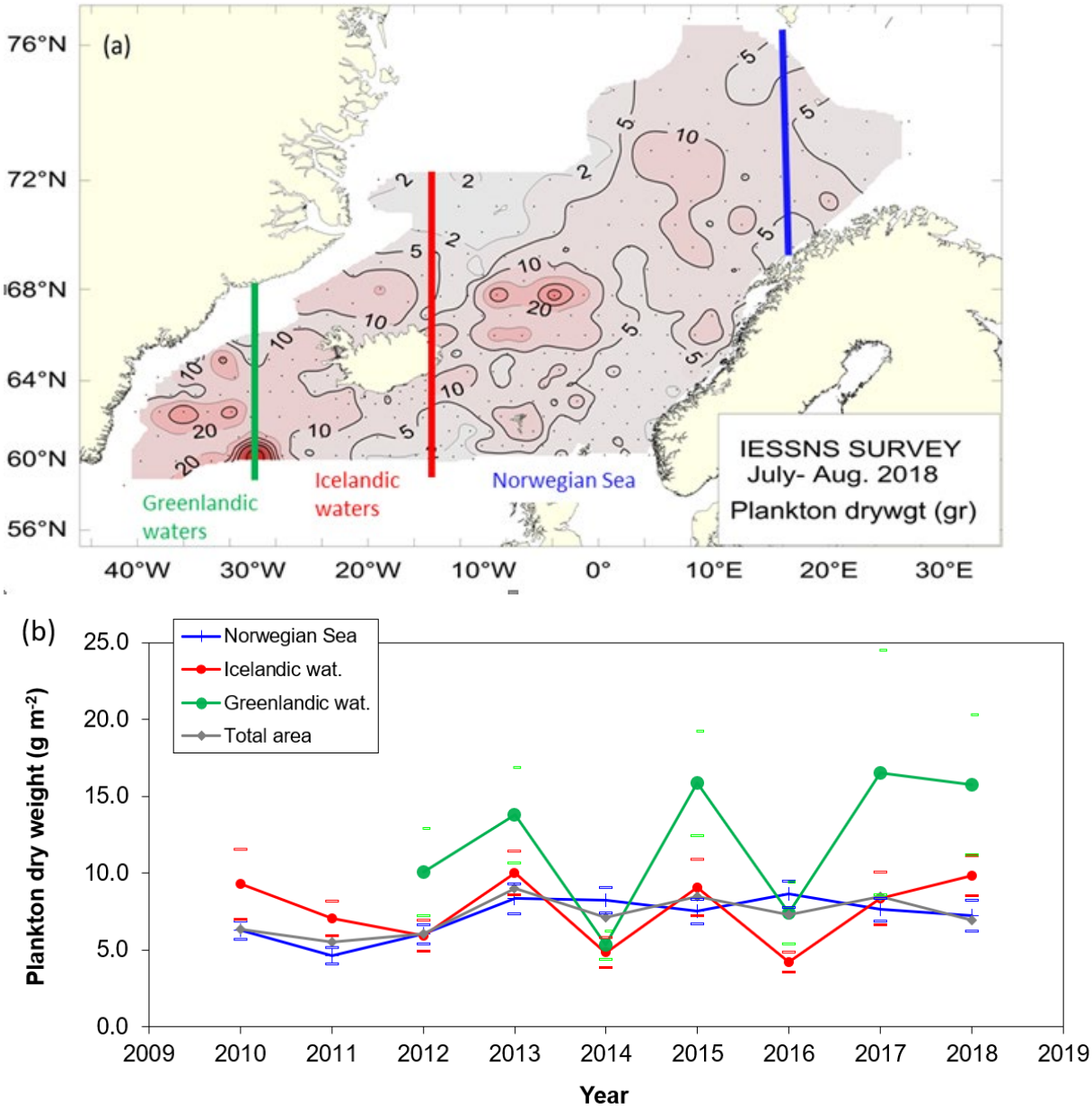

Figure 9. Zooplankton biomass indices (g dw/m^2, 0-200 m) (a) in Nordic Seas in July-August 2018 and (b) time-series of mean zooplankton biomass, with 95% confidence intervals, for the total survey area and three subareas within the survey range: Norwegian Sea (between 14°W-17°E & north of 61°N), Icelandic waters (14°W-30°W) and Greenlandic waters (west of 30°W). Boundaries of subareas displayed in (a).

4.3 Mackerel

The mackerel biomass index i.e. catch rates by trawl station (kg/km²) measured at predetermined surface trawl stations is presented in Figure 10a together with the mean catch rates per 1*2° rectangles. The map shows large variations in trawl catch rates throughout the survey area from zero to 5 tonnes, corresponding to approximately 2.3 tonnes/km² on average. High density areas were found in the Norwegian Sea as well as in south-eastward and westward of Iceland. The mackerel were spread over a greater area with a more easterly distribution than in 2017 (Figure 10a vs. 10b).

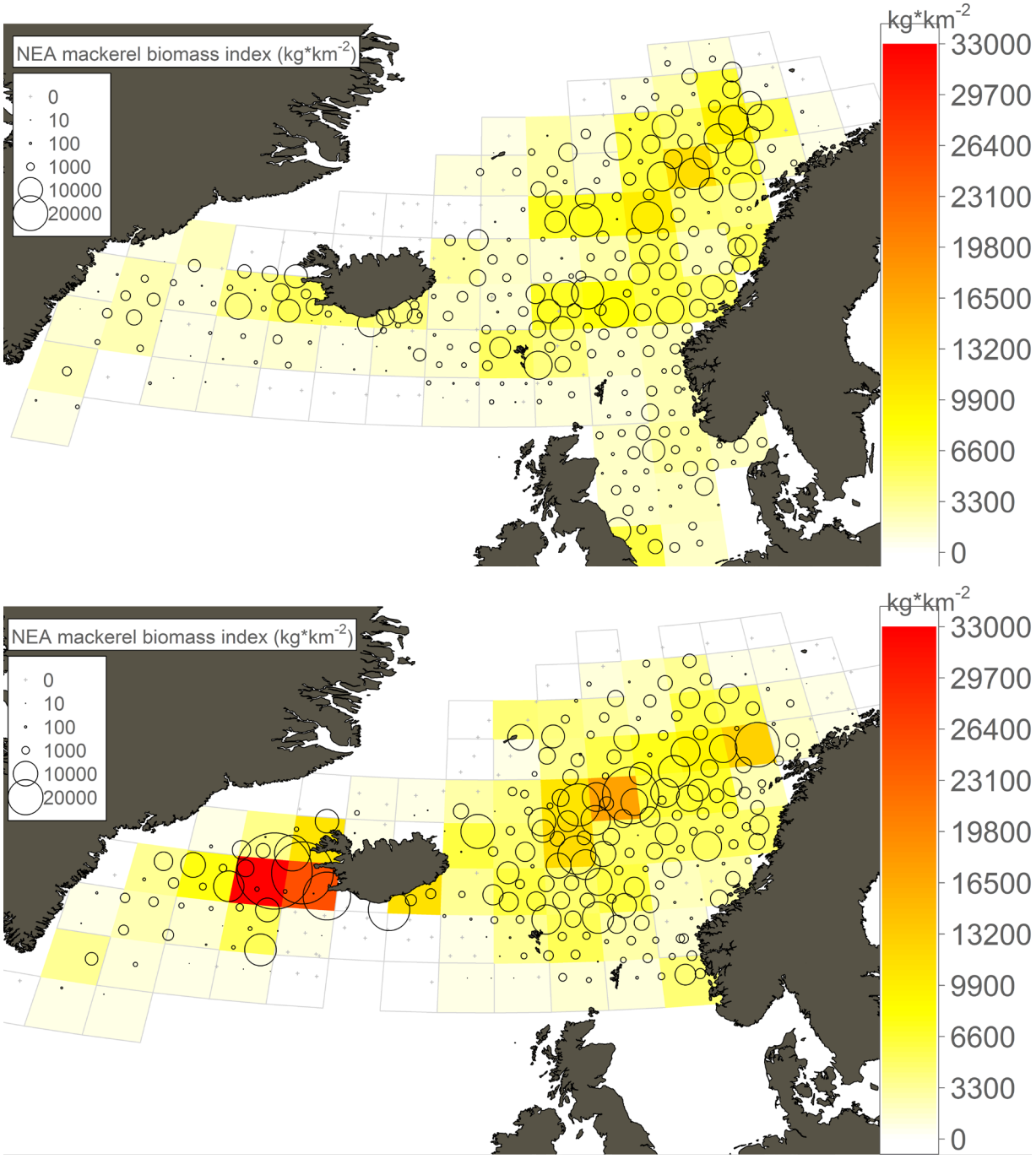

Figure 10. Mackerel catch rates by Multpelt 832 pelagic trawl haul at predetermined surface trawl stations (circle areas represent catch rates in kg/km²) overlaid on mean catch rates per standardized rectangles (1° lat. x 2° lon.). Upper map: IESSNS 2018, lower map: IESSNS 2017.

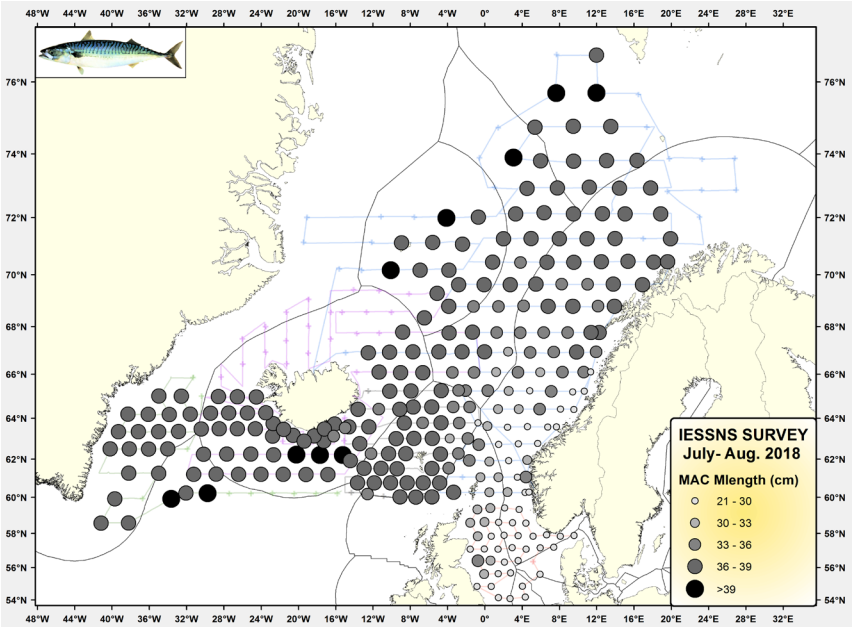

Figure 11. Average length of mackerel at predetermined surface trawl stations during IESSNS 2018.

Mackerel caught in the pelagic trawl hauls onboard the six vessels varied from 16.5 to 48.5 cm in length, with an average of 35.7 cm. Individuals in length range 35–38 cm dominated in numbers and biomass. The mackerel weight (g) varied between 32 to 952 g with an average of 424 g. As in previous years, age-1 dominated the catches along the Norwegian coast from Bergen in the south to Lofoten area in the north, and mackerel length distribution showed a trend of length-dependent distribution pattern both with regards to latitude and longitude. On average, larger mackerel were found further northward and eastward in the survey area (Figure 11). The spatial distribution and overlap between the major pelagic fish species (mackerel, herring, blue whiting, salmon (*Salmo salar*), lumpfish) in 2018 according to the catches is shown in Figure 12.

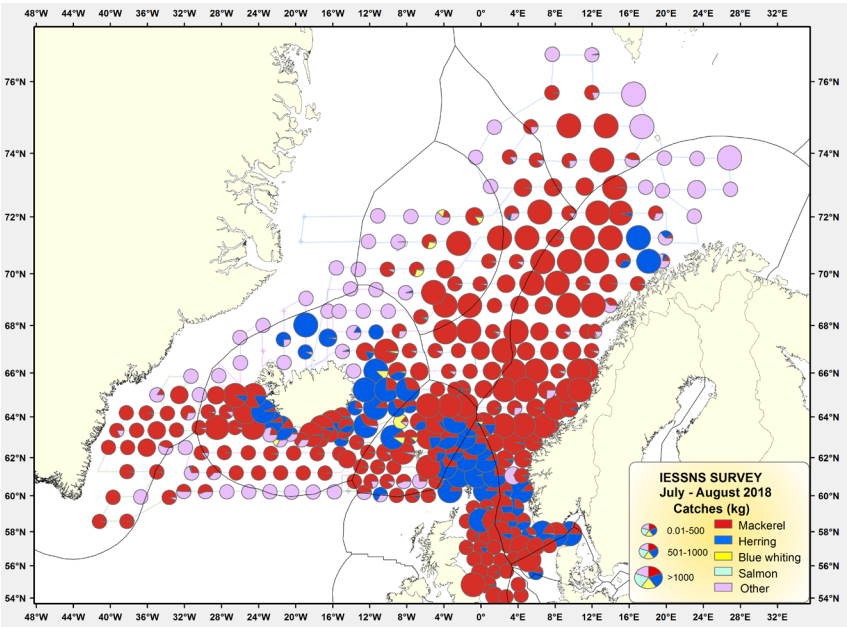

Figure 12. Distribution and spatial overlap between pelagic fish in 2018 at all surface trawl stations. Vessel tracks are shown as continuous lines.

Swept area analyses from standardized pelagic trawling with Multpelt 832

The swept area estimates of mackerel biomass from the 2018 IESSNS were based on abundance of mackerel per stratum (see strata definition in Figure 2) and calculated in StoX (version 2.6). Mackerel were distributed over more or less the entire survey area excluding the area north of Iceland. Mackerel biomass index and abundance index was average in 2018 compared to the whole timeseries from 2007 to 2017 (Table 7). Comparing the 2018 mackerel estimate to the 2017 results shows a 30 % decline in abundance and 40 % decline in biomass. The 2018 biomass index is lower than measured in the IESSNS for the last five years (Figure 13) The survey coverage area was 2.8 million km² in 2018 which is the same as in 2017. The most abundant year classes were 2010, 2011, 2014, 2016 and 2017 with 11, 14, 14, 15, and 13 % (in numbers). The incoming 2017-year class appears promising and is the largest age-1 cohort recorded in the IESSNS timeseries. The total survey index for number-at-age is 17 billion individuals. The dominating age groups are 1, 2, 4, 7 and 8 years old (Figure 14) and they contributed to 66 % of the total abundance estimate. Variance in age index estimation is provided in Figure 15.

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

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

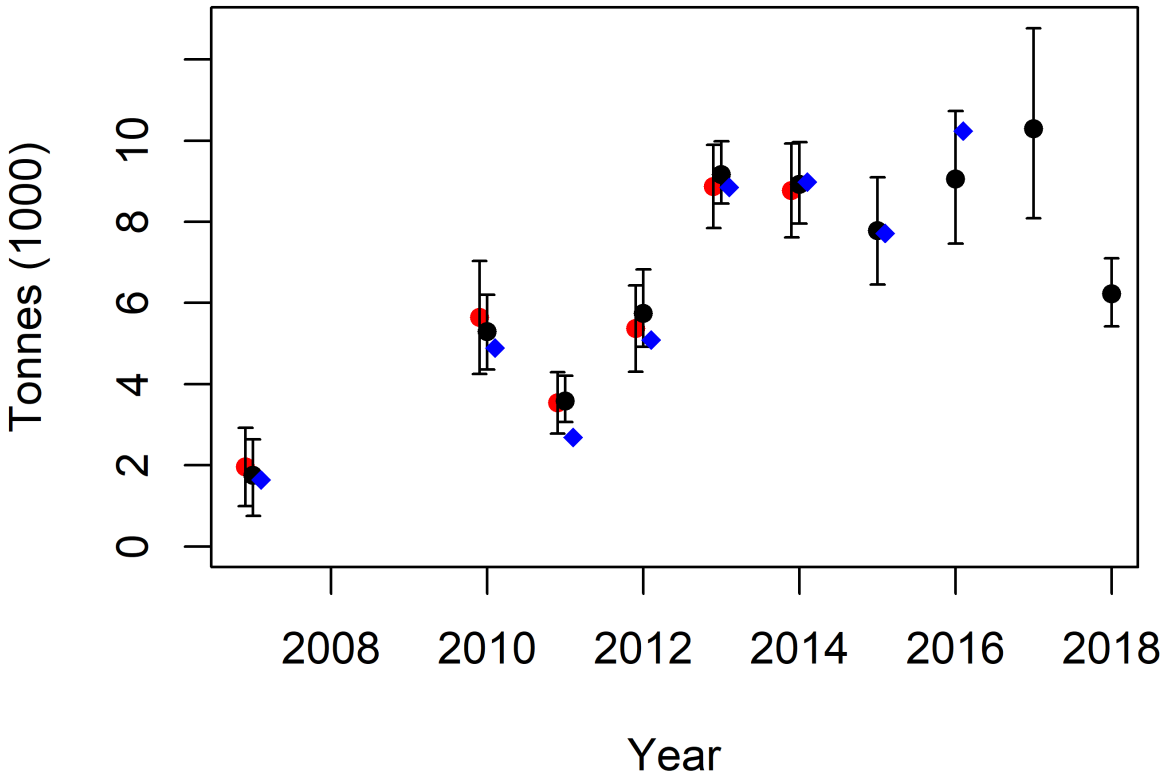

Figure 13. Estimated total stock biomass (TSB) of mackerel from StoX (black dots), Nøttestad et al. (2016) (red dots) and IESSNS cruise reports (blue diamonds). The error bars represent approximate 90 % confidence intervals.

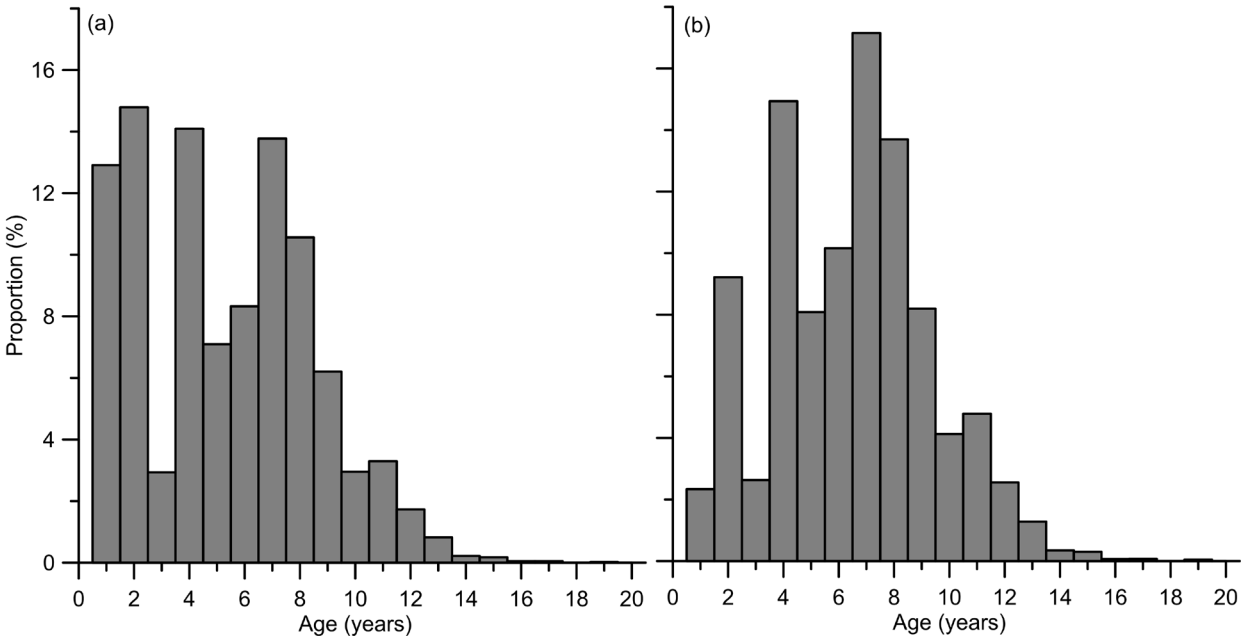

Figure 14. Age distribution in proportion represented as a) % in numbers and b) % in biomass of Northeast Atlantic mackerel in 2018.

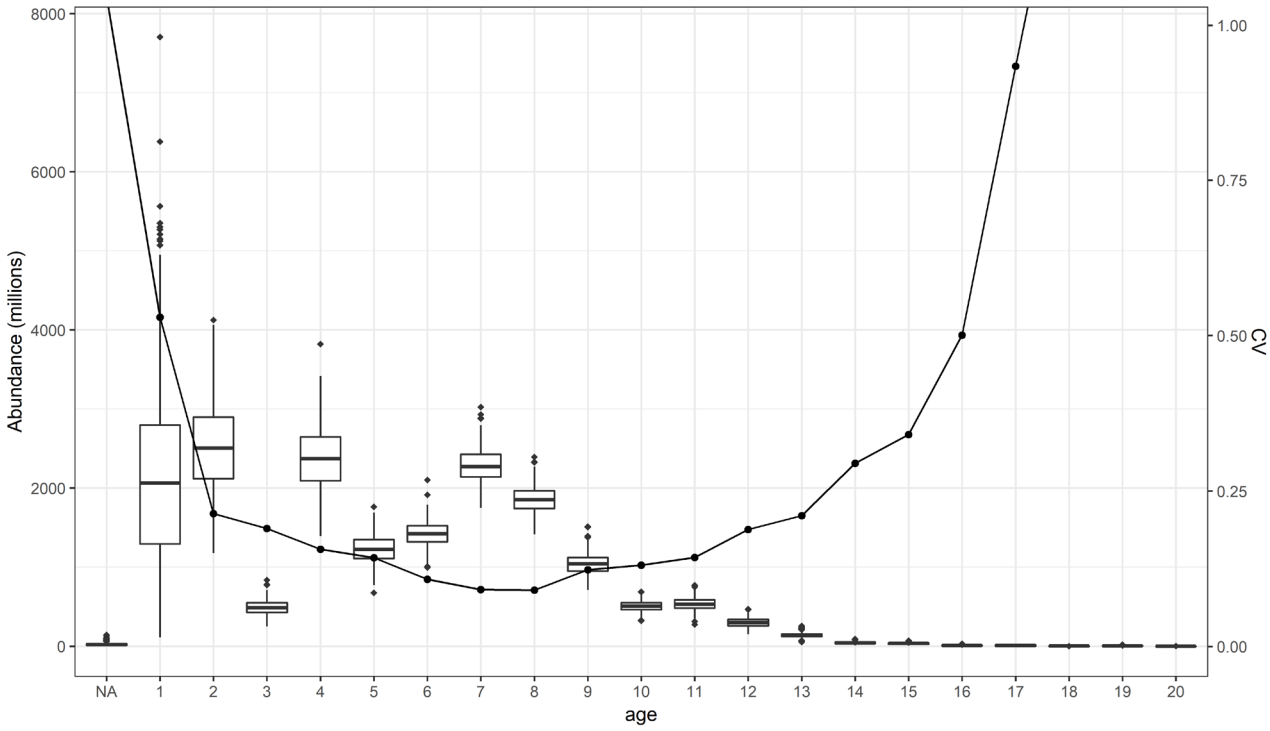

Figure 15. Number by age for mackerel. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 7. Time series of the IESSNS showing (a) age-disaggregated abundance indices of mackerel (billions), (b) mean weight (g) per age and (c) estimated biomass at age (million tonnes) from 2007 to 2018.

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
b)															
Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14(+)	W
2007	133	233	323	390	472	532	536	585	591	640	727	656	685	671	512
2010	133	212	290	353	388	438	512	527	548	580	645	683	665	596	469
2011	133	278	318	371	412	440	502	537	564	541	570	632	622	612	467
2012	112	188	286	347	397	414	437	458	488	523	514	615	509	677	426
2013	96	184	259	326	374	399	428	445	486	523	499	547	677	607	418
2014	228	275	288	335	402	433	459	477	488	533	603	544	537	569	441
2015	128	290	333	342	386	449	463	479	488	505	559	568	583	466	431
2016	95	231	324	360	371	394	440	458	479	488	494	523	511	664	367
2017	86	292	330	373	431	437	462	487	536	534	542	574	589	626	425
2018	67	229	330	390	420	449	458	477	486	515	534	543	575	643	368
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

The internal consistency plot for age-disaggregated year classes has improved since the benchmark in 2017 by the inclusion of two more survey years (Figure 16). This is especially apparent for 5–11 year old mackerel. There is now a strong internal consistency for ages 1 to 5 years, and a fair/good internal consistency for ages 5 to 11 years.

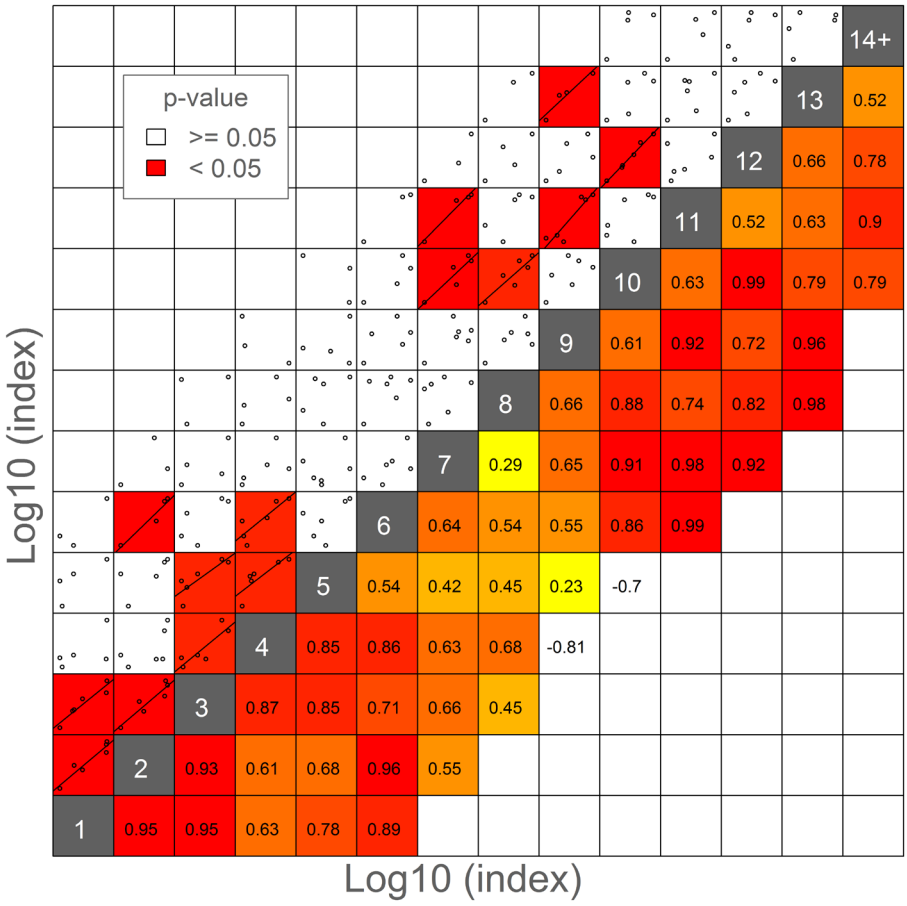

Figure 16. Internal consistency of mackerel density index from 2012 to 2018. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half.

4.4 Norwegian spring-spawning herring

Norwegian spring-spawning herring (NSSH) was recorded mainly in the southern and western part of the Norwegian Sea basin, north of the Faroes and east and north of Iceland (Figure 17). NSSH was also recorded in the northeastern part of the Norwegian Sea close to the Norwegian coast. The fish in the northeast consisted of young adults (4-5 years old) while the fish further southwest are a range of age groups, mainly from 5 to 13 years old. Herring registrations south of 62°N in the eastern part were allocated to a different stock, North Sea herring while the herring closer to the Faroes south of 62°N were Faroese autumn spawners. Also herring to the west in Icelandic waters (west of 14°W south of Iceland and west of 24°W north of Iceland, not shown on the map) were allocated to a different stock, Icelandic summer-spawners. The abundance of NSSH in the eastern and north-eastern part of the area surveyed were lower and consisted mainly of younger and smaller fish than in the western part. The 0-boundary of the distribution of the adult part of NSSH was considered to be reached in all directions.

The NSSH stock is dominated by 5-year old herring (year classes 2013) in terms of numbers and biomass (Table 8). This year class is mainly distributed in the north-eastern part of the Norwegian Sea and it contributes 20% to the total biomass. The total number of herring recorded in the Norwegian Sea was 13.7 billion in 2018 and the total biomass index was 4.47 million tonnes. Number by age, with uncertainty estimates, for NSSH is shown in Figure 18.

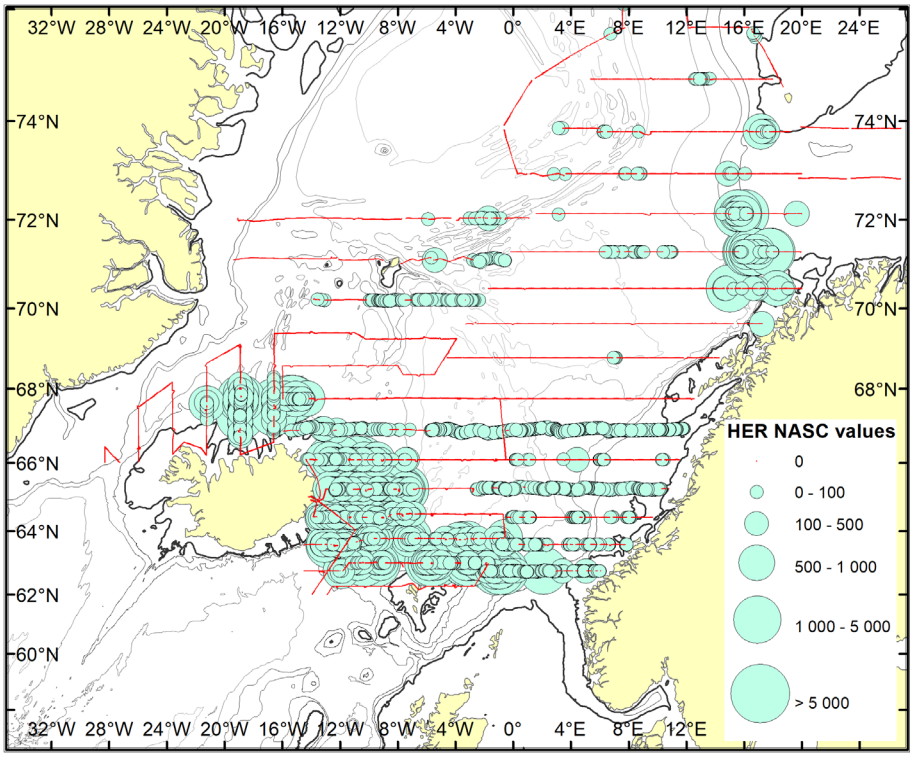

Figure 17. The s_A/Nautical Area Scattering Coefficient (NASC) values of Norwegian spring-spawning herring north of 62ºN and east of 14ºW, along the cruise tracks in 2018. South and west of this area the herring observed are other stocks, i.e. Faroese autumn spawners, North Sea herring and Icelandic summer spawning herring.

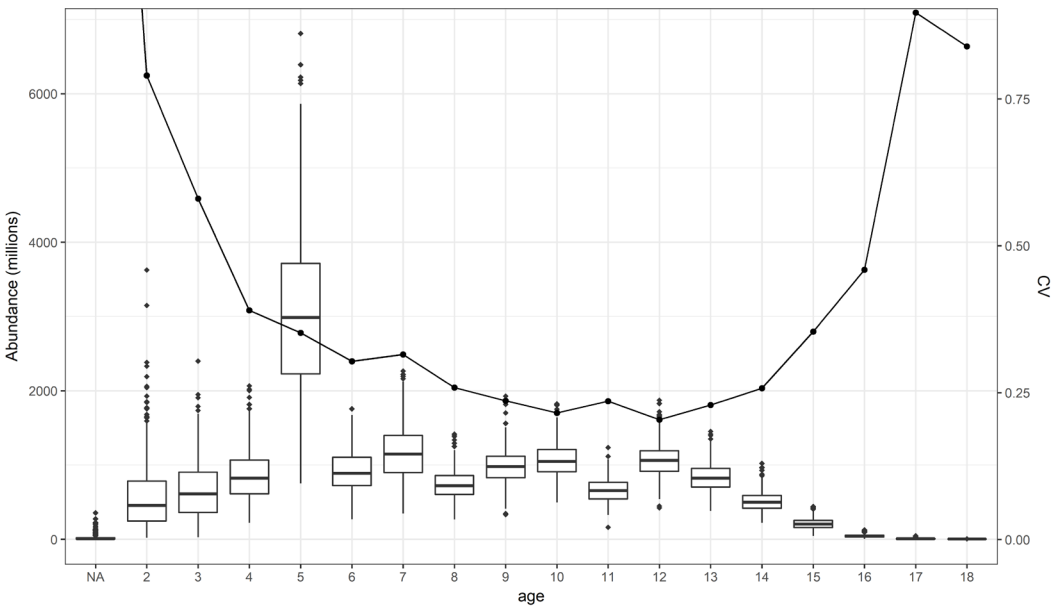

Figure 18. Number by age for Norwegian spring-spawning herring during IESSNS 2018. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

Table 8. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring based on calculation in StoX for IESSNS 2018.

	age																					
LenGrp		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Unknown	Number	Biomass	Mean W
																				-1,00E+03	(1E3kg)	(g)
17-18	|	10292	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10292	447.7	43.50
18-19	|	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19-20	|	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2264	2264	153.9	68.00
20-21	|	14497	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14497	996.8	68.76
21-22	|	52468	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	52468	4339.5	82.71
22-23	|	113478	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	113478	10901.2	96.06
23-24	|	167087	47818	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	214904	23541.5	109.54
24-25	|	147783	64018	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	211801	24829.2	117.23
25-26	|	59109	17956	-	11410	-	-	-	-	-	-	-	-	-	-	-	-	-	-	88475	12231.2	138.24
26-27	|	12361	61406	12723	-	18072	-	-	-	-	-	-	-	-	-	-	-	-	-	104562	16727.0	159.97
27-28	|	-	61024	-	42497	44904	-	-	6292	-	-	-	-	-	-	-	-	-	-	154716	28422.9	183.71
28-29	|	-	20311	28618	54703	9525	21411	-	-	-	-	-	-	-	-	-	-	-	-	134567	28349.1	210.67
29-30	|	-	58529	220195	47539	2578	-	25546	34506	-	-	36375	-	-	-	-	-	-	-	425269	100985.5	237.46
30-31	|	-	106259	220788	357674	68370	52219	58863	2637	62457	15614	11711	23421	5274	-	-	-	-	-	985287	255184.0	258.99
31-32	|	-	185583	167613	1091137	51260	29905	23137	27022	30884	7724	65595	-	-	-	-	-	-	-	1679860	474143.0	282.25
32-33	|	-	75252	80109	880209	229417	308324	-	12427	-	-	-	7429	-	-	-	-	-	-	1593168	485662.3	304.84
33-34	|	-	24234	127243	402250	327822	312089	24807	36581	21058	-	16596	-	-	-	-	3749	-	-	1296429	422052.1	325.55
34-35	|	-	-	21698	180555	108932	255273	206523	89302	118700	11797	55667	5103	14781	-	-	-	-	-	1068332	372617.4	348.78
35-36	|	-	-	-	9951	40468	224891	259078	405889	323944	201474	168535	69631	87407	81236	1260	-	-	-	1873763	701909.9	374.60
36-37	|	-	-	-	-	29812	59985	79844	128284	390552	300565	396800	301342	201506	11992	6032	-	-	-	1906715	759064.9	398.10
37-38	|	-	-	-	-	-	-	39769	176405	104649	137772	249625	404644	100843	49368	3781	1444	-	-	1268301	528268.4	416.52
38-39	|	-	-	-	-	-	-	16314	28384	18222	18657	35014	121698	80256	79185	22314	1860	1860	-	423763	183836.2	433.82
39-40	|	-	-	-	-	-	-	-	-	-	-	-	33193	18640	2360	14554	-	-	-	68747	30721.5	446.88
40-41	|	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1171	1171	-	-
TSN(1	|	577075	722390	878987	3077925	931162	1264097	733881	947728	1070466	693602	1035918	966461	508707	224140	47942	7053	1860	3435	13692829	-	-
TSB(1	|	62491.9	156106.0	228916.1	892608.0	290869.3	426574.7	258383.5	355348.4	406226.6	273767.6	402455.0	388876.2	206764.7	92574.2	19897.3	2574.9	796.8	153.9	-	4465385.1	-
Mean	|	23.21	28.86	30.75	31.70	32.46	33.44	34.41	35.17	35.26	35.86	35.50	36.57	36.48	36.69	37.96	35.14	38.00	26.49	-	-	-
Mean	|	108.29	216.10	260.43	290.00	312.37	337.45	352.08	374.95	379.49	394.70	388.50	402.37	406.45	413.02	415.03	365.10	428.50	68.00	-	-	326.14

4.5 Blue whiting

Blue whiting was distributed throughout the entire survey area with exception of the area north of Iceland influenced by the cold East Icelandic Current and in the East Greenland area. The highest sA-values were observed in the eastern and southern part of the Norwegian Sea, along the Norwegian continental slope, around the Faroe Islands as well as south of Iceland –the distribution in 2018 is quite similar to the 2017 distribution with perhaps a little less concentration west off Iceland. The main concentrations of older fish were observed in connections with the continental slopes both in the eastern and the southern part of the Norwegian Sea (Figure 19). The largest fish were found in the central and northern part of the survey area.

The total biomass of blue whiting registered during IESSNS 2018 was 2.0 million tons (Table 9), which is an 11% decrease compared to 2017 when the estimated index of age groups 1+ was 2.3 million tonnes. The stock estimate in number for 2018 is 16.3 billion compared to 22.3 billion of age groups 1+ in 2017, which is a 27% decrease. The age group four is dominating the estimate (39% of the biomass and by number).

Number by age, with uncertainty estimates, for blue whiting during IESSNS 2018 is shown in Figure 20.

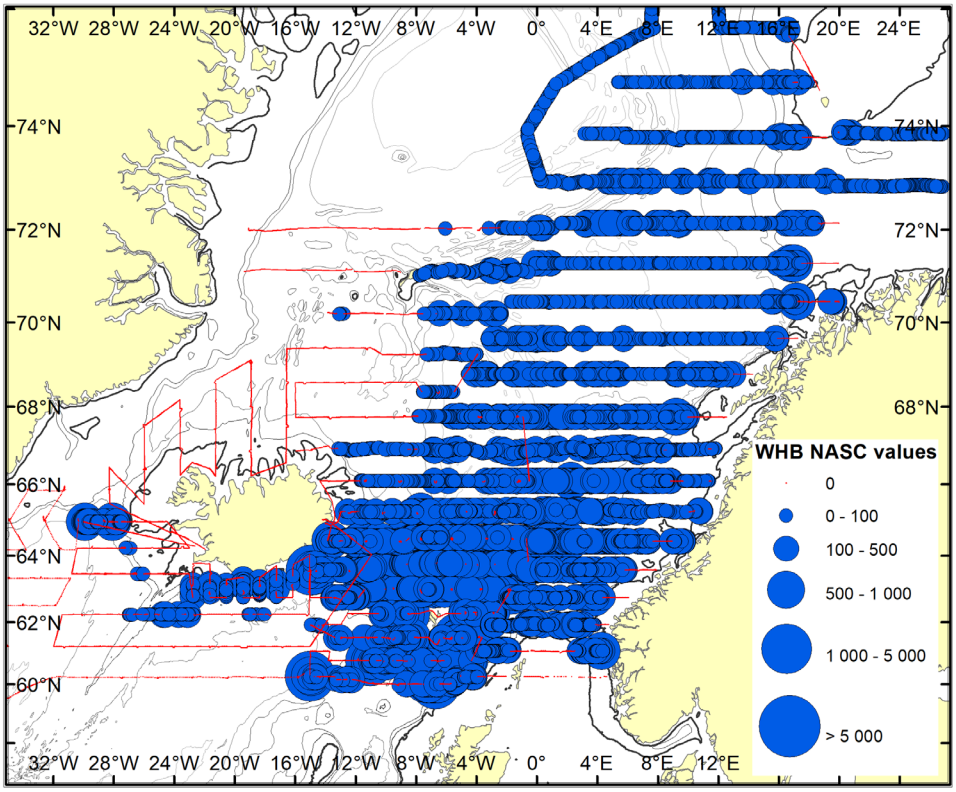

Figure 19. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS 2018.

Table 9. Estimates of abundance, mean weight and mean length of blue whiting based on calculation in StoX for IESSNS 2018.

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

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
20-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11016	11016	495.4	44.97
21-22	35568	26067	-	-	-	-	-	-	-	-	-	-	-	-	-	-	61635	3440.5	55.82
22-23	194497	62947	-	-	12138	-	-	-	-	-	-	-	-	-	-	-	269581	17753.8	65.86
23-24	246952	129453	11762	1060	-	-	-	-	-	-	-	-	-	-	-	-	389228	29380.1	75.48
24-25	343423	166977	93173	48828	17691	-	-	-	-	-	-	-	-	-	-	-	670092	56534.4	84.37
25-26	69234	387671	618132	570315	168980	10606	-	-	-	-	-	-	-	-	-	-	1824938	174933.4	95.86
26-27	21783	175860	921339	1528898	562484	58381	-	-	-	-	-	-	-	-	-	-	3268747	345041.9	105.56
27-28	3206	178698	872232	1531573	568516	24235	14597	-	-	-	-	-	-	-	-	-	3193057	380715.2	119.23
28-29	-	24592	429051	1351247	624348	119744	14222	25278	-	-	-	-	-	-	-	-	2588482	344020.6	132.90
29-30	-	4523	211757	781889	434152	106990	50613	903	-	-	-	-	-	-	-	-	1590826	233385.8	146.71
30-31	-	4045	36533	297721	428459	125672	61608	16893	-	-	-	-	-	-	-	-	970930	156092.2	160.77
31-32	-	4467	46996	173893	148891	165373	77032	3070	11422	-	-	-	-	-	-	-	631143	110657.7	175.33
32-33	-	-	9610	36084	101201	130985	47067	276	-	10101	-	-	531	-	-	-	335856	64249.1	191.30
33-34	-	-	-	2307	73371	98836	69831	18483	-	-	2026	-	-	-	-	-	264854	54436.4	205.53
34-35	-	-	-	5709	6798	8220	37960	9050	-	-	-	-	-	5164	-	-	72901	16611.6	227.87
35-36	-	-	1237	13619	-	13893	-	12682	3405	-	-	1856	-	-	-	-	46692	11944.8	255.82
36-37	-	-	-	6533	-	33136	11911	6037	-	-	-	-	-	-	3383	-	61001	15752.0	258.23
37-38	-	-	-	-	-	-	-	-	27235	-	-	1767	-	-	-	-	29002	8652.5	298.34
38-39	-	-	-	-	3627	3830	-	-	-	-	-	-	7660	-	-	-	15117	5187.7	343.18
39-40	-	-	-	-	-	353	-	-	6815	-	-	7766	-	-	-	-	14935	5574.7	373.27
40-41	-	-	-	-	-	-	-	-	2878	-	-	353	-	-	-	-	3232	1070.7	331.31
41-42	-	-	-	-	-	-	-	7660	-	-	-	-	-	-	-	-	7660	2734.5	357.00
TSN(1000)	914663	1165301	3251822	6349676	3150656	900253	384842	100330	51755	10101	2026	11743	8190	5164	3383	11016	16320922	-	-
TSB(1000 kg)	72758.2	110519.6	375377.4	788226.6	424900.3	152361.1	68014.1	20457.0	14396.2	2129.7	402.5	3878.7	2572.7	1248.5	927.0	495.4	-	2038664.9	-
Mean length (cm)	23.61	25.20	26.84	27.54	28.29	30.58	31.48	32.49	36.11	32.00	33.17	38.22	38.08	34.45	36.33	20.32	-	-	-
Mean weight (g)	79.55	94.84	115.44	124.14	134.86	169.24	176.73	203.90	278.16	210.83	198.67	330.31	314.12	241.78	274.00	44.97	-	-	124.91

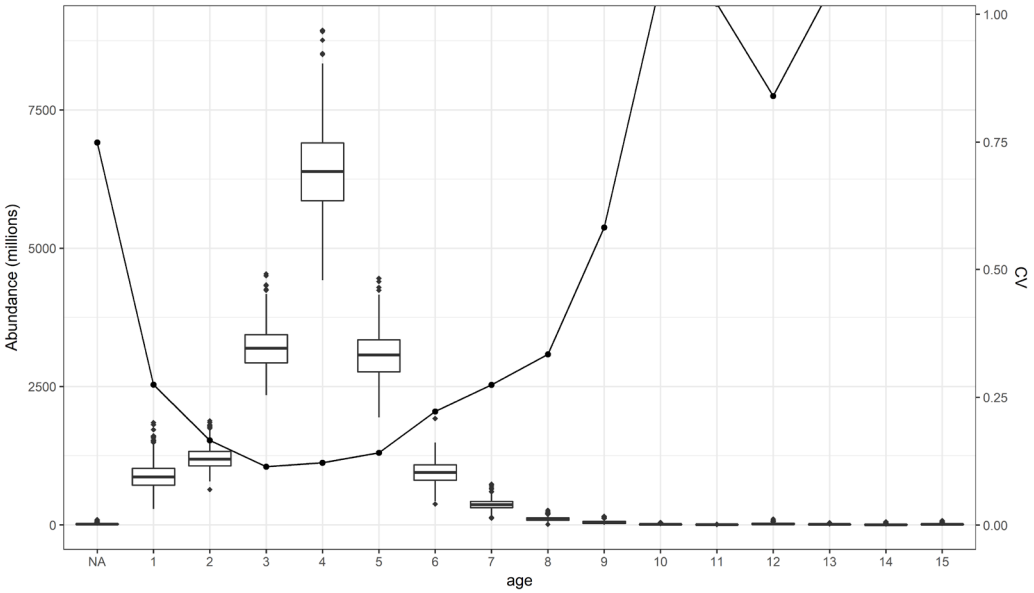

Figure 20. Number by age with uncertainty for blue whiting during IESSNS 2018. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

4.6 Other species

Lumpfish (*Cyclopterus lumpus*)

Lumpfish was caught in approximately 65% of trawl stations across the six vessels (Figure 21) and where lumpfish was caught, 79% of the catches were ≤10kg. Lumpfish was distributed across the entire survey area, from west of Cape Farwell in Greenland in the southwest to the central Barents Sea in the northeast part of the covered area. Of note, total trawl catch at each trawl station were processed on board R/V "Árni Friðriksson", M/V "Kings Bay", M/V "Vendla" and M/V "Finnur Fríði", whereas a subsample of 100 kg to 200 kg was processed onboard M/V "Trøndur i Gøtu" in Faroese waters. Therefore, small catches (<10 kg) of lumpfish might be missing from the survey track of M/V "Trøndur i Gøtu" (black crosses in Figure 21). However, it is unlikely that larger catches of lumpfish would have gone unnoticed by crew during sub-sampling of catch.

Abundance was greatest north of 66°N, and lower south of 65°N south of Iceland, in Faroese waters and northern UK waters. 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 3 to 51 cm with a bimodal distribution with the left peak (5-20 cm) likely corresponding to 1-group lumpfish and the right peak consisting of a mixture of age groups (Figure 22). For fish ≥20 cm in which sex was determined, the males exhibited a unimodal distribution with a peak around 25-27 cm. The females also exhibited a unimodal distribution but with a peak around 27-30 cm which was positively skewed. Aboard the Norwegian vessels, the ratio of males to females was approximately 1:1. Generally, the mean length and mean weight of the lumpfish was highest in the coastal waters and along the shelf edges in southwest, west, and northwest, and lowest in the central Norwegian Sea.

A total of 289 fish (253 by R/V "Árni Friðriksson" and 36 by M/V "Finnur Fridi") between 10 and 44 cm were tagged during the survey (Figure 23).

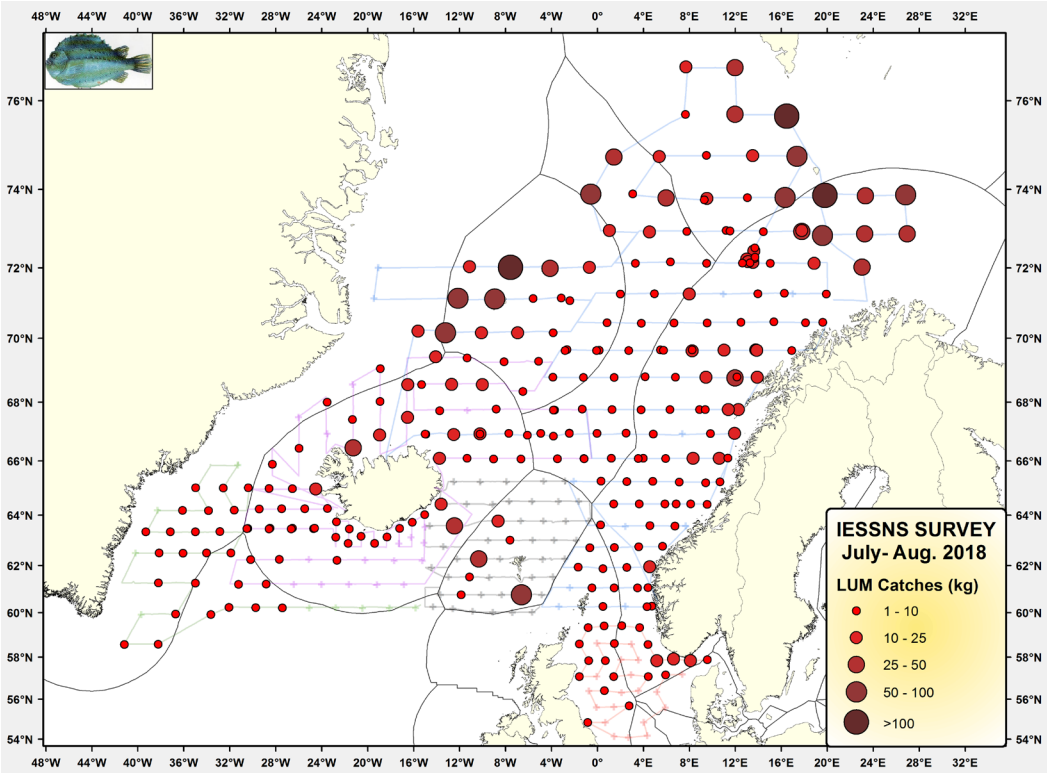

Figure 21. Lumpfish catches at surface trawl stations during IESSNS 2018.

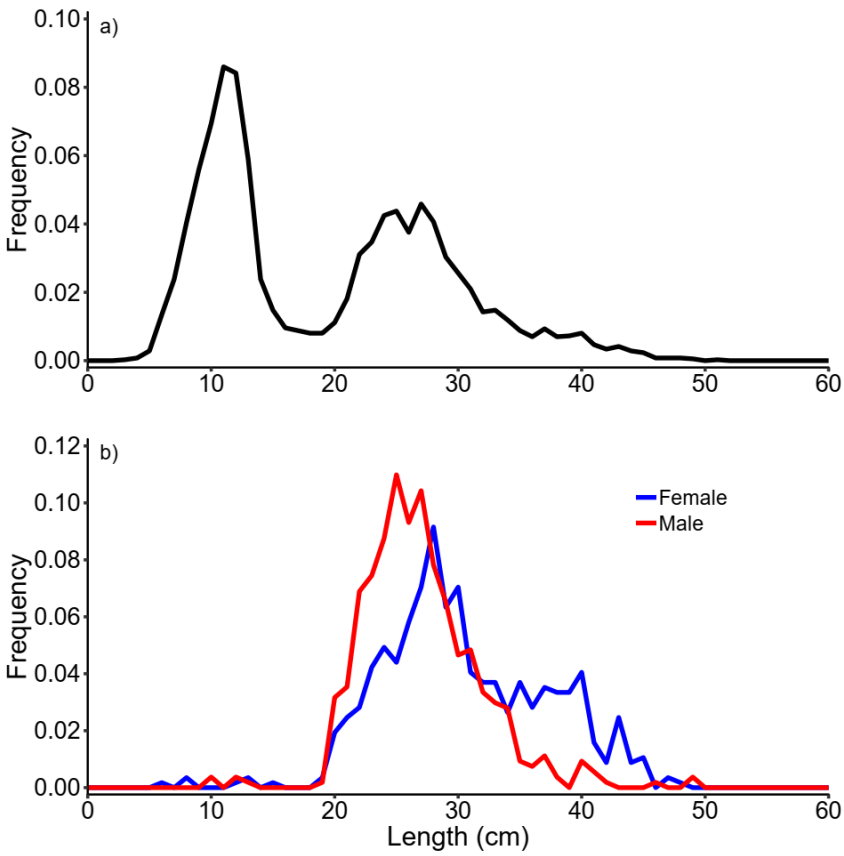

Figure 22. Length distribution of a) all lumpfish caught during the survey and b) length distribution of fish in which sex was determined.

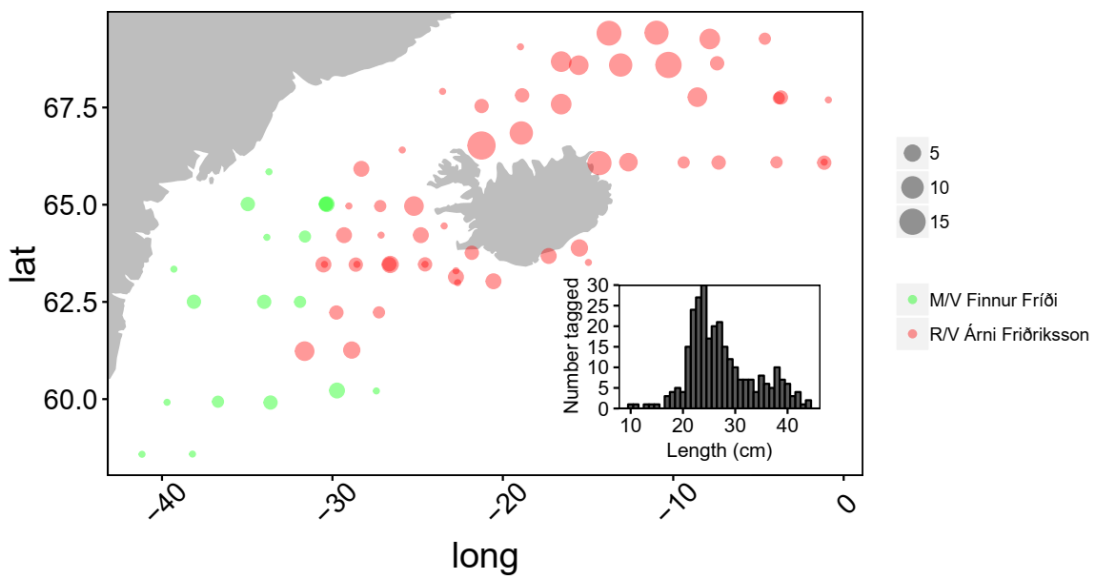

Figure 23. Number tagged, and release location, of lumpfish. Insert shows the length distribution of the tagged fish.

Salmon (*Salmo salar*)

A total of 80 North Atlantic salmon were caught in 44 stations both in coastal and offshore areas in the upper 30 m of the water column during IESSNS 2018 (Figure 24). The salmon ranged from 0.06 kg to 4.82 kg in weight, dominated by postsmolt weighing 80-200 grams. The length of the salmon ranged from 20 cm to 80 cm, with a large majority of the salmon <30 cm in length. The general impression was that postsmolt was distributed further to the east in 2018 than in 2017.

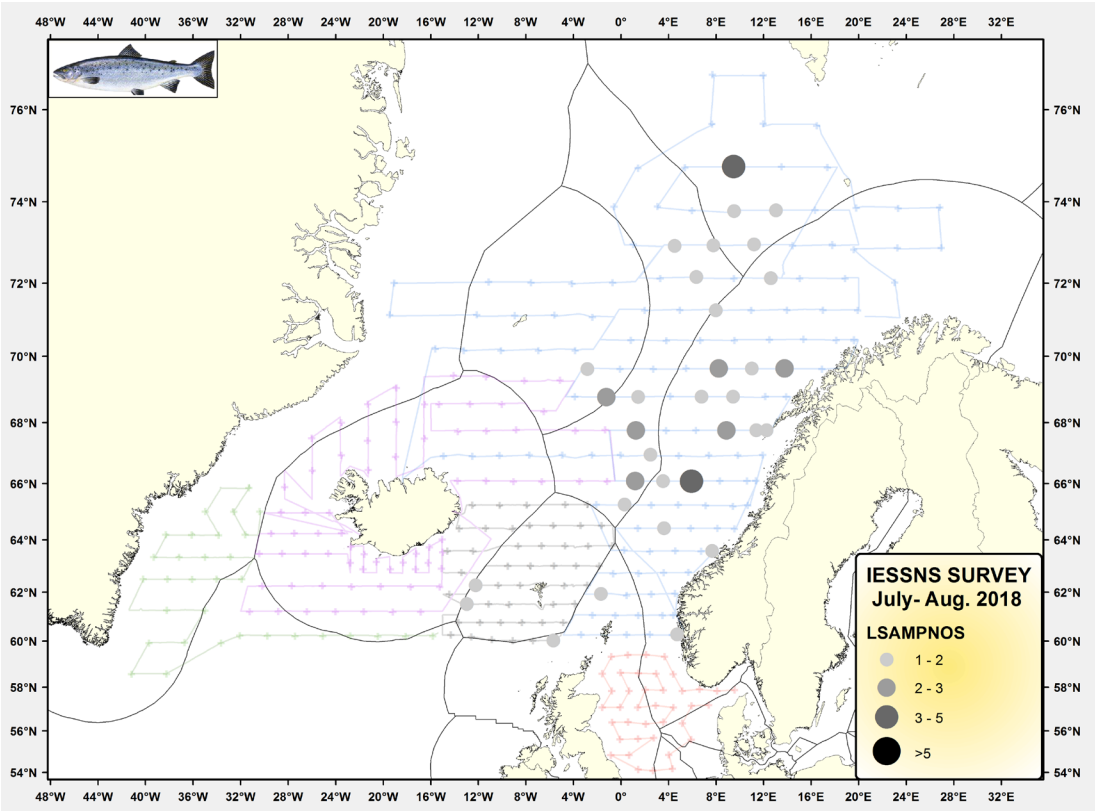

Figure 24. Catches of salmon at surface trawl stations during IESSNS 2018.

Capelin (*Mallotus villosus*)

Capelin was caught in the surface trawl on 12 stations along the cold front in SE Greenland, North of Iceland, North of Jan Mayen and at the entrance to the Barents Sea around Bear Island (Figure 25).

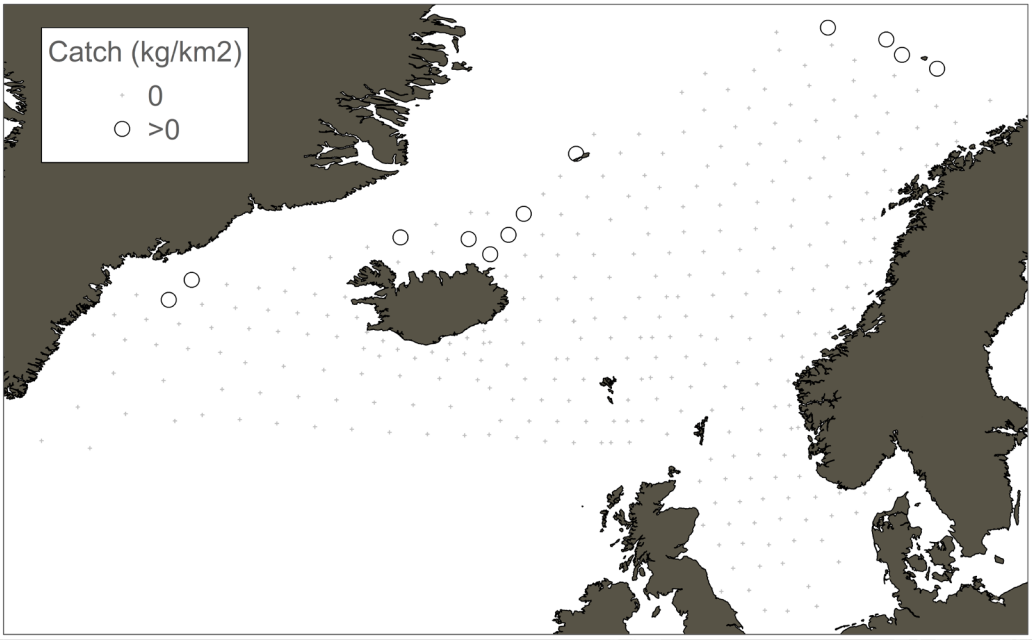

Figure 25. Presence of capelin in surface trawl stations during the IESSNS survey 2018.

4.7 Marine Mammals

Opportunistic whale observations were done by M/V "Kings Bay" and M/V "Vendla" from Norway in addition to R/V "Árni Friðriksson" from Iceland in 2018 (Figure 26). Overall, more than 600 marine mammals of nine different species were observed, which was a small reduction from last year 700+ observed individuals. This could partly be explained by reduced observation effort on R/V "Árni Friðriksson" as in 2017 dedicated whale observers were onboard which was not the case in 2018. The two Norwegian vessels with practically flat sea and excellent visibility during the entire survey period while Arni Fridriksson had occasional periods with fog north of Iceland. The species that was observed included; fin whales (*Balaenoptera physalus*), minke whales (*Balaenoptera acutorostrata*), humpback whales (*Megaptera novaeangliae*), blue whales (*Balaenoptera musculus*), pilot whales (*Globicephala sp.*), killer whales (*Orcinus orca*), sperm whales (*Physeter macrocephalus*), white-sided dolphins (*Lagenorhynchus acutus*) and white beaked dolphins (*Lagenorhynchus albirostris*). Marine mammal observations were north and south of Iceland, at the entrance to the Barents Sea, along the Norwegian coast and in the western outskirts of the Norwegian Sea. The observations were a mix of the species with no single species dominating. There were very few observations of marine mammals in the central Norwegian Sea and east of Iceland, and the spatial overlap between the pelagic fish and marine mammals seem to be low.

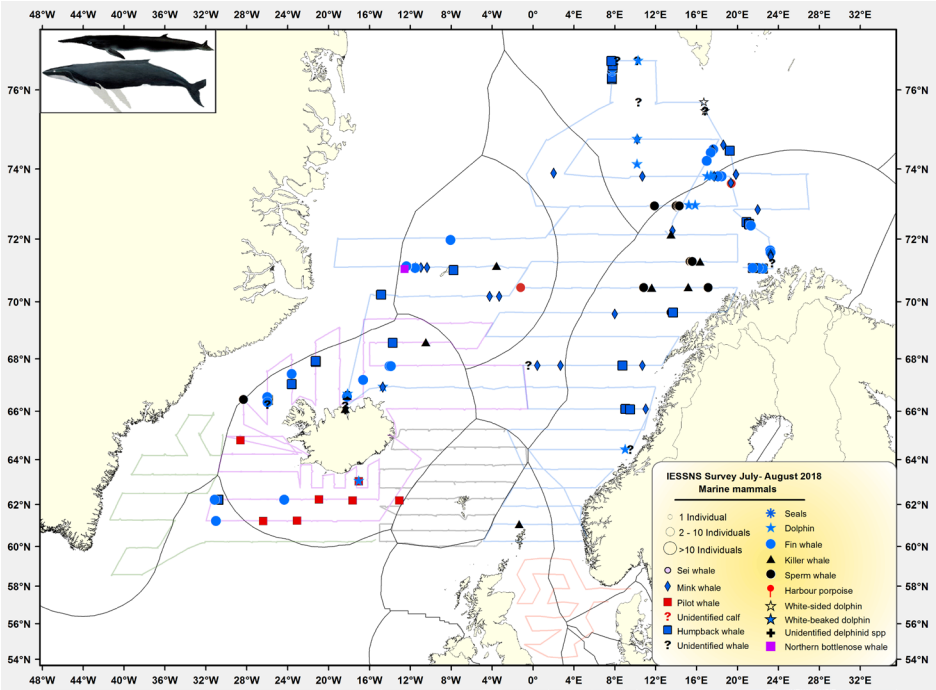

Figure 26. Overview of all marine mammals sighted during IESSNS 2018.

5 Discussion

The international coordinated ecosystem survey in the Norwegian Sea and adjacent areas (IESSNS) was performed during 30th June – 6th August 2018 by six vessels from Norway (2), Iceland (1), Faroes (1), Greenland (1), and Denmark (1). The survey coverage was slightly larger than in the previous year. Standardised surface trawling at predefined locations was used for a swept area abundance estimation of mackerel as in current years. The method is analogous to swept area bottom trawl surveys run for many demersal stocks. In addition to the surface trawling, CTD, zooplankton sampling and marine mammal sightings are also parts of the IESSNS. Deep water trawling aimed on acoustic registrations were undertaken by all vessels, except Ceton operation in the North Sea, for the third consecutive year to identify species and size distribution for acoustic estimation of blue whiting and Norwegian spring-spawning herring. The attempts are considered successful for all three years, 2016-2018, and a new time series for abundance estimation and biomass indices for blue whiting (north of 60°N) and Norwegian spring-spawning herring is being created. The IESSNS therefore provides abundance indices of three pelagic fish stocks, mackerel, blue whiting and Norwegian spring-spawning herring.

Mackerel was distributed in most of the 2.8 million km² survey area excluding the cold waters north and northwest of Iceland. The total swept area biomass index of mackerel in 2018 was average for the time-series from 2007 to 2018. There was a 40% decline in biomass in 2018 compared to 2017, and a 30% decline in numbers. The smaller decline in numbers is explained by record high values of age-1 mackerel and high values of age-2 mackerel in 2018. Biomass decline from 2017 to 2018 was most pronounced for age classes 3-7. The 2014 cohort (age 4) is not as large as recorded previous two summers and does not anymore appear at similar level as the big 2010 and 2011-year classes.

The mackerel appeared more evenly distributed within the survey area and more easterly distributed than in 2017. This difference in distribution primarily consists of a marked biomass decline in the west (76 % decrease in biomass west of stratum 3, see StoX results). In the eastern areas, the decline was less (21 %). Furthermore, there was also an eastward shift in distribution within the Norwegian Sea.

The marked decrease in the western areas since 2017 may have several causes, importantly; it reflects that the 2017 estimate was driven by relatively few exceptionally large catches. The strong impact of rare large catches on the index calls for an evaluation of the methods used to derive the index. Statistical methods that account for trawl catch distributions with over-dispersion has successfully been applied to mackerel trawl data before (Jansen et al. 2015; Nikolioudakis et al. 2018).

Mackerel cohort internal consistency remained relatively high. Internal consistency is strong for ages 1 to 5 years ($r > 0.8$) and a fair/good internal consistency for ages 5 to 11 years ($r > 0.5$), except for 7-8 years old mackerel.

As in previous years, the spatio-temporal overlap between mackerel and herring was highest in the southern and south-western part of the Norwegian Sea. There was practically no overlap between NEA mackerel and NSSH in the central and northern part of the Norwegian Sea, mainly because of very limited amounts of herring in this area (Figure 12).

The acoustic abundance index of NSSH was 13.6 billion corresponding to 4.46 million tonnes (Table 8). The abundance estimate of herring from the 2017 survey was 20.6 billion corresponding to 5.88 million tonnes, i.e. a reduction of approx. 24.2% in terms of biomass this year. This drop cannot be easily explained but migration of NSSH south of 62 ^{0}N, where it would mix with other stocks, might influence the result. Older fish dominated in the western and southwestern part and a range of year classes were present in this area. In the north-eastern part of the Norwegian Sea at the entrance to the Barents Sea is mainly juvenile fish age 5 years and younger present.

The acoustic abundance index of blue whiting was 16.3 billion corresponding to 2.0 million tonnes (Table 9). The abundance estimate of blue whiting from the 2017 survey was 22.3 billion corresponding to 2.3 million tonnes, corresponding to decrease in 2018 of approximately 11% in terms of biomass and 27% in terms of abundance of age 1+ fish. It should be noted that in 2017 some strong registrations of 0-group blue whiting south of the Faroe Islands which accounted for 15% of the abundance that year. However, in 2018 no 0-group was registered in the survey.

The group considered the two acoustic biomass estimates of herring and blue whiting to be of good quality in the 2018 IESSNS as in the two previous survey years.

Average zooplankton index for the survey area declined compared to 2017, however the decline was not uniform for the survey area. There was a slight decline in zooplankton in the Norwegian Sea and in Greenland waters (eastward of longitude 30 °W) compared to a substantial increase in Icelandic waters. These plankton indices, however, needs to be treated with some care due as it is only a snapshot of the standing stock biomass, not of the actual production in the area, which complicates spatio-temporal comparisons.

The swept-area estimate was, as in previous years, based on the standard swept area method using the average horizontal trawl opening by each participating vessel (ranging 60-68m; Table 5), assuming that a constant fraction of the mackerel inside the horizontal trawl opening are caught. Further, that if mackerel is distributed below the depth of the trawl (footrope), this fraction is assumed constant from year to year.

Results from the survey expansion southward into the North Sea is analysed separately from the traditional survey grounds north of latitude 60 °N as per stipulations from the 2017 mackerel benchmark meeting (ICES 2017).

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

6 Recommendations

Recommendation	To whom
Encourage EU to participate in the IESSNS survey again and survey the North Sea, and review the spatial coverage based on this years' results combined with the mackerel catches in IBTS Q3.	EU
The guidelines for trawl performance should be revised to reflect realistic manoeuvring of the Multpelt832 trawl.	Norway, Faroe Islands, Iceland, Greenland, EU
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. As predetermined surface trawl station, discarded hauls should be repeated until performance is satisfactory.	Norway, Faroe Islands, Iceland, Greenland, EU
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 weighted. 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.	Norway, Faroe Islands, Iceland, Greenland, EU
We recommend that observers collect sighting information of marine mammals and birds on all vessels.	Norway, Faroe Islands, Iceland, Greenland, EU

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2 Appendix 1:

StoX estimate of age segregated and length segregated mackerel index for the North Sea in 2018. Also provided is average length and weight per age class.

LenGrp	age 1	2	3	4	5	6	7	8	9	Number (1E3)	Biomass (1E3kg)	Mean W (g)
16-17	-	-	-	-	-	-	-	-	-	-	-	-
17-18	332	-	-	-	-	-	-	-	-	332	13.8	41.59
18-19	32024	-	-	-	-	-	-	-	-	32024	1712.7	53.48
19-20	134728	-	-	-	-	-	-	-	-	134728	7669.6	56.93
20-21	209419	-	-	-	-	-	-	-	-	209419	14330.2	68.43
21-22	155303	-	-	-	-	-	-	-	-	155303	12060.3	77.66
22-23	53594	-	-	-	-	-	-	-	-	53594	4615.5	86.12
23-24	9095	-	-	-	-	-	-	-	793	9888	985.3	99.65
24-25	9633	293	-	-	-	-	-	-	-	9926	1144.6	115.31
25-26	54163	3620	-	-	-	-	-	-	-	57783	7757.3	134.25
26-27	26501	120545	-	-	-	-	-	-	-	147046	23735.6	161.42
27-28	26069	282811	-	-	-	-	-	-	-	308879	54534.6	176.56
28-29	44374	287831	-	-	-	-	-	-	-	332205	63114.0	189.98
29-30	12520	207591	-	-	-	-	-	-	-	220111	47338.0	215.06
30-31	6963	83768	3760	1568	-	-	-	-	-	96060	22202.7	231.13
31-32	-	38363	31325	618	-	-	-	-	-	70305	18482.0	262.88
32-33	-	38580	65123	1438	-	-	-	-	-	105141	29753.3	282.98
33-34	-	20497	61592	10098	-	-	-	-	-	92186	28244.3	306.38
34-35	-	9949	33634	14386	2714	-	-	-	-	60683	19239.7	317.05
35-36	-	-	12031	10684	16019	1138	-	-	-	39872	14439.6	362.15
36-37	-	-	2177	4389	8905	5168	615	-	-	21254	8008.3	376.79
37-38	-	-	1038	157	4714	3406	256	805	-	10375	4359.1	420.15
38-39	-	-	-	-	1454	2340	295	343	-	4432	2016.2	454.96
39-40	-	-	-	-	264	941	580	89	-	1873	932.2	497.57
40-41	-	-	-	-	-	103	497	76	-	676	380.5	563.20
41-42	-	-	-	-	-	-	506	103	-	608	362.3	595.46
42-43	-	-	-	-	-	-	-	22	-	22	12.6	570.00
43-44	-	-	-	-	-	-	67	-	224	291	168.0	576.51
44-45	-	-	-	-	-	-	-	-	-	-	-	-
45-46	-	-	-	-	-	-	-	-	-	-	-	-
46-47	-	-	-	-	-	-	-	-	-	-	-	-
TSN(1000)	774717	1093847	210679	43338	34070	13095	2816	1437	1017	2175018	-	-
TSB(1000 kg)	72289.3	218580.4	61213.7	14858.2	12933.7	5428.8	1461.2	656.9	190.3	-	387612.5	-
Mean length (cm)	21.65	28.25	32.66	33.97	35.62	36.78	38.69	37.88	27.41	-	-	-
Mean weight (g)	93.31	199.83	290.55	342.84	379.62	414.57	518.85	457.06	187.09	-	-	178.21

Document 7a: GERAS 2018 survey summary table

Survey Summary Table WGIPS 2019	
Name of the survey (abbreviation):	GERAS / BIAS (GER) (FRV Solea SB754)
Target Species:	Herring (*Clupea harengus,* Western Baltic Spring Spawning Herring WBSSH; Central Baltic Herring CBH), Sprat (*Sprattus sprattus*), Anchovy (*Engraulis encrasicolus*), European Pilchard (*Sardina pilchardus*)
Survey dates:	01-19 Oct 2018
Summary:	
The objectives of the survey were carried out successfully and as planned in all of the covered ICES Subdivisions. Adverse weather conditions occurred during the first night of the survey in the southwestern part of SD 22 (Kiel Bight) but did not require interruption of survey operations and are not considered to affect acoustic estimates (see below). Altogether, 62 trawl hauls were carried out during the survey providing biological data for age stratified abundance estimation of target species herring and sprat (58 valid hauls utilized for estimates). Measured NASC values per 1 nmi EDSU allocated to clupeids were higher in most parts of the survey area compared with the previous year (exception SD 24), but below the long-term survey mean. A further decrease in abundance of Western Spring Spawning Herring (-22% and -49% in SD 21-24 and 22-24 respectively) was recorded to the second lowest levels of the time-series since 1993. Abundance increased (+56% and +19% respectively) due to a high contribution of 0-group herring. In sprat, abundance and biomass in the survey area declined by 37 % and 43% respectively. As in the previous years, dense aggregations of large, mature herring seemed to be absent from their overwintering area in SD23.	
	Description
Survey design	Stratified systematic (parallel where applicable) design. Start point not randomized.
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 were 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 in some areas but did not affect significant parts of the depth layers utilized for integration or occurred in an area with known low fish densities (southwestern part of SD 22).

Extinction (shadowing)	No particular issues as targets are scattered in loose aggregations in most of the surveyed areas during the survey operation.
Blind zone	Night-time distribution of clupeids in surface layers (i.e. within blind zone and nearfield) is assumed to occur but is not quantified. (Integration start depth 10 m).
Dead zone	No particular issue as clupeids are mostly distributed pelagic and away from seafloor during night-time survey operations.
Allocation of backscatter to species	Directed trawling. Mixed species category applied throughout survey. Species allocations based on combined trawl haul composition (per ICES statistical rectangle).
Target strength	As listed in SISP Survey manual (ICES, 2017).
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. 2018 survey: Survey area covered as planned. Stock containment considered achieved.
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). 2018 survey: The present results support the continued applicability of the SF despite occurrence of some CBH in the GERAS baseline samples of WBSSH in SDs 21 and 23.
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. 2018 survey: Biological information for some rectangles used/amended from neighbouring rectangles.

Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole time-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 7b: GERAS 2018 survey report

Please see the report on the next page.

Federal Research Institute for Rural Areas, Forestry and Fisheries

Thünen Institute of Sea Fisheries (TI-SF)[1]
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Survey Report FRV Solea

German Acoustic Autumn Survey (GERAS)

01 – 19 October 2018

Matthias Schaber[1] & Tomas Gröhsler[2]

1 INTRODUCTION

1.1 Background

The cruise was part of an international hydroacoustic survey providing information on stock parameters of small pelagics in the Baltic Sea, coordinated by the ICES Working Group of International Pelagic Surveys (WGIPS) and the ICES Baltic International Fish Survey Working Group (WGBIFS). Further WGBIFS contributors to the Baltic survey are national fisheries research institutes of Sweden, Poland, Finland, Latvia, Estonia and Lithuania. FRV Solea participated for the 31st 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). Altogether, 1211 nmi (plus 107 nmi night and daytime transects for comparison) of hydroacoustic transects were covered. The survey effort was comparable to previous years.

1.2 Objectives

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

The following objectives were planned:

- 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 European anchovy and cod for further analyses

1.3 Survey summary

In the majority of sampled rectangles, mean NASC values per nautical mile were distinctly higher than the values measured in 2017 and in SD 22 and SD 21 (in 2 and 3 cases, respectively) higher than the long-time mean values. Despite this increase from 2017, the majority of rectangles sampled in 2018 still showed mean NASC values below the long time mean. While NASC values measured were higher in ICES Subdivisions 21, 22 and 23 (in comparison with 2017), levels in SD 24 were in all but two rectangles distinctly lower than the already low NASC values measured in the previous year. While in SD 23, as in 2017, unusually low NASC values (albeit higher than in the previous year) were measured, indicating absence of the dense aggregations of herring usually observed in that area at this time of the year. On a repetition of the transect in SD 23 during daytime for comparison, NASC values measured were distinctly higher than those recorded during nighttime, indicating higher presence of clupeids in the area.

For species allocation and identification, altogether 62 fishery hauls were conducted (including 58 valid hauls during the survey and 3 valid hauls on comparison transects). Vertical hydrography profiles were measured on 106 stations.

2 SURVEY DESCRIPTION & METHODS APPLIED

2.1 Cruise narrative

The 754th cruise of FRV Solea represents the 31st subsequent GERAS survey. Embarkation of scientific crew as well as equipment of FRV Solea with all hydroacoustic equipment and biological sampling gear took place on the morning of October 1st in Kiel harbor. On the same afternoon, Solea left port for the calibration of scientific echosounders. The calibration site off Strande that had been chosen for calibration in the previous year was again approached based on the prevailing weather conditions that

were considered acceptable (4-5 Bft, westerly winds). After calibration the vessel returned to Kiel harbor in the late evening to allow switching of survey operations to night time. Leaving of port and start of survey was scheduled for October 2nd in the afternoon. The hydroacoustic survey operations commenced October 2nd at 06:00 PM in SD 22 in Kiel Bight.

Generally, survey operations were conducted during nighttime to account for the more pelagic distribution of clupeids during that time. Adverse weather conditions at the beginning of the survey required to start survey operations in the westerly survey area of the comparatively sheltered western Baltic SD 22. In the first night of survey operations, weather conditions deteriorated (10 Bft westerly winds) but allowed continuation of the survey in the narrow Belt Sea. After finishing SD 22, survey operations commenced in SD 24 and SD 23 which both were covered as planned due to favorable weather conditions, as was SD 21 afterwards. Regular survey operations were accomplished on October 16th. After a switch of survey operations back to daytime, a comparative sampling (hydroacoustics and fishery) of SD 23 (Sound) was conducted to validate weak registrations recorded during the regular, initial passage. The scientific program was finished on October 18th, 04:45 PM. The ship arrived at Marienehe port on October 19th, 07:00 AM.

Altogether, the following survey schedule was accomplished:

Belt Sea	(SD 22)	02. - 06.10.
Arkona Sea	(SD 24)	07. - 11.10.
Sound	(SD 23)	12.10.
Kattegat	(SD 21)	13. - 16.10.
Sound (day)	(SD 23)	18.10.

Total survey time	15 nights (+ 1 day comparison in SD 23)
Fishery hauls	62 (58 valid, 2 invalid, 3 daytime comparison)
CTD-casts	106
Hydroacoustic transects	1211 nmi (+ 107 nmi transects for comparison)

Overall regular hydroacoustic transect length was 1211 nmi (2016: 1167 nmi).

2.2 Survey design

ICES statistical rectangles were used as strata for all Subdivisions (ICES, 2014). 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 regular cruise track length was 1211 nmi covering a survey area of 12 400 nmi^2 (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. The main pelagic species of interest were herring and sprat. 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 were conducted with Echoview 9 software (Echoview Software Pty Ltd, 2018). 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 an anchored vessel in Strande Bay/Kiel Bight (54°25.35 N, 10°12.29 E). Overall calibration results were considered good based on calculated RMS values. Resulting

transducer parameters were applied for consecutive data-collection and 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 7-9 m was achieved. The trawling time usually lasted 30 minutes but was shortened when echograms and netsounder indicated large catches. To validate and allocate echorecordings, altogether 62 fishery hauls were conducted (Figure 1), out of which 57 valid (night time) hauls were utilized for further processing. From each haul sub-samples were taken to determine length and weight of fish. Samples of herring and sprat 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, 106 CTD-profiles were measured (Figure 6).

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
Clupeoids	= 20 log L (cm) - 71.2	ICES (1983)
Gadoids	= 20 log L (cm) - 67.5	Foote et al. (1986)
Scomber scombrus	= 20 log L (cm) - 84.9	ICES (2017)

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

In accordance with the guidelines in the "SISP Manual of International Baltic Acoustic Surveys (IBAS)" (ICES, 2017) further calculations were performed as follows:

<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*)
Saithe	(*Pollachius pollachius*)
Mackerel	(*Scomber scombrus*)

Fish species considered (contd.):

Sprat	(*Sprattus sprattus*)
Horse mackerel	(*Trachurus trachurus*)
Norway pout	(*Trisopterus esmarckii*)
Poor cod	(*Trisopterus minutus*)

Exclusion of trawl hauls with very low catches:

Haul No.	Rectangle	Subdivision (SD)
6	40G0	22
12	38G0	23
29	38G2	24
45, 49	41G2	21
53	43G1	21
57	42G2	21

Exclusion of trawl hauls due to net damage:

Haul No.	Rectangle	Subdivision (SD)
31	39G2	24
52	41G1	21

Exclusion of day time trawl hauls:

Haul No.	Rectangle	Subdivision (SD)
60-61	40G2	23
62	41G2	23

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)
2, 3	40G0	22
4	41G0	22
5	40G1	22
9	39G1	22
29	38G2	24
47	41G0	21

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

Rectangle/SD to be filled	with Haul No.	of Rectangle/SD
43G2/21	58 and 54-56	42G2 and 43G1/21
39F9/22	7 and 8	40F9 and 39G0/22
40F9/22	2, 3	40G0/22
39G2/23	32 and 33	39G2 and 39G3/24

37G4/24	23, 26, 27	38G4/24

Application of the separation function (SF):

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 based on baseline samples of WBSSH and CBH in 2011-2017 and in 2018 support the applicability of the SF (Oeberst et al., 2013, WD Oeberst et al., 2014; WD Oeberst et al., 2015; WD Oeberst et al., 2016; WD Oeberst et al., 2017; WD Gröhsler and Schaber, 2018, WD Gröhsler and Schaber, 2019). In SD 24, the SF was finally also applied to ICES rectangle 39G2 (SD 23 area) since biological samples of 39G2 (SD 24 area) were used to raise the corresponding recorded S_A values.

In 2018, the age-length distribution of herring in SD 22 and SD 23 indicated a low contribution of fish of CBH origin. Thus, the SF was not applied in subdivisions 22 and 23 in 2018.

Accordingly, the applicability of the SF continued in 2018 despite the occurrence of some CBH in the GERAS baseline samples of WBSSH in SD 21 and 23.

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 now excludes CBH in 2005-2017 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 2018. The majority of these NASC measurements can be allocated to clupeids. In many rectangles surveyed, mean NASC values were significantly higher than those recorded in 2017, in some rectangles also above the long-time survey average. However, despite this increase from the previous year, mean NASC per rectangle was in the majority of rectangles still well below the long-term average. On ICES subdivision scale, mean NASC values were higher than in the previous year in subdivisions 21, 22 and 23, but significantly lower in SD 24.

In SD 21, overall NASC values measured were distinctly higher than those measured in the previous year. Only in one rectangle (42G1), mean NASC per 1 nmi EDSU was lower. SD 21 had the largest fraction of rectangles with NASC values exceeding not only the 2017 measurements (in 6 out of 7 rectangles) but also the long-term survey mean (in 3 out of 7 rectangles). Aggregations were mostly patchy along the cruisetrack, with the exception of the northern part of the Kattegat area surveyed, where increased NASC levels were measured more continuously.

In SD 22, mean NASC values recorded were also higher than the previous year in 6 out of 11 rectangles surveyed (similar values recorded in 2 out of 11 rectangles). In some rectangles, the increase in NASC measured was almost tenfold, but originated from only short transect sections in the area that usually is characterized by very low NASC levels. In comparison to the long-term survey mean, all but 2 rectangles in SD 22 showed decreased NASC values. No clear aggregation or area of increased NASC measurements was evident.

As in the previous year, the large aggregations of big herring that usually can be observed in SD 23 in the Sound were not present in autumn 2018. Although NASC values were distinctly higher than the levels measured in 2017, they still were well below the long-term survey mean. A replicate measurement of parts of the transect in SD 23 during night time and a full daytime replicate a few days later corroborated these findings, although daytime measurements showed somewhat increased NASC values in the area.

In SD 24, mean NASC values were significantly lower than the values measured in 2017 in 6 out of 9 rectangles surveyed. The only exception -with a fourfold increase from the previous year- was rectangle 37G2 (west of Fischland-Darß-Zingst Peninsula), an area with usually very low NASC measurements. As in the years before, higher aggregations were detected north-east and east of Rügen Island, but also – to a lesser degree- in the central and northern parts of the Arkona Basin.

3.2 Biological data (T. Gröhsler)

Fishery hauls according to ICES Subdivision:

SD	Hauls (n)
21	15 (incl. 1 invalid haul)
22	18
23	8 (incl. 3 daytime hauls)
24	21 (incl. 1 invalid haul)

Altogether, 1 623 individual herring, 917 sprat, 295 European anchovies and 166 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, 41 different species were recorded. Herring were caught in 58, sprat in 56 hauls (of 58 day- and nighttime hauls). SD 23, which is typically characterized by the highest mean catch rates per station (kg 0.5 h^{-1}), showed the lowest values ever recorded (during nighttime hauls). In contrast to 2017, when sardines (*Sardina pilchardus*) only appeared in catches from SD 21, this species in 2018 was also caught in SD 22 and SD 23. As in previous years, anchovy (*Engraulis encrasicolus*) were present in the whole survey area, albeit in a higher frequency of occurrence compared to 2017 (7 of 57 hauls in 2017; 26 of 58 day- and nighttime hauls in 2018).

Altogether, the following fish species were sampled and processed:

Species	Length measurements (n)	Prevalence (n of hauls)
Aphia minuta	761	37
Belone belone	22	13
Clupea harengus	12 915	58
Ctenolabrus rupestris	49	8
Cyclopterus lumpus	8	5
Engraulis encrasicolus	523	26
Eutrigla gurnadus	14	7
Gadus morhua	248	24
Gasterosteus aculeatus	1 214	39
Gobius niger	14	7
Limanda limanda	222	19
Merlangius merlangus	887	44
Merluccius merluccius	12	3
Mullus surmuletus	3	3
Neogobius melanostomus	8	3
Platichthys flesus	51	13
Pleuronectes platessa	28	10
Pomatoschistus minutus	208	32
Sardina pilchardus	245	17
Scomber scombrus	195	16
Sprattus sprattus	10 515	56

Species	Length measurements (n)	Prevalence (n of hauls)
Trachinus draco	177	17
Trachurus trachurus	617	46
Trisopterus esmarkii	30	4
Others	183	-

Figures 3 and 4 show relative length-frequency distributions of herring and sprat in ICES subdivisions 21, 22, 23 and 24 for the years 2017 and 2018. Compared to results from the previous survey in 2017, the following conclusions for **herring** can be drawn (Figure 3):

- Catches in SD 21 showed a multimodal distribution with modes at 11.75 cm, 15.25-15.75 cm and 21.2.5-21.75 cm. This is in contrast to 2017, when a bimodal distribution showed modes at 14.75 and 17.75 cm,
- The catches in SD 22 were dominated by the incoming year class (ca. ≤15 cm) with a mode at 13.25 cm. This is in contrast to a multimodal distribution with two modes at 11.25 cm and 15.26 cm and one mode of 18.75 cm in 2017.
- As in the two years before, larger herring (>20 cm) were more or less absent from night time catches conducted in SD 23. The catches in 2018 as in 2017 were dominated by the contribution of the incoming year class (ca. ≤15 cm), showing a mode at 13.25 cm in 2017 and at 12.25 in 2018 cm.
- In SD 24, the herring length-frequency distribution was characterized by a similar contribution of the incoming year class (ca. ≤15 cm) and older herring (>15 cm) in both years. However, the bimodal distribution in 2018 showed a higher contribution of younger herring (ca. ≤15 cm) (≤15 cm: mode 2017/11.75 cm and mode 2018/13.75 cm; >15 cm: mode 2017/18.25 cm and mode 2018/17.75 cm).

Relative length-frequency distributions of **sprat** in the years 2017 and 2018 (Figure 4) can be characterized as follows:

- In SD 21 catches of the incoming year class (ca. ≤10 cm) were virtually absent in both years. The catches were dominated by the contribution of larger sprat.
- In SDs 22 and 24, the sprat length-frequency distribution was characterized by a similar contribution of the incoming year class (ca. ≤10 cm) and older sprat in both years. However, the bimodal distribution in 2018 showed slightly more of the incoming year class (<10 cm), at the same time less of older sprat.
- In SD 23, the catches were dominated by the incoming year class (ca. ≤10 cm) in 2018, whereas the catches in 2017 showed a bimodal distribution with equivalent contributions of the incoming year class (ca. ≤10 cm) and older sprat.
- Altogether, the present contribution of the incoming year class (ca. ≤10 cm) seemed to be rather low.

3.3 Biomass and abundance estimates

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

3.3.1 Herring incl. Central Baltic Herring (CBH)

The herring stock in Subdivisions 21-24 was estimated to be 4.3 x 10^9 fish (Table 7) or 90.0 x 10^3 tonnes (Table 9). For the included area of Subdivisions 22-24 the number of herring was calculated to be 2.9 x 10^9 fish or 59.8 x 10^3 tonnes.

3.3.2 Herring excl. Central Baltic Herring (CBH)

Estimated numbers of herring excluding CBH in SDs 21-24 by age group and SD/rectangle for 2017 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 SD 24 (and in rectangle 39G2 of SD 23) from the herring HAWG-GERAS index (standard index area: excl. results of rectangles 43G1 and 43G2 of SD 21 as well as 37G3 and 37G4 of SD 24) resulted in biomass reductions of 19.8 % with corresponding reductions in numbers of 10.9 % (-15.8 % and -12.7 %, respectively in 2017; Figure 5).

3.3.3 Sprat

The estimated sprat stock in Subdivisions 21-24 was 4.7 x 10^9 fish (Table 10) or 57.2 x 10^3 tonnes (Table 12). For the included area of Subdivisions 22-24 the number of sprat was calculated to be 3.8 x 10^9 fish or 43.1 x 10^3 tonnes. The overall abundance estimate in 2018 was dominated by on year old sprat (year class 2017, Figure 4 and Table 10).

3.4 Hydrography

Vertical profiles of temperature and salinity 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, 106 CTD casts were conducted during this survey.

Surface temperatures ranged from ca. 14°C in the Kiel Bight (SD 22) and ca. 13 °C in the Kattegat area to (SD 21) around 10-11°C in the northern Arkona Basin (SD 24)(Figure 6). Bottom temperatures were similar in most parts of Subdivisions 21, 22 and 23, but due to strong thermohaline layering in most parts of the Arkona Basin and the area of the Bornholm Basin covered were significantly different in SD 24. While bottom temperatures in the central Arkona Sea exceeded surface temperatures (maximum temperatures around 13 °C), bottom temperatures in the Bornholm Basin area were comparatively low at around 8 °C.

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 eastern Arkona Sea to > 25 PSU in the Kattegat). Compared to the previous year, surface salinity in the western parts of the survey area (SD 22) was comparatively high at levels of ca. 20 PSU. Salinity near the seafloor ranged from 8 PSU in the Arkona Sea to ca. 34 PSU in the Kattegat. Especially in the Sound (SD 23), a very strong stratification with steep salinity gradients was observed.

Surface waters were well oxygenated throughout the survey area. Near the seafloor, local anoxic conditions were measured in the inner Mecklenburg Bight/Bay of Lübeck as well as in the southwestern part of the Little Belt (SD 22). Anoxic conditions above the seafloor were observed in the southern part of the Little Belt and the inner Mecklenburg Bight. Reduced oxygen levels were also measured in the deeper parts of the Bornholm Basin area covered.

4 DISCUSSION

Compared to 2017, the present estimates of herring (total survey area incl. CBH) show a further significant decrease in stock biomass, whereas abundance values increased:

Herring (incl. CBH)	Difference compared to 2017	
Area	Numbers (%)	Biomass (%)
Subdivisions 22-24	+18	-41
Subdivisions 21-24	+56	-19

Herring (excl. CBH)	Difference compared to 2017	
Area	Numbers (%)	Biomass (%)
Subdivisions 22-24	+19	-49
Subdivisions 21-24	+63	-22

Compared to 2017, the present significant increase in numbers together with the continuing decrease in biomass was mainly driven by a higher contribution of 0-group herring (2018/2017: +177 %) that are characterized by lower mean weights, and also by a lower number of older and thus heavier herring of ages 2-7 (-39 %). The present herring biomass estimates (total survey area incl. CBH & excl. CBH) represent the second lowest recorded values in the whole time series since 1993.

The usually recorded dominant high number of large herring fish in SD 23 (the Sound), which is seen as an important transition and aggregation area for the WBSSH stock during its spawning migration (Nielsen, 1996), was in 2018 as in 2016-2017 for the third time since many years almost absent. This complete absence could, as in the previous year, be explained by delayed immigration of WBSSH from the feeding areas in the Skagerrak in 2018. The exceptionally low numbers in 2016 and even further decreased numbers in 2017 and 2018 of large and older herring could also be explained by the very low recruitment, which was recorded by the N20 during the last years. The sustained downward trend in recruitment could explain the further disappearance of older herring in time. The strong correlation of N20 with the 1-age group (Polte et al., 2018) of GERAS index supports this assumption. Methodological biases leading to the low numbers observed can again not be ruled out, but at least in terms of overall acoustic detections of clupeids seem unlikely. While differences in catchability might contribute to varying fractions of (old) herring in daytime vs. nighttime catches, as indicated by a higher fraction of big WBBSH in the daytime hauls, the small-scale NASC distribution recorded during the regular night-transect in SD 23 and another comparison sampling during daytime a few days later did not differ notably between the two transect runs (Figure 7). Possible shifts in distribution of the large herring aggregations towards shallower areas that cannot be surveyed with the current survey design and setup may also have occurred. During daytime passes of the survey area (transition) as well as during the comparison survey in SD 23 during daytime, aggregations of angling boats in shallow areas (but partly also areas covered in the survey) were observed with occupants catching big herring with rod and line. Additionally, during a diversion of the vessel into Copenhagen port for disembarking of a crew member after the survey had been accomplished, enormous and continuous aggregations of clupeids were detected on the echosounder in shallow water (depth < 15 m). A comparison with echorecordings from this section, if available from previous years, is intended to address these possible shifts and to investigate whether a corresponding fraction of herring had been distributed in these areas in years with high registrations along the regular transects as well.

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 2018, no such migration can be assumed since no older and bigger herring were detected in corresponding areas of the adjacent SD 24, nor was there an indication of according hydrographic conditions driving herring out of the Sound.

5 SURVEY PARTICIPANTS

Name	Function	Institute
Dr. M. Schaber	Hydroacoustics, Cruise leader	TI-SF
B. Lüdke	Hydroacoustics, Hydrography	TI-SF
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M. Koth	Fishery biology	TI-OF
S.-E. Levinsky	Fishery biology	DTU Aqua (DK)
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7 FIGURES

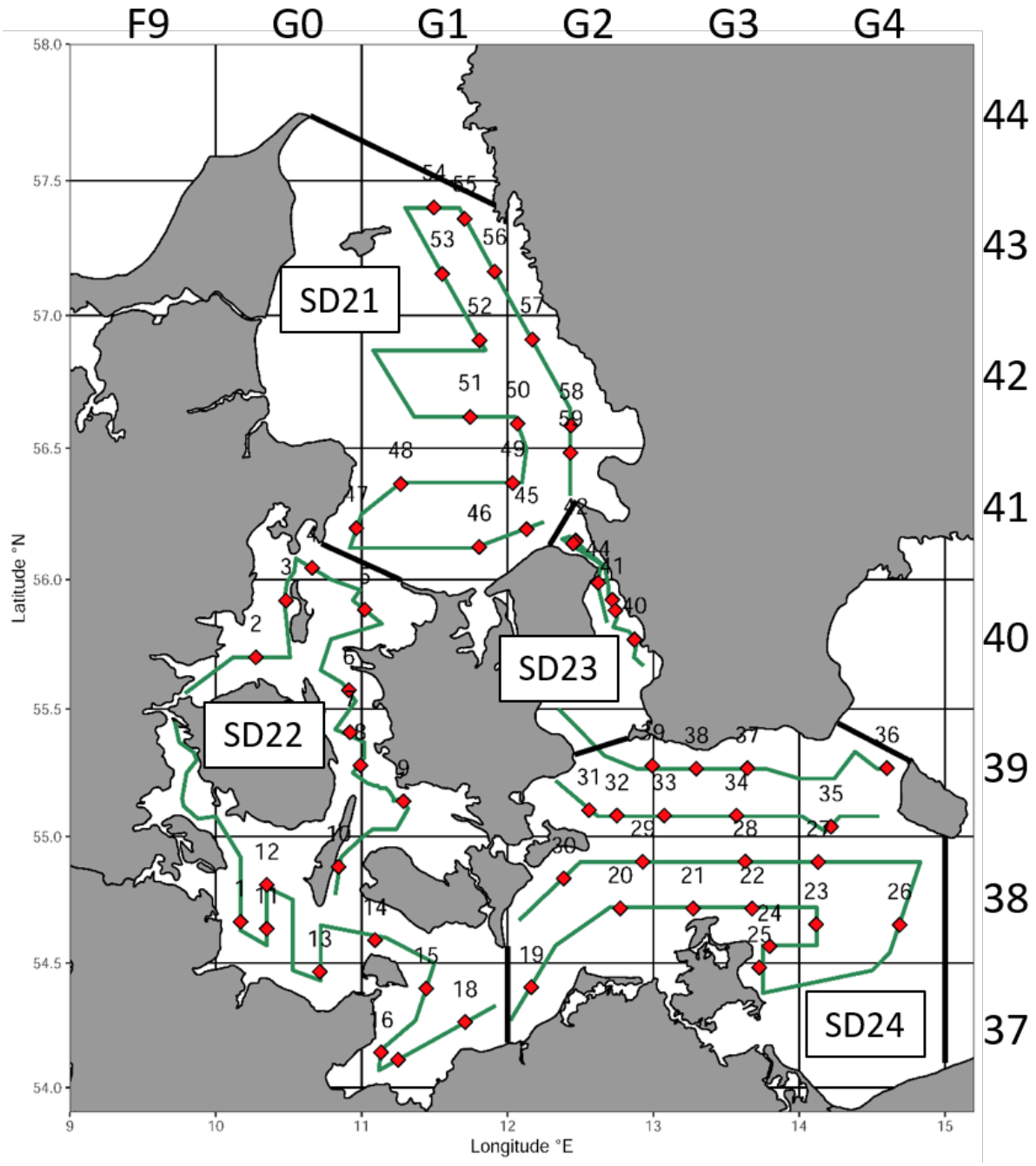


Figure 1: FRV Solea cruise 754/2018. Cruise track (dark green lines) and fishery hauls (red diamonds). ICES statistical rectangles are indicated in the top and right axis. Thick black lines separate ICES subdivisions (SD).

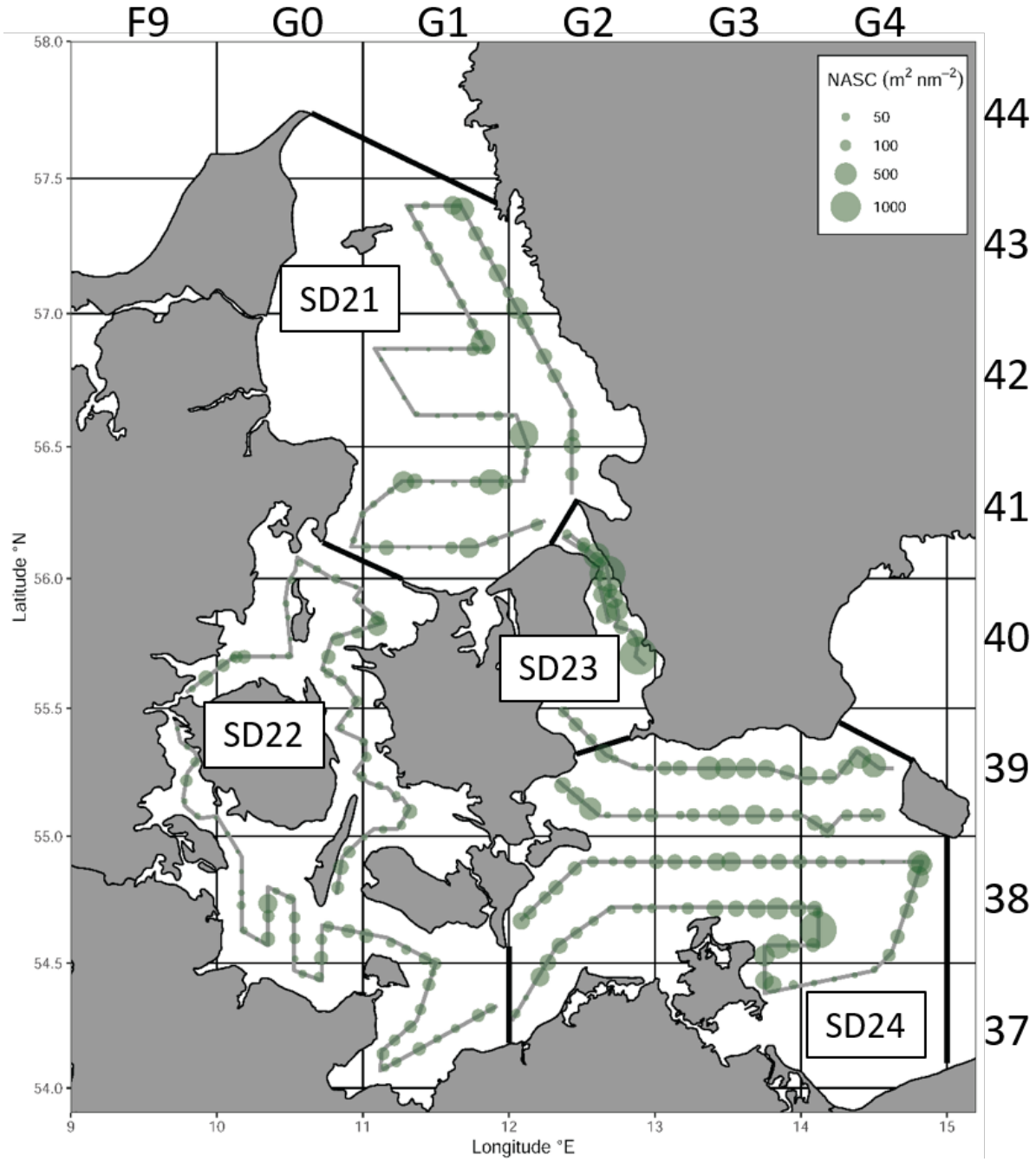


Figure 2: FRV Solea cruise 754/2018. Cruise track (thin grey lines) and mean NASC (5 nmi intervals, dots). ICES statistical rectangles are indicated in the top and right axis. Thick black lines separate ICES subdivisions (SD).

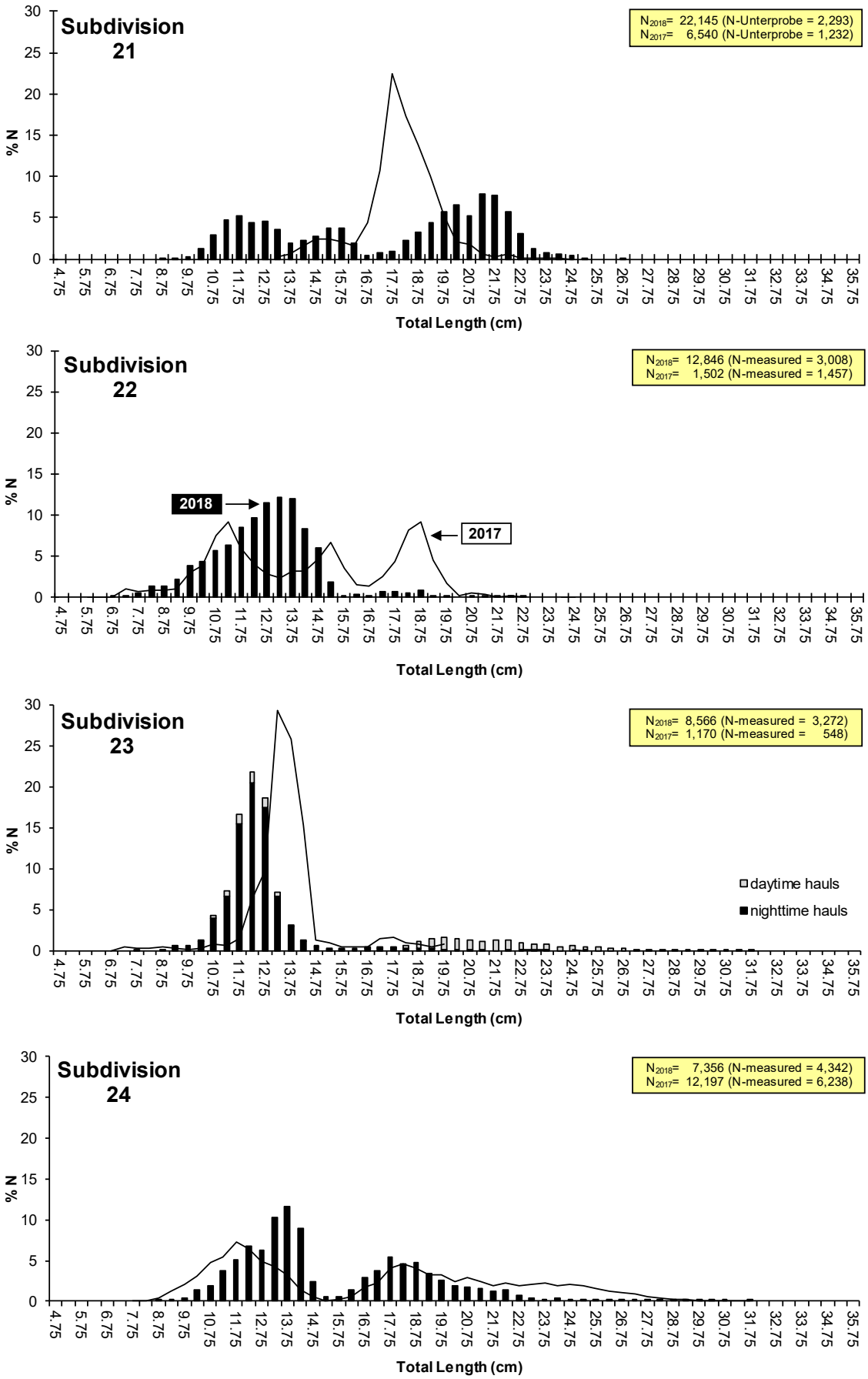


Figure 3: FRV Solea cruise 754/2018. Herring (*Clupea harengus*) length-frequency distribution (bars) compared to previous year (cruise 740/2017, lines). Daytime comparison hauls conducted in SD 23 are included.

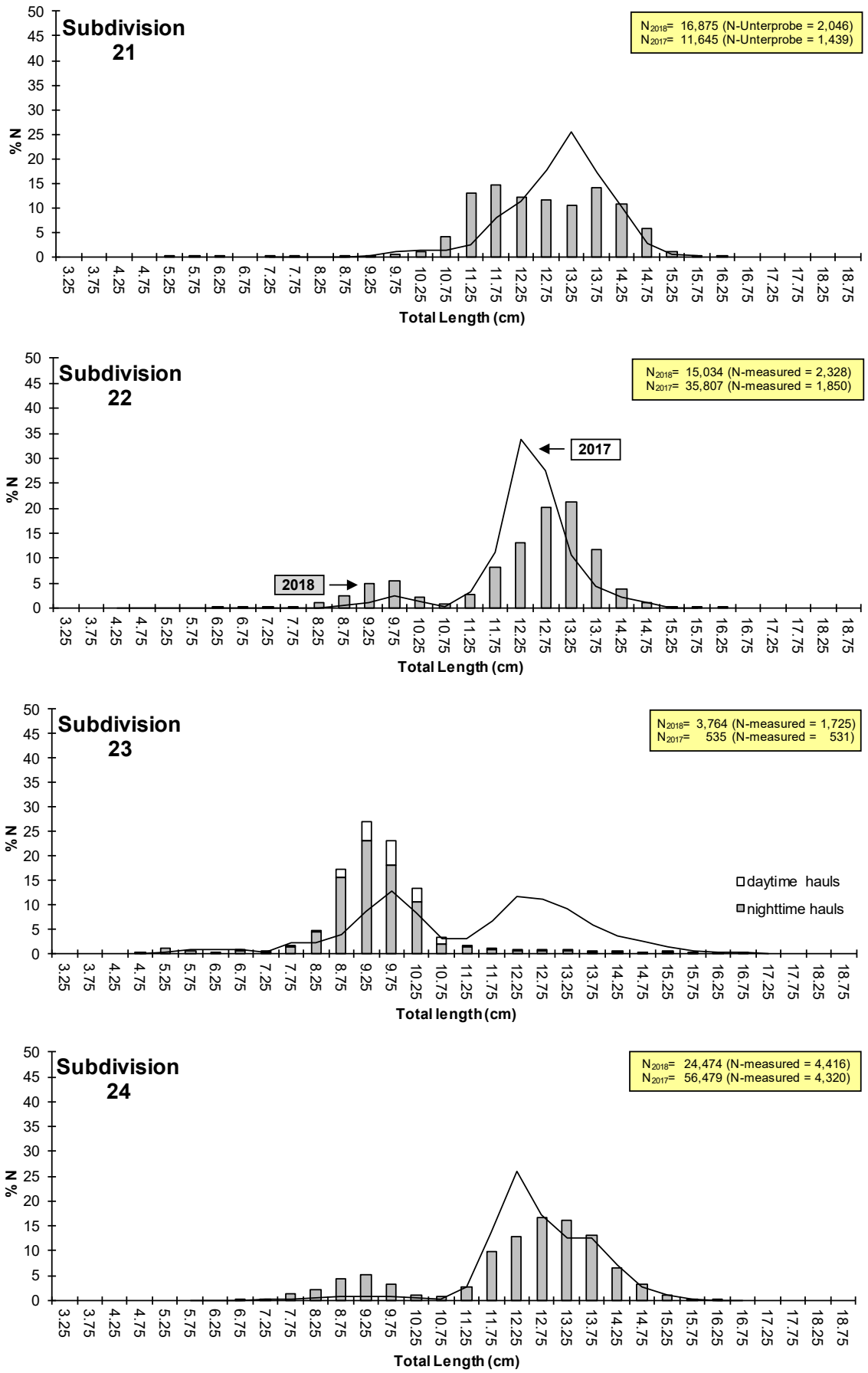


Figure 4: FRV Solea cruise 754/2018. Sprat (*Sprattus sprattus*) length-frequency distribution (bars) compared to previous year (cruise 740/2017, lines). Daytime comparison hauls conducted in SD 23 are included.

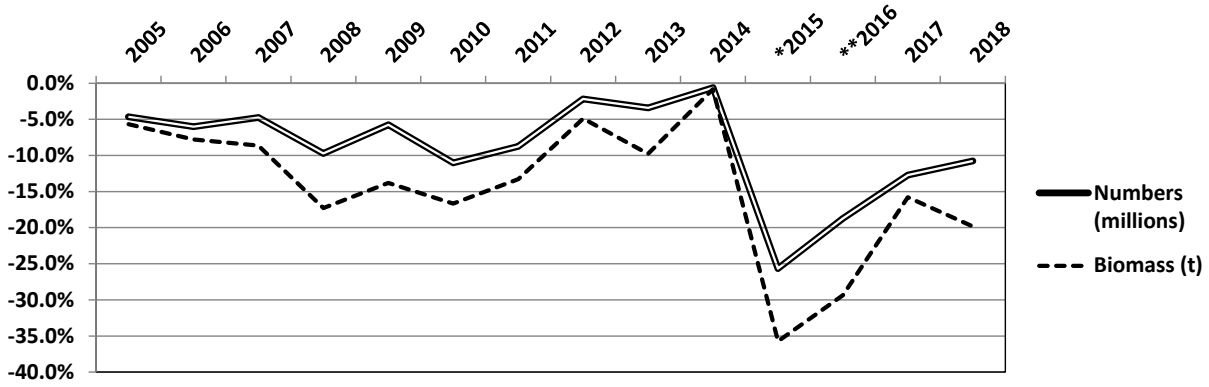


Figure 5: Relative changes in abundance and biomass of Western Baltic Spring Spawning herring in ICES Subdivisions 21-24 (2005-2018) after application of the stock separation function (SF, Gröhsler et al., 2013) to the abundance and biomass index generated from German acoustic survey data (GERAS). **2015 excl. of CBH in SD 22 and SD 24 and mature herring (stages ≥6) in SD 23;*
***2016 excl. of CBH in SD 22 and SD 24*

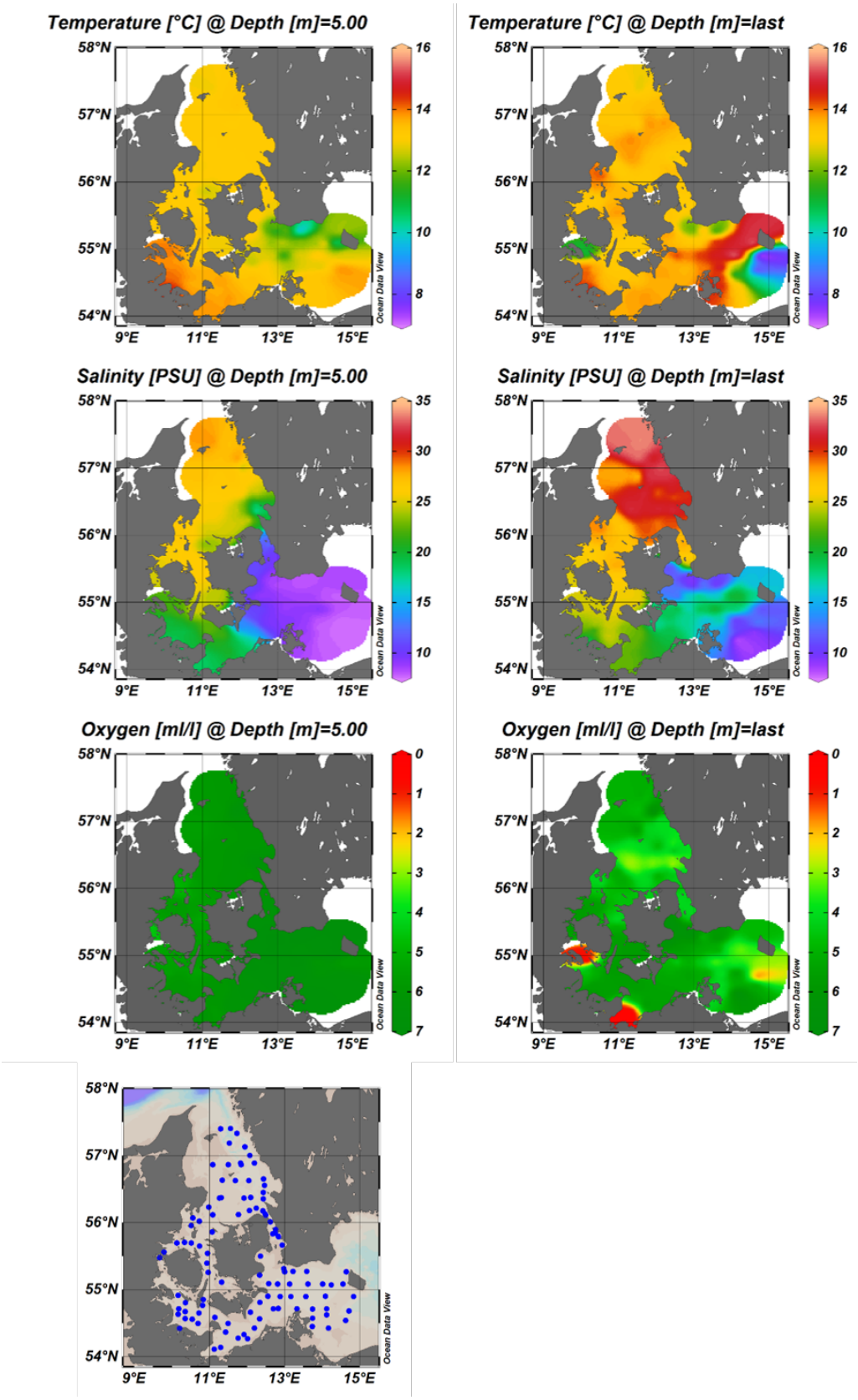


Figure 6: FRV Solea cruise 754/2018: Hydrography. CTD stations are depicted as blue dots in the area map (lower panel). Temperature (°C, top panels), salinity (PSU, middle panels and oxygen concentration (ml/l, lower panels) near the surface (left) and near the seafloor (right).

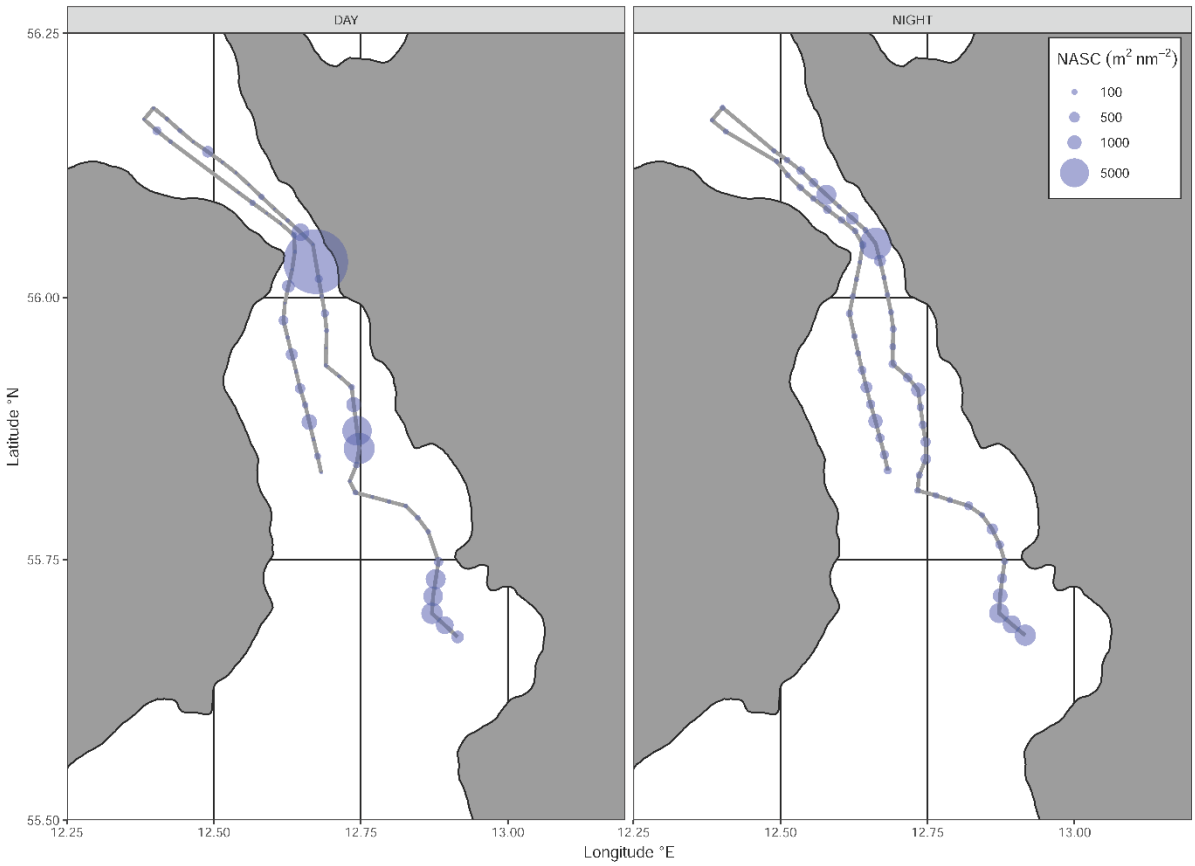


Figure 7: FRV Solea cruise 754/2018. Comparison of NASC-values/clupeid distribution during night (left) and daytime (right) sampling in the Sound (ICES Subdivision 23). Cruise track (thin grey lines) and mean NASC (1 nmi intervals, dots).

8 TABLES

Table 1: FRV Solea cruise 754/2018: Simrad EK80 calibration report (38 kHz Transducer).

Date:	01.10.2018		
Calibration Site:	Strande Bay/Kiel Bight (54°25.35 N, 10°12.29 E)		
Transceiver Type:	WBT		
Software Version:	EK80 1.12.2		
Reference Target:	Tungsten (WC-Co) 38.1 mm		
Transducer:	ES38-7 Serial No. 147		
Frequency:	38000 Hz	Beamtype:	Split/Narrow
Gain:	26.62 dB	Equivalent Beam Angle:	-20.7 dB
Beamwidth Athw.:	6.35 deg	Beamwidth Along.:	6.27 deg
Offset Athw.:	0.33 deg	Offset Along.:	-0.26 deg
Depth:	4.20 m		
Pulse Duration:	1.024 ms		
Power:	2000 W		
TS Detection:			
Min. Value:	-50.0 dB	Min. Spacing:	0.0
Max. Gain Comp.:	3.0 dB	Min. Echolength:	0.8
Max. Echolength:	1.8		
Environment:			
Absorption Coeff.:	0.005297	Sound Velocity:	1487.32 m/s
Temperature:	14.7 °C	Salinity:	19 PSU
Calibration results:			
Transducer Gain:	26.81 dB	SaCorrection:	-0.08 dB
Beamwidth Athw.:	6.32 deg	Beamwidth Along.:	6.19 deg
Offset Athw.:	-0.25 deg	Offset Along.:	0.08 deg
RMS-Error:	0.10		

Table 2: FRV Solea cruise 754/2018: Catch composition (kg 0.5 h^{-1}) by haul in SD 21.

Haul No.	45	46	47	48	49	50	51	53	54	55	56	57	58
Species/ICES Rectangle	41G2	41G1	41G0	41G1	41G2	42G2	42G1	43G1	43G1	43G1	43G1	42G2	42G2
APHIA MINUTA			0.02		0.01		+	+	+	0.01	0.01	+	0.01
BELONE BELONE						0.09	0.04		0.09	0.04			
CARCINUS									0.01	+		+	
CLUPEA HARENGUS	0.86	773.09	0.10	40.81	0.51	12.76	1.48	0.54	30.40	9.53	31.81	0.62	5.32
ENGRAULIS ENCRASICOLUS				0.14	0.54	0.02	2.08	0.02	0.77	1.38		0.04	0.01
EUTRIGLA GURNARDUS				0.12			+			+			
GASTEROSTEUS ACULEATUS		0.01			+	+	+		0.01				
LIMANDA LIMANDA				0.24									
LOLIGO	0.03			0.01	0.04	0.01				0.02		0.03	0.02
LOLIGO FORBESI				0.01		+	0.05	0.01	+	0.22	0.01	0.01	
MERLANGIUS MERLANGUS		0.15		0.15		0.12	0.30		0.18	0.46		0.01	0.52
MERLUCCIUS MERLUCCIUS								0.01		0.01			
MULLUS SURMULETUS										0.01			
POLLACHIUS VIRENS				1.04									
POMATOSCHISTUS MINUTUS			+					+	+	+		+	+
SARDINA PILCHARDUS		0.07		0.07		0.02			0.03	1.26	0.20		0.30
SCOMBER SCOMBRUS		3.51	0.23	1.18	0.59		1.98	11.99	0.28	0.22	0.17	3.19	2.83
SEPIOLA								+		0.05	0.01	+	
SPRATTUS SPRATTUS		114.26	0.05	92.57	0.08	0.10	2.32	0.01	0.21	4.33	14.41	0.56	32.28
SQUALUS ACANTHIAS										12.28	1.70		
TRACHINUS DRACO	0.03	1.52		4.82		0.39	2.53	0.11	0.18	0.08	0.04	0.28	0.37
TRACHURUS TRACHURUS		0.02	+	0.10	0.39	+	+	0.03	0.04	0.28	0.08	0.12	0.06
TRISOPTERUS ESMARKI									0.01	0.10			
TRISOPTERUS MINUTUS										0.08			
Total	**0.92**	**892.63**	**0.40**	**141.26**	**2.16**	**13.51**	**10.78**	**12.72**	**32.21**	**30.36**	**48.44**	**4.86**	**41.72**
Medusae	0.47	0.00	7.07	1.06	0.31	0.41	0.23	0.15	3.28	1.05	1.33	0.18	2.27

Haul 52 not valid

Haul No.	59	Total
Species/ICES Rectangle	41G2	
APHIA MINUTA	0.01	**0.07**
BELONE BELONE		**0.26**
CARCINUS		**0.01**
CLUPEA HARENGUS	6.59	**914.42**
ENGRAULIS ENCRASICOLUS		**5.00**
EUTRIGLA GURNARDUS		**0.12**
GASTEROSTEUS ACULEATUS	+	**0.02**
LIMANDA LIMANDA	0.05	**0.29**
LOLIGO	+	**0.16**
LOLIGO FORBESI		**0.31**
MERLANGIUS MERLANGUS	0.12	**2.01**
MERLUCCIUS MERLUCCIUS	0.00	**0.02**
MULLUS SURMULETUS		**0.01**
POLLACHIUS VIRENS		**1.04**
POMATOSCHISTUS MINUTUS		**+**
SARDINA PILCHARDUS	0.02	**1.97**
SCOMBER SCOMBRUS		**26.17**
SEPIOLA		**0.06**
SPRATTUS SPRATTUS	4.13	**265.31**
SQUALUS ACANTHIAS		**13.98**
TRACHINUS DRACO	0.29	**10.64**
TRACHURUS TRACHURUS	0.44	**1.56**
TRISOPTERUS ESMARKI		**0.11**
TRISOPTERUS MINUTUS		**0.08**
Total	**11.65**	**1243.62**
Medusae	3.81	21.61

+ = < 0.01 kg

Table 3: FRV Solea cruise 754/2018: Catch composition (kg 0.5 h^{-1}) by haul in SD 22.

Haul No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Species/ICES Rectangle	**38G0**	**40G0**	**40G0**	**41G0**	**40G1**	**40G0**	**39G0**	**39G0**	**39G1**	**38G0**	**38G0**	**38G0**	**37G0**
APHIA MINUTA		+	+	0.01	+	0.01	0.04		0.01	+		+	+
BELONE BELONE	0.03				0.05	0.09	0.05	0.13	0.05	0.18			
CLUPEA HARENGUS	0.86	0.44	0.79	0.91	0.81		2.08	103.78		6.58	4.62	0.42	10.25
CRANGON CRANGON			+				+		0.01	+			
CTENOLABRUS RUPESTRIS			0.02		0.01		0.05		0.23				0.02
CYCLOPTERUS LUMPUS	0.07									0.71			
ENGRAULIS ENCRASICOLUS	+		0.15	0.60	0.12		0.06	0.19	0.02				0.03
EUTRIGLA GURNARDUS								0.03					
GADUS MORHUA									0.04	0.30			
GASTEROSTEUS ACULEATUS	0.15	0.08		+			+		5.50	0.01	1.00	0.17	+
GOBIUS NIGER			0.01	+	+		+		0.02				
LIMANDA LIMANDA			0.37	0.01	0.01		0.02	0.13	0.03	0.22			0.13
LOLIGO							+						
LOLIGO FORBESI	+		+	0.01			+						
MERLANGIUS MERLANGUS	0.02		0.01	0.12	0.08		0.02	0.36		0.02		0.02	0.01
MULLUS SURMULETUS			0.01	0.01									
NEOGOBIUS MELANOSTOMUS					0.01				0.01				
PLATICHTHYS FLESUS													
PLEURONECTES PLATESSA								0.44					
POLLACHIUS VIRENS										3.94			
POMATOSCHISTUS MINUTUS			+		0.01		+		0.01			+	
PUNGITIUS PUNGITIUS									+				
SARDINA PILCHARDUS								0.16					0.01
SCOMBER SCOMBRUS								1.90					0.04
SOLEA VULGARIS										0.71	0.26		
SPRATTUS SPRATTUS	0.29	0.75	0.06	0.03	0.04		0.25	134.79		8.30	13.81		22.97
SYMPHODUS MELOPS								0.01					
SYNGNATHUS TYPHLE									+				
TRACHINUS DRACO				0.12	0.19								
TRACHURUS TRACHURUS		0.01	0.01	0.08	0.02	0.01	0.06	0.28	0.06	0.01	+		0.09
TRISOPTERUS ESMARKI	+												
TRISOPTERUS MINUTUS										+			
Total	**1.42**	**1.28**	**1.43**	**1.90**	**1.35**	**0.11**	**2.63**	**242.20**	**5.99**	**20.98**	**19.69**	**0.61**	**33.55**
Medusae	14.44	43.12	4.86	3.67	1.93	2.81	2.31	3.01	2.62	3.20	7.63	12.26	16.77

Haul No.	14	15	16	17	18	Total
Species/ICES Rectangle	**38G1**	**37G1**	**37G1**	**37G1**	**37G1**	
APHIA MINUTA	+		+		+	**0.07**
BELONE BELONE			0.09			**0.67**
CLUPEA HARENGUS	14.03	4.25	2.39	8.23	7.04	**167.48**
CRANGON CRANGON		+				**0.01**
CTENOLABRUS RUPESTRIS	+				0.01	**0.34**
CYCLOPTERUS LUMPUS						**0.78**
ENGRAULIS ENCRASICOLUS					0.03	**1.20**
EUTRIGLA GURNARDUS				0.01		**0.04**
GADUS MORHUA		0.38	2.13			**2.85**
GASTEROSTEUS ACULEATUS	0.05		0.04	0.58	0.17	**7.75**
GOBIUS NIGER						**0.03**
LIMANDA LIMANDA	0.67	19.80		0.08	0.92	**22.39**
LOLIGO						**+**
LOLIGO FORBESI						**0.01**
MERLANGIUS MERLANGUS	0.04	2.54		0.08	0.40	**3.72**
MULLUS SURMULETUS						**0.02**
NEOGOBIUS MELANOSTOMUS						**0.02**
PLATICHTHYS FLESUS		0.48	0.47		0.33	**1.28**
PLEURONECTES PLATESSA	0.45	1.15		0.18		**2.22**
POLLACHIUS VIRENS						**3.94**
POMATOSCHISTUS MINUTUS	+			+		**0.02**
PUNGITIUS PUNGITIUS						**+**
SARDINA PILCHARDUS		0.02				**0.19**
SCOMBER SCOMBRUS	0.04	0.10				**2.08**
SOLEA VULGARIS						**0.97**
SPRATTUS SPRATTUS	4.41	13.03	0.34	0.10	2.58	**201.75**
SYMPHODUS MELOPS						**0.01**
SYNGNATHUS TYPHLE						**+**
TRACHINUS DRACO						**0.31**
TRACHURUS TRACHURUS	0.01		0.02	0.06	1.36	**2.08**
TRISOPTERUS ESMARKI						**+**
TRISOPTERUS MINUTUS						**+**
Total	**19.70**	**41.75**	**5.48**	**9.32**	**12.84**	**422.23**
Medusae	7.02	5.09	2.80	8.85	10.89	153.29

+ = < 0.01 kg

Table 4: FRV Solea cruise 754/2018: Catch composition (kg 0.5 h^{-1}) by haul in SD 23.

Haul No.	40	41	42	43	44	*60	*61	*62	Total
Species/ICES Rectangle	40G2	40G2	41G2	41G2	40G2	40G2	40G2	41G2	
APHIA MINUTA	0.14	0.08	0.03	0.03	0.01	+		+	**0.29**
CLUPEA HARENGUS	4.31	9.52	14.98	38.02	12.60	0.51	95.03	2.48	**177.45**
CRANGON CRANGON	+		+						**+**
CTENOLABRUS RUPESTRIS		+							**+**
ENGRAULIS ENCRASICOLUS	0.01		0.01			+	0.03		**0.05**
EUTRIGLA GURNARDUS			+	0.24					**0.24**
GADUS MORHUA	4.77	29.29			9.29		3.70		**47.05**
GASTEROSTEUS ACULEATUS	+	0.06	0.03	+	0.01		0.02		**0.12**
LEANDER	+		+						**+**
LIMANDA LIMANDA			0.72	1.77					**2.49**
LOLIGO			+				+	0.38	**0.38**
MERLANGIUS MERLANGUS	0.11	0.04	0.09	1.31	11.57	0.06			**13.18**
PLATICHTHYS FLESUS	0.43								**0.43**
PLEURONECTES PLATESSA					0.40				**0.40**
POMATOSCHISTUS MINUTUS	+	+		+	+				**+**
PSETTA MAXIMA				0.54					**0.54**
SARDINA PILCHARDUS	0.01	0.01			0.14	+	0.03	+	**0.19**
SEPIOLA				0.02					**0.02**
SPRATTUS SPRATTUS	9.82	0.32	1.62	3.08	3.93	2.26	1.60	0.35	**22.98**
TRACHINUS DRACO			0.05	0.37	0.07				**0.49**
TRACHURUS TRACHURUS	+	0.03	0.02	0.64	0.02		0.23	0.01	**0.95**
TRISOPTERUS ESMARKI		+							**+**
Total	**19.60**	**39.35**	**17.55**	**46.02**	**38.04**	**2.83**	**100.64**	**3.22**	**267.25**
Medusae	0.23	0.83	0.75	0.13	0.51	4.31	0.15	0.58	**7.49**

+ = < 0.01 kg

Table 5: FRV Solea cruise 754/2018: Catch composition (kg 0.5 h-1) by haul in SD 24.

Haul No.	19	20	21	22	23	24	25	26	27	28	29	30	32
Species/ICES Rectangle	37G2	38G2	38G3	38G3	38G4	38G3	37G3	38G4	38G4	38G3	38G2	38G2	39G2
APHIA MINUTA	+					+						+	+
BELONE BELONE					0.19								
CLUPEA HARENGUS	2.51	0.80	1.45	1.07	1.33	4.78	8.12	33.12	4.51	8.95	0.95	1.24	2.02
CRANGON CRANGON		+	+	+				+		+			+
CYCLOPTERUS LUMPUS											0.13	0.47	
ENGRAULIS ENCRASICOLUS			+										0.03
GADUS MORHUA	0.20	0.11	2.02	1.91	5.43	28.19	8.98	7.20	0.42	0.74			0.01
GASTEROSTEUS ACULEATUS		0.47	0.19	0.02				+	0.12	0.03	2.22	1.13	1.00
GOBIUS NIGER											+		+
LIMANDA LIMANDA	1.42	0.08		0.31									
MERLANGIUS MERLANGUS	0.09	1.11	0.70	10.44		110.99	15.61		0.46	3.46		0.02	+
MYOXOCEPHALUS SCORPIUS										+			
NEOGOBIUS MELANOSTOMUS													+
PLATICHTHYS FLESUS		0.16	0.64	1.27		4.45	2.34	0.21		0.46			
PLEURONECTES PLATESSA		1.61	1.25			0.28		0.22		0.55			
POMATOSCHISTUS MINUTUS		+	0.02	+		+	0.01	+		0.01	+	+	0.02
PUNGITIUS PUNGITIUS			+										
SCOMBER SCOMBRUS						0.55							
SCOPHTHALMUS RHOMBUS	0.55												
SPRATTUS SPRATTUS	5.57	0.39	11.78	77.20	56.20	4.62	4.37	13.78	4.53	20.99	0.01	0.71	0.16
STIZOSTEDION LUCIOPERCA						0.71	1.27						
TRACHURUS TRACHURUS	0.09	0.21	0.11	0.11		0.15	0.02	0.04		0.01			+
Total	**10.43**	**4.94**	**18.16**	**92.33**	**63.15**	**154.72**	**40.72**	**54.57**	**10.04**	**35.20**	**3.31**	**3.57**	**3.24**
Medusae	1.64	16.14	4.95	1.97	64.22	2.13	2.18	2.64	18.35	4.51	10.93	16.19	3.62

Haul 31 not valid

Haul No.	33	34	35	36	37	38	39	Total
Species/ICES Rectangle	39G3	39G3	39G4	39G4	39G3	39G3	39G2	
APHIA MINUTA	+	+					+	**+**
BELONE BELONE								**0.19**
CLUPEA HARENGUS	5.27	13.03	7.49	17.44	15.63	12.40	50.41	**192.52**
CRANGON CRANGON	+		+					**+**
CYCLOPTERUS LUMPUS		0.79						**1.39**
ENGRAULIS ENCRASICOLUS	0.04				0.02			**0.09**
GADUS MORHUA	3.81	1.36	1.00		10.07	5.30		**76.75**
GASTEROSTEUS ACULEATUS	0.13	0.12	0.02	0.09		0.01		**5.55**
GOBIUS NIGER								**+**
LIMANDA LIMANDA								**1.81**
MERLANGIUS MERLANGUS	0.01	1.66	1.08	0.24	0.12	0.29		**146.28**
MYOXOCEPHALUS SCORPIUS								**+**
NEOGOBIUS MELANOSTOMUS								**+**
PLATICHTHYS FLESUS		0.26					+	**9.79**
PLEURONECTES PLATESSA								**3.91**
POMATOSCHISTUS MINUTUS	0.01		+		+	+	0.01	**0.08**
PUNGITIUS PUNGITIUS								**+**
SCOMBER SCOMBRUS								**0.55**
SCOPHTHALMUS RHOMBUS								**0.55**
SPRATTUS SPRATTUS	0.32	25.63	2.47	21.42	3.41	11.66	28.12	**293.34**
STIZOSTEDION LUCIOPERCA								**1.98**
TRACHURUS TRACHURUS	0.01	+						**0.75**
Total	**9.60**	**42.85**	**12.06**	**39.19**	**29.25**	**29.66**	**78.54**	**735.53**
Medusae	1.30	0.54	2.79	0.63	4.55	3.94	1.60	**164.80**

+ = < 0.01 kg

Table 6: FRV Solea, cruise 754/2018. 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	40.2	0.261	166.50	4.08	3.06	6.80	5.10
21	41G1	946.8	121.9	2.394	482.10	44.19	55.38	213.04	266.97
21	41G2	432.3	77.3	1.316	253.93	48.59	39.64	123.39	100.65
21	42G1	884.2	49.5	1.550	282.37	24.10	40.54	68.05	114.47
21	42G2	606.8	219.9	2.227	599.17	54.31	42.97	325.42	257.49
21	43G1	699.0	129.3	1.393	648.82	72.44	18.77	470.00	121.80
21	43G2	107.0	357.2	1.399	273.20	57.40	35.06	156.80	95.79
21	Total	3,784.2			2706.09			1363.50	962.27
22	37G0	209.9	99.1	1.543	134.81	32.78	65.17	44.20	87.85
22	37G1	723.3	94.7	1.383	495.27	51.43	28.09	254.69	139.15
22	38G0	735.3	92.6	1.120	607.94	37.57	40.90	228.43	248.67
22	38G1	173.2	121.8	1.082	194.97	61.77	35.60	120.42	69.41
22	39F9	159.3	40.7	1.227	52.84	37.76	30.09	19.95	15.90
22	39G0	201.7	36.0	1.227	59.18	37.76	30.09	22.34	17.81
22	39G1	250.0	65.2	0.262	622.14	0.00	0.00	0.00	0.00
22	40F9	51.3	150.7	1.231	62.80	45.80	28.71	28.77	18.03
22	40G0	538.1	71.8	1.231	313.86	45.80	28.71	143.76	90.11
22	40G1	174.5	279.2	1.497	325.45	43.06	2.78	140.12	9.04
22	41G0	173.1	46.9	1.368	59.34	26.81	1.45	15.91	0.86
22	Total	3,389.7			2928.60			1018.59	696.83
23	39G2	130.9	132.8	1.050	165.56	46.43	3.32	76.88	5.49
23	40G2	164.0	485.3	1.633	487.38	44.60	28.63	217.36	139.55
23	41G2	72.3	501.0	1.289	281.01	75.75	16.12	212.88	45.29
23	Total	367.2			933.95			507.12	190.33
24	37G2	192.4	132.9	1.623	157.55	26.97	70.02	42.49	110.31
24	37G3	167.7	192.4	3.105	103.91	16.49	74.83	17.13	77.75
24	37G4	875.1	21.7	1.898	100.05	20.48	74.26	20.49	74.30
24	38G2	832.9	131.8	0.670	1638.45	11.85	10.57	194.18	173.23
24	38G3	865.7	254.5	3.112	707.97	8.26	76.26	58.49	539.87
24	38G4	1034.8	229.5	1.898	1251.25	20.48	74.26	256.22	929.15
24	39G2	406.1	181.7	1.094	674.48	37.67	22.26	254.11	150.15
24	39G3	765.0	262.0	2.355	851.08	46.04	46.68	391.83	397.30
24	39G4	524.8	278.8	2.341	625.01	27.39	68.69	171.18	429.30
24	Total	5,664.5			6,109.75			1406.12	2881.36
22-24	Total	9,421.4			9,972.30			2931.83	3768.52
21-24	Total	13,205.6			12,678.39			4295.33	4730.79

Table 7: FRV Solea, cruise 754/2018. Numbers (millions) of herring incl. CBH by age/W-rings and area.

Sub-division	Rectangle/ W-rings	0	1	2	3	4	5	6	7	8+	Total
21	41G0	5.10	1.70								6.80
21	41G1	91.20	90.35	24.18	4.74	1.62	0.95				213.04
21	41G2	122.39	0.83	0.06	0.11						123.39
21	42G1	64.74	3.05	0.25							68.04
21	42G2	162.53	144.11	15.72	1.78	0.67	0.62				325.43
21	43G1	468.92	1.08								470.00
21	43G2	156.48	0.32								156.80
21	Total	1,071.36	241.44	40.21	6.63	2.29	1.57	0.00	0.00	0.00	1,363.50
22	37G0	41.12	2.66	0.13	0.07	0.15	0.07				44.20
22	37G1	229.70	21.86	0.56	1.07	1.39	0.10				254.68
22	38G0	223.66	4.09	0.36	0.09	0.22					228.42
22	38G1	120.11	0.06	0.19	0.06						120.42
22	39F9	19.07	0.70	0.13	0.03	0.03					19.96
22	39G0	21.35	0.78	0.14	0.03	0.03					22.33
22	39G1										0.00
22	40F9	28.77									28.77
22	40G0	143.76									143.76
22	40G1	113.75	14.93	10.25	0.90	0.28					140.11
22	41G0	12.25	2.69	0.72	0.03	0.23					15.92
22	Total	953.54	47.77	12.48	2.28	2.33	0.17	0.00	0.00	0.00	1,018.57
23	39G2	74.71	0.71	0.19	0.32	0.64	0.15	0.11		0.04	76.87
23	40G2	204.19	8.11	1.29	0.66	2.24	0.75	0.13			217.37
23	41G2	209.84	1.55	0.71	0.19	0.37	0.18	0.03			212.87
23	Total	488.74	10.37	2.19	1.17	3.25	1.08	0.27	0.00	0.04	507.11
24	37G2	36.63	2.00	0.64	0.97	1.79	0.30	0.12	0.02	0.02	42.49
24	37G3	3.30	0.94	2.28	3.06	3.20	2.16	0.95	0.36	0.89	17.14
24	37G4	7.41	2.49	1.18	2.37	3.96	1.87	0.57	0.28	0.36	20.49
24	38G2	177.60	5.74	0.51	2.05	6.23	1.23	0.60	0.11	0.11	194.18
24	38G3	27.44	4.67	3.41	5.77	9.12	4.50	1.63	0.64	1.32	58.50
24	38G4	92.61	31.09	14.71	29.63	49.56	23.43	7.16	3.51	4.53	256.23
24	39G2	234.24	6.64	1.13	2.66	6.76	1.58	0.76	0.17	0.17	254.11
24	39G3	169.98	55.86	14.87	36.25	73.55	26.79	8.03	3.21	3.29	391.83
24	39G4	9.09	25.49	11.82	28.75	46.53	30.02	10.15	4.29	5.05	171.19
24	Total	758.30	134.92	50.55	111.51	200.70	91.88	29.97	12.59	15.74	1,406.16
22-24	Total	2,200.58	193.06	65.22	114.96	206.28	93.13	30.24	12.59	15.78	2,931.84
21-24	Total	3,271.94	434.50	105.43	121.59	208.57	94.70	30.24	12.59	15.78	4,295.34

Table 8: FRV Solea, cruise 754/2018. 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	19.64	42.50								25.36
21	41G1	22.89	51.20	73.06	81.30	85.88	99.58				42.71
21	41G2	13.23	48.82	54.24	32.00						13.51
21	42G1	12.45	43.94	69.92							14.07
21	42G2	13.98	50.86	68.58	94.20	81.07	117.66				33.72
21	43G1	11.49	40.90								11.56
21	43G2	12.12	38.54								12.17
21	Total	13.23	50.77	71.26	83.95	84.47	106.72				22.16
22	37G0	10.90	34.81	68.00	31.00	33.56	52.00				12.68
22	37G1	10.06	34.69	63.16	46.61	34.77	52.00				12.60
22	38G0	9.07	36.19	78.50	31.06	34.43					9.70
22	38G1	9.33	63.80	63.80	63.80						9.47
22	39F9	14.16	35.77	66.43	48.78	34.32					15.34
22	39G0	14.16	35.77	66.43	48.78	34.32					15.32
22	39G1										0.00
22	40F9	11.77									11.77
22	40G0	11.77									11.77
22	40G1	18.89	42.80	65.12	63.80	35.94					25.14
22	41G0	18.07	38.02	71.90	32.41	37.50					24.18
22	Total	11.41	37.62	65.85	52.63	35.06	52.00	0.00	0.00	0.00	13.46
23	39G2	12.01	31.71	41.62	39.74	31.93	48.43	44.98		59.32	12.69
23	40G2	10.58	39.94	44.60	36.57	37.64	32.67	43.40			12.33
23	41G2	10.94	50.05	69.35	65.30	46.99	29.17	43.40			11.55
23	Total	10.95	40.89	52.37	42.10	37.58	34.28	44.04		59.32	12.06
24	37G2	12.92	29.79	27.81	36.72	32.09	35.43	41.92	67.38	67.38	15.58
24	37G3	9.04	38.06	59.92	59.90	55.09	56.46	62.23	65.36	62.02	47.94
24	37G4	10.12	34.25	53.15	50.08	42.32	51.20	54.82	54.15	60.90	32.86
24	38G2	10.08	33.15	36.89	36.25	34.34	38.23	36.73	47.05	51.17	12.19
24	38G3	10.49	34.57	56.06	56.09	47.02	57.99	57.79	65.73	62.27	32.01
24	38G4	10.12	34.25	53.15	50.08	42.32	51.20	54.82	54.15	60.90	32.87
24	39G2	12.69	32.48	35.51	37.85	33.77	41.66	39.73	45.23	56.11	14.44
24	39G3	13.53	33.45	43.73	41.97	37.16	43.47	51.71	47.85	58.31	28.07
24	39G4	14.19	33.96	53.72	68.89	54.06	86.92	90.18	91.30	89.49	61.30
24	Total	11.86	33.70	50.13	52.21	42.94	60.68	65.56	65.95	69.60	28.43
22-24	Total	11.46	35.06	53.22	52.12	42.77	60.36	65.37	65.95	69.57	20.40
21-24	Total	12.04	43.79	60.10	53.85	43.23	61.13	65.37	65.95	69.57	20.96

Table 9: FRV Solea, cruise 754/2018. Total biomass (t) of herring incl. CBH by age/W-rings and area.

Sub-division	Rectangle/ W-rings	0	1	2	3	4	5	6	7	8+	Total
21	41G0	100.2	72.3								172.4
21	41G1	2,087.6	4,625.9	1,766.6	385.4	139.1	94.6				9,099.2
21	41G2	1,619.2	40.5	3.3	3.5						1,666.5
21	42G1	806.0	134.0	17.5							957.5
21	42G2	2,272.2	7,329.4	1,078.1	167.7	54.3	73.0				10,974.6
21	43G1	5,387.9	44.2								5,432.1
21	43G2	1,896.5	12.3								1,908.9
21	Total	14,169.6	12,258.6	2,865.4	556.6	193.5	167.6	0.0	0.0	0.0	30,211.2
22	37G0	448.2	92.6	8.8	2.2	5.0	3.6				560.5
22	37G1	2,310.8	758.3	35.4	49.9	48.3	5.2				3,207.9
22	38G0	2,028.6	148.0	28.3	2.8	7.6					2,215.3
22	38G1	1,120.6	3.8	12.1	3.8						1,140.4
22	39F9	270.0	25.0	8.6	1.5	1.0					306.2
22	39G0	302.3	27.9	9.3	1.5	1.0					342.0
22	39G1										0.0
22	40F9	338.6									338.6
22	40G0	1,692.1									1,692.1
22	40G1	2,148.7	639.0	667.5	57.4	10.1					3,522.7
22	41G0	221.4	102.3	51.8	1.0	8.6					385.0
22	Total	10,881.4	1,797.0	821.8	119.98	81.7	8.8	0.00	0.00	0.0	13,710.6
23	39G2	897.3	22.5	7.9	12.7	20.4	7.3	5.0		2.4	975.4
23	40G2	2,160.3	323.9	57.5	24.1	84.3	24.5	5.6			2,680.4
23	41G2	2,295.7	77.6	49.2	12.4	17.4	5.3	1.3			2,458.8
23	Total	5,353.3	424.0	114.7	49.3	122.1	37.0	11.9	0.0	2.4	6,114.6
24	37G2	473.3	59.6	17.8	35.6	57.4	10.6	5.0	1.4	1.4	662.1
24	37G3	29.8	35.8	136.6	183.3	176.3	122.0	59.1	23.5	55.2	821.6
24	37G4	75.0	85.3	62.7	118.7	167.6	95.7	31.3	15.2	21.9	673.3
24	38G2	1,790.2	190.3	18.8	74.3	213.9	47.0	22.0	5.2	5.6	2,367.4
24	38G3	287.9	161.4	191.2	323.6	428.8	261.0	94.2	42.1	82.2	1,872.3
24	38G4	937.2	1,064.8	781.8	1,483.9	2,097.4	1,199.6	392.5	190.1	275.9	8,423.2
24	39G2	2,972.5	215.7	40.1	100.7	228.3	65.8	30.2	7.7	9.5	3,670.5
24	39G3	2,299.8	1,868.5	650.3	1,521.4	2,733.1	1,164.6	415.2	153.6	191.8	10,998.4
24	39G4	129.0	865.6	635.0	1,980.6	2,515.4	2,609.3	915.3	391.7	451.9	10,493.9
24	Total	8,994.7	4,547.0	2,534.3	5,822.1	8,618.3	5,575.6	1,964.9	830.3	1,095.5	39,982.8
22-24	Total	25,229.3	6,768.0	3,470.8	5,991.4	8,822.1	5,621.5	1,976.8	830.3	1,097.9	59,808.0
21-24	Total	39,398.8	19,026.6	6,336.2	6,547.9	9,015.6	5,789.0	1,976.8	830.3	1,097.9	90,019.1

Table 10: FRV Solea, cruise 754/2018. 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		2.13	1.27	1.36	0.23	0.11				5.10
21	41G1		107.64	44.24	63.62	40.74	9.80		0.93		266.97
21	41G2	2.76	95.15	2.15	0.48	0.07	0.05				100.66
21	42G1		104.95	6.08	2.18	0.80	0.30		0.16		114.47
21	42G2	1.29	152.89	23.71	45.14	27.57	6.89				257.49
21	43G1	0.33	114.65	5.68	0.70	0.36	0.09				121.81
21	43G2	0.44	90.48	4.09	0.51	0.23	0.06				95.81
21	Total	4.82	667.89	87.22	113.99	70.00	17.30	0.00	1.09	0.00	962.31
22	37G0	10.27	16.12	38.92	9.98	11.65	0.73		0.16		87.83
22	37G1	54.51	35.43	23.55	6.59	10.20	6.22		2.65		139.15
22	38G0	113.11	30.40	65.46	17.48	20.42	1.42		0.38		248.67
22	38G1	69.22	0.19								69.41
22	39F9	0.96	4.49	6.65	1.65	1.99	0.15				15.89
22	39G0	1.08	5.03	7.45	1.85	2.23	0.17				17.81
22	39G1										0.00
22	40F9	10.98	0.50	3.57	1.36	1.41	0.20				18.02
22	40G0	54.89	2.52	17.83	6.82	7.04	1.02				90.12
22	40G1			5.11	1.97	1.97					9.05
22	41G0		0.33	0.34	0.09	0.09					0.85
22	Total	315.02	95.01	168.88	47.79	57.00	9.91	0.00	3.19	0.00	696.80
23	39G2	0.62	2.10	1.67	0.58	0.45	0.07	0.01			5.50
23	40G2	121.04	12.10	2.49	0.53	3.08	0.16	0.16			139.56
23	41G2	43.45	1.66	0.14	0.01	0.03					45.29
23	Total	165.11	15.86	4.30	1.12	3.56	0.23	0.17	0.00	0.00	190.35
24	37G2	6.77	48.04	32.96	11.35	9.36	1.23	0.51	0.04	0.04	110.30
24	37G3	55.46	18.62	2.35	0.66	0.56	0.07	0.03			77.75
24	37G4	13.82	18.71	20.54	10.18	8.71	1.48	0.74	0.06	0.06	74.30
24	38G2	83.98	47.88	25.98	8.21	6.65	0.13	0.39			173.22
24	38G3	134.72	208.91	117.87	39.73	32.26	4.41	1.69	0.14	0.14	539.87
24	38G4	172.82	233.97	256.83	127.34	108.95	18.48	9.21	0.78	0.78	929.16
24	39G2	16.43	48.30	46.34	19.52	15.70	2.77	0.91	0.09	0.09	150.15
24	39G3	46.02	136.02	124.09	45.14	37.11	6.27	2.21	0.23	0.23	397.32
24	39G4	70.30	117.64	120.44	58.06	49.78	7.97	4.64	0.23	0.23	429.29
24	Total	600.32	878.09	747.40	320.19	269.08	42.81	20.33	1.57	1.57	2,881.36
22-24	Total	1,080.45	988.96	920.58	369.10	329.64	52.95	20.50	4.76	1.57	3,768.51
21-24	Total	1,085.27	1,656.85	1,007.80	483.09	399.64	70.25	20.50	5.85	1.57	4,730.82

Table 11: FRV Solea, cruise 754/2018. 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		16.32	17.41	18.44	18.11	19.08				17.30
21	41G1		14.69	18.28	19.39	20.76	20.68		23.63		17.58
21	41G2	3.43	10.52	15.50	18.81	18.60	19.08				10.48
21	42G1		12.55	15.85	19.16	21.03	20.76		23.63		12.95
21	42G2	2.86	12.73	18.12	19.55	20.17	19.71				15.36
21	43G1	3.00	12.62	15.15	19.13	19.92	19.66				12.78
21	43G2	2.92	12.46	15.17	18.91	19.73	19.61				12.59
21	Total	3.20	12.66	17.64	19.43	20.51	20.27		23.63		14.59
22	37G0	6.00	13.58	15.41	16.24	16.07	18.15		20.50		14.19
22	37G1	5.54	12.15	14.67	17.28	17.63	22.90		20.50		11.27
22	38G0	5.03	13.46	15.41	16.38	16.25	18.23		20.50		10.61
22	38G1	5.19	10.11								5.20
22	39F9	5.49	13.26	15.24	16.41	16.21	17.74				14.36
22	39G0	5.49	13.26	15.24	16.41	16.21	17.74				14.36
22	39G1										0.00
22	40F9	7.10	11.60	16.17	16.76	16.71	17.74				10.62
22	40G0	7.10	11.60	16.17	16.76	16.71	17.74				10.62
22	40G1			16.40	16.40	16.40					16.40
22	41G0		13.01	15.43	16.40	16.40					14.70
22	Total	5.62	12.90	15.42	16.54	16.53	21.08		20.50		10.92
23	39G2	6.14	11.76	13.99	14.75	15.01	16.78	18.23			12.46
23	40G2	5.75	11.41	17.24	17.84	19.76	25.00	25.00			6.84
23	41G2	4.87	10.87	15.72	15.00	15.68					5.13
23	Total	5.52	11.40	15.93	16.21	19.13	22.50	24.60			6.60
24	37G2	5.29	11.77	14.16	15.35	15.54	16.78	17.61	19.77	19.77	12.86
24	37G3	4.03	9.18	13.10	15.35	15.65	16.84	17.28			5.73
24	37G4	5.33	11.58	14.59	16.21	16.31	17.64	17.92	19.77	19.77	12.64
24	38G2	4.38	10.32	13.90	15.08	15.37	15.51	16.83			8.42
24	38G3	4.23	11.33	14.01	15.31	15.51	16.96	17.73	19.77	19.77	10.76
24	38G4	5.33	11.58	14.59	16.21	16.31	17.64	17.92	19.77	19.77	12.64
24	39G2	4.80	12.23	14.17	15.55	15.76	17.42	18.13	19.77	19.77	12.96
24	39G3	5.29	11.83	14.35	15.45	15.58	17.21	18.25	19.77	19.77	12.75
24	39G4	4.89	11.69	14.51	16.05	16.21	17.32	18.56	19.77	19.77	12.67
24	Total	4.76	11.50	14.37	15.86	16.01	17.40	18.07	19.77	19.77	11.89
22-24	Total	5.13	11.63	14.57	15.95	16.13	18.11	18.12	20.26	19.78	11.44
21-24	Total	5.12	12.05	14.84	16.77	16.90	18.64	18.12	20.89	19.78	12.08

Table 12: FRV Solea, cruise 754/2018. 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		34.8	22.1	25.1	4.2	2.1				88.2
21	41G1		1,581.2	808.7	1,233.6	845.8	202.7		22.0		4,693.9
21	41G2	9.5	1,001.0	33.3	9.0	1.3	1.0				1,055.1
21	42G1		1,317.1	96.4	41.8	16.8	6.2		3.8		1,482.1
21	42G2	3.7	1,946.3	429.6	882.5	556.1	135.8				3,954.0
21	43G1	1.0	1,446.9	86.1	13.4	7.2	1.8				1,556.3
21	43G2	1.3	1,127.4	62.1	9.6	4.5	1.2				1,206.1
21	Total	15.4	8,454.6	1,538.2	2,215.0	1,435.9	350.7	0.0	25.8	0.0	14,035.6
22	37G0	61.6	218.9	599.8	162.1	187.2	13.3		3.3		1,246.1
22	37G1	302.0	430.5	345.5	113.9	179.8	142.4		54.3		1,568.4
22	38G0	568.9	409.2	1,008.7	286.3	331.8	25.9		7.8		2,638.7
22	38G1	359.3	1.9								361.2
22	39F9	5.3	59.5	101.4	27.1	32.3	2.7				228.2
22	39G0	5.9	66.7	113.5	30.4	36.2	3.0				255.7
22	39G1										0.0
22	40F9	78.0	5.8	57.7	22.8	23.6	3.6				191.4
22	40G0	389.7	29.2	288.3	114.3	117.6	18.1				957.3
22	40G1			83.8	32.3	32.3					148.4
22	41G0		4.3	5.3	1.5	1.5					12.5
22	Total	1,770.7	1,226.0	2,604.0	790.6	942.3	208.9	0.0	65.4	0.0	7,607.9
23	39G2	3.8	24.7	23.4	8.6	6.8	1.2	0.2			68.5
23	40G2	696.0	138.1	42.9	9.5	60.9	4.0	4.0			955.3
23	41G2	211.6	18.0	2.2	0.2	0.5					232.5
23	Total	911.4	180.8	68.5	18.2	68.1	5.2	4.2	0.0	0.0	1,256.3
24	37G2	35.8	565.4	466.7	174.2	145.5	20.6	9.0	0.8	0.8	1,418.8
24	37G3	223.5	170.9	30.8	10.1	8.8	1.2	0.5			445.8
24	37G4	73.7	216.7	299.7	165.0	142.1	26.1	13.3	1.2	1.2	938.8
24	38G2	367.8	494.1	361.1	123.8	102.2	2.0	6.6			1,457.7
24	38G3	569.9	2,367.0	1,651.4	608.3	500.4	74.8	30.0	2.8	2.8	5,807.1
24	38G4	921.1	2,709.4	3,747.2	2,064.2	1,777.0	326.0	165.0	15.4	15.4	11,740.7
24	39G2	78.9	590.7	656.6	303.5	247.4	48.3	16.5	1.8	1.8	1,945.5
24	39G3	243.5	1,609.1	1,780.7	697.4	578.2	107.9	40.3	4.6	4.6	5,066.2
24	39G4	343.8	1,375.2	1,747.6	931.9	806.9	138.0	86.1	4.6	4.6	5,438.6
24	Total	2,857.9	10,098.5	10,741.7	5,078.4	4,308.3	744.9	367.3	31.1	31.1	34,259.2
22-24	Total	5,540.0	11,505.3	13,414.2	5,887.2	5,318.7	959.0	371.5	96.5	31.1	43,123.3
21-24	Total	5,555.4	19,960.0	14,952.4	8,102.2	6,754.5	1,309.7	371.5	122.2	31.1	57,158.9

Table 13: FRV Solea, cruise 754/2018. Numbers (m) of herring excl. CBH in SDs 24 (23) by age/W-rings & area.

Sub-division	Rectangle/ W-rings	0	1	2	3	4	5	6	7	8+	Total	
21	41G0	5.10	1.70								6.80	
21	41G1	91.20	90.35	24.18	4.74	1.62	0.95				213.04	
21	41G2	122.39	0.83	0.06	0.11						123.39	
21	42G1	64.74	3.05	0.25							68.04	
21	42G2	162.53	144.11	15.72	1.78	0.67	0.62				325.43	
21	43G1	468.92	1.08								470.00	
21	43G2	156.48	0.32								156.80	
21	Total	1,071.36	241.44	40.21	6.63	2.29	1.57	0.00	0.00	0.00	1,363.50	
22	37G0	41.12	2.66	0.13	0.07	0.15	0.07				44.20	
22	37G1	229.70	21.86	0.56	1.07	1.39	0.10				254.68	
22	38G0	223.66	4.09	0.36	0.09	0.22					228.42	
22	38G1	120.11	0.06	0.19	0.06						120.42	
22	39F9	19.07	0.70	0.13	0.03	0.03					19.96	
22	39G0	21.35	0.78	0.14	0.03	0.03					22.33	
22	39G1										0.00	
22	40F9	28.77									28.77	
22	40G0	143.76									143.76	
22	40G1	113.75	14.93	10.25	0.90	0.28					140.11	
22	41G0	12.25	2.69	0.72	0.03	0.23					15.92	
22	Total	953.54	47.77	12.48	2.28	2.33	0.17	0.00	0.00	0.00	1,018.57	
23	39G2	74.71	0.69	0.09	0.07						75.56	
23	40G2	204.19	8.11	1.29	0.66	2.24	0.75	0.13			217.37	
23	41G2	209.84	1.55	0.71	0.19	0.37	0.18	0.03			212.87	
23	Total	488.74	10.35	2.09	0.92	2.61	0.93	0.16	0.00	0.00	505.80	
24	37G2	36.63	1.75	0.05	0.07						38.50	
24	37G3	3.30	0.94	2.21	2.02	0.46	0.12	0.06	0.01	0.01	9.13	
24	37G4	7.41	2.49	0.97	0.73	0.24	0.12	0.04	0.00	0.00	12.00	
24	38G2	177.60	5.74	0.17							183.51	
24	38G3	27.44	4.56	3.05	2.87	0.73	0.38	0.14	0.07	0.03	39.27	excl. CBH
24	38G4	92.61	31.09	12.12	9.14	2.96	1.47	0.44	0.05	0.05	149.93	
24	39G2	234.24	6.46	0.37	0.15						241.22	
24	39G3	169.98	55.28	8.86	4.65	0.55	0.33	0.35	0.04	0.04	240.08	
24	39G4	9.09	25.49	9.88	14.45	8.77	12.72	3.85	0.90	0.98	86.13	
24	Total	758.30	133.80	37.68	34.08	13.71	15.14	4.88	1.07	1.11	999.77	
22-24	Total	2,200.58	191.92	52.25	37.28	18.65	16.24	5.04	1.07	1.11	2,524.14	
21-24	Total	3,271.94	433.36	92.46	43.91	20.94	17.81	5.04	1.07	1.11	3,887.64	

Table 14: FRV Solea, cruise 754/2018. Mean weight (g) of herring excl. CBH in SDs 24 (23) by age/W-rings & area.

Sub-division	Rectangle/ W-rings	0	1	2	3	4	5	6	7	8+	Total	
21	41G0	19.64	42.50								25.36	
21	41G1	22.89	51.20	73.06	81.30	85.88	99.58				42.71	
21	41G2	13.23	48.82	54.24	32.00						13.51	
21	42G1	12.45	43.94	69.92							14.07	
21	42G2	13.98	50.86	68.58	94.20	81.07	117.66				33.72	
21	43G1	11.49	40.90								11.56	
21	43G2	12.12	38.54								12.17	
21	Total	13.23	50.77	71.26	83.95	84.47	106.72				22.16	
22	37G0	10.90	34.81	68.00	31.00	33.56	52.00				12.68	
22	37G1	10.06	34.69	63.16	46.61	34.77	52.00				12.60	
22	38G0	9.07	36.19	78.50	31.06	34.43					9.70	
22	38G1	9.33	63.80	63.80	63.80						9.47	
22	39F9	14.16	35.77	66.43	48.78	34.32					15.34	
22	39G0	14.16	35.77	66.43	48.78	34.32					15.32	
22	39G1										0.00	
22	40F9	11.77									11.77	
22	40G0	11.77									11.77	
22	40G1	18.89	42.80	65.12	63.80	35.94					25.14	
22	41G0	18.07	38.02	71.90	32.41	37.50					24.18	
22	Total	11.41	37.62	65.85	52.63	35.06	52.00				13.46	
23	39G2	12.01	31.98	59.32	59.32						12.29	
23	40G2	10.58	39.94	44.60	36.57	37.64	32.67	43.40			12.33	
23	41G2	10.94	50.05	69.35	65.30	46.99	29.17	43.40			11.55	
23	Total	10.95	40.92	53.64	44.23	38.97	31.99	43.40			12.00	
24	37G2	12.92	31.04	67.38	67.38						13.91	
24	37G3	9.04	38.06	60.86	67.60	78.39	89.40	95.35	100.69	100.69	42.85	
24	37G4	10.12	34.25	58.64	73.04	84.22	122.79	114.97	100.69	100.69	25.83	
24	38G2	10.08	33.15	51.17							10.84	
24	38G3	10.49	34.90	59.63	71.32	95.56	140.93	106.93	148.80	100.69	25.09	excl. CBH
24	38G4	10.12	34.25	58.64	73.04	84.22	122.79	114.97	100.69	100.69	25.82	
24	39G2	12.69	32.82	54.77	59.32						13.32	
24	39G3	13.53	33.58	55.41	67.54	81.46	97.27	189.17	100.69	100.69	21.29	
24	39G4	14.19	33.96	58.92	97.27	119.05	138.88	150.81	180.98	194.47	78.10	
24	Total	11.86	33.81	58.10	82.02	106.80	135.94	148.10	171.37	183.49	23.14	
22-24	Total	11.46	35.14	59.78	79.29	88.34	129.11	144.77	171.37	183.49	17.00	
21-24	Total	12.04	43.85	64.77	80.00	87.92	127.14	144.77	171.37	183.49	18.81	

Table 15: FRV Solea, cruise 754/2018. Total biomass (t) of herring excl. CBH in SDs 24 (23) by age/W-rings & area.

Sub-division	Rectangle/ W-rings	0	1	2	3	4	5	6	7	8+	Total	
21	41G0	100.2	72.3								172.4	
21	41G1	2,087.6	4,625.9	1,766.6	385.4	139.1	94.6				9,099.2	
21	41G2	1,619.2	40.5	3.3	3.5						1,666.5	
21	42G1	806.0	134.0	17.5							957.5	
21	42G2	2,272.2	7,329.4	1,078.1	167.7	54.3	73.0				10,974.6	
21	43G1	5,387.9	44.2								5,432.1	
21	43G2	1,896.5	12.3								1,908.9	
21	Total	14,169.6	12,258.6	2,865.4	556.6	193.5	167.6	0.0	0.0	0.0	30,211.2	
22	37G0	448.2	92.6	8.8	2.2	5.0	3.6				560.5	
22	37G1	2,310.8	758.3	35.4	49.9	48.3	5.2				3,207.9	
22	38G0	2,028.6	148.0	28.3	2.8	7.6					2,215.3	
22	38G1	1,120.6	3.8	12.1	3.8						1,140.4	
22	39F9	270.0	25.0	8.6	1.5	1.0					306.2	
22	39G0	302.3	27.9	9.3	1.5	1.0					342.0	
22	39G1										0.0	
22	40F9	338.6									338.6	
22	40G0	1,692.1									1,692.1	
22	40G1	2,148.7	639.0	667.5	57.4	10.1					3,522.7	
22	41G0	221.4	102.3	51.8	1.0	8.6					385.0	
22	Total	10,881.4	1,797.0	821.8	119.98	81.7	8.8	0.00	0.00	0.0	13,710.6	
23	39G2	897.3	22.1	5.3	4.2						928.8	
23	40G2	2,160.3	323.9	57.5	24.1	84.3	24.5	5.6			2,680.4	
23	41G2	2,295.7	77.6	49.2	12.4	17.4	5.3	1.3			2,458.8	
23	Total	5,353.3	423.6	112.1	40.7	101.7	29.8	6.9	0.0	0.0	6,068.0	
24	37G2	473.3	54.3	3.4	4.7	0.0	0.0	0.0	0.0	0.0	535.7	
24	37G3	29.8	35.8	134.5	136.6	36.1	10.7	5.7	1.0	1.0	391.2	
24	37G4	75.0	85.3	56.9	53.3	20.2	14.7	4.6	0.0	0.0	310.0	
24	38G2	1,790.2	190.3	8.7	0.0	0.0	0.0	0.0	0.0	0.0	1,989.2	
24	38G3	287.9	159.1	181.9	204.7	69.8	53.6	15.0	10.4	3.0	985.3	excl. CBH
24	38G4	937.2	1,064.8	710.7	667.6	249.3	180.5	50.6	5.0	5.0	3,870.8	
24	39G2	2,972.5	212.0	20.3	8.9	0.0	0.0	0.0	0.0	0.0	3,213.7	
24	39G3	2,299.8	1,856.3	490.9	314.1	44.8	32.1	66.2	4.0	4.0	5,112.3	
24	39G4	129.0	865.6	582.1	1,405.6	1,044.1	1,766.6	580.6	162.9	190.6	6,727.0	
24	Total	8,994.7	4,523.6	2,189.4	2,795.4	1,464.2	2,058.2	722.7	183.4	203.7	23,135.1	
22-24	Total	25,229.3	6,744.1	3,123.3	2,956.1	1,647.6	2,096.8	729.7	183.4	203.7	42,913.7	
21-24	Total	39,398.8	19,002.8	5,988.7	3,512.6	1,841.0	2,264.3	729.7	183.4	203.7	73,124.9	

Document 8a: ISAS 2017 survey summary table

Survey Summary table WGIPS 2019	
Name of the survey (abbreviation):	**Irish Sea Acoustic Survey (ISAS)**
Target Species:	**Herring**
Survey dates:	**28th August – 14th September 2017**
Summary:	
The vessel departed Belfast at 2100 on the 28th August and proceeded to the east coast of the Isle of Man for acoustic calibration off Laxey on the 29th August. The survey started on the peripheral Irish Sea transects to the west of the Solway Firth at 05:30 on the 30th August and continued to the completion of transect 102 to the north of Angelsey on the 31st August. A short steam to the northeast of the Isle of Man saw the survey recommence at the start of transect 1 on the 01st Sept and end on transect 63 to the northwest of the Isle of Man on 04th Sept. The final set of transects for the first phase of this survey commenced at transect 64 and proceeded west and then north along the Mull of Galloway before crossing the channel and resuming 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 29 th August. Phase one of the survey ended on transect 94 on 06th Sept at which time a mid-survey break in Belfast was required to facilitate staff and crew changes. The survey recommenced on 09th September and concluded on the 14th September during which, the remaining peripheral Irish Sea transects and a further set of transects around the Isle of Man were completed.	
	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 reasonably good during the survey; particularly poor weather between the 12th and 13th September resulted in a temporary cessation of the survey.

Extinction (shadowing)	No perceived issues
Blind zone	NA
Dead zone	NA
Allocation of backscatter to species	Directed trawling, with 30 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 28th August off Laxey on the east coast of the Isle of Man. Conditions were good and the calibration results satisfactory. All procedures were according to those defined in the survey manual.
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 2017 survey: Complete coverage
Stock ID and mixing issues	Time-series: Winter hatched fish, of which the majority are thought to be of Celtic Sea origin, are present in the prespawning aggregations sampled in the Irish Sea during the acoustic survey. The presence of these winter hatched fish has implications for the estimates of 1-ringer+ biomass and SSB 2017 survey:No additional issues
Measures of uncertainty (CV)	CV of biomass and numbers at age
Biological sampling	2017 Survey: The biological sampling is deamed to be appropriate for the stock and area. The sampling levels are in line with historic levels.
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole time-series or for individual years? (please specify)	*To be answered by Assessment Working Group*
Did the Survey Summary Table contain adequate information to allow for evaluation of the quality of the survey for use in assessment? Please identify shortfalls	*To be answered by Assessment Working Group*

Document 8b: ISAS 2017 survey report

Please see the report on the next page.

ANNEX 5B: Irish Sea acoustic survey (Northern Ireland)

Survey report for RV Corystes

28th August – 14th September 2017

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
Jim McArdle
Victoria Poppleton
Rory O'Loughlin

2.2 Narrative

The vessel departed Belfast at 2100 on the 28th August and proceeded to the east coast of the Isle of Man for acoustic calibration off Laxey on the 29th August. The survey started on the peripheral Irish Sea transects to the west of the Solway Firth at 05:30 on the 30th August and continued to the completion of transect 102 to the north of Angelsey on the 31st August. A short steam to the northeast of the Isle of Man saw the survey recommence at the start of transect 1 on the 01st Sept and end on transect 63 to the northwest of the Isle of Man on 04th Sept. The final set of transects for the first phase of this survey commenced at transect 64 and proceeded west and then north along the Mull of Galloway before crossing the channel and resuming 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 29 th August. Phase one of the survey ended on transect 94 on 06th Sept at which time a mid-survey break in Belfast was required to facilitate staff and crew changes.

The survey recommenced on 09th September and concluded on the 14th September during which, the remaining peripheral Irish Sea transects and a further set of transects around the Isle of Man were completed. Sea conditions were reasonably good during the survey; particularly poor weather between the 12th and 13th September resulted in a temporary cessation of the survey.

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 29th August off Laxey on the east coast of the Isle of Man. Conditions were good and the calibration results satisfactory. All procedures were according to those defined in the survey manual. Summary of calibration results are presented in Table 5B.1.

2.5 Acoustic data collection

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

2.6 Biological data – fishing stations

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

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

2.7 Hydrographic data

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

2.8 Data analysis

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

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

3. RESULTS

3.1 Biological data

Sampling intensity was relatively high during the 2017 survey with 30 successful trawls completed Figure 5B.2. Table 5B.2 gives the positions, catch composition and mean length by species for these trawl hauls. Twenty-eight 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 $W = 0.00243 * L^{3.390}$ (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).

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 and for herring only in Figure 5B.5. The highest abundance of herring was to the east of the Isle of Man and off east coast 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 ~81% age 0, ~2% age 1, ~5% age 2, ~6% age 3, ~3% age 4 and 3% age 5+.

4. DISCUSSION

The herring stock estimate in the survey area (Irish Sea/North Channel) was estimated to be 53,741t The major contribution of ages to the total estimates is from ages 0 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 2017 were observed off the east coast of the Isle of Man, south of the Mull of Galloway and on the eastern coast of Northern Ireland (southwestern corner of stratum 5 and northwestern corner of stratum 7 respectively; Figure 5B.1 & 5B.5), with a fairly scattered lower abundance observed throughout the Irish Sea (Figure 5B.5). The length frequencies generated from these trawls highlight the spatial heterogeneous nature of herring age groups in the Irish Sea (Figure 5B.3). Whilst the estimate of herring SSB of 36,498t and biomass estimate of 40,973t show an overall decline from 2016, figures still remain within the observed range for time series. The survey estimates are influenced by the timing of the spawning migration. The highest proportion of the 1+ biomass estimates was to the east of the Isle of Man (strata 9, 36%), off the Irish coast (strata 13; 18%) and northwest of the Isle of Man, south of the Mull of Galloway (strata 2; 17%) which is unusual and a reflection 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.

5 TABLES AND FIGURES

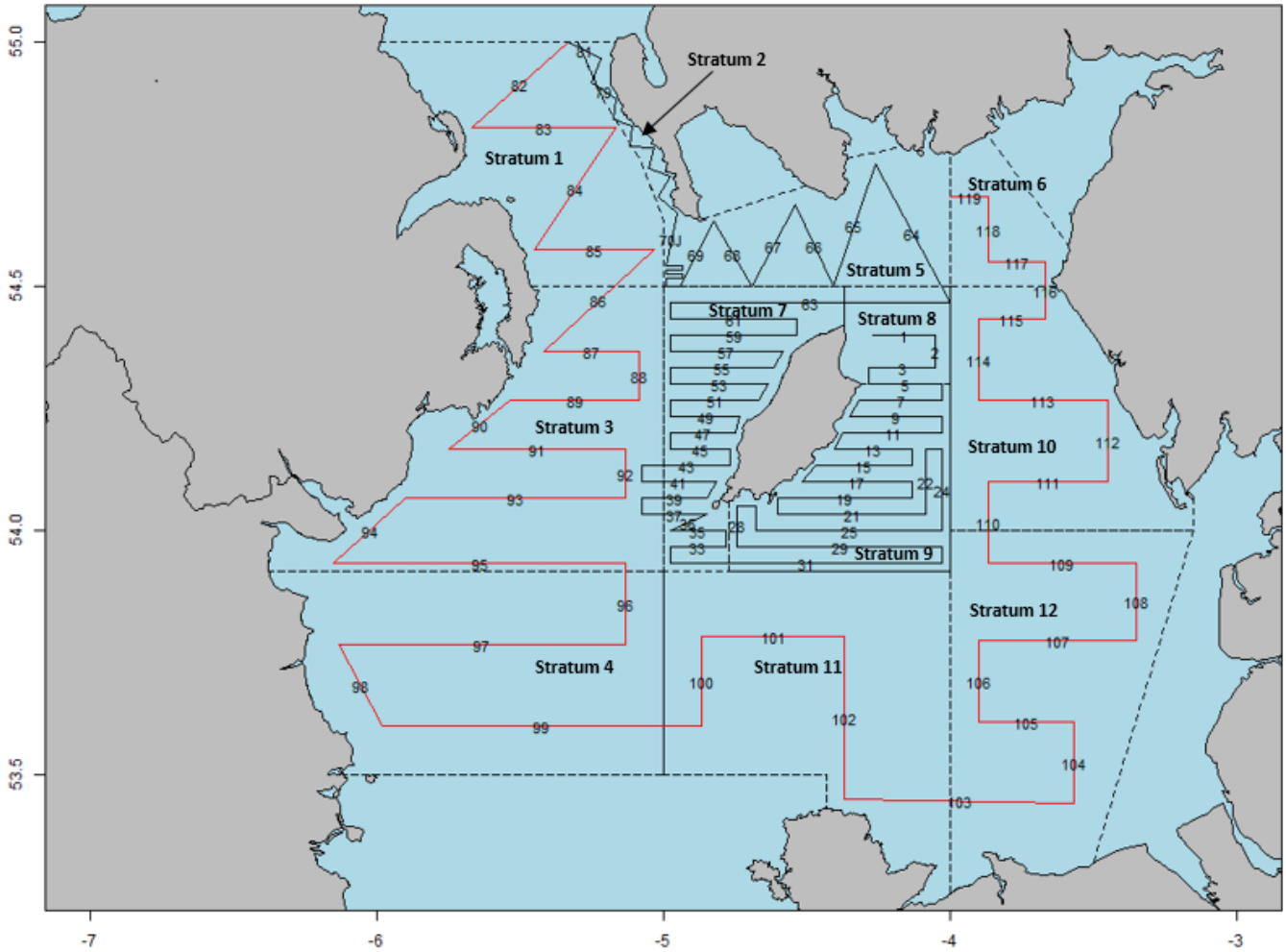


Figure 5B.1: Acoustic survey tracks for the 2017 Irish Sea acoustic survey. Survey design of systematic, parallel transects covers approximately 620 nm

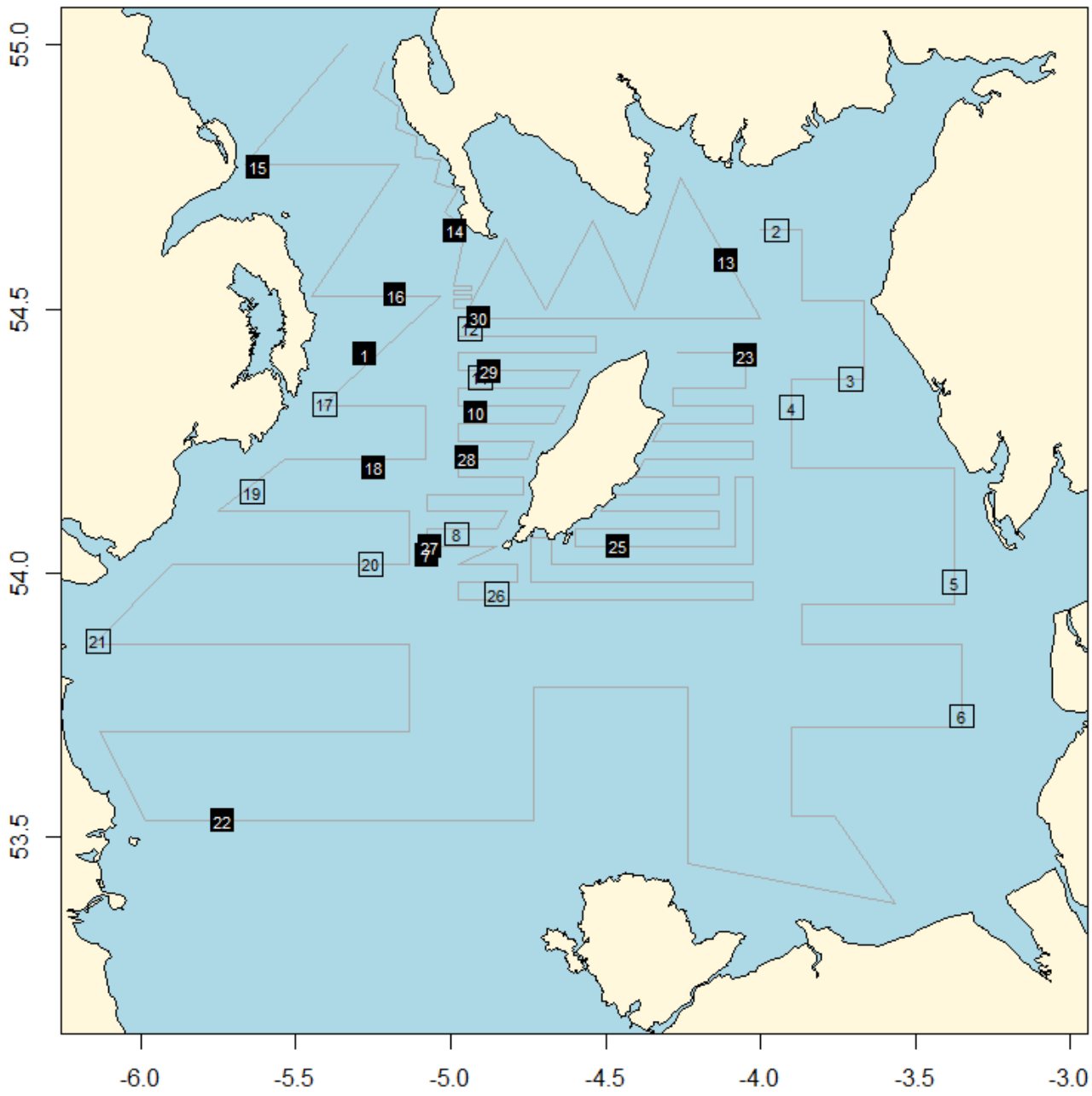


Figure 5B.2 Acoustic survey tracks with trawl positions of the 2017 Irish Sea and North Channel survey on RV "Corystes". Filled squares indicate trawls in which significant numbers of herring were caught or trawls with a high proportion of herring, while open squares indicate trawls with few or no herring.

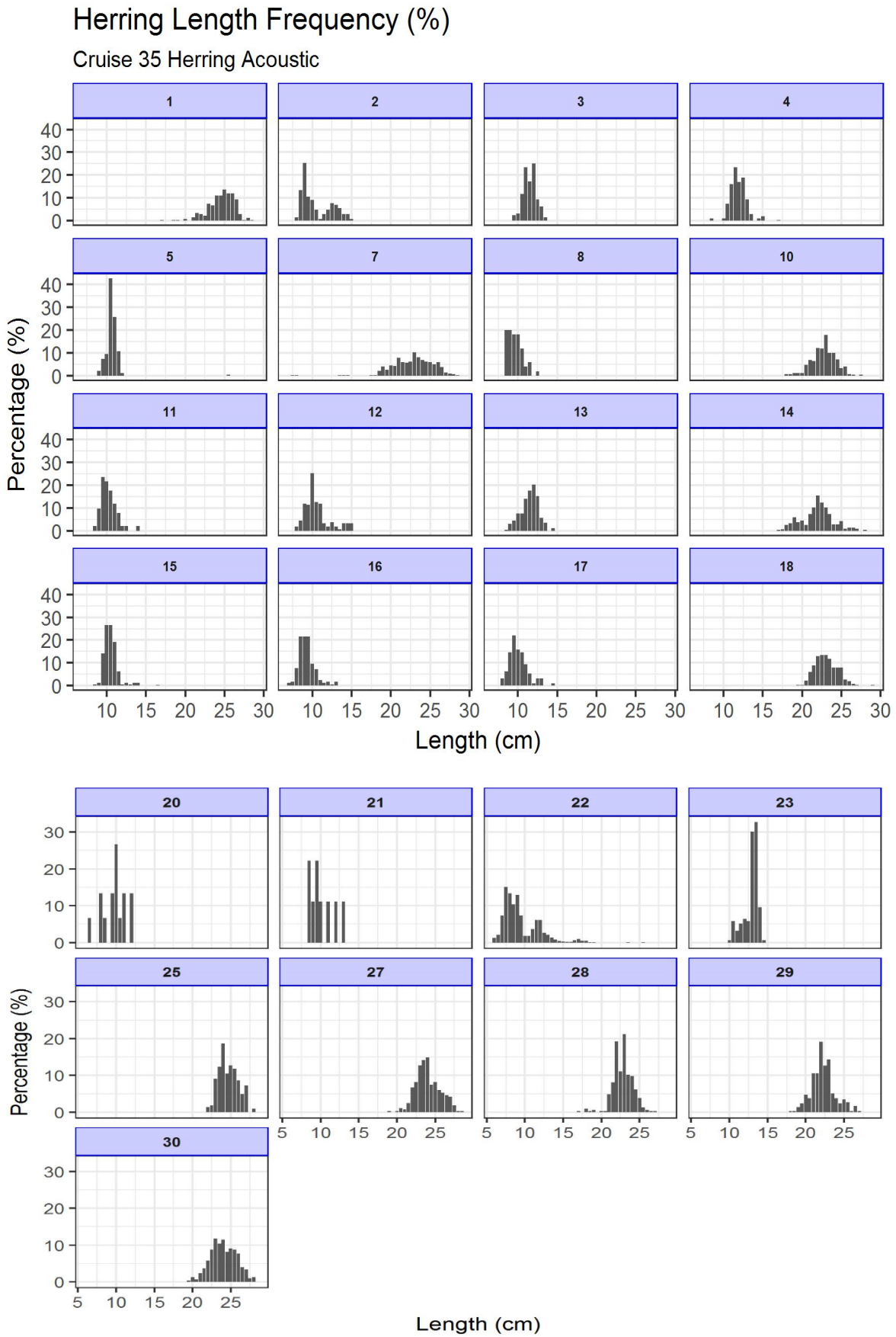


Figure 5B.3: Percentage length compositions of herring in each trawl sample in the September 2017 Irish Sea and North Channel acoustic survey on RV "Corystes".

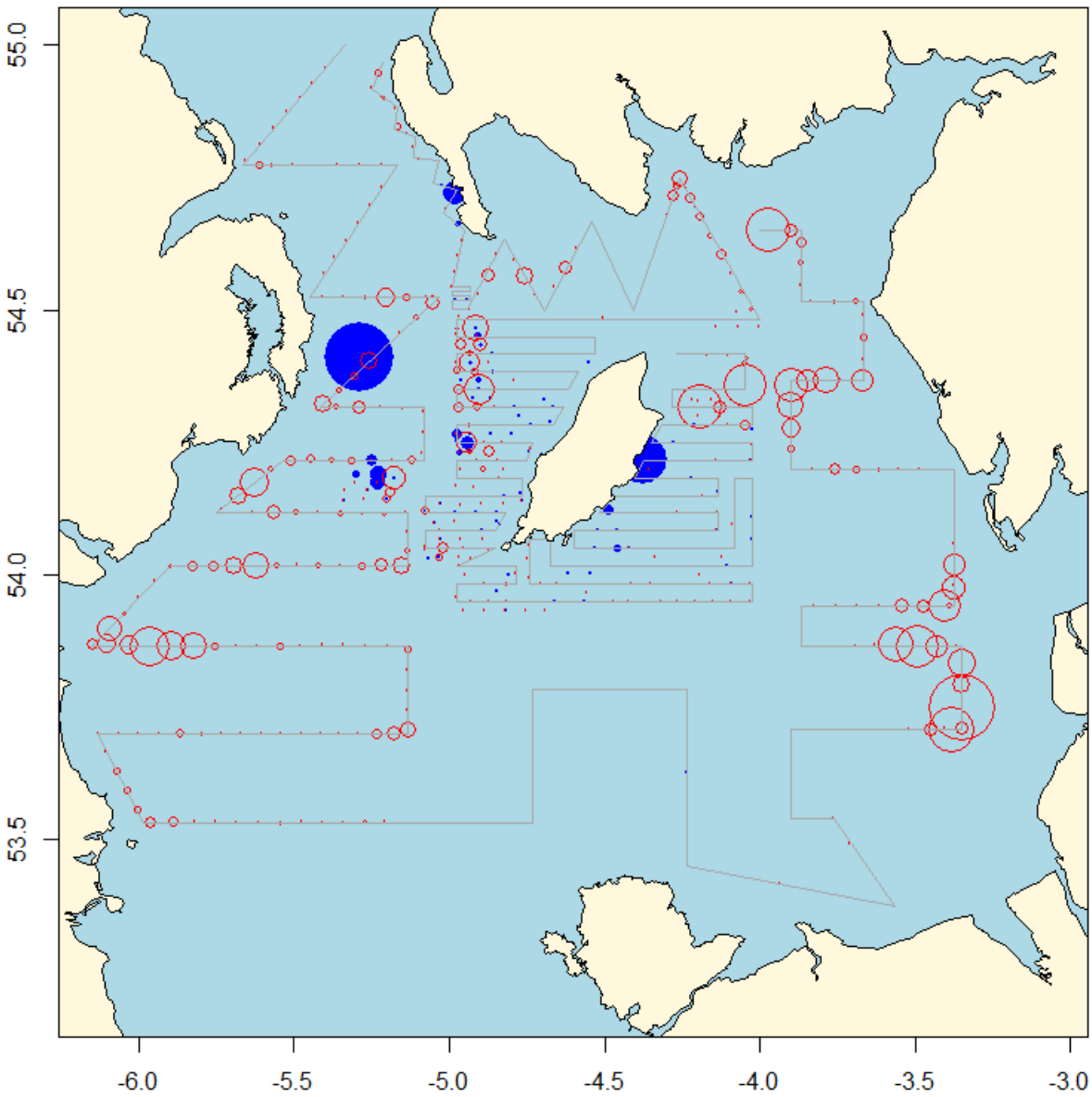


Figure 5B.4: Map of the Irish Sea and North Channel with a post plot showing the distribution of NASC values (size of elipses is proportional to square root of the NASC value per 15-minute interval) obtained during the 2017 acoustic survey on RV "Corystes". (a) Solid circles are for herring NASC values (maximum value was 13326) and (b) open circles are for clupeoid mix NASC, which include juvenile herring and sprat (maximum value was 8670).

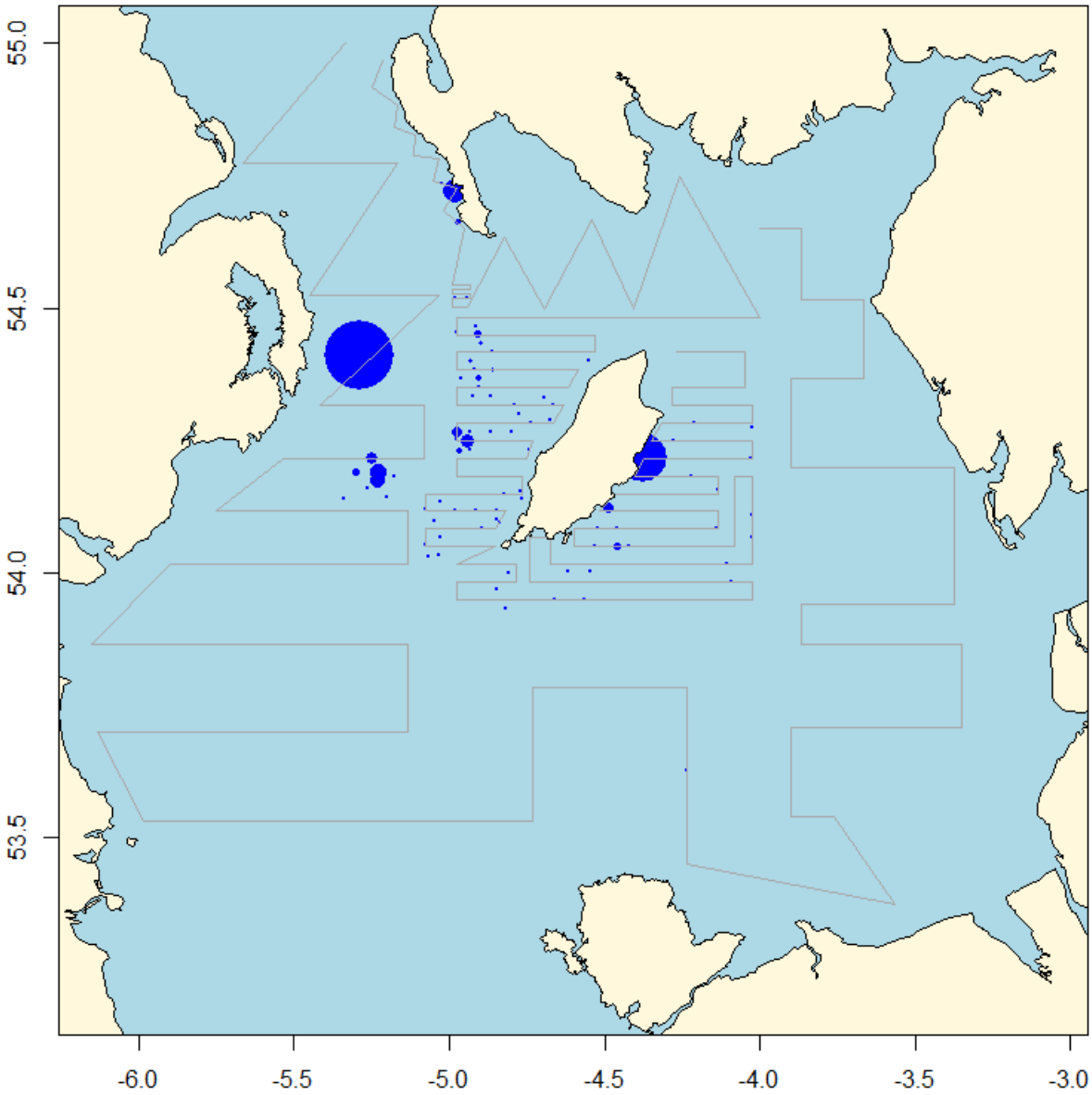


Figure 5B.5: Map of the Irish Sea and North Channel with a post plot showing the distribution of NASC values for assigned herring only (size of ellipses is proportional to square root of the NASC value per 15-minute interval) obtained during the 2017 acoustic survey on RV "Corystes" (maximum value was 13326).

Table 5B.1: Simrad EK60 and analysis settings used on the 2016 and 2017 Irish Sea and North Channel herring acoustic survey on RV "Corystes"

TRANSCEIVER MENU		
Year	2016	2017
Frequency	38 kHz	38 kHz
Sound speed	1513.3.s^{-1}	1511.3m.s^{-1}
Max. Power	2000 W	2000 W
Default Transducer Sv gain	24.86 dB	24.71 dB
Athw. Beam Angle	6.89 deg	6.90 deg
Athw. Offset Angle	0.04 deg	0.03 deg
Along. Beam Angle	6.97 deg	6.95 deg
Along. Offset Angle	0.12 deg	0.12 deg
Calibration details		
TS of sphere	-33.6 dB	-33.6 dB
Range to sphere in calibration	11.5m	11 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 2017.

Tow.	Date.	Shooting details						Total fish catch kg.	percentage composition of fish by weight							Mean length (cm)	
		Time.	Lat.		Long.		Depth (m)		sprat	herring	mackrel	scad	anchove	whiting	other fish	sprat	herring
1	29/08/2017	02:21	54	24.86	5	16.619	66.1		0.00	99.84	0.16	0.00	0.00	0.00	0.00		24.5
2	30/08/2017	07:58	54	38.95	3	56.7928	33		83.52	3.84	10.81	0.00	0.00	0.00	1.83	9.7	12
3	30/08/2017	11:40	54	21.98	3	42.56	26.03		85.44	3.69	10.61	0.00	0.00	0.00	0.26	9.5	11.7
4	30/08/2017	13:35	54	18.85	3	53.888	34.5		88.23	3.89	0.88	0.00	0.00	4.00	3.00	9.1	14
5	30/08/2017	18:18	53	59.00	3	22.431	19.23		81.19	2.33	6.25	0.00	0.97	0.05	9.20	8.2	13.1
6	31/08/2017	11:17	53	43.78	3	21.002	18		98.20	0.00	1.09	0.00	0.00	0.00	0.72	10	
7	02/09/2017	10:29	54	2.09	5	4.4745	73		0.00	96.54	0.00	0.01	0.00	1.10	2.35		22.4
8	02/09/2017	12:10	54	4.48	4	58.912	71.3		93.67	1.89	0.12	0.00	0.00	0.01	4.32	9	
10	02/09/2017	23:26	54	18.26	4	54.994	74.5		0.00	100.00	0.00	0.00	0.00	0.00	0.00		23
11	03/09/2017	04:47	54	22.27	4	54.256	78.09		33.15	4.19	10.75	0.00	0.00	24.46	27.47	9.8	11.4
12	03/09/2017	10:29	54	27.78	4	56.2038	76		88.10	6.48	4.64	0.00	0.00	0.00	0.78	8.8	12.1
13	04/09/2017	08:34	54	35.44	4	6.6713	51.8		36.78	63.20	0.02	0.00	0.00	0.00	0.00	10.4	16.3
14	05/09/2017	00:06	54	38.91	4	59.086	52.2		0.00	78.76	0.61	0.00	0.00	0.00	20.63		23.1
15	05/09/2017	08:13	54	46.14	5	37.3868	60.06		88.28	11.34	0.29	0.00	0.00	0.03	0.06	9.4	12.3
16	05/09/2017	13:47	54	31.58	5	10.732	137		78.46	12.84	4.05	0.00	0.00	0.25	4.39	6.7	10.8
17	05/09/2017	17:16	54	19.21	5	24.42	54.18		92.16	0.79	7.02	0.01	0.00	0.02	0.00	9.2	10.5
18	05/09/2017	21:32	54	11.96	5	14.9993	78.3		0.00	91.22	0.15	0.00	0.00	8.57	0.06		24.3
19	06/09/2017	09:04	54	9.26	5	38.32	30.5		80.20	0.04	16.06	0.00	0.00	0.00	3.70	9.3	9.6
20	06/09/2017	13:09	54	1.09	5	15.404	75.7		96.42	0.38	0.74	0.07	0.00	0.00	2.40	6.7	9.8
21	06/09/2017	17:39	53	52.34	6	8.26	21		27.18	0.23	52.35	0.00	0.00	0.00	20.24	8.5	11.1
22	09/09/2017	16:33	53	31.90	5	44.058	67.69		3.51	81.16	1.09	0.36	0.00	3.40	10.47	6.8	13.4
23	10/09/2017	06:38	54	24.73	4	2.858	30.04		63.02	14.88	5.28	0.00	0.00	0.00	16.83	9.7	12.9
25	11/09/2017	22:38	54	3.05	4	27.4573	33.59		0.00	83.66	16.34	0.00	0.00	0.00	0.00		24.8
26	12/09/2017	15:04	53	57.63	4	51.149	65.44		96.72	0.00	1.19	0.00	0.00	0.00	2.10	12.4	
27	12/09/2017	18:40	54	2.97	5	4.023	57.85		0.00	91.48	0.15	0.00	0.00	7.72	0.63		24.7
28	13/09/2017	05:38	54	13.11	4	56.854	85.44		0.00	99.14	0.13	0.01	0.00	0.37	0.36		22.9
29	13/09/2017	14:34	54	22.91	4	52.484	50		0.00	95.72	4.28	0.00	0.00	0.00	0.00		22.9
30	13/09/2017	22:34	54	29.03	4	54.4816	61.3		0.00	93.61	3.27	0.00	0.00	0.28	2.84		24.7

Table 5B.3: Preliminary age-length key for herring from which otoliths were removed at sea during the Irish Sea/North Channel survey 2017. 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
6.5	1	0	0	0	0	0	0	0	0	1
7	2	0	0	0	0	0	0	0	0	2
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	4	0	0	0	0	0	0	0	0	4
9	3	0	0	0	0	0	0	0	0	3
9.5	8	0	0	0	0	0	0	0	0	8
10	10	0	0	0	0	0	0	0	0	10
10.5	7	0	0	0	0	0	0	0	0	7
11	5	0	0	0	0	0	0	0	0	5
11.5	6	0	0	0	0	0	0	0	0	6
12	9	0	0	0	0	0	0	0	0	9
12.5	7	0	0	0	0	0	0	0	0	7
13	7	0	0	0	0	0	0	0	0	7
13.5	6	0	0	0	0	0	0	0	0	6
14	4	0	0	0	0	0	0	0	0	4
14.5	3	0	0	0	0	0	0	0	0	3
15	5	0	0	0	0	0	0	0	0	5
15.5	0	1	0	0	0	0	0	0	0	1
16	0	1	0	0	0	0	0	0	0	1
16.5	0	0	0	0	0	0	0	0	0	0
17	0	2	0	0	0	0	0	0	0	2
17.5	0	5	0	0	0	0	0	0	0	5
18	0	5	0	0	0	0	0	0	0	5
18.5	0	5	2	0	0	0	0	0	0	7
19	0	10	0	0	0	0	0	0	0	10
19.5	0	11	3	0	0	0	0	0	0	14
20	0	8	0	0	0	0	0	0	0	8
20.5	0	12	0	2	0	0	0	0	0	14
21	0	9	6	0	0	0	0	0	0	15
21.5	0	9	14	1	0	0	0	0	0	24
22	0	6	13	0	0	0	0	0	0	19
22.5	0	3	8	1	0	0	0	0	0	12
23	0	1	18	1	0	0	0	0	0	20
23.5	0	1	22	16	2	0	0	0	0	41
24	0	0	15	16	1	0	0	0	0	32
24.5	0	0	5	23	3	0	0	0	0	31
25	0	2	6	22	6	1	1	0	0	38
25.5	0	1	2	19	14	1	2	0	0	39
26	0	0	1	8	10	3	4	1	0	27
26.5	0	1	0	2	14	1	3	1	1	23
27	0	0	0	5	5	1	5	1	5	22
27.5	0	0	0	1	6	2	7	1	3	20
28	0	0	0	0	1	2	4	1	5	13
28.5	0	0	0	0	1	1	1	1	4	8
29	0	0	0	0	0	0	0	0	1	1
TOTAL	89	93	115	117	63	12	27	6	19	541

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 2017.

STRATUM	NO. SPRAT	BIOMASS SPRAT	NO. HER	BIOMASS HER
1	3771232	8137	254085	1596
2	738595	1722	107442	7299
3	18206423	41859	95865	3744
4	20924698	43986	341495	2331
5	1785551	5433	138303	1771
6	5463342	16459	69562	625
7	1358382	3804	68830	5122
8	1507878	6684	105514	1620
9	142295	564	113372	15139
10	22225100	37769	144318	1588
11	0	0	0	0
12	22671680	52769	243143	3294
13	0	0	56743	7559
14	0	0	19079	2051
Total	98795176	219186	1757750	53741

Document 8c: ISAS 2018 survey summary table

Survey Summary table WGIPS 2019	
Name of the survey (abbreviation):	**Irish Sea Acoustic Survey (ISAS)**
Target Species:	**Herring**
Survey dates:	**27th August – 13th September 2018**
Summary:	
The vessel departed Belfast at 2200 on the 27th August 2018 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 12:45 on the 29th August and continued to the completion of transect 102 to the northeast of Angelsey on the 31st August. A short steam to the northeast of the Isle of Man saw the survey recommence at the start of transect 1 on 31st August at 15:15 and continued through to the end of transect 93 on the 05th September at which time a mid-survey break in Belfast was required to facilitate staff and crew changes. The survey recommenced on 08th September and concluded on the 13th September during which time, the remaining peripheral Irish Sea transects and a further set of transects around the Isle of Man were completed. Additional survey transects in the vicinity of Slieve na Griddle and Rig Bank were conducted on the 05th September. Sea conditions were reasonably good during the survey; one particularly poor weather day on the 10th September resulted in a temporary cessation of the survey.	
	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 reasonably good during the survey; one particularly poor weather day on the 10th September resulted in a temporary cessation of the survey.
Extinction (shadowing)	No perceived issues
Blind zone	NA
Dead zone	NA

Allocation of backscatter to species	Directed trawling, with 32 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 28th August off Laxey on the east coast of the Isle of Man. Conditions were good and the calibration results satisfactory. All procedures were according to those defined in the survey manual.
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 2018 survey: Complete coverage
Stock ID and mixing issues	Time-series: Winter hatched fish, of which the majority are thought to be of Celtic Sea origin, are present in the prespawning aggregations sampled in the Irish Sea during the acoustic survey. The presence of these winter hatched fish has implications for the estimates of 1-ringer+ biomass and SSB 2018 survey:No additional issues
Measures of uncertainty (CV)	CV of biomass and numbers at age
Biological sampling	2018 Survey: The biological sampling is deamed to be appropriate for the stock and area. Sampling is in line with historic levels. Biological samples are not available at the time of WGIPS to update biological data. Ages (age–length-key) and maturity data for 2017 are used for initial biomass estimates and population age structure.
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole time-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 8d: ISAS 2018 survey report

Please see the report on the next page.

ANNEX 5B: Irish Sea acoustic survey (Northern Ireland)

Survey report for RV Corystes

27th August – 13th September 2018

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)
Pia Schuchert
Stephen Beggs
Peter McCorriston
Keith Erskine
Conor Dolan
Jamie McFerran
Gary Heaney
Kitie Lilly
Brendan Kerr

2.2 Narrative

The vessel departed Belfast at 21:00 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 12:45 on the 29th August and continued to the completion of transect 102 to the north of Angelsey on the 31st August. A short steam to the northeast of the Isle of Man saw the survey recommence at the start of transect 1 on the 31st August at 15:15 and end on transect 63 to the northwest of the Isle of Man on 03rd Sept. The final set of transects for the first phase of this survey commenced at transect 64 and proceeded west and then north along the Mull of Galloway before crossing the channel and resuming 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 05th Sept. Phase one of the survey ended on transect 93 on 05th Sept at which time a mid-survey break in Belfast was required to facilitate staff and crew changes.

The survey recommenced on 08th September and concluded on the 13th September during which, the remaining peripheral Irish Sea transects and a further set of transects around the Isle of Man were completed. Sea conditions were reasonably good during the survey; particularly poor weather between the 10th and 11th September resulted in a temporary cessation of the survey.

2.3 Survey design

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

2.4 Calibration

The hull mounted Simrad EK60 acoustic system with 38 kHz split-beam was calibrated on the 28th August off Laxey on the east coast of the Isle of Man. Conditions were good and the calibration results satisfactory. All procedures were according to those defined in the survey manual. Summary of calibration results are presented in Table 5B.1.

2.5 Acoustic data collection

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

2.6 Biological data – fishing stations

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

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

2.7 Hydrographic data

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

2.8 Data analysis

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

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

3. RESULTS

3.1 Biological data

Sampling intensity was relatively high during the 2018 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. Thirty-one hauls contained herring to be used in the analysis. The length frequency distributions of these hauls are illustrated in Figure 5B.3. Length frequency distributions reflect the general juvenile/adult herring distributions within the sampling area. The resulting weight-length relationship for herring was calculated from the sampling information as $W = 0.00243 * L^{3.383}$ (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 2017 have been included in this report as otoliths from the 2018 survey are still being analyised. Age-length data will be updated for the 2018 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 east coast 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 of herring by age will be updated when biological data becomes available.

4. DISCUSSION

The herring stock estimate in the survey area (Irish Sea/North Channel) was estimated to be 112,977t The major contribution of ages to the total estimates is from ages 0 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 2018 were observed off the east coast of the Isle of Man, and on the eastern coast of Northern Ireland (southwestern corner of stratum 7 and northwestern corner of stratum 3 respectively; Figure 5B.1&5), 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 44,332t is within the observed range for the time series and the biomass estimate of 57,615t for 1+ ringers for 2018 also remains within the observed range since 2011 and higher than the 2017 estimates. The survey estimates are influenced by the timing of the spawning migration. The highest proportion of the 1+ biomass estimates was to the west of the Isle of Man (strata 7), off the Irish coast (strata 13) and northwest of the Isle of Man, south of the Mull of Galloway (strata 2) which is unusual and a reflection 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.

5 TABLES AND FIGURES

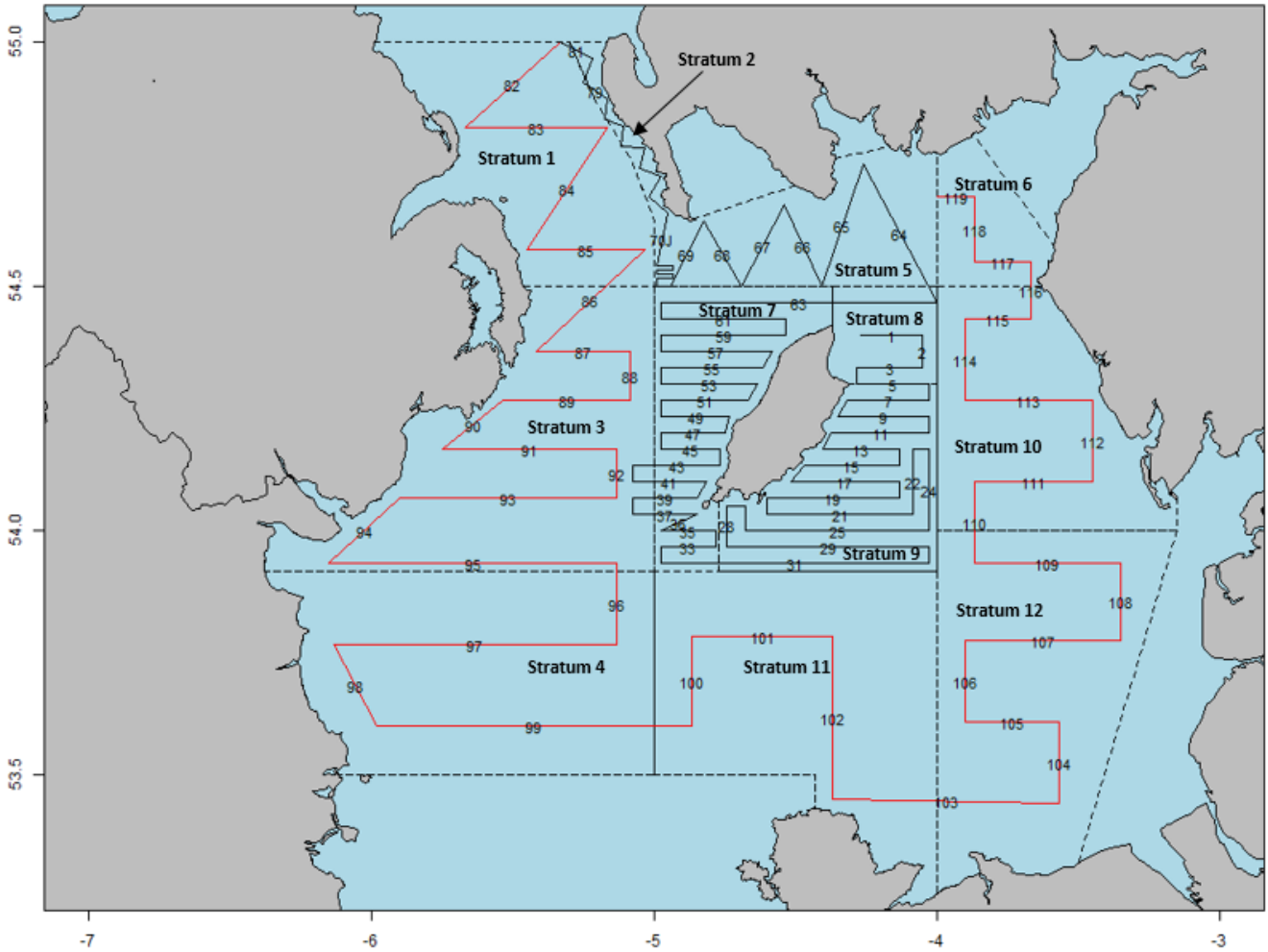


Figure 5B.1: Acoustic survey tracks for the 2018 Irish Sea acoustic survey. Survey design of systematic, parallel transects covers approximately 620 nm

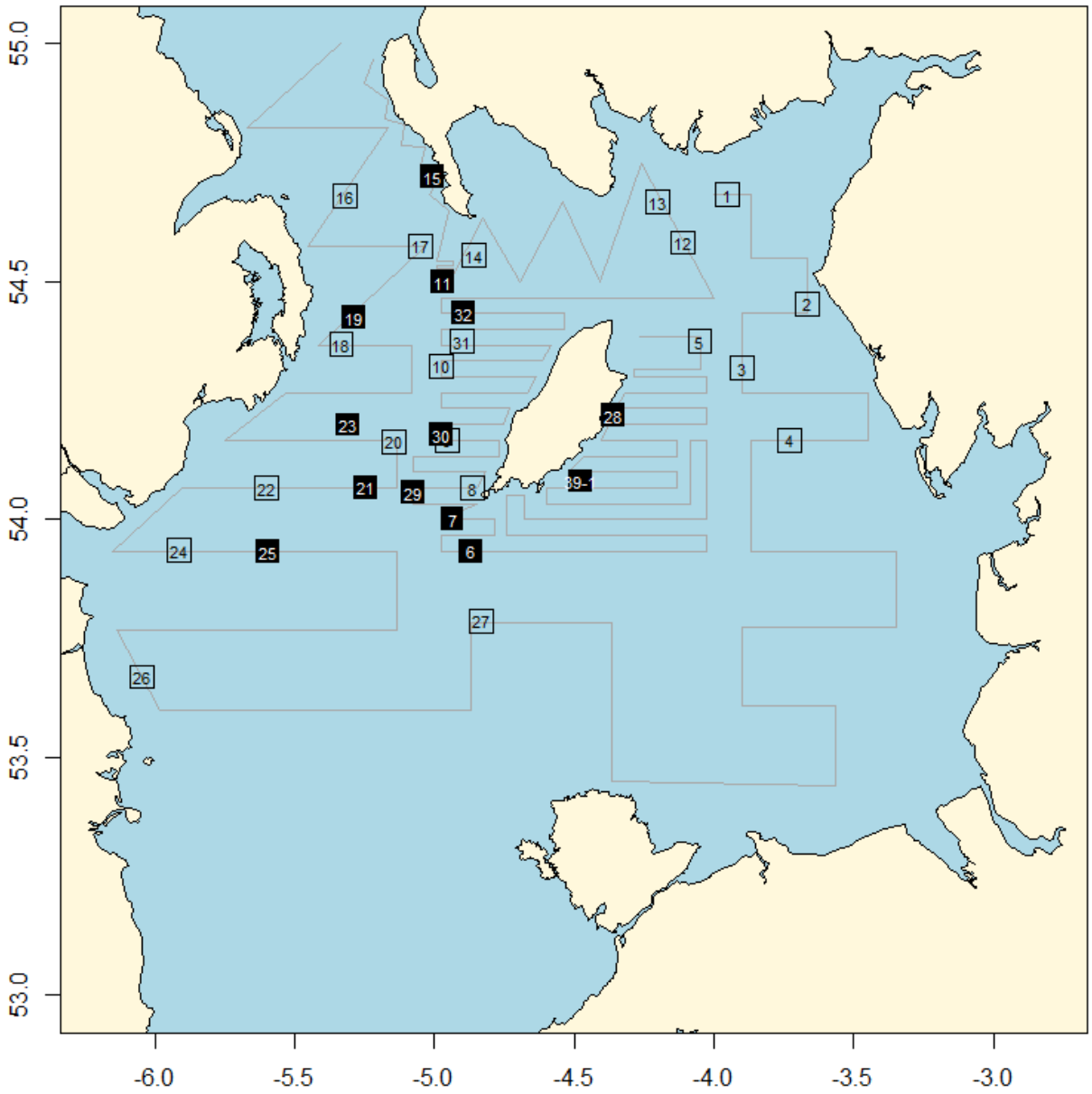
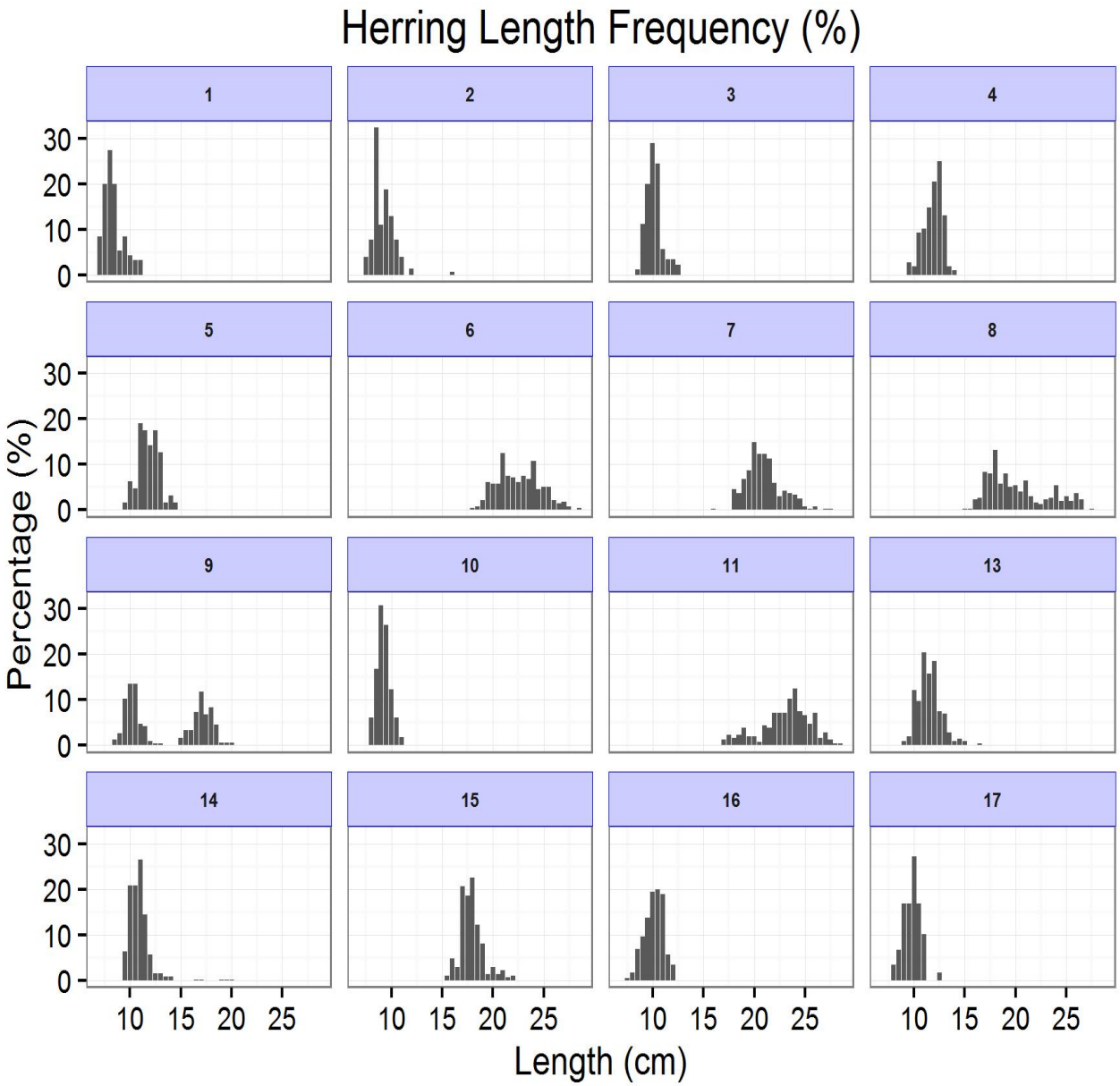


Figure 5B.2 Acoustic survey tracks with trawl positions of the 2018 Irish Sea and North Channel survey on RV "Corystes". Filled squares indicate trawls in which significant numbers of herring were caught or trawls with a high proportion of herring, while open squares indicate trawls with few or no herring.

Herring Length Frequency (%)

Cruise 35 Herring Acoustic



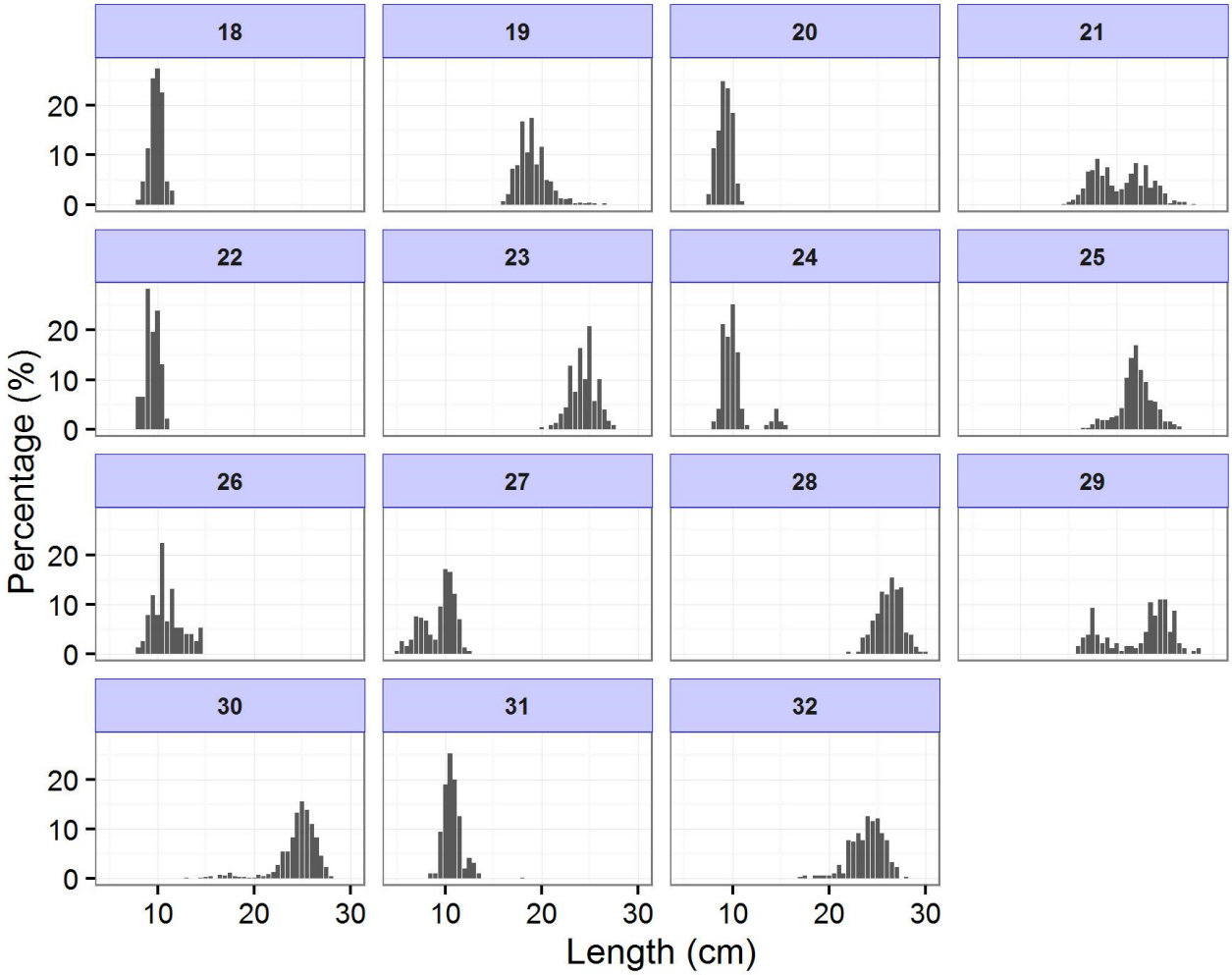


Figure 5B.3: Percentage length compositions of herring in each trawl sample in the September 2018 Irish Sea and North Channel acoustic survey on RV "Corystes".

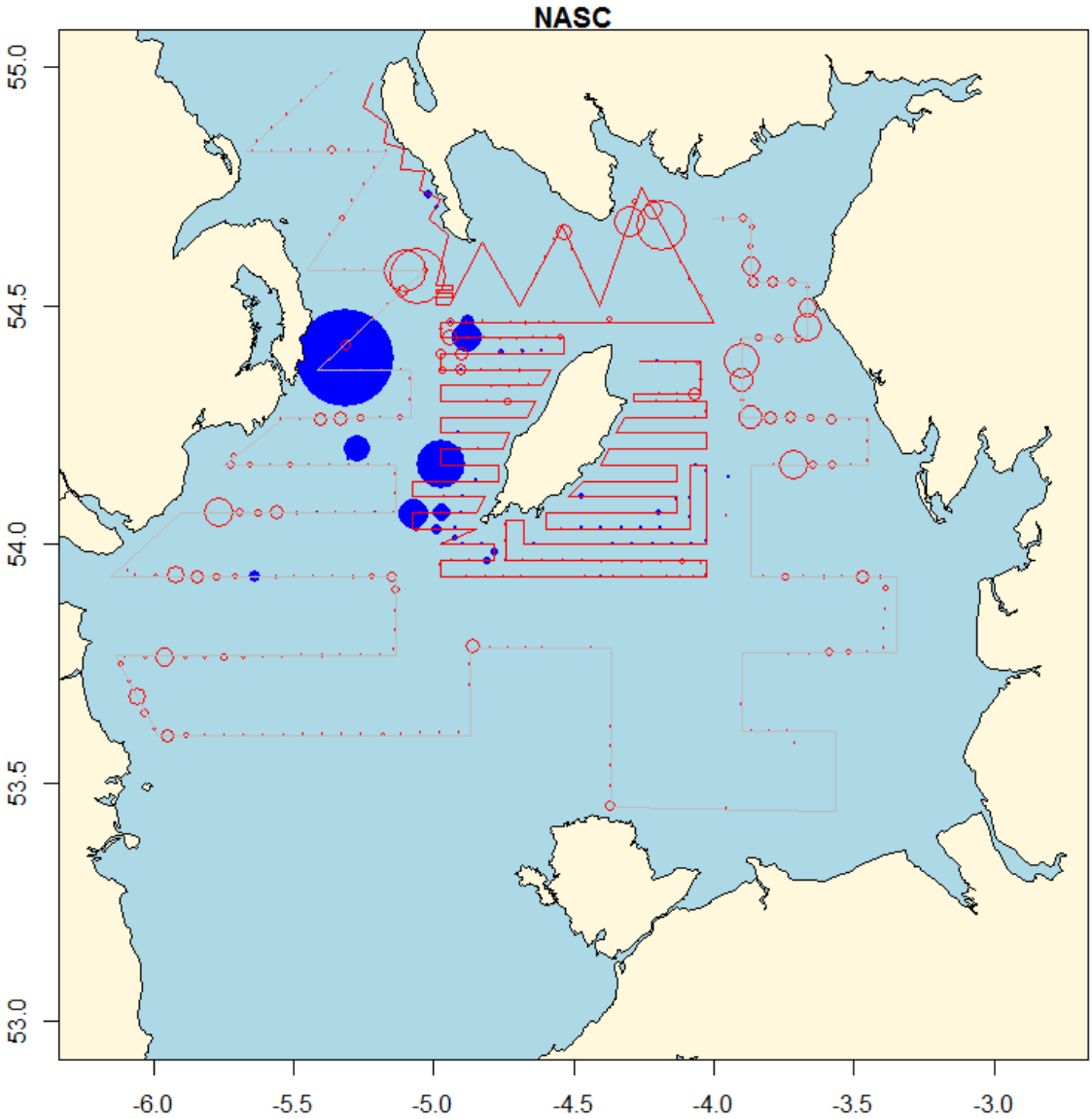


Figure 5B.4: Map of the Irish Sea and North Channel with a post plot showing the distribution of NASC values (size of elipses is proportional to square root of the NASC value per 15-minute interval) obtained during the 2018 acoustic survey on RV "Corystes". (a) Solid circles are for herring NASC values (maximum value was 18514) and (b) open circles are for clupeoid mix NASC, which include juvenile herring and sprat (maximum value was 10595).

Table 5B.1: Simrad EK60 and analysis settings used on the 2017 and 2018 Irish Sea and North Channel herring acoustic survey on RV "Corystes"

TRANSCEIVER MENU		
Year	2017	2018
Frequency	38 kHz	38 kHz
Sound speed	1511.3.s^{-1}	1481.7m.s^{-1}
Max. Power	2000 W	2000 W
Default Transducer Sv gain	24.71 dB	26.36 dB
Athw. Beam Angle	6.90 deg	7.02 deg
Athw. Offset Angle	0.03 deg	-0.03 deg
Along. Beam Angle	6.95 deg	6.95 deg
Along. Offset Angle	0.12 deg	0.18 deg
Calibration details		
TS of sphere	-33.6 dB	-33.6 dB
Range to sphere in calibration	11.5m	11.5 m
Log Menu		
Integration performed in Echoview post-processing based on 15 minute EDSUs		
Operation Menu		
Ping interval	0.7 s	0.7 s
Analysis settings		
Bottom margin (backstep)	0.5 m	0.5 m
Integration start (absolute) depth	8 m	8 m
Sv gain threshold	-60 dB	-60 dB

Tow	Date	Shooting details						Total catch kg.	percentage composition of fish by weight							Mean length	
		Time	Lat.		Long.		depth (m)		sprat	herring	mackerel	scad	anchovy	whiting	other fish	sprat	herring
1	29/08/2018	13:50	54	41.0	3	57.1	34.6	18	86.84	12.96	0.16	0.00	0.00	0.03	0.00	6.3	8.6
2	29/08/2018	18:34	54	27.2	3	39.9	18.2	155	81.48	5.97	0.59	0.00	0.10	0.00	11.86	7.2	9.5
3	30/08/2018	06:34	54	19.1	3	54.0	33.5	85	87.57	4.98	0.71	0.00	0.05	0.00	6.69	8.1	10.4
4	30/08/2018	11:10	54	10.1	3	43.5	26	122	82.09	14.83	2.91	0.00	0.00	0.00	0.16	9.1	12.1
5	31/08/2018	18:09	54	22.5	4	3.0	37.5	344	97.90	2.07	0.03	0.00	0.00	0.00	0.00	9.1	12.1
6	01/09/2018	21:19	53	56.0	4	52.1	54	251	0.00	99.69	0.31	0.00	0.00	0.00	0.00		22.3
7	01/09/2018	23:34	54	0.0	4	56.1	43.1	405	0.00	98.71	1.27	0.00	0.00	0.02	0.01		21.2
8	02/09/2018	02:32	54	4.0	4	51.8	41.6	69	2.52	69.99	19.83	0.00	0.00	1.76	5.90	12.9	20.4
9	02/09/2018	07:58	54	10.0	4	57.2	77	40	45.22	45.00	3.71	0.00	0.00	3.61	2.47	10.4	13.8
10	02/09/2018	13:19	54	19.4	4	58.6	108.6	7	73.43	25.55	0.00	0.00	0.00	0.56	0.45	7.7	9.5
11	02/09/2018	23:35	54	29.9	4	58.2	113	700	0.00	60.01	0.00	0.00	0.00	0.00	39.99		23.3
13	03/09/2018	09:50	54	40.0	4	12.0	38	36	68.36	20.94	2.43	0.00	0.00	0.00	8.28	9.2	11.8
14	03/09/2018	17:14	54	33.3	4	51.4	66.2	104	45.08	54.66	0.25	0.00	0.00	0.00	0.00	8.5	11.1
15	03/09/2018	21:20	54	43.2	4	0.5	35	700	0.00	98.51	0.18	0.00	0.00	0.00	1.31		18.2
16	04/09/2018	12:00	54	40.8	5	19.2	133	13	5.03	74.70	20.27	0.00	0.00	0.00	0.00	8.4	10.4
17	04/09/2018	14:32	54	34.5	5	2.9	194	7	90.98	5.40	2.59	0.00	0.00	1.02	0.00	8.2	10.1
18	04/09/2018	17:59	54	22.1	5	20.0	74.2	45	49.15	47.87	0.55	0.00	0.00	0.00	2.44	7.8	10.1
19	04/09/2018	23:17	54	25.4	5	17.2	86	82	0.00	100.00	0.00	0.00	0.00	0.00	0.00		19.3
20	05/09/2018	11:40	54	9.8	5	8.6	123	93	69.32	20.64	2.35	0.00	0.00	0.00	7.70	7.8	9.4
21	05/09/2018	13:29	54	4.0	5	14.7	100.7	53	0.00	100.00	0.00	0.00	0.00	0.00	0.00		20.6
22	05/09/2018	15:57	54	4.0	5	36.0	53.8	9	59.39	2.37	2.83	0.00	0.00	0.58	34.83	7.4	9.7
23	05/09/2018	22:02	54	11.9	5	18.4	87	215	0.00	100.00	0.00	0.00	0.00	0.00	0.00		24.6
24	08/09/2018	09:07	53	56.1	5	54.7	39	257	95.99	2.67	0.00	0.00	0.00	0.01	1.33	7.9	10.4
25	08/09/2018	10:20	53	55.9	5	35.8	107	117	0.00	97.88	0.00	0.00	0.00	2.12	0.00		22.2
26	08/09/2018	18:22	53	40.2	6	2.7	22	75	76.86	4.05	10.15	0.00	0.00	0.00	8.94	8.7	11.3
27	09/09/2018	11:10	53	47.2	4	50.0	88	53	15.51	82.21	0.00	0.00	0.00	0.00	2.29	7.4	9.6
28	10/09/2018	22:05	54	13.1	4	21.6	26	588	0.00	98.70	1.24	0.00	0.00	0.00	0.06		26.5
29	11/09/2018	17:02	54	3.4	5	4.4	61	1502	0.00	99.87	0.13	0.00	0.00	0.00	0.00		22.7
30	11/09/2018	22:33	54	10.7	4	58.4	83	184	0.00	50.80	0.00	0.00	0.00	48.53	0.67		24.8
31	12/09/2018	08:21	54	22.5	4	53.9	74	49	0.00	98.91	1.09	0.00	0.00	0.00	0.00		11.1
32	12/09/2018	12:39	54	26.0	4	53.7	63.2	2500	0.00	100.00	0.00	0.00	0.00	0.00	0.00		24.2

Table 5B.2: Catch composition and position of hauls undertaken by the RV *Corystes* during the Irish Sea/North Channel survey, August/September 2018.

Table 5B.3: Preliminary age-length key for herring from which otoliths were removed at sea during the Irish Sea/North Channel survey 2017. 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
6.5	1	0	0	0	0	0	0	0	0	1
7	2	0	0	0	0	0	0	0	0	2
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	4	0	0	0	0	0	0	0	0	4
9	3	0	0	0	0	0	0	0	0	3
9.5	8	0	0	0	0	0	0	0	0	8
10	10	0	0	0	0	0	0	0	0	10
10.5	7	0	0	0	0	0	0	0	0	7
11	5	0	0	0	0	0	0	0	0	5
11.5	6	0	0	0	0	0	0	0	0	6
12	9	0	0	0	0	0	0	0	0	9
12.5	7	0	0	0	0	0	0	0	0	7
13	7	0	0	0	0	0	0	0	0	7
13.5	6	0	0	0	0	0	0	0	0	6
14	4	0	0	0	0	0	0	0	0	4
14.5	3	0	0	0	0	0	0	0	0	3
15	5	0	0	0	0	0	0	0	0	5
15.5	0	1	0	0	0	0	0	0	0	1
16	0	1	0	0	0	0	0	0	0	1
16.5	0	0	0	0	0	0	0	0	0	0
17	0	2	0	0	0	0	0	0	0	2
17.5	0	5	0	0	0	0	0	0	0	5
18	0	5	0	0	0	0	0	0	0	5
18.5	0	5	2	0	0	0	0	0	0	7
19	0	10	0	0	0	0	0	0	0	10
19.5	0	11	3	0	0	0	0	0	0	14
20	0	8	0	0	0	0	0	0	0	8
20.5	0	12	0	2	0	0	0	0	0	14
21	0	9	6	0	0	0	0	0	0	15
21.5	0	9	14	1	0	0	0	0	0	24
22	0	6	13	0	0	0	0	0	0	19
22.5	0	3	8	1	0	0	0	0	0	12
23	0	1	18	1	0	0	0	0	0	20
23.5	0	1	22	16	2	0	0	0	0	41
24	0	0	15	16	1	0	0	0	0	32
24.5	0	0	5	23	3	0	0	0	0	31
25	0	2	6	22	6	1	1	0	0	38
25.5	0	1	2	19	14	1	2	0	0	39
26	0	0	1	8	10	3	4	1	0	27
26.5	0	1	0	2	14	1	3	1	1	23
27	0	0	0	5	5	1	5	1	5	22
27.5	0	0	0	1	6	2	7	1	3	20
28	0	0	0	0	1	2	4	1	5	13
28.5	0	0	0	0	1	1	1	1	4	8
29	0	0	0	0	0	0	0	0	1	1
TOTAL	89	93	115	117	63	12	27	6	19	541

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 2018.

Stratum	No. sprat	Biomass sprat	No. Her	Biomass Her
1	4233157	15302	1357520	9639
2	0	0	46562	3526
3	5678480	19104	1214026	20936
4	14519033	50253	606899	7715
5	2770894	14589	398297	4207
6	5551204	11496	267131	1275
7	1091963	3662	381095	22002
8	476232	2439	10284	932
9	314571	1180	45043	5109
10	17136504	62874	826623	7664
11	1099169	2797	2971707	17055
12	4676773	18876	501036	4734
13	0	0	109024	6096
14	0	0	16710	2088
Total	57547980	202572	8751957	112977

Document 9a: ISCAS 2017 survey summary table

Survey Summary table WGIPS 2019	
Name of the survey (abbreviation):	**Irish Sea Acoustic Spawning Survey (ISASS)**
Target Species:	**Herring**
Survey dates:	**25th September – 29th September 2017**
Summary:	
A commercial chartered fishing vessel departed Belfast at 2300 on the 25th September 2017 and proceeded to the east coast of the Isle of Man for acoustic calibration off Laxey on the 25th August. The survey started on Isle of Man grid on transect 1 on 25th and continued through to the end of transect 82 on the 29thth.	
	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 (ISAS section??).
Index Calculation method	Weighted mean TS is applied to the NASC value to give numbers per square nautical mile – further decomposed by age class according to length frequencies in relevant target identified trawls and survey age–length key.
Random/systematic error issues	NA
Specific survey error issues (acoustic)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Bubble sweep down	Sea conditions were reasonably good during the survey; A break in the survey was required.
Extinction (shadowing)	No perceived issues
Blind zone	NA
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 (scientific GPT) acoustic system with 38 kHz split-beam was calibrated on the 24th September off Laxey on

	the east coast of the Isle of Man. Conditions were good and the calibration results satisfactory. All procedures were according to those defined in the survey manual.
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. 2017 survey: As in previous years
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. 2017 survey: No additional issues
Measures of uncertainty (CV)	CV of biomass and numbers at age
Biological sampling	2017 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. Sampling is line with historic levels.
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole time-series or for individual years? (please specify)	*To be answered by Assessment Working Group*
Did the Survey Summary Table contain adequate information to allow for evaluation of the quality of the survey for use in assessment? Please identify shortfalls	*To be answered by Assessment Working Group*

Document 9b: ISCAS 2017 survey report

Please see the report on the next page.

ANNEX 5B: Irish Sea commercial acoustic survey (Northern Ireland)

Survey report for FV Haviliah

24th September – 28th September 2017

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
Jim McArdle
Jamie McFerran

2.2 Narrative

The vessel departed Belfast at 2100 on the 24th September and proceeded to the east coast of the Isle of Man for acoustic calibration off Laxey on the 25th Sept. The survey started at the start of transect 1 to the northeast of The Isle of Man on the 25th September proceeding through to the end of transect 81 on the 28th September, with the ship returning to Belfast at 14:00 on the 28th September. Sea conditions were reasonably good during the survey, but particularly poor weather on the 27th September resulted in a temporary cessation of the survey.

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 25th September off Laxey on the east coast of the Isle of Man. Conditions were good and the calibration results satisfactory. All procedures were according to those defined in the survey manual. Summary of calibration results are presented in Table 5B.1.

2.5 Acoustic data collection

Acoustic data 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 2017 main acoustic survey with 30 successful trawls completed (Figure 5B.2). Table 5B.2 gives the positions, catch composition and mean length by species for these trawl hauls and Table 5B.3 shows positions, catch composition and mean length by species for the further two 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 resulting weight-length relationship for herring was calculated from the sampling information as $W = 0.00243 * L^{3.390}$ (length measured in cm). 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) are presented in Figure 5B.5 The highest abundance of herring was to the southwest 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 number estimate comprises of ~33% age 0, ~7% age 1, ~27% age 2, ~21% age 3, ~7% age 4 and 4% age 5+.

4. DISCUSSION

The herring stock estimate for the Irish Sea commercial survey area was estimated to be 51.489t The major contribution of ages to the total estimates is from ages 0 fish by number and weight. The herring were distributed within a few distinct high abundance areas to the southwest and southeast of the Isle of Man. The bulk of 1+ herring targets in 2017 were observed in the southwestern corner of stratum 7 and southwestern corner of stratum 9. Figure 5B.5, shows a further, fairly scattered, lower abundance observed throughout the remainder of the Irish Sea survey area. (Figure 5B.5. 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 41,683t and biomass estimate of 48,809t for 1+ ringers for 2017 commercial acoustic survey remain within range for the time series. The survey estimates are influenced by the

timing of the spawning migration. The highest proportion of the 1+ biomass estimates was to the east of the Isle of Man (strata 9, 14%), and west of the Isle of Man, (strata 7; 61%) which is unusual and a reflection of a later migration into the Irish Sea.

5 TABLES AND FIGURES

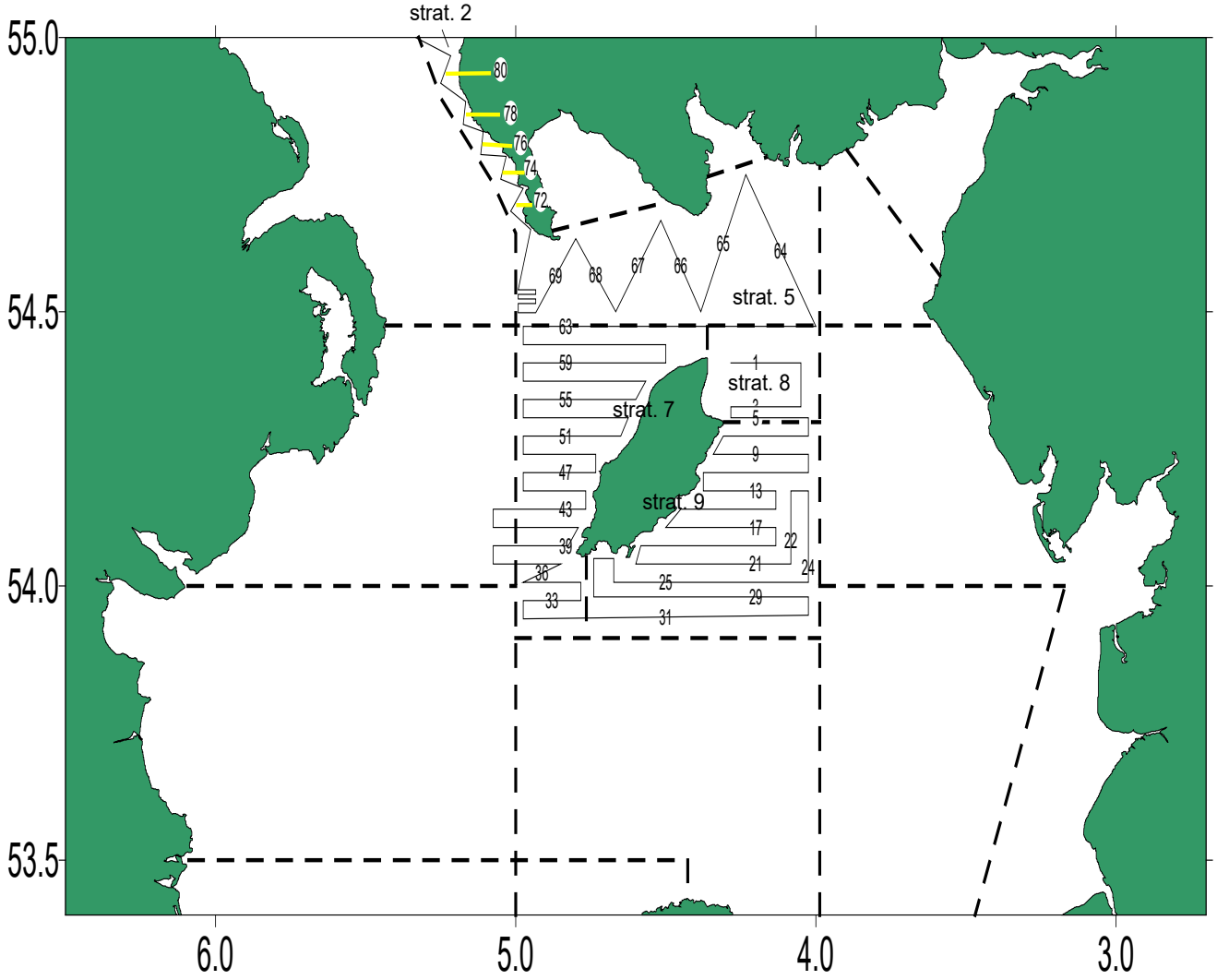


Figure 5B.1: Acoustic survey tracks and stratum boundaries for the 2017 Irish Sea commercialacoustic survey. Survey design of systematic, parallel transects covers approximately 640 nm.

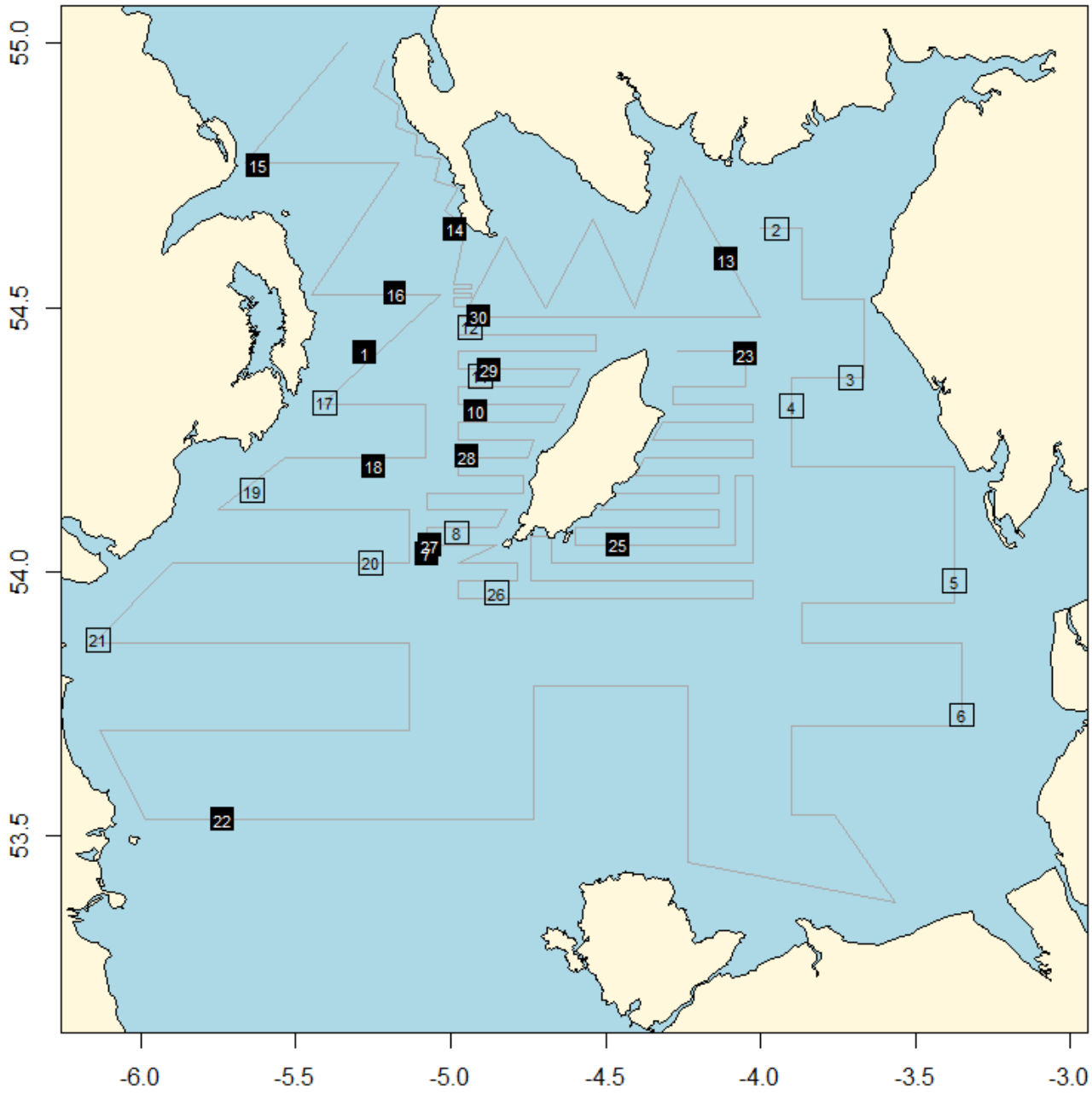


Figure 5B.2 Acoustic survey tracks with trawl positions of the 2017 Irish Sea and North Channel survey on RV "Corystes". Filled squares indicate trawls in which significant numbers of herring were caught or trawls with a high proportion of herring, while open squares indicate trawls with few or no herring.

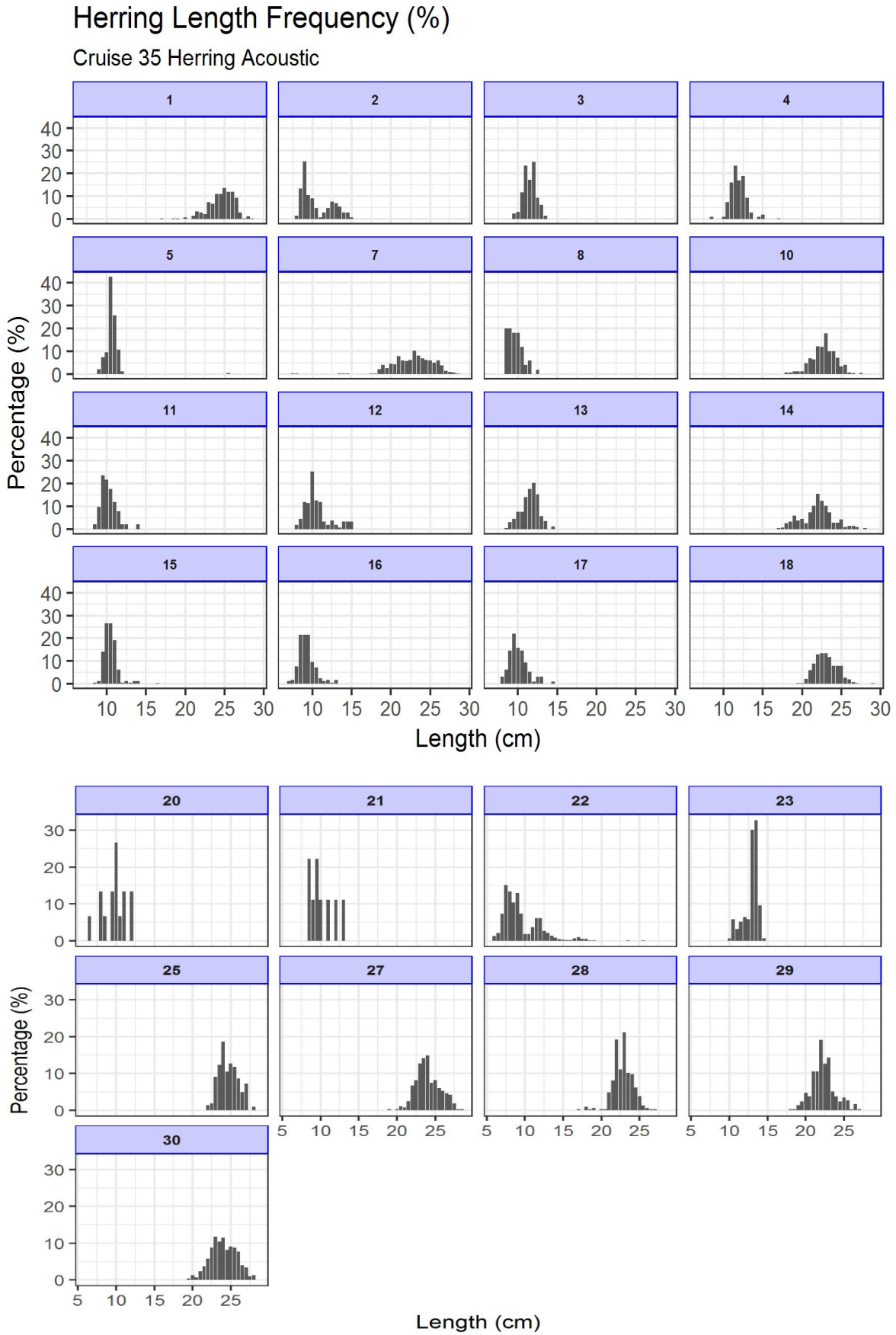


Figure 5B.3: Percentage length compositions of herring in each trawl sample in the September 2017 Irish Sea and North Channel acoustic survey on RV "Corystes".

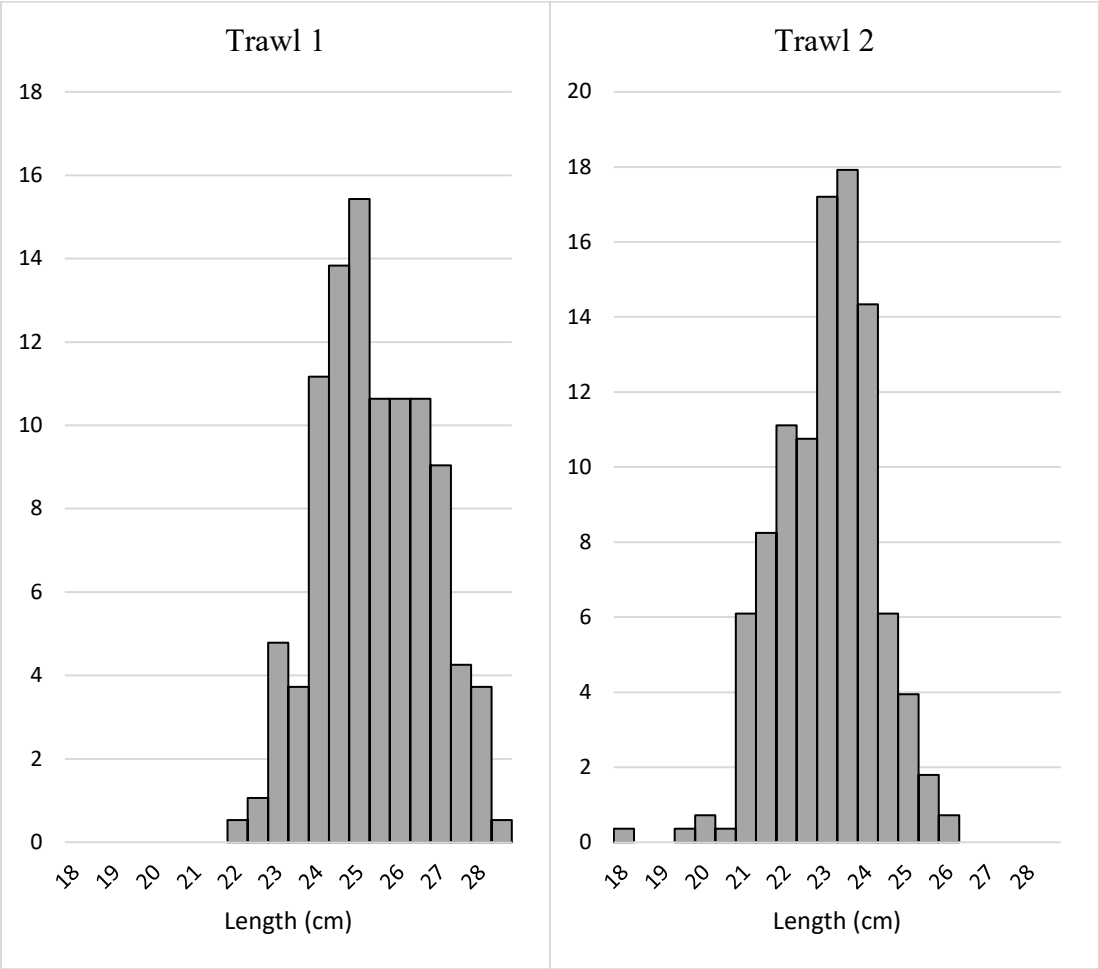


Figure 5B.4: **Percentage length compositions of herring in each trawl sample in the 2017 Irish Sea and North Channel commercial acoustic survey on the FV "Havilah".**

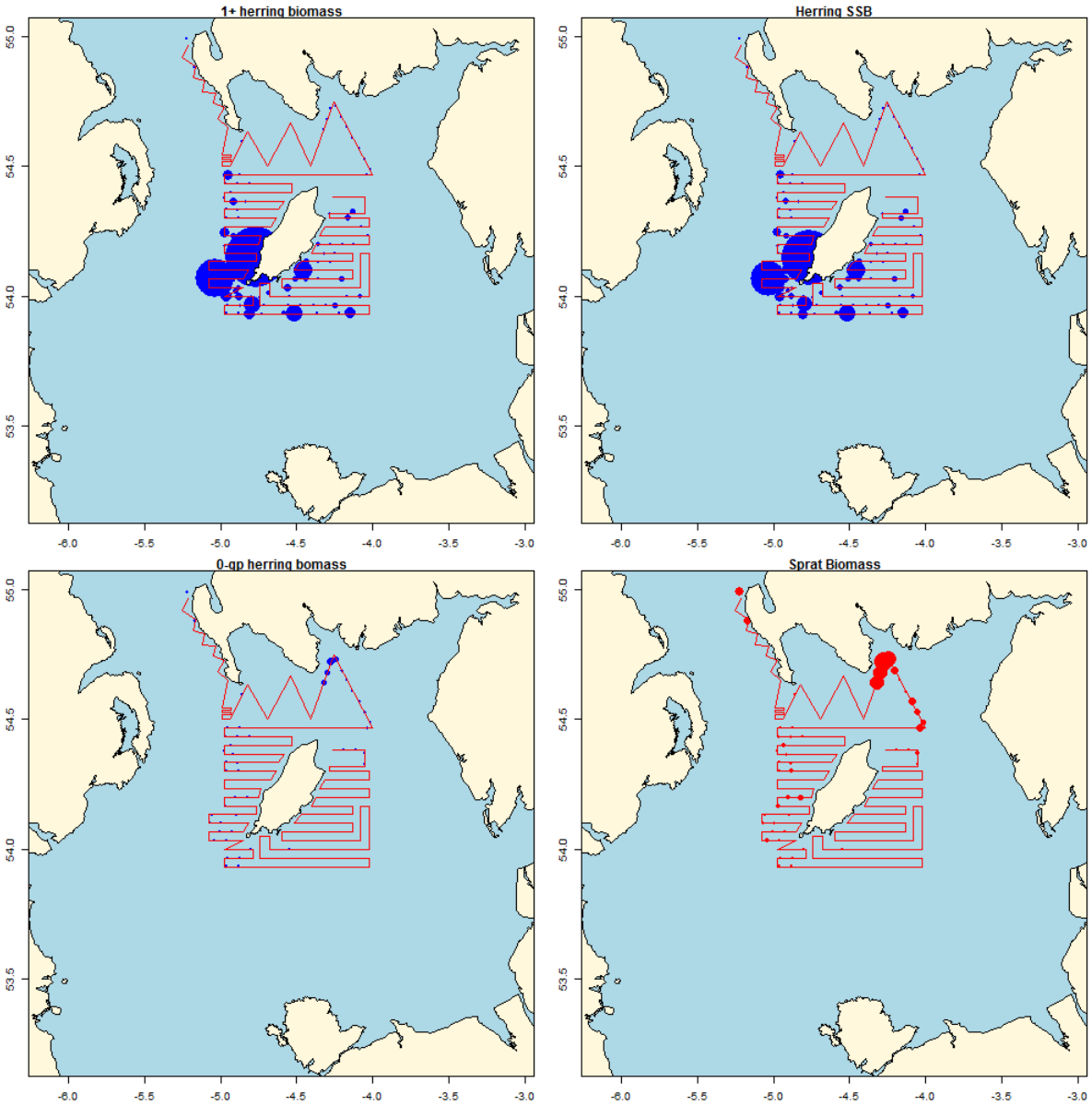


Figure 5B.5: Map of the Irish Sea and North Channel with a post plot showing the distribution of NASC values (size of elipses is proportional to square root of the NASC value per 15-minute interval) obtained during the 2017 commercial acoustic survey on FV "Haviliah". (a) Solid blue circles are for herring 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 2016 and 2017 Irish Sea commercial acoustic survey on FV "Haviliah"

TRANSCEIVER MENU		
Year	2016	2017
Frequency	38 kHz	38 kHz
Sound speed	1503.4.s^{-1}	1508.4m.s^{-1}
Max. Power	2000 W	2000 W
Default Transducer Sv gain	26.90 dB	26.94dB
Athw. Beam Angle	6.98 deg	6.99 deg
Athw. Offset Angle	-0.04 deg	-0.02 deg
Along. Beam Angle	6.98 deg	6.99 deg
Along. Offset Angle	-0.01 deg	-0.02 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 2017.

Tow.	Date.	Shooting details						Total fish catch kg.	percentage composition of fish by weight							Mean length (cm)	
		Time.	Lat.		Long.		Depth (m)		sprat	herring	mackrel	scad	anchove	whiting	other fish	sprat	herring
1	29/08/2017	02:21	54	24.86	5	16.619	66.1		0.00	99.84	0.16	0.00	0.00	0.00	0.00		24.5
2	30/08/2017	07:58	54	38.95	3	56.7928	33		83.52	3.84	10.81	0.00	0.00	0.00	1.83	9.7	12
3	30/08/2017	11:40	54	21.98	3	42.56	26.03		85.44	3.69	10.61	0.00	0.00	0.00	0.26	9.5	11.7
4	30/08/2017	13:35	54	18.85	3	53.888	34.5		88.23	3.89	0.88	0.00	0.00	4.00	3.00	9.1	14
5	30/08/2017	18:18	53	59.00	3	22.431	19.23		81.19	2.33	6.25	0.00	0.97	0.05	9.20	8.2	13.1
6	31/08/2017	11:17	53	43.78	3	21.002	18		98.20	0.00	1.09	0.00	0.00	0.00	0.72	10	
7	02/09/2017	10:29	54	2.09	5	4.4745	73		0.00	96.54	0.00	0.01	0.00	1.10	2.35		22.4
8	02/09/2017	12:10	54	4.48	4	58.912	71.3		93.67	1.89	0.12	0.00	0.00	0.01	4.32	9	
10	02/09/2017	23:26	54	18.26	4	54.994	74.5		0.00	100.00	0.00	0.00	0.00	0.00	0.00		23
11	03/09/2017	04:47	54	22.27	4	54.256	78.09		33.15	4.19	10.75	0.00	0.00	24.46	27.47	9.8	11.4
12	03/09/2017	10:29	54	27.78	4	56.2038	76		88.10	6.48	4.64	0.00	0.00	0.00	0.78	8.8	12.1
13	04/09/2017	08:34	54	35.44	4	6.6713	51.8		36.78	63.20	0.02	0.00	0.00	0.00	0.00	10.4	16.3
14	05/09/2017	00:06	54	38.91	4	59.086	52.2		0.00	78.76	0.61	0.00	0.00	0.00	20.63		23.1
15	05/09/2017	08:13	54	46.14	5	37.3868	60.06		88.28	11.34	0.29	0.00	0.00	0.03	0.06	9.4	12.3
16	05/09/2017	13:47	54	31.58	5	10.732	137		78.46	12.84	4.05	0.00	0.00	0.25	4.39	6.7	10.8
17	05/09/2017	17:16	54	19.21	5	24.42	54.18		92.16	0.79	7.02	0.01	0.00	0.02	0.00	9.2	10.5
18	05/09/2017	21:32	54	11.96	5	14.9993	78.3		0.00	91.22	0.15	0.00	0.00	8.57	0.06		24.3
19	06/09/2017	09:04	54	9.26	5	38.32	30.5		80.20	0.04	16.06	0.00	0.00	0.00	3.70	9.3	9.6
20	06/09/2017	13:09	54	1.09	5	15.404	75.7		96.42	0.38	0.74	0.07	0.00	0.00	2.40	6.7	9.8
21	06/09/2017	17:39	53	52.34	6	8.26	21		27.18	0.23	52.35	0.00	0.00	0.00	20.24	8.5	11.1
22	09/09/2017	16:33	53	31.90	5	44.058	67.69		3.51	81.16	1.09	0.36	0.00	3.40	10.47	6.8	13.4
23	10/09/2017	06:38	54	24.73	4	2.858	30.04		63.02	14.88	5.28	0.00	0.00	0.00	16.83	9.7	12.9
25	11/09/2017	22:38	54	3.05	4	27.4573	33.59		0.00	83.66	16.34	0.00	0.00	0.00	0.00		24.8
26	12/09/2017	15:04	53	57.63	4	51.149	65.44		96.72	0.00	1.19	0.00	0.00	0.00	2.10	12.4	
27	12/09/2017	18:40	54	2.97	5	4.023	57.85		0.00	91.48	0.15	0.00	0.00	7.72	0.63		24.7
28	13/09/2017	05:38	54	13.11	4	56.854	85.44		0.00	99.14	0.13	0.01	0.00	0.37	0.36		22.9
29	13/09/2017	14:34	54	22.91	4	52.484	50		0.00	95.72	4.28	0.00	0.00	0.00	0.00		22.9
30	13/09/2017	22:34	54	29.03	4	54.4816	61.3		0.00	93.61	3.27	0.00	0.00	0.28	2.84		24.7

Table 5B.3: Catch composition and position of hauls undertaken by the FV *Haviliah* during the Irish Sea/North Channel commercial survey, September 2017.

Tow.	Date.	Shooting details						Total fish catch kg.	percentage composition of fish by weight							Mean length (cm)	
		Time.	Lat.		Long.		Depth (m)		sprat	herring	mackrel	scad	anchove	whiting	other fish	sprat	herring
1	25/09/2017	21:33	54	6.050	4	27.290	21	1000	0.00	60.0	0.00	0.00	0.00	0.00	40.0		25
2	26/09/2017	21:53	54	3.900	5	1.315	25	1000	0.00	87.5	12.5	0.00	0.00	0.00	0.00		23.5

Table 5B.4: Preliminary age-length key for herring from which otoliths were removed at sea during the Irish Sea/North Channel survey 2017. 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
6.5	1	0	0	0	0	0	0	0	0	1
7	2	0	0	0	0	0	0	0	0	2
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	4	0	0	0	0	0	0	0	0	4
9	3	0	0	0	0	0	0	0	0	3
9.5	8	0	0	0	0	0	0	0	0	8
10	10	0	0	0	0	0	0	0	0	10
10.5	7	0	0	0	0	0	0	0	0	7
11	5	0	0	0	0	0	0	0	0	5
11.5	6	0	0	0	0	0	0	0	0	6
12	9	0	0	0	0	0	0	0	0	9
12.5	7	0	0	0	0	0	0	0	0	7
13	7	0	0	0	0	0	0	0	0	7
13.5	6	0	0	0	0	0	0	0	0	6
14	4	0	0	0	0	0	0	0	0	4
14.5	3	0	0	0	0	0	0	0	0	3
15	5	0	0	0	0	0	0	0	0	5
15.5	0	1	0	0	0	0	0	0	0	1
16	0	1	0	0	0	0	0	0	0	1
16.5	0	0	0	0	0	0	0	0	0	0
17	0	2	0	0	0	0	0	0	0	2
17.5	0	5	0	0	0	0	0	0	0	5
18	0	5	0	0	0	0	0	0	0	5
18.5	0	5	2	0	0	0	0	0	0	7
19	0	10	0	0	0	0	0	0	0	10
19.5	0	11	3	0	0	0	0	0	0	14
20	0	8	0	0	0	0	0	0	0	8
20.5	0	12	0	2	0	0	0	0	0	14
21	0	9	6	0	0	0	0	0	0	15
21.5	0	9	14	1	0	0	0	0	0	24
22	0	6	13	0	0	0	0	0	0	19
22.5	0	3	8	1	0	0	0	0	0	12
23	0	1	18	1	0	0	0	0	0	20
23.5	0	1	22	16	2	0	0	0	0	41
24	0	0	15	16	1	0	0	0	0	32
24.5	0	0	5	23	3	0	0	0	0	31
25	0	2	6	22	6	1	1	0	0	38
25.5	0	1	2	19	14	1	2	0	0	39
26	0	0	1	8	10	3	4	1	0	27
26.5	0	1	0	2	14	1	3	1	1	23
27	0	0	0	5	5	1	5	1	5	22
27.5	0	0	0	1	6	2	7	1	3	20
28	0	0	0	0	1	2	4	1	5	13
28.5	0	0	0	0	1	1	1	1	4	8
29	0	0	0	0	0	0	0	0	1	1
TOTAL	89	93	115	117	63	12	27	6	19	541

Table 5B.5: Acoustic survey estimates of biomass (t) and numbers ('000) of herring and sprat by survey stratum from the AFBI commercial acoustic surveys in 2017.

STRATUM	NO. SPRAT	BIOMASS SPRAT	NO. HER	BIOMASS HER
2	664225.4	1548.66	37906.57	236.402
3	72317.04	202.5375	106680	11186.52
5	3818274	14755.81	158034.9	2236.057
7	377193.2	1056.401	283397.8	30247.76
8	234725	930.0491	13335.51	516.0915
9	232.7772	0.611562	49089.41	7066.524
Total	5166968	18494.07	648444.2	51489.35

Document 9c: ISCAS 2018 survey summary table

Survey Summary table WGIPS 2019	
Name of the survey (abbreviation):	**Irish Sea Acoustic Spawning Survey (ISASS)**
Target Species:	**Herring**
Survey dates:	**24th September – 27th September 2018**
Summary:	
A commercial chartered fishing vessel departed Belfast at 2100 on the 24th September 2018 and proceeded to the east coast of the Isle of Man for acoustic calibration off Laxey on the 24th August. The survey started on Isle of Man grid on transect 1 on 31st xxxx and continued through to the end of transect 82 on the 27thth.	
	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 (ISAS section??).
Index Calculation method	Weighted mean TS is applied to the NASC value to give numbers per square nautical mile – further decomposed by age class according to length frequencies in relevant target identified trawls and survey age–length key.
Random/systematic error issues	NA
Specific survey error issues (acoustic)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Bubble sweep down	Sea conditions were reasonably good during the survey; A break in the survey was required..
Extinction (shadowing)	No perceived issues
Blind zone	NA
Dead zone	NA
Allocation of backscatter to species	One dediacetd trawl was 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 24th September off Laxey on the east coast of the Isle of Man. Conditions were good and the calibration results

	satisfactory. All procedures were according to those defined in the survey manual.
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. 2018 survey: As in previous years
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. 2018 survey: No additional issues
Measures of uncertainty (CV)	CV of biomass and numbers at age
Biological sampling	2018 Survey: The biological sampling uses biological sampling for the main Irish Sea acoutiscs survey and is deamed 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 2017 are used for initial biomass estimates and population age structure.
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole time-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 9d: ISCAS 2018 survey report

Please see the report on the next page.

ANNEX 5B: Irish Sea acoustic survey (Northern Ireland)

Survey report for RV Corystes

23rd September – 27th September 2018

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

Belfast, Northern Ireland

1. INTRODUCTION

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

2. SURVEY DESCRIPTION & METHODS

2.1 Personnel

Gavin McNeill (SIC)
Peter McCorriston
Keith Erskine
Jamie McFerran

2.2 Narrative

The vessel departed Belfast at 2100 on the 23rd September and proceeded to the east coast of the Isle of Man for acoustic calibration off Laxey on the 24th September. The survey started at the start of transect 1 to the northeast of The Isle of Man on the 24th September proceeding through to the end of transect 81 on the 27th September, with the ship returning to Belfast at 00:00 on the 27th September. Sea conditions were reasonably good during the survey, but particularly poor weather on the 25th September resulted in a temporary cessation of the survey.

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 24th September off Laxey on the east coast of the Isle of Man. Conditions were good and the calibration results satisfactory. All procedures were according to those defined in the survey manual. Summary of calibration results are presented in Table 5B.1.

2.5 Acoustic data collection

Acoustic data 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 2018 survey with 32 successful trawls completed Figure 5B.2. Table 5B.2 gives the positions, catch composition and mean length by species for these trawl hauls and Table 5B.3 shows positions, catch composition and mean length by species for a further haul 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) are presented in Figure 5B.4 and for herring only in Figure 5B.5. The highest abundance of herring was to the east of the Isle of Man and off east coast 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 is 41.7t

4. DISCUSSION

The herring stock estimate for the Irish Sea commercial survey area was estimated to be 67,181t The major contribution of ages to the total estimates is from ages 0 fish by number and weight. The herring were distributed within a few distinct high abundance areas to the southwest and southeast of the Isle of Man. The bulk of 1+ herring targets in 2018 were observed in the southwestern corner of stratum 7 and southwestern corner of stratum 9. 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 49,835t and biomass estimate of 57,387t for 1+ ringers for 2018

commercial acoustic survey remain within range for the time series. The survey estimates are influenced by the timing of the spawning migration.

5 TABLES AND FIGURES

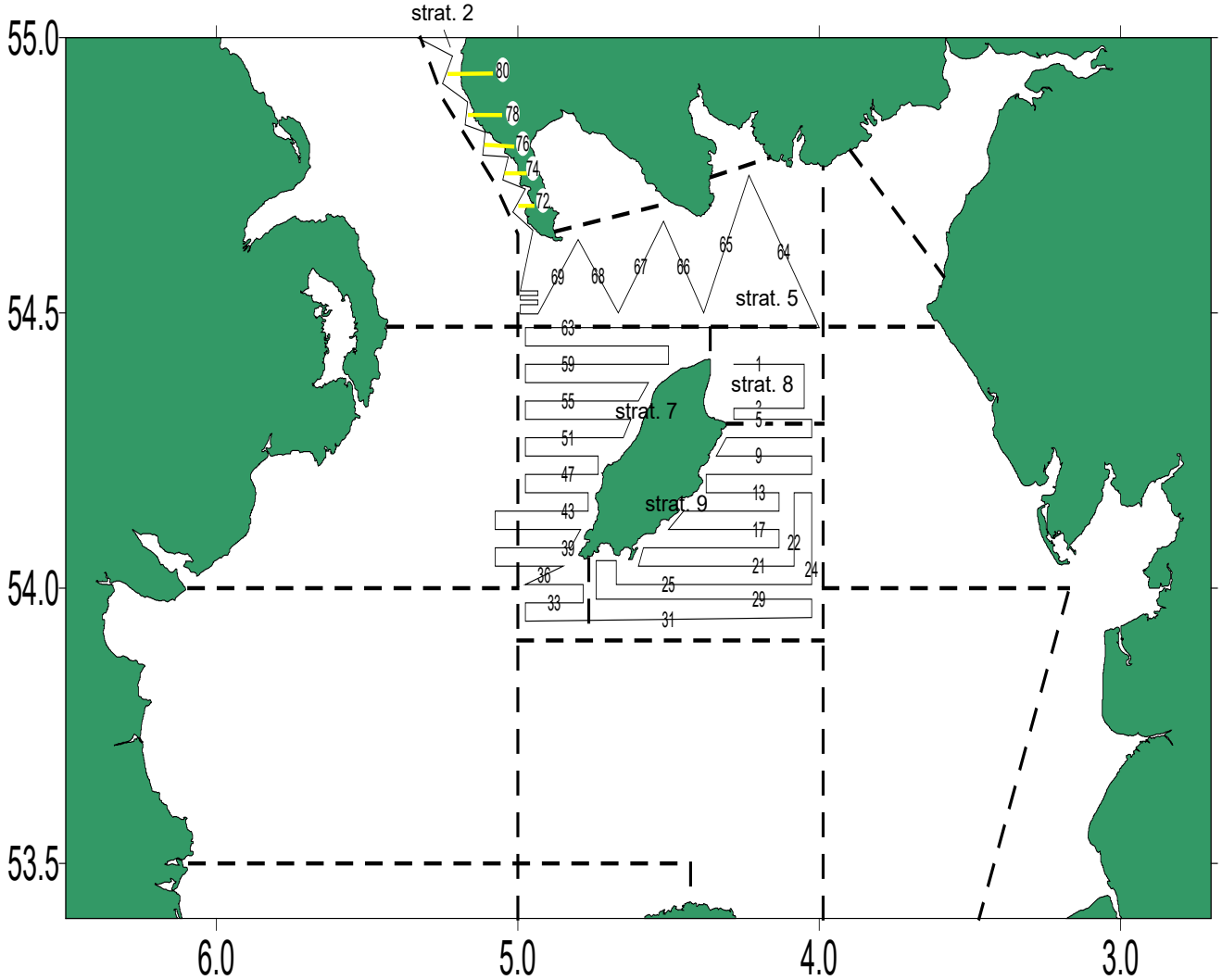


Figure 5B.1: Acoustic survey tracks for the 2018 Irish Sea acoustic survey. Survey design of systematic, parallel transects covers approximately 620

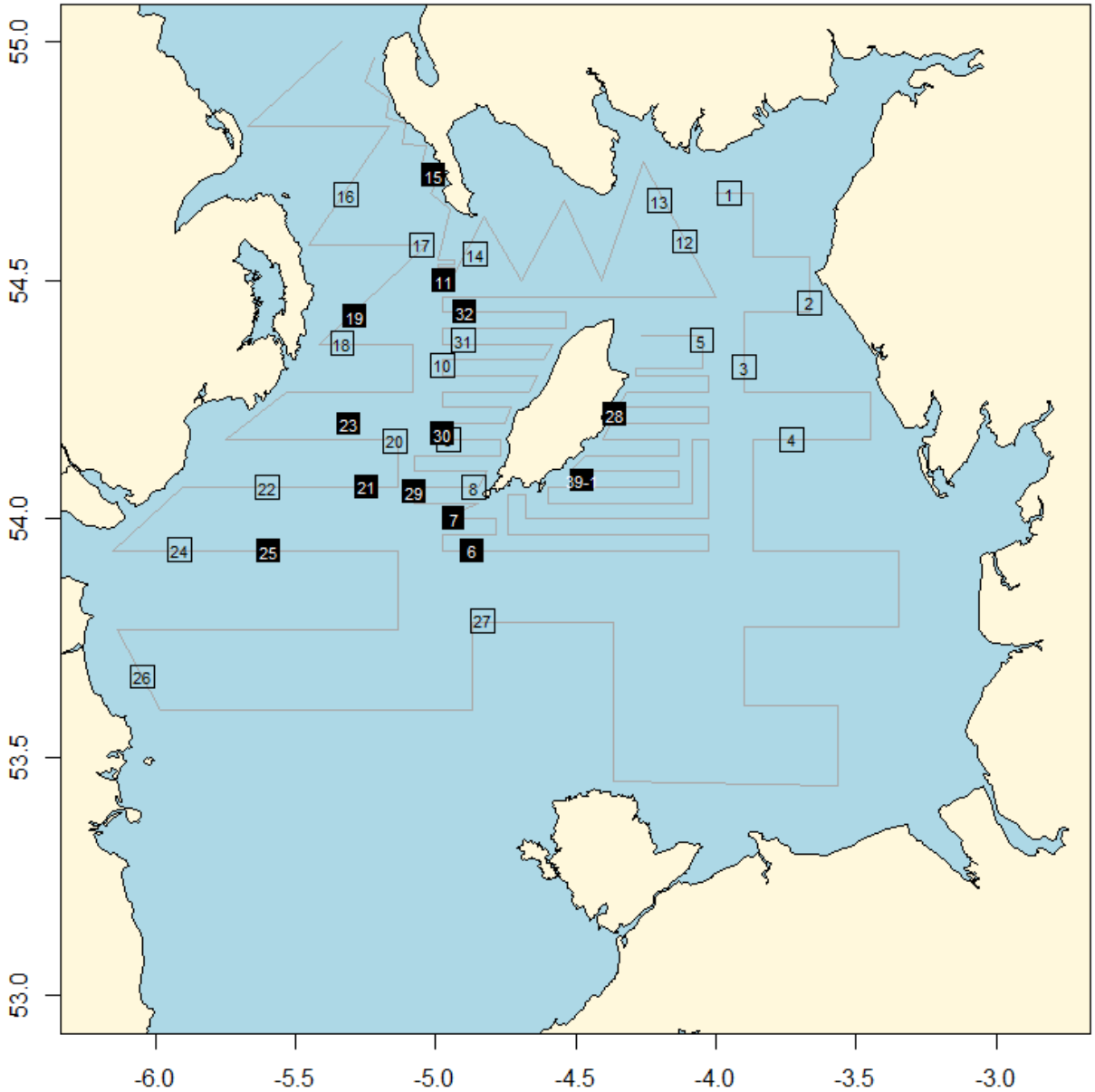


Figure 5B.2 Acoustic survey tracks with trawl positions of the 2018 Irish Sea and North Channel survey on RV "Corystes" and 2018 Irish Sea and North Channel commercial survey on FV "Haviliah" . Filled squares indicate trawls in which significant numbers of herring were caught or trawls with a high proportion of herring, while open squares indicate trawls with few or no herring.

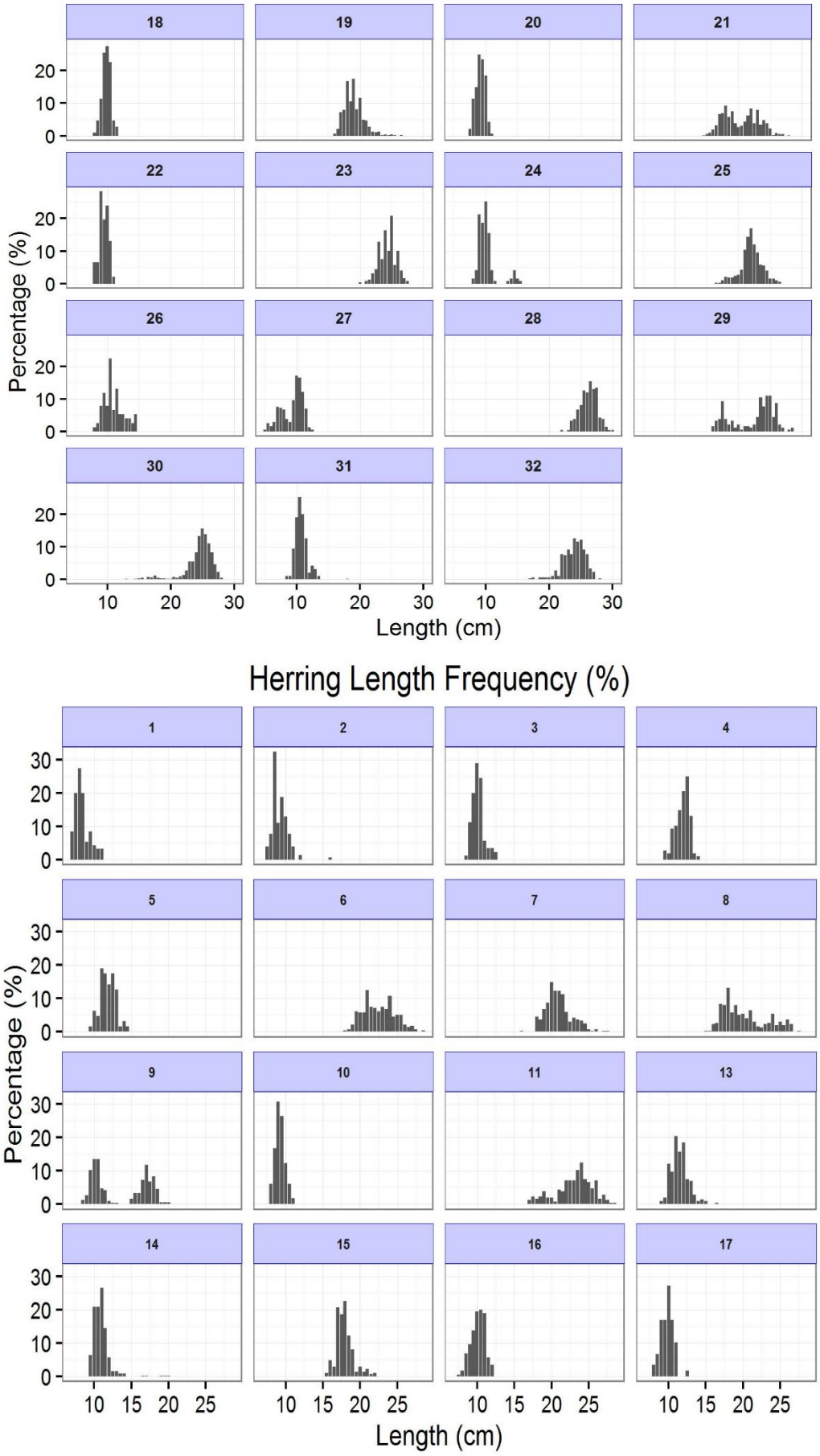


Figure 5B.3: Percentage length compositions of herring in each trawl sample in the September 2018 Irish Sea and North Channel acoustic survey on RV "Corystes".

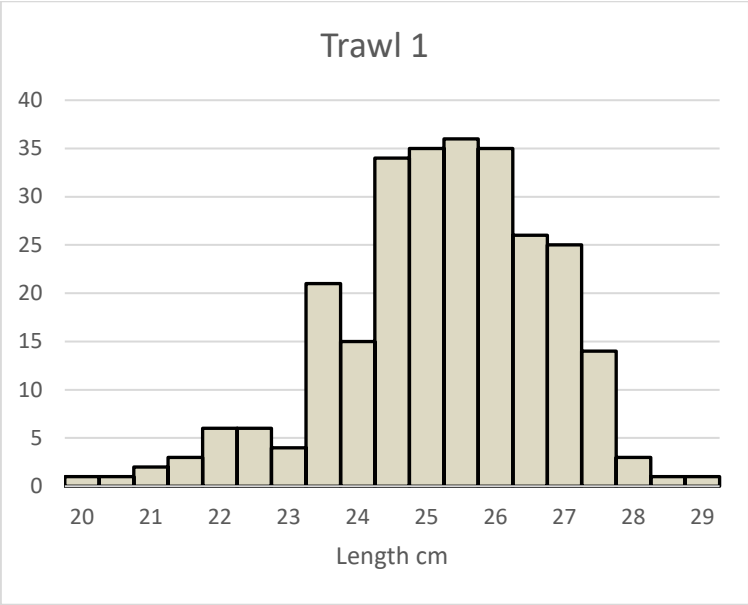


Figure 5B.4: **Percentage length compositions of herring in each trawl sample in the 2018 Irish Sea and North Channel commercial acoustic survey on the FV "Havilah".**

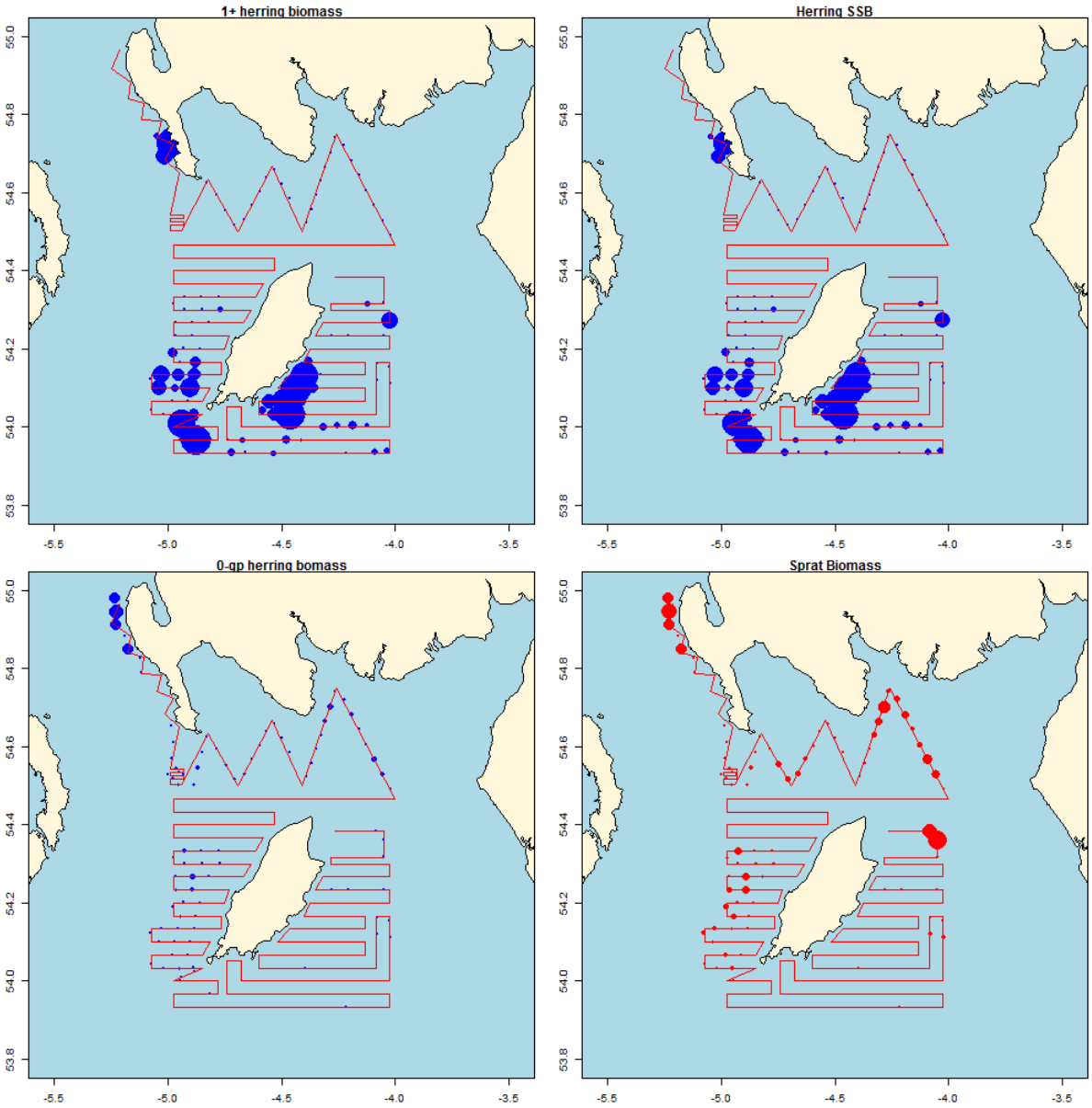


Figure 5B.5: Map of the Irish Sea and North Channel with a post plot showing the distribution of NASC values (size of elipses is proportional to square root of the NASC value per 15-minute interval) obtained during the 2018 commercial acoustic survey on FV "Haviliah". (a) Solid blue circles are for herring 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 2017 and 2018 Irish Sea and North Channel herring acoustic survey on RV "Corystes"

TRANSCEIVER MENU		
Year	2017	2018
Frequency	38 kHz	38 kHz
Sound speed	1508.4m.s^{-1}	1503.4m.s^{-1}
Max. Power	2000 W	2000 W
Default Transducer Sv gain	26.94dB	27.03 dB
Athw. Beam Angle	6.99 deg	6.99 deg
Athw. Offset Angle	-0.02 deg	-0.01 deg
Along. Beam Angle	6.99 deg	6.97 deg
Along. Offset Angle	-0.02 deg	-0.02 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 2018

Tow	Date	Shooting details						Total fish catch kg	percentage composition of fish by weight							Mean length (cm)	
		Time	Lat.		Long.		depth (m)		sprat	herring	mackerel	scad	anchovy	whiting	other fish	sprat	herring
1	29/08/2018	13:50	54	41.0	3	57.1	34.6	18	86.84	12.96	0.16	0.00	0.00	0.03	0.00	6.3	8.6
2	29/08/2018	18:34	54	27.2	3	39.9	18.2	155	81.48	5.97	0.59	0.00	0.10	0.00	11.86	7.2	9.5
3	30/08/2018	06:34	54	19.1	3	54.0	33.5	85	87.57	4.98	0.71	0.00	0.05	0.00	6.69	8.1	10.4
4	30/08/2018	11:10	54	10.1	3	43.5	26	122	82.09	14.83	2.91	0.00	0.00	0.00	0.16	9.1	12.1
5	31/08/2018	18:09	54	22.5	4	3.0	37.5	344	97.90	2.07	0.03	0.00	0.00	0.00	0.00	9.1	12.1
6	01/09/2018	21:19	53	56.0	4	52.1	54	251	0.00	99.69	0.31	0.00	0.00	0.00	0.00		22.3
7	01/09/2018	23:34	54	0.0	4	56.1	43.1	405	0.00	98.71	1.27	0.00	0.00	0.02	0.01		21.2
8	02/09/2018	02:32	54	4.0	4	51.8	41.6	69	2.52	69.99	19.83	0.00	0.00	1.76	5.90	12.9	20.4
9	02/09/2018	07:58	54	10.0	4	57.2	77	40	45.22	45.00	3.71	0.00	0.00	3.61	2.47	10.4	13.8
10	02/09/2018	13:19	54	19.4	4	58.6	108.6	7	73.43	25.55	0.00	0.00	0.00	0.56	0.45	7.7	9.5
11	02/09/2018	23:35	54	29.9	4	58.2	113	700	0.00	60.01	0.00	0.00	0.00	0.00	39.99		23.3
13	03/09/2018	09:50	54	40.0	4	12.0	38	36	68.36	20.94	2.43	0.00	0.00	0.00	8.28	9.2	11.8
14	03/09/2018	17:14	54	33.3	4	51.4	66.2	104	45.08	54.66	0.25	0.00	0.00	0.00	0.00	8.5	11.1
15	03/09/2018	21:20	54	43.2	4	0.5	35	700	0.00	98.51	0.18	0.00	0.00	0.00	1.31		18.2
16	04/09/2018	12:00	54	40.8	5	19.2	133	13	5.03	74.70	20.27	0.00	0.00	0.00	0.00	8.4	10.4
17	04/09/2018	14:32	54	34.5	5	2.9	194	7	90.98	5.40	2.59	0.00	0.00	1.02	0.00	8.2	10.1
18	04/09/2018	17:59	54	22.1	5	20.0	74.2	45	49.15	4 7.87	0.55	0.00	0.00	0.00	2.44	7.8	10.1
19	04/09/2018	23:17	54	25.4	5	17.2	86	82	0.00	100.00	0.00	0.00	0.00	0.00	0.00		19.3
20	05/09/2018	11:40	54	9.8	5	8.6	123	93	69.32	20.64	2.35	0.00	0.00	0.00	7.70	7.8	9.4
21	05/09/2018	13:29	54	4.0	5	14.7	100.7	53	0.00	100.00	0.00	0.00	0.00	0.00	0.00		20.6
22	05/09/2018	15:57	54	4.0	5	36.0	53.8	9	59.39	2.37	2.83	0.00	0.00	0.58	34.83	7.4	9.7
23	05/09/2018	22:02	54	11.9	5	18.4	87	215	0.00	100.00	0.00	0.00	0.00	0.00	0.00		24.6
24	08/09/2018	09:07	53	56.1	5	54.7	39	257	95.99	2.67	0.00	0.00	0.00	0.01	1.33	7.9	10.4
25	08/09/2018	10:20	53	55.9	5	35.8	107	117	0.00	97.88	0.00	0.00	0.00	2.12	0.00		22.2
26	08/09/2018	18:22	53	40.2	6	2.7	22	75	76.86	4.05	10.15	0.00	0.00	0.00	8.94	8.7	11.3
27	09/09/2018	11:10	53	47.2	4	50.0	88	53	15.51	82.21	0.00	0.00	0.00	0.00	2.29	7.4	9.6
28	10/09/2018	22:05	54	13.1	4	21.6	26	588	0.00	98.70	1.24	0.00	0.00	0.00	0.06		26.5
29	11/09/2018	17:02	54	3.4	5	4.4	61	1502	0.00	99.87	0.13	0.00	0.00	0.00	0.00		22.7
30	11/09/2018	22:33	54	10.7	4	58.4	83	184	0.00	50.80	0.00	0.00	0.00	48.53	0.67		24.8
31	12/09/2018	08:21	54	22.5	4	53.9	74	49	0.00	98.91	1.09	0.00	0.00	0.00	0.00		11.1
32	12/09/2018	12:39	54	26.0	4	53.7	63.2	2500	0.00	100.00	0.00	0.00	0.00	0.00	0.00		24.2

Table 5B.3: Catch composition and position of hauls undertaken by the FV Haviliah during the Irish Sea/North Channel commercial survey, September 2018.

Tow.	Date.	Shooting details					Total fish catch kg.	percentage composition of fish by weight							Mean length (cm)	
		Time.	Lat.		Long.		Depth (m)		sprat	herring	mackrel	scad	anchove	whiting	other fish	sprat	herring
1	25/09/2018	01:26	54	4.89	4	28.62	40	600	0	100.00	0.00	0.00	0.00	0.00	0.00	0.00	25.5

Table 5B.4: Preliminary age-length key for herring from which otoliths were removed at sea during the Irish Sea/North Channel survey 2017. 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
6.5	1	0	0	0	0	0	0	0	0	1
7	2	0	0	0	0	0	0	0	0	2
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	4	0	0	0	0	0	0	0	0	4
9	3	0	0	0	0	0	0	0	0	3
9.5	8	0	0	0	0	0	0	0	0	8
10	10	0	0	0	0	0	0	0	0	10
10.5	7	0	0	0	0	0	0	0	0	7
11	5	0	0	0	0	0	0	0	0	5
11.5	6	0	0	0	0	0	0	0	0	6
12	9	0	0	0	0	0	0	0	0	9
12.5	7	0	0	0	0	0	0	0	0	7
13	7	0	0	0	0	0	0	0	0	7
13.5	6	0	0	0	0	0	0	0	0	6
14	4	0	0	0	0	0	0	0	0	4
14.5	3	0	0	0	0	0	0	0	0	3
15	5	0	0	0	0	0	0	0	0	5
15.5	0	1	0	0	0	0	0	0	0	1
16	0	1	0	0	0	0	0	0	0	1
16.5	0	0	0	0	0	0	0	0	0	0
17	0	2	0	0	0	0	0	0	0	2
17.5	0	5	0	0	0	0	0	0	0	5
18	0	5	0	0	0	0	0	0	0	5
18.5	0	5	2	0	0	0	0	0	0	7
19	0	10	0	0	0	0	0	0	0	10
19.5	0	11	3	0	0	0	0	0	0	14
20	0	8	0	0	0	0	0	0	0	8
20.5	0	12	0	2	0	0	0	0	0	14
21	0	9	6	0	0	0	0	0	0	15
21.5	0	9	14	1	0	0	0	0	0	24
22	0	6	13	0	0	0	0	0	0	19
22.5	0	3	8	1	0	0	0	0	0	12
23	0	1	18	1	0	0	0	0	0	20
23.5	0	1	22	16	2	0	0	0	0	41
24	0	0	15	16	1	0	0	0	0	32
24.5	0	0	5	23	3	0	0	0	0	31
25	0	2	6	22	6	1	1	0	0	38
25.5	0	1	2	19	14	1	2	0	0	39
26	0	0	1	8	10	3	4	1	0	27
26.5	0	1	0	2	14	1	3	1	1	23
27	0	0	0	5	5	1	5	1	5	22
27.5	0	0	0	1	6	2	7	1	3	20
28	0	0	0	0	1	2	4	1	5	13
28.5	0	0	0	0	1	1	1	1	4	8
29	0	0	0	0	0	0	0	0	1	1
TOTAL	89	93	115	117	63	12	27	6	19	541

Table 5B.5: Acoustic survey estimates of biomass (t) and numbers ('000) of herring and sprat by survey stratum from the AFBI commercial acoustic surveys in 2018.

STRATUM	NO. SPRAT	BIOMASS SPRAT	NO. HER	BIOMASS HER
2	1739140	5972.305	941034.7	14868.49
3	70506.76	224.0668	29603.72	1978.323
5	1818947	9011.666	410332.2	6915.795
7	746858.1	2373.476	280991	18393.71
8	654594.7	3319.893	9489.658	300.3927
9	83360.55	297.975	172759.2	24724.43
Total	5113407	21199.38	1844210	67181.15

Document 10: CSHAS 2018 survey summary table

Survey Summary table WGIPS 2019	
Name of the survey (abbreviation):	Celtic Sea Herring Acoustic Survey (CSHAS) 2018
Target Species:	Herring, Sprat
Survey dates:	8 – 28 October, 2018
Summary:	**Cruise Report Link:** http://hdl.handle.net/10793/1385

The objectives of the survey were carried out successfully and as planned. Approximately 48 hours was lost due to weather but the survey area was covered nonetheless. The broad scale survey used a laddered approach generating 2 independent estimates for the wider area. High intensity adaptive surveys were carried close inshore and on historic offshore abundance areas. The stock was considered contained within the survey area. Mature fish were encountered in low to medium abundance in inshore waters and no offshore aggregations were observed indicating the migratory component of the stock had yet to aggregate. 0-group herring were found distributed over the entire survey area in small numbers, indicating the potential of an emerging year class in a period of prolonged poor recruitment, and low standing stock biomass.

Broad scale surveys yielded relatively low herring biomass (Pass 1: 9,788 t and Pass 2: 2,008 t) with fish distributed primarily in inshore coastal waters. Of the total standing stock biomass 20.7% was composed of immature fish relating to 57% of total abundance. Dominant age classes within the stock were 3, 1 and 2 winter rings respectively and are somewhat comparable with the co-occurring fishery.

Standing stock within the survey time-series remains at low levels.

	Description
Survey design	Stratified systematic parallel design (8 nmi spacing) with randomized start point for broad scale replicate surveys. High intensity stratified adaptive surveys (1 nmi spacing) on highly localized offshore aggregations.
Index Calculation method	StoX (via the ICES database)
Random/systematic error issues	Stock aggregated in localized inshore area that was also the focus of high intensity fishing effort. This has the effect of dispersing schools making accurate acoustic measurement difficult. This is more pronounced due to the current low standing stock biomass at this time.
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)	ADZ presented more of an issue for the adaptive surveys
Blind zone	NA

Dead zone	High intensity surveys carried out on herring aggregations within <0.5m of the seabed and in the ADZ
Allocation of backscatter to species	Directed trawling for verification purposes
Target strength	Recommended values for target species
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	No schools observed on the survey periphery
Stock ID and mixing issues	Non- identified
Measures of uncertainty (CV)	0.49 (herring)
Biological sampling	Sampling was carried out on schools as and when they were encountered and was concentrated (for herring) close inshore where the co-occuring fishery was foucsed. This area was composed of schools of juvenile and migratory components of the stock. Sampling was considered representative for the schools encountered. Sprat samples were more numerous and widely distributed.
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole time-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 11a: WESPAS 2018 survey summary table

Survey Summary table WGIPS 2019	
Name of the survey (abbreviation):	WESPAS / MSHAS (IRL)

Target Species:	Herring (C Sea, Malin Shelf), boarfish, horse mackerel
Survey dates:	10 June – 24 July, 2019

Summary: **Cruise Report Link:** http://hdl.handle.net/10793/1380

The objectives of the survey were carried out successfully and as planned. The objectives of the survey were carried out successfully and as planned. Good weather conditions dominated during the survey allowing for extended marine mammal and seabird survey effort. No weather induced downtime was recorded. Comprehensive trawling was carried out over the course of the survey (n=42) providing good confidence in school recognition and supporting biological data for age stratified abundance estimation of target species (herring, boarfish, horse mackerel).

Herring were distributed further south in 2018 compared to 2017, with some herring south of 56°N, particularly young fish (1- and 2-wr). There was very little herring distributed south of 56°N in both 2016 and 2017. Malin Shelf herring biomass was ~18% higher in 2018 compared to 2017. The distribution of boarfish was comparable to 2017 and earlier years in the time-series with the exception of the northern region. The northern distribution of the stock was observed to extend almost continuously, albeit it in low abundance, northward of 59°N north. Cohort tracking was poor and likely due to the application of an age length key to assign ages to biological samples as opposed to actual survey ages. Horse mackerel were distributed in comparable regions along the Irish west coast, Porcupine Bank and Celtic Sea. Geographical distribution was thus comparable to previous surveys but the number and acoustic density of aggregations was lower than in 2017, but more comparable to 2016, in this as yet short time-series.

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 (15 & 7.5 nmi spacing) with randomized start point. Adaptive surveying was used in areas of interest, namely focusing on herring in the Celtic Sea. Survey design followed methods as laid out in SISP #9
Index Calculation method	StoX (via the ICES database)
Random/systematic error issues	NA, outside of those already described in literature for standardized 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. Transducer positioned at 8.8m (drop keel)
Extinction (shadowing)	No particular issues as target schools primarily located in the lower water column and low to medium relief bathymetry in the main. Towards the shelf edge issues are thought to be small but relevant
Blind zone	Near-surface schools were within the tolerances of echo-integration thresholds (12m)
Dead zone	Possibility of issue with species tight on the seabed, namely horse mackerel and Celtic Sea herring.
Allocation of backscatter to species	Directed trawling for verification an species composition purposes. Multifrequency analysis

Target strength	Recommended values for target species from literature
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	Herring (C. Sea) – not confirmed, low stock biomass Herring (M Shelf) – (see HERAS summary sheet) Boarfish – No (doesn't include Channel or Bay of Biscay) W horse mackerel – No (doesn't include Channel or Bay of Biscay)
Stock ID and mixing issues	Herring (C. Sea) – not resolved Herring (M Shelf) – See HERAS summary sheet Boarfish – No W horse mackerel – No
Measures of uncertainty (CV)	Herring (C. Sea) – 0.74 (experimental, non-assesment index) Herring (M Shelf) – 0.28 (Irish effort only, see HERAS summary sheet) Boarfish – 0.20 W horse mackerel – 0.37
Biological sampling	Sampling levels for HOM & BOC was considered representative and well distributed across strata, in line with previous years. M. Shelf sampling was considered representative as part of the wider HERAS survey effort. For C Sea herring sampling effort was poor and representative of the low abundance of schools encountered. Few schools equals few samples.
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole time-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 11b: WESPAS 2018 survey report

Please see the report on the next page.

FSS Survey Series: 2018/03

Western European Shelf Pelagic Acoustic Survey (WESPAS)

10 June – 24 July, 2018

Ciaran O'Donnell[1], Michael O'Malley[1], Deirdre Lynch[1], Eugene Mullins[1], Niall Keogh[2*], John Power[3*], Aidan Long[4*], Peter Croot[4*]

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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 54°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 and since then have been carried out onboard the RV *Celtic Explorer* over a 42 day period providing synoptic coverage of shelf waters from 47°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 2018. 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 2019.

2 Materials and Methods

2.1 Scientific Personnel

Leg	CE180609	CE180610
Dates	09-28 June	04-24 July
Days	20	22
Start	Galway	Galway
End	Galway	Galway
Acou (Chief Sci)	Ciaran O'Donnell	Michael O'Malley
Acou	Turlough Smith	Brendan O'Hea
Acou	Deirdre Lynch	Eugene Mullins
Acou	David Tully	Tobi Rapp
Bio (Deck Sci)	Marcin Blaszkowski	Ian Murphy
Bio	Seán McLaughlin	Sean O'Connor
Bio	Hannah Keogh	Artur Opanowski
Bio	Michael Kineen	John Power
MMO	John Power	Catherine O'Sullivan
SBO	John Collins	Ashley Johnston
SBO	Dannielle Crowley	Sally O'Meara
Zoo/Saps	Aidan Long	Aidan Long
Zoo/Saps	Leigh Barnwal	Stephanie Linehan
CDOM –	Catherine Jordan	Monica Mullins
CDOM –	Mark Dwyer	John Phelan
CDOM –	Kevin McGookin	-

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 multi 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 target stocks
- Take morphometric and genetic samples of individual herring in 6a/7b,c for stock identification analysis
- Use vertical CTD casts to determine hydrographic conditions and the extent of shelf frontal 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 (ESAS) and surface litter.
- Use multi-beam echosounders (EM2040) collect data on the aggregation morphology and behaviour of small pelagics
- Visual survey for to determine the abundance and distribution of jellyfish. Combined with analysis of trawl and plankton net caught individuals.
- Analysis of water samples to determine the composition and spatial distribution of pico- and nano- plankton populations, bacteria and CDOM
- Determine a survey plan to be conducted by unmanned surface vessel (USV) collecting acoustic density measurements within a pre-defined area. Carry out an acoustic inter-calibration exercise with the USV for data comparison purposes.

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 and 2011).

The survey area was stratified based on acoustic sampling effort strata and geographical stock boundaries. Transect start points were randomised within each stratum. Transect spacing was set at 15nmi (nautical miles) in open water areas and zigzag transects in the restricted Minch area. High intensity small scale surveys were carried out in specific areas of interest with a transect spacing of between 5-10nmi. Coverage extended from the 50 m contour to the shelf slope (250 m). An elementary distance sampling unit (EDSU) of 1nmi was used during the analysis of acoustic data during the main body of the survey area. In total the planned survey covered 5,096nmi using 66 transects relating to a total area coverage of 61,284nmi^2.

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 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 Dunmanus Bay on June 11th at the start of the survey. A calibration was also conducted in Killary Harbour on July 22nd at the end of the survey. Calibration procedures followed methods laid out in Demer *et al.* (2015). The results of the calibration (38 kHz transducer) 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 were based on established settings employed by FEAS on previous surveys (O'Donnell *et al.,* 2004).

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 8.8 m 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. 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. Myriax Echoview® Echolog (Version 8) 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 strata. 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 8) 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 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 using Target Strength (TS) to provide a species specific NASC value. This process was conducted within the StoX program.

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 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 Fassler 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 software package recently adopted for WGIPS coordinated surveys (ICES 2016). A description of StoX can be found here: http://www.imr.no/forskning/prosjekter/stox/nb-no. 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 24). 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 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 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 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 1m from the bottom to be taken in areas of clean ground.

2.4.1 Herring stock identification

When possible, a sample of 120 herring (>23cm) are taken for morphometric and genetic analysis from herring in the Malin Shelf area (6a/7b, c). These fish are processed according to SGHERWAY procedures (ICES 2010).

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 typically 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. These data are processed according to GO-SHIP guidelines and incorporated into ODV files for the continuous downcast data and the discrete bottle data collected during the up cast.

Raw seawater samples were drawn from Niskin bottles mounted (n=21) on the ships CTD system. Typically six depths from just below the surface to 10 m above the maximum bathymetry depth were sampled. Raw samples were collected from the Niskin bottles into 1 ltr brown LDPE bottles. Sub samples were then obtained from the LDPEs.

2.5.2 CDOM measurements

Samples for the analysis of Colour Dissolved Organic Matter (CDOM) absorption were collected from the CTD cast directly from the Niskin bottles. They were then immediately filtered through a 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.

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 fluorphore components in seawater which can be used to identify sources of FDOM from terrestrial or marine processes.

2.5.3 Nutrient sampling

Seawater samples are collected from the CTD and immediately filtered through 0.2 µm syringe filters. The filtrate is then frozen at -20 ℃ until analysis in the laboratory. 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 (García-Robledo et al., 2014; Koroleff, 1976; Murphy and Riley, 1962; Schnetger and Lehners, 2014).

2.5.4 Bacteria, Heterotrophic nanoflagellates, Pico and nanoplankton abundance

An Accuri C6 flow cytometer was used to analyse raw and treated seawater samples to determine the presence and abundance of a number of species of micro planktonic organisms. This instrument employs a combination of the fluorescence and light scattering characteristics of the organisms present to identify and count the populations of the distinct species in each sample. Unfiltered seawater samples collected directly from the CTD are run on an Accuri C6 flow cytometer while at sea according to established protocols (Marie et al., 1997; Marie et al., 2014). An untreated raw sample is used 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).

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 Fiber 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 pathlength 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

Water samples from Niskin bottles collected at near surface (5-6m depth) were filtered. Filtered samples were labelled and frozen for analysis in the laboratory after the survey.

2.6 Zooplankton and jellyfish sampling

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 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.

Single tow stations samples were split in 50:50 for wet and dry processing. Sample splitting was carried out using a plankton 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. For replicate stations one sample was fixed in its entirety and the second was processed for dry weight.

Dry processing was carried out with each sample filtered through 2000 µm, 1000 µm and 125 µm sieves. For the largest gauge sample (2000 µm) including jellyfish and or krill volume displacement (ml) was measured using a graduated cylinder. For finer gauge samples (1000 and 125 µm) dry weight analysis was carried out. Samples were transferred to petri-dishes and dried onboard (70 ℃ 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 +/- 0.00016g).

2.6.2 Jellyfish

Jellyfish samples recovered from the directed zooplankton vertical trawls were separated from the dry weight and fixed component samples for further analysis. Once recovered, the cod end was washed into a 30 L bucket. Considering the rapid degradation and underrepresentation of many ctenophore species in fixed samples, those that were visible to the naked eye were enumerated and recorded separately by passing fresh zooplankton samples through a 180 µm sieve. The sample was then fixed in 4% formalin solution for further analysis in a laboratory on land. In total, 86 ring net stations were successfully deployed along the cruise track line (Figure 12).

A multinet (type midi) was deployed opportunistically to sample plankton in different depth strata during the survey. The sampling equipment has a computer-controlled opening and closing mechanism and electronic flow meters. An integrated pressure sensor allows constant supervision of the operating depth which is indicated at the display of the deck command unit. The multinet had a 300 µm net mesh size and a net opening of 50 cm. For each station, the water column was broken into 5 vertical depth strata and sampled via an oblique tow. Sampling lasted approximately 7 minutes per stratum and a minimum water volume of 100 m^3 was filtered. Changes were made to the depth strata depending on the depth position of the migrating plankton layer at any one time, ensuring a single net bag filtered the diurnal plankton layer. The contents of the cod end buckets (x5) were placed in labelled 500 ml containers and fixed in 4% buffered formalin for taxonomic identification and enumeration back at the laboratory. Four multinet stations were undertaken. To evaluate the whether acoustic survey techniques can quantify abundances of gelatinous zooplankton in discrete depth strata, the multinet data will be compared with the single beam and multi-beam data that was collected during the multinet deployments.

By-caught gelatinous fauna collected in the pelagic survey trawl (Figure 24) were also recorded, weighed, measured and discarded after each haul. As the fishing was targeted and involved variable subsampling of catches, only qualitative data could be attained for gelatinous species using this large net. A total of 21 pelagic net hauls contained jellyfish taxa.

To quantify surface abundances of large jellyfish, surface counts of jellyfish from the bow of the Celtic Explorer were made during transits between sampling stations Ob-

servations were made from an elevated position from the bow of the ship, during day light hours (07:00–21:00 h). Jellyfish were identified to species level, and their numbers estimated per 5-min intervals using the following categories: 0, 1–10, 11–50, 51–100, 101–500, and >500 (jellyfish abundance estimates of much greater than 500 are impractical). Sample periods were 15 min long with 5 min breaks between successive samples. After three successive sample periods a 20 min break is taken, and after every 3–4 h a 1-h rest period is taken. Nearly 80 hours of visual surveys (933 surveys) were carried out over the duration of the research cruise.

2.7 Marine mammal and seabird surveys

2.7.1 Marine mammal abundance and distribution

The cetacean survey was conducted using a team of two marine mammal observers (MMOs), with one cetacean observer deployed per survey leg. To prevent MMO fatigue and optimise the validity of the data, survey effort was carried out in two-hour shifts, with a break of one hour between shifts.

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 17.45m above sea level during all daylight hours, when weather conditions permitted. During periods of unfavourable weather conditions, observations were carried out from the bridge (10.63m 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 100-400mm 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 IFAW Logger 2000™ (IFAW, 2000) data collection software package 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 10 seconds.

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 Logger and saved in the Access database.

The distance of each sighting from the ship was estimated using a fixed interval range finder, 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 ceta-

ceans was also recorded on the time stamped Logger 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

Surveys of seabirds at sea were conducted from the RV *Celtic Explorer* across 18 days between 10th and 27th June during Leg 1 and 19 days between 4th and 23rd July 2018 during Leg 2. While on transect, the ship travelled at an average speed of 10 knots, except when increased swell prohibited this. A standardised 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.

A single observer surveyed while the ship was travelling along transect lines during daylight hours, between 06:00 and 21:00 each day. Surveying ceased when the ship broke track (e.g. during fishing tows) or when stopped (e.g. during the deployment of the CTD and plankton nets). Environmental conditions, including wind force and direction, sea state, swell height, visibility, precipitation and cloud cover as well as the ship's speed and heading were noted at the start of each survey period and when significant changes occurred thereafter. No surveys were conducted out on deck in conditions greater than sea state six, when high swell made working on deck unsafe. During such periods of inclement weather or heavy seas, surveying was conducted from inside the bridge. Survey effort was also stopped when visibility was reduced to less than 300m due to heavy rain or sea fog.

The seabird observation platform varied between the bridge deck and the monkey island, which are 10m and 12m above the waterline respectively and provide a good view of the survey area. The monkey island was used during periods of calm weather while the bridge deck was utilised during windier conditions as more shelter was afforded there. The survey area was defined as a 300m wide band operated on one side (in a 90˚ arc from the bow) and 300m ahead of the ship. This survey band was subdivided (A = 0-50m from the ship, B = 50-100m, C = 100-200m, D = 200-300m, E = >300m) to subsequently allow correction of species differences in detection probability with distance from the observer. A fixed-interval range finder (Heinemann 1981) was used to check distance estimates for birds sitting on the water or those flying birds which were recorded during 'snapshot' counts. The area was scanned by eye, with binoculars used only to confirm species identification or count the number of birds present in a flock. All birds seen within the survey area were counted, and those recorded sitting on the water in survey bands A to D noted as 'in transect'. All flying birds within the survey area were also noted, but only those recorded during a 'snapshot' were regarded as 'in transect'. This method avoids overestimating bird numbers in flight (Tasker et al. 1984). The frequency of the snapshot scan was ship-speed dependent, such that they were timed to occur when the ship passed from one survey area to the next (every 300m). Any bird recorded within the survey area that was regarded as being associated with the survey vessel was noted as such (to be excluded from abun-

dance and density calculations). Survey time intervals were set at one minute. Additional bird species observed outside the survey area or ad hoc counts of birds not occurring in the survey area were also recorded and added to the database for the research cruise, but are not included in abundance or density analysis.

During the 2018 survey, a series of point counts were made of seabirds associating with the vessel during fishing operations. These began as soon as the towed net began to appear near the surface of the water and finished once the fishing operation was complete, with the net back on board and any surplus fish cleared from the deck. Details such as date, time, location and details of the haul (gross tonnage, species present etc.) were noted for each of these point counts.

In this report, we present the daily total count data for each species along with the daily survey effort. It is envisaged that this data will be analysed such that seabird abundance (birds per km travelled), and seabird density (birds per km^2) will be mapped per ¼ ICES square (15˚ latitude x 30˚ longitude), allowing comparison to the results of previous seabird surveys in Irish waters (e.g. Hall et al. in press, Mackey et al. 2004, Pollock et al. 1997). Through further analysis, species-specific correction factors will be applied to birds observed on the water.

The binomial species names for the birds recorded are presented in the results section, for which taxonomy and nomenclature follows that of the Irish Rare Birds Committee (2015).

3 Results

3.1 Malin Shelf herring (6aS, 7b, c and 6aN south of 58°30'N)

3.1.1 Biomass and abundance

Herring	Abund ('000)	Biomass (t)
Total stock (TSB)	1,698,261	183,186
Spawning stock (SSB)	750,614	129,740

The Malin Shelf Herring total stock biomass (TSB) was 183,186 t and total stock numbers (TSN) was 1,698,261,000 (Table 3). The spawning stock biomass (SSB) was 129,740 t and spawning stock numbers (SSN) was 750,614,000. The CV for the survey was 0.28.

The Malin Shelf survey area was divided into 6 strata representing a total area coverage of 29,847 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 Figures 3 & 4. The Malin Shelf survey time series is provided in Table 4.

3.1.2 Stock distribution

A total of 42 trawl hauls were carried out during the survey (Figure 1), with 4 hauls containing >50% herring by weight of catch within the Malin Shelf survey area (Table 2). A total of 228 echotraces were assigned to herring as compared to 161 in 2017.

Herring were distributed in five out of the six strata (Figure 2). There were no herring allocated to echotraces in the NW Coast Strata. A total of 117 EDSUs (1nmi. long) contained herring in the Malin Shelf survey area. This included a small number of high NASC value EDSUs, with areas of high density occurring to the southwest of St. Kilda and the southern Stanton Banks area (Figure 3). The area covered by the RV Celtic Explorer was similar to the 2017 survey. The area of 6aN to the north of 58°30'N was again covered by RV Scotia in 2018; the overall estimate of the survey for the stock assessment of herring in 6a will therefore be complete when both surveys are combined during WGIPS 2019. Herring were found further south than in 2017, with the distribution south of the 56 ˚N more similar to the historical distribution of herring found during this time series. Herring schools were predominantly located in pillars in close proximity to the seabed (Figure 11f and 11h), but there was evidence of 1-wr herring displaying more midwater behaviour (Figure 11g). Overall the stock was distributed throughout a slightly larger area compared to 2017 (Figure 3). Particularly encouraging was the distribution of 1- and 2-wr fish in the N Malin strata (South Stanton Bank). The seasonal distribution of herring during the survey period is most commonly 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 2018 largely followed these norms, with the added distribution of 0-group herring found in the Minch strata area (Figure 11j).

3.1.3 Stock composition

A total of 681 herring were aged from survey samples with 3,231 length measurements and 782 length-weights recorded. Herring age samples ranged from 0-11 year olds (Table 3 & Figure 4). A further 360 herring were processed for morphometric and genetic analysis under SGHERWAY protocols (ICES 2010) in 2018; from hauls 35, 37 and 39. Genetic samples were taken from herring in haul #32, these fish were mainly <23cm, therefore SGHERWAY morphometric samples were not taken from this haul.

4-wr herring dominated the 2018 survey estimate representing around 30% of TSB and 22% of TSN (Table 3). 2-wr herring were ranked second representing 19% of TSB and 24% of TSN. The third most dominate age group was 5-wr herring contributing 14% to the TSB and 10% to TSN. Combined these three age classes represented 63% of TSB and 55% of TSN.

Maturity analysis of herring samples indicated overall 71% of fish were mature. In 2017, 99% of fish were mature. Maturity analysis by age class showed that 23% of 2 year old fish, 85% of 3 year old fish, and 97% of 4 year olds were mature, rising to 100% of fish of 6-wr and older (Table 3).

3.2 Boarfish

3.2.1 Biomass and abundance

Boarfish	Abund ('000)	Biomass (t)
TSB estimate	3,221,110	186,252
SSB estimate	3,041,284	184,235

Boarfish TSB (total stock biomass) and abundance (TSN) estimates were 186,252 t and 3,221,110,000 individuals (CV 19.9 %) respectively.

The boarfish survey area was divided into 6 strata representing a total area coverage of 56,403 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 42 trawl hauls were carried out during the survey (Figure 1), with 15 hauls containing >50% boarfish (Table 2).

A total of 817 echotraces were assigned to boarfish as compared to 394 in 2017. Boarfish were observed in all survey strata (Table 7). The highest occurrence was in the Celtic Sea where over 42% of the total survey biomass was observed. Within the Celtic Sea the highest density of fish was observed in the southern survey area, south of 50°N and characterised by an area containing a high density of schools (Figure 9a). This pattern of distribution is similar to previous years (Figure 5). The west coast stratum contained the second largest biomass of 27% and again followed the previously

observed pattern of abundance. The shelf area between 53-54°N including the porcupine Bank was an area of high abundance. Interestingly the southwest (between 51-52°N) saw fewer schools than in previous years. The distribution of boarfish to the northwest and north of Ireland was mainly restricted to the shelf edge (<180m). This year for the first time boarfish aggregations were observed during the Scottish summer herring survey extending the latitudinal range to north of 59°N (Steven O'Connell *Pers communication)*. Previously boarfish have not been observed during this survey further north than 57°30N.

3.2.3 Stock composition

A total of 945 boarfish were aged from survey samples in addition to 4,807 length measurements and 2,234 length-weights recorded. Boarfish age samples ranged from 1-15+ years (Table 6 & Figure 6). Age structure of the stock was determined using an established age length key.

The 10 year age class dominates the 2018 estimate contributing over 20.4% of TSB and 19.4% of TSN (Table 6). The 11 group and 15+ year age class ranked second and third respectively representing over 12.9% of TSB and 9.3 and 10.5% of TSN each to the overall biomass. The fourth ranked group was the 12 year olds 10.8% to the TSB and 8.2% to TSN. Combined, the 10, 15+ and 11 year age classes represent 46.1% of TSB and 39.2% of TSN.

Maturity analysis of boarfish samples indicated 98.8% of observed biomass was composed of mature individuals (94.4% for abundance). Maturity analysis by age class showed that 33% of 3 year old fish were mature, rising to 100% for fish four years and older (Table 6).

3.3 Horse mackerel

3.3.1 Biomass and abundance

Horse mackerel	Abund ('000)	Biomass (t)
TSB estimate	540,422.0	92,931.9
SSB estimate	503,903.0	89,050.4

Horse mackerel TSB (total stock biomass) and abundance (TSN) estimates were 92,931.9 t and 540,422,000 individuals (CV 36.8%) respectively.

The horse mackerel survey area was composed of 8 strata relating to an area coverage of 61,285 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 42 trawl hauls were carried out during the survey (Figure 1), with 3 hauls containing >50% horse mackerel out of 20 containing horse mackerel overall (Table 2).

A total of 198 echotraces were assigned to horse mackerel. Horse mackerel were widely distributed along the west coast or Ireland, the Porcupine Bank and Celtic Sea where the bulk of the standing stock was located (Figure 7). Observations of horse mackerel along the west coast and Celtic Sea were comparable to 2016-17 in terms of distribution but the number and overall acoustic density was lower. The 2017 estimate of abundance was bolstered by a large single aggregation of spawning fish that contributed over 24% to the total biomass. No aggregations of this scale were observed this year. The west coast stratum remains a significant contributor to the TSB contributing 58% in 2018 followed by the Celtic Sea (35%). Schools of horse mackerel were frequently observed on the seabed and most often over a rocky substrate and along the west coast were often observed in areas containing boarfish (Figure 11b).

3.3.3 Stock composition

A total of 541 horse mackerel were aged from survey samples in addition to 1,466 length measurements and 750 length-weights recorded. Horse mackerel age samples ranged from 1-17 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 3 year age class dominated this year's survey estimate representing over 32.2% of TSB and 45% of TSN (Table 9). The 7 year age class ranked second representing over 14.5% of TSB and 9.1% of TSN (Table 9). Fourteen year old fish were ranked third contributing 11.2% to TSB and 5.0% to TSN. Combined these three age classes represented 57.9% of TSB and 59.2% of TSN.

Maturity analysis of horse mackerel samples indicated 95.8% of the TSB was mature. Maturity analysis by age class showed that 99% of 5 year old fish were mature, rising to 100% for fish three years and older (Table 9).

3.4 Celtic Sea herring (7g and j)

3.4.1 Biomass and abundance

CS Herring	Abund ('000)	Biomass (t)
Total stock	132,419.0	22,745.5
Spawning stock	129,088.8	22,248.5

The estimate of Celtic Sea (CS) herring TSB (total stock biomass) and abundance (TSN) estimates were 22,745.5 t and 132,419,000 individuals (CV 74%) respectively.

The herring survey area was composed of two strata, one broad scale (Celtic Sea) and one high intensity (NW Bank and Celtic Deep). The former represented an area of over 26,626 nmi² and was surveyed using a transect spacing of 15 nmi, whereas the latter was surveyed using a higher intensity of 4-6 nmi and covered an area of 2,644 nmi. A breakdown of CS herring stock abundance and biomass by age, maturity and stratum is detailed in Tables 12 & 13 and Figures 9 & 10.

3.4.2 Stock distribution

CS herring were observed in two regions during the survey. A single high density school of herring was observed south of the Jones's Bank (Figure 11d). During the 2017 survey, a small number of individual herring were also observed around this area, occurring as a by-catch. Numbers were insufficient; both acoustically and biologically to produce a reliable estimate of abundance for the wider Celtic Sea stratum and this is reflected in the high CV value for the combined estimate (74%).

Herring were also observed on the Northwest Bank and in the western Celtic and were composed in the main of a higher number (n=41) of low density schools spread over a wide area (Figures 9 & 11e).The distribution of herring around this area is spatially consistent with observations from this survey in 2017. The Celtic Deep region was surveyed using the USV while the northwest Bank was survey by the Celtic Explorer.

Genetic samples were taken from both locations where herring were located and will be used in part of a larger project to determine the identity of stock components.

3.4.3 Stock composition

A total of 213 CS herring were aged from survey samples in addition to 337 length measurements and 122 length-weights recorded. CS Herring age samples ranged from 1-9 years (Table 12 & 13 and Figure 10). Age structure of the stock was determined from aged otoliths.

Five, four and six winter ring fish dominated the total estimate (Table 12). The age structure of fish was found to very between strata, with a wider range of age classes encountered around the Celtic Deep stratum (Figure 10).

3.5 Hydrography and biogeochemical sampling

3.5.1 CTD sampling

In total 86 CTD casts were carried out (Figure 12). Horizontal temperature and salinity maps for the survey area are provided for depths 5 m, 20, 40 and 60 m in Figures 13-16 respectively.

Surface waters were strongly influenced by the strong and persistent spell of clear and sunny weather experienced before during and after the survey. Thermocline depth varied by location but ranged between 20-45m across the spatial extent of the survey. Strong tidally mixed areas to the north of Ireland and those influenced by riverine inputs such as the River Shannon in the southwest of Ireland are visible as areas of cooler near surface conditions (Figure 14). At 50m depth cooler waters ring the Irish coastline and Celtic Sea (Figure 15) whereas warmer Atlantic origin water is visible to the west of Ireland and Scotland and denotes the boundary region of the Irish Shelf front. Seafloor temperatures show a similar pattern with a ring of cooler, less saline water ringing western Ireland and the Celtic Sea (Figure 16). Warmer, southern water masses in the Celtic Sea are clearly visible with near uniform seabed temperature along the west coast of Ireland and Scotland.

Comparing herring distribution with hydrographic conditions herring are observed in areas of cooler water (Figure 17). Salinity is variable for most areas where herring were located, but temperature was in the most part cooler than the surrounding area. The exception to this observation occurs in the southern Celtic Sea where a herring

school was observed and identified (by trawling) in waters exceeding 11 °C at the sea-floor.

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 pattern of distribution changes relative to temperature and depth along the west coast and Porcupine Bank where boarfish take a midwater position below the thermocline.

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.

3.5.2 CDOM measurements

CDOM sampling was undertaken at all of the 86 hydrographic stations during the survey. Analysis of samples is underway.

3.5.3 Nutrient sampling

Samples were collected from all of the 86 hydrographic stations during the survey. Analysis of samples is underway.

3.5.4 Pico/nano plankton sampling

Sampling of pico and nano plankton communities was carried out at all of the 86 oceanographic stations during the survey. The software that controls the Accuri C6 flow cytometer is able to graphically display the optical and physical characteristics of the organisms present in any sample. The forward scattering of incident light gives an indication on the size of an organism whereas the side scatter of the light relates to the shape of that particular organism. The three fluorescence sensors are set to respond to different colours of fluorescence, orange, green and red, and help to differentiate between the photosynthetic pigments that are unique to the individual species of plankton that are being studied. Further analysis is currently on-going.

3.5.5 Hyperspectral analysis

3.5.6 Chlorophyll measurements

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 using a Telfon grinder 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 of Jeffrey and Humphrey (1975).

Generally good agreement was achieved between the satellite data collected data and data collected at sea (Figure 21). A more detailed analysis of this dataset will be conducted over the next few months.

3.6 Zooplankton biomass and jellyfish abundance

3.6.1 Zooplankton

Plankton samples were collected at 83 stations during the survey. Species composition analysis is currently underway using chemically fixed samples. Dry weight biomass for zooplankton on a per station basis is shown in Figure 18.

Zooplankton biomass (dry weight) by station was higher overall than compared to the same time in 2016 (Figure 18). Zooplankton distribution, as determined from dry weight analysis, showed a relatively uniform distribution throughout the survey with little sign of the spatial patchiness observed in 2016. This defined difference between years is difficult to explain over such a short sampling time frame (2 successive years) but given the sampling effort and intensity this has the potential to provide important information on plankton distribution that was previous lacking.

3.6.2 Jellyfish

Preliminary data for this method are provided below. On leg 1, a total of 2,424 jellyfish were enumerated from visual surveys. The three most abundant species included the hydrozoan *Aqueora sp.* (1,235 observations), the ctenophore *Beroe sp.* (633 observations) and the pleustonic hydrozoan *Velella velella* (435 observations). The highly venomous lion's mane jellyfish *Cyanea capillata* was only spotted 19 times in the Celtic sea using this method. On the second leg, 2,577 jellyfish were observed in total. The most abundant was the cosmopolitan *Aurelia aurita* (1805 spotted), followed by the lion's mane jellyfish *C. capillata* (310) and the blue jellyfish *Cyanea lamarckii* (152 spotted). Further data processing will allow the quantitative description of surface jellyfish abundance along the cruise track line. Results are not available for other jellyfish methodologies as they require several months of laboratory analysis for taxonomic enumeration.

3.7 Marine mammals and seabirds

3.7.1 Visual abundance survey

In total, 272 hours and 18 minutes of survey effort was conducted over the course of the WESPAS 2018 survey, 132 hours and 45 minutes of survey effort was conducted on Leg 1, while 139 hours and 33 minutes of survey effort was conducted on Leg 2 of the survey. In total, 255 hours and 25 minutes of survey effort were conducted using a line transect methodology, while 16 hours and 52 minutes of effort were conducted using the point sampling methodology. Environmental data was collected a total of 1,698 times during the survey.

A total of 160 sightings, were recorded throughout the survey. This includes 47 sightings recorded as auxiliary sightings and 38 sightings recorded as incidental sightings. From the total 160 sightings, marine mammals accounted for 122 sightings. Decomposing marine mammal carcases were also sighted on two occasions. The remaining 36 sightings consisted of other marine megafauna. The marine mammal sightings included; 2 whale species, 6 dolphin species, 1 seal species, and a number of sightings which could not be identified to species level. Mixed species sightings were recorded on two separate occasions.

Of the 160 sightings, 159 were recorded while conducting line transects, while 1 was recorded while conducting point sampling. A list of the species encountered can be seen in Table 14, and the distribution of the sightings can be seen in Figures 22 & 23.

Minke whales (*Balaenoptera* acutorostrata) were the most frequently encountered species accounting for 39 sightings (24% of all sightings) comprising of 41 individuals in total.

Common dolphins (*Delphinus delphis*) were the second most frequently observed and most abundant species. Common Dolphins were encountered on 29 occasions, accounting for 18% of all sightings. These sightings consisted of a total of 436 individuals (46% of all encountered individuals).

The ocean sunfish (*Mola mola*) were the third most frequently encountered species, and the most frequently encountered species of marine megafauna excluding marine mammals. The sunfish were spotted on 25 separate occasions, accounting for 15% of all sightings. Each sighting consisted of a lone individual (3% of encountered individuals).

A number of elasmobranch species were encountered including; blue shark (*Prionace glauca*), porbeagle shark (*Lamna nasus*) and basking shark (*Cetorhinus maximus*). Leatherback turtles (*Dermochelys coriacea*) were encountered on two occasions.

3.7.2 Seabird abundance and distribution

The cumulative total of dedicated seabird survey effort during WESPAS 2018 comes to 156 hours and 16 minutes (9376 minutes) across 37 days. The cumulative total of individual seabirds recorded comes to 11151 of 26 species, of which 7,481 were noted as 'off survey' (outside of dedicated survey time or associating with the vessel, including during fishing operations point counts) and as such will be excluded from future analysis of abundance and density.

Leg 1: A total of 65 hours and 45 minutes (3,945 minutes) of dedicated seabird surveys was conducted across 18 days between 10th and 27th June 2018. A cumulative total of 4,434 individual seabirds of 18 species were recorded, of which 3,662 were noted as 'off survey' (Table 16).

Leg 2: A total of 90 hours and 31 minutes (5,431 minutes) of dedicated seabird surveys was conducted across 19 days between 4th and 23rd July 2018. A cumulative total of 6717 individual seabirds of 24 species were recorded, of which 3,819 were noted as 'off survey' (Table 16).

In addition, daily totals for six species of migrant terrestrial birds recorded on or around the vessel are also presented (Table 16).

4 Discussion and Conclusions

4.1 Discussion

The objectives of the survey were carried out successfully and as planned. Good weather conditions dominated during the survey allowing for extended marine mammal and seabird survey effort. No weather induced downtime was recorded.

Malin Shelf herring distribution was concentrated in an area to the west of the Hebrides in 6aN and in the southern and western Stanton Bank area in 6aS (Figure 3). There was an 18% increase in the SSB in 2018 compared to 2017 (O'Donnell et al 2017). There were good signs of young herring (1- and 2-wr fish) distributed in 6aS and in the area to the east and west of the Butt of Lewis in particular. 0-wr herring were found in the Minch, distributed near the surface in mixed schools that were dominated by 0-wr sprat. This was in contrast to 2016 and 2017 where there were relatively few herring observed south of 56°N in 6aS or 7b, c and no 0- and 1- wr fish. The age profile of survey samples in 2018 is encouraging in the context of cohort tracking for the assessment; 4 year old herring dominated the stock (30% in terms of biomass, and 22% in terms of abundance). The survey was dominated by 3-wr fish in 2017. In 2016, there was a much more even distribution of year classes. The CV estimate for the 2018 survey is lower than in 2017 (0.28 compared to 0.45); this is more comparable to previous years in the time-series.

The distribution of boarfish was comparable to 2017 and earlier years in the time series with the exception of the northern region. The northern distribution of the stock was observed to extend almost continuously, albeit it in low abundance, northward of 59°N north. Distribution was reported to continue up to 60°N as reported by the RV *Scotia*. Although important, these schools were not considered to be significant to the overall estimate. Overall, the acoustic density and number of echotraces of boarfish was lower than observed in 2017 for the same trawl and acoustic sampling effort. The age profile of dominant cohorts was different to 2017 and this is likely attributed to the use of an age length key to assign ages to biological samples rather than the aging of actual survey collected otoliths collected that year.

Horse mackerel were distributed in comparable regions along the Irish west coast, Porcupine Bank and Celtic Sea. Geographical distribution was thus comparable to previous surveys but the number and acoustic density of aggregations was lower than in 2017. That said the total stock estimate is more in line with 2016 than 2017. However, more years of survey effort are required for trends to emerge. The age composition of the stock in 2018 was strongly influenced by the 3 year old component, something not evident in 2017 as two year old fish. Seven and fourteen year class remain dominant.

Observations of Celtic Sea herring survey were continued in 2018. Combining RV and ASV platform effort allowed for a wider area to be covered. Acoustic inter-calibration of instruments from each platform allowed the data to be combined to produce an overall estimate of abundance. Containment issues still exist and thus limit the reliability of estimates of abundance for this stock. The stock identity of larger, older individuals in the southern survey area remains to be determined from genetic sampling. The presence of feeding herring around the Celtic Deep across years highlights the importance of this area to a portion of the stock throughout the summer and autumn period prior to the spawning migration.

Hydrographic conditions in surface waters were as to be expected during the summer months with warmer waters dominating more southern latitudes and well stratified water masses with a strong thermocline. The start of the survey coincided with the start of a prolonged period of hot and sunny weather. Thermocline depth ranged from 20-55m depending on location, with the lower limit observed areas with strong tidal mixing. Below the thermocline and at seafloor, Ireland appeared to be ringed by an area of cool water close to the coast with a district boundary front. Seafloor temperatures along the shelf area on the oceanic side of the front appeared almost uniform along the west coast of Ireland and Scotland with temperatures over 10 ℃ in the northernmost latitudes. Interestingly herring were encountered only within the cool water ribbon to the west of Scotland and not in the warmer regions. Boarfish and horse mackerel, as open ocean species, were primarily distributed in full seawater conditions and on the oceanic side of the Irish shelf front regardless of temperature or latitude.

4.2 Conclusions

- Malin Shelf herring biomass was ~18% higher in 2018 compared to 2017 (SSB_{2018} =130,000 t; SSB_{2017} = 107,000 t). The CV on the survey was lower in 2018 (0.28) when compared with 2017 (0.46); the CV in 2018 is comparable to previous years in the time series
- Malin Shelf herring TSB (total stock biomass) and abundance (TSN) estimates were 183,188 t and 1,698,300,000 individuals respectively
- Herring were distributed further south in 2018 compared to 2017, with some herring south of 56°N, particularly young fish (1- and 2-wr). There was very little herring distributed south of 56°N in both 2016 and 2017.
- The dominant age class of herring in the 2018 survey was 4-wr fish (30% TSB, and 22% TSN). This compares well with the 2017 survey, showing good cohort tracking; the dominant age class in the 2017 survey was 3-wr fish (43% TSB).
- The three most dominant year classes of herring were 2-, 4- and 5-wr fish and together represented over 63% of the TSB in 2018.The three most dominant year classes in 2017 were 3-, 4- and 6-wr fish, representing over 78% of the TSB.
- 1-wr herring were found in the survey for the first time since 2015. There were also 0-wr herring found mixed in surface schools of sprat in the Minch.
- Herring were found in very small numbers off the west coast of Ireland for the first time in many years on this survey.
- Boarfish distribution showed a similar pattern to previous years. The number of schools and acoustic density was lower than in 2017.
- Boarfish TSB (total stock biomass) and abundance (TSN) estimates were 186,252 t and 3,221,110,000 individuals (CV 19.9%) respectively.
- The northern distribution of boarfish continued north of the Hebrides outside of the core survey area and schools were observed the RV *Scotia*. However, it is important to note that the number and acoustic density were considered low.
- Horse mackerel biomass is considered a reliable estimate of the standing stock in 2018 given comparable survey effort and area coverage. Improvements are required to ensure greater containment in the southern boundary and western approaches to the Channel.
- Horse mackerel TSB (total stock biomass) and abundance (TSN) estimates were 92,931 t and 540,422,000 individuals (CV 36.8%) respectively.
- The positive influence of the 3 year class of horse mackerel is notable.
- Celtic Sea herring were observed around the banks in the eastern Celtic Sea as well as in the mid Celtic Sea. The size and age of schools observed, although low in number were notably different. Containment remains an issue for reliable estimates abundance during this survey. However, it is intended that this will be further developed to provide an additional measure of this stock.

5 Recommendations

- Continuation of the south to north work flow to align with surveys in the south (PELGAS- France) and north (HERAS- Scotland) and provide synoptic estimates of abundance for a multiple species.
- Real time aging of horse mackerel survey samples to provide within year age estimates of survey data.
- Research the possibility of egg counts from plankton samples (WP2) as a means to track spawning, and peak spawning events by geographic region for boarfish and horse mackerel.
- To further develop this survey more ship-time is required. As the survey is observing not only target species for the focal component but also the distribution of other species that are also surveyed during the year, specifically Celtic Sea herring.
- Westward extension of some transects in the northwest of the survey area to ensure boarfish stock containment. This may also require some extra survey days.

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8 Tables and Figures

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

Echo Sounder System Calibration Report

Vessel :	RV Celtic Explorer	Date :	10.06.18
Echo sounder :	Drop Keel	Locality :	Dunmanus Bay
Type of Sphere :	WC 38.1	TS_{Sphere}: -42.2 dB	Depth(Sea floor) : 36 m

Calibration Version 2.1.0.12

Comments:
Dunmanus Bay Survey Start

Reference Target:

TS	-42.2 dB	Min. Distance	18.0m
TS Deviation	5 dB	Max. Distance	22.0m

Transducer: ES38B Serial No.

Frequency	38000 Hz	Beamtype	Split
Gain	26.65 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	7.09 deg	Along. Beam Angle	7.03 deg
Athw. Offset Angle	-0.01 deg	Along. Offset Angl	-0.05 deg
SaCorrection	-0.58 dB	Depth	8.80 m

Transceiver: GPT 38 kHz 009072033933 1 ES38B

Pulse Duration	1.024 ms	Sample Interval	0.190 m
Power	2000 W	Receiver Bandwidth	2.43 kHz

Sounder Type:
ER60 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	Max. Echolength	180%

Environment:

Absorption Coeff.	10.2 dB/km	Sound Velocity	1481.5 m/s

Beam Model results:

Transducer Gain =	25.29 dB	SaCorrection =	-0.60 dB
Athw. Beam Angle =	7.04 deg	Along. Beam Angle	6.97 deg
Athw. Offset Angle =	-0.02 deg	Along. Offset Angl	-0.06 deg

Data deviation from beam model:
RMS = 0.23 dB
Max = 0.79 dB No. = 237 Athw. = 2.8 deg Along = 3.3 deg
Min = -0.74 dB No. = 212 Athw. = -3.7 deg Along = -0.4 deg

Data deviation from polynomial model:
RMS = 0.22 dB
Max = 0.74 dB No. = 211 Athw. = -4.8 deg Along = -0.6 deg
Min = -0.70 dB No. = 212 Athw. = -3.7 deg Along = -0.4 deg

Comments :
SE wind F3, strong tide
Wind Force : F4 **Wind Direction :** N
Raw Data File: C:\Program files\Simrad\Scientific\EK60\Data\Calibration\WESPAS 2018\Drop Keel
Calibration File: C:\Program files\Simrad\Scientific\EK60\Data\Calibration\WESPAS 2018\Drop Keel

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	11.06.18	50.34	-7.25	10:58	104	104	450	4.5	1.8	13.9	0.2	79.6
2	13.06.18	47.72	-6.60	10:01	170	150	109	2.3			51.9	45.8
3	14.06.18	48.23	-8.57	13:50	174	174	235	39.4	3.3			57.3
4	14.06.18	48.23	-7.91	19:14	180	180-155	193	86.5			13.0	0.5
5	15.06.18	48.47	-6.27	11:04	130	130	225		14.5		71.4	14.1
6	16.06.18	48.48	-9.50	08:36	184	184-160	600	84.7			2.3	13.0
7	16.06.18	48.73	-8.98	17:51	160	160-120	160	99.6			0.2	0.3
8	17.06.18	48.99	7.58	05:27	146	125-100	27		30.1	5.4	53.3	11.2
9	17.06.18	49.00	-7.49	07:28	134	134-110	172	94.7	0.5	0.5		4.3
10	18.06.18	49.24	-10.98	10:00	173	173-153	85	79.7			0.4	19.9
11	18.06.18	49.24	-10.48	13:57	143	125-100	700	99.1	0.7		0.3	0.0
12	19.06.18	49.49	-8.90	18:01	124	85-60	79	99.7				0.3
13	20.06.18	49.75	-10.46	13:26	139	30-50	400		83.9		16.1	0.0
14	21.06.18	50.00	-8.53	15:50	131	131-115	235		0.3			99.7
15	22.06.18	50.25	-10.46	09:47	143	100-75	300	87.5	2.0		9.8	0.8
16	22.06.18	50.25	-9.29	16:51	132	132	3,000		3.6			96.4
17	23.06.18	50.50	-7.73	10:05	107	90	145		1.9	11.2		86.9
18	24.06.18	50.75	-9.75	09:58	115	85-65	3		6.7			93.3
19	25.06.18	50.86	-6.53	15:55	93	80-60	650					100.0
20	27.06.18	51.76	-10.98	11:20	158	75	7		43.4		24.6	32.0
21	04.07.18	52.51	-10.89	11:06	127	100-127	80	0.3		1.6		98.1
22	05.07.18	53.01	-10.74	05:23	130	125-130	51	0.6		0.2		99.2
23	05.07.18	53.26	-11.43	17:06	146	125-145	7	37.1	53.0		6.5	3.4
24	06.07.18	53.51	-11.41	06:17	175	50-100	1,000	91.0	0.2		8.8	0.0
25	08.07.18	53.51	-13.72	05:40	210	60-90	1,000	93.8	6.0			0.2
26	09.07.18	54.01	-10.82	08:20	183	75-100	1,500	95.6		0.6	3.5	0.3
27	09.07.18	54.26	-10.36	15:33	100	75-100	500		0.1			99.9
28	10.07.18	54.76	-10.31	11:51	125	100-125	171	73.0	17.6	0.1	0.1	9.2
29	10.07.18	55.02	-10.01	16:59	115	75-115	1,500	95.9	0.5		1.3	2.2
30	11.07.18	55.52	-9.01	13:30	100	80-100	182	10.4	0.3	0.1	9.4	79.7
31	11.07.18	55.52	-7.71	20:07	65	40-65	12					100.0
32	12.07.18	55.54	-7.77	04:46	69	20-40	4,000			99.0		1.0
33	13.07.18	55.77	-9.14	09:15	134	110-134	160	59.8	8.1		29.2	2.8
34	13.07.18	56.02	-8.58	14:32	145	125-145	29		8.8	23.7		67.6
35	14.07.18	56.52	-8.66	19:34	140	120-140	306		35.4	64.5		0.1
36	15.07.18	56.77	-8.71	12:56	122	115-122	8					100.0
37	16.07.18	57.27	-8.52	07:42	144	115-140	117		7.7	90.3		2.1
38	16.07.18	57.52	-9.23	16:16	180	90-110	139	99.5			0.3	0.2
39	17.07.18	57.77	-8.89	11:20	152	110-152	1,250		0.9	97.5		1.6
40	19.07.18	58.54	-7.25	06:21	97	50-100	320		55.7	35.5		8.8
41	19.07.18	58.54	-5.64	12:36	140	120-140	500			0.8		99.2
42	20.07.18	57.30	-6.30	15:51	81	0-40	84			7.2		92.8

Table 3. Malin Shelf herring stock estimate 2018 (6aS, 7bc and 6aN (south of 58°30'N).

	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	9586	-	-	-	-	-	-	-	-	-	-	-	-	9586			0
6	61349	-	-	-	-	-	-	-	-	-	-	-	-	61349			0
6.5	115030	-	-	-	-	-	-	-	-	-	-	-	-	115030			0
7	49846	-	-	-	-	-	-	-	-	-	-	-	-	49846			0
7.5	24923	-	-	-	-	-	-	-	-	-	-	-	-	24923			0
8	-	-	-	-	-	-	-	-	-	-	-	-	-	0			0
8.5	3834	-	-	-	-	-	-	-	-	-	-	-	-	3834			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	|	1284	-	-	-	-	-	-	-	-	-	-	-	1284			0
16	|	8068	-	-	-	-	-	-	-	-	-	-	-	8068	291.9	36.18	0
16.5	|	26772	-	-	-	-	-	-	-	-	-	-	-	26772	1086.5	40.58	0
17	|	53633	-	-	-	-	-	-	-	-	-	-	-	53633	2226.4	41.51	0
17.5	|	53062	-	-	-	-	-	-	-	-	-	-	-	53062	2444.5	46.07	0
18	|	54239	-	-	-	-	-	-	-	-	-	-	-	54239	2786.7	51.38	0
18.5	|	65759	-	-	-	-	-	-	-	-	-	-	-	65759	3659.5	55.65	0
19	|	42590	2462	-	-	-	-	-	-	-	-	-	-	45052	2719.2	60.36	0
19.5	|	34646	-	-	-	-	-	-	-	-	-	-	-	34646	2239.5	64.64	0
20	|	36564	6611	-	-	-	-	-	-	-	-	-	-	43175	3106.6	71.95	0
20.5	|	6091	30269	-	-	-	-	-	-	-	-	-	-	36360	2738.8	75.33	0
21	|	11286	17917	-	-	-	-	-	-	-	-	-	-	29203	2446.8	83.79	19
21.5	|	1774	31122	-	-	-	-	-	-	-	-	-	-	32896	3113.3	94.64	9
22	|	-	35701	-	-	-	-	-	-	-	-	-	-	35701	3589.5	100.54	0
22.5	|	-	47818	-	-	-	-	-	-	-	-	-	-	47818	4918.8	102.87	5
23	|	-	68001	2450	-	-	-	-	-	-	-	-	-	70451	7887.3	111.96	29
23.5	|	-	50475	9823	-	-	-	-	-	-	-	-	-	60298	7085.4	117.51	17
24	|	-	27927	6372	1398	1774	-	-	-	-	-	-	-	37471	4856.1	129.6	87
24.5	|	-	7759	12698	7142	-	-	-	-	-	-	-	-	27599	3666.9	132.86	75
25	|	-	10460	9250	22271	-	-	-	-	-	-	-	-	41981	5858.5	139.55	83
25.5	|	-	2647	21656	28277	5083	-	-	-	-	-	-	-	57663	8625.1	149.58	93
26	|	-	-	27383	48058	6585	820	-	-	-	-	-	-	82846	13087.2	157.97	100
26.5	|	-	-	13555	47902	19485	-	-	-	-	-	-	-	80942	14073.8	173.88	99
27	|	-	-	3188	60333	37803	1074	-	-	-	-	-	-	102398	18567.3	181.32	98
27.5	|	-	-	3189	48507	24002	-	9136	-	-	-	-	-	84834	15988.6	188.47	100
28	|	-	-	2891	29339	24105	11430	10544	3147	-	-	-	-	81456	16328.3	200.45	100
28.5	|	-	-	-	12064	12537	13657	11194	3259	2015	-	-	-	54726	11331.5	207.06	100
29	|	-	-	-	6211	6164	6759	15670	3431	1229	1282	-	-	40746	8887.9	218.13	100
29.5	|	-	-	-	2632	-	9982	8982	5535	-	-	-	-	27131	6081	224.13	100
30	|	-	-	-	-	-	-	3998	1414	4920	-	-	-	10332	2291.8	221.84	100
30.5	|	-	-	-	-	-	-	-	-	-	-	3511	-	3511	793.6	226	100
31	|	-	-	-	-	-	-	-	-	-	-	602	-	602	133	221	100
32	|	-	-	-	-	-	-	-	-	-	-	1038	-	1038	276.2	266	100
TSN (1000)	264568	395768	339168	112454	314133	137539	43721	59524	16786	8164	1282	5151		1698261			
TSB (t)		21464.2	35763	17223.8	54787.7	25648.5	9149.3	12289	3591.5	1786.1	281.4	1202.8			183187.5		
Mean length (cm)		18.3	22.54	25.44	26.71	27.28	28.59	28.64	28.96	29.48	29	32					
Mean weight (g)		54.41	105.44	153.16	174.41	186.48	209.27	206.46	213.96	218.78	219.6	266				127.89	
SSB (t)		307.03563	7789.5909	14571.6424	53387.77	25216	9149.49	12289	3591.5	1786.1	281.53	1370.2			129740		
% mature		1	22	85	97	98	100	100	100	100	100	100					

Table 4. Malin Shelf herring survey time series 2008-2018. Survey coverage: - ^ 6aS & 7bc; * 6aS, 6aN & 7b; ** 6a & 7bc; ***6aS, 7bc & 6aN (south of 58°30'N).

Age	2008^	2009^	2010*	2011*	2012*	2013*	2014*	2015**	2016*	2017***	2018***
0	-	-	-	-	-	-	-	-	-	-	264.6
1	6.1	416.4	524.8	82.1	608.3	-	1,115.4	4.9	-	-	395.8
2	75.9	81.3	504.3	202.5	451.5	96.2	214.7	162.1	9.7	11.0	339.2
3	64.7	11.4	133.3	752.0	444.6	254.3	166.3	291.7	102.3	273.4	112.5
4	38.4	15.1	107.4	381.0	516.1	265.8	380.0	580.7	91.4	111.0	314.1
5	22.3	7.7	103.0	110.8	180.3	78.7	352.1	487.3	91.4	71.6	137.5
6	26.2	7.1	83.7	124.0	115.4	26.9	125.0	513.4	58.2	94.4	43.7
7	9.1	7.5	57.6	118.4	116.9	18.5	18.9	143.9	46.5	28.0	59.5
8	5.0	0.4	35.3	70.7	83.8	10.8	9.7	33.4	2.7	9.9	16.8
9	3.7	0.9	17.5	41.6	56.3	4.1	4.7	-	0.5	2.6	8.2
10+	-	-	-	25.6	42.0	1.2	-	8.3	-	-	6.4
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
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
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
CV	34.2	32.2	24.7	22.4	22.8	21.5	28.6	28.6	31.3	46.6	28.3

Table 5. Malin Shelf herring spawning stock biomass and abundance by strata 2018

Strata	Name	Area (nmi^2)	Transects	Abundance ('000)	Bio (t)
1	Minches	3105	9	318989	2,494
2	W Hebrides	6148	7	657518	108,588
3	SW Hebrides	5030	4	233196	36,301
4	NW Coast	2251	2	0	0
5	W Coast	10212	12	9731	750
6	N Malin	3102	2	477546	35053.9
	Total	29,847	36	1,696,980	183,186

Table 6. Total boarfish stock estimate.

Length	Age (years)																Numbers	Biomass	Mn Wt	Mature
(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Unknown	(000's)	(t)	(g)	(%)
5	25.2																12612	25.2	2	0
5.5	18.9																6306	18.9	3	0
6																				
6.5	113.5																18918	113.5	6	0
7	253.8																32514	253.8	8	0
7.5	50.4																6306	50.4	8	0
8		239.3															20016	239.3	12	0
8.5		72.4	438.9														36738	511.3	14	0
9			543.8														34446	543.8	16	0
9.5			400.2														21652	400.2	18	0
10		96.7	287.8														18384	384.5	21	100
10.5			381.2	275.7													25384	656.9	26	100
11				1515.1	863.7												82695	2378.8	29	100
11.5				210.3	1465	3350.5											153631	5025.9	33	100
12					770.4	1107	3344.9	73.8									143938	5296.1	37	100
12.5					442.7	754.7	3167.9	1876.2									148018	6241.5	42	100
13						603	4236	3415.3	568.5	215.3							185259	9038.1	49	100
13.5							3788.2	3950.8	7993.9	75.8							301310	15808.7	52	100
14								87.2	7087.2	17155.4	106.4				76.6		425790	24512.7	58	100
14.5								260.5	370.7	20311.9	2791.8	3049.2	1439.7	1135.9	1945.8		485278	31305.4	65	100
15										302.2	21042.2	536.9	2878.6	2785.5	5245.7		458932	32791.1	71	100
15.5												16500.5			7485.5		305973	23986	78	100
16													11599.3		4459.8		187800	16059.1	86	100
16.5														5610.4	1932.8		80135	7543.2	94	100
17															2617.7		25313	2617.7	103	100
17.5																275.2	2572	275.2	107	100
18																				
18.5																				
19																				
19.5															19.6		297	19.6	66	100
20																				
20.5															155.3		892	155.3	174	100
TSN (10^{-3})	76655	31222	115019	68265	106679	165920	320741	197749	293448	624683	339214	264184	198415	116492	299850	2572	3221110			
TSB (t)	461.9	408.4	2051.9	2001.1	3541.8	5815.2	14537	9663.8	16020.2	38060.6	23940.5	20086.5	15917.6	9531.8	23938.8	275.2		186252		
Mean length (cm)	6.47	8.4	9.28	10.97	11.54	11.83	12.72	13.11	13.71	14.25	14.93	15.31	15.63	15.7	15.57	17.5				
Mean weight (g)	6.03	13.08	17.84	29.31	33.2	35.05	45.32	48.87	54.59	60.93	70.58	76.03	80.22	81.82	79.84	107			57.82	
% mature*	0	24	33	100	100	100	100	100	100	100	100	100	100	100	100	100				
SSB	0.0	96.7	669.0	2001.1	3541.8	5815.2	14537.0	9663.8	16020.3	38060.6	23940.4	20086.6	15917.6	9531.8	23938.8	275.2	184235.0			

Table 7. Boarfish biomass and abundance by strata.

Name	Area (nmi^2)	Transects	Abun ('000)	Bio (t)
W Hebrides	4,690.8	8	274,422	17,407
S Hebrides	1,980.8	4	146,345	7,361
W Coast	14,726.6	20	908,062	50,201
Porcupine Bk	5,734.6	6	365,017	27,824
Celtic Sea	26,626.7	16	1,422,426	78,530
Celtic Deep	2,644.2	8	104,837	4,929
Total	56,403.7	62	3,221,109	186,252.2

Table 8. Boarfish survey time series. Note: 2016 CV estimate calculated using StoX.

Age (Yrs)	2011	2012	2013	2014	2015	2016	2017	2018
0	-	-	-	-	-	-	-	-
1	5.0	21.5	-	-	198.5	4.6	110.9	76.7
2	11.6	10.8	78.0	-	319.2	35.7	126.7	31.2
3	57.8	174.1	1,842.9	15.0	16.6	45.5	344.6	115
4	187.4	64.8	696.4	98.2	34.3	43.6	367.3	68.3
5	436.7	95.0	381.6	102.3	80.0	6.0	156.0	106.7
6	1,165.9	736.1	253.8	104.9	112.0	10.0	209.0	165.9
7	1,184.2	973.8	1,056.6	414.6	437.4	169.0	493.1	320.7
8	703.6	758.9	879.4	343.8	362.9	112.6	468.3	197.7
9	1,094.5	848.6	800.9	341.9	353.5	117.6	397.2	293.4
10	1,031.5	955.9	703.8	332.3	360.0	96.6	285.8	624.7
11	332.9	650.9	263.7	129.9	131.7	17.0	120.9	339.2
12	653.3	1,099.7	202.9	104.9	113.0	32.0	82.1	264.1
13	336.0	857.2	296.6	166.4	174.0	48.7	74.4	198.4
14	385.0	655.8	169.8	88.5	108.0	18.3	220.4	116.5
15+	3,519.0	6,353.7	1,464.3	855.1	1,195.0	400.1	931.0	302.4
TSN (10^{-3})	11,104	14,257	9,091	3,098	3,996	1,157	4,387	3,221
TSB (t)	670,176	863,446	439,890	187,779	232,634	69,690	223,860	186,252
SSB (t)	669,392	861,544	423,158	187,654	226,659	69,103	218,810	184,235
CV	21.2	10.6	17.5	15.1	17.0	16.4	21.9	19.9

Table 9. Horse mackerel stock estimate.

Length	Age (years)																					Numbers	Biomass	Mn Wt	Mature
(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21 Unknown	(000's)	(t)	(g)	(%)
11																						125			0
12																									
13																					5.5	262	5.5	21	0
14																					7.3	262	7.3	28	0
15																									
16																									
17		49.4																				1048	49.4	47.11	0
18																					22.9	441	22.9	52	0
19	63.2	113.1																				2830	176.3	62	0
20		351.9																				4363	351.9	81	100
21		1441.8																				16587	1441.8	87	50
22		4289	422.5																			46985	4711.5	100	81
23		592.9	10029	70.4																		95236	10692.6	112	91
24		51.6	10579	768.4	222.3																	93979	11621	124	98
25			8366.6	1201.8	50.8	75.2																70202	9694.4	138	93
26			291.7	5889.6	356.1																	41741	6537.4	157	98
27			48.6	5199.5	490.7	517.4	223.1	69.7														36858	6549	178	100
28			257.2	477.9	258.4	276.5	1349.5															13507	2619.5	194	100
29					338.7	271.9	782.1	99.8														6695	1492.4	223	100
30					171.9	168.8	2488.5															11400	2829.3	248	100
31						59.8	1798.1															7110	1857.9	261	100
32						187.3	2457.4	487.3				170.6										11246	3302.5	294	100
33							921.6	851.5	53.5		166.5	209.9		383.8								8166	2586.8	316.78	100
34							2605.3	2868.1	1543.8			2008.2	2145	2277.7								39210	13448.1	342.98	100
35							818				305.3			639.8								4682	1763.1	376.56	100
36										610.5		132	30.3	4422.4								13878	5195.1	374.33	100
37									2186.2		77.4		855.9	2202.9								12325	5322.4	431.84	100
38														83.5								203	83.5	411	100
39														196.9								394	196.9	499.95	100
40														209.8								425	209.8	494	100
41																	164					262	163.5	624	100
42																									
TSN (10^{-3})	1015	72408	243280	85252	10495	7562	49329	13338	10047	1511	1547	7356	8462	27469			262				1090	540422			
TSB (t)	63.2	6889.6	29995	13608	1888.9	1556.9	13444	4376.4	3783.5	610.5	549.1	2520.6	3031.2	10417			164				35.8		92931.9		
Mean length (cm)	19	21.59	23.89	26.14	26.82	28.17	31.07	33.18	35.57	36	34.56	33.84	34.69	35.62			41				15				
Mean weight (g)	62.29	95.15	123.29	159.61	179.98	205.88	272.53	328.1	376.59	404	355.09	342.69	358.22	379.23			624				37			172	
% mature*	0	75	94	98	99	100	100	100	100	100	100	100	100	100			100				0				
SSB	0	5,137	28,209	13,384	1,874	1,552	13,444	4,376	3,784	611	549	2,521	3,031	10,417			164				0	89050.4			

Table 10. Horse mackerel biomass and abundance by strata.

Name	Area (nmi²)	Transects	Abun ('000)	Bio (t)
W Hebrides	4,690.8	8	2,800	356
S Hebrides	1,980.8	4	1,116	141.8
N Stanton	1,522.3	3	9,552	1212.9
S Stanton	2,323.8	5	7,917	1003.1
W Coast	14,726.6	20	323,584	53,733
Porc Bank	5,734.6	6	14,689	3,043
Celtic Sea	26,626.7	17	176,882	32,727
Celtic Deep	2,121.5	8	3,884	715
Minch	1,557.6	9	-	-
Total	61,284.8	80	540,424	92,932

Table 11. Horse mackerel survey time series.

Age (Yrs)	2016	2017	2018
0	-	-	-
1	1.1	11.7	1.015
2	100.2	181.8	72.408
3	4.9	147	243.28
4	43.5	45.4	85.252
5	19.0	16.2	10.495
6	7.6	46	7.562
7	40.6	113	49.329
8	66.6	67.7	13.338
9	8.5	25.4	10.047
10	1.8	33.2	1.511
11	9.5	32.6	1.547
12	10.6	37.7	7.356
13	4.7	37.6	8.5
14	21.1	160.8	27.5
15	6.5	8.6	-
16	1.6	5.2	-
17	5.3	-	0.262
18	-	-	-
19	-	-	-
20	-	-	-
21	1.1	-	-
TSN (10^{-3})	354.5	969,655	540,422
TSB (t)	69,267	228,116	92,931.90
SSB (t)	65,194	227,395.6	89,050.40
CV	42.0	25.5	36.8

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Table 12. Celtic Sea herring stock estimate.

Length (cm)	Age (years) 1	2	3	4	5	6	7	8	9	10	11 Unknown	Numbers (10^{-3})	Biomass (t)	Mn Wt (g)	Mature (%)
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											10.6	125	10.6	85	0
22			63.4									689	63.4	92	0
22.5			43.2	46.4								961	89.6	93	0
23		12.6	108.7		19.6							1377	140.9	102	66
23.5			102.5	120.6	13.9							2321	237	102	69
24			83.5	201.3	25.5							2701	310.4	115	81.25
24.5			136.1	165.8	222.5							4198	524.4	125	85
25				193.4	133.7							2517	327.1	130	85.72
25.5			34.7	142.7	170.7	163.7						3661	511.9	140	95
26			928.8	6.8	271.8	62.3	48.9	27.7				9020	1346.4	149	100
26.5				56.7	3441.4	164.8	109.5	104.3	82.4			24521	3959	161	100
27				768	3871	57.3	277.3	105.4	24.3			29398	5103.3	174	100
27.5					1757.9	1634.3	258.2	45.7	15.7			20481	3711.8	181	100
28					1218.6		102.1	45.4	43.6			7375	1409.6	191	100
28.5						1253	91.3					6656	1344.3	202	100
29							1334					6234	1334	214	100
29.5				2292.2								10059	2292.2	228	100
30									29.6			125	29.6	236	100
30.5															
31															
31.5															
TSN (10^{-3})		125.0	11556.0	22209.0	65532.0	18550.0	11243.0	1971.0	1107.0		125	132419			
TSB (t)		12.6	1501.0	3993.8	11146.8	3335.3	2221.3	328.5	195.5		10.6		22745.5		
Mean length (cm)		23.0	24.8	27.2	26.8	27.6	28.2	27.0	27.3		21.5				
Mean weight (g)		101.0	129.9	179.8	170.1	179.8	197.6	166.7	176.6		85			171.77	
% mature*		66	86	95	99	100	100	100	100						
SSB ('000 t)		8.3	1287.3	3811.7	11069.3	3326.4	2221.3	328.5	195.6			22248.5			

Table 13. Celtic Sea herring total stock biomass and total abundance by strata.

Name	Area (nmi²)	Transects	Abun ('000)	Bio (t)
Celtic Sea	26,626.7	15	99,738	18,175
C Deep/NW Bank	2,644.2	11	32,681	4,570
Total	29,270.9	26	132,419	22,745.5

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	Species name	No. of Sightings	No. of individuals	Group Size
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	1	3	3
Bottlenose dolphin	*Tursiops truncatus*	5	105	8-45
Common dolphin	*Delphinus delphis*	28	336	2-50
Common/ striped dolphin	*D. delphinus/ S. coeruleoalba*	1	1	1
Humpback whale	*Megaptera novaeangliae*	1	1	1
Long finned pilot whale	*Globicephala melas*	3	20	4-11
Minke whale	*Balaenoptera acutorostrata*	38	39	1-2
Mix (Bottlenose dolphin & pilot whale)	*Mix (T. truncatus & G. melas)*	1	(20 & 20)	40
Mix (Common dolphin & minke whale)	*Mix (D. delphinus & B. acutorostrata)*	1	(100 & 2)	102
Risso's dolphin	*Grampus griseus*	5	47	6-15
White beaked dolphin	*Lagenorhynchus albirostris*	4	10	2-3
Unid Baleen Whale	*Mysticeti sp*	4	4	1
Unid Cetacean	*Cetacea sp*	2	2	1
Unid Dolphin	*Delphinid sp*	20	192	1-70
Unid Large Whale		2	2	1
Unid Small Whale		1	1	1
	Total	**160**	**950**	
Grey Seal	*Halichoerus grypus*	3	4	1-2
	Unidentified Seal	2	2	1
	Total	**5**	**6**	
Decomposing Carcass	Unid. marine mammal	2	2	1
	Total	**2**	**2**	
Basking shark	*Cetorhinus maximus*	1	1	1
Blue shark	*Prionace glauca*	4	4	1
Leatherback turtle	*Dermochelys coriacea*	2	2	1
Ocean sunfish	*Mola mola*	25	25	1
Porbeagle shark	*Lamna nasus*	1	1	1
Tuna Sp	*Thunnus sp*	1	1	1
Unidentified Fish	*Teleost sp*	1	2	2
Unidentified Shark	*Selachii sp*	1	1	1
	Total	**36**	**37**	

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Table 15. Totals for all seabird species recorded between 10th June and 23rd July 2018.

Leg 1:

Vernacular Name	Scientific Name	On Survey	Off Survey	Total
Wilson's storm-petrel	*Oceanites oceanicus*	0	1	1
European storm-petrel	*Hydrobates pelagicus*	38	277	315
Fulmar	*Fulmarus glacialis*	61	356	417
Sooty shearwater	*Ardenna griseus*	1	4	5
Great shearwater	*Ardenna gravis*	3	1	4
Manx shearwater	*Puffinus puffinus*	89	92	181
Gannet	*Morus bassanus*	248	2334	2582
Kittiwake	*Rissa tridactyla*	5	10	15
Sabine's gull	*Xema sabini*	2	0	2
Great black-backed gull	*Larus marinus*	4	23	27
Herring gull	*Larus argentatus*	0	21	21
Lesser black-backed gull	*Larus fuscus graellsii*	176	446	622
Unidentified gull sp.	*Larus sp.*	0	2	2
Common tern	*Sterna hirundo*	0	6	6
Great skua	*Stercorarius skua*	4	19	23
Arctic Skua	*Stercorarius parasiticus*	0	1	1
Guillemot	*Uria aalge*	38	9	47
Razorbill	*Alca torda*	5	1	6
Puffin	*Fratercula arctica*	98	59	157
Total		772	3662	4434

Leg 2:

Vernacular Name	Scientific Name	On Survey	Off Survey	Total
Great Northern Diver	Gavia immer	1	0	1
European storm-petrel	*Hydrobates pelagicus*	22	19	41
Unidentified storm-petrel		1	6	7
Fulmar	*Fulmarus glacialis*	275	667	942
Cory's shearwater	*Calonectris borealis*	4	2	6
Sooty shearwater	*Ardenna griseus*	2	6	8
Great shearwater	*Ardenna gravis*	0	2	2
Manx shearwater	*Puffinus puffinus*	285	302	587
Unidentified shearwater sp.		1	0	1
Gannet	*Morus bassanus*	784	1208	1992
Shag	*Phalacrocorax aristotelis*	0	5	5
Cormorant	*Phalacrocorax carbo*	0	4	4
Kittiwake	*Rissa tridactyla*	25	44	69
Common gull	*Larus canus*	2	10	12
Great black-backed gull	*Larus marinus*	2	12	14
Herring gull	*Larus argentatus*	2	11	13
Lesser black-backed gull	*Larus fuscus graellsii*	62	141	203
Unidentified large gull sp.	*Larus sp.*	21	4	25
Common tern	*Sterna hirundo*	0	1	1
Arctic tern	*Sterna paradisaea*	0	3	3
Unidentified *Sterna* tern sp.	*Sterna sp.*	0	17	17
Great skua	*Stercorarius skua*	17	24	41
Pomarine skua	*Stercorarius pomarinus*	0	1	1
Arctic skua	*Stercorarius parasiticus*	1	1	2
Guillemot	*Uria aalge*	393	243	636
Razorbill	*Alca torda*	227	88	315
Unidentified Guillemot/Razorbill		552	651	1203
Puffin	*Fratercula arctica*	219	346	565
Black Guillemot	*Cepphus grylle*	0	1	1
Total		2898	3819	6717

Table 16. Totals of migrant terrestrial bird species recorded between 10th June and 23rd July 2018.

Leg 1:

Vernacular Name	Scientific Name	Total
Unidentified passerine sp.		1
Racing pigeon	*Columba livia* domest.	7
Swift	*Apus apus*	1
Collared dove	*Streptopelia dedaocto*	6
Total		15

Leg 2:

Vernacular Name	Scientific Name	Total
Dunlin	*Calidris alpina*	25
Total		25

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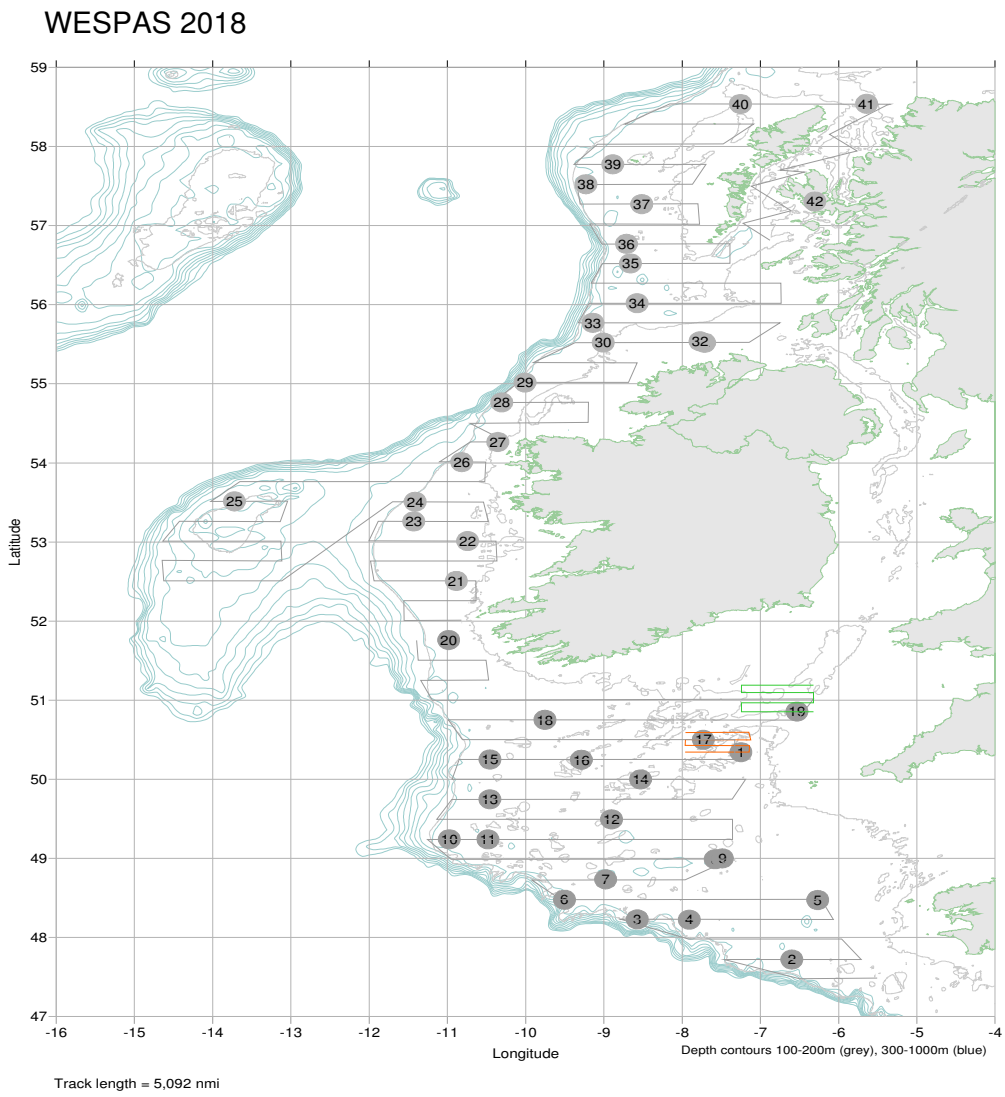

Figure 1. Survey cruise track (grey line) and numbered directed pelagic trawl stations. Corresponding catch details are provided in Table 2. Green line indicates transect survey conducted by autonomous vehicle in the western Celtic Deep and orange line indicates survey carried out by the *C. Explorer* on the Northwest bank.

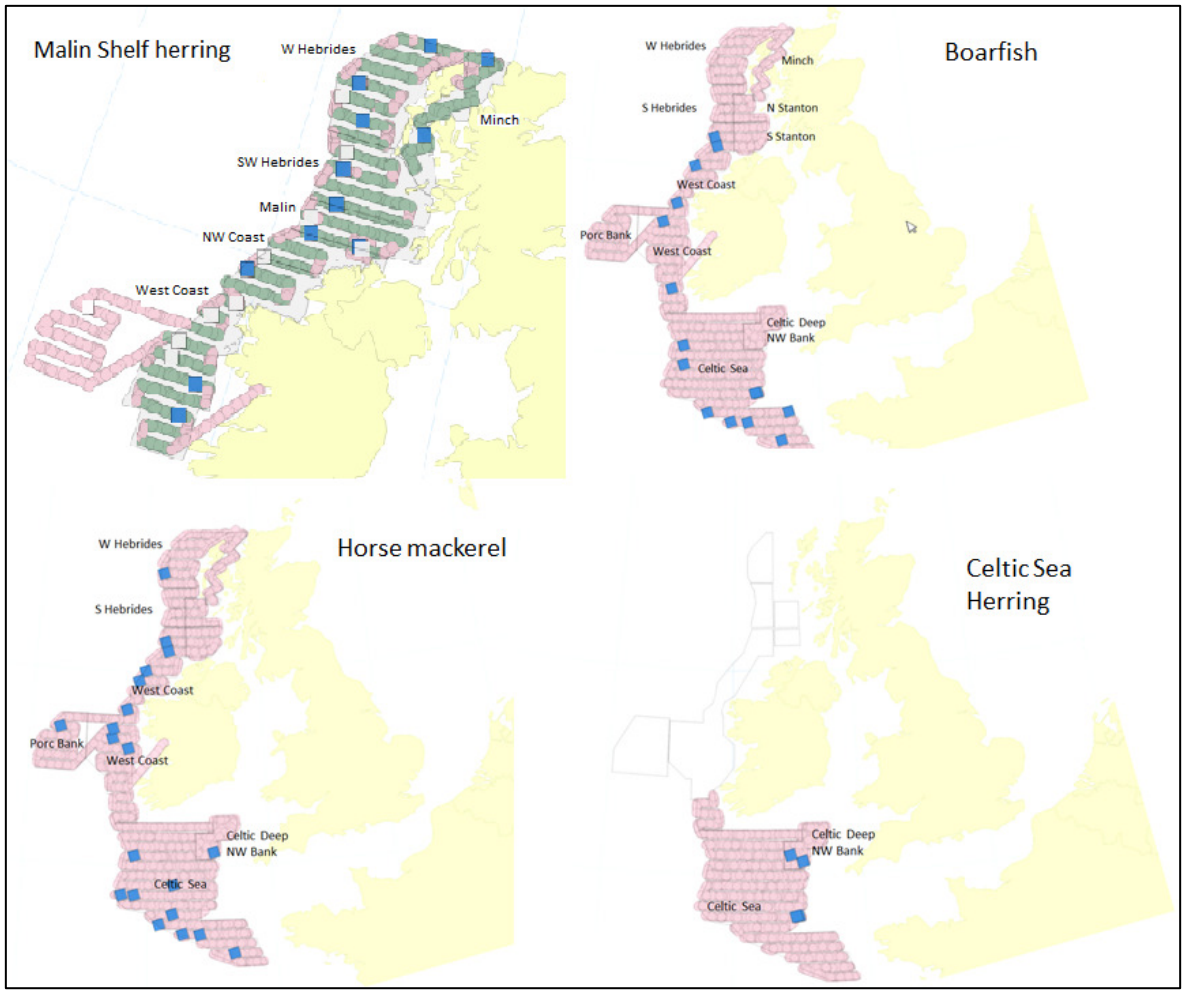

Figure 2. Acoustic sampling area stratification as applied during the calculation of species specific acoustic abundance.

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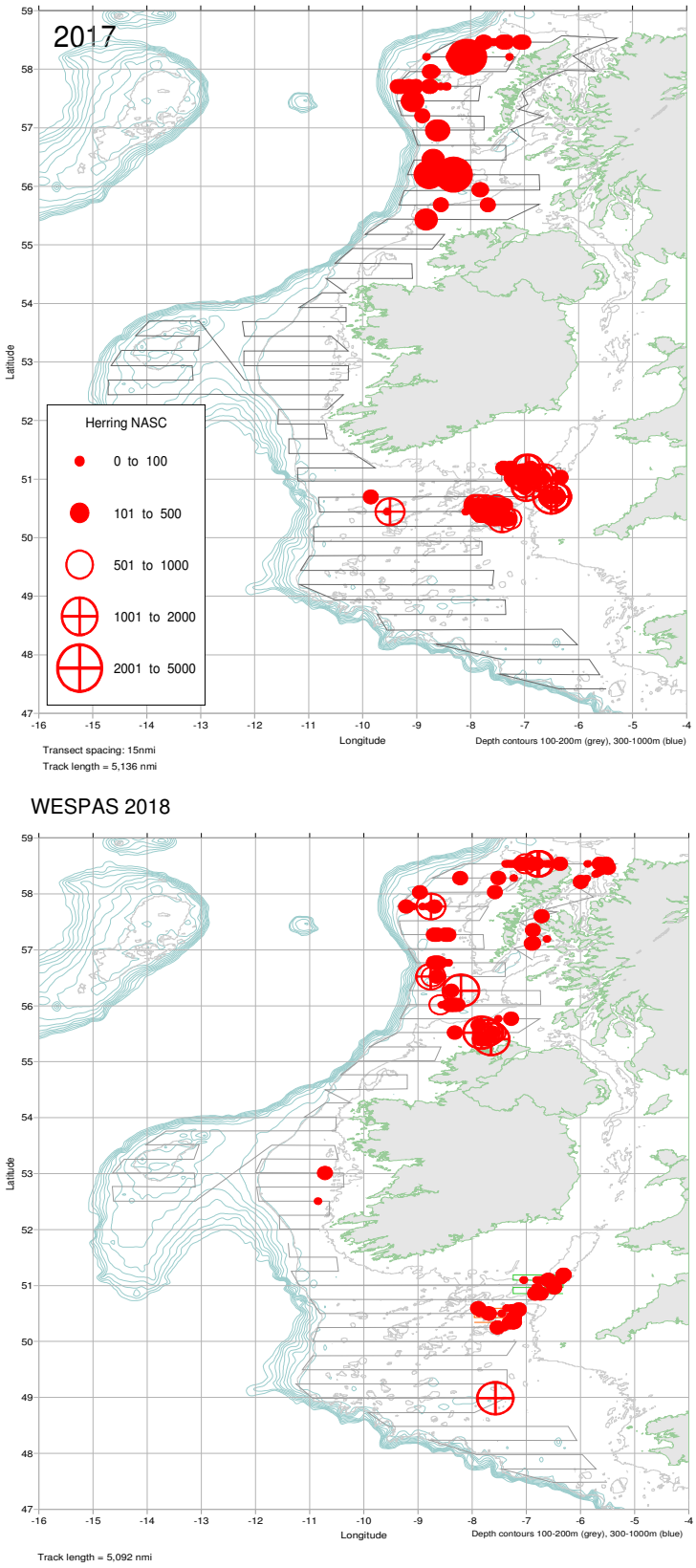

Figure 3. Malin Shelf (north of 54°N) and Celtic Sea (south of 52°N) herring distribution by weighted acoustic density and Celtic Sea her. Top panel 2017, bottom panel 2018.

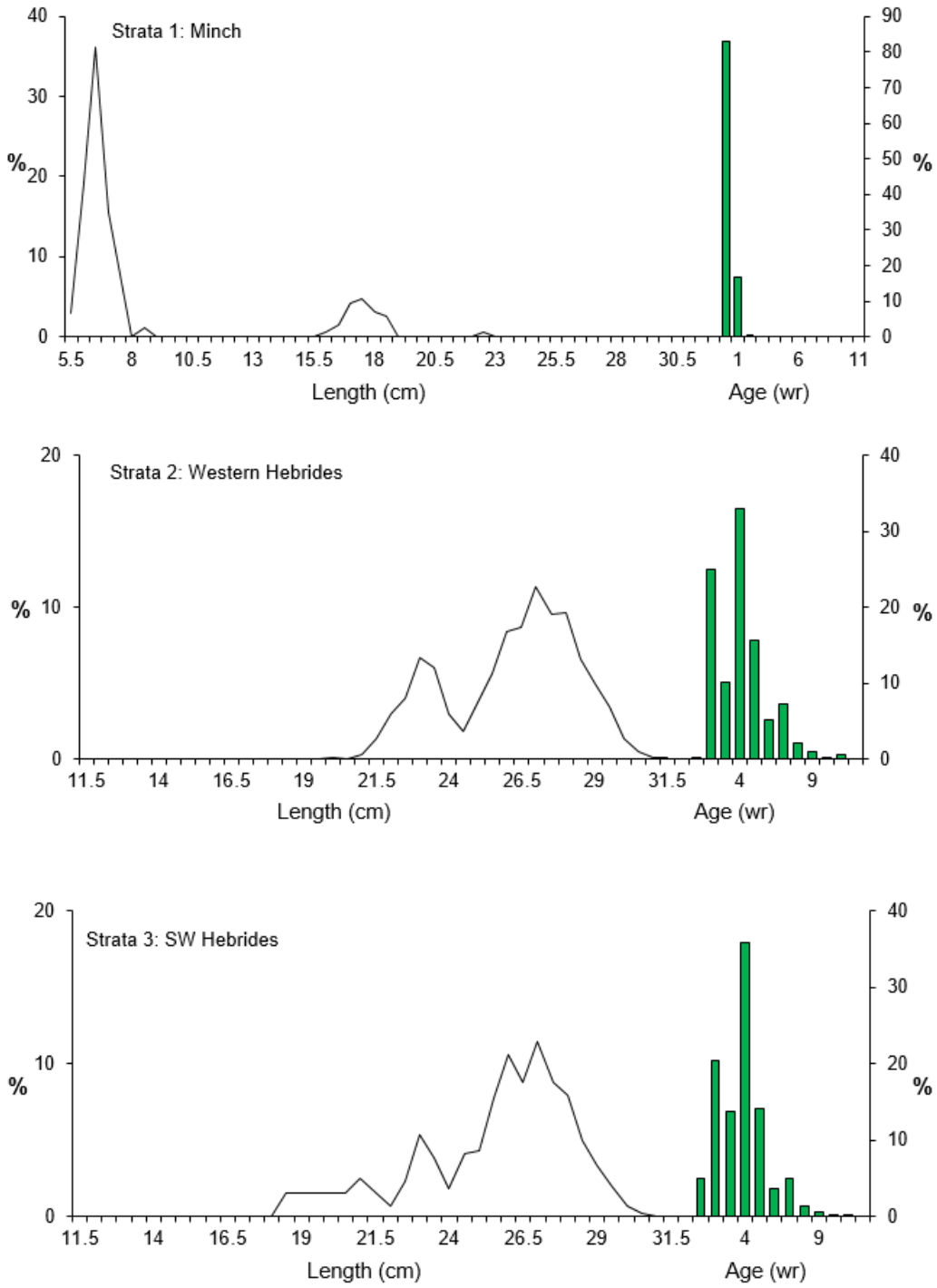

Figure 4. Length and age distribution of Malin Shelf herring by stratum and total survey area during WESPAS 2018.

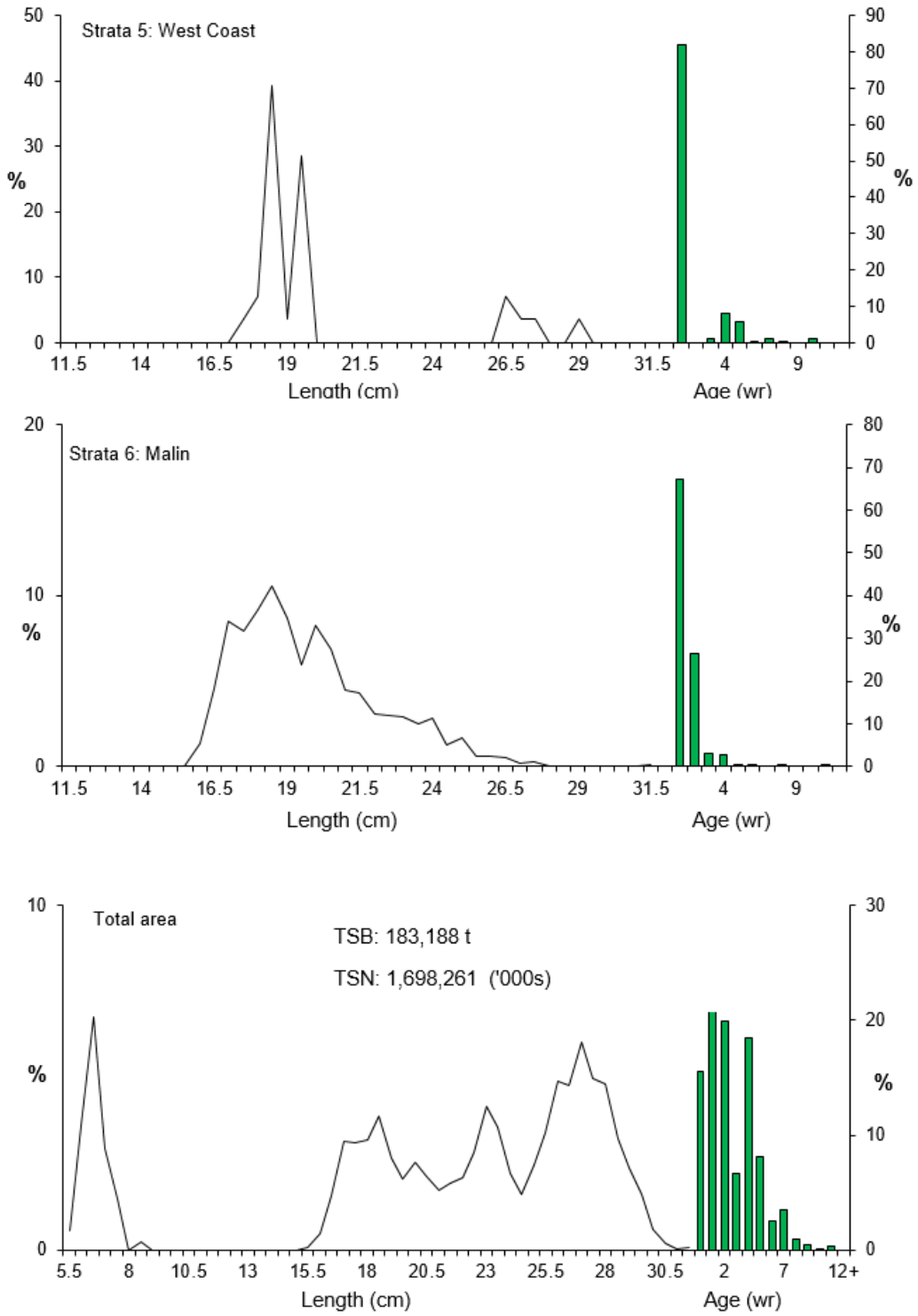

Figure 4. Cont.

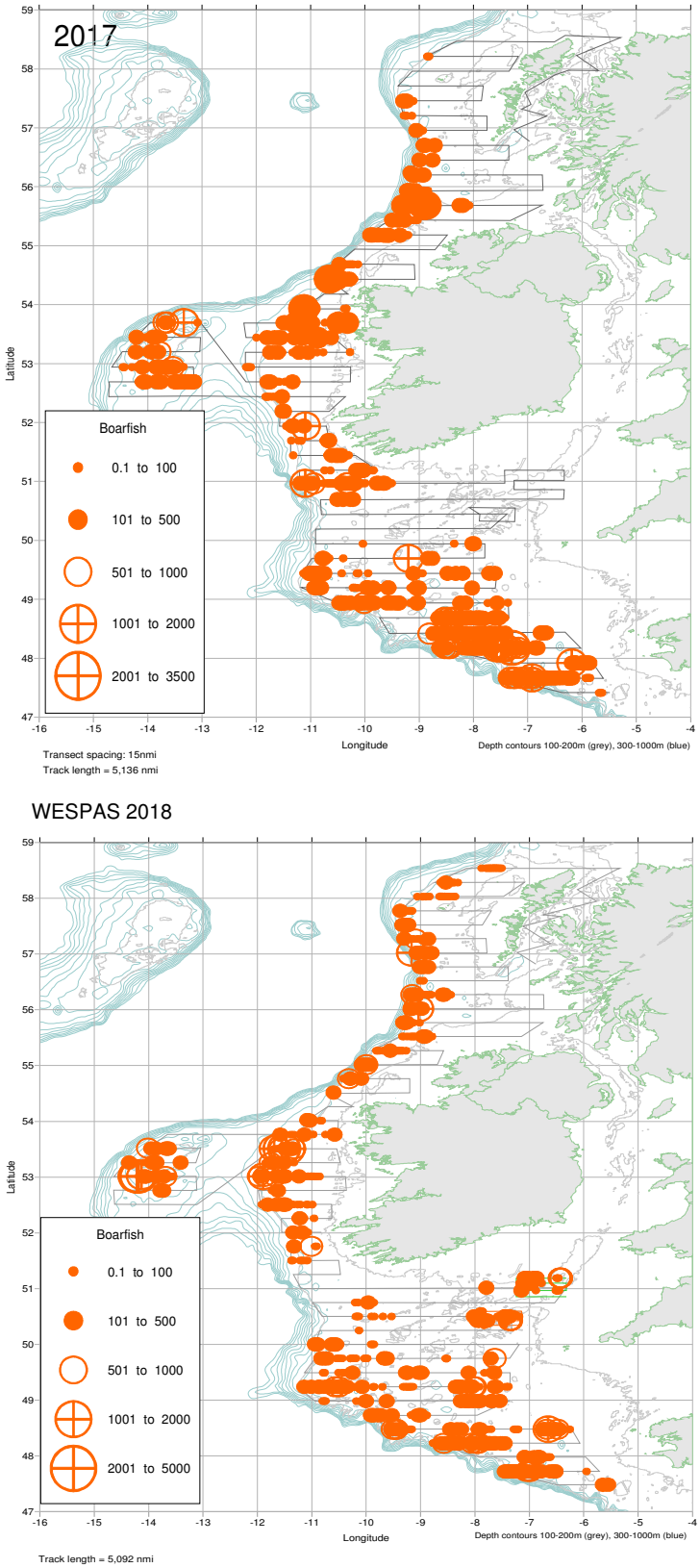

Figure 5. Boarfish distribution by weighted acoustic density. Top panel 2017, bottom panel 2018.

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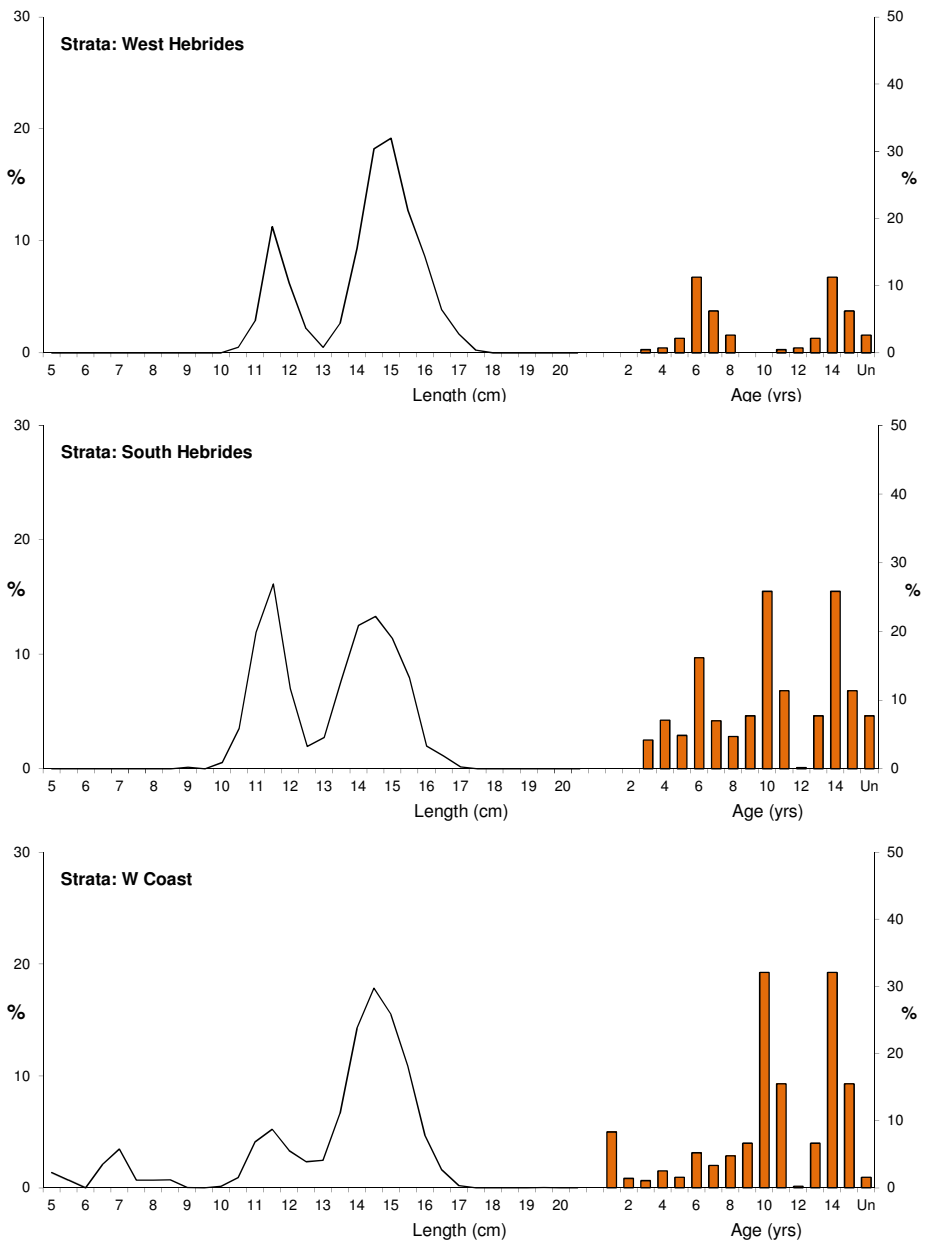

Figure 6. Length and age distribution of boarfish by stratum and total survey area.

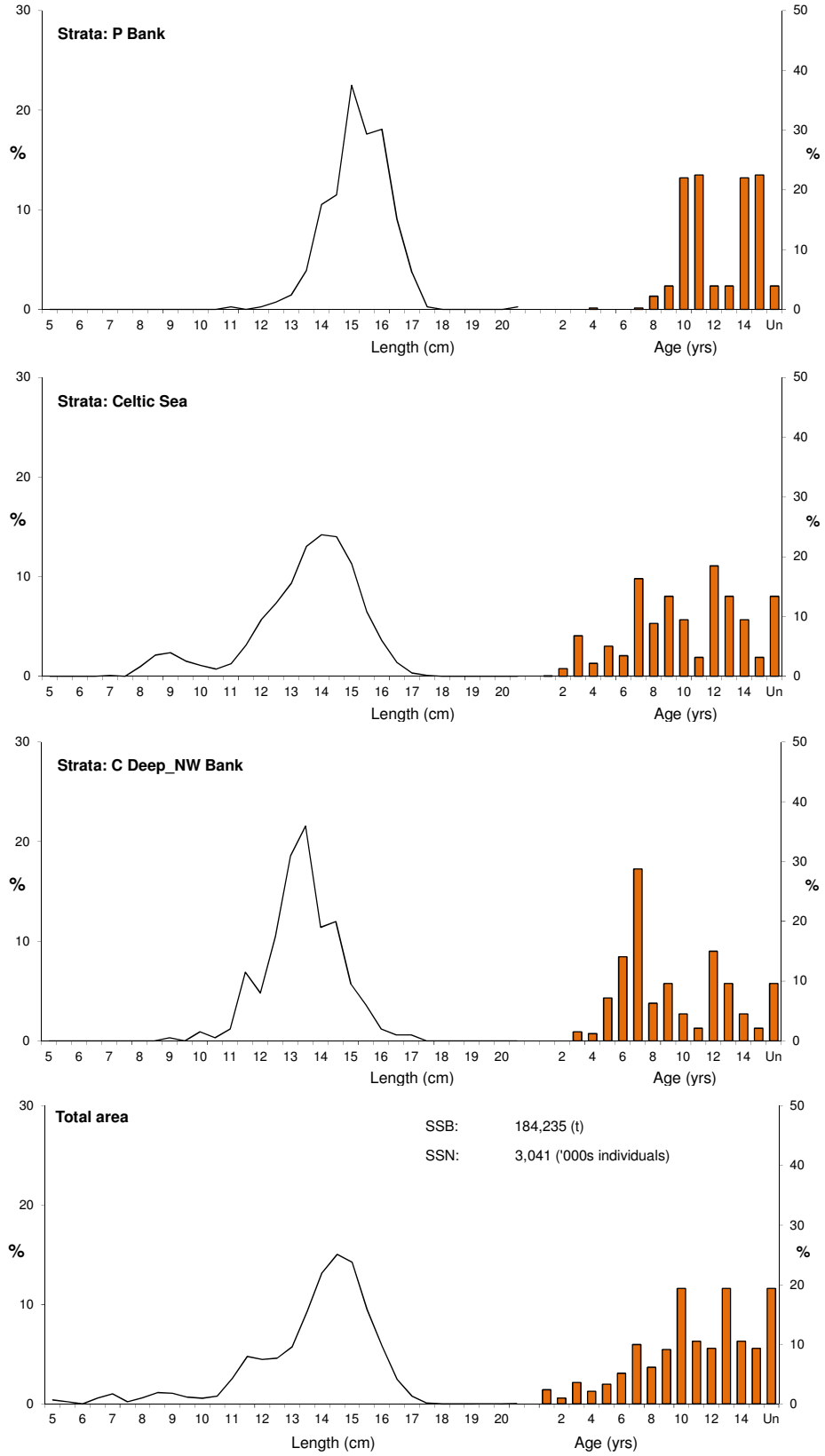

Figure 6. cont.

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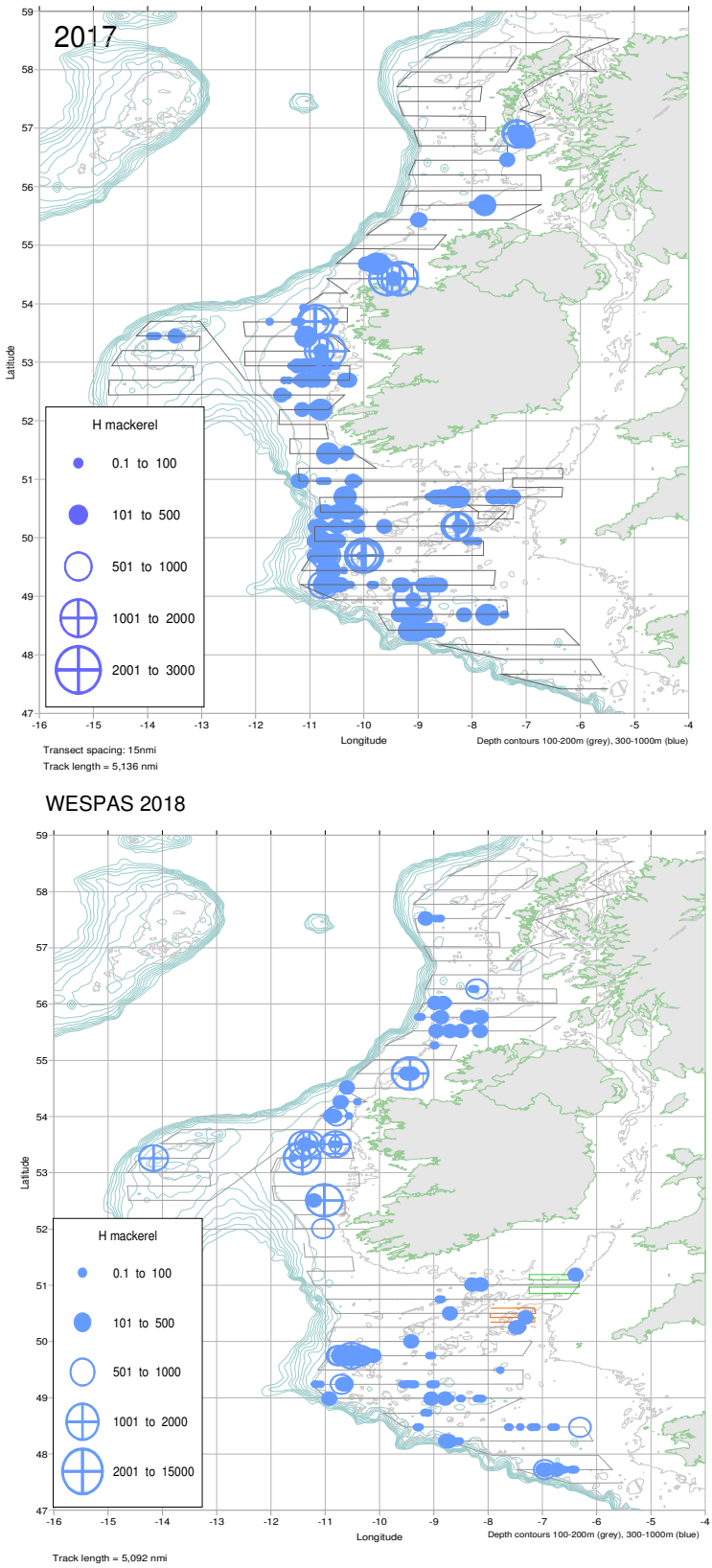


Figure 7. Horse mackerel distribution by weighted acoustic density. Top panel 2017, bottom panel 2018.

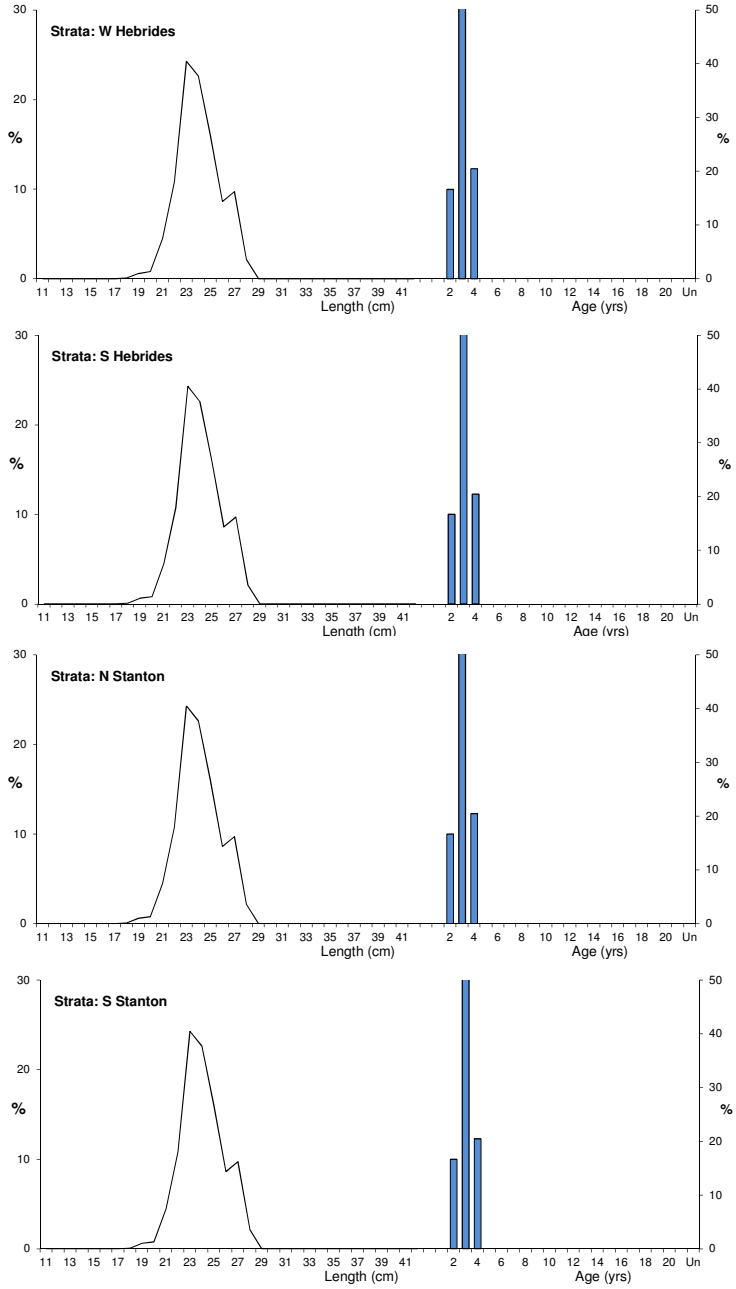


Figure 8. Length and age distribution of horse mackerel by stratum and total survey area.

Fisheries Ecosystems Advisory Services

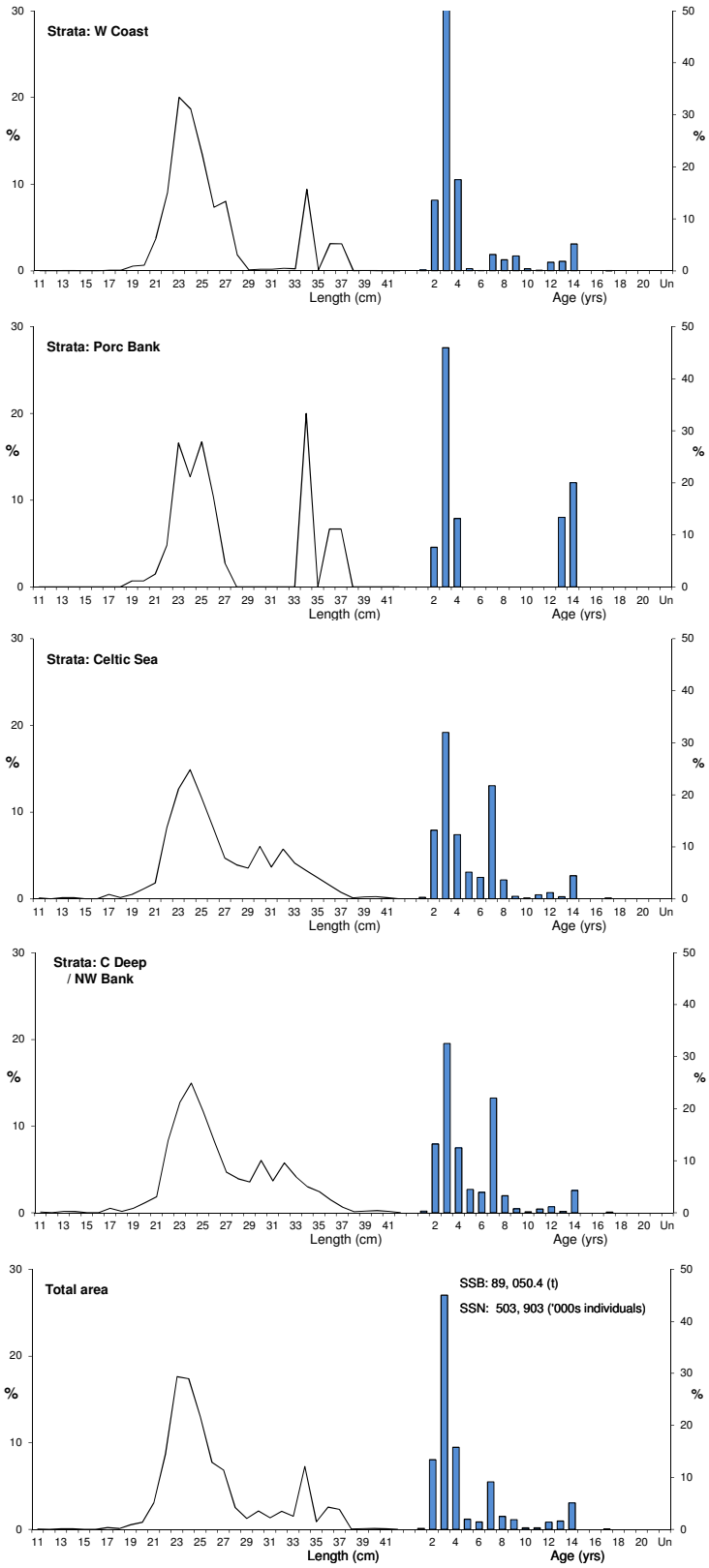


Figure 8. continue

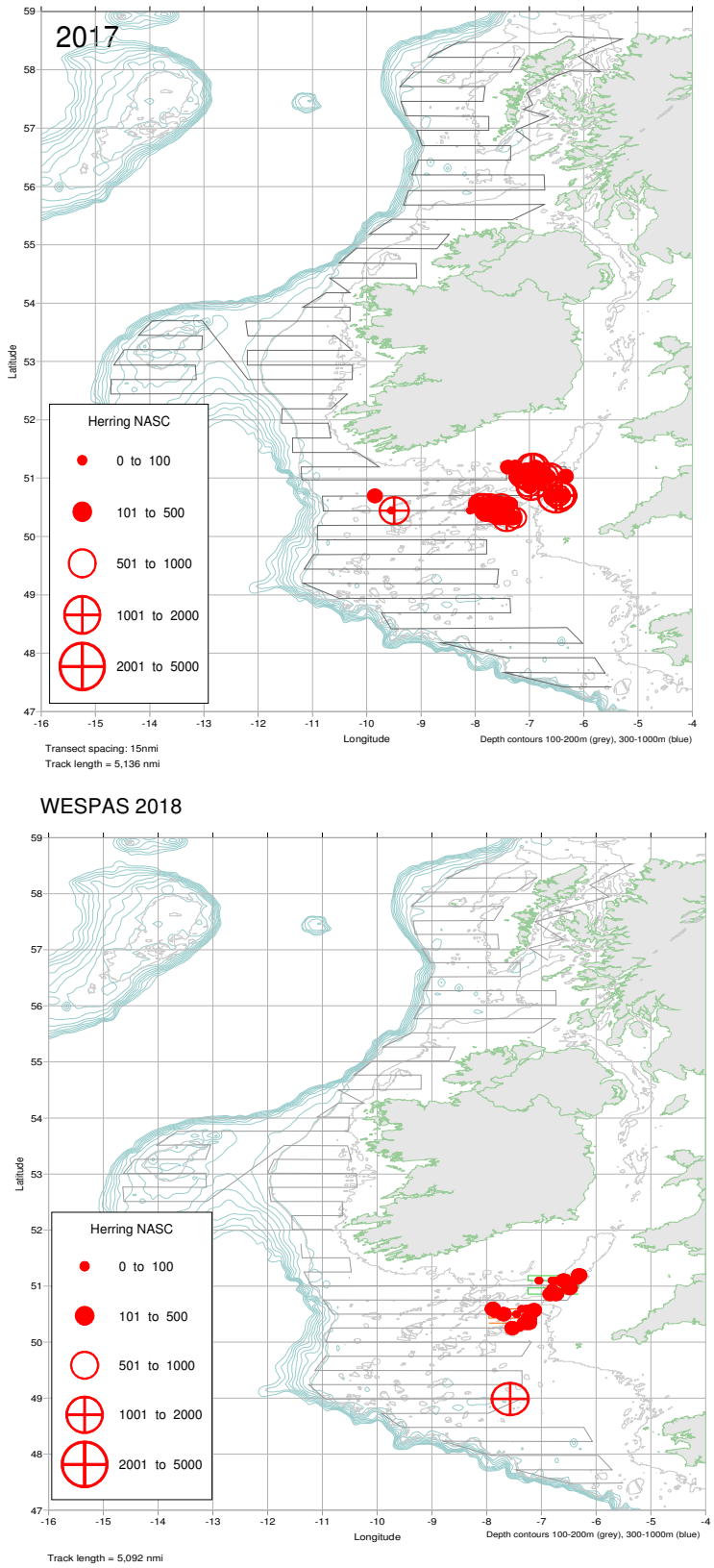


Figure 9. Celtic Sea herring distribution by NASC (Nautical area scattering coefficient)

Fisheries Ecosystems Advisory Services

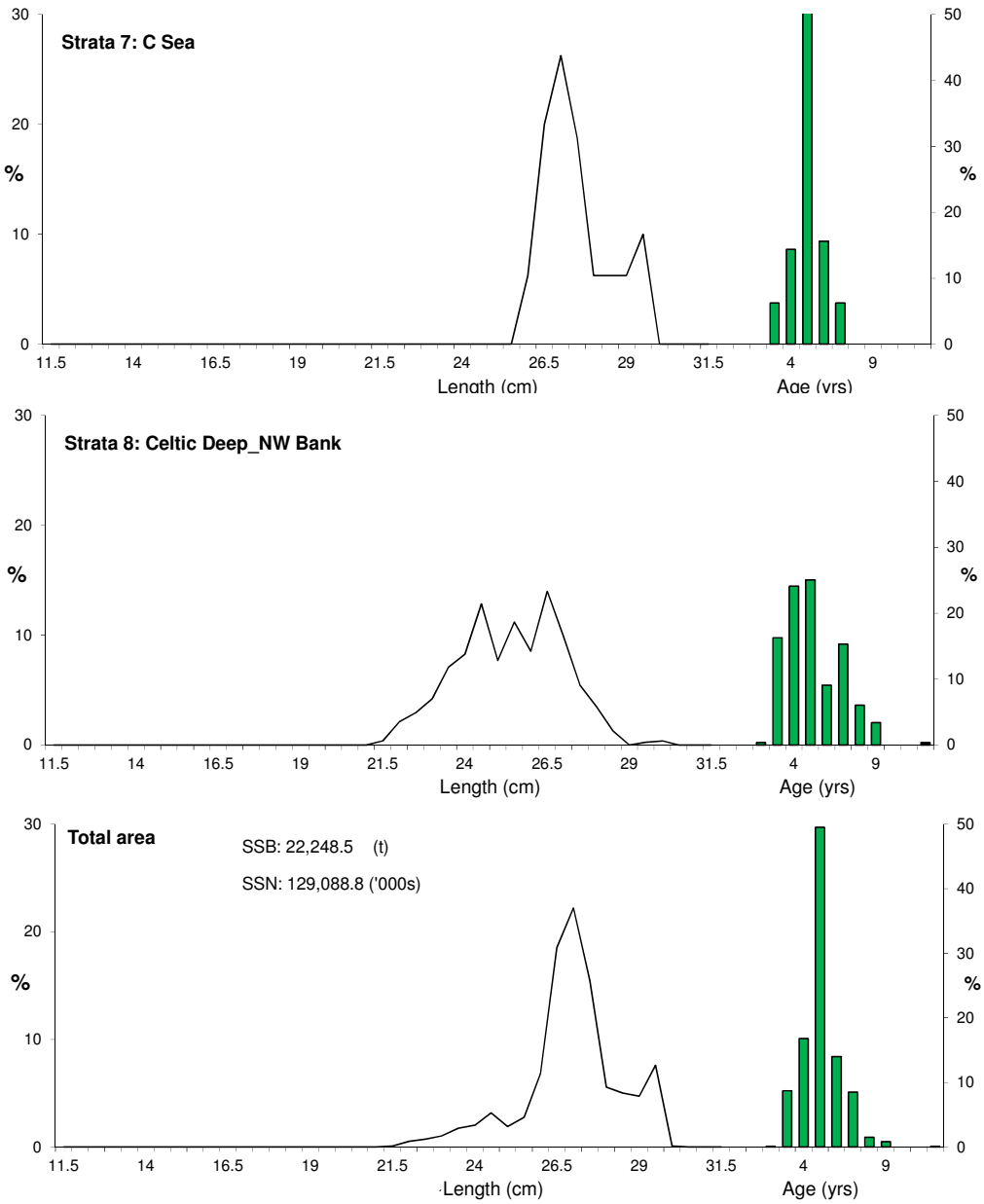
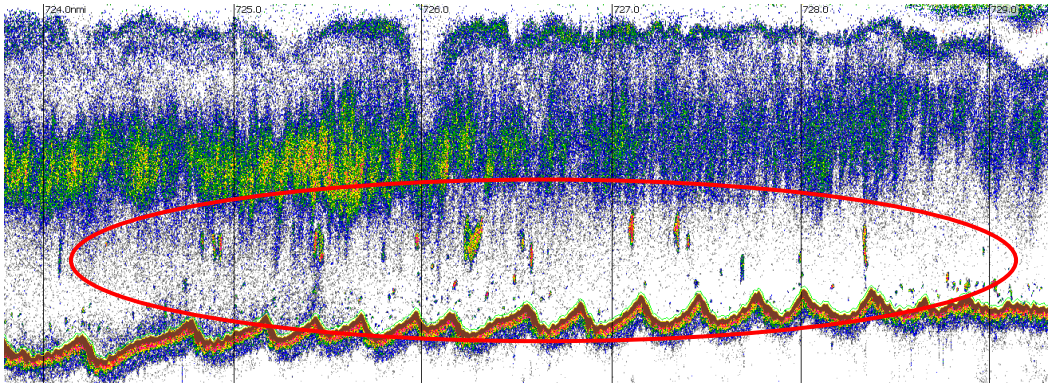
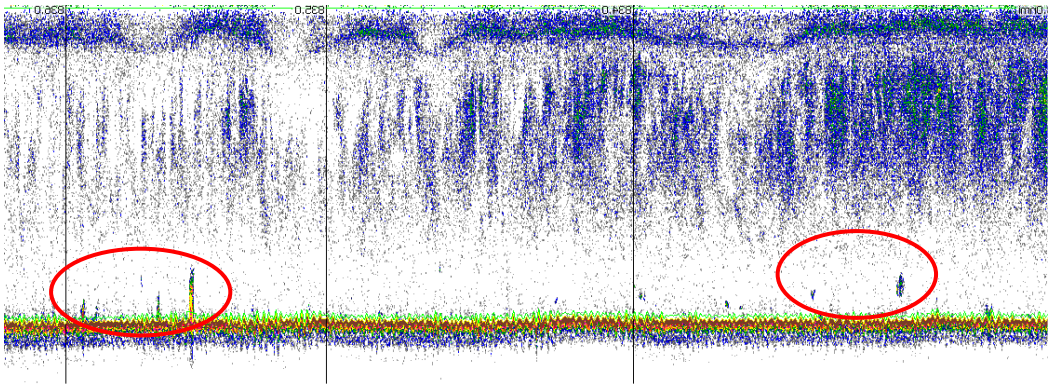


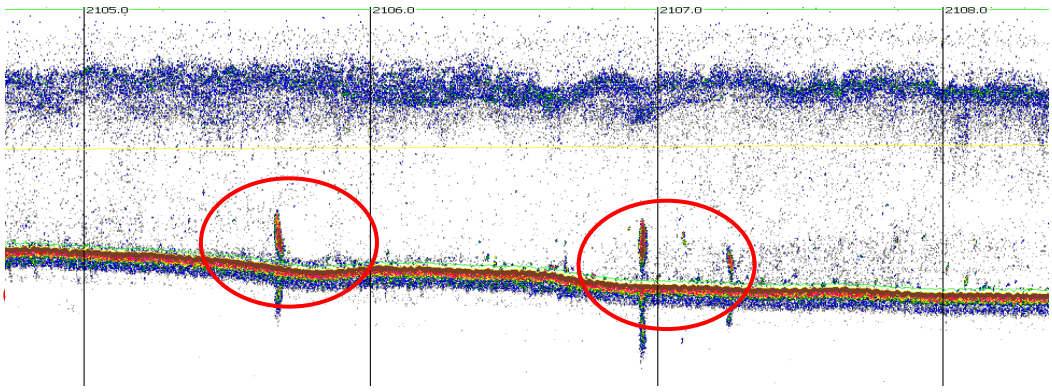
Figure 10. Length and age distribution of Celtic Sea herring by stratum and total survey area.



a). *Haul 04, Southern Celtic Sea. Pelagic schools of mature boarfish (circled red) close to the shelf edge. Water depth 180 m.*

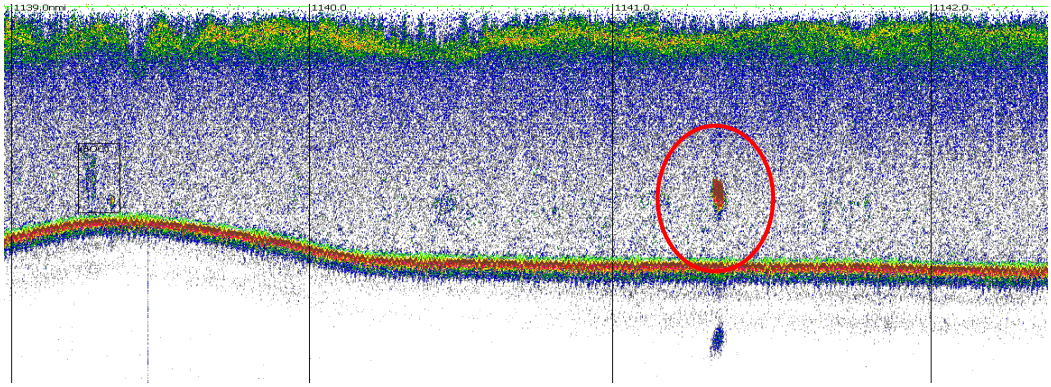


b). *Haul 05, Southern Celtic Sea. Medium density horse mackerel schools in the eastern survey area off the French coast. Water depth 130 m.*

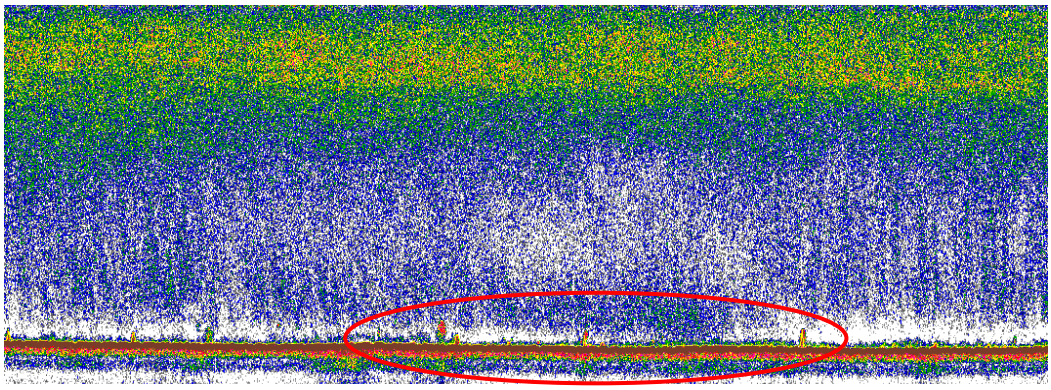


c). *Haul 16. Mid Celtic Sea. Example of high density schools of juvenile (0-group) blue whiting commonly encountered in the mid Celtic Sea. Water depth 132 m.*

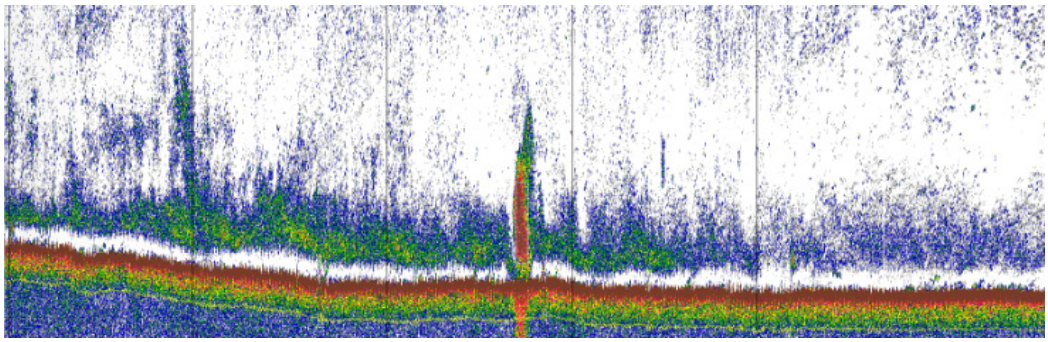
Figures 11a-j. Echotraces recorded on an EK60 echosounder (38 kHz) with images captured from Echoview. Note: Vertical bands on echogram represent 1nmi (nautical mile) intervals.



d). *Haul 08. High density single herring school located close to Jones Bank, water depth 146 m.*

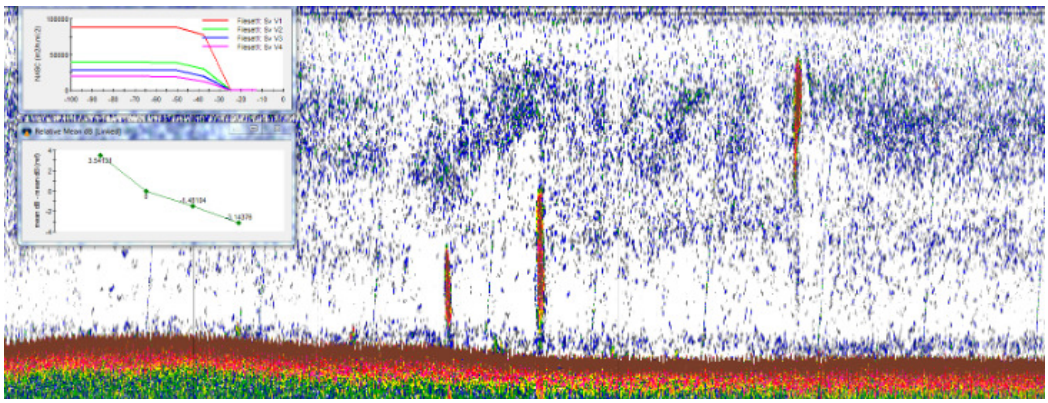


e). *Haul 01. Northwest Bank. Small, medium density schools of herring located on the bottom. Water depth 104 m.*

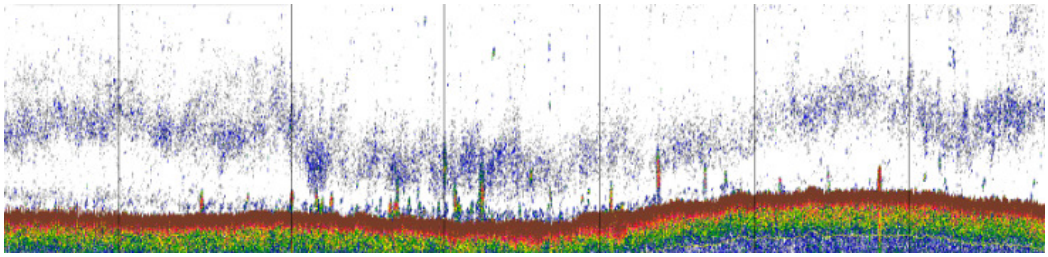


f). *Haul 39. SW of St. Kilda, high density herring school, water depth 152 m.*

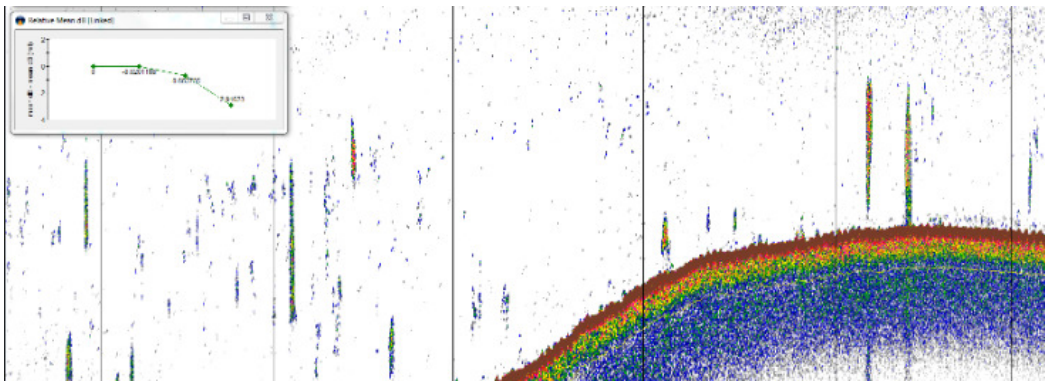
Figures 11a-i. continued



g). *Haul 32. SE Stanton Bank, mid-water herring schools (mainly 1- and 2-wr) depth 69 m.*

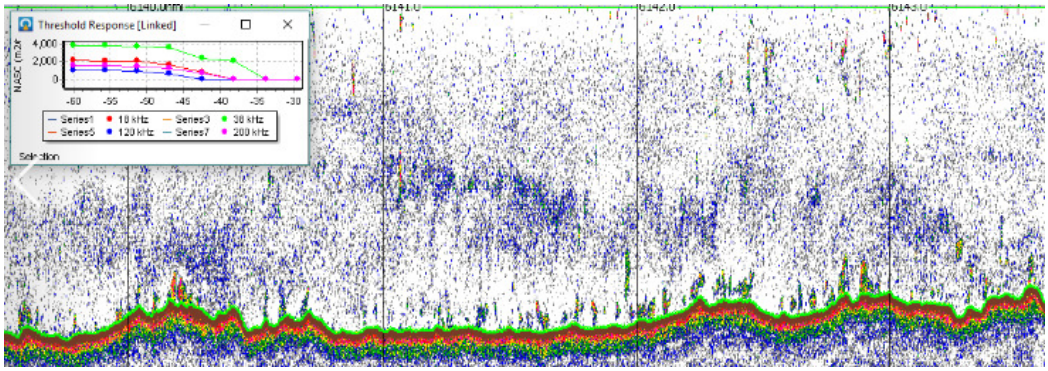


h). *Haul 35. W Stanton Bank, herring marks along bottom on hard ground, water depth 140 m.*

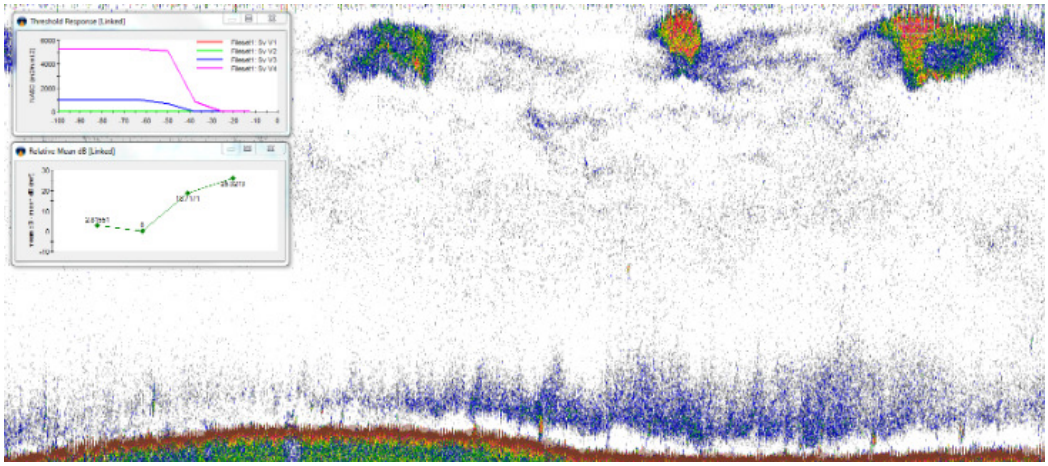


i). *Haul 29. West of Aranmore. High density marks of boarfish close to the shelf edge. Water depth 115-200 m.*

Figures11-i. continued.



J). *Surface marks of 0-group sprat and herring (with mixed gadoids on the bottom) in the Minch*



k). *Surface marks of mackerel as observed on the 200 kHz west of the Hebrides; common throughout the Malin Shelf area.*

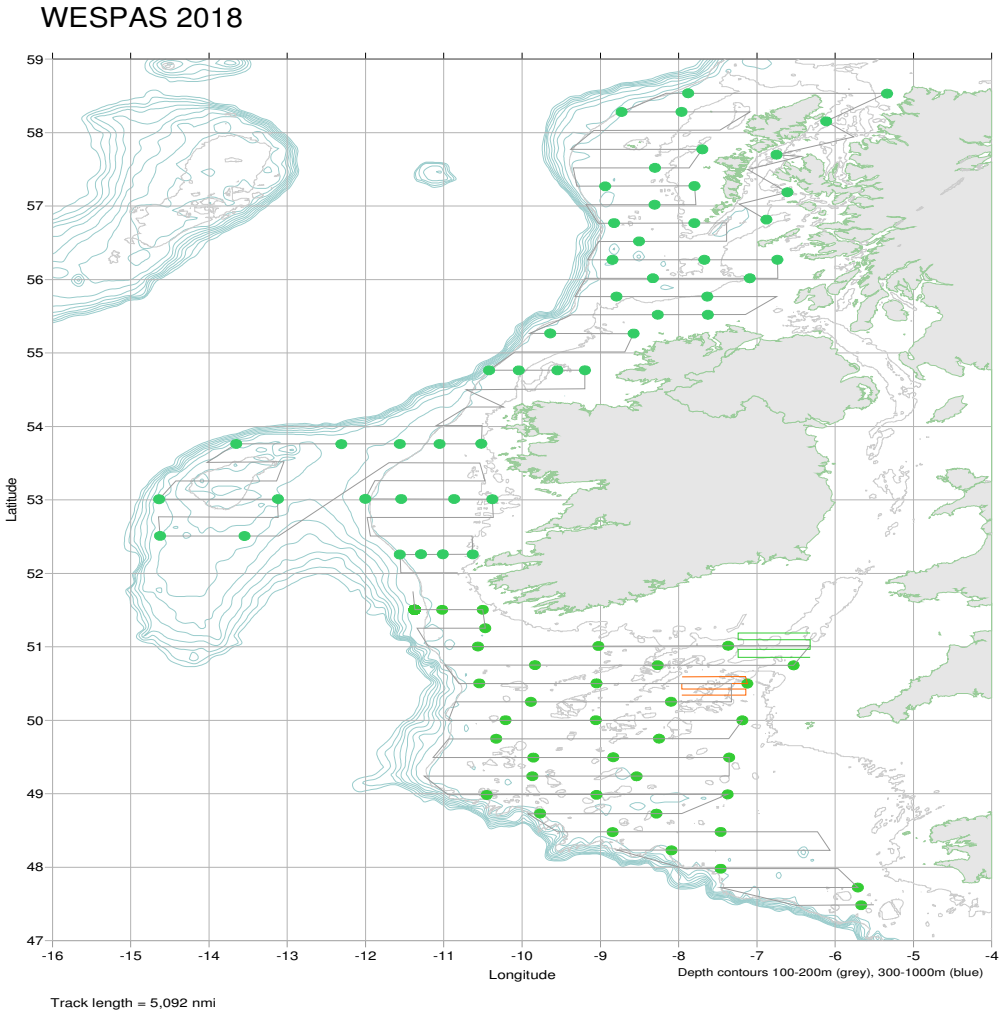


Figure 12. Position of hydrographic and co-occurring zooplankton sampling stations (n=86).

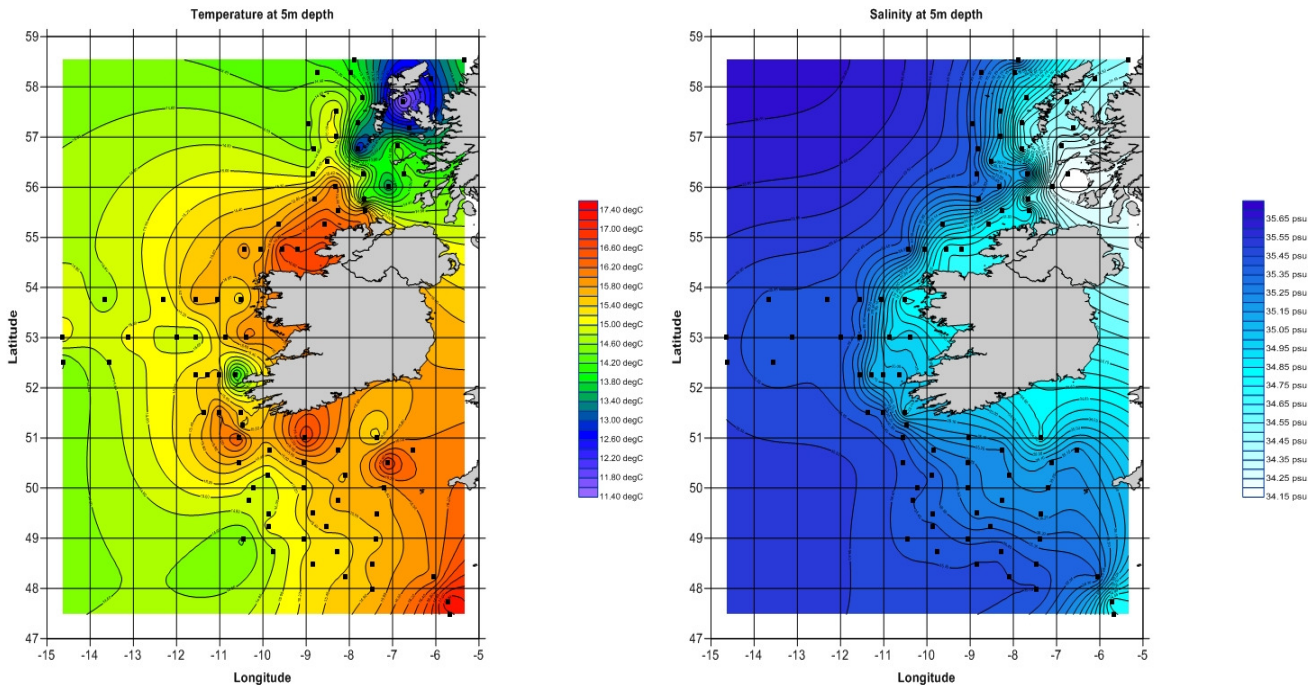


Figure 13. Surface (5m) plots of temperature and salinity compiled from CTD cast data. Station positions with valid data shown as block dots (n=86).

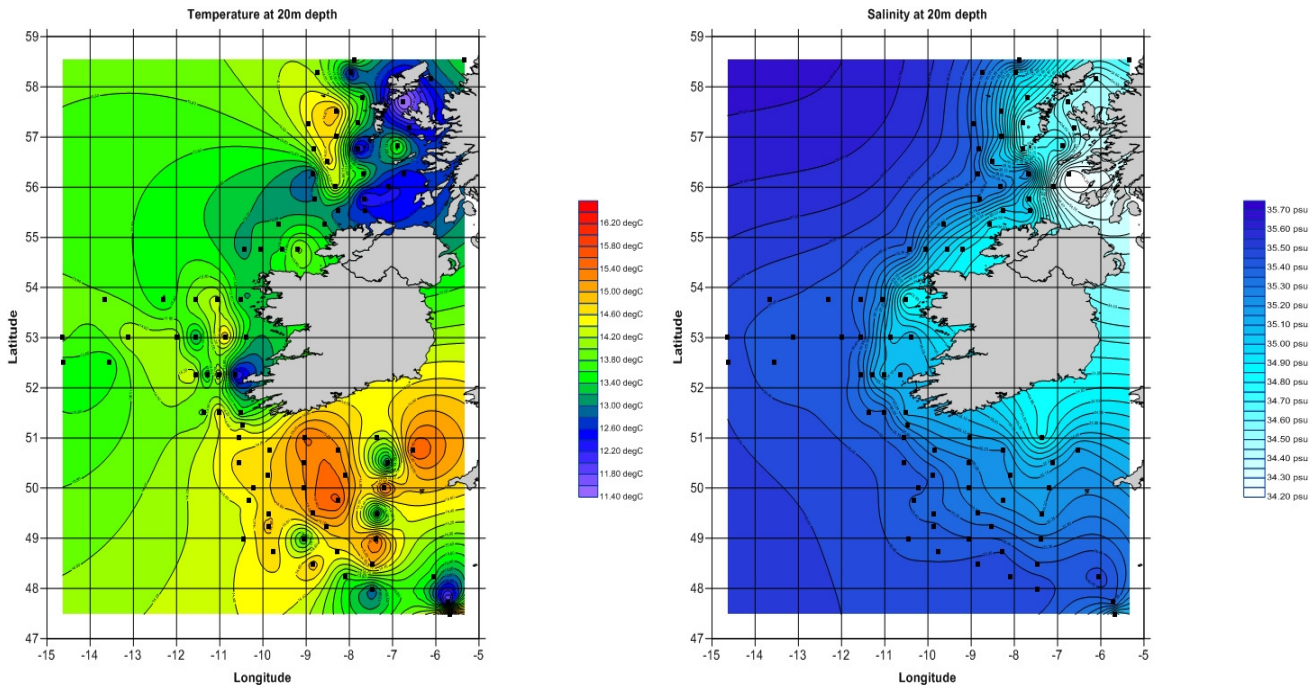


Figure 14. Plots of temperature and salinity compiled from CTD cast data at 20m depth. Station positions with valid data shown as block dots (n=86).

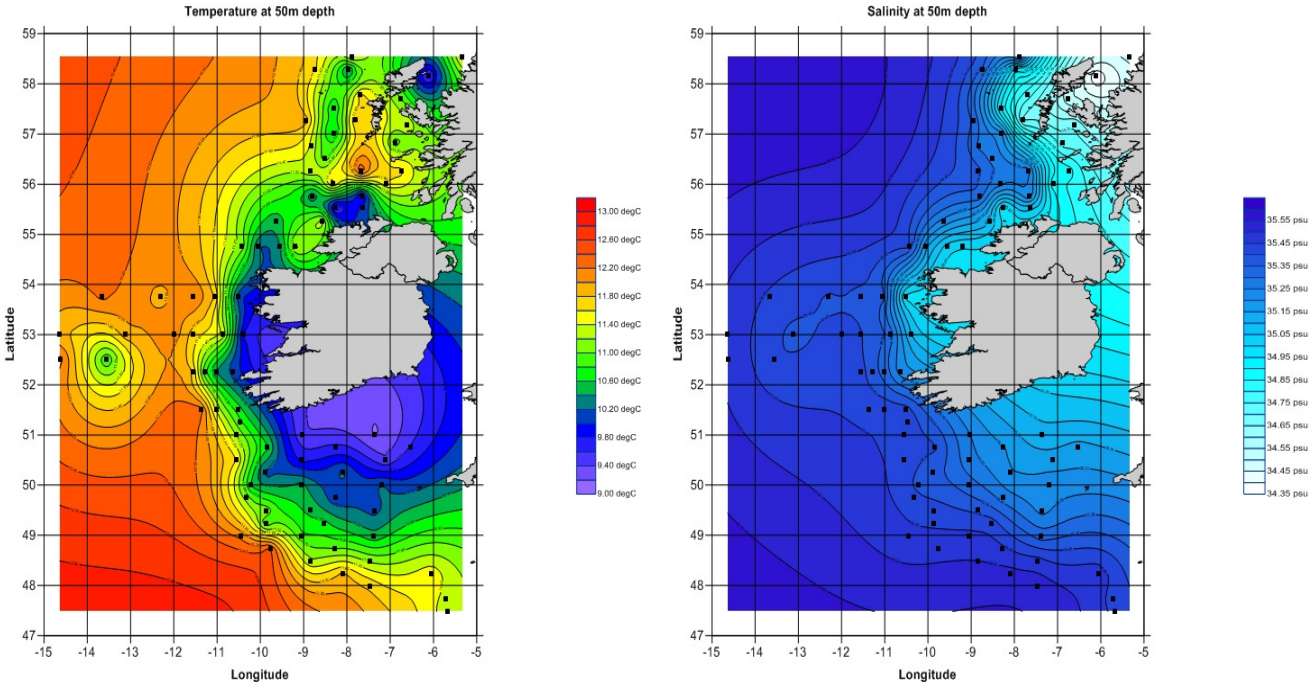


Figure 15. Plots of temperature and salinity compiled from CTD cast data at 50m depth. Station positions with valid data shown as block dots (n=86).

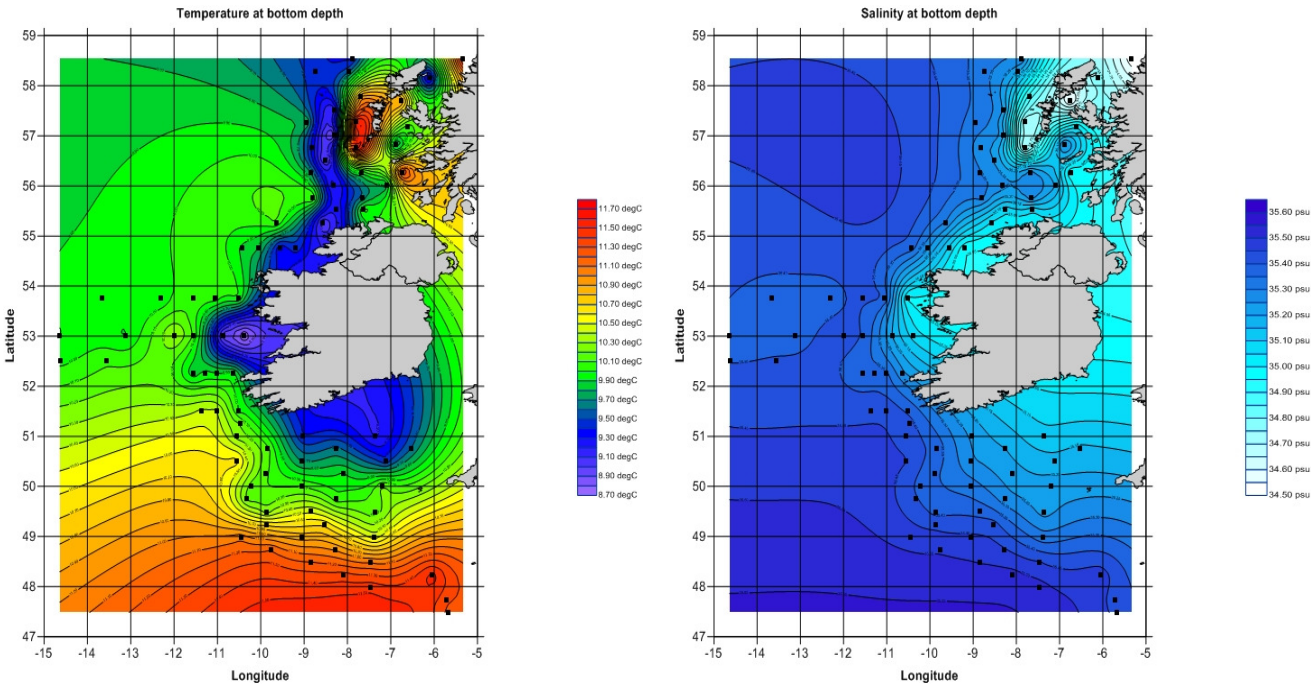


Figure 16. Plots of temperature and salinity compiled from CTD cast data at the seabed (+3-5m). Station positions with valid data shown as block dots (n=86).

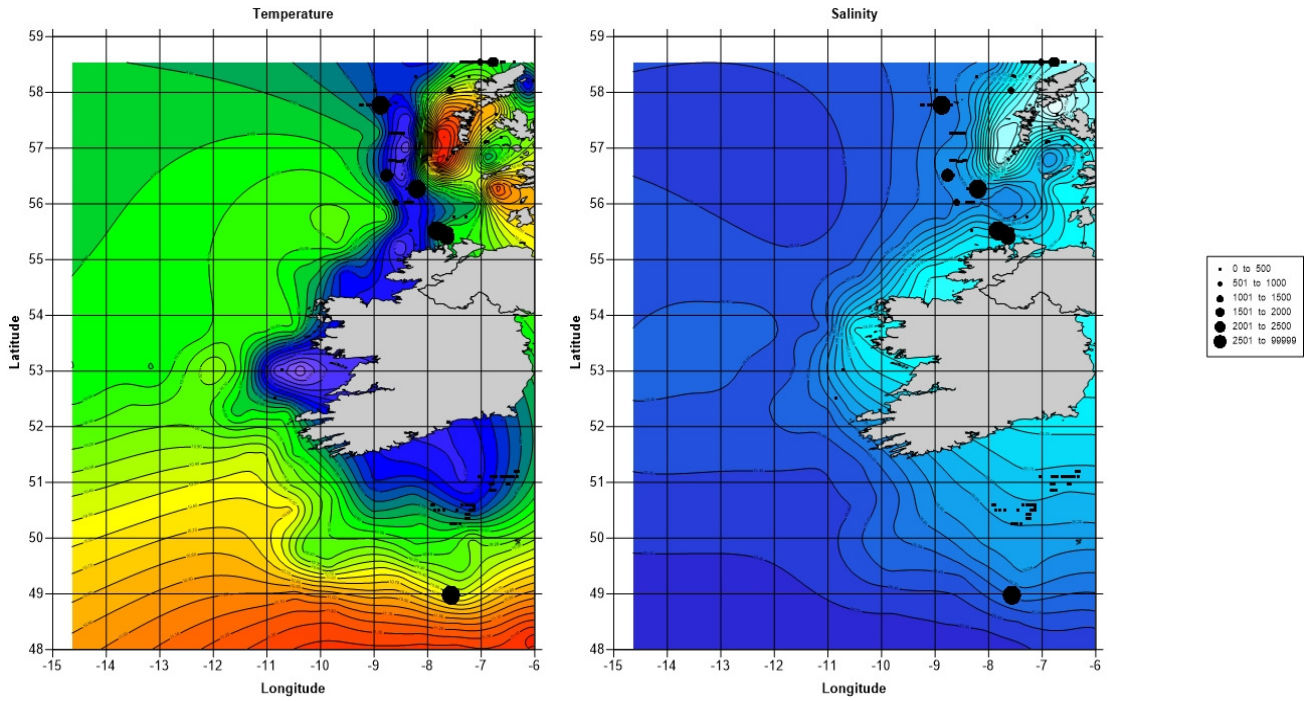


Figure 17. Habitat plots of temperature and salinity with herring distribution. Sea floor values overlaid with herring NASC values (black circles).

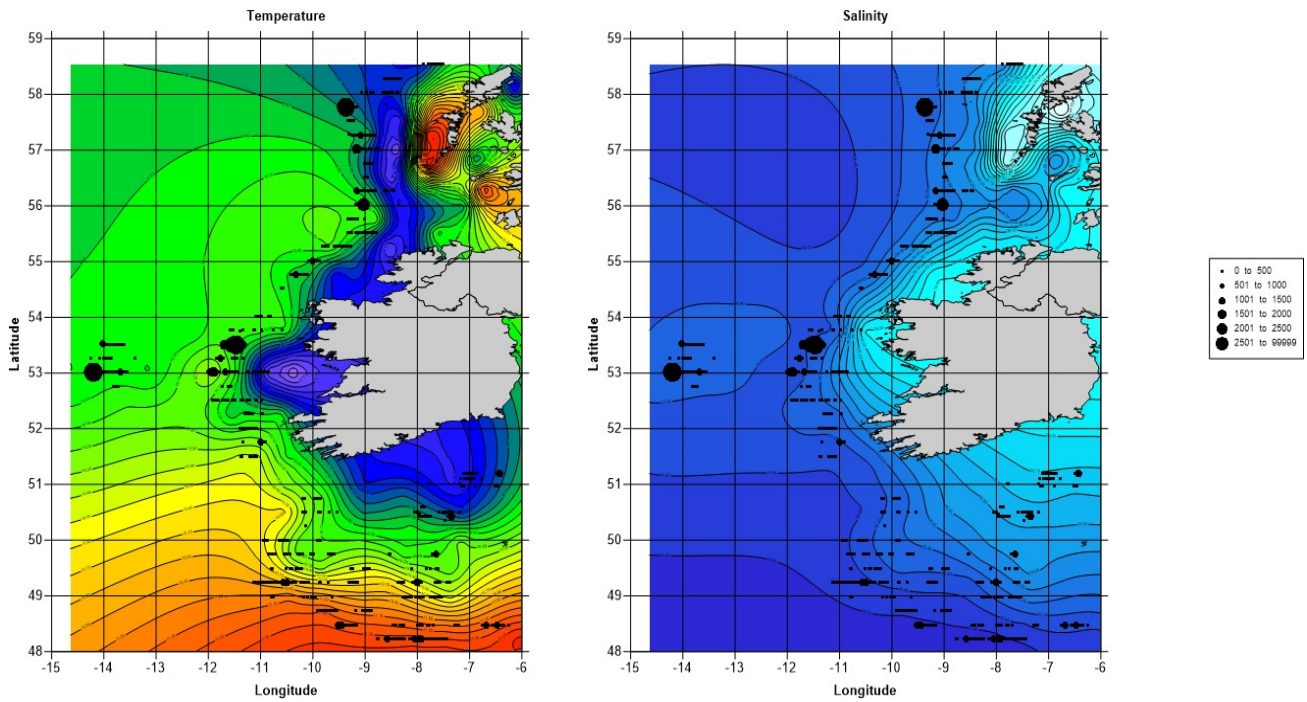


Figure 18. Habitat plots of temperature and salinity with boarfish distribution. Sea floor values overlaid with boarfish NASC values (black circles).

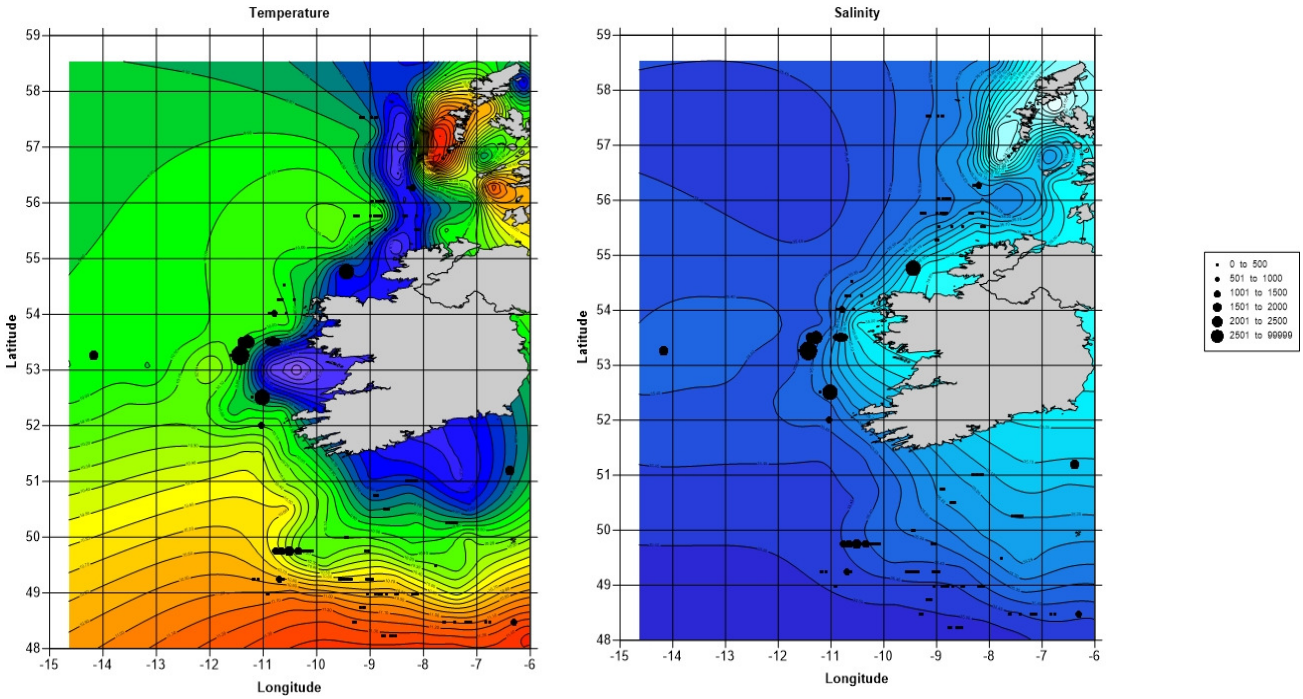


Figure 19. Habitat plots of temperature and salinity with horse mackerel distribution. Sea floor values overlaid with horse mackerel NASC values (black circles).

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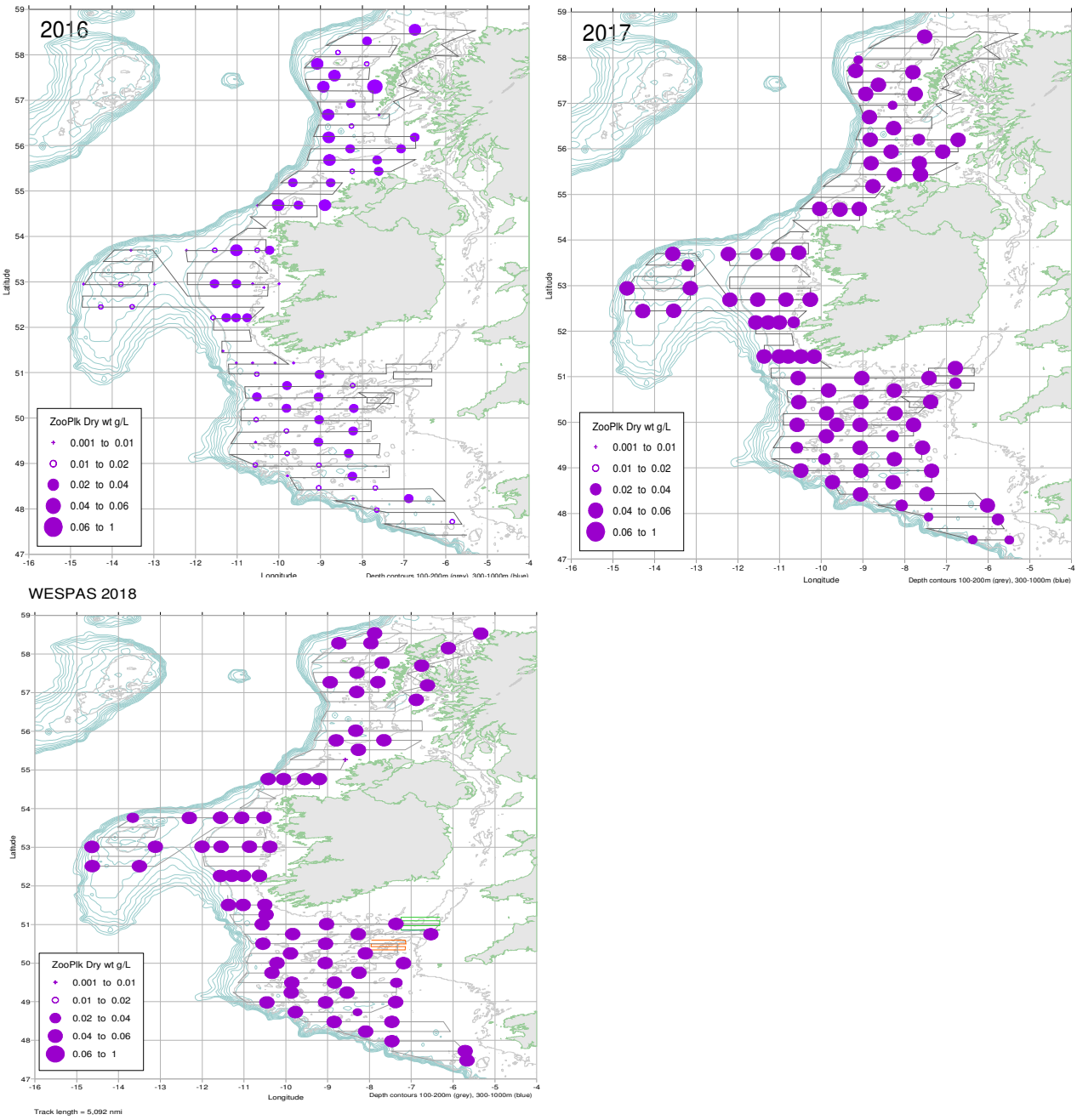

Figure 20. Zooplankton dry weight biomass by station (g dry Wt. m^3) 2016-2018.

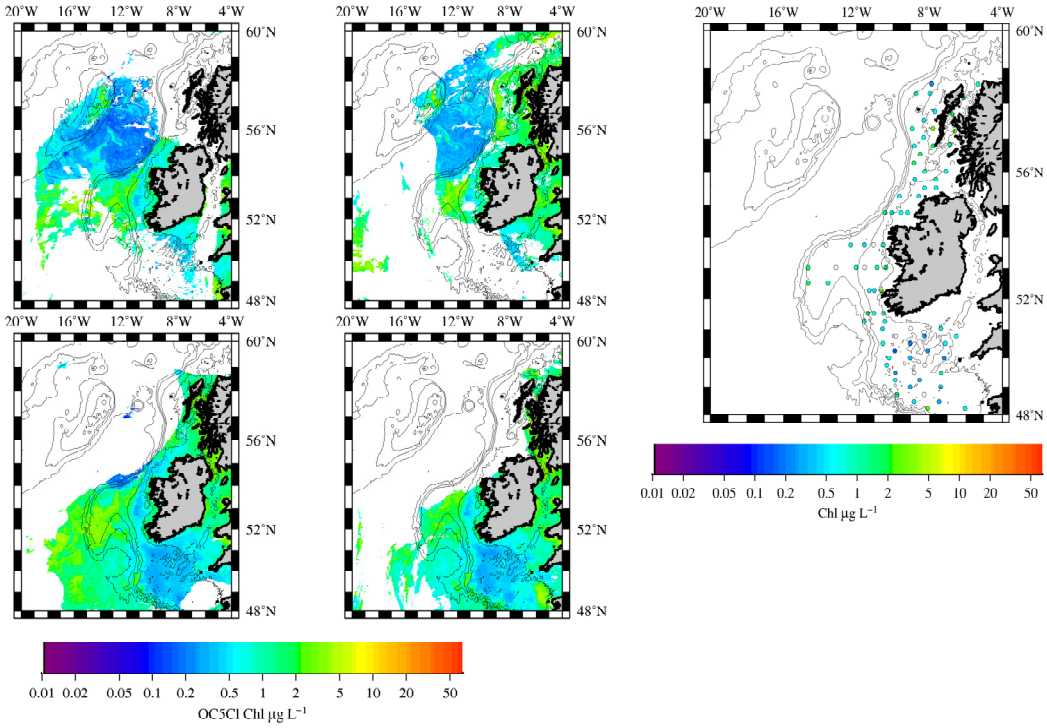

Figure 20. Left panel: OC5Cl Chlorophyll images from June 27, 28, 29 and 30 (Source: CMEMS). Right panel: Near surface mixed layer chlorophyll measurements during WESPAS 2018

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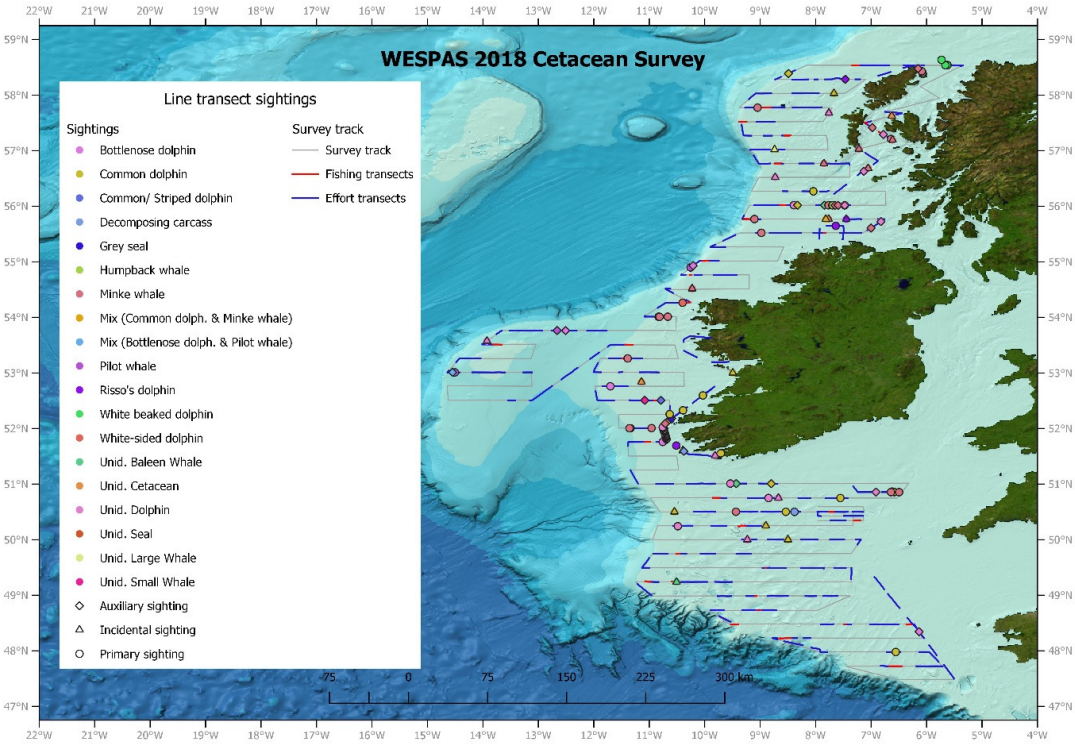

Figure 22. Distribution of marine mammal sightings while on-effort profiled with observer effort.

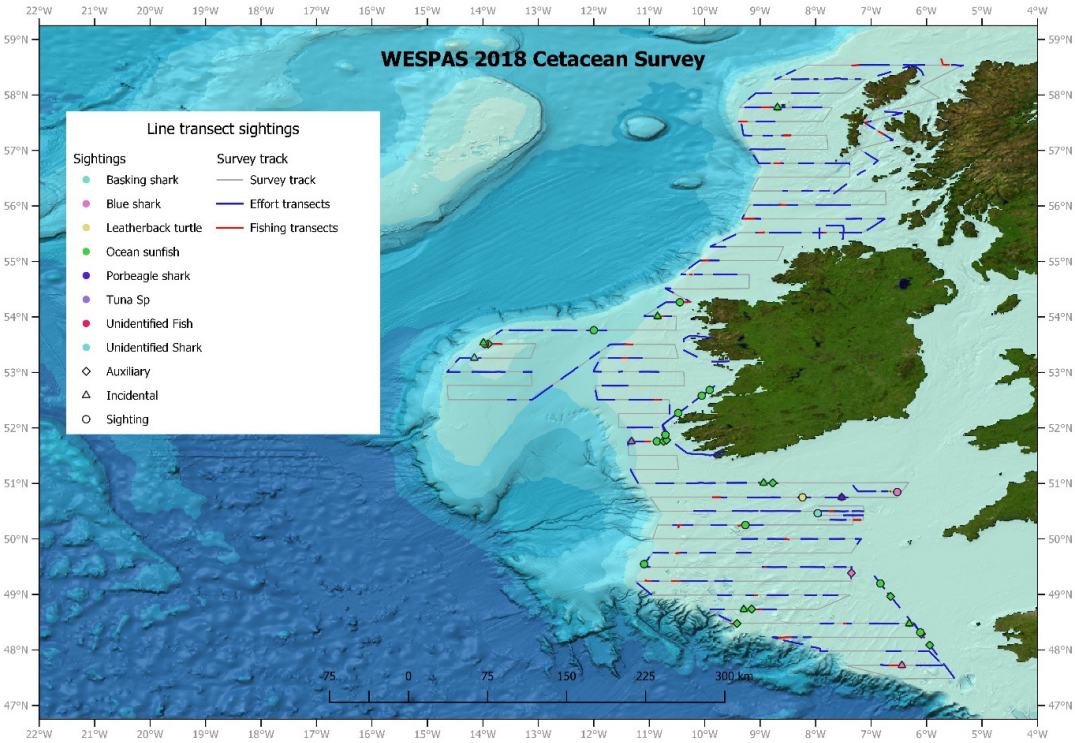

Figure 23. Distribution of marine megafauna sightings during the survey profiled with observer effort.

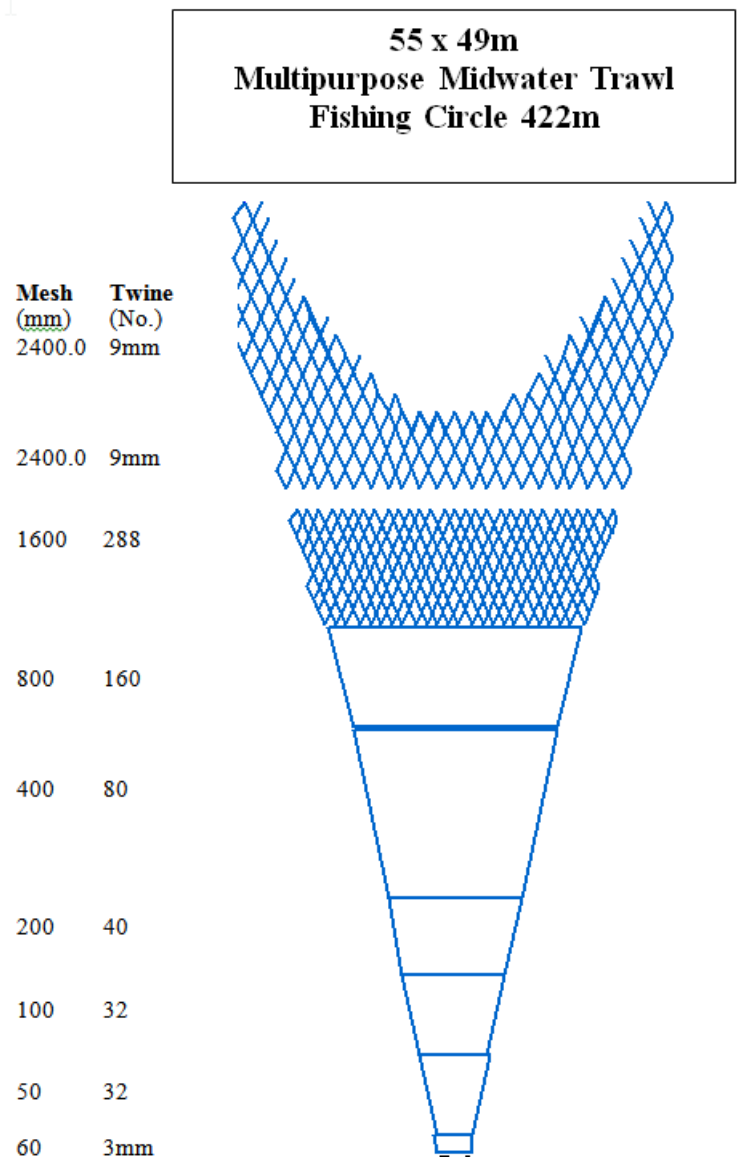

Figure 24. Single multipurpose midwater trawl net plan and layout.

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

Document 12a: PELTIC 2018 survey summary table

Survey Summary table WGIPS 2019	
Name of the survey (abbreviation):	PELTIC
Target Species:	Sprat, sardine, anchovy, mackerel, horse mackerel
Survey dates:	6th October – 10th of November 2018
Summary:	
Peltic18 constituted the 7th autumn survey on small pelagic fish and their ecosystem in the waters of the western English Channel and eastern Celtic Sea. For the second year, the survey was extended beyond the area covered between 2012 and 2016, which had focused solely on the Mackerel Box. The 2018 survey coverage included the French waters of western English Channel and a large part of the eastern Channel. The survey commenced on the 6th of October and ran for 36 effective survey days, starting in the Bristol Channel working into the English Channel. The 2200 nautical miles of effective acoustic coverage were supplemented with 46 valid trawls which provided details on species composition and biological information. Preliminary results indicated that, despite the hot summer preceding the survey, surface temperatures were similar to the ones recorded in 2017, although the stratification was stronger. In addition, salinity was higher than previous years, most likely due to reduced rainfall. Sardine dominated the pelagic ichthyofauna, Anchovy was found in larger numbers than in 2017 but sprat biomass decreased in the whole survey area, although it was more widespread north of the Cornish Peninsula. Sardine egg- and larval maps showed similar geographical areas of sardine spawning compared to previous years with the waters at the mouth of the English Channel being most important. For the first time since 2012, Atlantic bonito (*Sarda sarda*) were caught (at four different stations). Feeding Atlantic Bluefin Tuna (*Thunnus thynnus*) observations increased again	
	Description
Survey design	Systematic stratified parallel (5-10 and 15 nmi), perpendicular to bathymetry
Index Calculation method	EchoR to StoX transition
Random/systematic error issues	None; tested risk of undersampling sprat in shallow (<15 m) waters of Lyme Bay which is not covered by RV, in a parallel survey aboard a small sprat fishing vessel. Negligible contribution found.
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 issue. Weather was reasonably favourable and survey was suspended during stormy conditions. Occasional noise was removed during processing so does not affect .
Extinction (shadowing)	Not an issue (school backscatter explored *in situ* for high values >20,000 NASC)

Blind zone	*Time-series*: survey daylight only to avoid effects of diurnal vertical migration. High pingrate (0.5 s-1) also ensures that surface fish schools just below nearfield are captured acoustically at 10 knots. *2018*: one incidence of juvenile anchovy schools at surface which may be undersampled. Negligible impact on estimates as very little backscatter contribution
Dead zone	0.5m; no known issue for target species
Allocation of backscatter to species	Echotypes which are allocated to trawls based on combination of nearest distance of acoustic data to trawl and expertise
Target strength	Recommended (-71.2 clupeids, -66.2 boarfish; -68.9 horse mackerel; -67.4 gadoids); Mackerel processed at 200 kHz using b20 of 84.03
Calibration	On drift at 0.512 amd 0.256 µs for 38, 120 and 200 kHz (333 kHz too noisy). 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** extends into Bay of Biscay which is covered by JUVENA survey (AZTI); bulk of biomass in English Channel; **sprat** questions remain about the link of Lyme Bay sprat to other populations in Channel and beyond although seemingly isolated in autumn. Sprat in Celtic Sea not captured as extending further west (covered by MI, Ireland during CSHAS) *2018 survey*: Eastern Channel covered for first time but low biomass suggests that can be dropped. French side of Channel is crucial to be included and dependent on coverage by AZTi (JUVENA) may need to extend further south on occasio
Stock ID and mixing issues	*Time-series*: genetic work in progress on sardine, sprat and anchovy. Sardine is single stock although some question about autumn and spring spawners; anchovy also. Sprat show little discrimintation *2018 survey*: as above
Measures of uncertainty (CV)	In progress; StoX and EchoR based but some questions about how the global value is calculated when there are starta with different
Biological sampling	*Time-series*: good *2018 survey*: probably oversampling as station based rather than stratum based
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole	*To be answered by Assessment Working Group*

time-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 12b: PELTIC 2018 survey report

Please see the report on the next page.

RESEARCH VESSEL SURVEY REPORT

RV CEFAS ENDEAVOUR
Survey: C END 19- 2018.

STAFF:

Name	Role	Name	Role
Part 1		**Part 2**	
Jeroen van der Kooij	SIC/acoustics	**Elisa Capuzzo**	SIC/hydro
Elisa Capuzzo	2IC/hydro	**Jeroen van der Kooij**	2IC/acoustics
Joana Silva	2IC/fish	**Joana Silva**	2IC/fish
Marc Whybrow	Tech	**Marc Whybrow**	Tech
Richard Humphreys	Fish Lead	**Richard Humphreys**	Fish Lead
Matt Eade	Fish	**Louise Cox**	Fish
Piera Carpi	Fish	**Allen Searle**	Fish
Fabio Campanella	Acoustics	**Sílvia Rodríguez-Climent**	Acoustics
Sam Barnett	Fish	**Catarina Maia**	Fish
Hayden Close	Plankton	**Sam Barnett**	Plankton
James Pettigrew	Plankton	**Nevena Almeida**	Plankton
Chris Brodie	PhD (Uni Salford)	**Axayacatl Molina-Ramirez**	Tech
Marine Cusa	PhD (Uni Salford)	**Chris Brodie**	PhD (Uni Salford)
Julian Tilbury	PIA	**Jahcub Trew**	PhD (Uni Exeter)
Pete Howlett	ML observer	**Pete Howlett**	MARINE Life observer
Fiona McNie	ML observer	**Sara Bisset**	ML observer

DURATION: **6th October-10th November**
6th -22nd Oct (Part 1); 23rd Oct- 10th Nov (Part 2)

LOCATION: **Eastern Celtic Sea and Western Channel (ICES Subareas 27.7 e, f, g)**

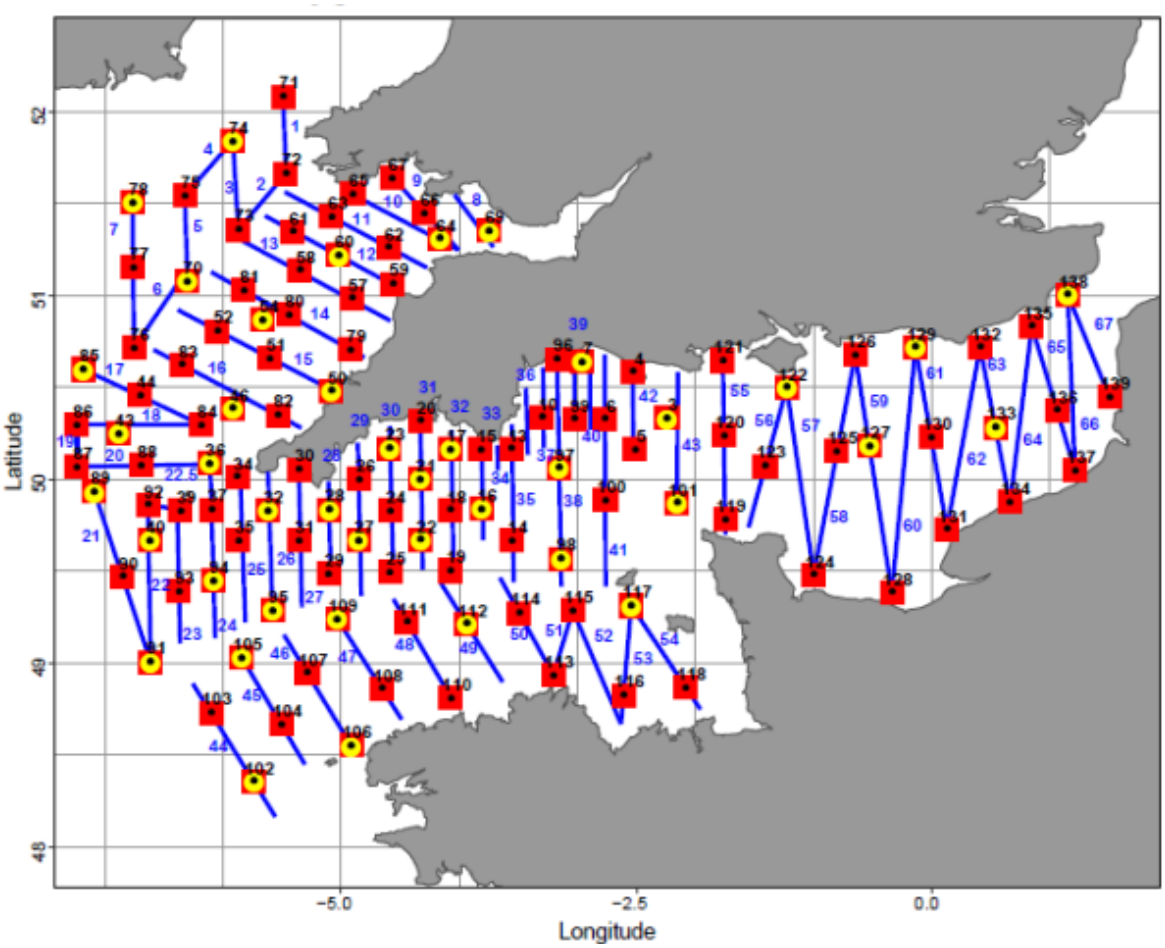

Figure 1. Overview of the planned survey area, with the acoustic transect (blue lines), plankton stations (red squares) and hydrographic stations (yellow circles).

AIMS:

1. Map, quantify and collect biological data on the small pelagic fish (SPF) community in the English Channel and Eastern Celtic Sea, using combination of fisheries acoustics and trawl (daylight). Specifically to assess:
    i. Area 7e sprat biomass for stock assessment (ICES HAWG)
    ii. Area 7 sardine biomass for stock assessment (ICES WGHANSA)
    iii. Importance role of Mackerel Box for juvenile mackerel
2. Investigate the distribution, and abundance of the zooplankton community throughout the survey area using two mesh ringnets (at night). Specifically:
    i. map and quantify sardine eggs and larvae to study the spawning habitat of sardine (1m diameter ringnet with 270 µm mesh)
    ii. map and quantify zooplankton by size and taxonomic group (0.5 m diameter ringnet with 80 µm mesh)
3. Characterise the physical oceanographic properties (pelagic habitat) of the survey area using a combination of CTD profilers (SAIV, ESM2 and SeaBird) and discrete water-samples (Rosette-sampler) at night. Samples for determination of chlorophyll concentration, dissolved oxygen, salinity, temperature, turbidity, and dissolved inorganic nutrients concentration are collected, and will be used for validation of the

CTD and FerryBox sensors . Water samples collected will be fixed on board for analysis at sea or post-hoc.

4. Record marine mammal, bird and bluefin tuna observations to map and quantify the top predators in the survey area (Marine Life observers).
5. Conduct continuous measurements throughout the survey, of the environmental properties at the subsurface (4 m depth) by the Jena 4HFerrybox (Continuous CTD/Thermo-salinograph).
6. Collect hourly measurements of phytoplankton functional groups, size and abundance, with online flow-cytometer, connected to the FerryBox (collaboration with project JERICHO NEXT).
7. Collect water samples from the Rosette-sampler (at the oceanographic stations) and the FerryBox flow-through (during trawling operations) to extract environmental DNA (eDNA) to detect small pelagic fish and other pelagic organisms. This work is part of a PhD which focusses on the use of eDNA in marine environment to validate acoustic data and as a monitoring tool for rare organisms (PhD candidate Chris Brody, University of Salford).
8. Continuously collect data on mesozooplankton populations with the continuous Plankton Image Analyser (PIA). Collaboration with Plankton Analytics Ltd (Julian Tilbury, Plymouth).
9. Collect and freeze sardine, sprat and anchovy specimens from different areas for a genetic study on the stock structure of the small pelagic fish community.
10. Collect and freeze up to 50 herring specimens at three different locations: Eastern English Channel, Western English Channel and Bristol Channel. (D. Clarke, Swansea University).
11. Collect a zooplankton sample using the 200 µm mesh ringnet at the West Gabbard 2 SmartBuoy, for the Lifeform project (Defra, PI Sophie Pitois) as part of the UK monitoring network for zooplankton.
12. Collect daily water samples with the automatic water sampler on the Ferrybox for analysis of phytoplankton community abundance and composition and dissolved inorganic nutrients concentration, (ASMIAE project PI Sophie Pitois).
13. Collect zooplankton samples at 10 preselected coastal and estuarine stations (primes 10, 13, 15, 17, 20, 21, 23, 50, 79 and 82), to investigate the presence of lineages of microscoporidia on copepods (PhD candidate Jahcub Trew, University of Exeter).
14. Collect stomachs from common small pelagic fish species to determine trophic interactions and microplastic ingestion.
15. Collect subsurface chlorophyll samples at coastal stations in the Western English Channel to investigate the presence of phytoplankton toxins (Cefas, PI Andy Turner).
16. To tag and release elasmobranchs species caught in the trawl with conventional - (Petersen discs) and/or electronic (DSTs) tags (Defra/MMO project(s), PI Jim Ellis/Sophy Phillips).

NARRATIVE:

All staff joined the RV Cefas Endeavour in Swansea between 12:00 -18:00 (BST) on the 5th of October. Those requiring inductions (11) were all present for 15:30 induction. Pilot joined at 01:45 on the 6th of October and RV left shortly after to steam to St Brides Bay north of Milford Haven. Arrived on location at 08:00 and first had toolbox/introduction with scientists and crew at 08:15. Set up acoustic calibration equipment afterwards which was completed at 11:00. Conditions were far from ideal but speed through water (on the drift) had not exceeded 0.2 knots so still planned to conduct a calibration after Muster drill (11:30) which was completed before lunch. After lunch the RV moved to the northern part of bay to have a sufficiently long period of drift to the south to complete calibration procedures. At 13:30 all was set but as the drift shifted to a westerly direction towards rocks, the calibration spheres had to be brought up. Because the wind had freshened, it was decided to postpone calibrations until better conditions. Instead, the RV steamed into Bristol Channel to conduct a shakedown tow with the pelagic trawl. This year a new rigging of the Marport (headline sensor) vastly improved the trawl deployment due to a reduced risk of the system getting caught in the bigger mesh. Next, the RV steamed to a sheltered spot to trial the new CTD and Rosette-sampler, which was also successfully completed. Overnight the first plankton and water-sampling stations ('rosette stations') were completed. On Sunday the 7th of October the daylight routine kicked in, running acoustic transects and deploying the trawl when needed. At night, a series of plankton and rosette stations was conducted. The order of transects was adjusted to continue work despite freshening weather conditions. On Thursday the 11th of October, the RV steamed into Bideford Bay, North Devon, having completed transects 8-14 and half of 15, to shelter from the gales forecasted. The very favourable conditions during the remaining 2 hours of daylight and the first hours after nightfall on the 11th were used to conduct the calibration of the 38, 120 and 200 kHz echosounders (at 0.512 and 0.256 ms pulse duration). Adverse weather conditions prevented any work to be undertaken on Friday the 12th and most of Saturday the 13th of October, until, at 15:00, a small weather window permitted the inshore component of transect 15 to be completed. From Sunday the 14th until Wednesday the 17th of October, the transects and stations of the Bristol Channel and Isles of Scilly were completed (dropping transect 21 following last year's observations of lack of target species on the western-most transects). Overnight, while steaming into French waters, paperwork provided by the FCO was deemed insufficient as a dispensation by the French maritime authorities. Instead, from Thursday the 18th of October until Monday the 22nd of October, the RV continued work on the UK side of the western Channel, completing transects 25-30 and most of transect 31 as well as the associated plankton and rosette stations. At 17:30 on the 22nd of October, the RV docked in Fowey for a scheduled mid-survey break, which included a full crew change and partial staff change. Fortunately, while docking, the official dispensation to work in French waters came through, enabling the survey to proceed and catch up with the western transects in the French sector.

At 18:00 on Tuesday the 23rd of October, the RV left Fowey as scheduled to transit across to French waters. Between Wednesday the 24th of October and Sunday the 28th of October, transects 45-54 were completed (44 was removed for the same reasons stated above for transect 21), as well as the associated plankton and rosette stations. A noticeable reduction in fish schools on the echosounders limited the number of trawls conducted along the transects around the Channel Islands. From Monday the 29th of October until Sunday the 4th of November, fair conditions enabled the RV to resume surveying transects in UK waters, gradually working eastwards. In contrast with the previous days, good numbers of trawls were conducted. From Monday the 5th of November surveying commenced in the eastern Channel, sailing across transects from French to UK coast. Very few schools were observed but, despite that, relatively small but representative catches were obtained when weather and static gear permitted trawling operations (often at first and last daylight). During the final days of surveying, transects 58 and 59 were run in northerly direction due to fresh southerly winds, which on the 7th of November also led to a trawl operation being abandoned due to adverse weather conditions. Fishing operations were resumed on the 8th of November and the last trawl was conducted on the morning of the 9th of November before the last transect was completed (#60) and the RV Cefas Endeavour commenced the transit back to Lowestoft.

Very strong southerly winds during the night of the 9 to 10th prevented the collection of the West Gabbard zooplankton sample (objective #11). At 09:20 on the 10th of November the pilot was collected off Lowestoft and the RV docked shortly after.

RESULTS:

Pelagic Ichthyofauna

After removing the off-transect data a total of 2200 nautical miles of acoustic sampling units were collected for further analysis (Figure 2). These included several transects in the eastern Channel, which was sampled for the first time this year. A total of 46 valid trawls were made with the mid-water trawl, providing a suitable source of species and length data to partition the acoustic data. Both the number of completed acoustic transects and trawls exceeded those achieved in 2017, despite having more weather induced downtime in 2018. A significant contributing factor to this was the improvement on the rigging of the headline sensor which previously often got entangled in the large mesh upon deployment. The new rig removed these issues which sped up the trawling process and also meant that the trawls were more accurate at catching target schools.

Preliminary results indicated some differences in ichthyofauna observations when compared to 2017. In the Bristol Channel, other than the usual hotspot inside the estuary, the majority of fish biomass was found more inshore, as demonstrated also by the location of the trawl effort. In the French waters of the western Channel more fish activity was found along the western-most transects. Further east in the western Channel, very few schools were encountered, which matched last year's results. The transects east of Lyme Bay, sampled for the first time during Peltic, yielded little fish biomass.

Sprat (*Sprattus sprattus*) was widespread in most of the survey area with to more important areas, one in the Bristol Channel, including in the coastal waters in the west, and the other in English waters of the western Channel (Lyme bay, Figure 3). Medium sized fish (mode of 9 cm) dominated all main areas. As in previous years, the smallest fish were found in the Bristol Channel and the largest (mode of 12 cm) in Lyme Bay. However, only small numbers of sprat found in the trawls conducted in French waters of the southern English Channel, with relatively high numbers of mainly intermediate size specimens caught on transect 47 (Figure 1, 3). A total of 110 sprat specimens from four different stations were collected for genetic processing.

Sardine (*Sardina pilchardus*) distribution was comparable to previous years with the bulk of biomass found in the English Channel (Figure 4). This year, more large sardines (mode of 14 cm and to a lesser extent 18 cm) were found north of the Cornish Peninsula. A wide range of sardine sizes was found in the northern Channel waters, from the Isles of Scilly to the eastern Channel. In French waters, the very smallest sardines dominated (mode of 9.5 cm) although bigger specimens (mode of 15 cm) were also found. A total of 173 sardine specimens from six different stations were collected for further genetic processing.

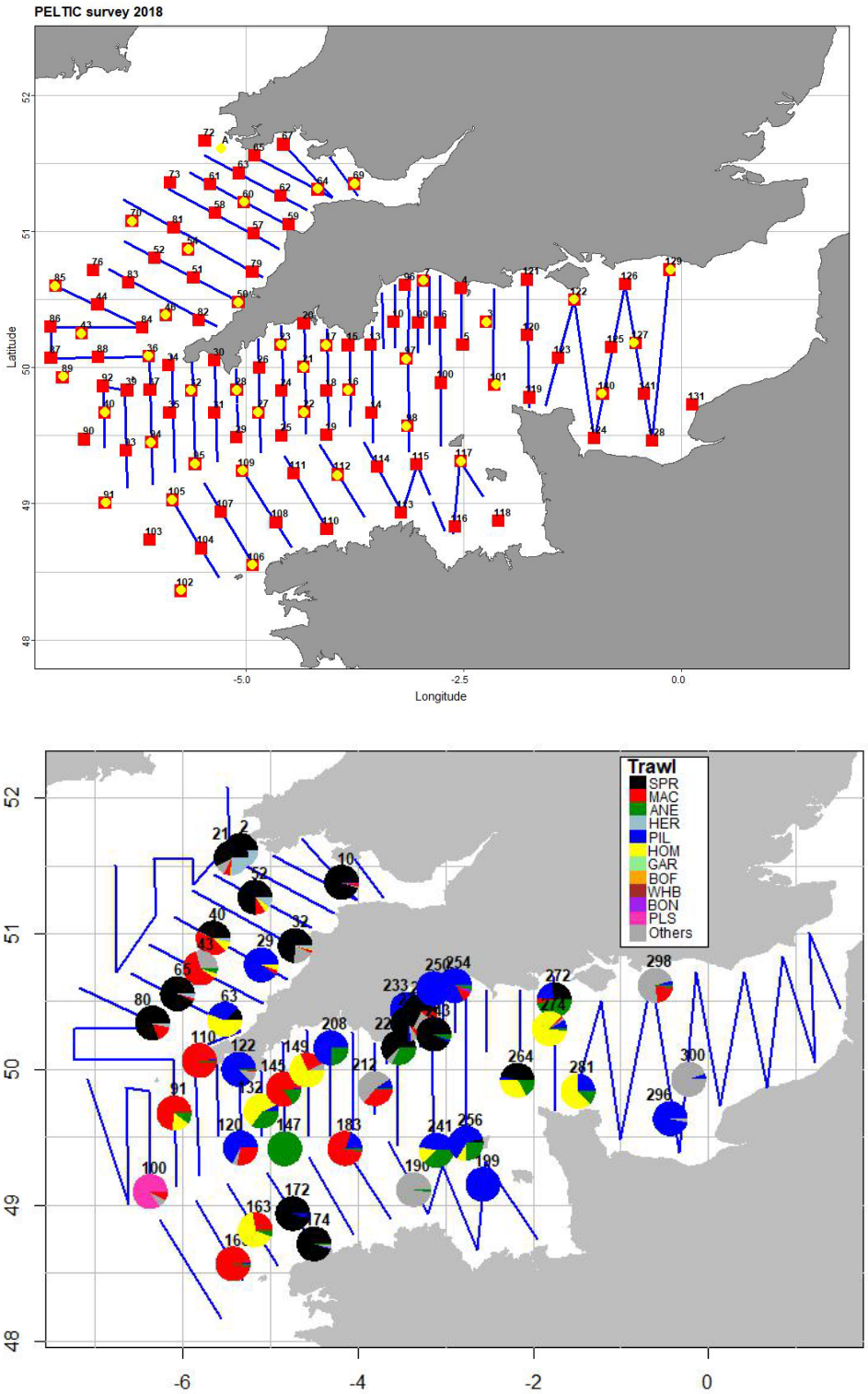

Figure 2. Overview map and detail of the survey area. Top: Acoustic transects (blue lines) and prime stations completed during PELTIC18. Bottom: Trawl stations (pies) with relative catch composition by key species. Three letter codes: SPR=sprat, MAC=mackerel, ANE=anchovy, HER=herring, PIL=sardine, HOM= horse mackerel, GAR=garfish, BOF=Boarfish, WHB=Blue whiting, BON=Atlantic bonito, PLS=pearlside.

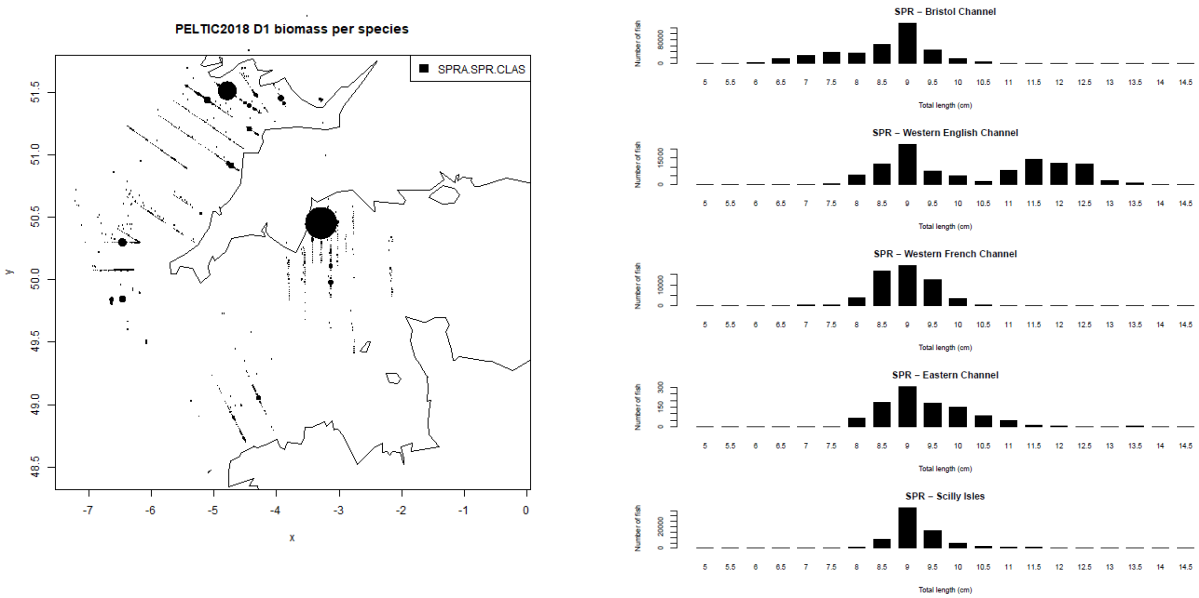

Figure 3. Acoustically derived sprat biomass distribution (left) and trawl-based length frequency histogram for sprat in each of the subareas of the Peltic survey (right). Please note that bubble size has not been standardised between species.

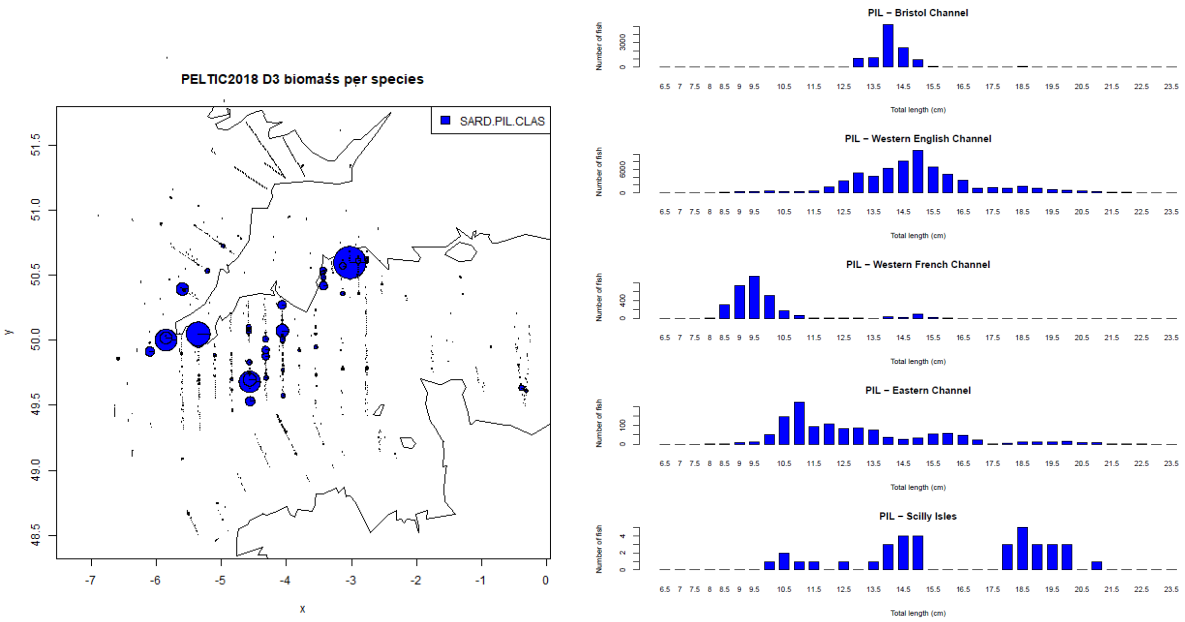

Figure 4. Acoustically derived sardine biomass distribution (left) and trawl-based length frequency histogram for sardine in each of the subareas of the Peltic survey. Please note that bubble size has not been standardised between species.

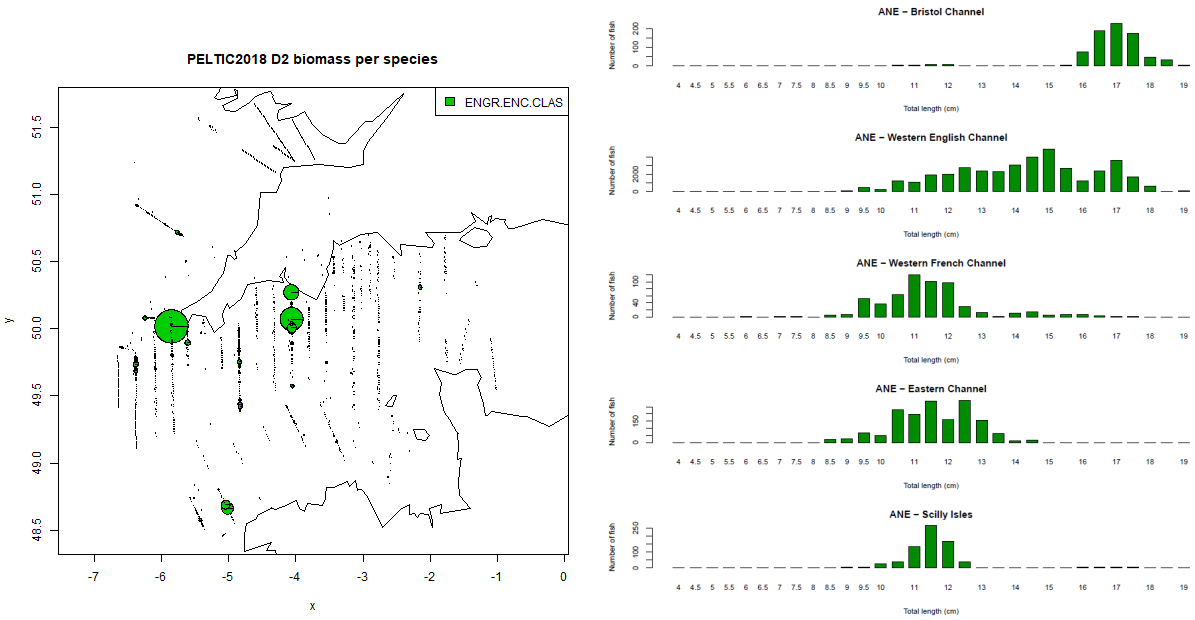

Figure 5. Acoustically derived anchovy biomass distribution (left) and trawl-based length frequency histogram for anchovy in each of the subareas of the Peltic survey. Please note that bubble size has not been standardised between species.

Anchovy (*Engraulis encrasicolus*) distribution was much more widespread than observed in recent years and preliminary results suggested a higher biomass than in 2017. Coverage in the French waters as well as in the eastern Channel resulted in a consistent presence in species mix. Another notable observation included the presence of juvenile anchovy in small surface schools on the French side. In contrast to last year, the whole size spectrum was found in each of the main survey strata. In 2018 anchovy in the Bristol Channel were dominated by the largest fish (mode at 17 cm) whereas smaller fish dominated in French waters (6 cm smallest fish caught). Figure 5).

Herring (*Clupea harengus*), normally only found in mixed schools with sprat in a handful of Bristol Channel stations, this year contributed to all but one of the Bristol Channel trawl stations and in some occasions in large numbers. The majority of fish were aged 0 years old.

For the first time in the survey series (since 2012), several **Atlantic bonito *(Sarda sarda*,** Figure 6***)*** were caught: in the Bristol Channel at stations 10 (82 specimens) and 40 (1), and in Lyme Bay at stations 243 (2) and 254 (6). The bonitos from the Bristol Channel ranged between 15 -23 cm and those in Lyme Bay were slightly bigger at 21-30 cm, though all were aged as 0-year old. Although a typical species of warmer waters, the survey area is part of the species' natural distribution range. The limited records found in UK waters suggest it's most likely found during summer.

Figure 6. Specimen of Atlantic bonito (*Sarda sarda*) collected during the survey.

Zooplankton

Samples of mesozooplankton and ichthyoplankton communities were collected at 107 stations using 80 and 270 micron ringnets, respectively. Preliminary results on the distribution of sardine eggs suggested a similar distribution as found in previous years with key spawning areas on both side of the Cornish Peninsula (Figure 7). Sardine eggs appeared to be distributed perpendicular to the coast, with highest concentrations associated with the boundary between mixed and stratified waters. Plankton samples were again collected in the southern half of the English Channel and, for the first time in the eastern Channel; both eggs and larvae were found here although in relatively low densities. Size information and taxonomic group of zooplankton samples collected at the same stations, will be obtained by Zooscan processing back in the lab.

Additional zooplankton samples (with ring nets, mesh sizes 80 µm and 200 µm) were collected at 10 sampling stations for investigation of Microsporidia infection in copepods (Table 1).

For the duration of the survey, the Plankton Image Analyser (PIA) was run to collect images of zooplankton organisms, which will be processed and analysed at PML.

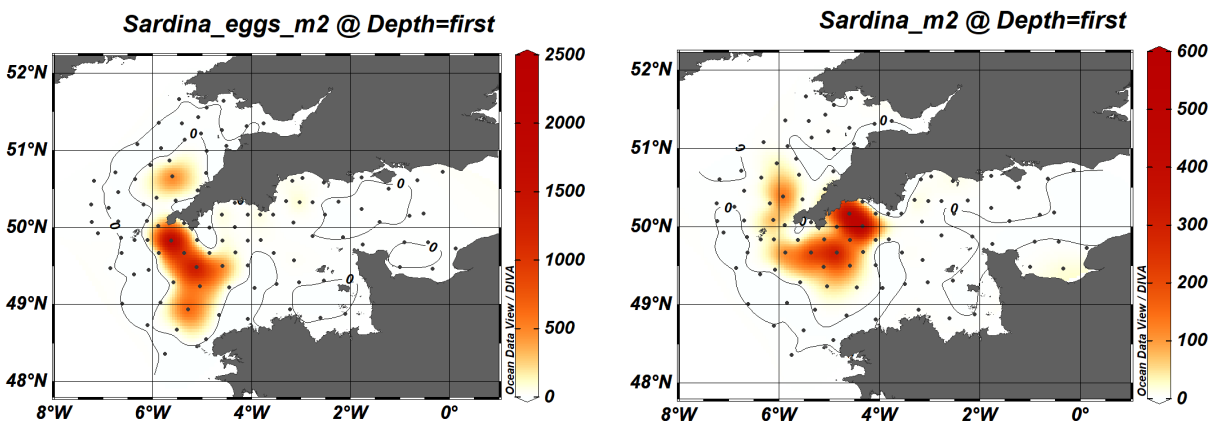

Figure 7. Sardine eggs (left) and larvae (right) densities in m^2 as sampled during the 2018 Peltic survey. Note that the larvae section only includes those larvae that could be identified as sardine (*Sardina pilchardus).* More larvae were observed and although they could not be identified to species, the vast majority was considered to also be sardine.

Physical Oceanography

A SAIV mini CTD was deployed at the 107 zooplankton stations, providing information on temperature (°C) and salinity). A Rosette sampler, equipped with 12 Niskin bottles was used at 38 of those stations ('rosette stations') to collect discrete water samples to determine phytoplankton and microzooplankton communities and the physical and chemical properties. The later included: dissolved oxygen, salinity, phytoplankton pigments (including chlorophyll-a) and dissolved inorganic nutrients (nitrate, nitrite, ammonium, phosphate and silicate). This year, additional water samples were collected both at rosette stations and during trawls (Table 1). These were filtered to extract environmental DNA (eDNA). A SeaBird CTD (equipped with temperature, salinity, PAR, oxygen, turbidity and fluorescence sensors) mounted on the Rosette provided live measurements of the vertical properties of the water column.

Surface water conditions (at 4 m depth) were continuously monitored by the FerryBox, which recorded temperature, salinity, fluorescence, turbidity, and oxygen. A flow cytometer, connected to the FerryBox, carried out measurements of abundance and size of the phytoplankton community every hour.

Table 1. Number of samples collected (top) and CTD profiles carried out (bottom) during CEnd19_18.

Measured variables	Total (N)
Salinity	39
Dissolved oxygen (triplicates)	15
Chlorophyll/Pigments analysis (HPLC - duplicates)	38
Chlorophyll (HABs detection)	22
Inorganic nutrients	38
Phytoplankton	38
Microzooplankton	38
Mesozooplankton (80 µm)	107
Mesozooplankton (270 µm)	107
Mesozooplankton parasitic copepods (80 µm - duplicates)	10
Mesozooplankton parasitic copepods (200 µm - duplicates)	10
CTD profiles with Rosette	35
CTD profiles with ESM2	2
CTD profiles with SAIV MiniCTD	113

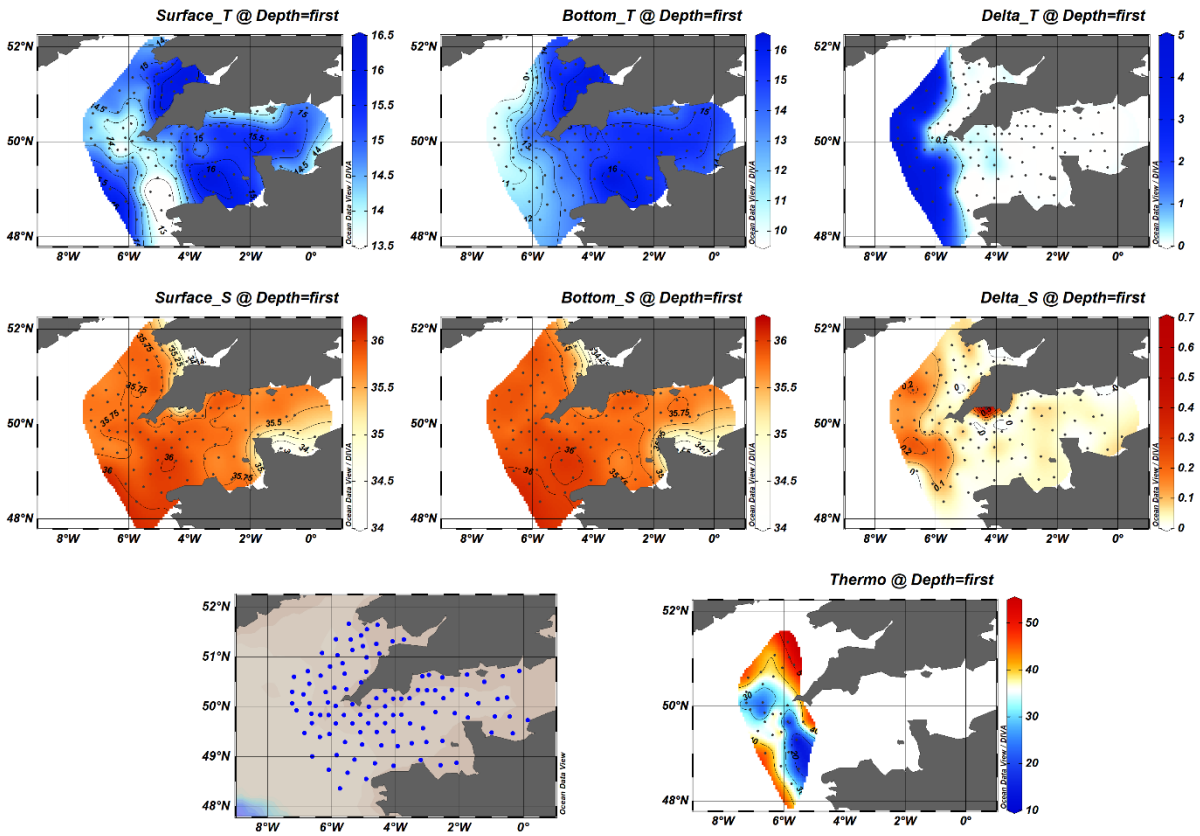

Figure 8. Temperature (T, °C, top) and salinity (S, middle) distribution at the surface (left column) and bottom (central column) as recorded by the SAIV MiniCTD at the 99 sampling stations. The difference in temperature (Delta_T, right) and salinity (Delta_S) between surface and bottom is also given, together with depth (m) of the thermocline (Thermo), at the stratified stations (Delta_T > 0.5 °C).

Sea surface temperature during the survey was highest in the Bristol Channel, and in the French waters of the Western Channel (off St Malo). The maximum temperature of 16.4 °C (Table 2) was slightly lower than the maximum temperature recorded during the previous surveys (16.7 °C in 2017 and 17 °C in 2016). This is unexpected as sea surface temperatures prior the survey, in September, were generally higher than

September 2017. As observed in previous years, lowest surface temperatures were recorded in the cool water patch in the southern areas of the Channel, off France (clearly visible in Figure 8). Furthermore, the lowest temperature recorded this year at the surface (12.8 °C) was almost 0.5 °C cooler than lowest temperatures in 2017. Lowest bottom temperatures were recorded at the most westerly stations in the Celtic Sea and the minimum bottom temperature was almost 1 °C lower than last year. The boundary layer where the patch of cooler water meets the warmer waters of the English Channel and the Celtic Sea was marked by a series of frontal systems.

Table 2. Summary statistics (minimum, maximum, mean, standard deviation, and number of observations) of temperature and salinity measurements, recorded by the SAIV MiniCTD at the sampling stations. Column titles are the same as in Figure 8.

	Surface_T	Bottom_T	Surface_S	Bottom_S	Delta_T	Delta_S	Thermo
Min	12.84	9.78	34.21	34.22	0	0	11
Max	16.41	16.43	36.03	36.06	4.92	0.70	53
Mean	14.80	13.94	35.69	35.75	0.88	0.06	34.7
StDev	0.76	1.76	0.30	0.30	1.46	0.08	10.4
Number	106	106	106	106	106	106	30

Offshore stations in the Bristol Channel and in the Western approaches, west of Lizard Point, were thermally stratified (Delta_T > 0.5 °C; Figure 8), while coastal stations, on both sides of the English Channel were vertically mixed (Figure 8). The difference between surface and bottom temperatures was highest at offshore stations in the Celtic Sea and up to 4.92 °C (Table 2). The offshore stratified stations (in the Bristol Channel) were characterized by the deepest thermocline depth (> 30 m) while stratified stations associated with the cooler patch of surface water had a shallower thermocline (minimum of 11 m depth; Table 2 and Figure 8). Stratification in 2018 survey was stronger than last year with maximum "Delta_T of 4.92 °C versus the 4.31 °C in 2017). Salinity was lowest in the inner stations of the Bristol Channel and in the Bay of Sein, France (34.21, while highest values were recorded in offshore (south west) waters of the Celtic Sea (34.21; Table 2 and Figure 8). Minimum, maximum and average values of salinity in 2018 were all higher than the same statistics in 2017; this could have been the results of lower precipitation and higher temperature in summer 2018 or could be a results of different sensor settings in the SAIV MiniCTD profiler (with the second point to be addressed during the validation of the sensors versus discrete samples).

Surface distribution of chlorophyll concentration was estimated by fluorometers on the FerryBox and on the SeaBird profiler mounted on the Rosette sampler. Remote sensed images of ocean colour from MODIS (algorithm OC3) from Neodaas.co.uk (PML) were also used to obtain a synoptic view of the study area. Unfortunately, due to poor weather conditions and often overcast sky, a very limited number of satellite pictures was available. From (uncalibrated) measurements of fluorescence (proxy for chlorophyll) from the FerryBox some areas with slightly higher chlorophyll concentrations were identified: one in Eddystone/Mount Bay, another one offshore in the Celtic Sea, and last one towards the eastern English Channel. Presence of phytoplankton in the water (particularly large diatoms such as *Coscinodiscus* spp. and *Rhizosolenia* spp.) was observed during microscopy analysis of ring net samples.

Observer data: Marine Mammal, Birds and large pelagic fish

During both halves of the 2018 survey, two experienced volunteer MARINElife surveyors, stationed on the bridge in a central position, employed an effort-based 300m box methodology for recording birds (an adapted version of ESAS methodology) with an additional 180° scan area surveyed along each transect line, as used on the majority of MARINElife's year-round surveys. During transits between transects, the team recorded incidental observations when possible, logging significant species only. Furthermore,

casual observations were regularly conducted during the net-retrieval stage of many trawls to identify species of birds associated with the fishing activity of the survey vessel but only significant species were logged as incidental records. During survey transects, all species of birds (both seabirds and terrestrial migrants) were recorded, along with all sightings of marine mammals. During the deployment of the fishing net, both teams paused effort. However, during the net-retrieval phase, incidental records of significant species were logged (e.g. Balearic Shearwater, Sooty Shearwater, cetaceans) whenever time permitted. During these times, observations were conducted from the rear of the Bridge to cover a 180° arc, aft of the vessel. Whilst this data was not part of the standard transect data it provided an opportunity to observe behaviour and associations with a fishing vessel and could provide useful comparisons with future surveys in these waters.

The weather was difficult for surveying in 2018, though on average slightly better than 2017 with approx. 63% of effort made in sea state 4 or less. However, there were a few days within the survey, particularly part 1, where the team were faced with storms. Resulting in a day off effort and in shelter early on in the survey on 12th October. Unlike the previous year, north-easterly airflow was predominant

A summary of all species recorded during the survey are provided in the following tables. A total of 4,534 sightings of 14,151 birds, from 41 species were recorded throughout the duration of the survey. As in all previous surveys, the gannet (*Morus bassanus*) was the highest recorded species. Though 2018 also saw higher numbers than previously of kittiwake (*Rissa tridactyla*) and most notably, significant higher numbers of Great shearwater (*Puffinus gravis*). However, recorded figures of a number of other species were notably down on previous years, particularly considering the extended survey effort. For example the total for European Storm Petrel (*Hydrobates pelagicus*) was significantly less in 2018.

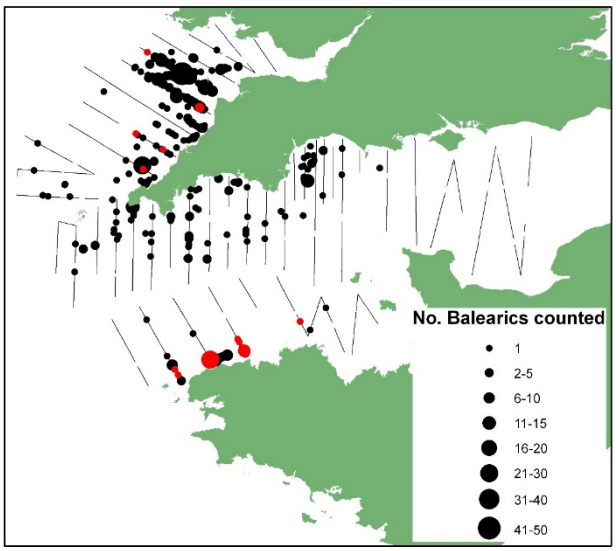

Figure 9: Distribution of Balearic Shearwater sightings recorded on effort in 2018 (red circles) in comparison to 2013, 2014, 2015, 2016 and 2017 (black circles). Sightings are scaled to abundance as shown in the figure legend. Grey lines show survey effort.

Of significant note, the total number of Balearic Shearwater (*Puffinus mauretanicus*) was again lower in 2018 than in in previous years (16 sightings of 51 individuals), and similar to 2017, the majority were recorded during the more southern section of the survey off the North coast of France (Figure 9). Not only did the 2018 survey yield a much lower count of Balearic Shearwater *Puffinus mauretanicus* than in previous years, the distribution was again seemingly different from historical surveys and more in line with the distribution recorded in 2017. Historically this survey observed the main concentration of this species to the west of Lundy and in transects off the north Devon coast. However, this year the only concentrations were off the northwest corner of Brittany, with a few additional smaller sightings of the north coasts of Devon and Cornwall. Most notably, 2018 was the first year that not a single sighting was made of this species off the south coast of Cornwall, Devon or Dorset, and therefore the first year no single sighting was made during the survey of a Balearic shearwater in Lyme Bay.

The MARINElife observers recorded a total of 204 cetacean encounters, totalling approximately 3,049 animals from 8 species. The cetacean sightings recorded on effort are given in Table 3.

Table 3. Observations of marine mammals during Peltic 18

Species	Scientific Name	No. sightings	No. animals
Fin Whale	*Balaenoptera physalus*	9	14
Minke Whale	*Balaenoptera acutorostrata*	4	4
Unidentified whale sp.		3	3
Common Bottlenose Dolphin	*Tursiops truncates*	6	31
Short-beaked Common Dolphin	*Delphinus delphis*	145	3049
Risso's Dolphin	*Grampus griseus*	1	3
White-beaked Dolphin	*Lagenorhynchus albirostris*	1	3
Long-finned Pilot Whale	*Globicephala melas*	1	2
Harbour Porpoise	*Phocoena phocoena*	28	131
Unidentified dolphin sp.	*Odontocete sp.*	6	13
	Total:	204	3,253

A greater diversity of species were recorded in 2018, with the addition of Risso's dolphin and Minke whale, not recorded during the 2017 survey. Comparable sightings of Fin whale *Balaenoptera physalus* were again made this year, with 9 sightings of 14 animals, predominantly in deeper waters west of north Cornwall and Devon, towards the Celtic Deep. Short-beaked common dolphin *Delphinus delphis* was again by far the most frequently recorded species, with nearing 150 sightings of over 3000 animals (Table 3). Similar to previous years, the highest concentration of Common Dolphin encounters were in the Celtic Sea and the waters around the Isles of Scilly (Figure 10). Notably, no Common dolphins were recorded on transect in the eastern English Channel, beyond Lyme Bay (Figure 10). One group of 3 White-beaked Dolphin *Lagenorhynchus albirostris* were seen this year in Lyme Bay.

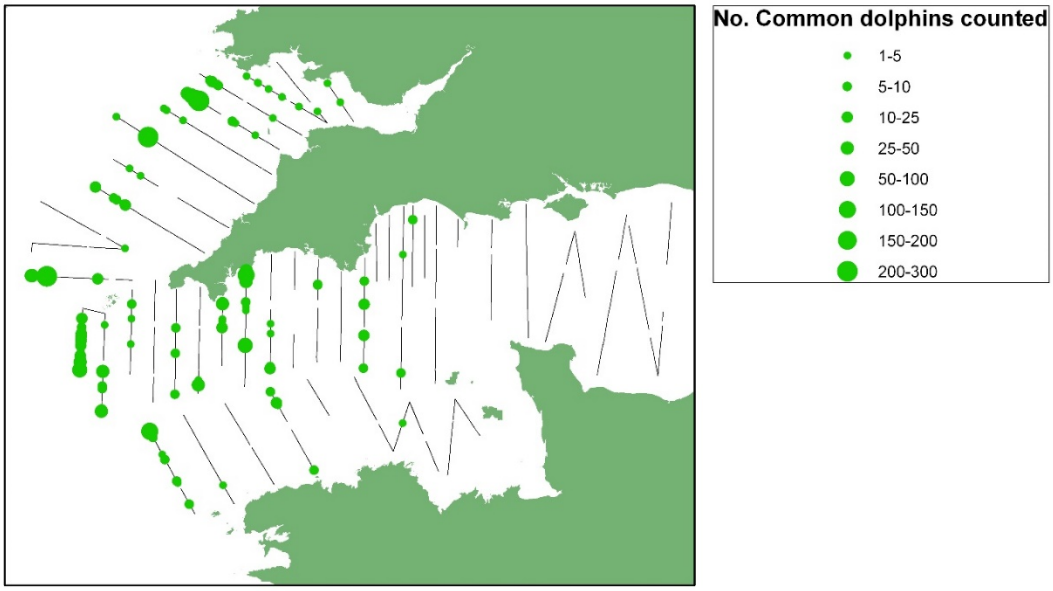

Figure 10: Distribution of Common dolphin sightings recorded on effort in 2018 (green circles). Sightings are scaled to abundance as shown in the figure legend. Grey lines show survey effort.

Numbers of Atlantic Bluefin tuna (*Thunnus thynnus*) observations increased again compared to 2017 with in total 67 different feeding observations observed.

Summary
Peltic18 constituted the 7th autumn survey on small pelagic fish and their ecosystem in the waters of the western English Channel and eastern Celtic Sea. For the second year, the survey was extended beyond the area covered between 2012 and 2016, which had focussed solely on the Mackerel Box. The 2018 survey coverage included the French waters of western English Channel and a large part of the eastern Channel. The survey commenced on the 6th of October and ran for 36 effective survey days, starting in the Bristol Channel working into the English Channel. The 2200 nautical miles of effective acoustic coverage were supplemented with 46 valid trawls which provided details on species composition and biological information. Preliminary results indicated that, despite the hot summer preceding the survey, surface temperatures were similar to the ones recorded in 2017, although the stratification was stronger. In addition, salinity was higher than previous years, most likely due to reduced rainfall. Sardine dominated the pelagic ichthyofauna, Anchovy was found in higher numbers than in 2017 but sprat biomass decreased in the whole survey area, although it was more widespread north of the Cornish Peninsula. Sardine egg- and larval maps showed similar geographical areas of sardine spawning compared to previous years with the waters at the mouth of the English Channel being most important. For the first time since 2012, Atlantic bonito (*Sarda sarda*) were caught (at four different stations). Feeding Atlantic Bluefin Tuna (*Thunnus thynnus*) observations increased again.

Jeroen van der Kooij, Elisa Capuzzo
Scientists In Charge
1st Mar 2018

SEEN IN DRAFT

Master:
Senior Fishing Mate:

INITIALLED:

DISTRIBUTION:

Document 13a: 6a7bc Industry acoustic 2018 survey summary table

Survey Summary table WGIPS 2019	
Name of the survey (abbreviation):	6a7bc herring industry survey (6aSPAWN)
Target Species:	Herring
Survey dates:	27 August – 19 September (6aN) 1-21 November (6aS,7b)
Summary:	
2018 was the third industry-led survey of herring in 6a/7bc. Three industry vessels were used in the 6aN, each equipped with a calibrated Simrad EK80 transceiver using the ship's hull-mounted transducer. In 6aN, each vessel undertook an acoustic survey in sequence, covering four known prespawning/ spawning areas. Sea state was variable but at no time bad enough to prevent the collection of good quality acoustic data. The industry vessels were proven to be very stable platforms for acoustic surveys. This survey was planned to coincide with the known spawning period, but spawning in 2018 was two or more weeks later than during previous surveys. In particular, the first two acoustic surveys were considered too early because no spawning ready/ spawning fish were found during the survey and because commercial fishing occurring at the end of September/Oct saw considerably more herring in areas where they were largely absent during the acoustic surveys. Particularly in the area east of Cape Wrath. A notable feature of the 2018 survey was the recording of a good abundance 0-group herring in the Minches, generally mixed with similar sized sprat. The main concentration of mature herring found during the acoustic survey in 6aN was aggregated mainly in Area 3 – North Minch, (same as 2017). An abundance of 0-group mackerel (10-15cm) were found distributed throughout the area, being caught in almost every haul. Sprat were also common again, distributed throughout the area in surface schools. Close attention was given to distinguishing these from herring schools during scrutinization of the acoustic data. Total biomass estimates of herring recorded during the survey in 6aN was 118000t. In 6aS/7b herring were distributed similar to 2016 and 2017. Herring were again found close inshore with the overall distribution dominated by aggregations of herring in a few discrete areas. Total biomass estimates of herring recorded during the survey in 6aS/7b was 50 145 t. The acoustic survey in 6aS/7b also estimated horse mackerel in the survey area to be 57 162 t. This species inhabits a large geographical range (outside the area of the survey) therefore the index is only useful as a subset of the larger stock, albeit an important area for the horse mackerel fishery during this time of the year. Horse mackerel were distributed mainly in an area to the north and west the Stags of Broadhaven, Co. Mayo. A detailed survey report for the 6aS/7b survey can be found in O'Malley et al. (2019) http://hdl.handle.net/10793/1390	
	Description
Survey design	6aN - Stratified systematic parallel design (2-4 nmi spacing) with randomized start point. All vessel surveyed all strata in sequence with 7 day lag. 6aS/7b - Stratified systematic parallel design (3 – 7.5 nmi spacing) with randomized start point for the broad area. Increased transect intensity in areas where herring distribution is expected. Transect design was zig-zag in Lough Swilly and Lough Foyle.

Index Calculation method	StoX (via the ICES acoustic database)
Random/systematic error issues	NA, outside of those already described in literature for standardized acoustic surveys
Specific survey error issues (acoustic)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Bubble sweep down	6aN- Not an issue in 2018 due to fair weather conditions. Stabilty of boats aided by filling fish tanks with water. 6aS/7b - Not an issue in 2018 due to the use of towed body. Weather was poor during the survey but bubble sweep down did not adversely effect echograms. Stabilty of boats aided by filling fish tanks with water.
Extinction (shadowing)	6aN- Occurred on several occasions when very dense sprat schools were detected. Can occur with spawning aggregations, but these not recorded in 2018. Dense schools on rocky outcroppings can be subject to side lobes, but effort made to exclude these. 6aS/7b – may be an issue where extremely dense schools occurred in areas like Lough Swilly
Blind zone	NA, herring and other schools at significant depth
Dead zone	6aN- Dense herring schools tight to the bottom in places making delineation difficult, but detailed school by school scrutiny in place. 6aS/7b – not an issue in 2018
Allocation of backscatter to species	6aN- Directed trawling for verification and species composition purposes and age structure. Insufficient in some areas so nearest sample allocated. In Area 4 there we no samples so data from MSHAS was taken as best alternative. 6aS/7b – directed trawling and samples from the fishery taking place at same time and in same areas as the survey
Target strength	TS = 20log10(L) – 71.2
Calibration	6aN- 38KHz calibrated on all vessels 6aS/7b – 38kHz calibrated in 2017
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- The 2018 estimate of abundance is considered reliable estimate of herring present during the survey, but not reflecting the biomass during peak spawning time which occurred later than the survey in 2018. 6aS/7b – there is suspected lack of containment in shallow areas. Fish have been distributed in areas difficult to survey, therefore the estimate should be considered as a minimum estimate with herring expected to be distributed outside of the survey area inshore. The stock is most likely contained offshore.

Stock ID and mixing issues	No issues – the surveys are designed to target spawning aggregations, the stocks are most likely separated at the time of the individual surveys
Measures of uncertainty (CV)	6aN- CV of biomass used for estimate of spawning biomass in each strata ranged from 0.26 to 0.68. 6aS/7b – CV was poor for the survey again in 2018 (~0.5). The survey relies on a few dense marks in very localized areas, causing the CV to be high.
Biological sampling	6aN- Biological data to allocate to acoustic marks identified as herring were poor in 2018, despite more sample hauls being taken than in previous years. Targetting of sufficient representative samples needs to improve. 6aS/7b Good sampling was achieved in 2018 with high confidence in the identification of herring marks.
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole time-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: 6a7bc Industry acoustic 2018 survey report

Please see the report on the next page.

The 2018 industry–science acoustic survey of herring in the Western British Isles (ICES div 6a, 7b,c)

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King Cross (Adam Wiseman & William Buchan), Voyager (Arnold McCullough), Alida (Bert Plug), Wiron 5&6 (Jan Melis/ Adrie Hoek), Christina S (Alistair Smith), Dirk Dirk (Jaco van Duijvenvoorde), Sparkling Star (Donal O'Neill) and Eilean Croine (Eric Murphy)

Contents

Executive summary

2018 was the third industry-led survey of herring in 6a/7bc. Industry and scientific institutions from Scotland, Northern Ireland, Netherlands, Ireland, and England 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 5 800 t (4 170 t in 6aN and 1 630 t in 6aS/7bc) (EU 2018/120), the scientific survey was designed based on ICES advice, and experience from 2016-17 on the timing, location and number of samples required to collect assessment-relevant data from the monitoring fishery (ICES 2016a).

Three industry vessels were used for acoustic surveys in 6aN and one in 6aS/7b. The vessels used in 6aN were each equipped with a calibrated Simrad EK80 transceiver using the ship's hull-mounted transducer. One industry vessel was dedicated to taking samples for morphological and genetic analyses in 6aN, and two others were directed to searching and fishing in specific areas so as to maintain comparability with previous commercial catch data. In 6aS/7b biological, genetic and morphometric samples for were collected by numerous inshore vessels.

In 6aN, each vessel undertook an acoustic survey in sequence, covering four known pre-spawning/ spawning areas. This was planned to coincide with the known spawning period, but spawning in 2018 was two or more weeks later than during previous surveys. In particular, the first two acoustic surveys were considered too early because no spawning ready/ spawning fish were found during the survey and because commercial fishing occurring at the end of September/ early Oct saw considerably more herring in areas where they were largely absent during the acoustic surveys. For example, in the area east of Cape Wrath. A notable feature of the 2018 survey was the recording of a good abundance 0-age group herring in the Minches, generally mixed with similar sized sprat. The main concentration of mature herring found during the acoustic survey in 6aN was aggregated in Area 3 – North Minch, (same as 2017). 0-age group mackerel (10-15cm) were found in abundance distributed throughout the area, being caught in almost every haul. Sprat were also common again, distributed throughout the area in surface schools. Close attention was given to distinguishing these from herring schools during classification of the acoustic data. Total biomass estimates of herring recorded during the survey in 6aN was 118 000 t.

In 6aS/7b herring were distributed similar to 2016 and 2017. Herring were again found close inshore with the overall distribution dominated by aggregations of herring in a few discrete areas. Total biomass estimates of herring recorded during the survey in 6aS/7b was 50 145 t. The acoustic survey in 6aS/7b also estimated horse mackerel in the survey area to be 57 162 t. This species inhabits a large geographical range (outside the area of the survey) therefore the index is only useful as a subset of the larger stock, albeit an important area for the horse mackerel fishery during this time of the year. Horse mackerel were distributed mainly in an area to the north and west the Stags of Broadhaven, Co. Mayo. A detailed survey report for the 2018 6aS/7b survey can be found in O'Malley et al. (2019) http://hdl.handle.net/10793/1390

With provision made for 5 800 t monitoring fishery in 2019 (EU 2019/124), plans are underway for a fourth survey in 2019, taking into account the recommendations of ICES WGIPS (ICES 2019a).

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 and German fishery interests to set about providing the much needed evidence required to establish reliable stock assessments for the separate stocks, and develop a rebuilding plan.

In response to the STECF 2015 autumn plenary recommendation that it would be beneficial to maintain an uninterrupted time series of fishery-dependent catch data, and a subsequent special request (to ICES) by the European Commission, ICES provided advice on methods for undertaking a scientific monitoring fishery for the purpose of obtaining relevant data for assessment (ICES 2016a). In particular, the advice referred to collection of data necessary to determine the identity and structure of the two stocks, collected in a way that (i) satisfies standard length, age, and reproductive monitoring purposes by EU Member States for ICES, and (ii) ensures that sufficient spawning-specific samples are available for morphometric and genetic analyses as agreed by the Pelagic Advisory Council monitoring scheme 2016 (Pelagic Advisory Council, 2016).

This advice, and a resulting EU Council regulation (EU 2016/0203) that made provision for a scientific monitoring TAC of 5 800 tonnes (4 170 t in 6aN and 1 630 t in 6aS, 7bc) were the enablers for the industry-led survey to take place. EU Council regulation (EU 2018/120) made the same provision, enabling the third survey to take place.

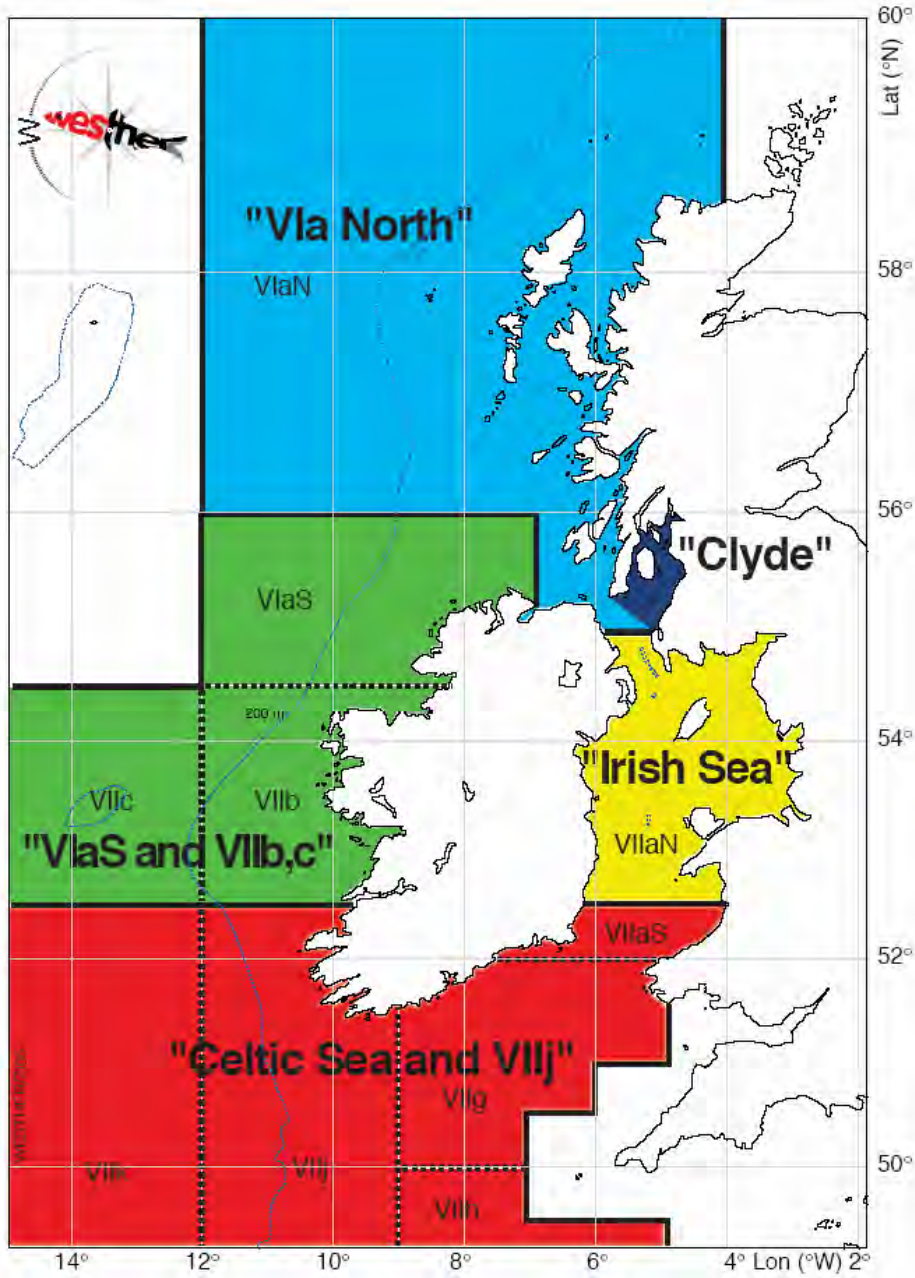


Figure 1.1. Herring stock assessment areas.

1.2 Overall Aim

To improve the knowledge base for the spawning components of herring in 6aN and 6aS/7b, and submit relevant data to ICES to assist in assessing the herring stocks and contribute to establishing a rebuilding plan.

1.3 Objectives

In this report, only information on the methods and results pertaining to objective 1 are documented. A full survey report is available on request.

1. **Abundance estimation**: Collect acoustic data and information on the size and age of herring and use it to generate an age-disaggregated acoustic estimate of the biomass of pre-spawning/ spawning components of herring in 6aN and 6aS/7bc ('Western herring').
2. **Stock identity separation:** Collect morphometric and genetic data to distinguish whether the 6aN stocks are different from the stocks in 6aS, 7bc.
3. **Age composition of the commercial catch:** Collect catch-at-age data from the monitoring fishery to provide continuous fishery-dependent time series required for assessment.
4. **Rationale for continued monitoring:** Use the results of the surveys as evidence for consideration and design of a scientific monitoring fishery in 2019.
5. **Evidence for a rebuilding plan:** Use the results of the surveys to contribute to the scientific basis for development of a rebuilding plan for Western herring.

2 Material and methods

2.1 Research plan

The overall research plan involves the planning, implementation and analysis & reporting stages outlined in Figure 2.1.

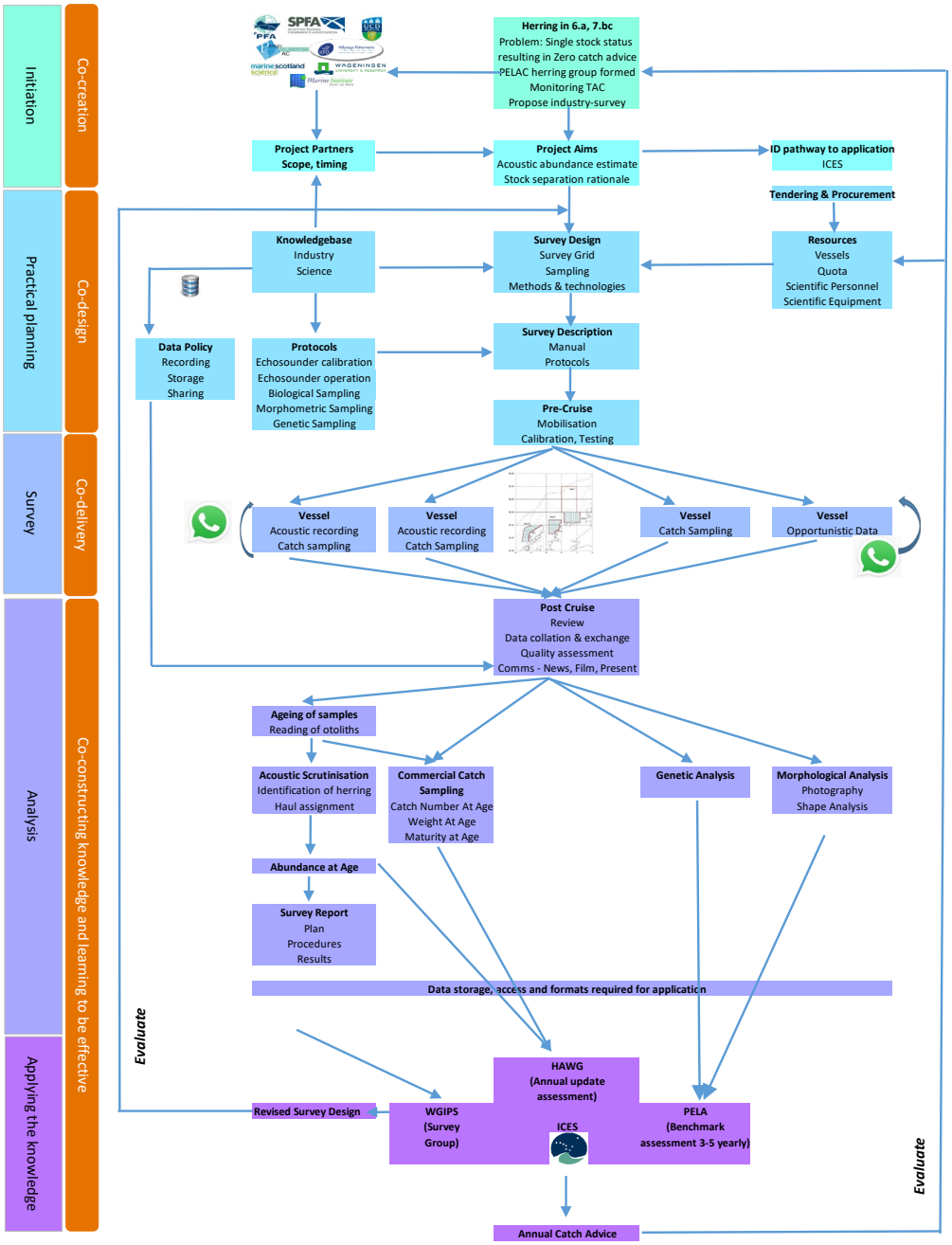


Figure 2.1. Overview of the planning, implementation and analysis stages in the Western herring surveys.

2.1.1 Specific survey objectives

Specific objectives for the field surveys followed objectives 1-3, described in section 1.3. Each of the 7 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

Utilising ICES advice on the monitoring fishery (ICES 2016a) together with the experience from previous surveys, a review of spawning areas and timing (Mackinson 2017) and discussions with fishing skippers during the planning meeting (27 June 2018), 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 a new addition for 2018 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 recorded by other vessels also.

In 6aS/7b, the acoustic survey area (Figure 2.5) collected data from known spawning areas (Figure 2.6). Spawning time in this area is variable, generally between October and February (Table 2.1). Survey design was similar to previous years (O'Malley et al. 2017; O'Malley et al. 2018).

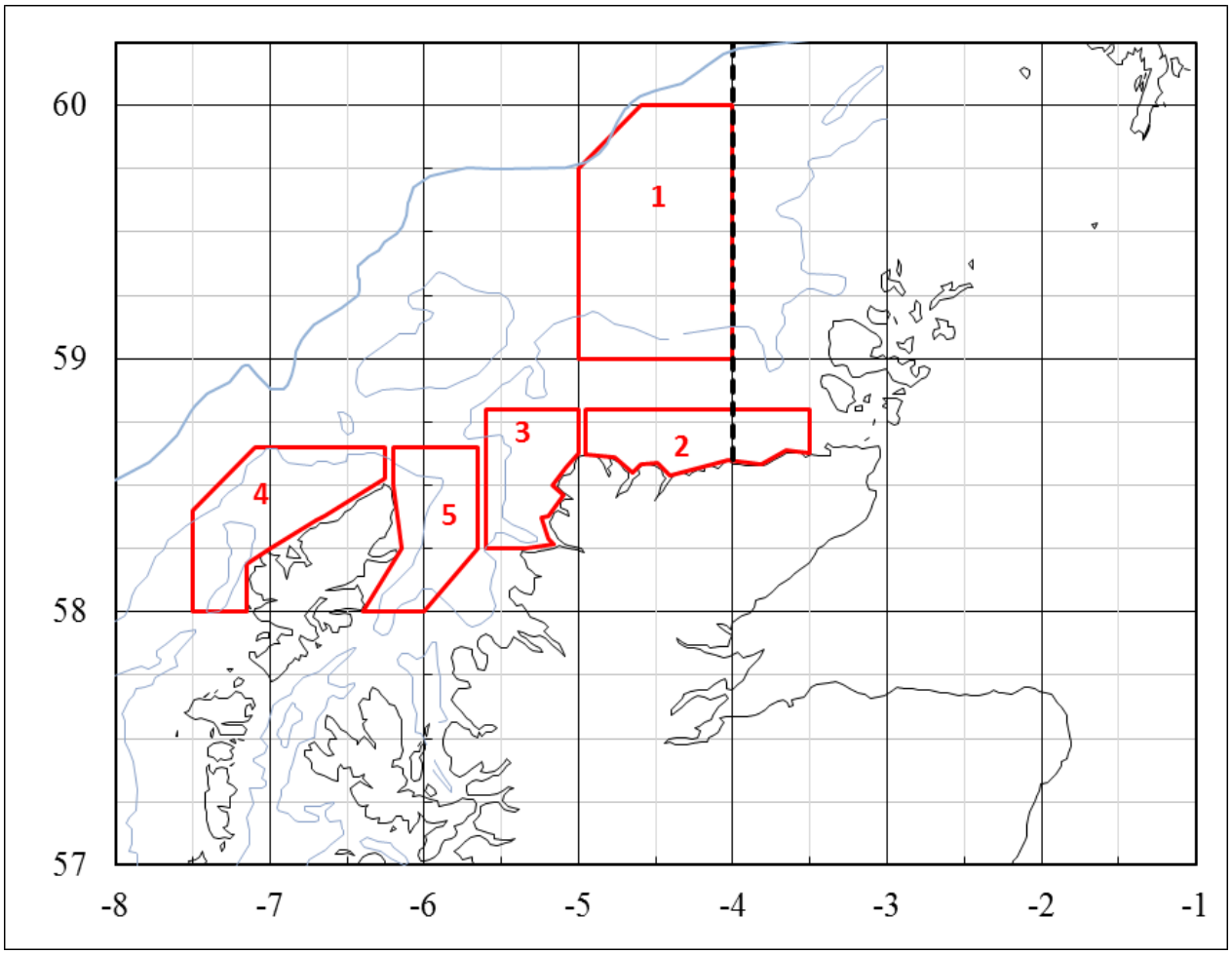


Figure 2.2. Planned survey areas used in the 6aNorth surveys. Area 1- North pre-spawning mixing area, Area 2 -East of cape Wrath, Area 3 – The Minch, Area 4 – Outer Hebrides, Area 5 – east Minch.

1 Pre-spawning mixed area (47E5 and 48E5)
2 East of Cape Wrath (46E5)
3 West of Cape Wrath (46E4)
4 Butt of Lewis /west of Hebrides (45E2)
5 North Donegal (39E2 and 39E1)
6 West Donegal (38E1)

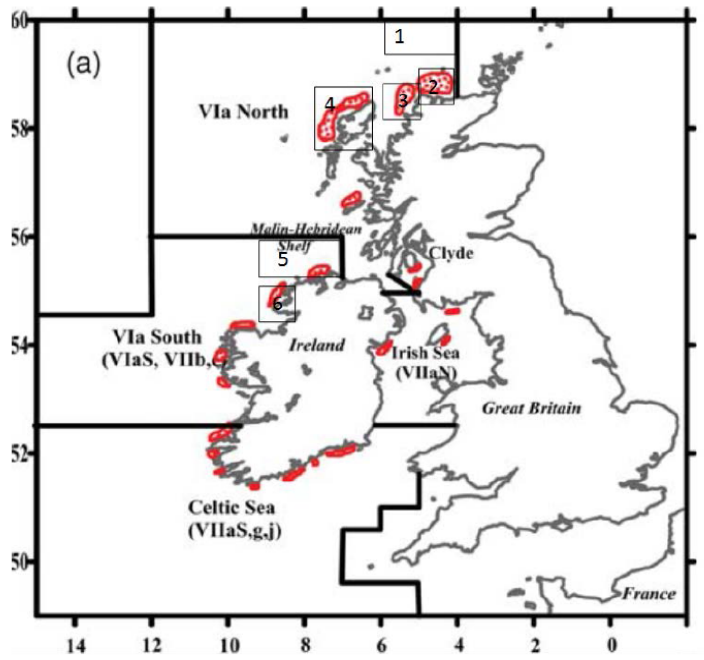


Figure 2.3. Spawning areas for herring in ICES subareas 6 and 7, with currently active spawning areas and pre-spawning aggregation areas for each stock indicated by black rectangles. Used in ICES 2016, redrawn from Geffen *et al.* (2011).

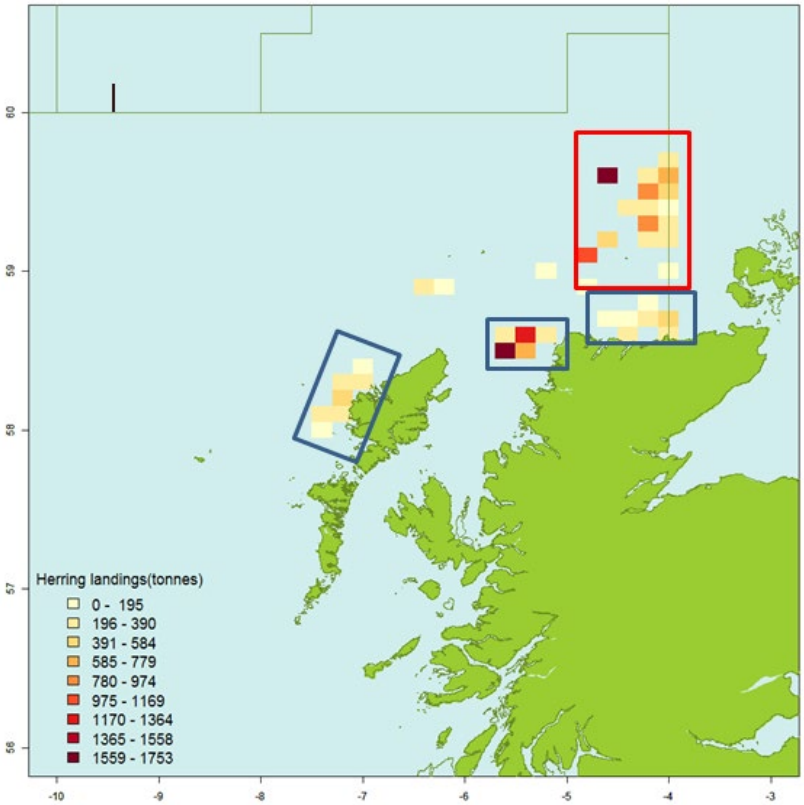


Figure 2.4. Distribution of commercial catches reported in 6aN in 2011.

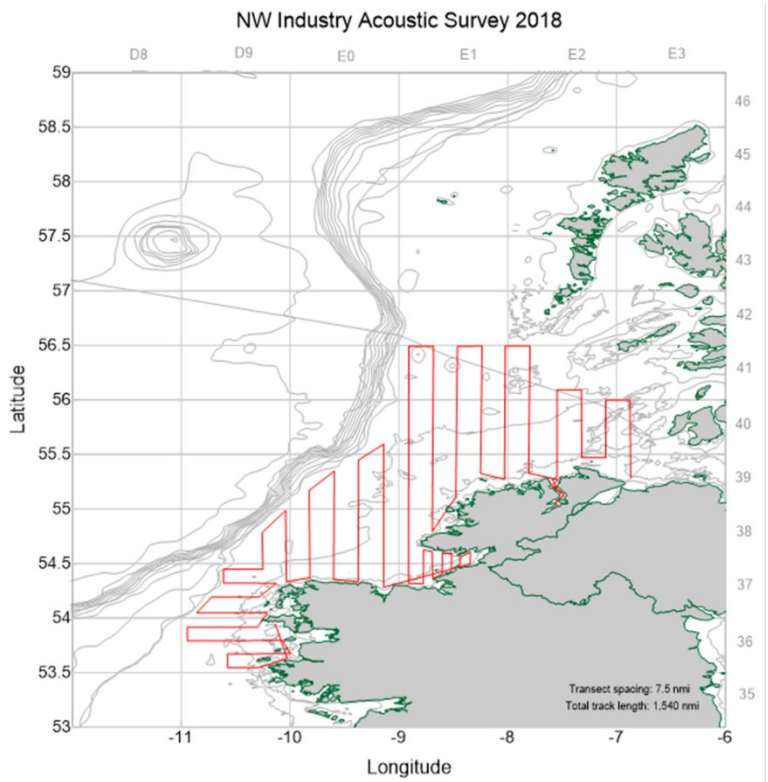


Figure 2.5. Planned acoustic survey area and transects for 6aS/7b, in 2018. Acoustic survey area for 6aS and 7b. The total planned transect length was 1540 nmi (start 55˚17N and 6.52˚W) with progress from east to west. The survey design allows for some intense surveys in areas where fish are observed and also in areas known to contain herring from information from the fleet (e.g. Lough Swilly, Lough Foyle, Inver Bay, Bruckless Bay, Teelin, Killala Bay, and around Glen Head/Rathlin O'Beirne).

Table 2.1. Spawning areas, spawning grounds and spawning beds in 6aS/7bc. Area (km²) 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

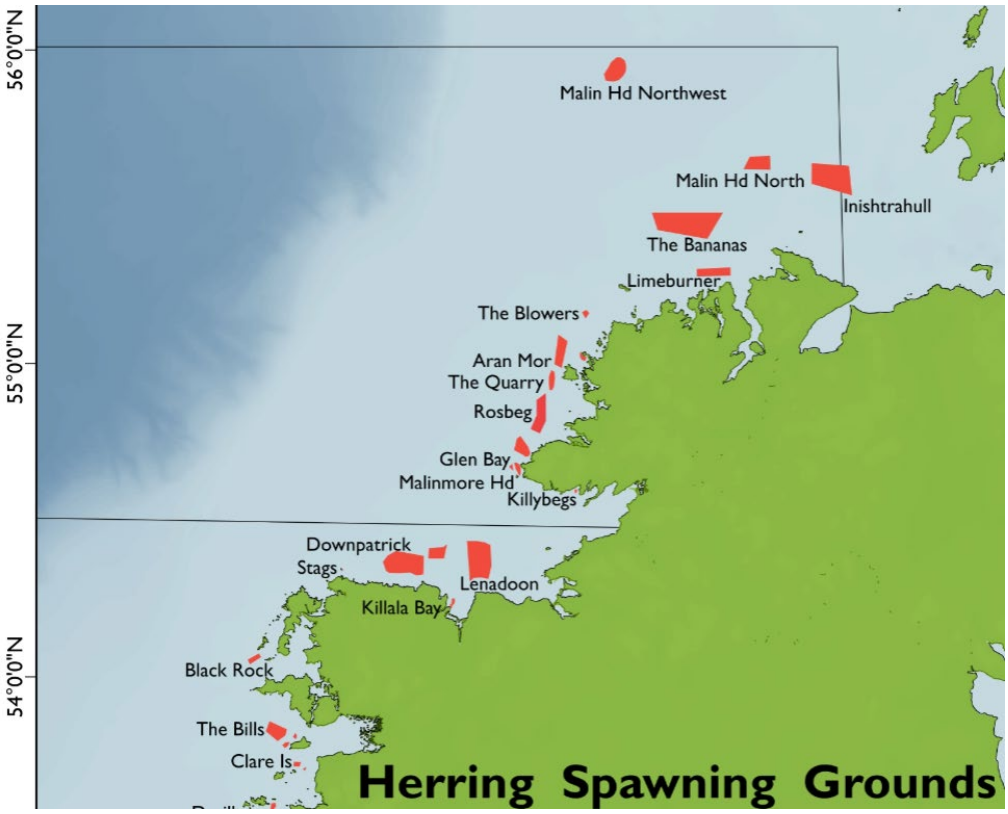
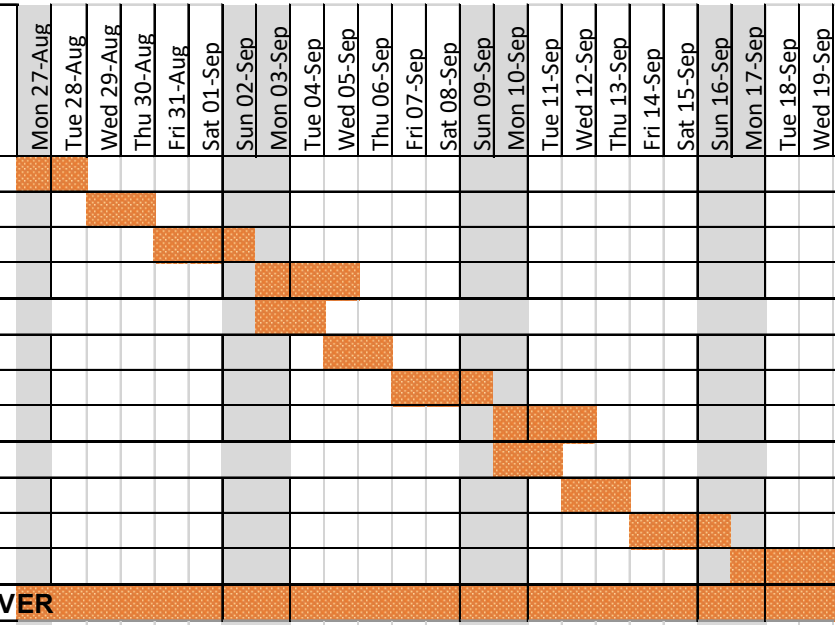


Figure 2.6. Herring Spawning grounds in 6aS/7b,c (from O'Sullivan, 2013).

2.1.3 Timing, vessels and areas for each of the survey vessels (Table 2.2).

Table 2.2a. Deployment in 6aN. Sequencing shown for vessels undertaking acoustic survey work. Vessels deployed for catch sampling only have flexible period of operation covering known spawning timing.

Acoustics vessel	Start	End	Duration	Timing and area coverage
Kings Cross	**27-Aug**	28-Aug	2	**Area 4**
	29-Aug	30-Aug	**2**	**Area 5**
	31-Aug	02-Sep	**3**	**Area 3**
	03-Sep	**05-Sep**	**3**	**Area 2**
Voyager	**03-Sep**	04-Sep	2	**Area 4**
	05-Sep	06-Sep	**2**	**Area 5**
	07-Sep	09-Sep	**3**	**Area 3**
	10-Sep	**12-Sep**	**3**	**Area 2**
Alida	**10-Sep**	11-Sep	2	**Area 4**
	12-Sep	13-Sep	**2**	**Area 5**
	14-Sep	16-Sep	**3**	**Area 3**
	17-Sep	**19-Sep**	**3**	**Area 2**
TOTAL COVER	27-Aug	19-Sep	**24**	**TOTAL COVER**



	Task	Start dates	End date
Kings Cross	Acoustic	27-Aug	05-Sep
Voyager	Acoustic	03-Sep	12-Sep
Alida	Acoustic	10-Sep	19-Sep
Christina S	Genetic	03-Sep	13-Sep
Dirk Dirk	Catch samp.	15-Aug	19-Sep
Wirons	Catch samp.	15-Aug	19-Sep

	Area 2	Area 3	Area 4	Area 5	TOTAL
Spacing (nmi)	2	2	4	4	
Duration (d)	2.3	2.2	1.9	1.4	**7.7**
Length (nmi)	320	301	260	197	**1079**

Table 2.2b. Deployment in 6aS/7b

Area	Earliest survey date	End date	Calibration date	Acoustic Survey distance (nm), one coverage	Vessel and type (Refrigerated Sea Water (RSW) or Freezer)	Flag	Homeport	Vessel#	Role	Skipper
Area 5 (North Donegal) & 6 (West Donegal/Mayo)	01-Nov	21 Nov	18-Nov 2017	1400 nmi approx.	Eilean Croine (RSW acoustic vessel) and Sparkling Star (RSW biological vessel)	IRL	Skibbereen /Killybegs	S238 and D437	**Acoustic and catch sampling**	Eric Murphy (Eilean Croine) and Donal O'Neill (Sparkling Star)

2.2 Abundance estimation

2.2.1 Acoustic survey design

The purpose of the acoustic surveys was to estimate the minimum spawning biomass of herring within the boundaries of the survey areas.

Acoustic surveys were conducted in Area 2-5 (6aN) and Area 5&6 (6aS/7b), each designed on regularly spaced parallel transects (Figure 2.2 & 2.5). 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. Each vessel surveying in sequence with a lag of seven days, replicate acoustic surveys were conducted in each of the areas in 6aN to try and capture the peak time of spawning abundance (Table 2.2a). The survey dates in each area were decided based on records of known spawning times and advice of fishermen familiar in working the areas. Vessel skippers were also confirmed that the transect direction was not following the natural line of fish density, which would have led to a biased estimate.

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 2.3 summarises the design and equipment for each area, and notes any adaptations to the original planned survey transects.

2.2.2 Equipment specifications and calibration

See Table 2.3 for specification.

The standard calibration procedure described in Demer et al. (2015: http://courses.washington.edu/fish538/resources/CRR326_Calibration.pdf) was used to calibrate each of the echosounders deployed on each of the vessels. Echomaster Marine successfully performed the calibration of Kings Cross, stern on to the breakwater in Peterhead at the slack of a high tide (22m under transducer) in calm conditions (Figure 2.7).

Figure 2.7. Location of calibration of the Simrad EK80 on Kings Cross at Peterhead Harbour.

Calibration of the EK60 towed body transducer on the Eilean Croine was attempted in Lough Swilly prior to the start of the survey. Conditions were poor, although the calibration site was in a relatively sheltered area, the winds were strong and the currents at depth were also strong. A chain clump was dropped off the stern of the vessel to assist in keeping the vessel in position but the vessel moved laterally with the current and wind. Water depth was approximately 20m at the calibration site. It was decided to abort the calibration and use the results from the successful calibration obtained during the previous survey in 2017. This calibration was carried out using standard methodology as described by Foote et al (1987). Standard LOBE calibration (SIMRAD 2003) was carried out on the Eilean Croine on the morning of 18/11/2017 in Lough Swilly, Co. Donegal, close to the pier at Rathmullan. The successful calibration was made possible by good conditions in the deep water (~20m slack high). There was minimal interference from biota in the water column.

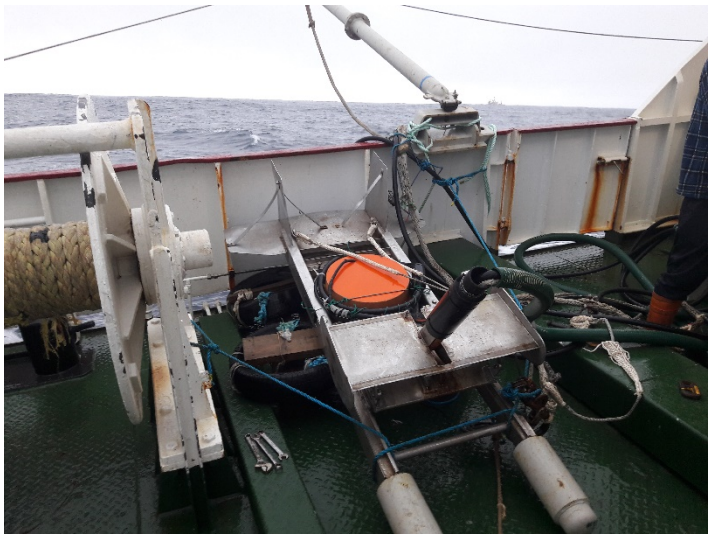


Figure 2.8. Towed-body mounted 38kHz transducer (Eilean Croine S238) were calibrated in Lough Swilly.

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. Surveys in 6aS/7b were continuous over 24 hours due to the limited daylight in November and scale of coverage planned. Survey speed was 8 - 10 knots, reducing as needed in the case of poor sea state. The FV Eilean Croine was the designated 'acoustic' vessel, with two acousticians aboard, and the FV Sparkling Star was the designated 'biological' vessel, with two biologists aboard to conduct sampling.

To maximise 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 on Kings Cross to compensate for pitch and roll.

Raw acoustic data were recorded and stored on the PC and backed up each day on portable hard disk drives 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.

2.2.4 Fishing operations for scientific samples

During the acoustic surveys, selected fish marks were targeted with a fishing operation (Figure 2.9) 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.

The fishing operations of RSW vessels were directed to take a catch of the smallest possible size sufficient for biological sampling. The operation for freezer trawlers was a typical commercial catch.

Each surveying vessel was granted a derogation to discard fish that were not retained for biological sampling and to retain any catches of herring, up to the maximum specified quota taken either during or outside the survey period.

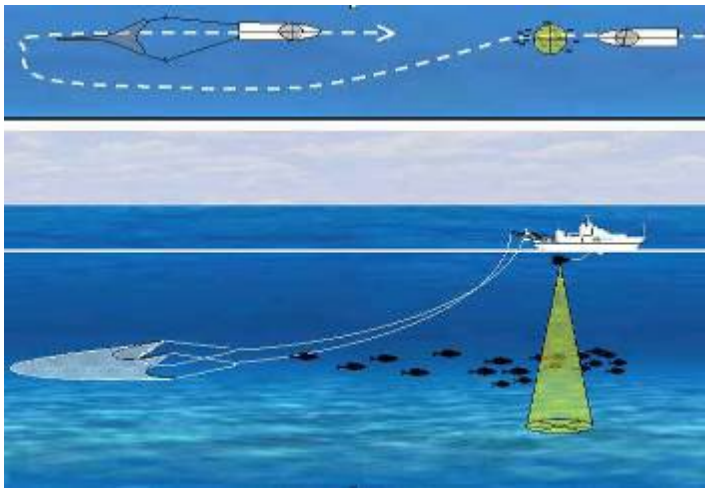


Figure 2.9. Schematic description of fishing operation to collect a biological catch sample during an acoustic survey.

Table 2.3. Acoustic survey summary

Area surveyed	Vessel	Transducer and Frequency	Echo-sounder	Power Pulse duration Ping interval	Environment	Calibration Location/ date, supplier	Survey area changes
4,5,3,2	Kings Cross (PD 365)	Hull mounted split beam ES38B (38Khz), draft ~5.5m With heave compensation. ES200-7C (200Khz) split beam [not used]	SIMRAD EK80	**@38Khz** Power: 2000W Pulse duration: 1.024ms Pulse form: Continuous wave Ping interval = 0.5 sec	Temp = 10C, Salinity =35ppt, Sound speed 1491.5 m/s	Peterhead breakwater 26 Aug, Echomaster Marine	
4,5,3,2	Voyager (N 905)	Hull mounted split beam ES38B (38Khz), draft ~6m Without heave compensation. ES200-7C (200Khz) split beam [not used]	SIMRAD EK80	**@38Khz** Power: 2000W Pulse duration: 1.024ms Pulse form: Continuous wave Ping interval = 0.5 sec	Temp = 10C, Salinity =35ppt, Sound speed 1491.5 m/s	Killybegs harbour, Mike O'Malley and Ciaran O'Donnell (Marine Institute)	
5,3,2	Alida (SCH 6)	Hull mounted split beam ES38B (38Khz), draft ~5m Other frequencies used 120, 200 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	Scapa Flow Benoit Berges (WMR)	Weather meant unable to survey area 4.
5 South Donegal & 6 West Donegal/ Mayo	Eilean Croine	Towed body mounted split beam ES38B (38kHz)	SIMRAD EK60	Power: 2000W (38kHz); Pulse duration: 1.024ms Ping interval = 0.33 Hz	Temp = 10˚C, Salinity =34ppt, Sound speed 1488.6 m/s	Rathmullan, Lough Swilly, Co. Donegal 18th November 2017	Additional transects in Lough Swilly and Lough Foyle. Additional searching with sonar in the Glen head and Mayo coast.

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 to indicate the location and timing of spawning, (iii) for genetic analysis (which are not reported here).

2.2.5.1 *Haul information*

Haul data were recorded using the same template for all surveys, 1 sheet per haul. Information was recorded on the date, time, fishing position, depth, gear, catch composition, total weight of catch and weight of the sub sample taken for length frequency and biological sampling. To aid in scrutinisation, screen captures (Figure 2.10) were taken during the haul operation identifying first the targeted mark and later the marks covered while trawling. Comments about the marks were written on the haul sheet, as well as whether or not the herring were spawning (based on "running" eggs and sperm upon capture) and whether any catch remaining after biological sampling was retained or discarded.

2.2.5.2 *Catch sampling*

The catch sampling procedure was as follows:

- Weight of the catch of all species, or where the catch was too large, 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 determine lengths, weight, age and for genetic samples. (see below). (Figure 2.11)

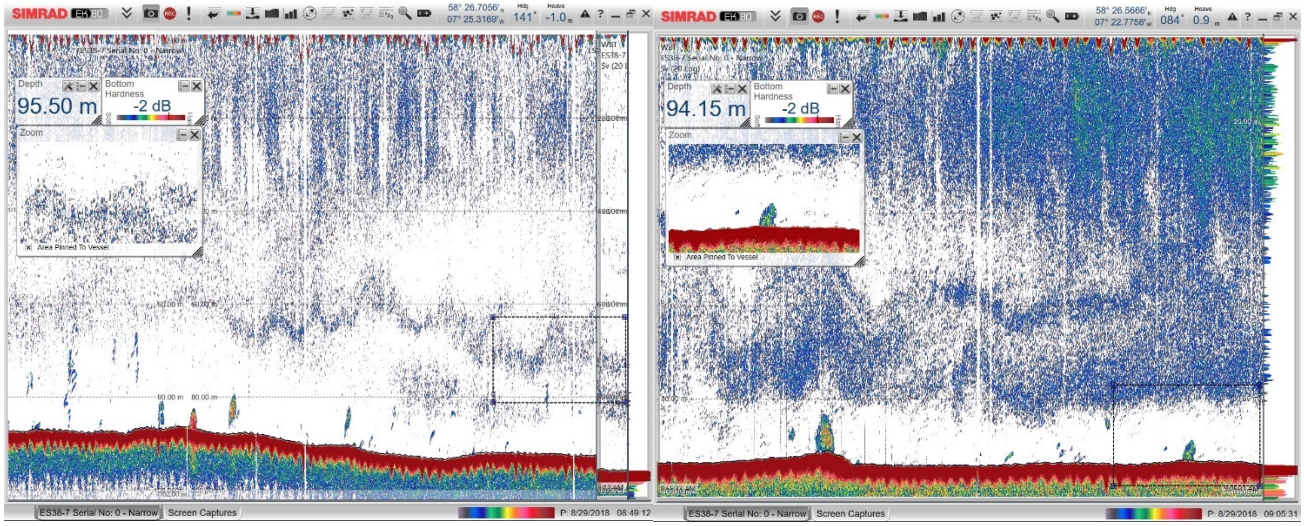


Figure 2.10. Example screen shots of targeted marks (first panel) and those trawled on.

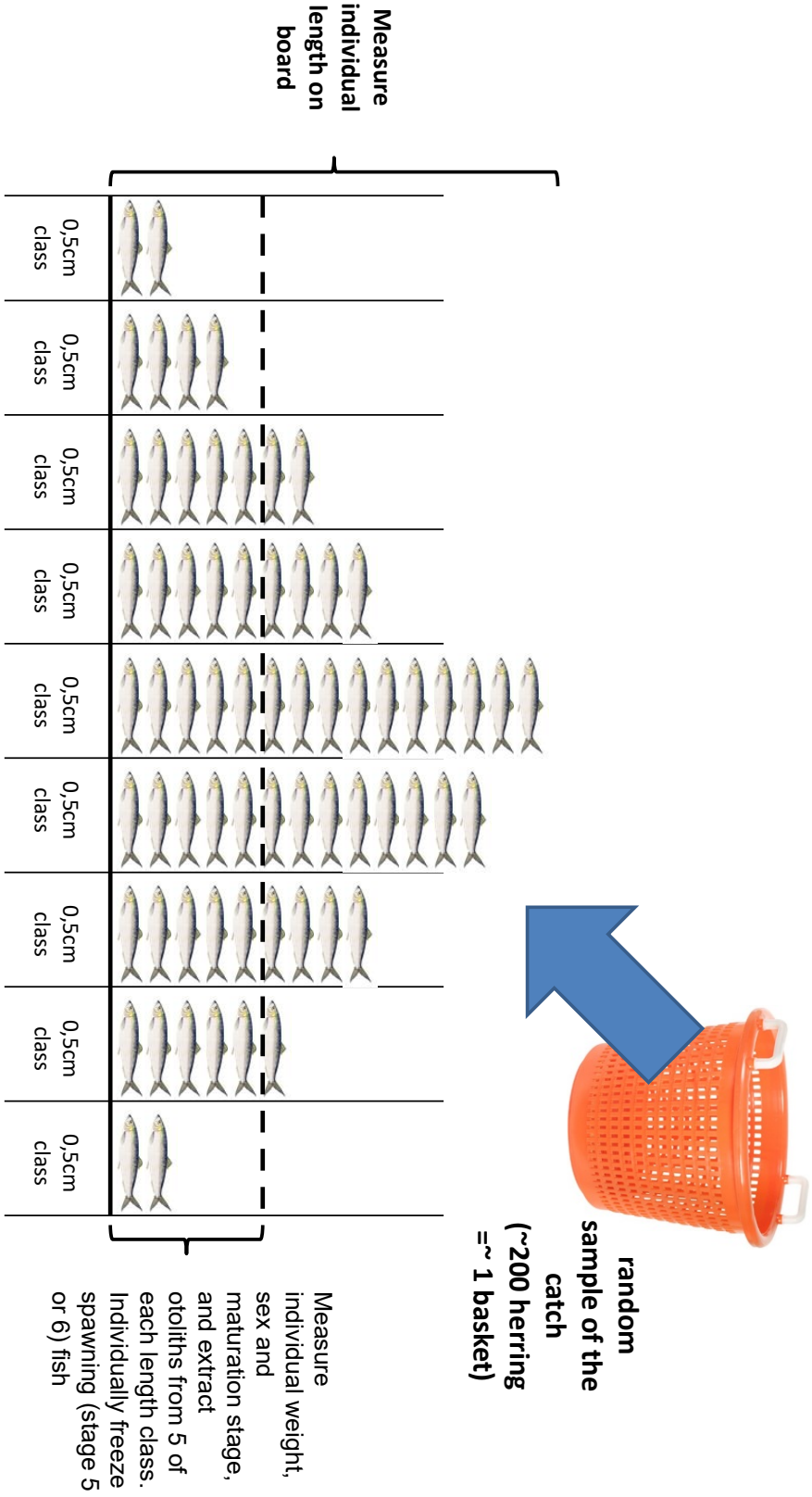


Figure 2.11. Illustration of the required catch sampling procedure.

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. Five fish from each half centimetre length class were saved for additional biological measures (next section).

2.2.5.4 *Whole weight, Sex, Maturity stage, Otolith, Genetics*

Taking the 5 fish in each length class, each measured fish was assigned an ID number so that subsequent genetic samples can be cross-referenced to biological data.

The following information was recorded for each fish.

- Length to nearest 0.5cm
- Weight in g
- Sex
- Maturity stage from 1-9 based on the classification in the Scottish and Irish sampling (MSS manual 2011) or on the ICES 6 point scale (ICES 2011) for the Dutch-collected samples. All maturity estimates were later converted to the ICES scale.
- Otoliths were extracted for age determination at the lab. Standard procedures for age determination from the growth rings on the otoliths (ear bones) of herring were used to determine the age of fish sampled (ICES 2005). This age data was used to create an age-length key (ALK).
- If the fish was from a spawning haul (see 2.2.5.1), it was bagged, labelled and frozen for later genetic analysis.

2.2.6 Acoustic Analysis methods

2.2.6.1 *Echogram scrutinisation – partitioning to species*

Scrutinising echograms involves identifying fish marks and assigning them to species, and ensuring that any non-fish acoustic signals are not included as fish (e.g. bottom signals).

Assigning fish marks to species is a heuristic process that relies upon (i) evidence from the targeted hauls made during the survey (Figure 2.10), (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 (ii) 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, and hence in the quality and comparability of the biomass estimates.

Acoustic fish marks were classified in to the following categories (See examples in Figure 2.12):

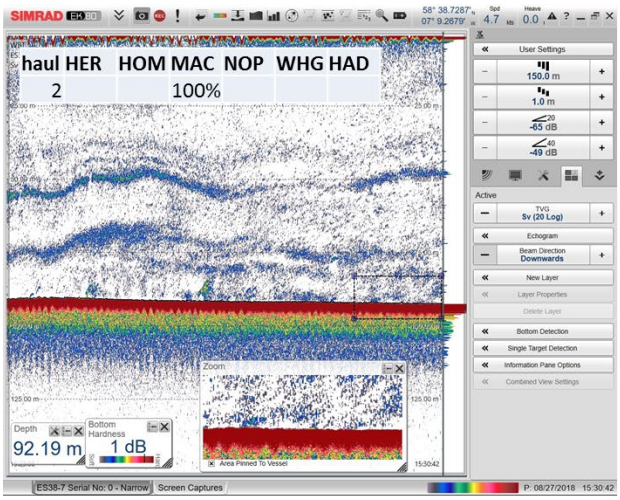
- **Herring** – confident that the marks were herring based on either evidence from a targeted haul or proximity and similarity to other schools known to be herring.

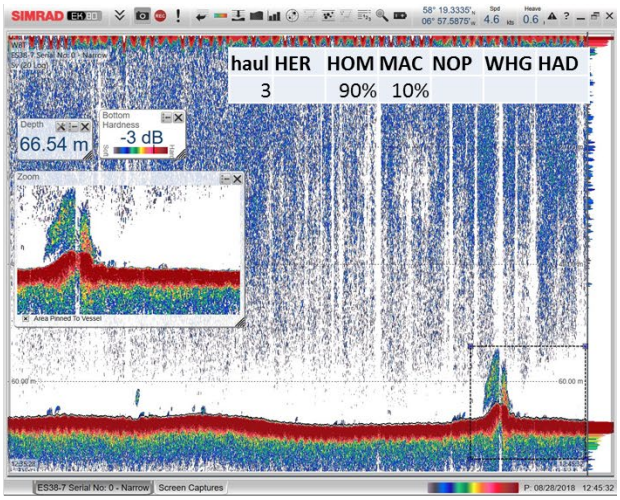
- **Maybe herring** - concentrations of fish tightly associated with prominent outcroppings on the seabed. Believed to be herring, but not possible to confirm with trawling. Where marks on the sides of steep slopes of the outcropping occurred, they were excluded from the analysis because of the possibility of being registration of acoustic side lobes. Also included are other herring-like marks that were not possible to trawl on due to the nature of the ground or water depth.
- **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 were believed to be juvenile sprat. Targeted hauls had low success rate due to fish going through the net and difficulties in fishing close to the surface.
- **Unclassified –** confident that the marks were not herring or sprat based on either evidence from a targeted haul or proximity and similarity to other schools known to not be herring, or characteristics atypical of herring schools.
- **Horse mackerel –** a lot of horse mackerel marks were observed through 6aS/7b. Marks were verified with numerous trawls.

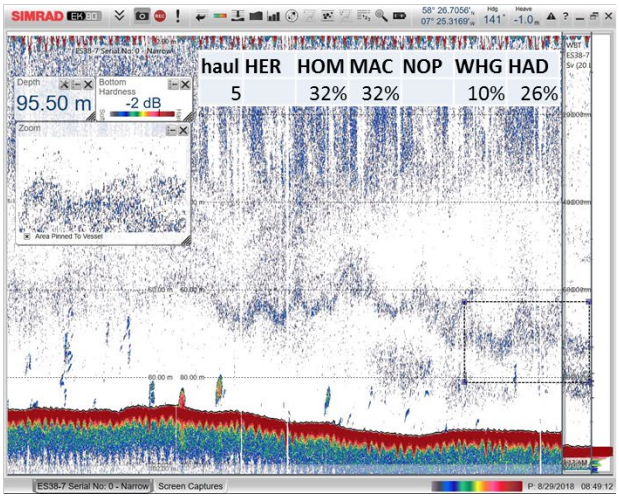
How strongly the acoustic marks are displayed on the screen (backscatter threshold) can have a bearing on the interpreters classification of the acoustic marks and their selection using school detection algorithms. While it is desirable to be consistent in the setting of this parameter, in practice the setting is determined largely by the need to filter out fish schools from other acoustic signals that create noisy backscatter data. Other methods used to help distinguish herring marks from other fish and organisms causing backscatter included looking at the 'frequency response' (i.e. how the backscatter properties look at different acoustic frequencies), and the application of filters (Figure 2.13). 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.

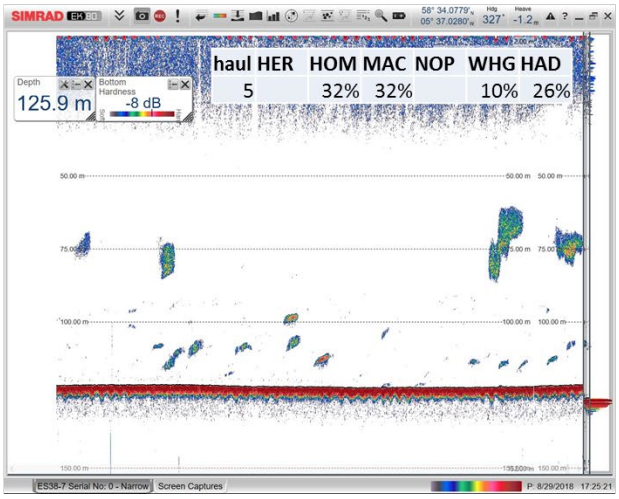
In 2018, the diversity of acoustic marks (Figure 2.12) and the availability of trawls samples with which to verify them, made the classification of marks and assignment of herring biological sample data to acoustic transects (Table 3.5, Figure 2.15) particularly challenging.

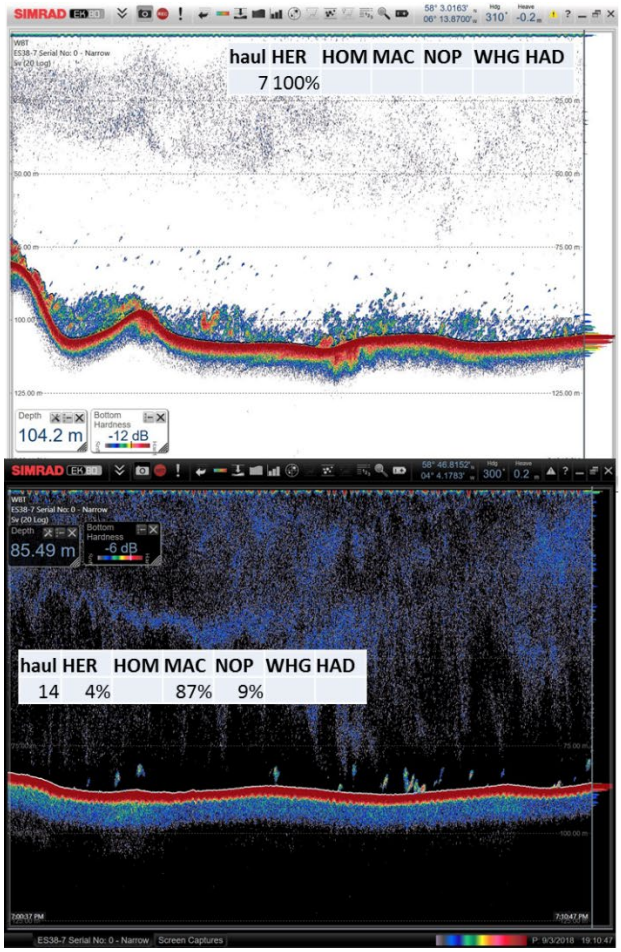
6aN acoustic marks recorded by King Cross

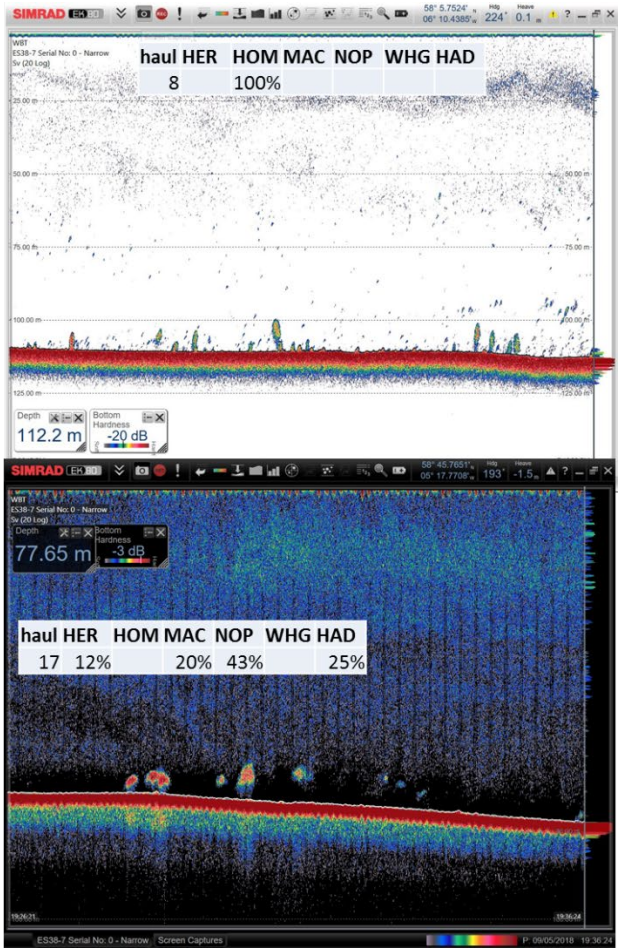








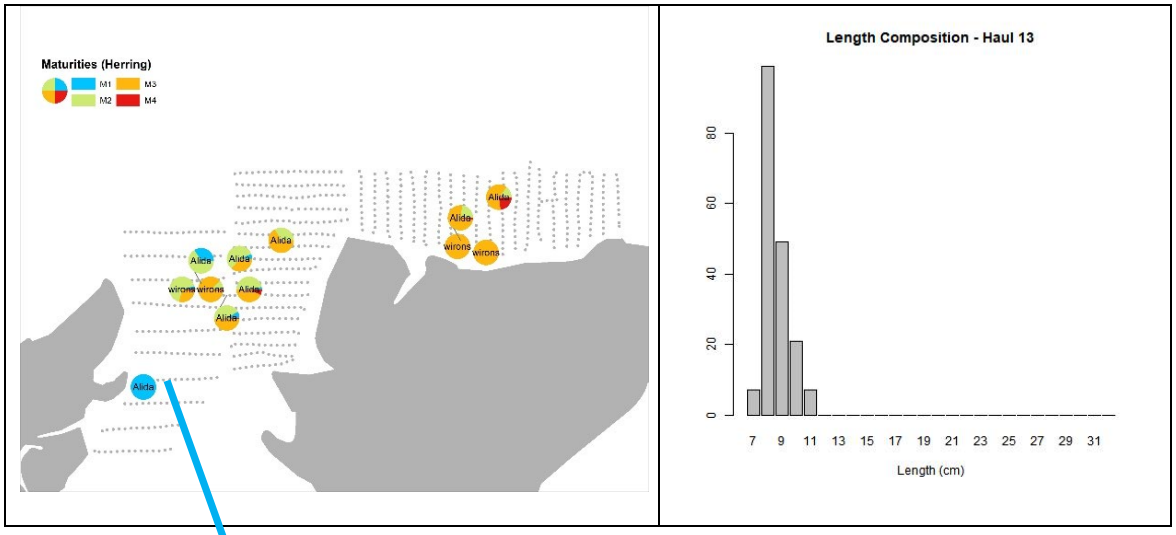

SIMRAD
haul HER HOM MAC NOP WHG HAD
7 100%
Depth
104.2 m
Bottom Hardness
-12 dB

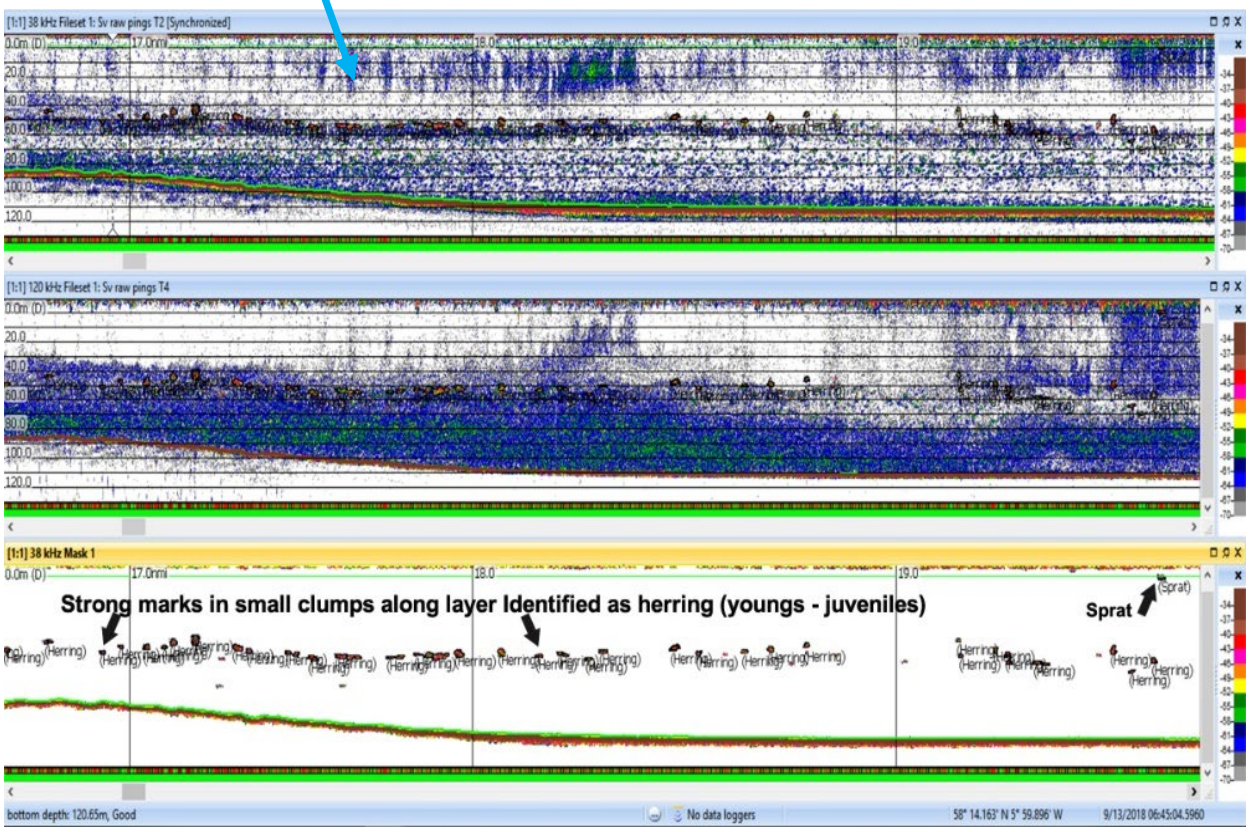

SIMRAD
haul HER HOM MAC NOP WHG HAD
8 100%
Depth
112.2 m
Bottom Hardness
-20 dB

SIMRAD
Depth
85.49 m
Bottom Hardness
-6 dB
haul HER HOM MAC NOP WHG HAD
14 4% 87% 9%

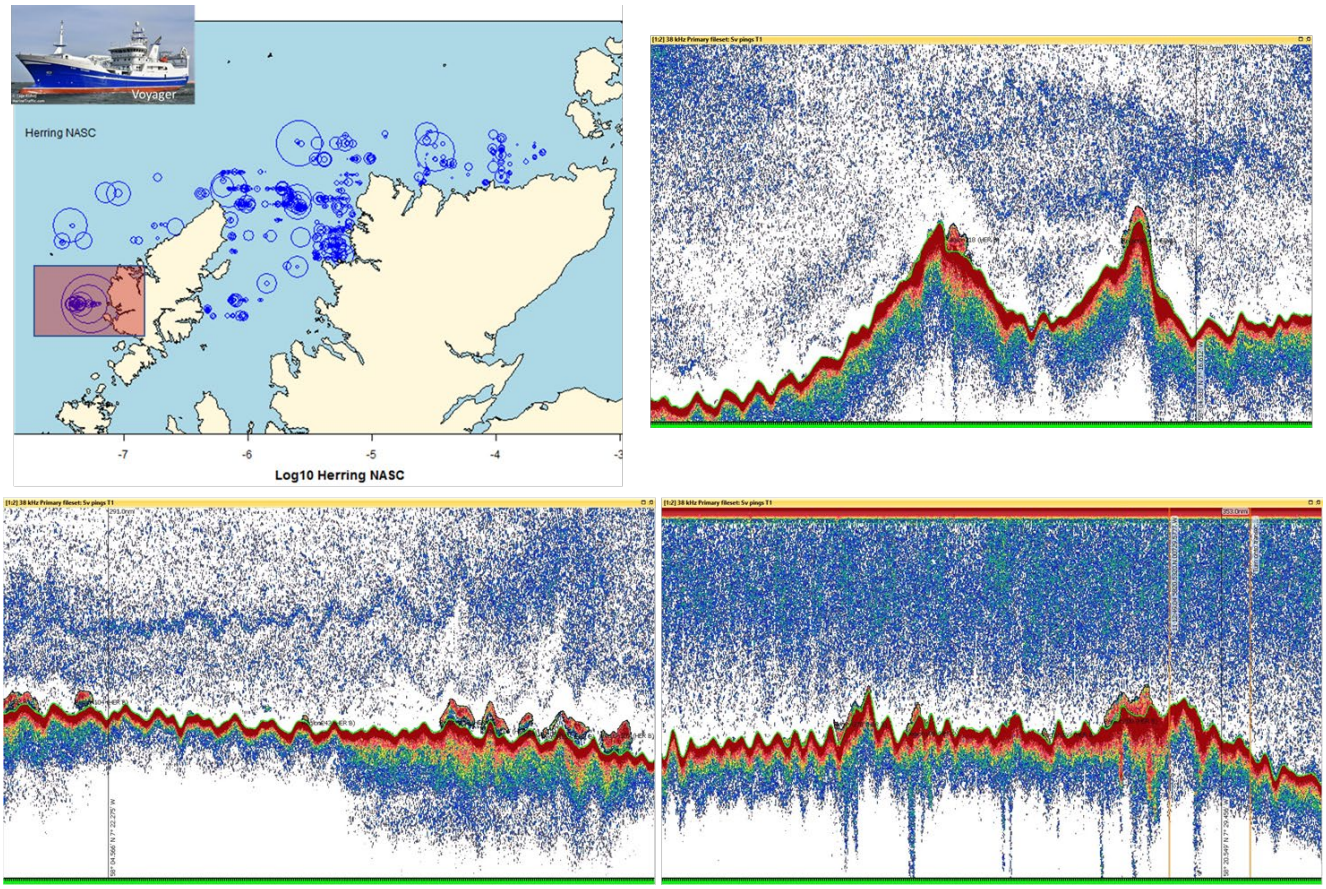
SIMRAD
Depth
77.65 m
Bottom Hardness
-3 dB
haul HER HOM MAC NOP WHG HAD
17 12% 20% 43% 25%

6aN acoustic marks of Juvenile herring recorded by Alida

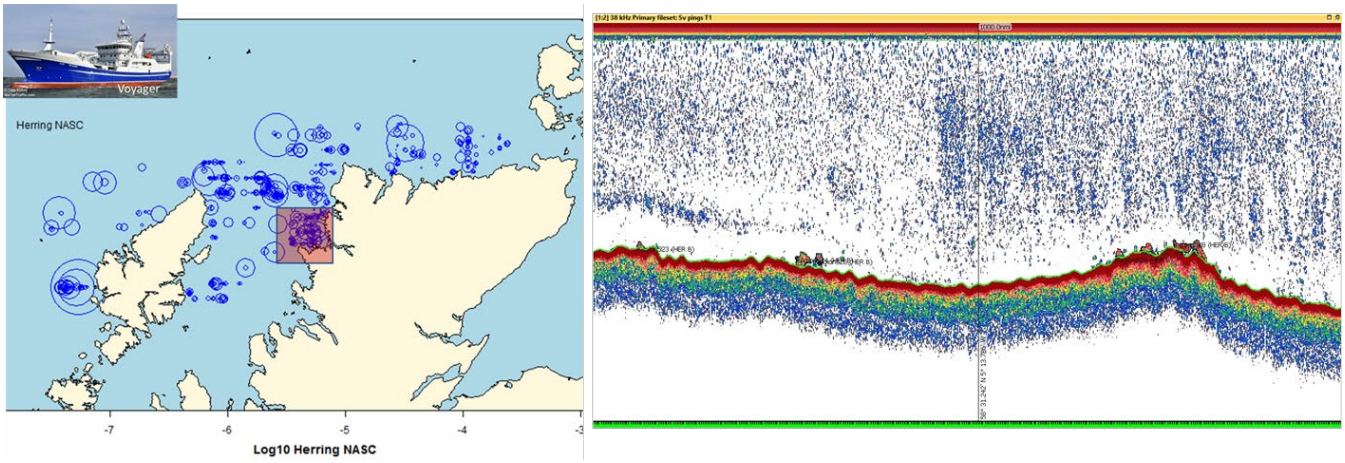




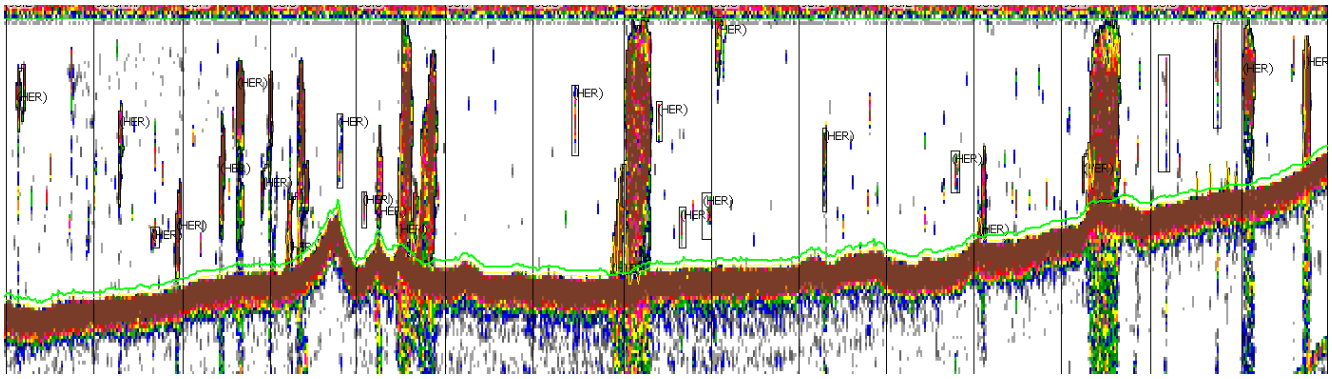
6aN acoustic marks associated with outcroppings in Area 4 and classified as herring



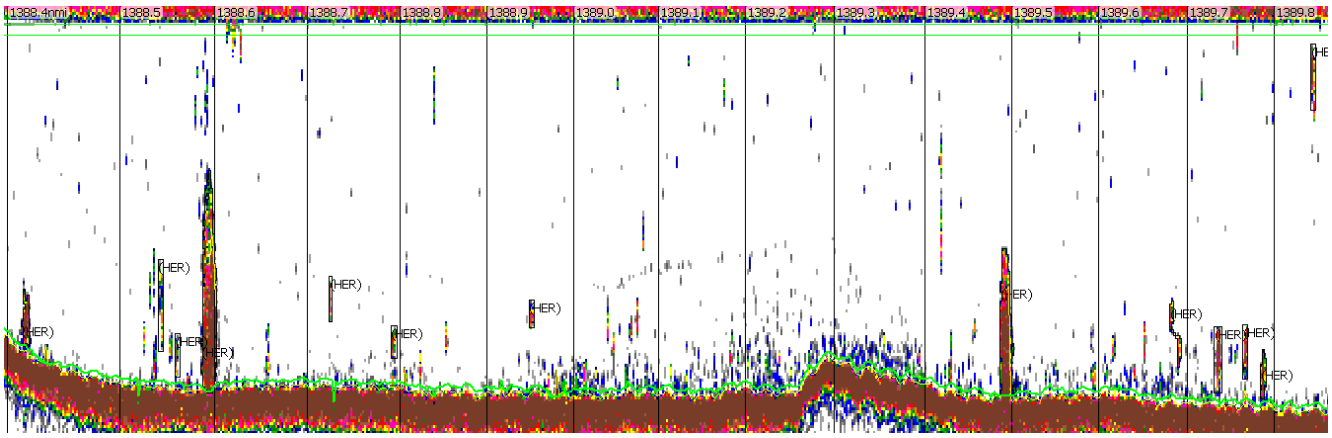
6aN acoustic marks close to bottom on rough ground Area 3 and classified as herring



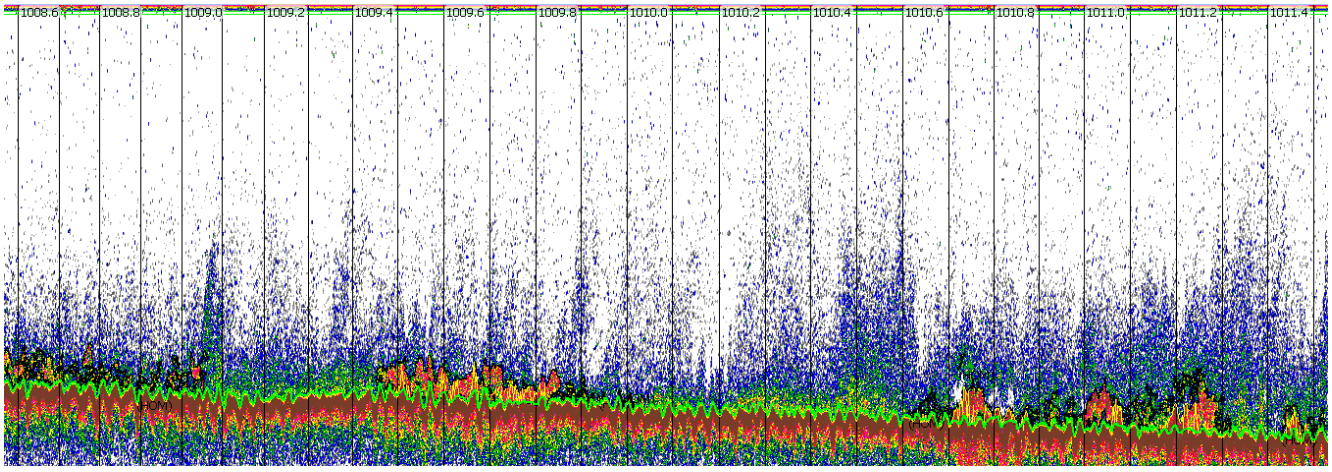
6aS/7b acoustic marks recorded by Eilean Croine



Large herring marks in Lough Swilly, (6aS) on 2/11/18

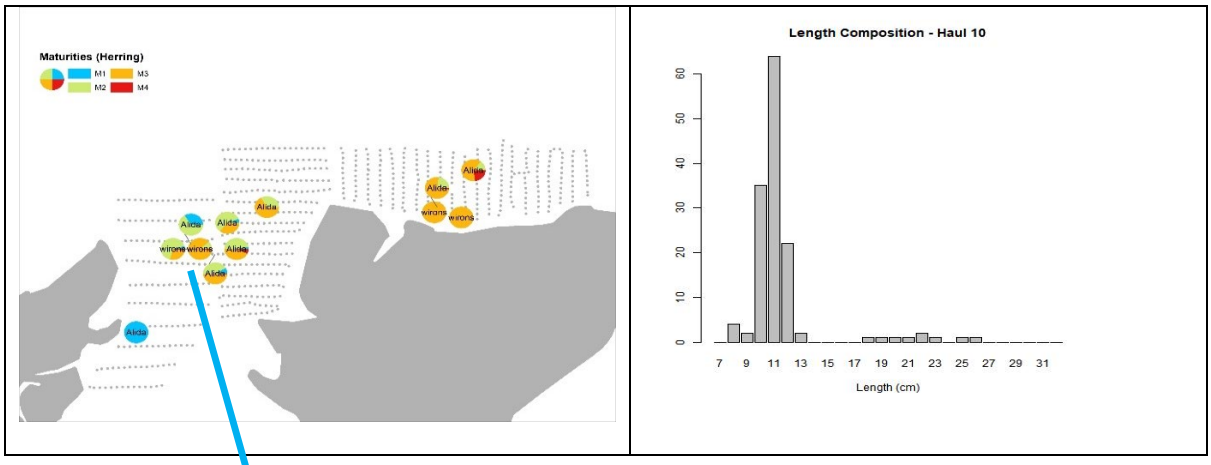


Series of herring marks in Bruckless Bay (6aS) on 21/11/18



Horse mackerel marks obsereved NW Broadhaven Stags (7b) 09/11/18

Figure 2.12. Examples of acoustic marks and their identification.



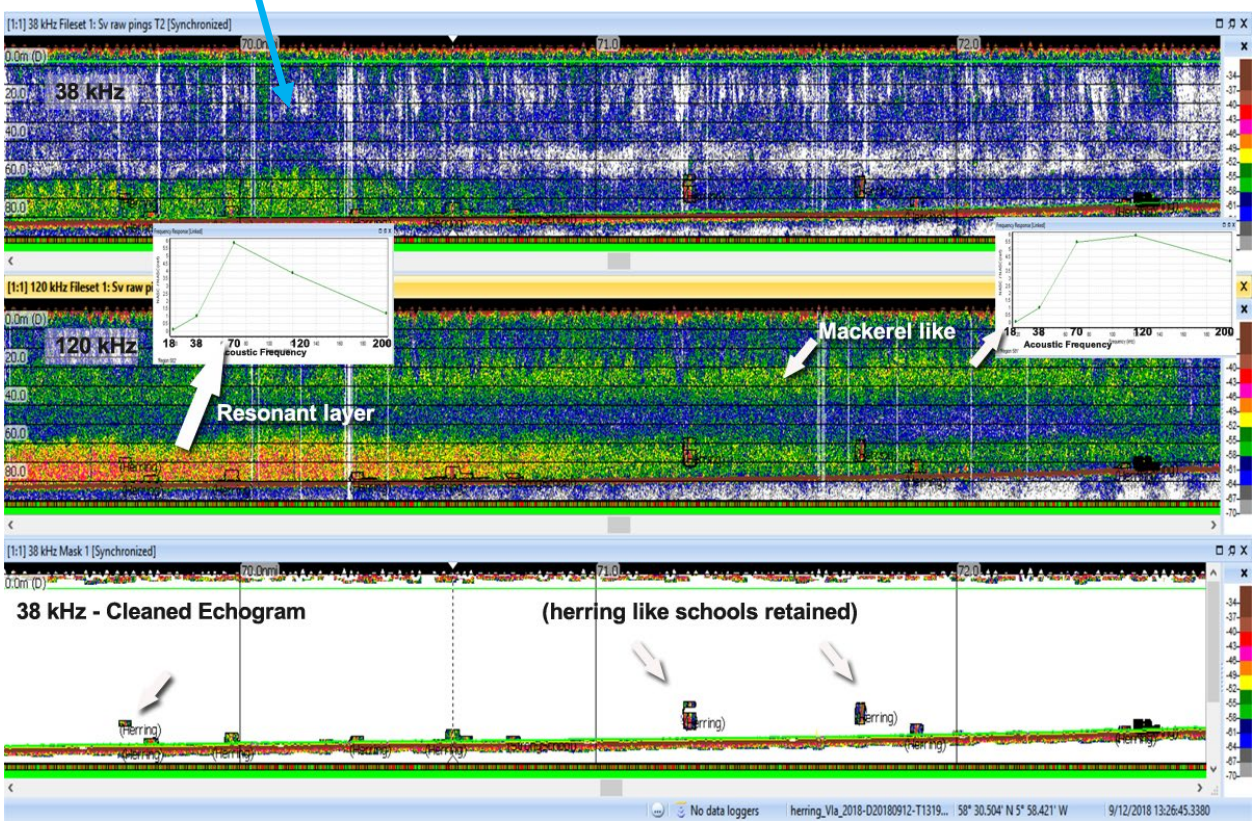


Figure 2.13. Analysis of acoustic properties to help classify schools in 6aN from Alida acoustic data.

2.2.6.2 *Age disaggregated abundance estimation*

The process for estimating abundance and biomass from the acoustic data is shown in Figure 2.14, with additional description given below.

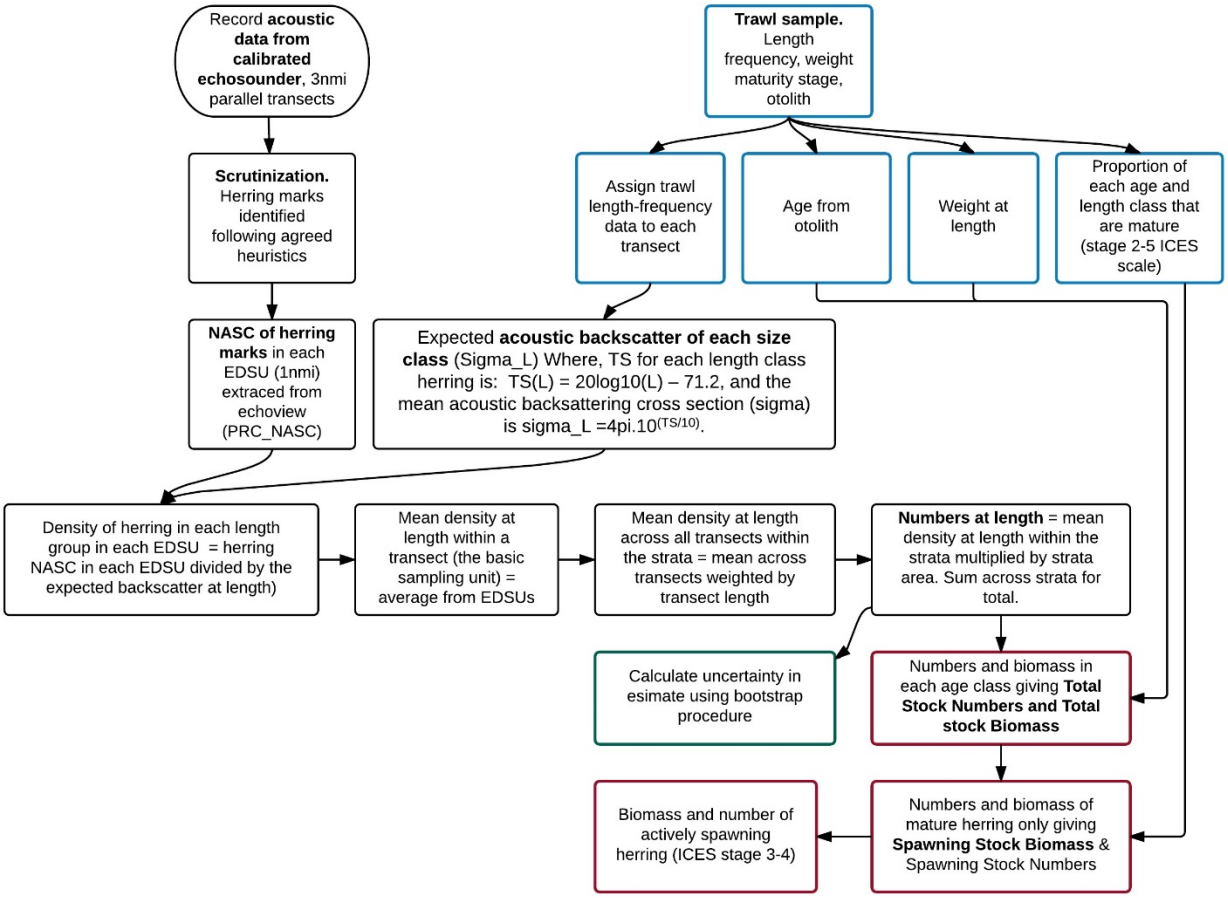


Figure 2.14. Flow diagram of the analysis methods to estimate abundance and biomass. Blue boxes – biological data; black boxes – treatment of acoustic data; red boxes- derived abundances indices; green box – uncertainty estimates

The StoX software (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).

Following scrutinisation of the echograms and export of the Nautical Area Scattering Coefficient assigned to herring marks for each 1nm cell (PRC_NASC from Echoview software), the calculation of age disaggregated abundance was as follows:

1. **Define survey strata.** In 6aN, each of the 4 areas surveyed was assigned as a strata. In 6aS/7b 4 strata were defined, (i) Lough Swilly, using zig-zag transects, where the boundaries of the strata was delineated approximately 250m either side of the centre line of the deepest part of the Lough Swilly channel in approximately 10 – 20m water depth. (ii) Donegal bay using parallel transects with 3.5 nmi spacing including shallow inshore areas of Bruckless Bay and Inver Bay, (iii) the rest of the northwest area of the survey, using parallel transects 7.5nmi apart, and (iv) Achill using parallel transects with 3.5 nmi spacing.

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 (e.g. Figure 2.15).

   In 2018, difficulties in getting sufficient representative biological survey samples to allocate to the echograms necessitated borrowing sample data from other vessel hauls that were considered representative based on their time, location, catch composition and comparison with the identified acoustic marks (see Figure 2.15, Table 3.3).

3. **Expected backscattering cross section of fish in each length group.** The mean acoustic backscattering cross-section "sigma" (σ_{bs}) for each length group of herring was calculated from the length frequency data assigned to each transect using the target strength-length relationships for herring recommended by the ICES Working Group on International Pelagic Surveys. Where, the target strength (TS) relationship used to calculate the mean acoustic backscattering cross-sections for herring is:

$$TS = 20\log10(L) - 71.2 \quad \text{[at 38kHz]} \textit{ for herring}$$

$$TS = 20\log10(L) - 67.5 \quad \text{[at 38kHz]} \textit{ for horse mackerel}$$

   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 2.4) (ICES 2011).

7. **Estimate of the relative sampling error.** Within StoX a bootstrap procedure was used to estimate the coefficient of variance (CV) of the estimate of numbers at length. The procedure randomly selects transects within a stratum in every n bootstrap iteration (n =1000 check). For each selected transect, biological information from trawl stations that were assigned to the transect are randomly sampled and used as input to estimate fish abundance in the stratum in that particular bootstrap iteration. Each bootstrap iteration follows the same estimation procedures as used in StoX and described above (using the combination of mean acoustic density per transect and associated biological information, to estimate fish numbers at length in each stratum). This procedure was not performed for the 6aN survey this year because of difficulties in getting stox programme to work.
8. **Choosing the best estimate from replicates**. In the 6aN, where replicate acoustic surveys were conducted for each stratum, the maximum biomass estimate of these was chosen as the best estimate.

Acoustic data were recorded on hard-drives at sea and uploaded to network facilities back at the laboratory. The acoustic metadata and cleaned post-processed EV files are stored using 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 from the surveys are stored in the ICES acoustic database.

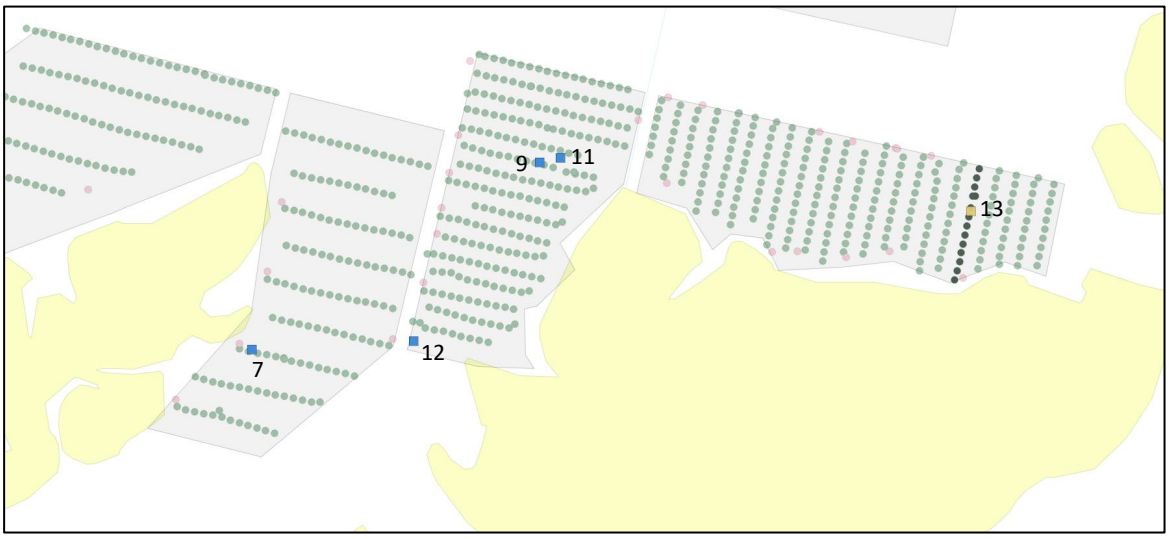


Figure 2.15a. Kings Cross acoustic survey in 6aN – marking haul numbers for biological data assignment.

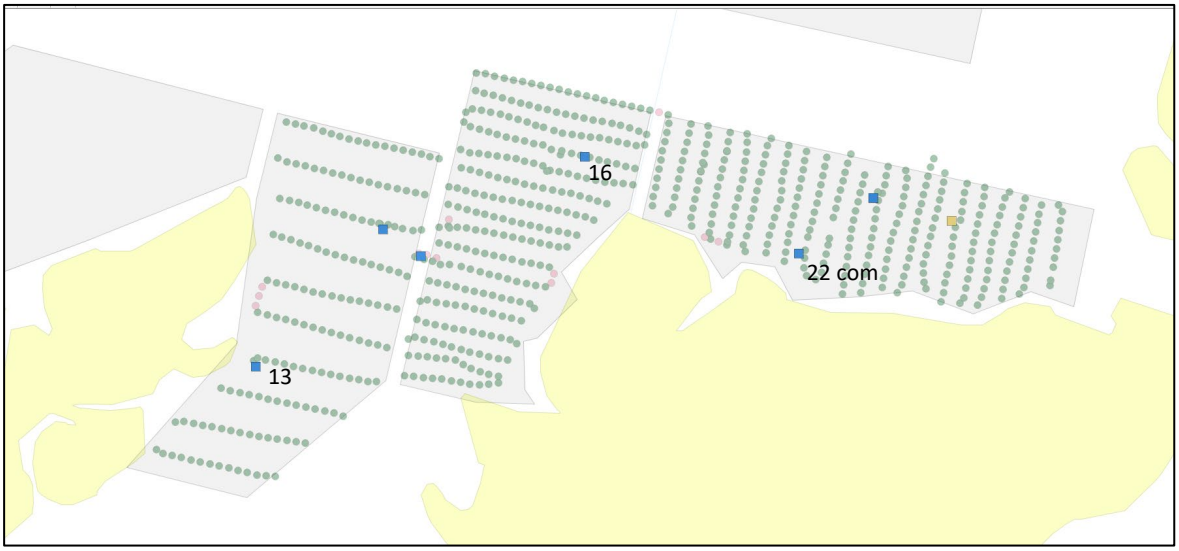
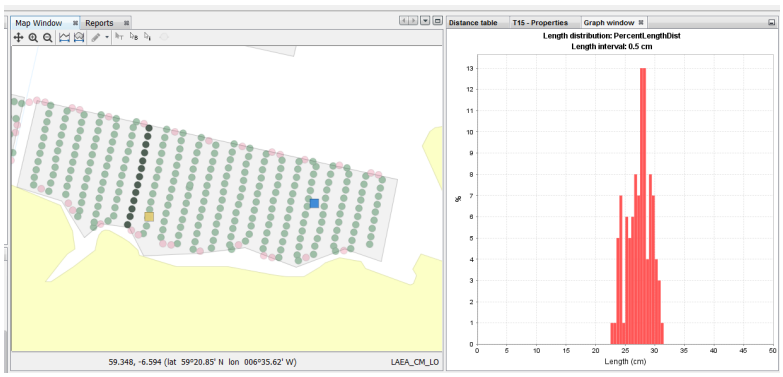
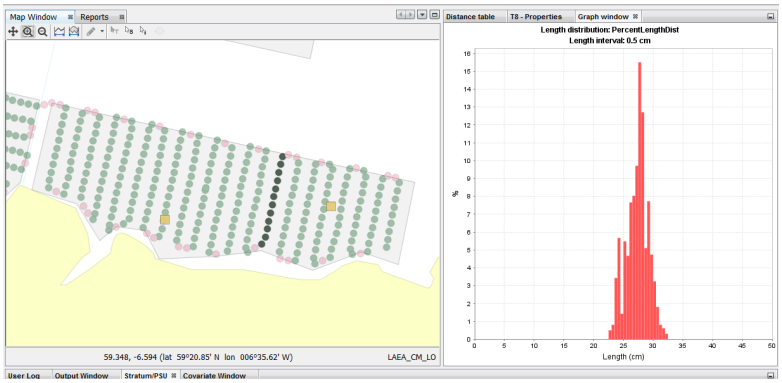
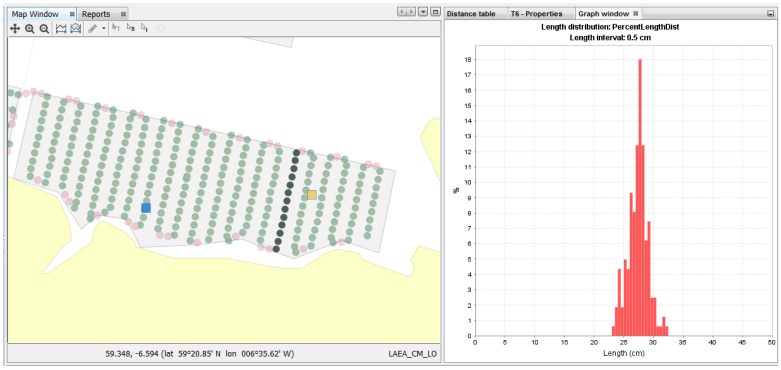
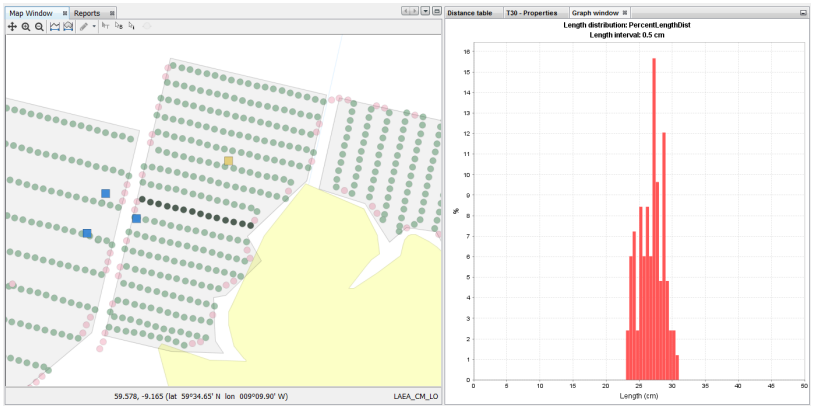
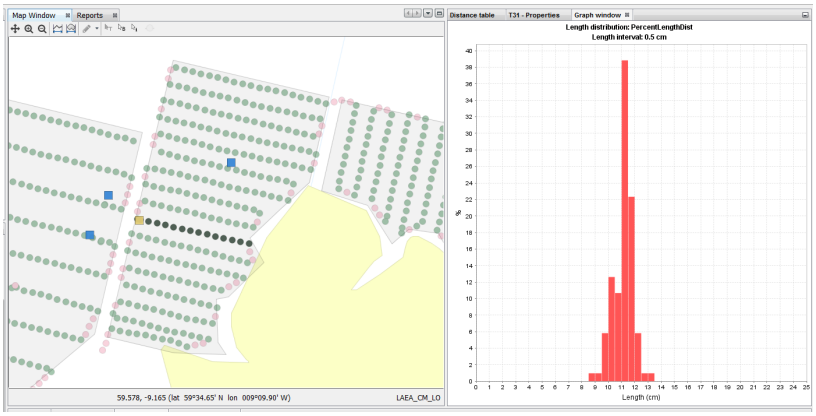
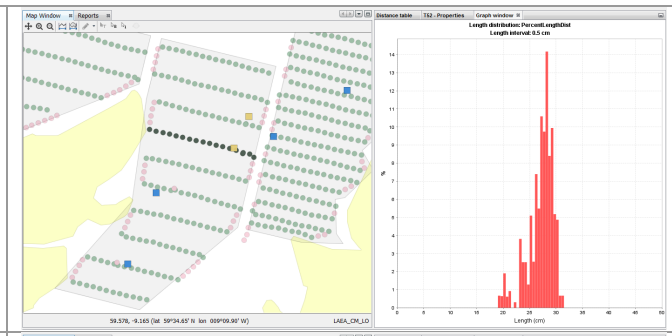
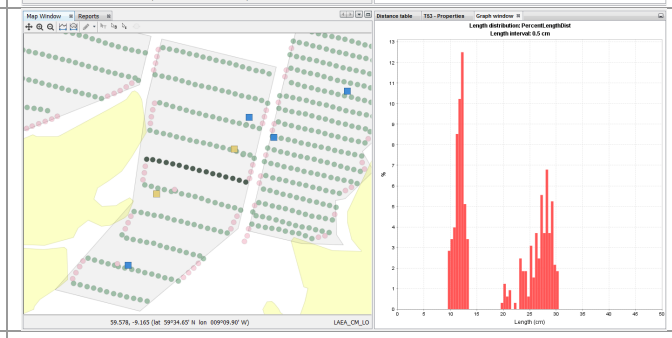
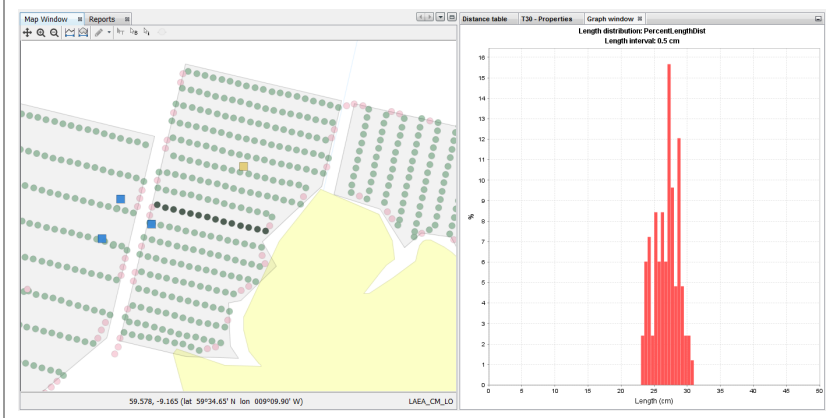
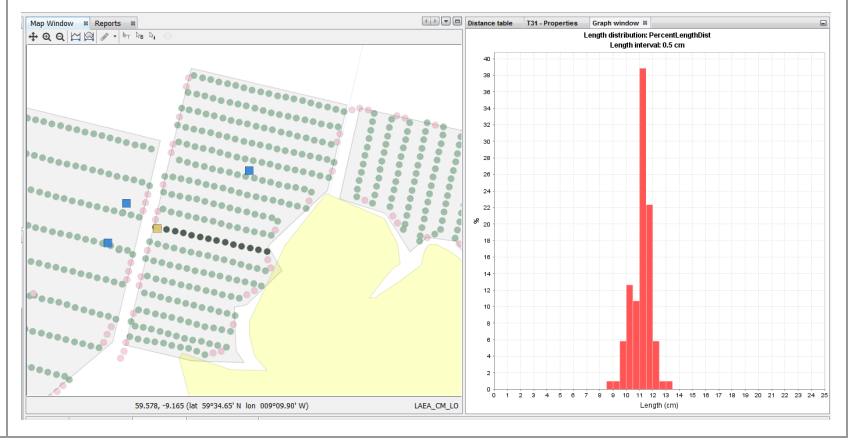
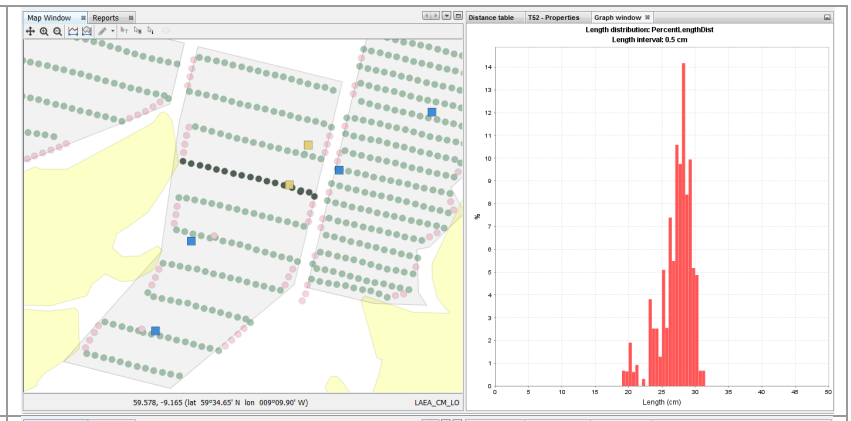
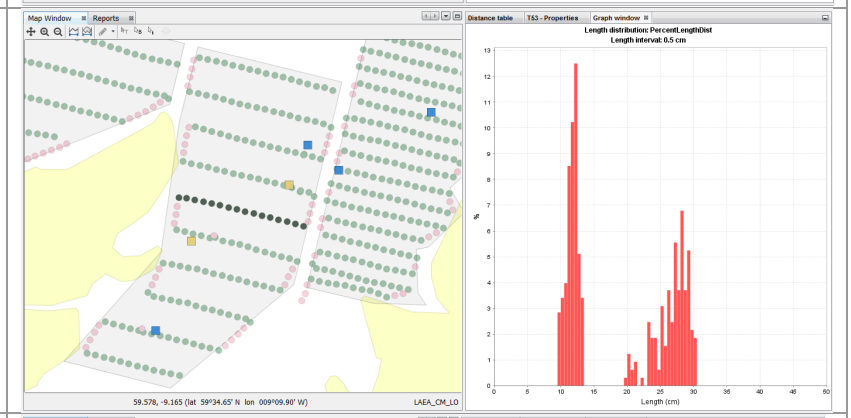
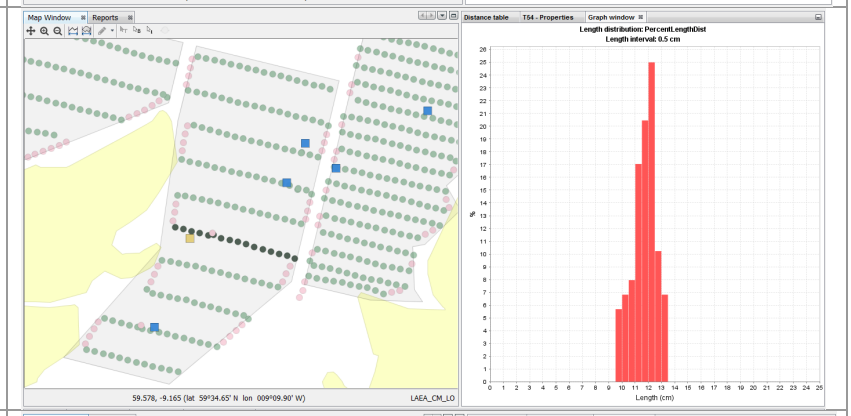
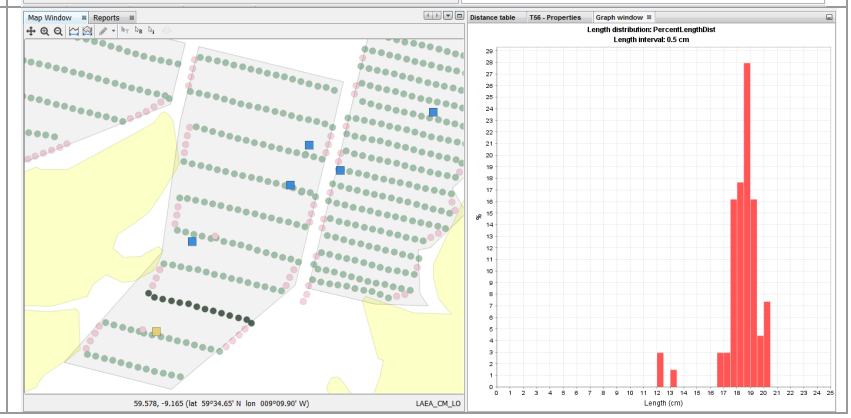


Figure 2.15b. Alida acoustic survey in 6aN – marking haul numbers for biological data assignment.

Area, transects	**Hauls**	**StoX view**
Area 2, transects 1 – 9	AL COM 22	

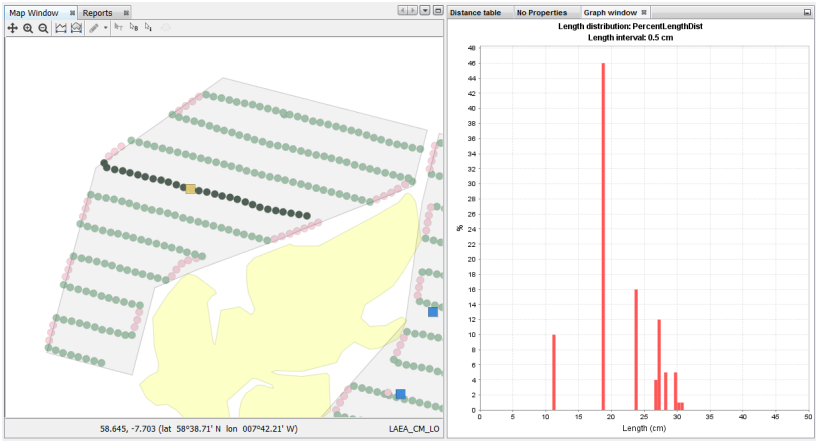
Area 2, transects 10 - 14	AL COM 22 KC 13	
Area 2, transects 15 - 21	KC 13	
Area 3, transects 1 – 9 (All transects north of and including the highlighted one)	KC 9	
Area 3, transects 10 – 17 (all transects south of and including the highlighted one)	VO 6	

Area 5, transects 1 - 4	VO2 VO3	
Area 5, transects 5	VO 3 VO 4	
Area 3, transects 1 – 9 (All transects north of and including the highlighted one)	KC 9	
Area 3, transects 10 – 17 (all transects south of and including the highlighted one)	**VO 6**	

Area 5, transects 1 - 4	VO2 VO3	
Area 5, transects 5	VO 3 VO 4	
Area 5, transects 6 - 7	VO 4	
Area 5, transects 8 - 10	VO 5	

Area 4, transects 1 - 10

Assumed same proportion at age as MSHAS 2018. Assumed same mean length and mean weights at age as results from Voyager strata 2,3 and 5.



Age (ring)	% abundance at age in MSHAS 2018	Mean Weight (g)	Mean Length (cm)
0	10	9	11.0
1	46	48	18.6
2	16	113	23.9
3	4	169	26.6
4	12	182	27.3
5	5	203	28.1
6	2	224	29.8
7	3	233	29.8
8	1	254	30.1
9+	1	258	30.6

Figure 2.15c. Voyager acoustic survey in 6aN – assignment of haul biological data.

Figure 2.15d. 6aS/7b industry acoustic survey in 2018: StoX strata delineated for the 4 scrutiny areas for herring (Lough Swilly, Northwest, Achill and Donegal Bay). The Northwest strata was also used in the horse mackerel abundance and biomass estimation. The haul samples stations where herring were obtained for length frequency analysis are also shown as blue squares.

Table 2.4. 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

The six vessels covered four different areas between 2018-08-27 and the 2018-10-06 (Figure 3.1), making a total of 112 hauls, of which 43 were taken in survey mode and 44 during commercial fisheries in 6aN. Twenty five commercial hauls were taken in ICES area 4a (North Sea) as part of the trips of Freezer Trawlers.

Within ICES area 6aN, herring were caught and sampled during 37 hauls, resulting in biological information collected from a total of 2555 herring (Table 3.1). In addition 5 hauls of herring in the adjacent North Sea are were sampled and biological information was collected from 335 individual herring. Details on the sampling per trip are shown in Table 3.2, Figure 3.2 and for spawning herring in Table 3.3. Details on the number of measurement per trip and haul are shown in Table 3.4.

With the exception of area 5 where and abundance of small young herring were found, length distributions of herring were largely similar by survey area and by haul (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. Mature herring close to spawning were only detected after mid-September. (Figure 3.4).

Maps of the survey tracks, 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 3.5, Table 3.2.

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 6aN are shown in Figure 3.6 and Table 3.5.

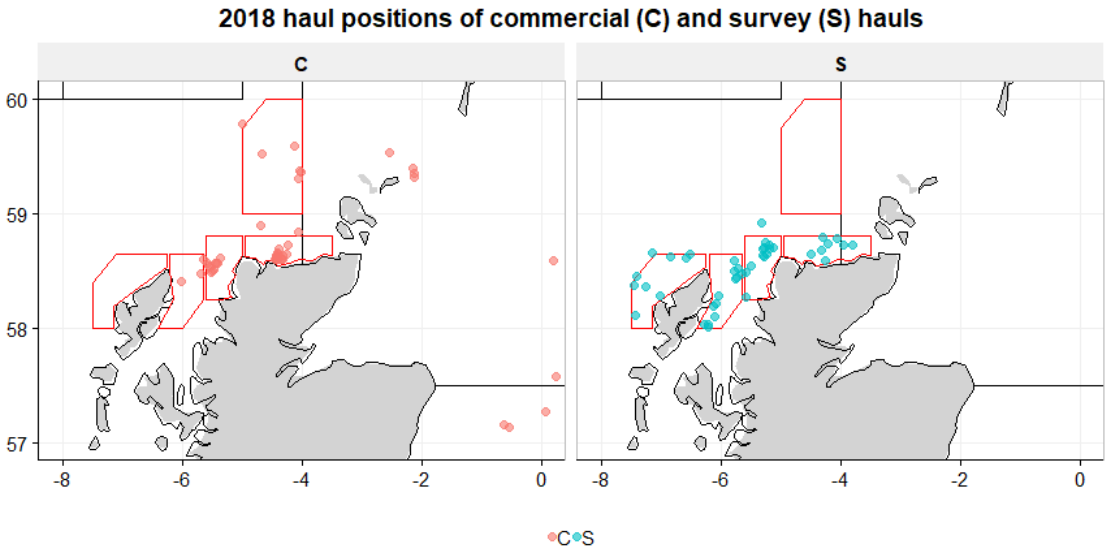


Figure 3.1. Spatial distribution of commercial hauls (C) and survey hauls (S)

Table 3.1. Overview of number of hauls and number of herring collected during commercial fishing operation (C) or survey operations (S) and for which either morphometric or genetic samples have been collected. Either all observations or for spawning herring only.

haultype	datatype	n hauls	n fish	n haul with spawners	n spawning fish
C	genetics	26	1302	13	993
C	morphometrics	0	0	0	0
C	sampledhauls	45	1726	23	1254
S	genetics	7	411	2	11
S	morphometrics	4	330	0	0
S	sampledhauls	29	1164	5	93

Table 3.2. Overview of trip properties. 'Type' refers to the type of activity (S=survey, C=commercial). The variables starting with 'n' denote the number of fish measured for the specific variable.

vessel	trip	type	begin	end	nhaul	nlen	nwght	nage	nsex	nmat	nphoto	ngen
-												
Unity (FR165)	UN0218	C	2018-09-16	2018-09-16	1	.	102	0	102	101	0	102
Christina S (FR244)	CH0118	S	2018-09-03	2018-09-12	12	913	330	0	330	224	330	300
Christina S (FR244)	CH0218	C	2018-09-18	2018-09-18	4	556	411	0	410	411	0	400
Dirk Dirk (KW172)	201807	C	2018-09-25	2018-10-06	15	1035	170	82	170	170	0	100
Voyager (N905)	VO0118	C	2018-09-10	2018-09-10	2	.	67	60	67	67	0	0
Voyager (N905)	VO0118	S	2018-09-03	2018-09-08	7	570	141	140	141	89	0	11
Voyager (N905)	VO0218	C	2018-09-25	2018-09-25	1	.	46	42	46	46	0	0
Kings Cross (PD365)	KC0118	S	2018-08-27	2018-09-05	17	627	388	0	388	358	0	0
Kings Cross (PD365)	KC0218	C	2018-09-17	2018-09-18	2	.	199	0	200	200	0	200
Wiron5+6 (PH2200)	2018077	C	2018-08-29	2018-09-09	15	245	100	39	100	100	0	100
Wiron5+6 (PH2200)	2018078	C	2018-09-21	2018-09-29	11	.	241	185	241	241	0	100
Alida (SCH6)	2018L3	C	2018-09-08	2018-09-16	18	1708	389	137	389	389	0	300
Alida (SCH6)	2018L3	S	2018-09-12	2018-09-18	7	451	305	230	205	305	0	100

Table 3.3. Overview of the number of spawning herring and the measurements taken on these fish.

name	trip	type	nlen	nwght	nage	nsex	nphoto	ngen
Alida (SCH6)	2018L3	C	262	262	91	262	0	218
Alida (SCH6)	2018L3	S	80	80	80	80	0	0
Christina S (FR244)	CH0218	C	263	263	0	262	0	257
Dirk Dirk (KW172)	201807	C	79	79	41	79	0	56
Kings Cross (PD365)	KC0118	S	2	2	0	2	0	0
Kings Cross (PD365)	KC0218	C	195	194	0	195	0	195
Unity (FR165)	UN0218	C	75	75	0	75	0	75
Voyager (N905)	VO0118	C	53	53	49	53	0	0
Voyager (N905)	VO0118	S	11	11	10	11	0	11
Voyager (N905)	VO0218	C	34	34	32	34	0	0
Wiron5+6 (PH2200)	2018077	C	93	93	36	93	0	93
Wiron5+6 (PH2200)	2018078	C	200	200	144	200	0	99

Table 3.4. Overview of haul properties. 'Type' refers to the type of activity (S=survey, C=commercial). The variables starting with 'n' denote the number of fish measured for the specific variable.

name	trip	type	haul	area	nlen	nwght	nage	nsex	nmat	nphoto	ngen
Alida (SCH6)	2018L3	C	1	div4.b	83	.	.	.	.	.	.
Alida (SCH6)	2018L3	C	2	div4.b	82	.	.	.	.	.	.
Alida (SCH6)	2018L3	C	3	div4.b	38	100	45	100	100	0	100
Alida (SCH6)	2018L3	C	4	div4.b	85	.	.	.	.	.	.
Alida (SCH6)	2018L3	C	5	div4.b	76	.	.	.	.	.	.
Alida (SCH6)	2018L3	C	6	div4.b	90	.	.	.	.	.	.
Alida (SCH6)	2018L3	C	7	area3	93	.	.	.	.	.	.
Alida (SCH6)	2018L3	C	8	area3	99	.	.	.	.	.	.
Alida (SCH6)	2018L3	C	9	area3	107	.	.	.	.	.	.
Alida (SCH6)	2018L3	C	11	area3	104	.	.	.	.	.	.
Alida (SCH6)	2018L3	C	12	area3	113	.	.	.	.	.	.
Alida (SCH6)	2018L3	C	14	area3	97	.	.	.	.	.	.
Alida (SCH6)	2018L3	C	15	area3	102	39	0	39	39	0	0
Alida (SCH6)	2018L3	C	17	area3	104	.	.	.	.	.	.
Alida (SCH6)	2018L3	C	18	area3	114	100	42	100	100	0	100
Alida (SCH6)	2018L3	C	19	area3	117	50	0	50	50	0	0
Alida (SCH6)	2018L3	C	21	area2	101	.	.	.	.	.	.
Alida (SCH6)	2018L3	C	22	area2	103	100	50	100	100	0	100
Alida (SCH6)	2018L3	S	10	area5	138	59	59	59	59	0	0
Alida (SCH6)	2018L3	S	13	area5	183	100	25	0	100	0	100
Alida (SCH6)	2018L3	S	16	oth	117	72	72	72	72	0	0
Alida (SCH6)	2018L3	S	24	area2	7	74	74	74	74	0	0
Alida (SCH6)	2018L3	S	25	div4.a	6	.	.	.	.	.	.
Christina S (FR244)	CH0118	S	1	area5	293	100	0	100	0	100	100
Christina S (FR244)	CH0118	S	2	area5	324	121	0	121	115	121	100
Christina S (FR244)	CH0118	S	7	oth	296	109	0	109	109	109	100
Christina S (FR244)	CH0218	C	1	area2	129	102	0	102	102	0	100
Christina S (FR244)	CH0218	C	2	area2	148	103	0	103	103	0	100
Christina S (FR244)	CH0218	C	3	area2	123	102	0	102	102	0	100
Christina S (FR244)	CH0218	C	4	area2	156	104	0	103	104	0	100
Dirk Dirk (KW172)	201807	C	1	div4.b	94	.	.	.	.	.	.
Dirk Dirk (KW172)	201807	C	2	div4.b	89	.	.	.	.	.	.
Dirk Dirk (KW172)	201807	C	3	div4.a	158	.	.	.	.	.	.
Dirk Dirk (KW172)	201807	C	4	div4.a	114	.	.	.	.	.	.
Dirk Dirk (KW172)	201807	C	5	area1	91	100	46	100	100	0	100
Dirk Dirk (KW172)	201807	C	6	div4.a	126	.	.	.	.	.	.
Dirk Dirk (KW172)	201807	C	8	div4.a	140	.	.	.	.	.	.
Dirk Dirk (KW172)	201807	C	10	area1	111	34	0	34	34	0	0
Dirk Dirk (KW172)	201807	C	14	div4.a	112	.	.	.	.	.	.
Kings Cross (PD365)	KC0118	S	7	area5	188	105	0	105	87	0	0
Kings Cross (PD365)	KC0118	S	9	area3	83	55	0	55	55	0	0
Kings Cross (PD365)	KC0118	S	11	area3	154	65	0	65	65	0	0
Kings Cross (PD365)	KC0118	S	12	area3	41	41	0	41	29	0	0
Kings Cross (PD365)	KC0118	S	13	div4.a	161	68	0	68	68	0	0
Voyager (N905)	VO0118	S	2	area5	149	50	50	50	48	0	9
Voyager (N905)	VO0118	S	3	area5	162	40	39	40	40	0	2
Voyager (N905)	VO0118	S	4	area5	88	16	16	16	0	0	0
Voyager (N905)	VO0118	S	5	area5	68	19	19	19	1	0	0
Voyager (N905)	VO0118	S	6	area3	103	16	16	16	0	0	0
Wiron5+6 (PH2200)	2018077	C	7	div4.a	103	.	.	.	.	.	.
Wiron5+6 (PH2200)	2018077	C	10	div7.a	73	.	.	.	.	.	.
Wiron5+6 (PH2200)	2018077	C	12	div7.a	43	.	.	.	.	.	.
Wiron5+6 (PH2200)	2018077	C	13	div7.a	26	.	.	.	.	.	.

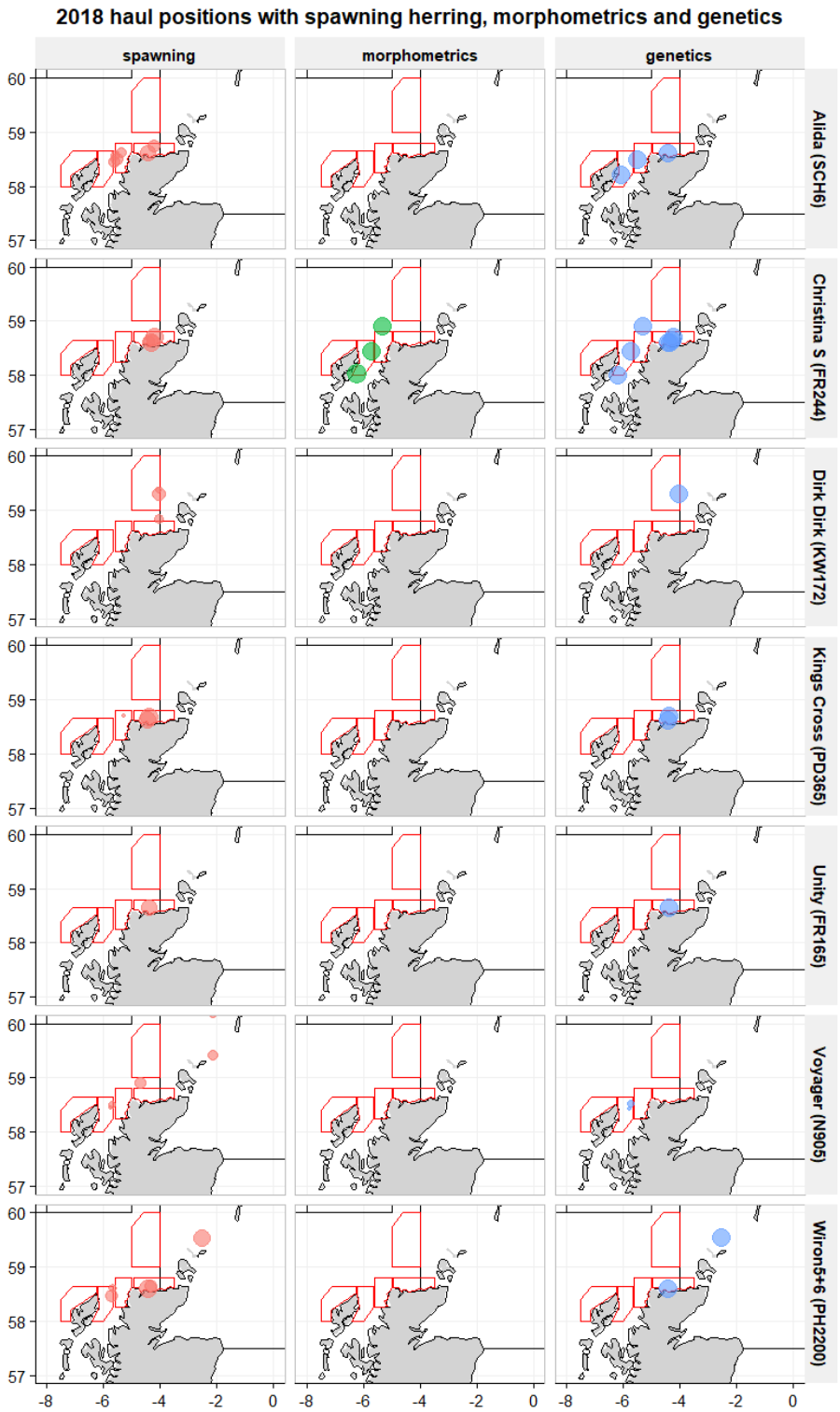


Figure 3.2. Spatial distribution of hauls with number of spawning herring and number of morphometric samples and genetic samples.

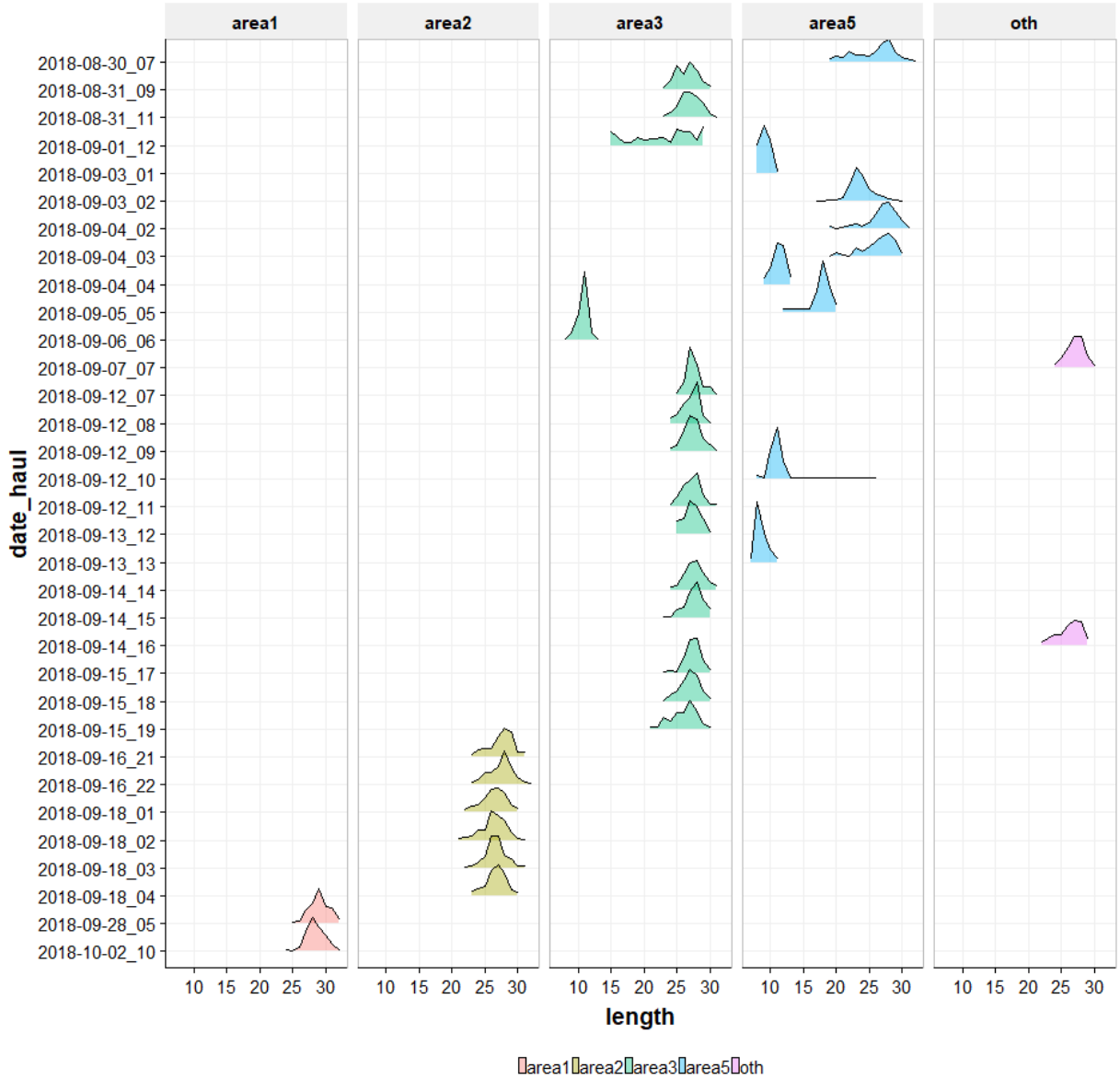


Figure 3.3. Relative length frequencies of herring by date and survey area.

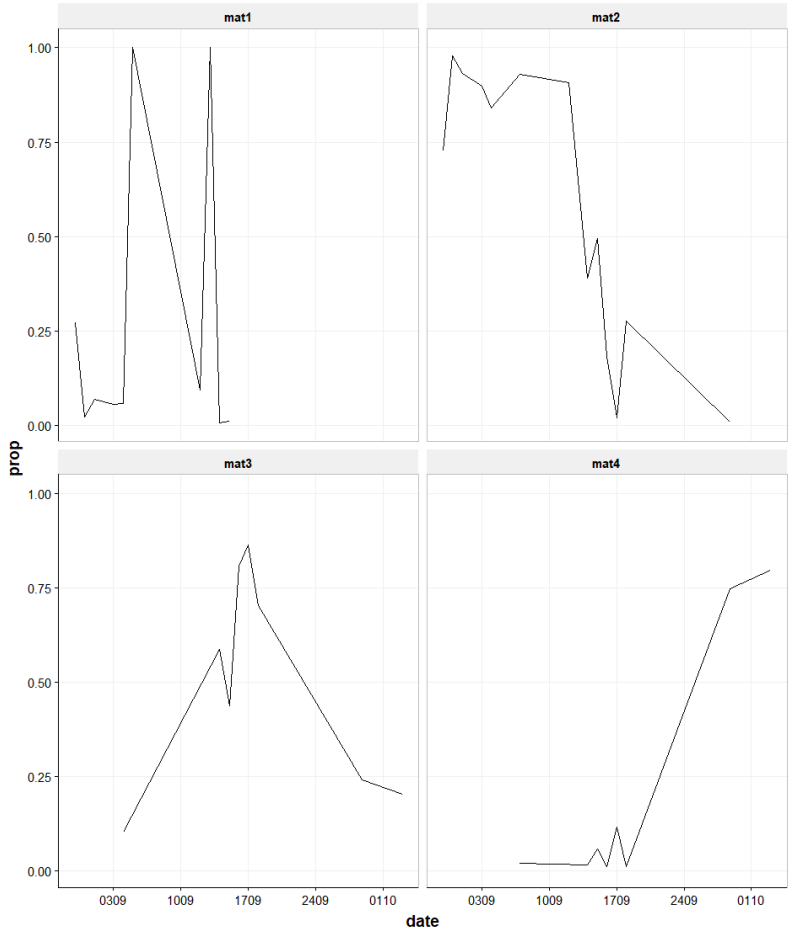


Figure 3.4. Proportion of maturity stage by date. Maturity stage 3 refers to spawning herring.

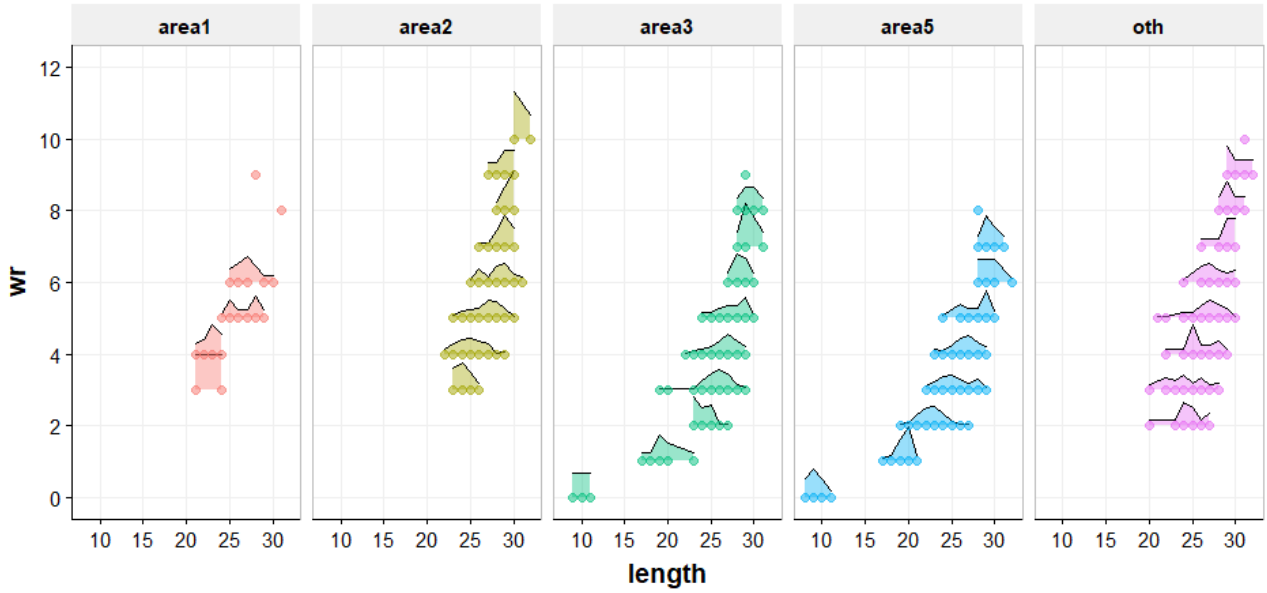


Figure 3.5. Age-length key by survey area.

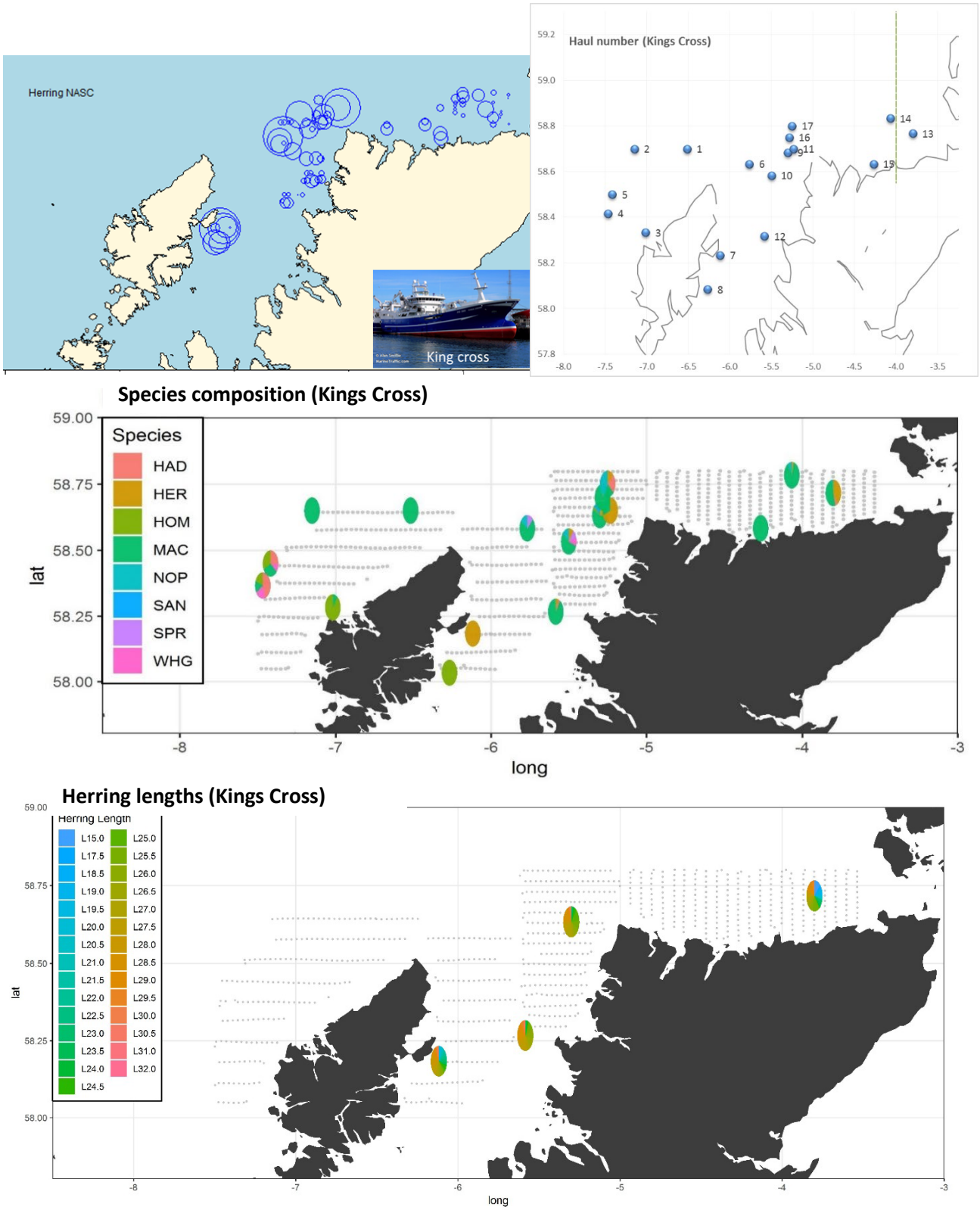


Figure 3.6a. Relative acoustic densities (NASC m²/mn²) and trawl haul details for Kings Cross. NASC is scaled to be comparable with the other two vessels.

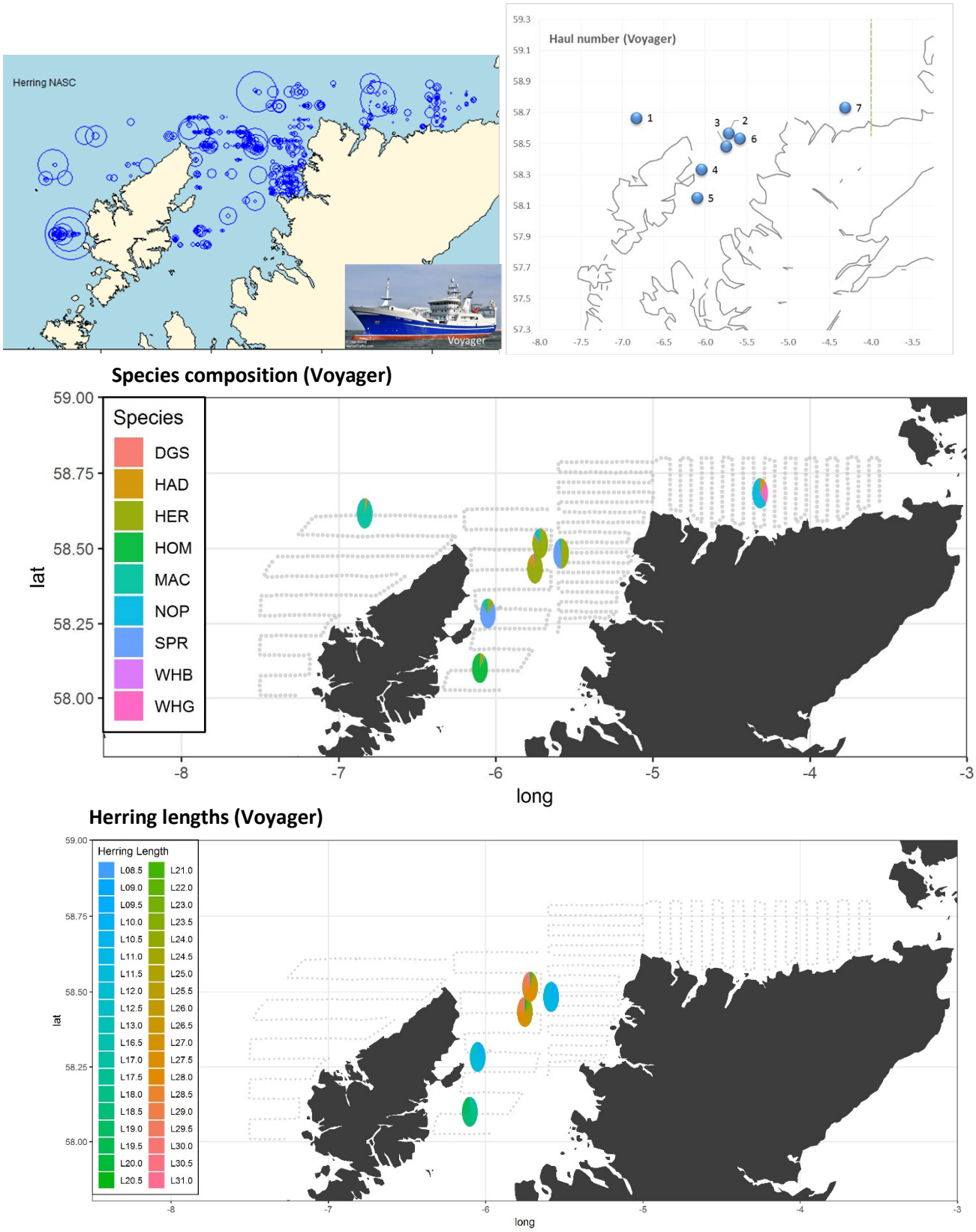


Figure 3.6b. Relative acoustic densities (NASC m²/mn²) and trawl haul details for Voyager. NASC is scaled to be comparable with the other two vessels.

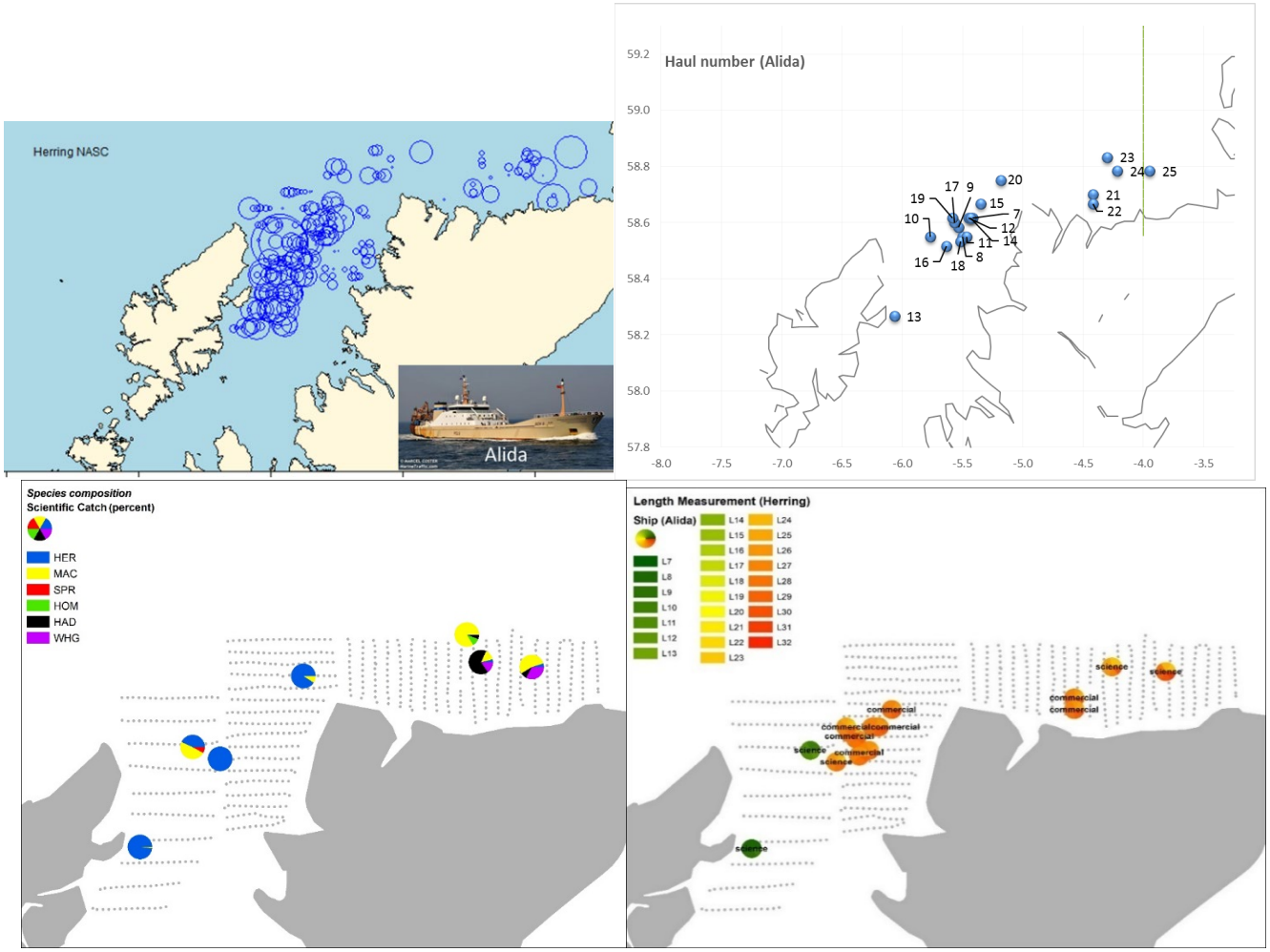


Figure 3.6c. Relative acoustic densities (NASC m²/mn²) and trawl haul details for Voyager. NASC is scaled to be comparable with the other two vessels.

Table 3.5. Haul information and catch composition for hauls relevant to the analysis of the acoustic surveys in 6a North in 2018).

				Position			**Catch (kg)**								
Vessel	**Haul no.**	**Date**	**Time UTC**	**North**	**West**	**Used in analysis area**	**HER**	**MAC**	**SPR**	**HOM**	**HAD**	**WHG**	**NOP**	**WHB**	**SAN**
Kings Cross	7	30/08/2018	12:43	58°11'	06°07'	5	2000	0	0	0	0	0	0	0	
	9	31/08/2018	07:30	58°38'	05°18'	3 (also applied to Voyager transects north of Voyager haul 6)	34	70	0	4	0	0	0	0	17
	11	31/08/2018	20:00	58°39'	05°14'	3	139	61	0	0	0	0	0	0	
	12	01/09/2018	11:40	58°16'	05°35'	3	22	351	0	9	4	7	8	0	
	13	03/09/2018	12:04	58°43'	03°48'	2 (applied also to Voyager transect in eastern area 2)	103	123	0	0	13	0	11	0	
Voyager	2	04/09/2018	10:59	58°31'	05°43'	5	835	72	0	0	5	24	60	5	
	3	04/09/2018	15:18	58°26'	05°45'	5	415	6	0	6	57	16	0	0	
	4	04/09/2018	19:38	58°17'	06°03'	5	31	35	175	0	0	2	0	0	
	5	05/09/2018	11:30	58°06'	06°06'	5	1	0	0	15	0	0	0	0	
	6	06/09/2018	12:50	58°29'	05°35'	3	113	2	101	0	0	0	9	0	
Alida	13	13/09/2018	09:05	58°13'	06°04'	5	197	3							
	16	14/09/2018	09:50	58°28'	05°38'	3	10000								
	22 (com)	16/09/2018	03:15	58°37'	04°25'	2 (applied also to Voyager transects in western area 2)	90000								
Malin shelf survey data (July 2018)						4 – MSAS average length and age data used to breakdown Voyager acoustic data in area 4.									

3.1.2 Sampling statistics 6aS/7bc

Approximately 1,400nmi of transects were completed successfully. A total of four samples were obtained from commercial tows during the survey. In some areas where marks of herring were observed on the echosounder, the vessel was unable to fish due to the shallow water depth (e.g. <20m in Lough Swilly) and size of the commercial gear available. The monitoring fishery was being conducted on smaller boats in the same areas and at the same time as the survey. Biological samples from some of these vessels were used to augment the samples from the survey. Samples were taken from boats fishing in Lough Swilly and Bruckless Bay as close spatially and temporally as possible to the survey in these areas (Table 3.9). Samples were also obtained from the RV Celtic Explorer during their 6a groundfish survey, but these were not used in the survey estimation. These fish were young (0 and 1 –wr) and not considered representative of the marks observed on echograms during the acoustic survey.

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 3.9 & 3.10.

The location of survey hauls and samples from the fishery is shown in Figure 3.7. The fishery in 6aS/7b began in mid-November and continued throughout the survey period. Most of the fishing activity, particularly in November/early December was inshore in shallow water.

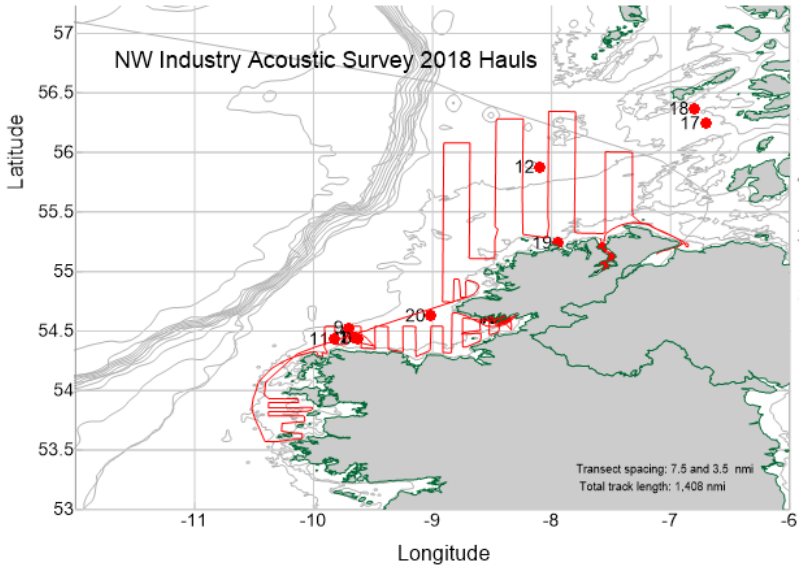


Figure 3.7. Distribution of biological samples obtained in 6aS/7b - all samples from the survey and the monitoring fishery.

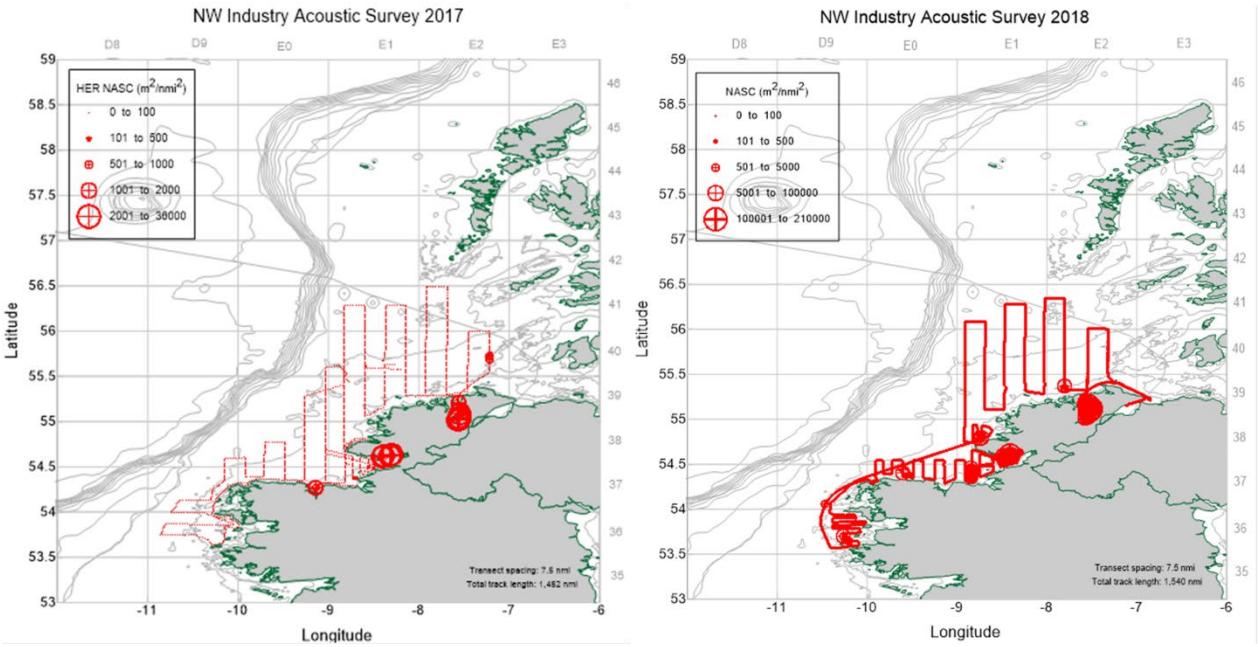


Figure 3.8a. 6aS/7b industry acoustic survey in 2017 & 2018: distribution of NASC allocated to herring.

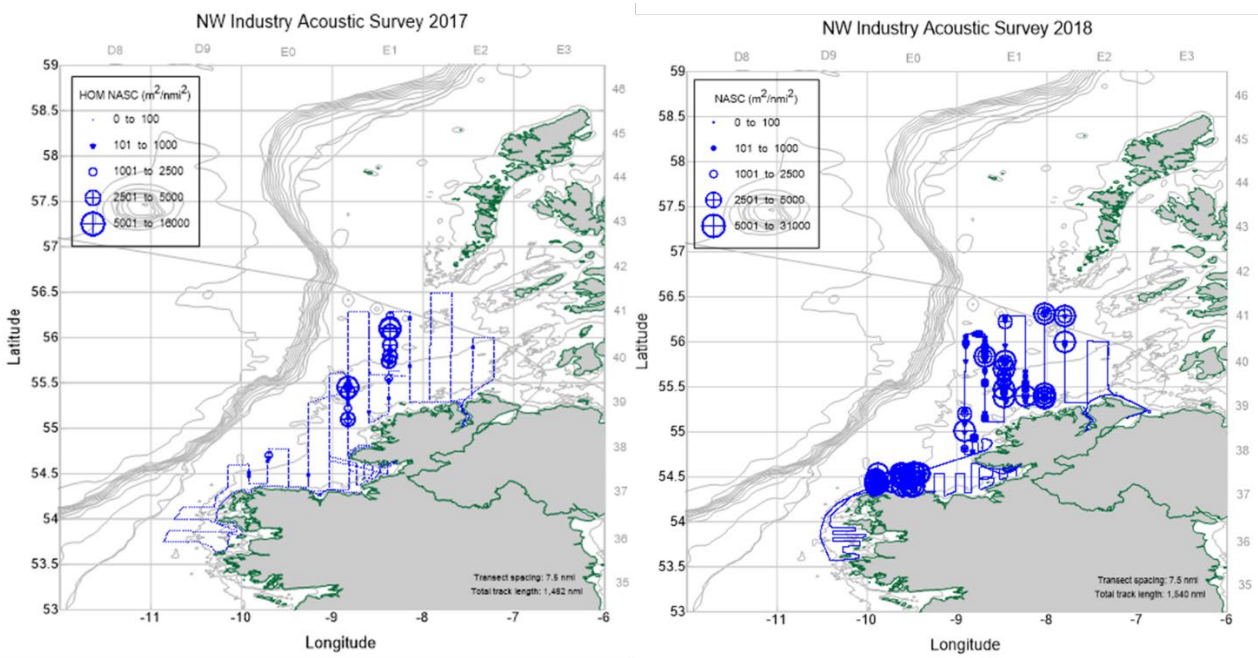


Figure 3.8b. 6aS/7b industry acoustic survey in 2017 & 2018: distribution of NASC allocated to horse mackerel.

Table 3.9. Biological sampling summary statistics from survey hauls and samples from the fishery in 6aS/7b in 2018.

Haul No	Date	Target Species	Location	Fish (measured lengths)	Age, weight, maturity, sex
1	08/11/2018	*Trachurus trachurus*	Stags of Broadhaven	329	50
2	08/11/2018	*Trachurus trachurus*	Stags of Broadhaven	305	50
3	07/11/2018	*Clupea harengus*	Lough Swilly	254	61
4	07/11/2018	*Clupea harengus*	Lough Swilly	256	63
5	12/11/2018	*Clupea harengus*	Lough Swilly	364	68
6	12/11/2018	*Clupea harengus*	Lough Swilly	397	72
7	12/11/2018	*Clupea harengus*	Lough Swilly	455	75
8	16/11/2018	*Clupea harengus*	Lough Swilly	195	47
9	21/11/2018	*Trachurus trachurus*	Stags of Broadhaven	49	49*
10	20/11/2018	*Trachurus trachurus*	Stags of Broadhaven	31	31*
11	13/11/2018	*Trachurus trachurus*	Stags of Broadhaven	38	38*
12	05/11/2018	*Trachurus trachurus*	Stags of Broadhaven	0**	0**
13	20/11/2018	*Clupea harengus*	Bruckless Bay	271	70
14	21/11/2018	*Clupea harengus*	Bruckless Bay	273	67
15	20/11/2018	*Clupea harengus*	Bruckless Bay	353	77
16	21/11/2018	*Clupea harengus*	Bruckless Bay	338	70

* not aged

** no sample

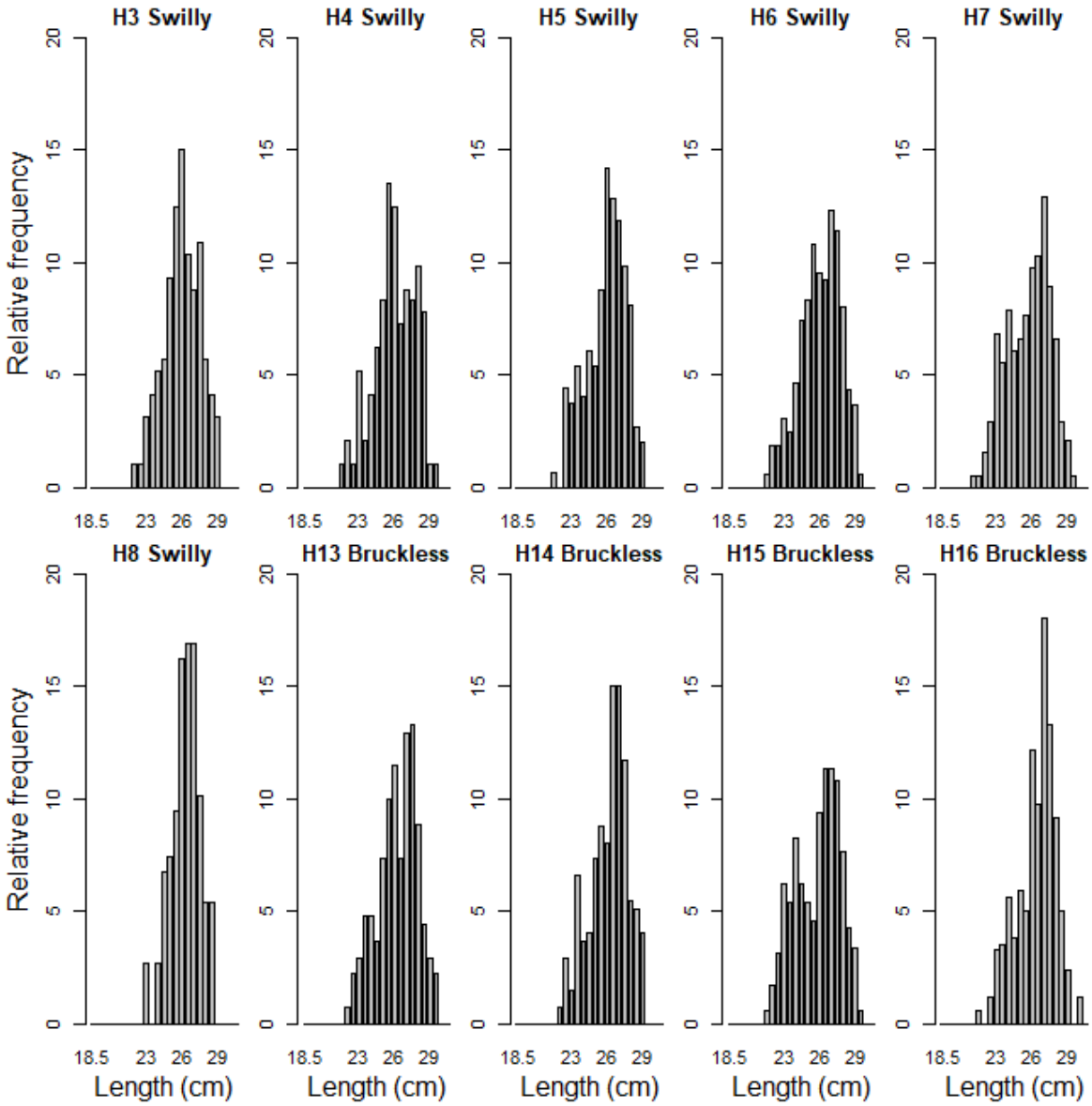


Figure 3.9a. 6aS/7b industry acoustic survey in 2018: relative length (cm) frequency distributions of herring in each haul.

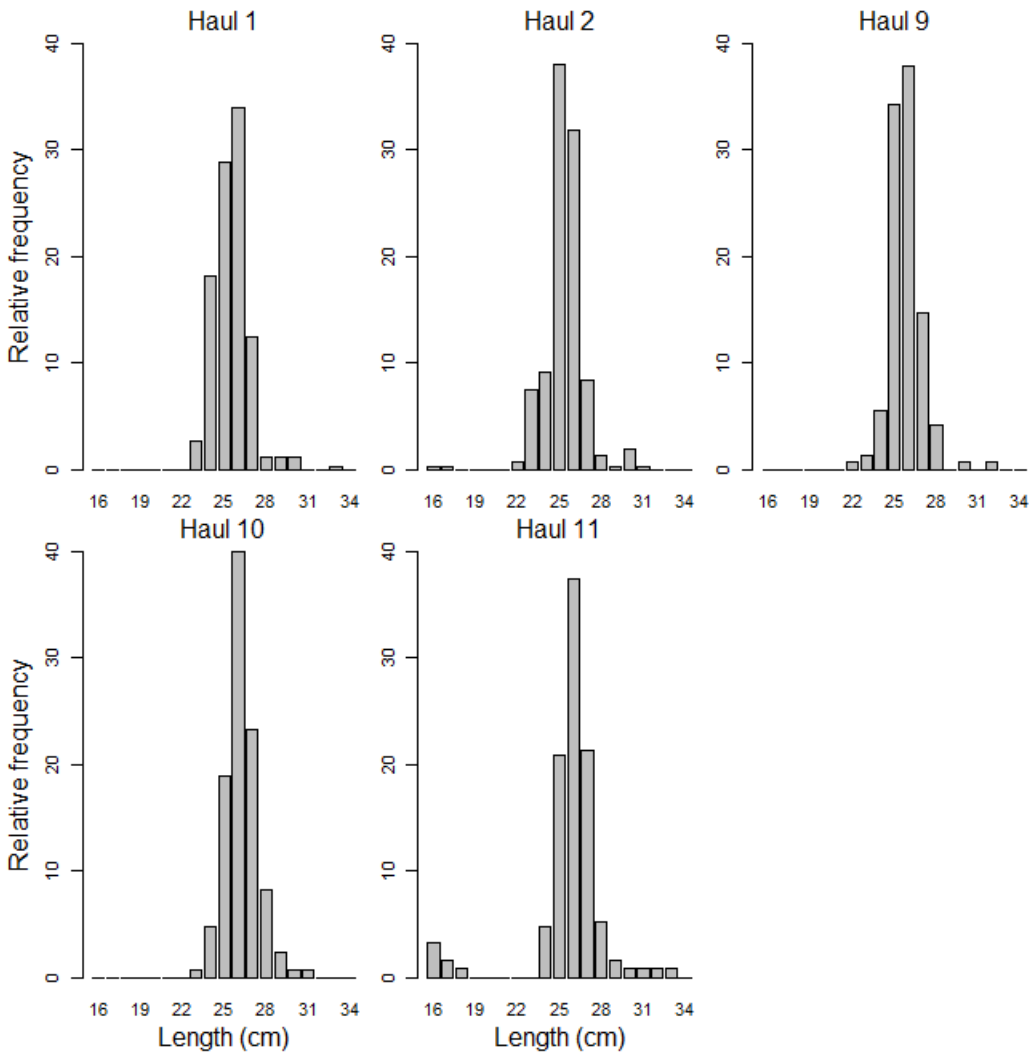


Figure 3.9b. 6aS/7b industry acoustic survey in 2018: relative length (cm) frequency distributions of horse mackerel in hauls 1, 2, 9, 10 and 11.

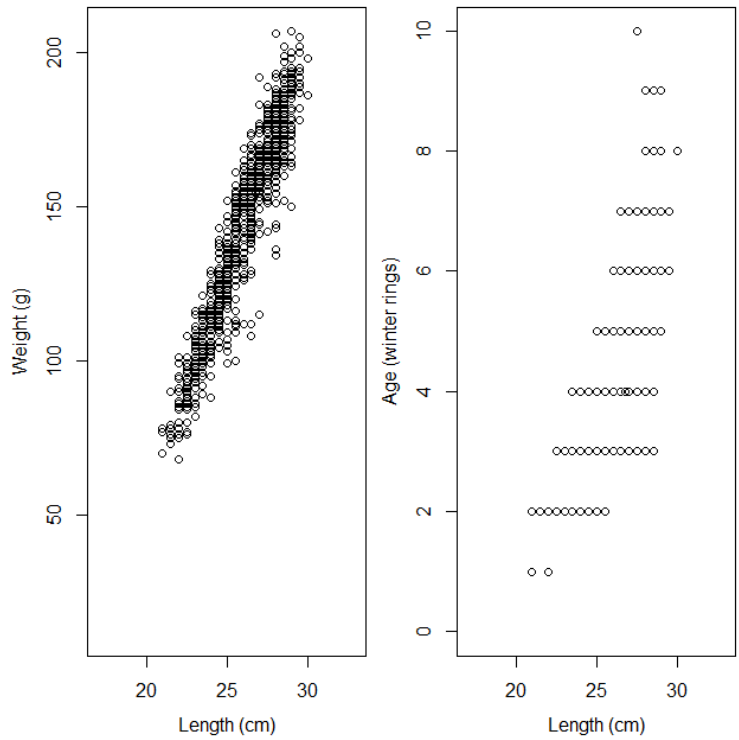


Figure 3.10. 6aS/7b industry acoustic survey in 2018: weight at length and age at length of herring.

Maturity at age for 6aS/7b herring is shown in Table 3.10. 50% of 1-wr herring were immature, and 5.3% of 2-wr herring were immature.

Table 3.10. Maturity at age for 6aS/7bc herring in 2018.

Age (winter rings)	Immature (%)	Mature (%)
1	50	50
2	5.3	94.7
3	0.8	99.2
4	1.3	98.7
5	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 (Tables 3.11 to 3.13)

A summary table for each vessel's coverage of their entire surveyed area (Table 3.11) and breakdown for each area (Table 3.12) is followed by a summary of the maximum biomass recorded in each of the surveyed areas, included the CV of the biomass estimate (Table 3.13).

Additional details on the uncertainty estimates (CV) for each vessel and survey area are shown in Table 3.14 and adjoining tables/ figures from StoX. CVs on biomass estimates are highest where the biomass estimates are derived from few concentrated marks occurring over a limited number of transects, and lower where marks are more evenly spread across the area. CVs on abundance at age are poor for Alida and Voyager due to low sample sizes, while those for Kings Cross are reasonably good.

Table 3.11a. Combined results for all strata covered by Kings Cross in 2018.

Results for all areas combined Kings Cross					
Age (ring)	Numbers (mill)	Biomass (kt)	Maturity	Mean Weight (g)	Mean Length (cm)
0	6	0.0	0.00	6.8	9.9
1	23	1.4	0.00	60.3	19.7
2	64	7.4	0.49	114.8	23.5
3	110	20.1	0.95	182.2	26.8
4	73	14.2	0.98	196.1	27.5
5	22	5.0	0.89	227.8	28.9
6	16	3.7	1.00	230.0	28.9
7	7	1.6	1.00	230.3	29.5
8	5	1.4	1.00	255.6	29.4
9+	3	0.8	1.00	256.4	30.3
Immature	70	6		89.6	21.2
Mature	258	49		190.5	27.1
Total	329	56	0.79	168.8	25.9

Table 3.11b. Combined results for all strata covered by Alida in 2018.

No coverage in strata 4.

Results for all areas combined Alida *Strata 4 was not covered*					
Age (ring)	Numbers (mill)	Biomass (kt)	Maturity	Mean Weight (g)	Mean Length (cm)
0	4502	34.6	0.00	7.7	9.8
1	25	1.4	0.00	54.7	18.5
2	15	1.1	0.08	75.1	21.2
3	61	6.1	0.73	99.2	22.3

4	52	6.7	1.00	127.6	24.2
5	86	15.2	0.97	175.2	27.0
6	8	1.4	1.00	173.7	26.7
7	10	2.3	1.00	230.1	29.2
8	5	1.1	1.00	211.0	28.5
9+	4	1.0	1.00	260.8	30.1
Immature	4561	38		8.4	9.9
Mature	209	32		155.2	25.7
Total	4769	71	0.04	14.8	10.6

Table 3.11b. Combined results for all strata covered by Voyager in 2018.

Results for all areas combined Voyager					
Age (ring)	Numbers (mill)	Biomass (kt)	Maturity	Mean Weight (g)	Mean Length (cm)
0	523	4.7	0.00	8.9	11.0
1	271	13.0	0.00	47.9	18.6
2	95	10.7	0.95	113.1	23.9
3	79	13.4	0.98	169.1	26.6
4	158	28.8	0.98	182.3	27.3
5	56	11.3	1.00	203.0	28.1
6	21	4.6	1.00	222.2	29.8
7	18	4.2	1.00	234.8	29.8
8	6	1.5	1.00	252.7	30.1
9+	7	1.7	1.00	252.4	30.5
Immature	804	19		23.7	13.7
Mature	430	75		174.4	26.9
Total	1234	94	0.35	76.1	18.3

Table 3.12. Summary for each survey area covered by three acoustic vessels in 2018.

	Kings Cross 2018			
Area	**Abundance (mill)**	**Biomass (kt)**	**Mean weight (g)**	**% Mature**
2	30	5.6	187.2	0.95
3	142	23.4	165.5	0.86
4	0	0	-	-
5	157	26.5	168.4	0.69
TOTAL		56		
	Alida 2018			
Area	**Abundance (mill)**	**Biomass (kt)**	**Mean weight (g)**	**% Mature**
2	61	11.5	188.2	1.00
3	92	14.1	153.4	0.92
5	4617	45.2	9.8	0.01
TOTAL		71		
	Voyager 2018			
Area	**Abundance (mill)**	**Biomass (kt)**	**Mean weight (g)**	**% Mature**
2	65	12.1	185.8	0.97
3	533	16.0	30.0	0.12
4	384	37.1	96.4	0.44
5	252	28.8	114.4	0.53
TOTAL		94		

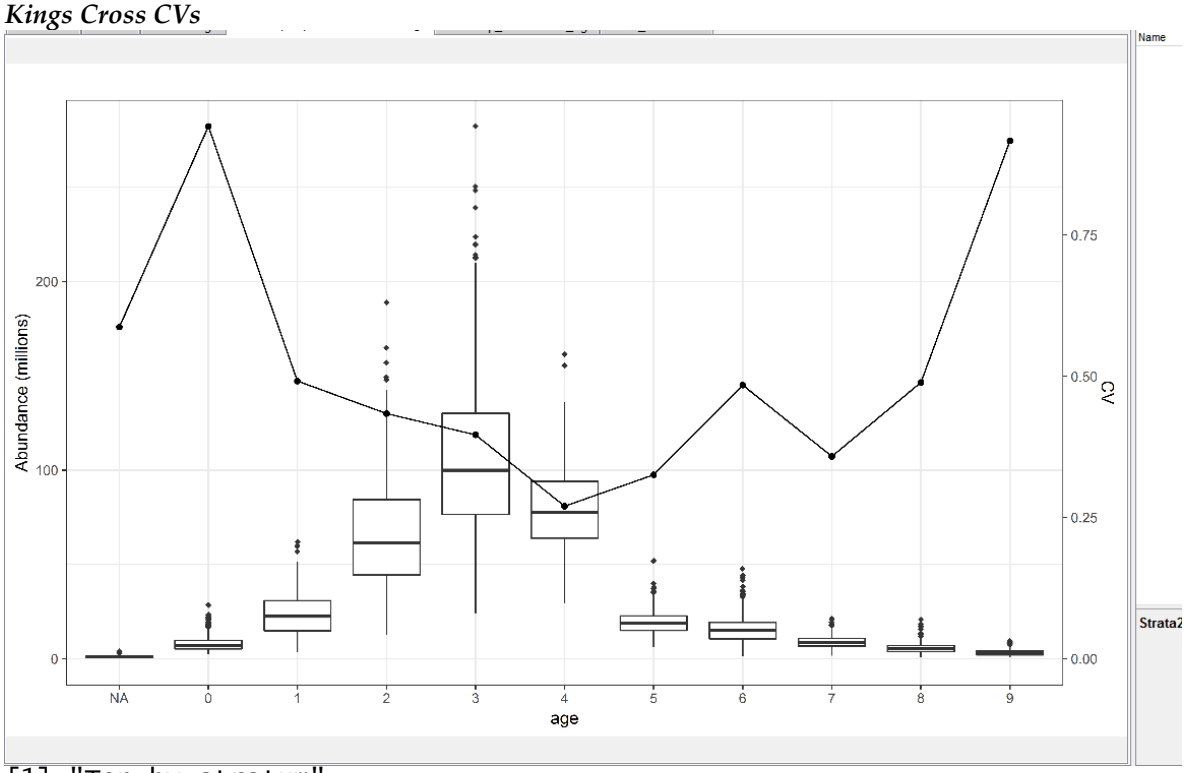
Table 3.13. Summary for each survey area covered by three acoustic vessels in 2018.

AREA	MAXIMUM SSB ESTIMATE (KT)	CV ON BIOMASS EST	SURVEY VESSEL
4	37.1	0.68	Voyager
5	45.2	0.26	Alida
3	23.4	0.39	Kings Cross
2	12.1	0.40	Voyager
TOTAL	**118 kt**		

Table 3.14 CVs on biomass estimate for vessel and area, with additional details

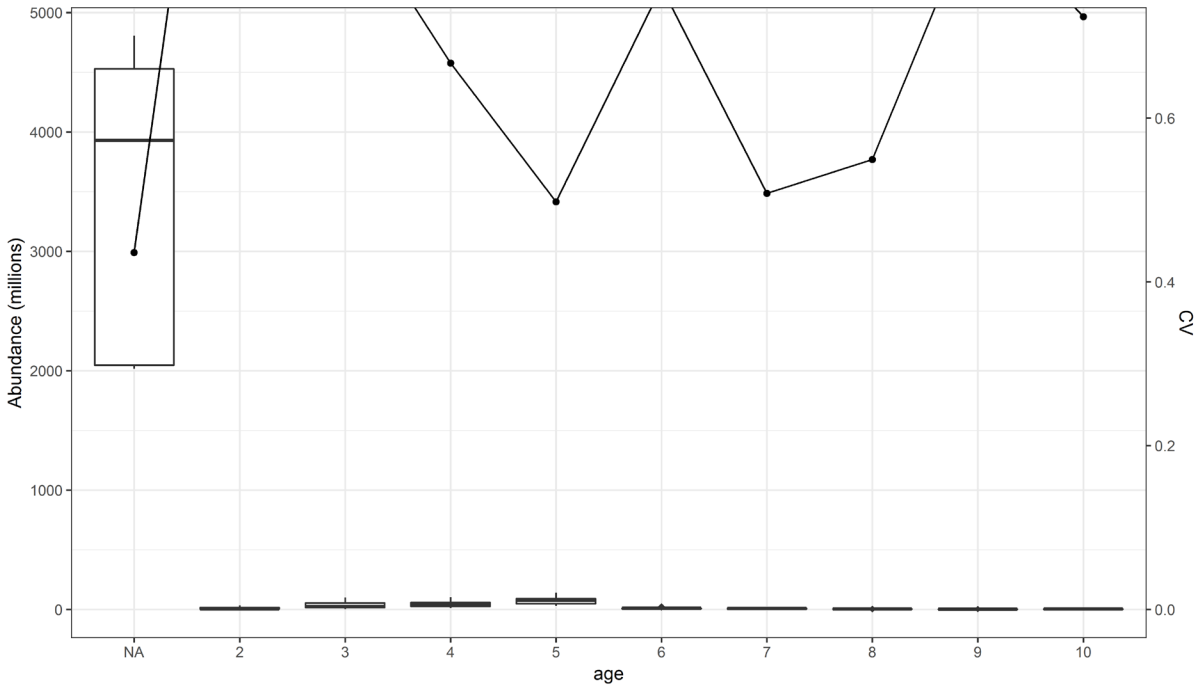
VESSEL	AREA 2	AREA 3	AREA 4	AREA 5	OVERALL
Kings Cross	0.23	0.39		0.80	0.41
Voyager	0.40	0.61	0.68	0.36	0.43
Alida				0.26	0.15

Kings Cross CVs



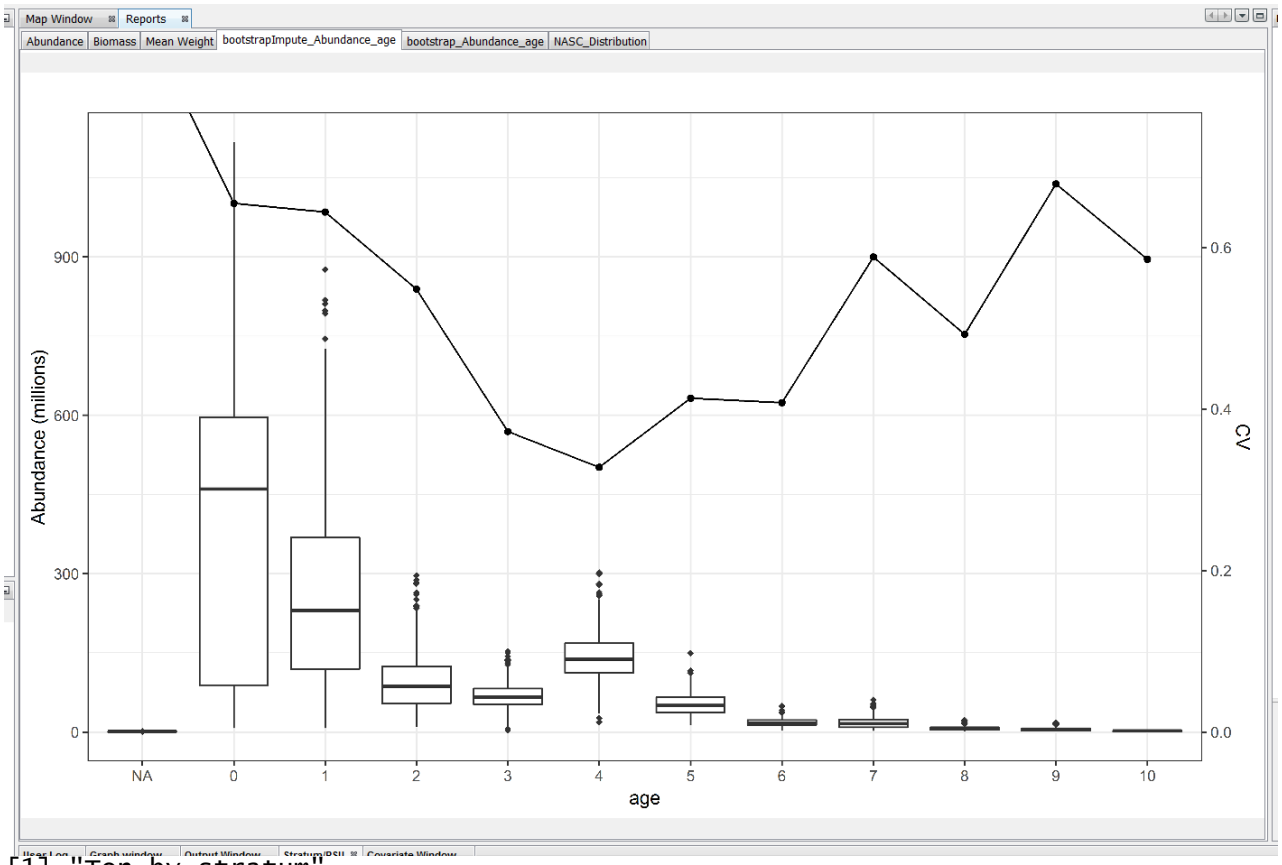

```
[1] "Ton by stratum"
   Stratum    Ton.5%   Ton.50%   Ton.95%  Ton.mean    Ton.sd    Ton.cv
1: Strata2  4176.466  6122.852  7311.222  6011.923  1404.062 0.2335463
2: Strata3 10595.877 18155.166 28510.752 19563.692  7796.846 0.3985365
3: Strata5  7818.752 32776.315 56051.794 32281.585 25919.634 0.8029232
[1] "Total number by stratum (mill)"
   Stratum Ab.Sum.5% Ab.Sum.50% Ab.Sum.95% Ab.Sum.mean Ab.Sum.sd Ab.Sum.cv
1: Strata2  22590037   32979631   39552692    32498569   7597518 0.2337801
2: Strata3  69226496  120821124  175220252   125118267  47633406 0.3807070
3: Strata5  46375728  195623279  333643796   192321210 154572447 0.8037202
[1] "Ton by survey"
     Ton.5%  Ton.50%  Ton.95% Ton.mean   Ton.sd    Ton.cv
1: 31913.14 44295.29 76357.23 51400.88 20692.47 0.4025702
[1] "Total number by survey (mill)"
   Ab.Sum.5% Ab.Sum.50% Ab.Sum.95% Ab.Sum.mean Ab.Sum.sd Ab.Sum.cv
1: 187094836  280261960  463992073   311473804 127522465 0.4094163
```

Alida CVs




```
[1] "Ton by stratum"
   Stratum   Ton.5%  Ton.50%  Ton.95% Ton.mean   Ton.sd    Ton.cv
1: Strata2 11467.29 11467.29 11467.29 11467.29    0.000 0.0000000
2: Strata3 14080.96 14080.96 14080.96 14080.96    0.000 0.0000000
3: Strata5 25645.99 34755.68 44770.21 33617.74 8889.697 0.2644347
[1] "Total number by stratum (mill)"
   Stratum  Ab.Sum.5% Ab.Sum.50% Ab.Sum.95% Ab.Sum.mean  Ab.Sum.sd Ab.Sum.cv
1: Strata2   60941129   60941129   60941129    60941129          0 0.0000000
2: Strata3   91799068   91799068   91799068    91799068          0 0.0000000
3: Strata5 2122659794 3927409973 4478814785  3343361104 1149320981 0.3437621
[1] "Ton by survey"
     Ton.5%  Ton.50%  Ton.95% Ton.mean   Ton.sd    Ton.cv
1: 51194.24 60303.93 70318.46 59165.99 8889.697 0.1502501
[1] "Total number by survey (mill)"
    Ab.Sum.5% Ab.Sum.50% Ab.Sum.95% Ab.Sum.mean  Ab.Sum.sd Ab.Sum.cv
1: 2275399990 4080150169 4631554982  3496101301 1149320981 0.3287436
```

Voyager CVs




```
[1] "Ton by stratum"
   Stratum    Ton.5%   Ton.50%  Ton.95%  Ton.mean    Ton.sd    Ton.cv
1: Strata2  4831.107  9394.411 13537.27  9827.368  3990.706 0.4060809
2: Strata3  7177.673 10503.236 26845.14 14814.908  9027.623 0.6093607
3: Strata4 11297.354 57887.218 70564.58 43624.668 29896.023 0.6853009
4: Strata5 14486.520 24909.388 33009.10 23124.195  8354.019 0.3612675
[1] "Total number by stratum (mill)"
   Stratum Ab.Sum.5% Ab.Sum.50% Ab.Sum.95% Ab.Sum.mean Ab.Sum.sd Ab.Sum.cv
1: Strata2  26159001   49925126   72542334    52710722  21319172 0.4044561
2: Strata3  40213736   58803952  894238699   345160526 423302262 1.2263924
3: Strata4 117192471  600489813  731997696   452538055 310124719 0.6853009
4: Strata5 107977496  165381489  286336930   184019372  79486273 0.4319451
[1] "Ton by survey"
     Ton.5%  Ton.50% Ton.95% Ton.mean   Ton.sd    Ton.cv
1: 44691.32 113615.3  126180 91391.14 39149.11 0.4283688
[1] "Total number by survey (mill)"
   Ab.Sum.5% Ab.Sum.50% Ab.Sum.95% Ab.Sum.mean Ab.Sum.sd Ab.Sum.cv
1: 317417140 1029564148 1839365699  1034428674 703671631 0.6802515
```

3.2.2 6aS/7b herring (Table 3.15 to 3.19)

The estimated total stock biomass (TSB), number at age (TSN), numbers at length class and mean weight of herring found in the total survey area and each of the survey strata areas is shown in Tables 3.15 – 3.19. The transects in Lough Swilly were conducted in a zig-zag pattern due to the shallow nature of the habitat, therefore for estimation purposes, Lough Swilly was treated as a separate strata within StoX. There were three other stratum; NW (parallel transects, 7.5 nmi. Spacing throughout) and Donegal Bay and Achill (parallel transects with 3.5nmi. spacing). The TSB estimate of herring for the combined 6aS/7b area was 50,145 tonnes (Lough Swilly = 32,372 tonnes, Donegal Bay = 9,517 tonnes, NW area = 7,710 tonnes and Achill = 545 tonnes).

Table 3.15. 6aS/7b industry acoustic survey in 2018: age-disaggregated estimate of herring in the total survey area. The total estimated TSB for the entire survey area = 50,145 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: TOTAL
SpecCat: Clupea herangus

LenGrp	age 1	2	3	4	5	6	7	8	9	10	Number (1E3)	Biomass (1E3kg)	Mean W (g)
21.0-21.5	27	354	-	-	-	-	-	-	-	-	382	29.2	76.57
21.5-22.0	-	1730	-	-	-	-	-	-	-	-	1730	136.5	78.89
22.0-22.5	628	3557	-	-	-	-	-	-	-	-	4184	359.6	85.93
22.5-23.0	-	7390	340	-	-	-	-	-	-	-	7729	694.7	89.87
23.0-23.5	-	14319	291	-	-	-	-	-	-	-	14610	1465.5	100.31
23.5-24.0	-	10362	2322	833	-	-	-	-	-	-	13516	1451.1	107.36
24.0-24.5	-	12236	3356	2280	-	-	-	-	-	-	17872	2011.0	112.52
24.5-25.0	-	6879	12651	1508	-	-	-	-	-	-	21038	2554.3	121.41
25.0-25.5	-	729	17054	6532	655	-	-	-	-	-	24970	3167.7	126.86
25.5-26.0	-	1713	14272	11381	4167	-	-	-	-	-	31532	4426.2	140.37
26.0-26.5	-	-	12042	20336	5412	1509	-	-	-	-	39298	5727.2	145.74
26.5-27.0	-	-	1203	19715	12396	3190	16	-	-	-	36520	5527.3	151.35
27.0-27.5	-	-	1710	21437	12887	2756	2723	-	-	-	41513	6678.4	160.88
27.5-28.0	-	-	572	9834	17040	2603	4522	-	-	672	35244	5939.7	168.53
28.0-28.5	-	-	573	6252	11671	2939	3977	1221	18	-	26652	4673.8	175.37
28.5-29.0	-	-	390	1717	2019	5645	5988	1746	656	-	18162	3224.9	177.57
29.0-29.5	-	-	-	-	1704	1530	4470	1123	257	-	9084	1666.7	183.48
29.5-30.0	-	-	-	-	-	162	1746	-	-	-	1907	364.7	191.19
30.0-30.5	-	-	-	-	-	-	-	246	-	-	246	47.2	192.00
TSN(1000)	655	59268	66776	101824	67951	20334	23443	4336	931	672	346189	-	-
TSB(1000 kg)	48.0	6180.9	8730.5	15457.7	11064.8	3431.8	4192.3	768.7	160.4	110.3	-	50145.5	-
Mean length (cm)	21.96	23.39	25.21	26.41	27.11	27.64	28.22	28.57	28.63	27.50	-	-	-
Mean weight (g)	73.20	104.29	130.74	151.81	162.83	168.77	178.83	177.30	172.37	164.00	-	-	144.85

Table 3.16. 6aS/7b industry acoustic survey in 2018: age-disaggregated estimate of herring in survey - Lough Swilly area. The estimated TSB for the Lough Swilly strata = 32,372 t.

Variable: Abundance
EstLayer: 1
Stratum: Swilly
SpecCat: Clupea herangus

LenGrp	age 1	2	3	4	5	6	7	8	9	10	Number (1E3)	Biomass (1E3kg)	Mean W (g)
21.0-21.5	-	244	-	-	-	-	-	-	-	-	244	18.8	77.00
21.5-22.0	-	1262	-	-	-	-	-	-	-	-	1262	100.0	79.25
22.0-22.5	426	2450	-	-	-	-	-	-	-	-	2876	250.8	87.22
22.5-23.0	-	4545	296	-	-	-	-	-	-	-	4842	435.6	89.98
23.0-23.5	-	9945	221	-	-	-	-	-	-	-	10166	1040.4	102.35
23.5-24.0	-	5496	1763	726	-	-	-	-	-	-	7985	883.0	110.58
24.0-24.5	-	8104	1424	1971	-	-	-	-	-	-	11499	1314.6	114.32
24.5-25.0	-	4214	9482	1405	-	-	-	-	-	-	15100	1844.1	122.12
25.0-25.5	-	476	10818	4993	594	-	-	-	-	-	16881	2176.4	128.92
25.5-26.0	-	1552	8832	7877	3700	-	-	-	-	-	21960	3150.2	143.45
26.0-26.5	-	-	7358	13751	4342	844	-	-	-	-	26296	3869.9	147.17
26.5-27.0	-	-	-	12257	8092	2856	-	-	-	-	23204	3570.4	153.87
27.0-27.5	-	-	928	9981	9749	1857	2321	-	-	-	24837	4062.8	163.58
27.5-28.0	-	-	-	5698	9652	2210	3024	-	-	581	21165	3602.2	170.19
28.0-28.5	-	-	-	4262	6336	2074	2995	691	-	-	16358	2912.6	178.06
28.5-29.0	-	-	-	739	862	4065	3696	1232	616	-	11210	1985.4	177.10
29.0-29.5	-	-	-	-	1253	627	2297	835	209	-	5221	972.9	186.34
29.5-30.0	-	-	-	-	-	-	957	-	-	-	957	182.5	190.67
TSN(1000)	426	38287	41122	63660	44581	14532	15290	2758	825	581	222064	-	-
TSB(1000 kg)	32.0	4057.8	5418.9	9699.4	7238.1	2442.9	2747.4	498.6	142.3	95.4	-	32372.7	-
Mean length (cm)	22.00	23.39	25.09	26.29	27.00	27.57	28.11	28.53	28.63	27.50	-	-	-
Mean weight (g)	75.00	105.98	131.78	152.36	162.36	168.10	179.68	180.74	172.49	164.00	-	-	145.78

Table 3.17. 6aS/7b industry acoustic survey in 2018: age-disaggregated estimate of herring in survey - Northwest area. The estimated TSB for the Northwest strata = 7,710 t.

Variable: Abundance
EstLayer: 1
Stratum: NW
SpecCat: Clupea herangus

LenGrp	age 1	2	3	4	5	6	7	8	9	10	Number (1E3)	Biomass (1E3kg)	Mean W (g)
21.0-21.5	27	110	-	-	-	-	-	-	-	-	137	10.4	75.80
21.5-22.0	-	261	-	-	-	-	-	-	-	-	261	20.5	78.65
22.0-22.5	89	655	-	-	-	-	-	-	-	-	744	63.8	85.86
22.5-23.0	-	1161	44	-	-	-	-	-	-	-	1205	108.4	89.99
23.0-23.5	-	1897	70	-	-	-	-	-	-	-	1967	196.0	99.62
23.5-24.0	-	1429	374	107	-	-	-	-	-	-	1910	201.6	105.58
24.0-24.5	-	1676	416	308	-	-	-	-	-	-	2400	268.9	112.06
24.5-25.0	-	912	1751	103	-	-	-	-	-	-	2766	336.7	121.74
25.0-25.5	-	136	2485	773	61	-	-	-	-	-	3455	436.7	126.40
25.5-26.0	-	161	2303	1595	467	-	-	-	-	-	4526	628.8	138.91
26.0-26.5	-	-	1779	3008	709	205	-	-	-	-	5700	830.1	145.63
26.5-27.0	-	-	223	3259	1733	334	16	-	-	-	5565	837.6	150.52
27.0-27.5	-	-	201	3943	1593	325	402	-	-	-	6463	1025.0	158.59
27.5-28.0	-	-	121	1560	2530	394	636	-	-	91	5332	894.8	167.82
28.0-28.5	-	-	176	965	2071	579	702	228	18	-	4740	825.4	174.15
28.5-29.0	-	-	100	341	562	1004	1145	402	40	-	3595	639.9	178.01
29.0-29.5	-	-	-	-	273	386	771	112	48	-	1591	291.6	183.27
29.5-30.0	-	-	-	-	-	41	413	-	-	-	455	87.2	191.91
30.0-30.5	-	-	-	-	-	-	-	35	-	-	35	6.7	192.00
TSN(1000)	116	8399	10043	15963	9999	3268	4086	777	106	91	52846	-	-
TSB(1000 kg)	8.3	862.5	1314.2	2426.6	1644.1	556.9	728.5	136.1	18.2	14.9	-	7710.3	-
Mean length (cm)	21.76	23.31	25.27	26.51	27.23	27.85	28.30	28.49	28.64	27.50	-	-	-
Mean weight (g)	71.68	102.70	130.86	152.02	164.43	170.44	178.30	175.09	171.43	164.00	-	-	145.90

Table 3.18. 6aS/7b industry acoustic survey in 2018: age-disaggregated estimate of herring in survey - Donegal Bay area. The estimated TSB for the Donegal Bay strata = 9,517 t.

Variable: Abundance
EstLayer: 1
Stratum: Donegal Bay
SpecCat: Clupea herangus

LenGrp	age 1	2	3	4	5	6	7	8	Number (1E3)	Biomass (1E3kg)	Mean W (g)
21.0-21.5	-	-	-	-	-	-	-	-	-	-	-
21.5-22.0	-	195	-	-	-	-	-	-	195	15.0	77.00
22.0-22.5	107	427	-	-	-	-	-	-	534	42.5	79.50
22.5-23.0	-	1592	-	-	-	-	-	-	1592	142.2	89.34
23.0-23.5	-	2343	-	-	-	-	-	-	2343	216.7	92.47
23.5-24.0	-	3260	166	-	-	-	-	-	3425	346.8	101.26
24.0-24.5	-	2329	1429	-	-	-	-	-	3758	404.3	107.58
24.5-25.0	-	1661	1339	-	-	-	-	-	3000	353.2	117.75
25.0-25.5	-	111	3551	721	-	-	-	-	4383	524.9	119.75
25.5-26.0	-	-	2954	1818	-	-	-	-	4773	612.1	128.25
26.0-26.5	-	-	2773	3372	326	435	-	-	6906	971.2	140.62
26.5-27.0	-	-	930	3939	2462	-	-	-	7331	1058.7	144.43
27.0-27.5	-	-	546	7095	1474	546	-	-	9660	1504.7	155.77
27.5-28.0	-	-	438	2465	4547	-	822	-	8273	1363.9	164.86
28.0-28.5	-	-	379	975	3087	271	271	271	5254	885.5	168.56
28.5-29.0	-	-	274	602	547	547	1095	109	3175	567.0	178.60
29.0-29.5	-	-	-	-	165	496	1322	165	2149	380.2	176.97
29.5-30.0	-	-	-	-	-	117	351	-	469	89.7	191.50
30.0-30.5	-	-	-	-	-	-	-	199	199	38.3	192.00
TSN(1000)	107	11918	14780	20987	12609	2412	3861	745	67418	-	-
TSB(1000 kg)	7.3	1194.1	1891.6	3150.8	2056.7	411.1	680.3	125.1	-	9517.0	-
Mean length (cm)	22.00	23.43	25.51	26.70	27.39	27.80	28.51	28.83	-	-	-
Mean weight (g)	68.00	100.20	127.99	150.13	163.12	170.45	176.19	167.95	-	-	141.16

Table 3.19. 6aS/7b industry acoustic survey in 2018: age-disaggregated estimate of herring in survey - Achill area. The estimated TSB for the Achill strata = 545 t.

Variable: Abundance
EstLayer: 1
Stratum: Achill
SpecCat: Clupea herangus

LenGrp	age 1	2	3	4	5	6	7	8	Number (1E3)	Biomass (1E3kg)	Mean W (g)
21.0-21.5	-	-	-	-	-	-	-	-	-	-	-
21.5-22.0	-	11	-	-	-	-	-	-	11	0.9	77.00
22.0-22.5	6	24	-	-	-	-	-	-	31	2.4	78.80
22.5-23.0	-	91	-	-	-	-	-	-	91	8.4	91.79
23.0-23.5	-	134	-	-	-	-	-	-	134	12.4	92.51
23.5-24.0	-	177	19	-	-	-	-	-	196	19.6	99.98
24.0-24.5	-	127	88	-	-	-	-	-	215	23.2	107.58
24.5-25.0	-	92	80	-	-	-	-	-	172	20.2	117.54
25.0-25.5	-	6	200	44	-	-	-	-	251	29.8	118.76
25.5-26.0	-	-	182	91	-	-	-	-	273	35.1	128.42
26.0-26.5	-	-	131	206	34	25	-	-	396	56.0	141.51
26.5-27.0	-	-	50	260	110	-	-	-	420	60.6	144.34
27.0-27.5	-	-	34	419	72	28	-	-	553	85.9	155.34
27.5-28.0	-	-	13	110	311	-	41	-	474	78.9	166.50
28.0-28.5	-	-	19	50	177	16	9	31	301	50.3	167.13
28.5-29.0	-	-	16	34	47	28	53	3	182	32.6	179.47
29.0-29.5	-	-	-	-	13	22	79	9	123	21.9	178.21
29.5-30.0	-	-	-	-	-	3	23	-	27	5.2	192.13
30.0-30.5	-	-	-	-	-	-	-	11	11	2.2	192.00
TSN(1000)	6	664	831	1214	763	122	206	55	3861	-	-
TSB(1000 kg)	0.4	66.5	105.7	181.0	125.9	20.9	36.2	9.0	-	545.5	-
Mean length (cm)	22.00	23.42	25.42	26.67	27.44	27.70	28.58	28.62	-	-	-
Mean weight (g)	68.00	100.11	127.17	149.13	165.00	170.68	175.91	162.94	-	-	141.29

The CV estimates on biomass and abundance for herring 6aS/7b are high (~0.50) for the survey in 2018. This is most likely caused by the over-reliance on a few acoustic marks of herring in Lough Swilly and Donegal Bay in particular. Bias considerations for the survey are outlined in section 2.4.4. Many of the considerations are common to all acoustic surveys, particularly when dealing with spawning or pre-spawning aggregations and should be dealt with and reduced if possible at the survey design stage.

There was good evidence of offshore containment of herring in 6aS/7b in the 2018 survey, however, there is still a concern regarding stock containment inshore due to the hyper-aggregating behaviour and shallow distribution (<15m) of herring in some areas. There was evidence from the fishery and the survey itself (marks on the boundaries of the survey grid at the limit of where the vessel could go) of fish inshore in areas where the survey did not cover. The over-reliance of the estimate on few areas of high herring density led to the high CV on the estimates of abundance and biomass (~0.50). Additional areas off the west Mayo and Galway coasts were covered by this survey again in 2018. These included a number of grounds that were known to have spawning in the past, however, few herring aggregations were located in these areas apart from a couple of marks in near Inishbofin. Spawning is known to occur, but the lack of occurrence of herring marks in these areas suggest that timing of the survey may not have been adequate, and therefore containment may not have been achieved in these areas in 2018.

3.2.3 6aS/7b horse mackerel (Table 3.20)

The horse mackerel stock was not contained by the survey; this species is known to inhabit a large geographical range (outside the area of the survey) therefore the index is only useful as a subset of the larger stock, albeit an important area for the horse mackerel fishery during this time of the year. The CV estimates on biomass and abundance of horse mackerel was ~ 0.36 for the survey in 2018.

Table 3.20. 6aS/7b industry acoustic survey in 2018: age-disaggregated estimate of horse mackerel in total survey area. The total estimated TSB for the entire survey area = 57,162 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: NW
SpecCat: Trachurus trachurus

LenGrp	age 2	3	4	6	7	10	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
16-17	8551	-	-	-	-	-	-	8551	295.0	34.50
17-18	4276	-	-	-	-	-	-	4276	153.9	36.00
18-19	2138	-	-	-	-	-	-	2138	89.8	42.00
19-20	-	-	-	-	-	-	-	-	-	-
20-21	-	-	-	-	-	-	-	-	-	-
21-22	-	-	-	-	-	-	-	-	-	-
22-23	-	2191	-	-	-	-	-	2191	199.3	91.00
23-24	-	8163	6122	-	-	-	-	14285	1472.2	103.06
24-25	-	-	59329	-	-	-	-	59329	6888.3	116.10
25-26	-	-	94993	-	-	-	-	94993	12409.6	130.64
26-27	-	-	94130	-	-	-	-	94130	13251.8	140.78
27-28	-	-	57420	-	-	-	-	57420	8892.9	154.87
28-29	-	-	35793	-	-	-	-	35793	6056.4	169.21
29-30	-	-	13391	-	-	-	-	13391	2551.1	190.50
30-31	-	-	-	2077	4847	2077	-	9002	2101.0	233.38
31-32	-	-	-	-	-	-	4758	4758	1132.5	238.00
32-33	-	-	-	-	-	-	3796	3796	939.5	247.50
33-34	-	-	-	-	-	-	2138	2138	729.0	341.00
TSN(1000)	14965	10353	361178	2077	4847	2077	10692	406190	-	-
TSB(1000 kg)	538.7	1041.7	50679.9	479.9	1128.7	492.3	2801.0	-	57162.3	-
Mean length (cm)	16.57	22.79	25.83	30.00	30.00	30.00	31.75	-	-	-
Mean weight (g)	36.00	100.62	140.32	231.00	232.86	237.00	261.97	-	-	140.73

4 Achievements and Recommendations

4.1 Abundance estimation –acoustics

4.1.1 Recommendations for data users

4.1.1.1 *6aN*

The 2018 acoustic surveys in the three strata surveyed in 6aN are considered to

- Have contained a significant part of the area where herring spawn in 6aN.
- Provide a reliable estimate of
  - the minimum biomass of mature herring at age observed in survey areas 5,4,3,2 during the survey period.
- Does not provide a reliable estimate of
  - the biomass of immature herring because (i) small herring passed easily through the trawl net (ii) mixing with sprat means they may have been underestimated.
  - the minimum spawning biomass, because many fish were still in the maturing stage. In area 2 in particular, evidence from the monitoring fishery shows a significant biomass of herring appeared there 2 weeks after the acoustic surveys were completed. All commercial catches outside the acoustic survey period came from area 2.

The acoustic survey has particular value in relation to

- Providing and new index of 6aN SSB and changes in the timing of spawning and distribution at this time of year. Mapping in detail the spawning locations in 6aN is also useful in relation to marine spatial planning considerations.
- Promoting positive example of industry-science and developing industry's skills to assess pelagic stocks.
- Comparison with the MALIN shelf/ WoS herring acoustic survey.

4.1.1.2 *6aS/7bc*

- The survey is a good example of industry/science survey partnerships, providing a third data point to what may become a time-series of herring surveys in the 6aS/7b area at this time of the year.
- It is reasonable to consider the herring surveyed were 6aS/7b fish due to the inshore distribution and proximity to the spawning grounds.
- The survey reflected what was experienced in the monitoring fishery occurring at the same time.

- The 2018 TSB estimate of 50,145 tonnes is considered to be a minimum estimate of herring in the 6aS/7b survey area at the time of the survey
- The majority of herring marks were observed inshore in shallow areas, particularly in Lough Swilly. The stock appears to have been largely contained, however these is still a concern regarding containment inshore in very shallow areas and in bays not covered by the survey
- The inshore/shallow distribution of herring meant that it was difficult to obtain samples on the survey. Industry nets are large, therefore it was decided to obtain samples from the fishery rather than targeting relatively large marks. The potential to obtain samples that were too large for the purpose of the survey was a consideration; this is a vulnerable stock, and it was decided in 2018 that this was the best approach. The fishery is conducted on the same marks and at the same time as the survey, therefore the sampling is considered representative of the surveyed biomass.
- Cohort tracking - there appears to be good cohort tracking in the survey over the 3-year time-series
- The survey in 2018 was conducted ~ 3 weeks earlier than in 2017. It was hoped that earlier timing would capture herring as they migrate towards the inshore spawning areas and before they hyper-aggregate. This was achieved in Bruckless and Inver Bays in the south, but was not achieved in Lough Swilly in the north. The survey began before the fishery started in 2018. The fish were in Lough Swilly in large numbers before the beginning of the survey on November 1st. Consideration needs to be given to the benefits of surveying early and the increased risk of stock mixing with 6aN fish. It is reasonable to assume that fish inshore close to the spawning ground in 6aS/7b in winter are most likely 6aS/7b fish. The further offshore the fish are, the more likely there is mixing occurring with stocks from further north (e.g. 6aN).
- There is a need to reduce uncertainty of estimate through better survey design. The CV would be reduced if schools were more widely distributed, before inshore hyper-aggregating behaviour is apparent. A design that deals with the inshore behaviour during this time could overcome this issue. It is hoped that a survey review workshop on herring acoustic spawning surveys (WKHASS 2019) will examine the survey design and recommend a design that reduces the uncertainty in the survey
- There is a need to develop protocols in areas where large aggregations or hyper aggregating behaviour of herring is observed (i.e. in areas like Lough Swilly)
- For horse mackerel the TSB estimate of 57,162 tonnes is considered to be a minimum estimate in the 6aS/7b survey area at the time of the survey.
- Horse mackerel are a widely distributed stock, therefore the stock was not contained by this survey.
- The survey was dominated by 4-wr horse mackerel, following on from the 3-wr fish picked up in the survey last year. This appears to be a sign of a good year class coming through.
- The 6aS/7b area is known to contain young horse mackerel during this time of the year, therefore the survey could be useful as an index of the younger ages going forward.

4.1.2 Recommendations for future surveys from WGIPS

4.1.2.1 *6aN*

- 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 to try and provide continuous coverage in key areas.
- Consider shifting some acoustic survey effort to June/July at same time as HERAS and seek to add value there
- Plan for a flexible date acoustic survey of the spawning stock based on 'scouting first' by PFA vessels.
- If the scientific TAC is considered to put the stock at risk, consider alternative payment options for industry participation. (N. Sea herring scientific quota?)
- Early planning of ways to handle any sample discard issues without compromising the methodology an acoustic survey. Consider different options for different vessel roles.
- Continue to ensure that industry vessels are equipped with nets appropriate for taking small samples for biological analysis.
- Notify creel fishermen of survey transects in advance

4.1.2.2 *6aS/7bc*

- Survey in 2019 and beyond – funding of the survey is currently uncertain. In 2018, the use of part of the monitoring TAC to pay for the survey was not permitted, and is unlikely to be permitted in the future. The survey in 2017 and 2018 was funded by using horse mackerel scientific quota as the survey was focused on generating abundance estimates for both horse mackerel and herring for the survey area.
- Need to reduce uncertainty of estimate through better survey design and strata delineation. The estimates in 2016, 2017 and 2018 relied heavily on herring aggregations from a few areas, resulting in a high cv (~0.37 (2016), ~0.50 (2017) and ~0.50 (2018))
- Need to develop protocols surrounding inshore areas, particularly when large aggregations or hyper aggregating behaviour is observed (i.e. in areas like Lough Swilly)

Acknowledgements

Skippers and crew of the Sunbeam, Lunar Bow, Antares, Wiron 5&6, Voyager, Sparkling Star, Eilean Croine.

Echomaster Marine, Peterhead.

Killybegs Fishermen's Organisation (KFO)

Irish South and West Fish Producers Organisation (IS&WFPO)

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Document 14a: PELACUS-IBWSS 2018 survey summary table

Survey Summary Table WGIPS 2019	
Name of the survey (abbreviation):	PELACUS-IBWSS 0318
Target Species:	Blue whiting
Survey dates:	11-23/03/18; on survey area: 14-20/03/2019
Summary:	
PELACUS-IBWSS is a new time-series, mainly covering the Porcupine Seabight, an area complementary to the main spawining ground. The rationality for covering this area is to investigate the connectivity between the those spwaners located off British Islands which perform a northward migration after spawning and those locted in the Bay of Biscay and the Spanish continental self. This firs covering was characterized for the rough weather conditions at the beginning, stopping the survey due to the impossibility to perform fishing stations and to record echograms due to bubble issues. A total of 100 thousand tonnes were assessed over an area of 7000 square nautical miles, with a length distribution similar to that found in Spanish waters. Together with blue whiting müller pearlside was also found in high quantities, occurrying in a pelagic layer located above the blue whiting one. It should be also noted the few mackerel eggs found in the surveyed area compared with those found in the Spanish area	
	Description
Survey design	Stratified systematic parallel design (20 - 30 nmi spacing) with randomized start point. Adaptive surveying was used in the southern outer border areas to the west where blue whiting spawning concentrations disappear (e.g. change of transect after 30 empty nmi).
Index Calculation method	Own method using Nakken and Dommasness method. STOX for future
Random/systematic error issues	Same as described at the bibliography. Given the spatial autocorrelation observed in blue whiting, variance estimates due to survey design would be low.
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. RV Miguel Oliver has not drop keel and bubbles is an important issue in rough weather conditions
Extinction (shadowing)	Not observed
Blind zone	Not observed for the target species
Dead zone	Main blue whiting concentrations were found in pelagic layers. Dead zone issues are considered minor
Allocation of backscatter to species	Directed trawling for verification and species composition purposes and age structure.

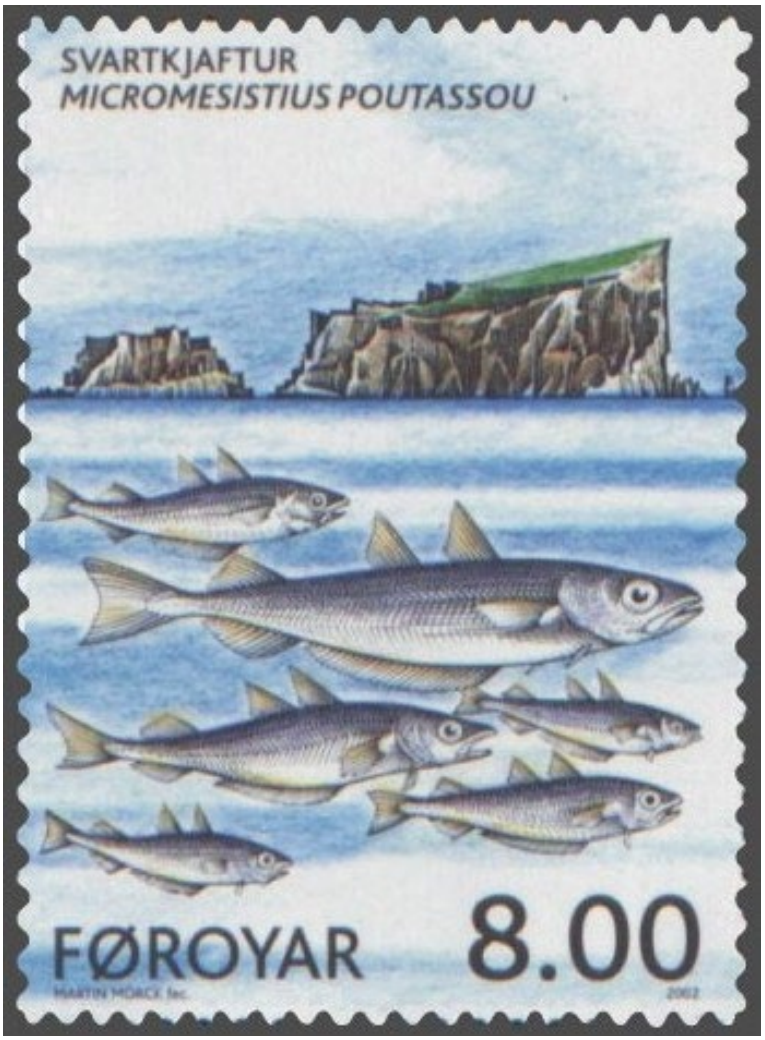
Target strength	TS = 20 log10 (L) - 65.2 Pedersen et al. 2011
Calibration	All survey frequencies were calibrated and results were within recommended tolerances
Specific survey error issues (biological)	*There are some bias considerations that apply to acoustic-trawl surveys only, and the respective SISP should outline how these are evaluated:*
Stock containment	Time-series: New time-series 2018 survey: The survey is prosècting off the main core of the blue whiting spawning grounds, which are covered by IBWSS.
Stock ID and mixing issues	Time-series: New time-series 2018 survey: Survey covers the southern branch of the blue whiting distribution aiming at to investigate the connectivity with the northern spawners, migrating northwards
Measures of uncertainty (CV)	*No yet determined*
Biological sampling	Time-series: New time-series 2018 survey: Only few samples were taken due to the bad weather conditions, although seemed to be representative of the population
Were any concerns raised during the meeting regarding the fitness of the survey for use in the assessment either for the whole time-series or for individual years? (please specify)	Time-series is not used for assessment purposes for the time being
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 14b: PELACUS-IBWSS 2018 survey report

Please see the report on the next page.

WD to WIDE 2018 (28/08-03/09/2018). Tórshavn

PELAGIC ECOSYSTEM ACOUSTIC-TRAWL SURVEY PELACUS-IBWSS 0318: BLUE WHITING AND MÜELLER'S PEARLSIDE FISH ABUNDANCE ESTIMATES IN PORCUPINE SEABIGHT



Instituto Español de Oceanografía

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Unión Europea
Fondo Europeo Marítimo y de Pesca (FEMP)

Index

TECHNICAL SUMMARY

Institution:	INSTITUTO ESPAÑOL DE OCEANOGRAFÍA
Survey name:	PELACUS(IBWSS) 0318
Vessel name:	Miguel Oliver (70 mn length, 2x1000 kW diesel-electric)
Dates:	11-23/03/2018 On survey area: 14-20/03/18
Area:	Porcupine Seabight (7j-k, between 49°N and 52°30'N and 13°W and 11°45'W)
Type:	Acoustic-Trawl
Main objective:	Biomass estimation by means of echointegration of the main pelagic fish population present in the surveyed area. Physical, chemical and biological characterisation of the pelagic ecosystem.
Sampling strategy	Systematic grid with random start, tracks 30 nmi apart in the southern part, 20nmi in the northern part, from self-break in the eastern limit to 13°W in the wesrtern limit
Main sampling procedures	EK-60 at 18-38-70-120-200 kHZ. 1009 nmi prospected. Day/night observation CUFES, Intake at 5 m depth, 600 l min^{-1}. 3 nmi/sample, 191 samples (mackerel, blue whiting and horse mackerel eggs) Pelagic fishing stations: 4 (3 Gloria hexagon, 1 gloria HOD 352) Marine mammals and birds observations (apical observer) Manta trawl hauls (microplastics). 3 tows done at the same time as the fishing tows Hydrological characterisation. 32 stations (CTD with plankton nets)

Personnel

Name	Role	Name	Role
CARRERA LÓPEZ, PABLO	Chief mission	HERNÁNDEZ GONZÁLEZ, ALBERTO	Apical observer
CARRETERO PERONA, OLGA	Pollution, microplastics	LOPEZ DÍAZ, EDUARDO	Apical observer
DÍAZ CONDE, PAZ	CUFES (ichthyoplankton)	LOUREIRO CARIDE, ISABEL	Acoustic analyser
DÍEZ GARCÍA, IRENE PILAR	Acoustic analser	OTERO PINZÁS, ROSENDO	Ichthyology
DOMÍNGUEZ PETIT, ROSARIO	Ichthyology (fecundity)	POMAR VERT, BIEL	Ichthyology
DONNELY, ALISON	Irish observer	REGUERA TURIENZO, IGNACIO	Physical oceanography
FDEZ. CORREGIDOR, FRANCISCO	MULTINET (ichthyoplankton)	SOLLA COVELO, ANTONIO JOSÉ	Ichthyology (fecundity)
GÓMEZ GONZÁLEZ, ANTONIO	Ichthyology	VARELA ROMAY, JOSÉ	Physical oceanography
GONZÁLEZ GONZÁLEZ, ISABEL C.	CUFES (ichthyoplankton)	VILLAVERDE ROSALES, JOSÉ LUIS	MULTINET (ichthyoplankton)
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INTRODUCTION

IEO undertook several studies on blue whiting distribution and abundance in the Bay of Biscay under the frame of the EU project SEFOS. Namely, the question to answer was whether there is southward post-spawning migration from Porcupine area, accomplished the well known northward one. Two surveys (1994 and 1996) were carried out with a double coverage, without any clear indication of such southward post-spawning migration.

From this experience, it should be highlighted the different distribution pattern observed north Cantabrian sea in relation to that recorded off Spanish north coast. While in the former the bulk of the distribution is located from slope to open waters in a pelagic layer at 300-500 m depth, in the later, most of the fish use to be found at the end of the continental self and around the slope without any important pelagic layer progressing towards highseas.

In 2018, on account the Spanish duties related to DCF, the IEO has joined the International Blue Whiting Spring Survey (IBWSS). Therefore, the ICES Working Group of International Pelagic Surveys acknowledged this new collaborator and agreed B/O Miguel Oliver will cover the off-core spawning area located southwest of Porcupine Bank (e.g. Porcupine Seabight). This new strata (number 7) was firstly designed with a zig-zag coverage, changed by a parallel one. And, in case of available time, another extra strata (number 8), located southwards would be covered.

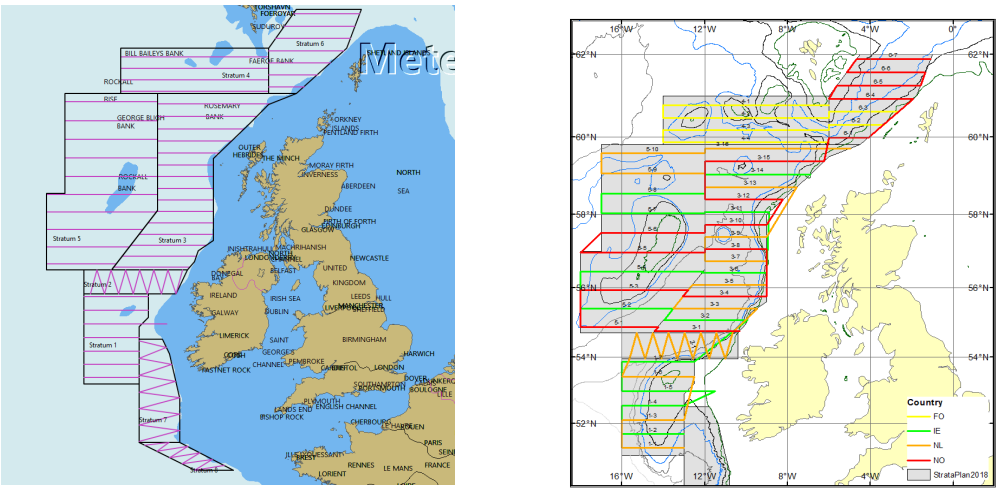

Figure 1: IBWSS tracks foreseen for 2018.

This area was surveyed between 14th and 20th March, when the vessel sailed towards Santander harbour to start the normal PELACUS coverage. This WD provides acoustic estimates, distribution and mean size for blue whiting and müeller's pearlside.

OBJECTIVES

Main objective of this survey was to achieve a biomass estimates by echointegration of the main pelagic fish distributed in Porcupine Seabight. Together with this, the following objectives were also foreseen:

- Determine the distribution area and density of the main fish species
- Determine the main biological characteristics (length, sex, maturity stage and age) of the main fish species
- Estimate the relative abundance and distribution area of mackerel eggs by means of CUFES
- Characterise the main oceanographic conditions of the surveyed area

- Determine the distribution area and density of apical predators
- Determine the distribution area and density of marine microplastics litter

MATERIAL AND METHODS

The methodology followed the recommendations for the IBWSS at the Manual for International Pelagic Surveys (IPS) (ICES 2015). Stratum 7 will be covered with a grid with random start (52º22.06N (52.3676). From this track to 51ºN, distance among track was fixed at 20 nmi; and between 51ºN and 49ºN, the distance was 30 nmi. Starting point of the tracks was located at 200m isobath (e.g. slope), extending westward until 13ºW, but with adaptive ending (negligible of empty abundance of blue whiting in a leg of 20 nmi will result in a change of track).

First track in the south will be started at the coastal point, allowing to have the adaptive end in high seas. Contrary to the normal way in PELACUS, acoustic will be recorded 24/24h, but fishing station will be only performed between 8 to 20 hours. CTD casts are regularly distributed on each acoustic track.

Stratum 8 (south Grand Sole, zones 7jh and 8ad), in case of available time, will have a random startin point located at 48º59.63N and 10º32.29W, with tracks equally spaced every 30 nmi.

Stratum	No Tracks	Number of nmi		TIME (24 hours at 10 knots)
		Track	Union	
7	9	656	206	3.6
Sailing between 7 and 8	Na	na	228	0.9
8	6	333	150	2.0
Total	15	989	583	6.6

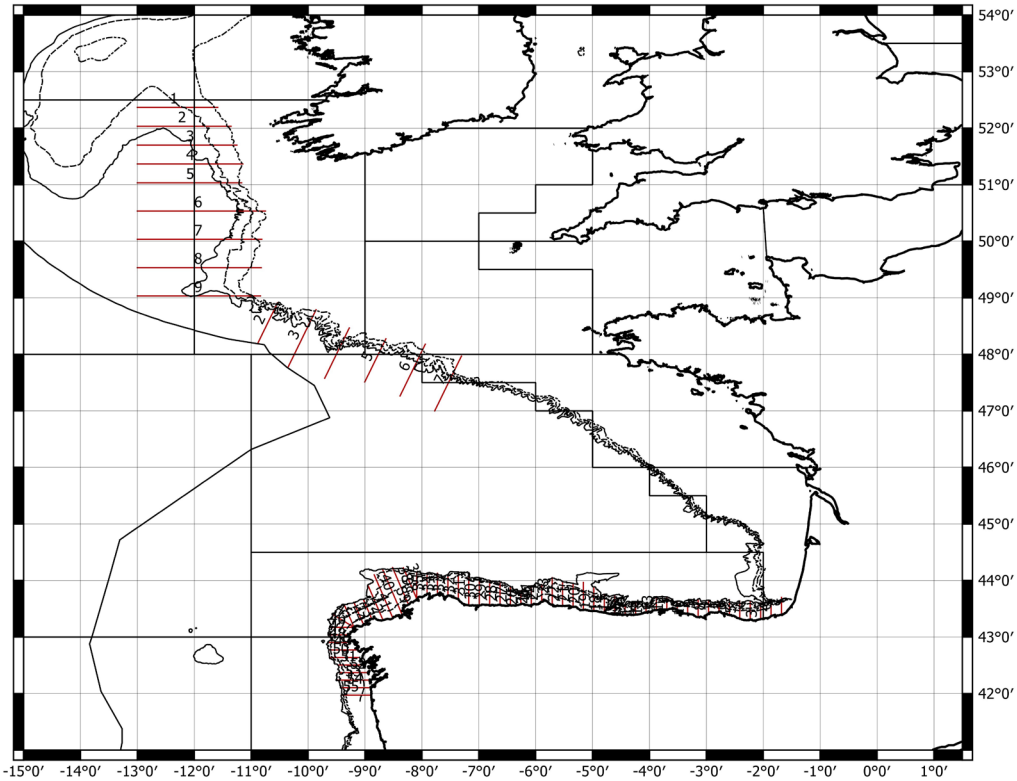

Figure 2 Whole survey track

Sampling procedures

Acoustic

Acoustic equipment consisted on a Simrad EK-60 scientific echosounder, operating at 18, 38, 70, 120 and 200 kHz. Due to the bad weather condition previous to the survey, all frequencies were calibrated after the survey, according to the standard procedures (Foote et al 1987). The elementary distance sampling unit (EDSU) was fixed at 1 nm. Acoustic data were obtained only during daytime at a survey speed of 8-10 knots. Data were stored in raw format and post-processed using SonarData Echoview software (Myriax Ltd.) (Higginbottom et al , 2000). All echograms were first scrutinized and also background noise was removed according to De Robertis and Higginbottom (2007). Fish abundance was calculated with the 38 kHz frequency as recommended at the IPS (ICES 2015), although echograms from 18, 70, 120 and 200 kHz frequencies were used to visually discriminate between fish and other scatter-producing objects such as plankton or bubbles, and to distinguish different fish species according to the frequency response. The 18, 70, 120 and 200 kHz frequencies have been also used to create a mask allowing a better discrimination between fish species and plankton. The threshold used to scrutinize the echograms was –70 dB. The integration values were expressed as nautical area scattering coefficient (NASC) units or s_A values (m^2 nm^{-2}) (MacLennan et al., 2002).

This year, due to the bad weather conditions, a previous filter to remove bubble swept-down (Honkalehto et al. 2011) has been applied (see appendix 1 for further details).

Main echosounder settings are shown in table 1

Transducer power	2000/2000/1000/200/90 W for 18/38/70/120/200 kHz
Pulse duration	1.024 ms
Ping rate	Maximum, in case of ghost echo-bottom, change to time interval starting at 0.30 ms
Range (echograms, files)	500 when depth is between 100-200m; and 1000 when depth is>500m

Table 1: Main echosounder settings.

Fishing stations

Fishing stations are used for both NASC allocation and length analysis. Therefore, they were located on account the results obtained during the acoustic prospection (i.e. opportunistic accounting the echotraces).

Two fishing gears were used. A gloria hexagon, with a vertical opening of about 30 m and around 70 m horizontal one, was used as main fishing gear. As general rig, 400 kg of clump weight were put at each side of the set back (2 m lower wing). Dyneema bridles (wings) had 100 m. Besides a set of Apollo 4.0 m^2 and 1400 kg weight polyice doors were used. Gear performance was controlled using a wired Simrad Sonar FS20 net sounder. Close to the codend a MARPORT Trawl speed Exploreer SPE155 with the Scala system was placed in order to ensure that flux at high towing speed (I.e. 4.5-5 knots) is good and no fish school is escaping below the footrope or at the end of the fishing station. Together with this a smaller gloria HOD 352, was also used as it was provided with a smaller codend (5 mm), for catching small organisms such as krill or pearlsides

CUFES

CUFES system uses an internal pumping system with the intake located at 5 m depth. The sea water goes first to a tank of about 1m^3before to be pumped towards the concentrator.

Samples from CUFES were collected every three nmi while acoustically prospecting the transects. Once the sample is taken it is fixed in a buffered 4% formaldehyde solution. Anchovy and sardine eggs are sorted out and counted before being preserved in the same solution. The remaining ichthyoplankton (other eggs and larvae) are also preserved in the same way. Information on horse mackerel and mackerel (qualitative) was also recorded.

Hydrological characterisation

Continuous records of SSS, SST and flourometry are taken using a SeaBird Thermosalinograph coupled with a Turner Flourometer. CTD casts were evenly distributed over the surveyed area. Due to the maximum range of some of the sensors, the maximum depth was fixed at 500 m.

Top predator observations

Three observers placed at the bridge of the vessel at a height of 16 m above sea level work in turns of two prospecting an area of 180° (each observer cover a field of 90°). Observations are carried out with the naked eye although binoculars are used (7x50) to confirm species identification and determine predator behaviour. Observations are carried out during daylight while the vessel prospects the acoustic transects. Observers record species, number of individuals, behaviour, distance to the vessel and angle to the trackline and observation conditions (wind speed and direction, sea state, visibility, etc.). Observers also record presence, number and type of boats and

type, size and number of floating litter. The same methodology is used on the PELGAS surveys and both observer teams shared a common database.

Marine Microplastic Litter characterisation

A “manta net neuston sampler” was used. This trawl device has a collector of 350µm. Tows were performed for 15 min at 4 knots speed. The samples were evenly distributed along the surveyed area.

Fish Biological sampling

Catches from fishing trawl hauls were sorted and weighted. All fish species were measured (total length, 1cm classes for all species except clupeids measured at 0.5 cm). When needed, random subsamples of 80-200 specimen were taken. For the main species an additional biological sampling was done for weight, age, sex, maturity stage analysis; and, sampling for estimation of fecundity adult parameters of blue whiting.

Data analysis

Although data are being processed using STOX, data are not yet available, thus the same method used to analyse PELACUS was used, as described hereafter. Formula are the same but not c.v. is associated to the biomass estimation.

NASC Allocation

A pelagic gear has been used to identify the species and size classes responsible for the acoustic energy detected and to provide samples. Haul duration was variable and ultimately depended on the number of fish that enters the net and the conditions where fishing takes place although a minimum duration of 20 minutes is always attempted. The quality of the hauls for ground-truthing of the acoustic data was classified on account of weather condition, haul performance and the catch composition in numbers and the length distribution of the fish caught as follows (table 2):

	0	1	2	3
Gear performance Fish behaviour	Crash	Bad geometry Fish escaping	Bad geometry No escaping	God geometry No escaping
Weather conditions	Swell >4 m height Wind >30 knots	Swell: 2 -4 m Wind: 30-20 knots	Swell: 1-2m Wind 20-10 knots	Swell <1 m Wind < 10 knots
Fish number	total fish caught <100	Main species >100 Second species <25	Main species > 100 Second species< 50	Main species > 100 Second species > 50
Fish length distribution	No bell shape	Main species bell shape	Main species bell shape Seconds: almost bell shape	Main species bell shape Seconds: bell shape

Hauls considered as the best representation of the fish community for a specific area were used to allocate NASC of each EDSU within this area when no direct allocation was feasible. This process involved the application of the Nakken and Dommasnes (1975, 1977) method for multiple species, but instead of using the mean backscattering cross section, the full length class distribution (1 or 0.5 cm length classes) has been used, as follows:

$$NASC_l = NASC \cdot \left(\frac{\sigma_{l,\rho}}{\sigma_\rho}\right)$$

where *NASC* is the total backscattering energy to calculate densities by length, $NASC_l$ is the proportion of the total *NASC* which can be attributed to length group l for a particular fish species. $\sigma_{l,p}$ is the backscattering cross-section at length l for a particular species at length l multiplied by the proportion of (p_l) of length of this particular species on the overall catch and σ_p is the sum of all $\sigma_{l,p}$ for all species,

$$\sigma_{l,\rho} = \rho_l * \sigma_l$$

$$\sigma_\rho = \sum_l \sigma_{l,\rho}$$

finally σ_l, is backscattering cross-section (m^2) for a fish of length l for a particular species and is computed as follows:

$$\sigma_l = \frac{l^{\left(\frac{m}{10}\right)} * 10^{\left(\frac{b_{20}}{10}\right)}}{4 * \pi}$$

This is computed from the formula TS =20 $\log L_T$+ b_{20} (Simmonds and MacLennan, 2005), where L_T is the length class . The b_{20} values for the most important species present in the surveyed area are shown in following table:

Sp	b_{20}	Ref	Observations	Otherb_{20}	Ref.
MAV	-71.4	In press	In situ analysis	-70.6*	Sawada et al, 2011
WHB	-65.2	Pedersen et al., 2011			

* 70kHz frequency, *Diaphus theta*.

Table 4.- b_{20} values from the length target strength relationship

When possible, direct allocation was also done, accounting for the shape of the schools and also the relative frequency response (Korneliussen and Ona, 2003, De Robertis et al, 2010). Due to the aggregation pattern found in the surveyed area, fish schools were extracted using the following settings:

Sv threshold	-70 dB for all frequencies
Minimum total school length	2/20 m
Min. total school height	1/5 m
Min. candidate length	1 m
Min. candidate height	0.5 m
Maximum vertical linking distance	2.5 m
Max. horizontal linking distance	10 m
Distance mode	Vessel log
Main frequency for extraction	38/120 kHz

Table 4: Main morphological and backscattering energy characteristics used for schools detection

For all school candidates, several of variables were extracted, among them the NASC (s_A, m^2/nmi^2) together with the proportioned region to cell (ESDU, 1 nmi) NASC and the s_V mean and s_V max and geographic position and time. PRC_NASC values were summed for each ESDU and distances were referenced to a single starting point for each transect. Results for 38 and 120 kHz were compared. Besides, the frequency response for each valid school (i.e. those with length and s_V which allows them be properly measured) was calculated as the ratio $s_{A(fi)}/s_{A(38)}$, being f_i the $s_A$values for 18, 70, 120 and 200 kHz.

Echointegration estimates

Once backscattering energy was allocated to fish species, the spatial distribution for each species was analysed taking into account both the NASC values and the length frequency distributions (LFD) to provide homogeneous assessment polygons. These are calculated as follows: an empty track

determine the along-coast limit of the polygon, whilst three consecutive empty ESDU determine a gap or the across-coast limit. Within each polygon, the LDF is analysed.

LFD were obtained for all positive hauls for a particular species (either from the total catch or from a representative random sample of 100-200 fish). For the purpose of acoustic assessment, only those LFD which were based on a minimum of 30 individuals were considered. Differences in probability density functions (PDF) were tested using Kolmogorov-Smirnov test. PDF distributions without significant differences were joined, providing a homogeneous PDF strata. Spatial distribution was then analysed within each stratum and finally mean s_A value and surface (square nautical miles) were calculated using a GIS based system (Q-gis). These values, together with the length distributions, are used to calculate the fish abundance in number as described in Nakken and Dommasnes (1975) (see previous section for further details). Estimatesfor each species was carried out on each strata (polygon) using the arithmetic mean of the backscattering energy (NASC, s_A) attributed to each fish species and the surface expressed in square nautical miles using the following formula:

$$\rho_l = \frac{NASC_l}{\sigma_l}$$

$$N_l = \rho_l * A_p$$

where $\rho_l$is the areal density of fish (numbers per square nautical mile in length group l and the total number for length group l (N_l) within each strata is calculated the product ρ_l of times the total area of the strata (A_p)

Numbers were converted into biomass using the length weight relationships derived from the fish measured on board.

RESULTS

Weather conditions were, in general, bad. Although swell was not high, wind reached up to 70 knots, changing from south to west and the turning east to be again west. In most of the cases, wind was agains the vessel cup, thus decreasing speed, and increasing the turbulence, hence, more bubbles sweptdown scenarios. Bad weather condition also limited the number of fishing station.

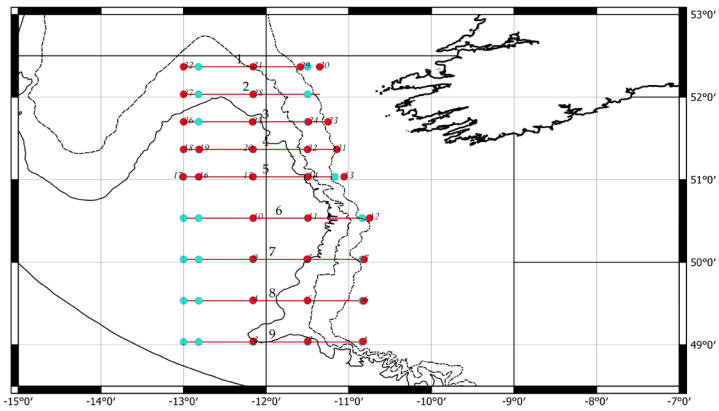

Figure 3: Tracks and CTD stations in Porcupine sea bight. Note that only those stations encircled in red were performed. Also, tracks 6 to 9 were only surveyed until the third CTD (numbers 3, 4, 9 and 10)

Fishing stations and NASC allocation

Only 4 fishing stations were performed, as shown in figure 4. The first was done using the gloria HOD 352, and focussing only on mueller's pearlside. Once identified those echotraces, only direct allocation was done. In the same way, due to the lack of time, the clear blue whiting pelagic layers were only sampled northwards.

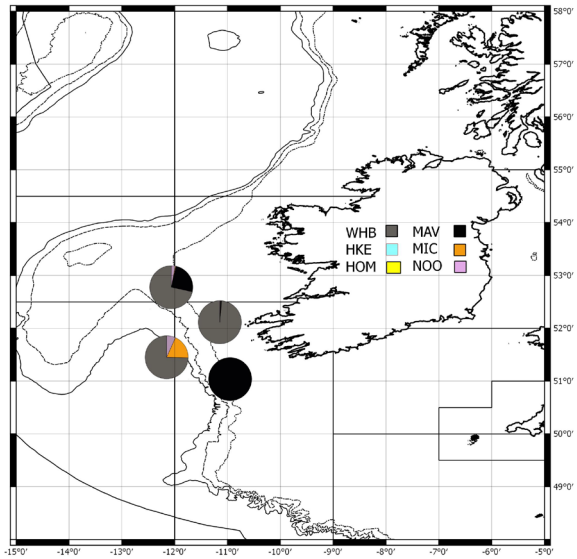

Figure 4: Fishing stations and catch composition (% in number of fish caught). WHB-blue whiting; HKE-hake; MAV-müller's pearlside; NOO- Notoscopelus kroyerii; MIC-mictophidae and other mesopelagic species.

Almost 1 mt of fish were caught corresponding to 24*10^3 fish (table 5). 98% of the catch in weight was blue whiting while in number müeller's pearlside (42%) together with blue whiting (55%) accounted for the 97% of the total catch in number.

	TOTAL CAP (Kg)	No ind.	No Fishing st	Sample weight (kg)	Measured fish	Mean length	%PRES	% Catch_W	% Catch_No
WHB	961	13313	3	41.6	527	25.21	75.00	98.46	54.73
MAV	5	10296	3	0.2	220	4.49	75.00	0.48	42.33
HKE	4	13	1	6.9	13	36.27	25.00	0.43	0.05
HOM	0.2	1	1	9.1	1	32.50	25.00	0.02	0.00
MIC	2	428	3	4	154	10.44	75.00	0.26	1.76
NOO	3	274	3	3	239	12.38	75.00	0.35	1.13
Total	**976**	**24325**	**4**	**65**	**1154**				

Table 5: Summary of catch composition

Although catches, it should be highlighted the amount of müller's pearlside observed all around de surveyed area. Once identified the echotraces, few fishing stations were performed on these schools, as long as they were easy to discriminate.

Mackerel egg distribution

A total of 191 samples were collected over the acoustic track. Only few mackerel eggs were collected in this area as shown in figure 5. Only 119 egg (0.62egg/station, 0.05 eggs per cubic meter on average) which is far from the records obtained in the Spanish area where 94315 eggs were collected (248 egg/station, 24 eggs per cubic meter on average)

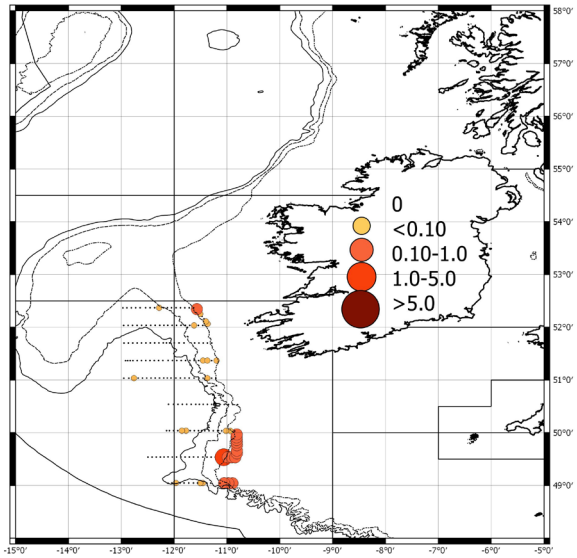

Figure 5: Mackerel egg abundance (number per cubic meter) from CUFES

Blue whiting assessment

<u>Adult distribution</u>

Bad weather conditions have limited the operative of the vessel and the southernmost tracks were partially covered. Figure 6 shows the spatial distribution accounting the allocated backscattering energy per ESDU. In spite of that, it seems outer limit of the blue whiting distribution was reached; only the three northernmost tracks showed a continuity in the blue whiting distribution between the Irish continental shelf, Porcupine Seabight and the Porcupine bank.

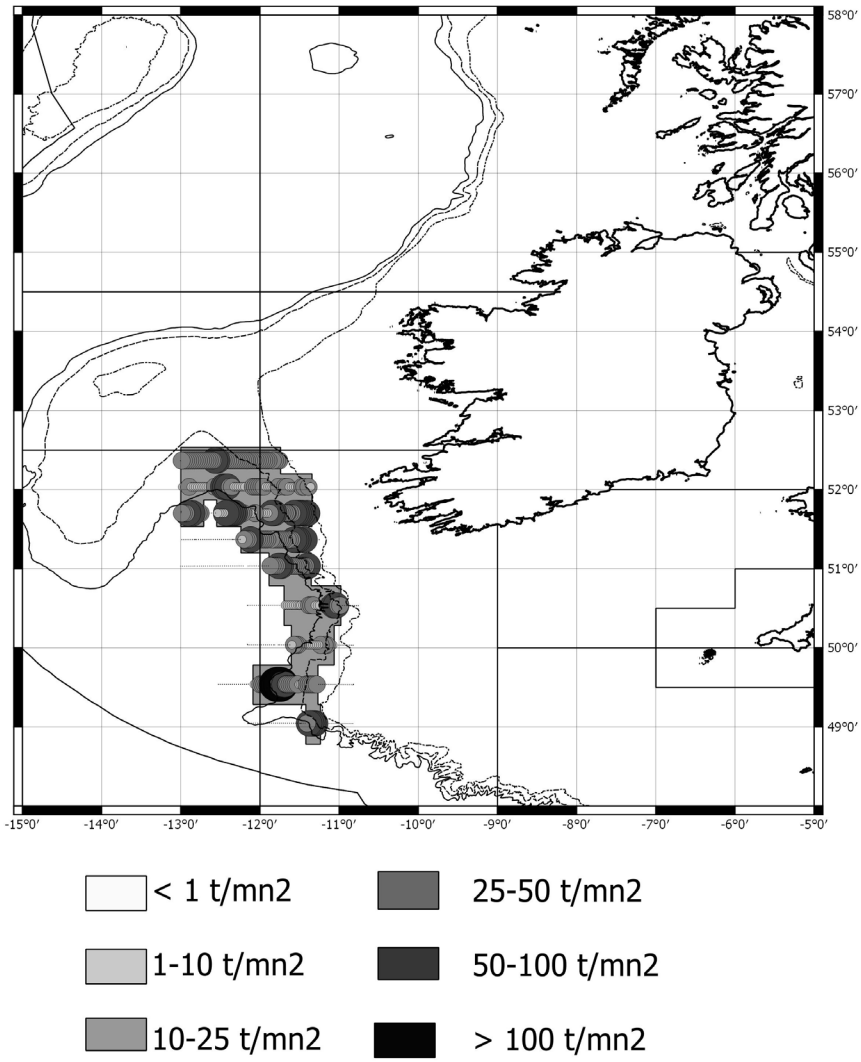

Figure 6: Blue whiting spatial distribution

Abundance estimates

100 thousand tonnes, corresponding to 1136 millions fish were assessed for the whole surveyed area.

Zone	Area	No	Mean	Area	Fishing st.	No (million f ish)	Biomass (tonnes)	Density (Tn/nmi-2)
7j-k	Porcupine SB	327	231.17	7039.21	P02-P03-P04	1136	100331	14
	Total	***327***	**231**	***7039***		***1136***	***100331***	**14**

Table 6: Blue whiting assessment

Mean length was estimated to be 25.2 cm, over a three modal length distribution (figure 7), being the main located at 25 cm and the others in 29 and 19 cm respectively. Interesting, no significant differences were observed between this distribution and that obtained in Spanish waters (figure 8).

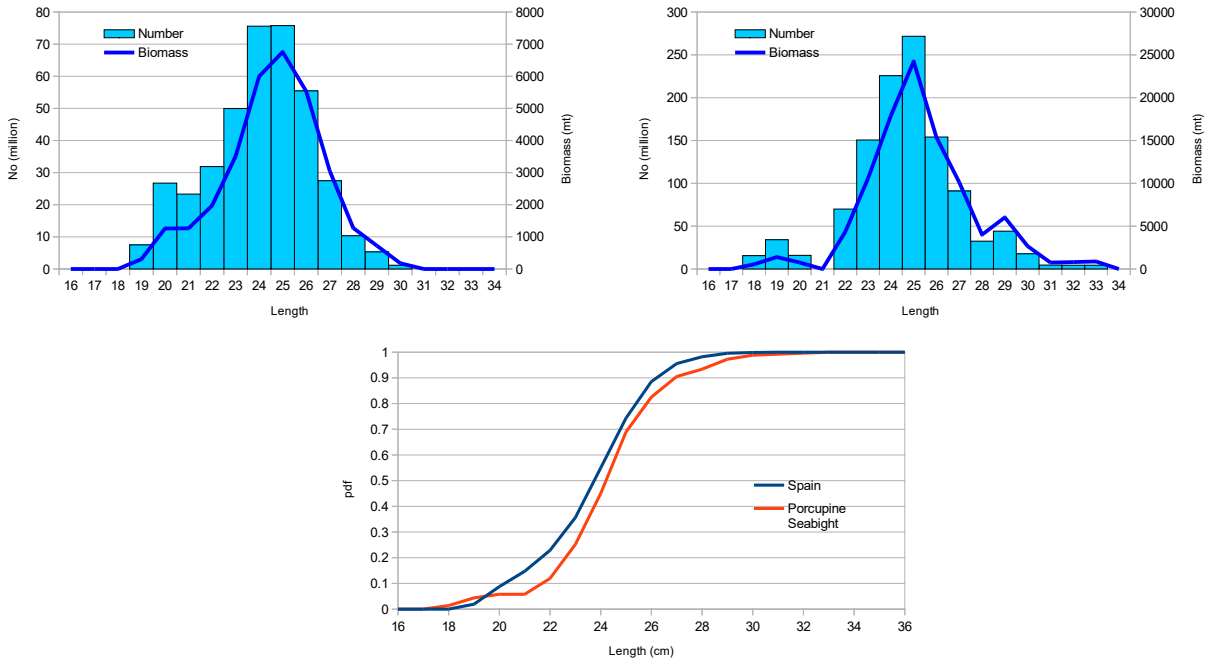

Figure 7: Above: blue whiting abundance and biomass estimates by length group in Spanish waters (8c-9a, left) and in Porcupine Seabight (7jk). Below: cumulated length distribution of abundance estimated Spanish waters (blue line) and Porcupine Seabight (red line)

Müeller's pearlside

As previously stated, this year a considerable amount of müeller's pearlside schools have been detected all along the surveyed area. Few trawl hauls were performed on these echotraces in order to correctly identify it and to estimate the length structure.

Adult distribution

Müeller's pearlside spatial distribution was wider than that observed for blue whiting and it is located at different depth strata. While the former are mainly located at 150 m depth during daytime (at night they rise up to 50 m depth), the later are mainly at around 300-500 depth. At night the schools are less denser than in daytime and can almost reach the surface. The outer limits of the distribution area seem to not have been reached (figure 8).

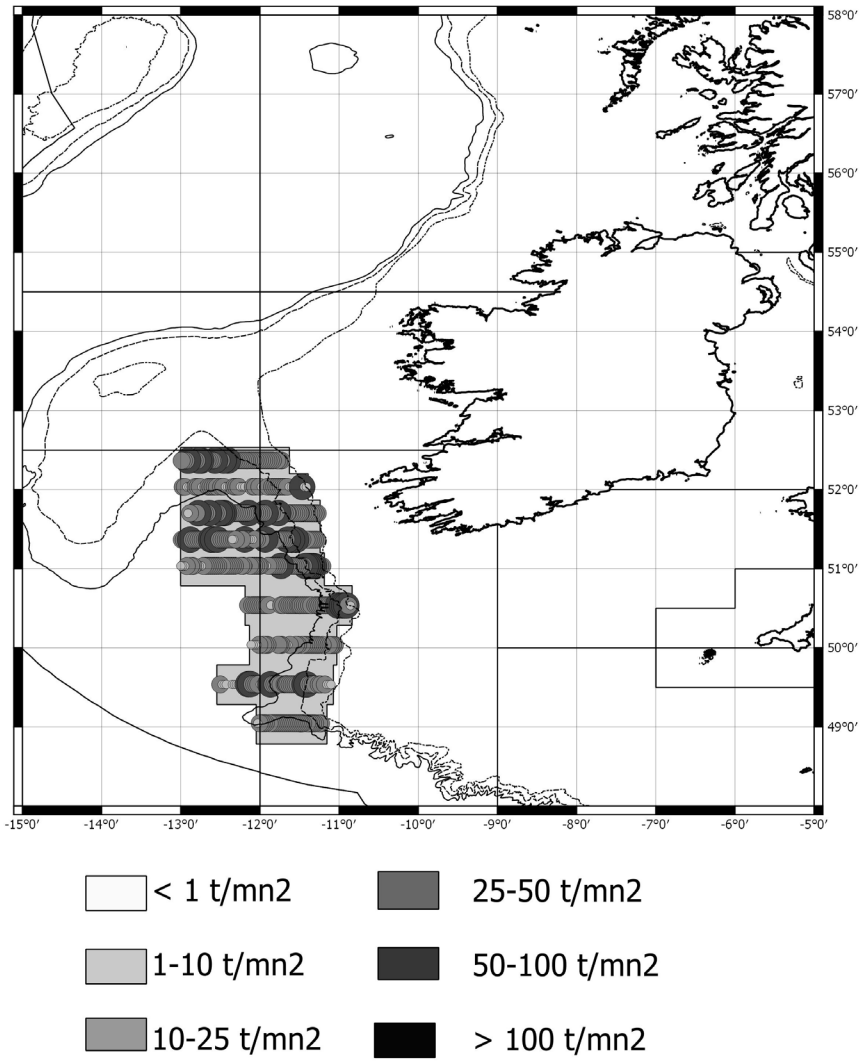

Figure 8: Müeller's pearlside spatial distribution

Biomass estimates

For this species a b_{20} of -71.4 was chosen. By applying it, a total of 112 thousand mt corresponding to 96 billion fish were estimated (table 7).

Zone	Area	No	Mean	Area	Fishing st.	No (million fish)	Biomass (tonnes)	Density (Tn/nmi-2)
7j-k	Porcupine	511	184.95	12162	P10-P13-P21-P27-P29	95771.23	112368.47	9
	Total	***511***	**185**	***12162***		***95771***	***112368***	**9**

Table 7: Müeller's pearlside summary assessment

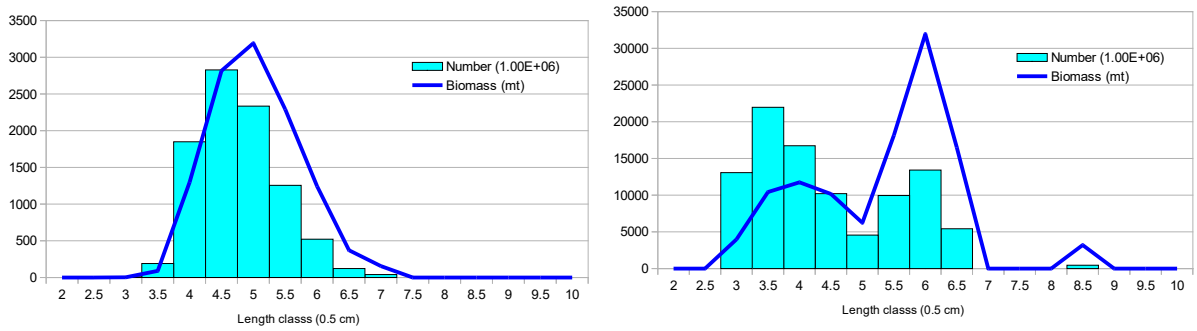

Figure 9: Müeller's pearlside abundance and biomass estimates by length group in Spanish waters (8c-9a, left) and in Porcupine Seabight (7jk).

In Porcupine Seabight, the length distribution was quite different to that observed in Spanish waters, being almost complementary, as shown in figure 9.

ACKNOWLEDGEMENTS

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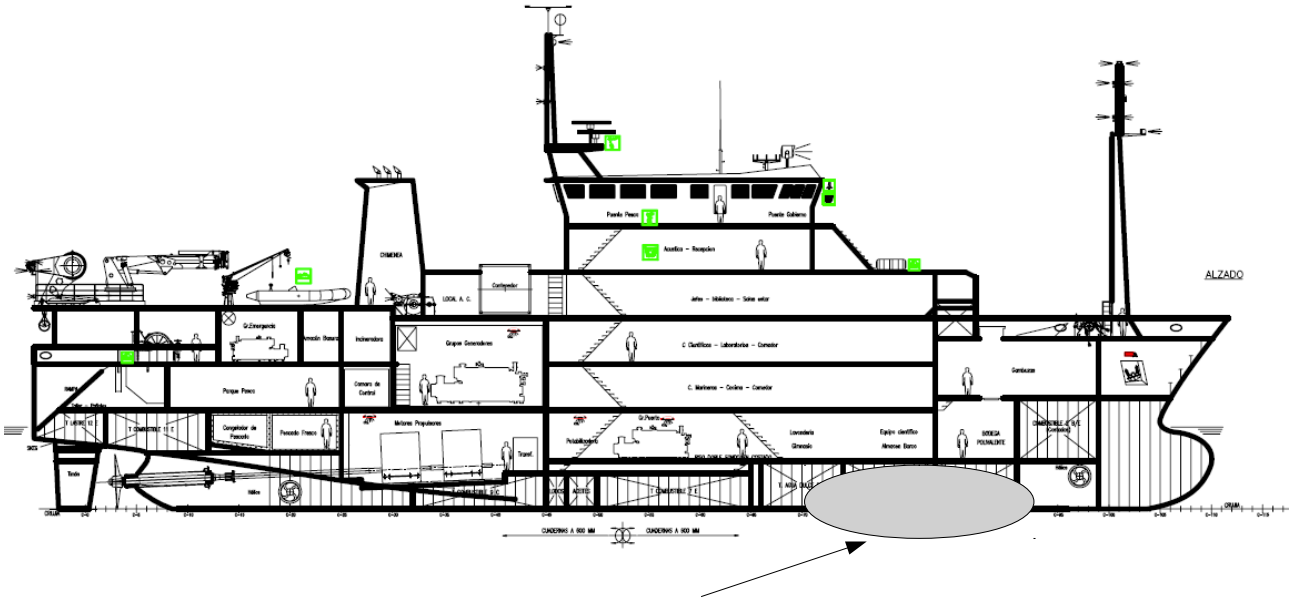
ANNEX 1

An application of the Honkalehto et al (2011) bubble swept-down filter in PELACUS

As observed in other research vessels, hull-mounted transducer on a gondola, although useful in calm water, often have problems in bad weather conditions (high winds and/or swell). This is because the turbulence along the hull surface produces a layer of bubble which interferes with sound propagation. This may led to an underestimation of the fish biomass and, in some cases, to the total lost of the acoustic signal.

PELACUS is an acoustic-trawl survey aiming at the estimation of the biomass and distribution of the main pelagic fish species in NW Spanish water in spring time. It's conducted on board R/V Miguel Oliver, built in 2007 with all transducers in a gondola

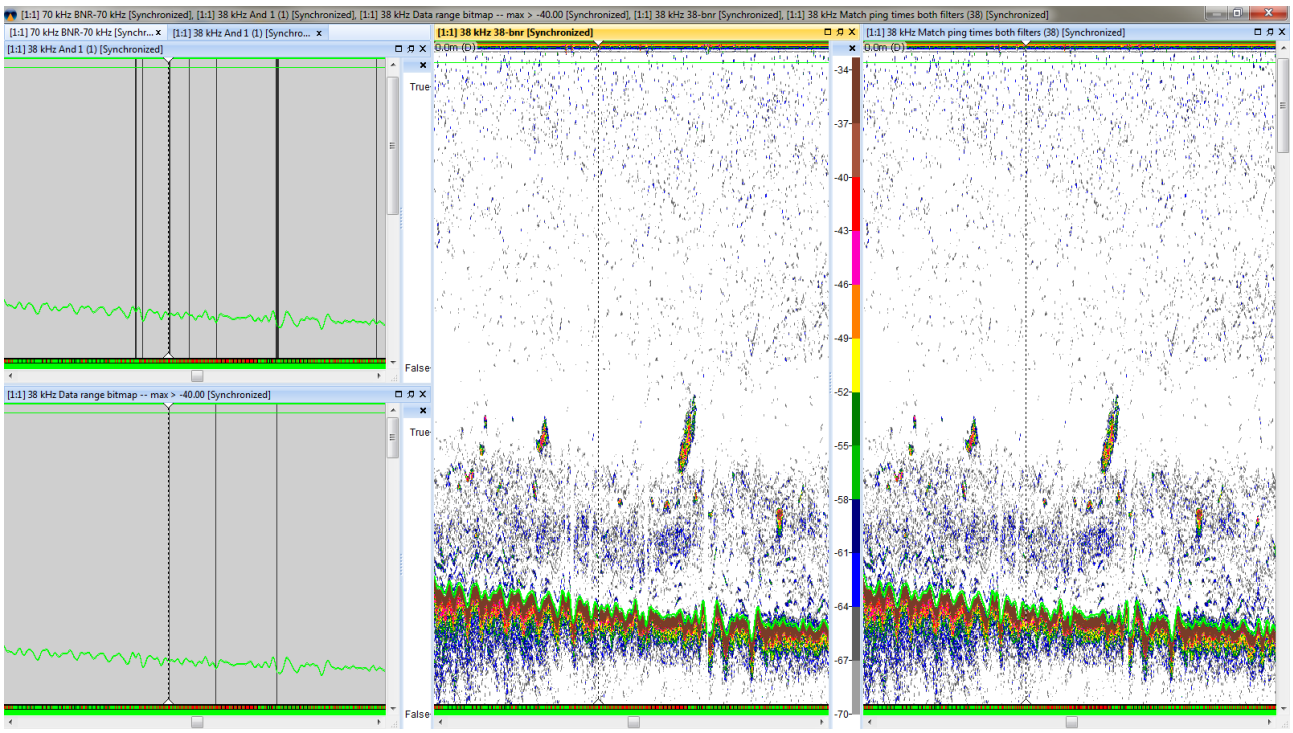


R/V Miguel Oliver, with the location of the gondola

The performance of the vessel is good, but in rough seas, bubbles are an important issue. If time is available, this weather conditions use to be avoided, by resting at harbour, thus decreasing the risk of bubbles but also the different fish behaviour due to the turbulence. However in case of continuous bad weather conditions, acoustic data has to be recorded. In such conditions, acoustic data are pre-processed by applying a filter which reduces the pings with significant bubble swept-down effect.

The filter consists on a double check. On account both the bottom return and the transmit pulse. For bottom, because of the slope, the analysis has been done on a layer of 30 m width, counted from the true bottom depth (either calculated manually or automatically) to down. Within this layer, any ping with a maximum value in S_V lower than 40/30 dB is removed. In the case of the transmit pulse, after an analysis, a double filter for lower and higher values is applied removing those pings outside de boundaries of 16.77 and 18.40 dB.

Next figure is showing the application of both filters to a particular region.



Swept-down bubble filter. Left, boolean (true/false matching rule according to criteria); middle the original echogram (with previous noise filtering) and the resulting echogram once applied the filter.

Unión Europea
Fondo Europeo Marítimo y de Pesca (FEMP)

Funded by the EU through the European Maritime and Fisheries Fund (EMFF) within the National Program of collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy.

Document 15: Ecosystem Index Overview Table

	IBWSS					IESNS					HERAS						IESSNS			Western Baltic	CSHAS	WESPAS	Irish Sea	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 observa-tions 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		6	2				4	4	2		3/5	4	5	2		4	4	4	2	4
Physical/chemical oceanography																								
Continuous underway measurements	✓	✓	✓	✓		✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Station measurements	✓	✓	✓	✓		✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Water movement						✓					✓													
Nutrients						✓					✓											(✓)		✓
Biological oceanography																								
Microbiological sampling																						(✓)		
Phytoplankton sampling						✓			✓					✓	✓									✓
Zooplankton samples	✓	✓	✓			✓	✓		✓					✓	✓		✓	✓				✓		✓
Multifrequency echosounder data for zooplankton identification & abundance estimation (number of high frequencies >=38 kHz)	4		1	1		5					2	3	1		2/3	1	4			1	3	3	1	3
	IBWSS					IESNS					HERAS						IESSNS			Western Baltic	CSHAS	WESPAS	Irish Sea	Peltic
Participating countries																								

Charismatic megafauna																							
Visual observations			✓	(✓)		✓					(✓)	✓				(✓)	✓				✓	✓	✓	✓
Towed hydrophones																						✓	✓	
Seabird observations																								
Species counts			✓									✓									✓	✓		✓
Abundance survey (ESAS)			✓									✓									✓	✓		✓
Habitat description																								
Camera observations			✓									✓					✓	(✓)			✓	✓		
Sidescan sonar						✓																		
Bathymetric multibeam echo-sounder			✓			✓						✓									✓	✓		
Physical ground samples																								
Pollution																								
Litter			✓	✓		✓			✓			✓		✓	✓	✓				✓	✓	✓		✓
Pollution in water column																								
Pollution in sediments																								
Pollution in organisms																								

Environmental conditions																								
Weather condition/sea state	✓	✓	✓	✓		✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓

Document 16: WGIPS Survey Planning 2019

Please see the report on the next page.

Annex 3: WGIPS Survey Plans 2019

IBWSS

Four vessels representing the Faroe Islands, the Netherlands (EU), Ireland (EU) and Norway are scheduled to participate in the 2019 blue whiting spawning stock survey. In addition, also this year Spain will participate with 3 days of survey time, at the start time of the core survey, investigating the area east and south of the standard survey area. This coverage is regarded as exploratory and will not be included in the estimates for assessment purposes.

Survey timing and design were discussed during the 2018 IBWSS post-cruise and 2019 WGIPS meetings. The group decided that in 2019, the survey design should follow the principle of the one used during the last survey. 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 A16.1.)

The design is based on variable transect spacing, ranging from 30 nm in areas containing less dense aggregation (areas 1 and 5), to 20 nm in the core survey area (area 2, 3 and 4) (Figure A16.1.). The western borders of the transects in area 3 are set to 12°W in order to cover potential blue whiting aggregations extending further from the continental slope into the Rockall Trough. Transects are drawn systematically with a random start location.

The aim is to have three vessels surveying on their transects in area 3 at the same time. That way, the core survey area 3 can be covered synoptically by several vessels with similar temporal progression.

The Dutch vessels will start the survey in the southern areas. 5-6 days before the Irish and Norwegian vessel will join and all three will progress northwards. The Faroese vessel will primarily survey area 4 (Faroese/Shetland) and join the other vessels in the north of area 3 once they are present there towards the end of the survey period. 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) on 25 - 26. March 2019. Nonetheless, if some vessels are found to lag behind others, the 20 n.m. transect spacing will allow for adaptation of the survey design without great loss of coverage. For instance, this may mean either skipping or extending some of the horizontal transects to catch up or keep pace with the other vessels. Biological sampling should be carried out following methods normally applied to sampling acoustic registrations.

If registrations of blue whiting marks are continuing at the end of any planned transects, the length of these transects should be extended until no more marks are registered for a distance of 5 n.m. (or 30 minutes at normal survey speed). The transect at the outer western boarder can be cut off, if no registration of blue whiting for 5 n.m.

Detailed cruise lines for each ship are uploaded on the WGIPS sharepoint (/2019 Meeting docs/Working documents/IBWSS 2019 Post Cruise).

As the survey is planned with inter-vessel cooperation in mind it is vitally important that participants stick to the planned transect positioning.

Participants are also required to use the logbook system for recording course changes, CTD stations and fishing operations. The survey will be carried out according to survey procedures described in the ICES WGIPS Manual for Acoustic Surveys.

Table A16.1. Individual vessel dates for the active surveying period in the 2019 International Blue Whiting Spawning stock Survey (IBWSS).

SHIP	NATION	ACTIVE SURVEYING TIME (DAYS)	DEFINITIVE SURVEYING DATES
Celtic Explorer	Ireland (EU)	15	27.3.2019 – 12.4.2019
Kings Bay	Norway	14	25.3.2019 – 7.4.2019
Tridens	Netherlands (EU)	14	19.3.2019 – 1.4.2019
Magnus Heinason	Faroes	10	30.3.2019 –9.4.2019
Miguel Oliver	Spain	3	19.3.2019-22.3.2019

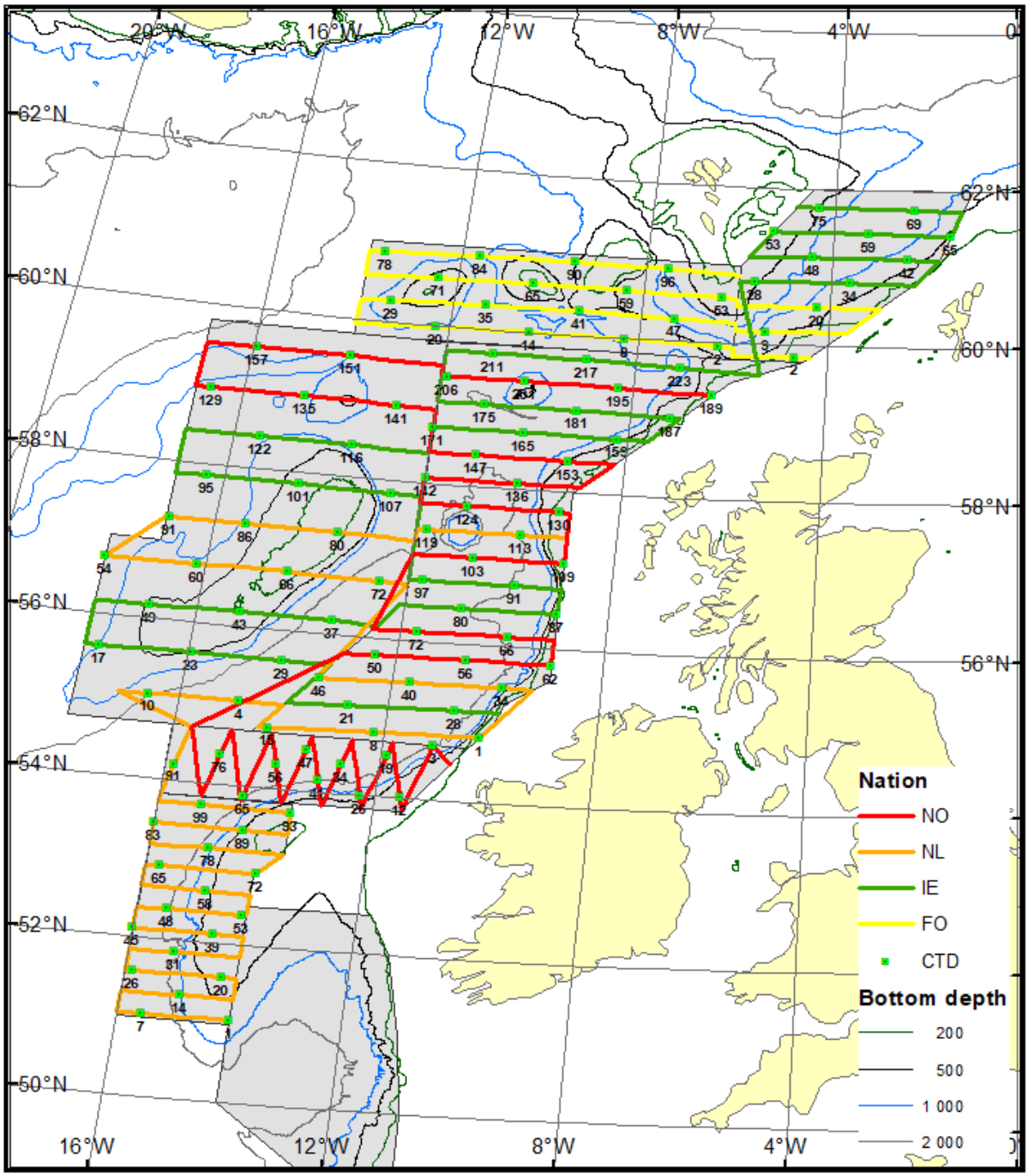


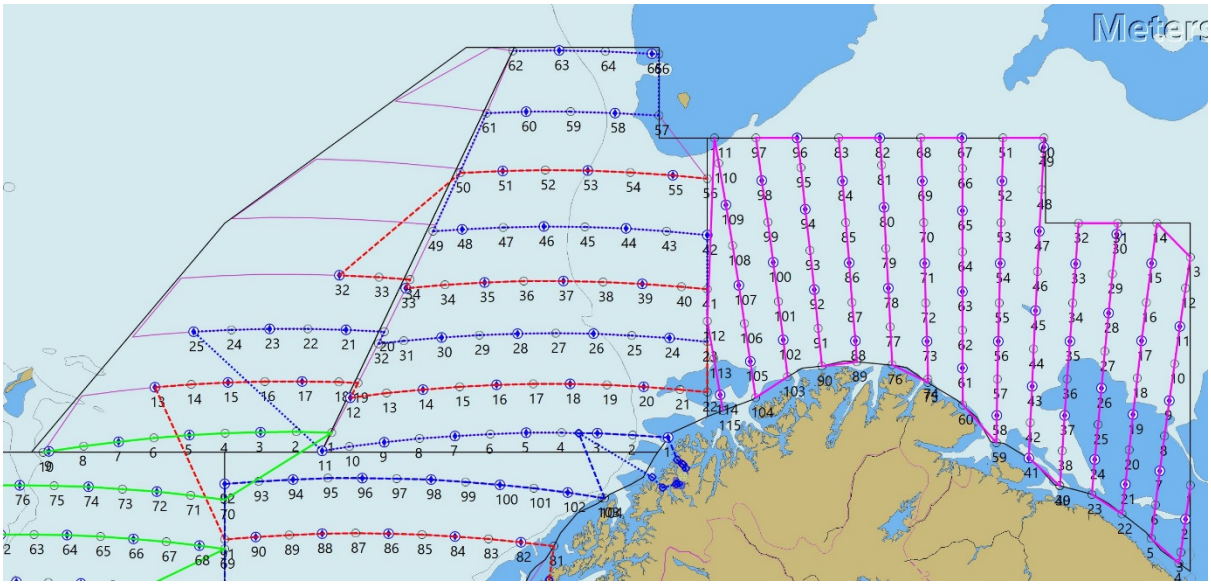
Figure A16.1. Planned survey tracks for the combined 2019 International Blue Whiting Spawning stock Survey (IBWSS).

IESNS

Denmark (EU-coordinator), Faroe Islands, Iceland, Russia and Norway will participate in the IESNS survey in April-June 2019. Ships and preliminary dates are given in Table A16.2. Survey days exclude time for: hydrographic cross sections, coverage outside the IESNS area and crew change. As in the four previous years, the plan is to use a stratified systematic transect design with random starting points. The suggested transects in each stratum are shown in Figure A16.2. The new survey planning function in Rstox was used to generate the transects. Norway will cower two rows of transects across the Norwegian Sea (between Iceland and Norway) in order to collect plankton data from this "cross-basin section". Norway will be the survey coordinator during the cruise. A post-cruise meeting is suggested to be held 18-20 June 2019 in Reykjavik, Iceland.

Table A16.2. Individual vessel dates for the active surveying period in the 2019 IESNS (preliminary).

Ship	Nation	Dates (harbour to harbour)	Effective survey days	Crew change
Dana	**Denmark (EU)**	**2 May – 31 May**	**21**	**15-16 May, Bodø**
Magnus Heinason	**Faroe Islands**	**2 May – 13 May**	**11**	
ÁrniFriðriksson	**Iceland**	**3 May – 22 May**	**19**	
G.O. Sars	**Norway**	**29 Apr – 4 June**	**30**	**15 May, Bodø and 22-23 May, Tromsø**
Fridtjof Nansen	**Russia**	**11 May – 3 June**	**22**	



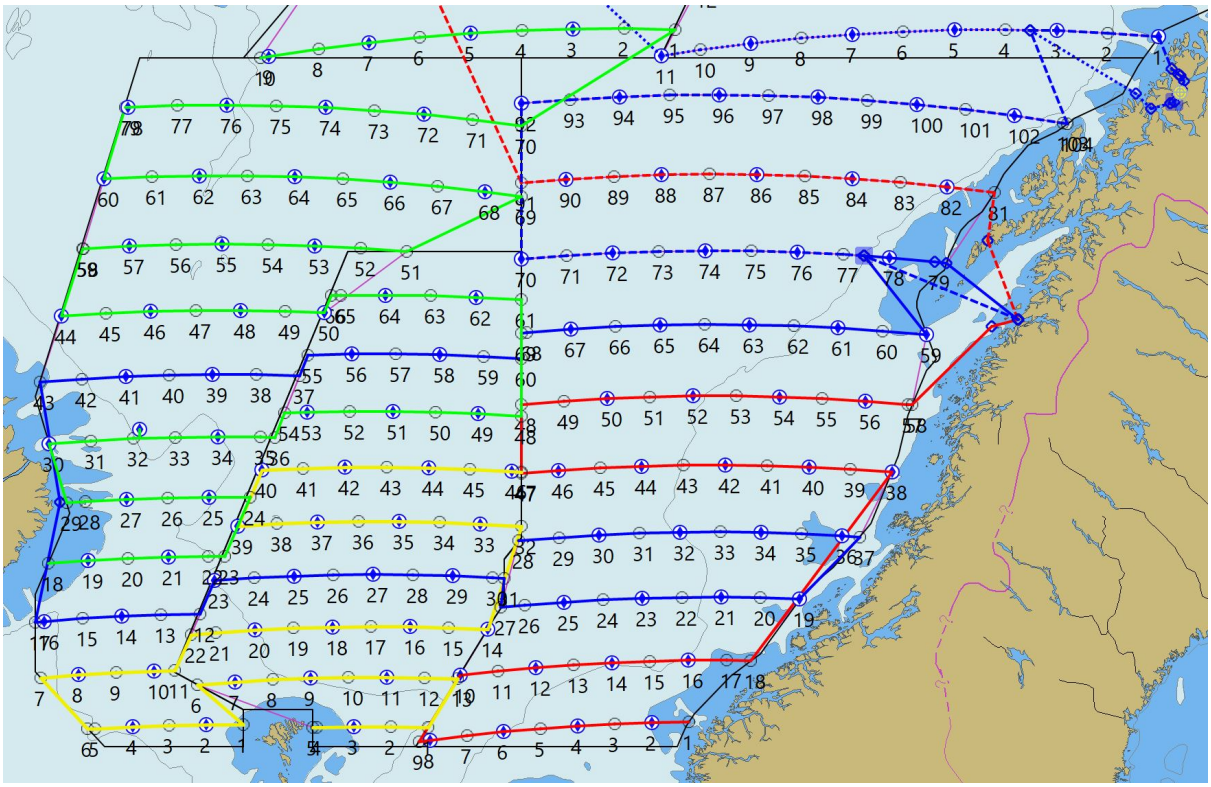


Figure A16.2. Suggested transects for the IESNS survey in 2019. Colors represent the different vessels/nations (yellow: FO, green: IS, dark blue: NO, red: EU, purple: RU). Suggested CTD stations are shown as blue circles with a diamond inside (the numbered positions are transect points for each 30 nautical mile).

IESSNS

The major aim is abundance estimation with precision estimates of Northeast Atlantic (NEA) mackerel. Secondary aim is abundance estimation of Atlantic blue whiting and Norwegian spring-spawning herring, thereby establishing new fishery independent indices on abundance to be used in the assessment of these stocks. An important objective is also to understand the Norwegian Sea ecosystem and especially the distribution, migration, feeding and spatial overlap of important pelagic planktivorous species (mackerel, herring and blue whiting) in relation to hydrography, plankton and top predators. There are also concrete plans to cover the North Sea during the IESSNS 2019 by a Danish vessel in July 2019. The final preparation is not yet available. There is also an intention to perform a survey west of the British Isles with a Scottish vessel during IESSNS 2019.

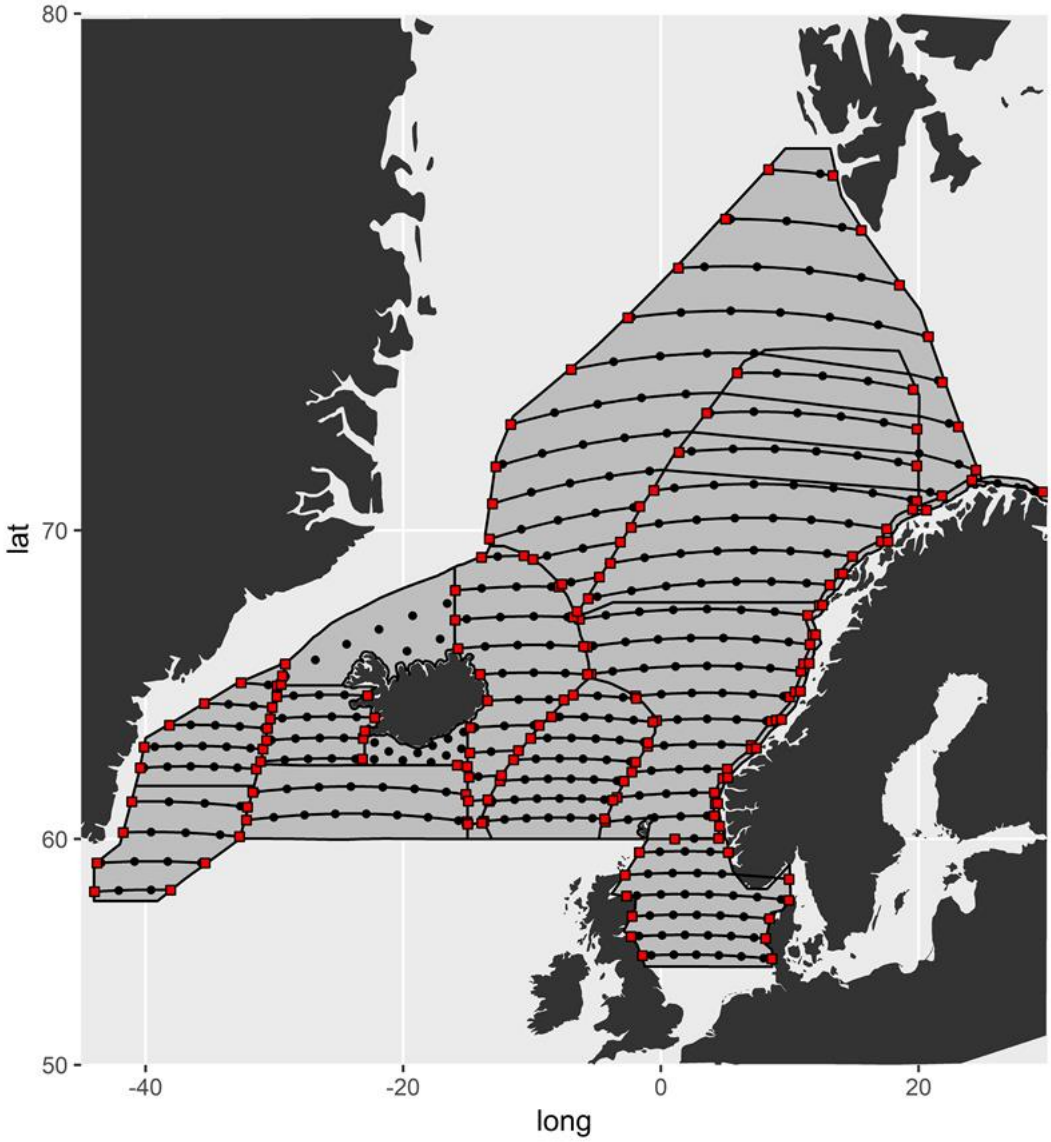


Figure A16.3a. Preliminary surface stations (black circles) and transects (black lines) including Norway with 2 vessels, Faroe Islands, Iceland, Greenland) for IESSNS in July-August 2019.

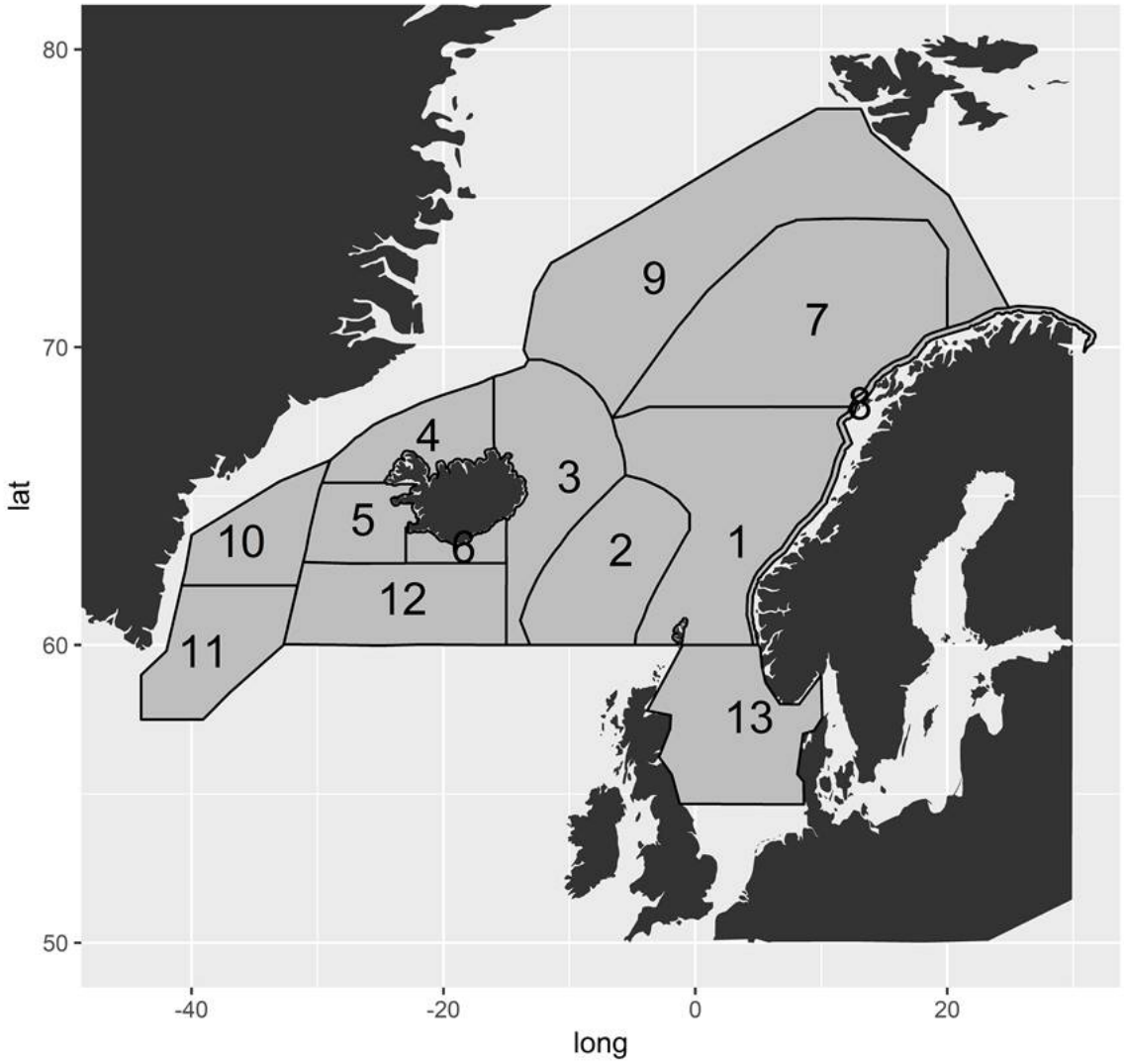


Figure A16.3b. Predefined number and area of each strata for IESSNS 2019.

HERAS

Norway, Denmark, Germany, Netherlands, Scotland and Ireland will participate in the 2019 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 northwestern boundary. The strata for 2019 are displayed in Figure A7.4 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 is used in instances where parallel lines are not practical due to operational reasons, such as bays and inlets, and are stratified accordingly (Strata 2).

The survey effort, i.e. transect spacing, will be maintained at similar level to 2019. 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 final design of strata and allocation of transects will be confirmed over the coming months in discussion with participants. 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 as well as photographs of herring and otoliths, and to carry out analysis of otolith shape and body morphometry 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. Denmark does this based on otolith shape analysis and provides stock discrimination on the individual fish level, whereas Norway uses a vertebral count method that provides information only at the strata level. A workshop to standardise the method to one that will provide stock information at the individual fish level was held in Galway in November 2017 (WKSIDAC). This is work in progress, as there is a need for more samples to agree on adequate methods. Additional sampling on the 2019 survey should be continued for this work, and there might be requests for both collection of otoliths for shape analysis and genetic samples from the survey.

Analysis and reporting

A post-cruise meeting will be held in Hirtshals, Denmark late November 2019. The post-cruise meeting will allow the group to evaluate survey data, discuss issues arising from the surveys and produce the combined survey estimate. Data uploaded to the ICES acoustic database for the 2016-2018 survey is not complete in all cases. This should be rectified in time for the 2019 post cruise meeting. Survey data for the 2019 survey is to be uploaded to the ICES Acoustic database in the agreed format no later than **31 October 2019.**

Table A16.3. Time periods, areas and rectangles to be covered in the 2019 acoustic survey.

Vessel	Available days for survey	Period available	Strata to cover
Celtic Explorer (IRE)	21	4 – 24 July	2, 3, 4, 5, 6
Scotia (SCO)	23	27 June – 19 July	1, 121, 111, 91 (North of 58°30′N)
Johan Hjort (NOR)	18	29 June – 16 July	11, 141
Dana (DEN)	15	25 June – 9 July	21, 31, 41, 42, 151, 152
Tridens (NED)	19	1 – 19 July*	81, 91 (North of 58°30′N), 101
Solea (GER)	21	28 June – 18 July	51, 61, 71, 131

* 24-29 June Calibration

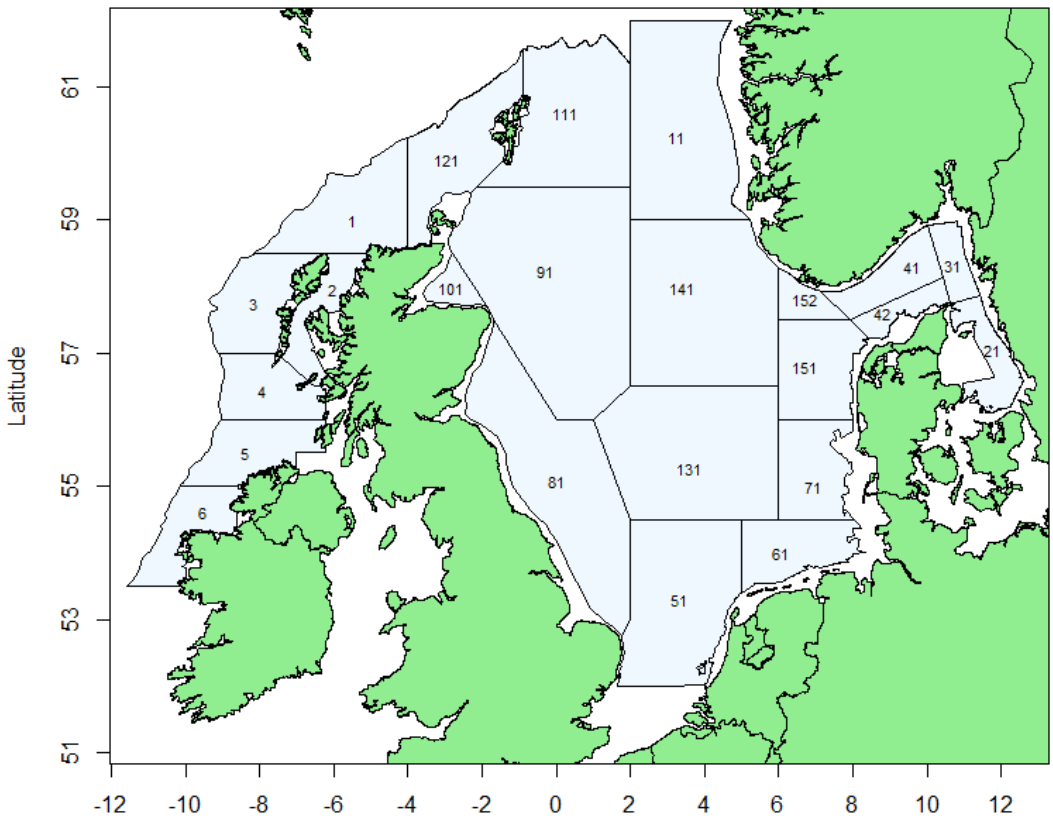


Figure A16.4. Strata for the HERAS 2019 survey.

WESPAS

The 2019 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 13th June and work progressively northwards over 42 days ending on the 24 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.

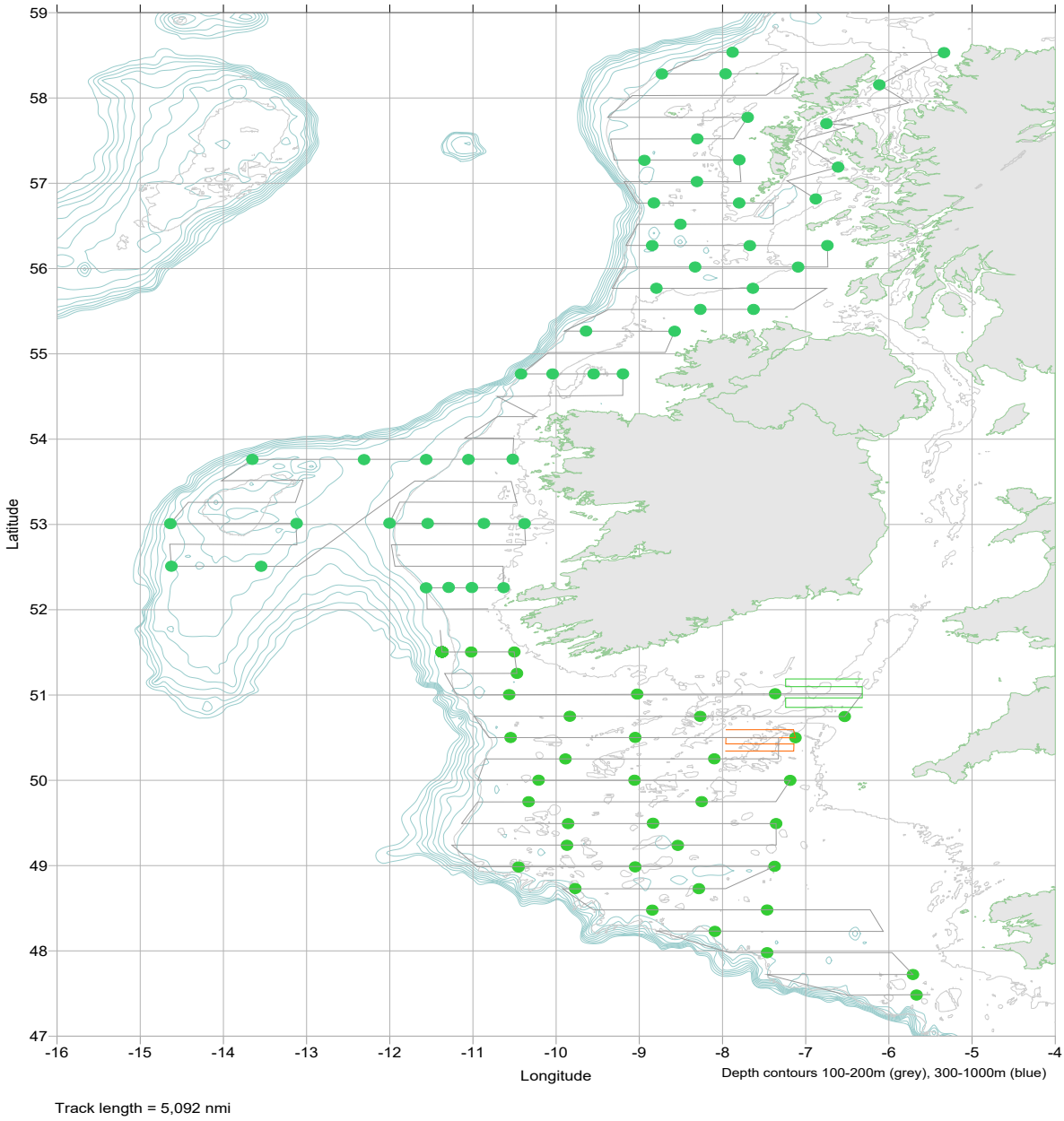


Figure A16.5. Proposed survey design and hydrographic station layout, WESPAS 2019.

CSHAS

The 2019 Celtic Sea acoustic survey will be carried out on board the RV *Celtic Explorer* from the 9th - 29th October (21 days). Survey design utilises a laddered broad scale survey and focused adaptive high resolution site surveys.

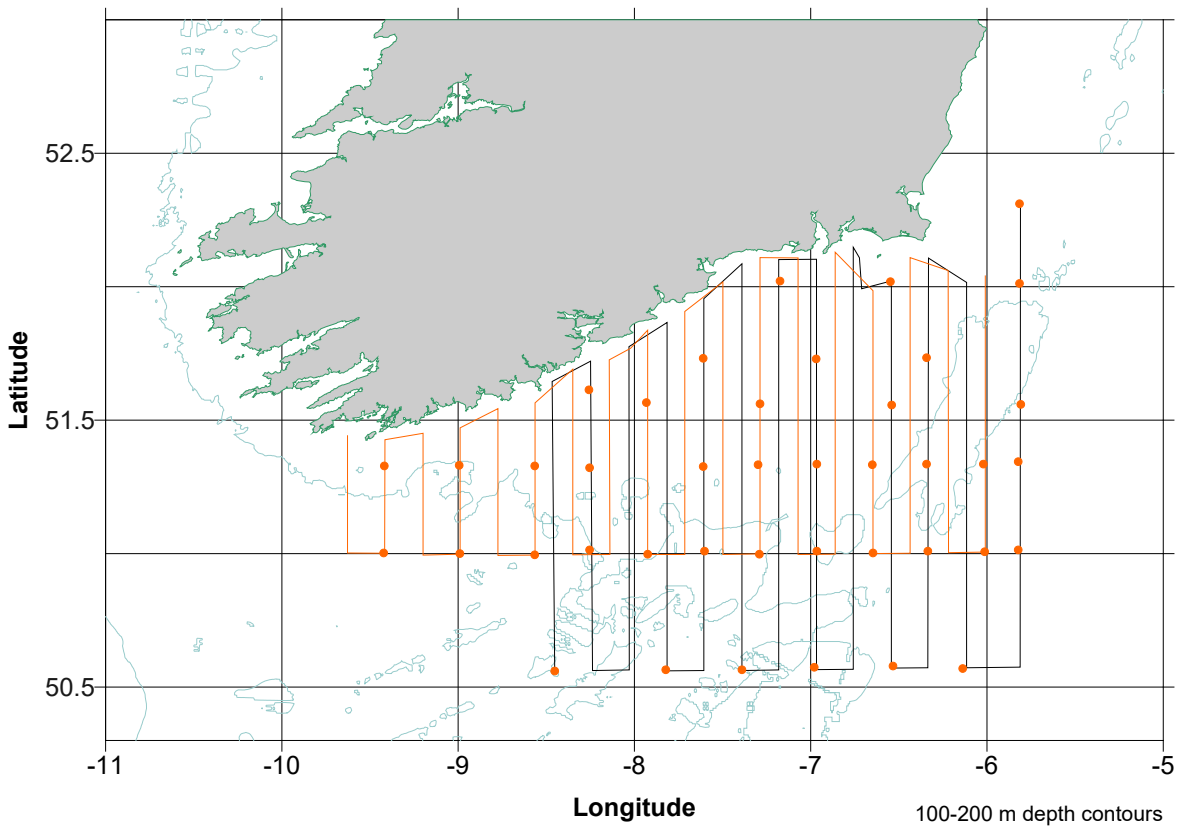


Figure A16.6. Proposed laddered survey design and hydrographic station layout, CSHAS 2019.

ISAS

The 2019 Irish Sea acoustic survey (ISAS) will be carried out onboard the RV *Corystes* between August 26th and September 14th. Figure A16.7 shows the plan and acoustic tracks for cruise C03519. The survey design of systematic, parallel transects covers approximately 620 nm and will be divided into two parts, transects around the periphery of the Irish Sea is randomized within +/- 4 nm of a baseline position each year with spacing set between 8-10 nm. Transect spacing is reduced to 2 nm in strata around the Isle of Man to improve precision of estimates of adult herring biomass.

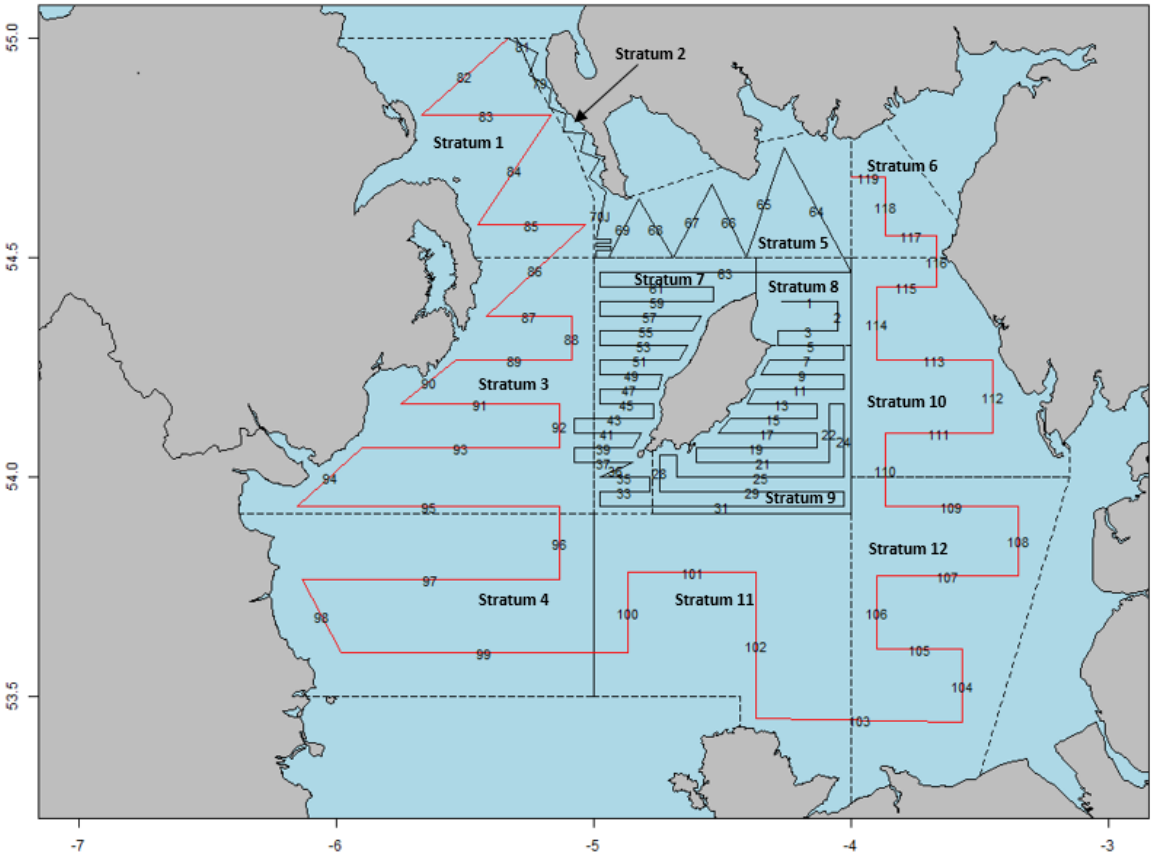


Figure A16.7. Map of Irish Sea and North Channel showing proposed coverage for the 2019 herring acoustic survey C03519.

GERAS

The GERAS acoustic survey 2019 will be carried out on board RV *Solea* from October 1 until October 21. The plan for cruise SB768 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.

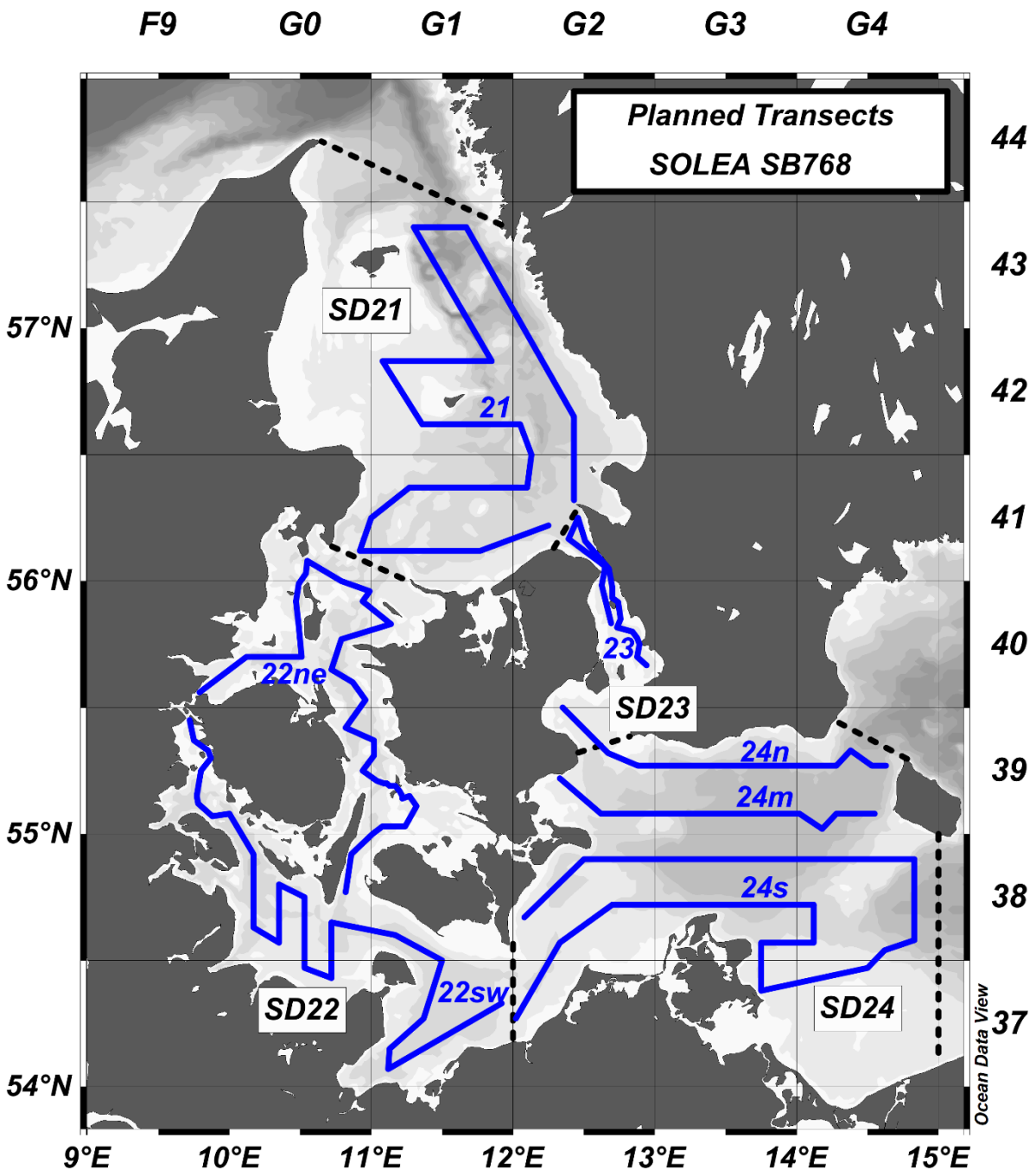


Figure A16.8. Map of the planned coverage in ICES Subdivisions (SD) 21-24 and acoustic transects (blue, transect ID indicated) for the German Acoustic Autumn Survey (GERAS) in 2019 (cruise SB768).

PELTIC

The 2019 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 26th September to the 30th October.

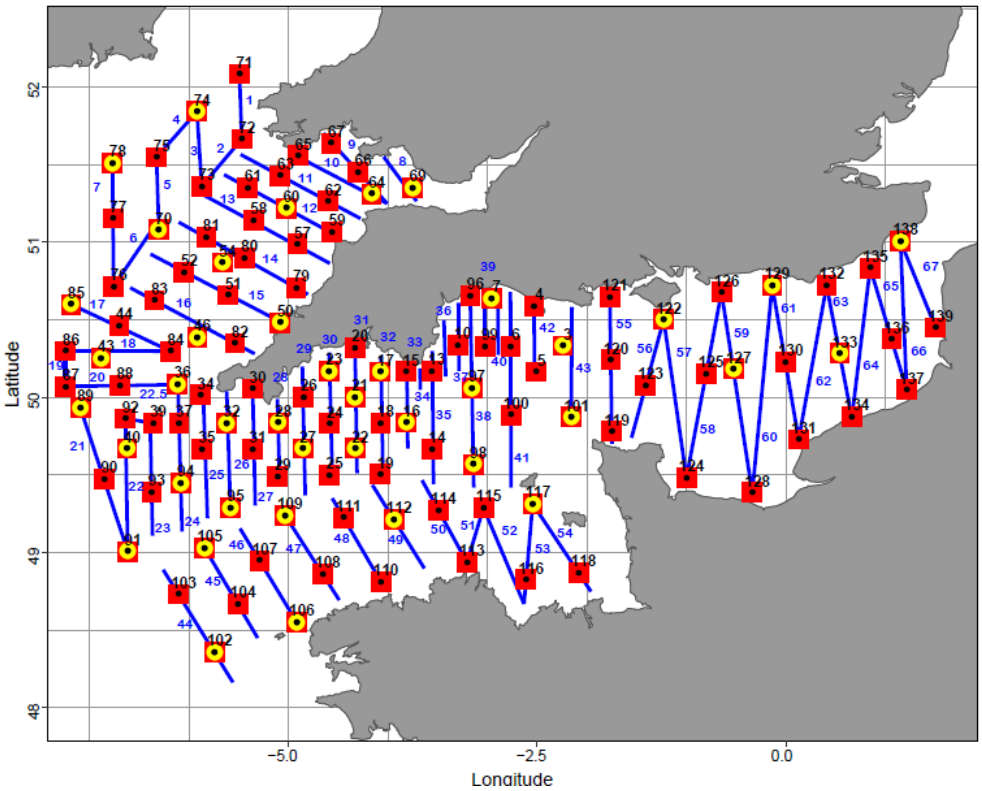


Figure A16.9 Overview of the planned survey area, with the acoustic transect (blue lines), plankton stations (red squares) and hydrographic stations (yellow circles)., PELTIC 2019.

Industry Survey in 6.a.N

In 2019, the August-September survey will cover the same ground at the same resolution as in 2018, utilising 20 days survey time (Figure A.16.10). This will be the fourth survey in a time series that is hoped will be developed into a long-term index of spawning/pre-spawning herring in 6aN, to be considered as an index for use in stock assessments in the future. The survey is part of a collaborative partnership between UK (Scotland), Netherlands and Ireland that aims to improve understanding of the individual stock components of herring in 6.a and 7.b, c. The work will continue the time-series of data on the spawning components of herring stocks in 6.a.N and 6.a.S and 7.b, c. Samples from spawning herring fish may also be used for morphometric studies, ageing, genetic analyses and otolith microstructure.

Plans are also underway to deploy 10 days of acoustic survey effort to undertake a detailed acoustic survey of the Minch at the same time that the MSHAS survey takes place. An important objective of this survey will be to try and sample 'possibly herring' marks in the area that are typically associated with outcropping of hard areas on the seabed.

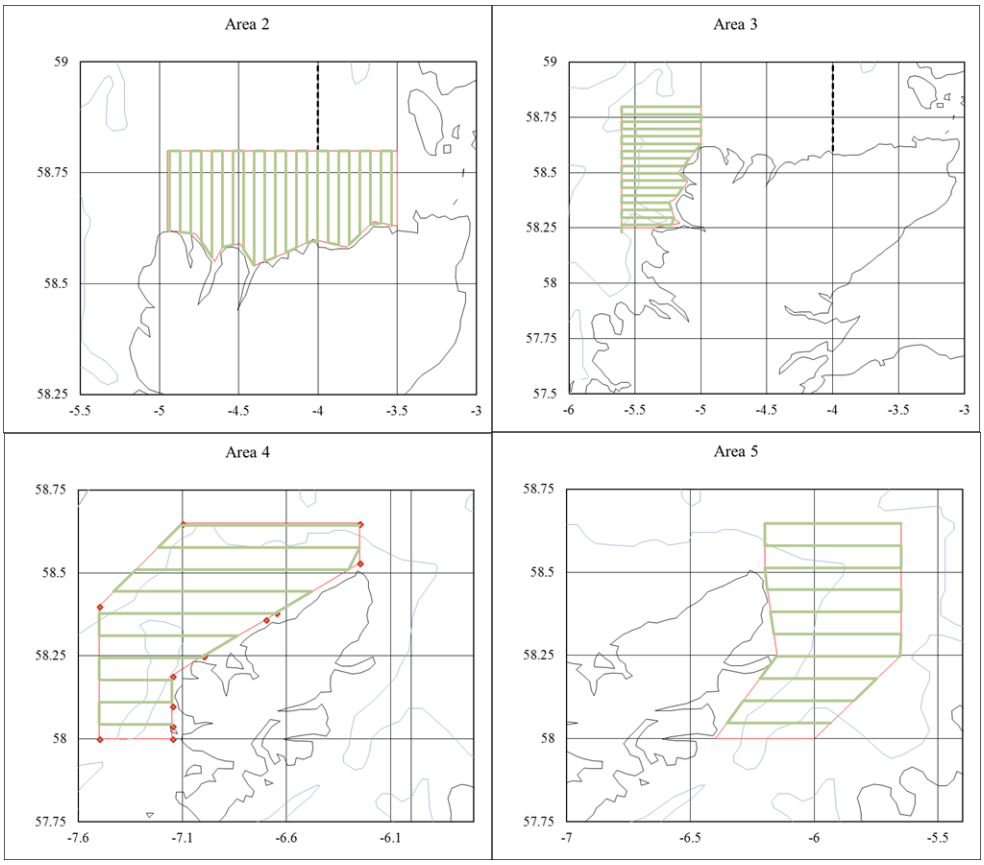


Figure A16.10. Planned acoustic survey areas used in the 6aNorth surveys in 2019. Area 2 -East of cape Wrath, Area 3 – The Minch, Area 4 – Outer Hebrides, Area 5 – east Minch.

Industry Survey in 6.a.S

An acoustic survey of herring *Clupea harengus* and horse mackerel *Trachurus trachurus* will be conducted in 6.a.S/7.b,c in Dec 2019. The survey in 2019 will therefore be the fourth in a time series that is hoped will be developed into a long-term index of spawning/pre-spawning herring and horse mackerel in 6.a.S/7b, c, for use in stock assessments in the future. The survey is part of a collaborative partnership between Ireland, The Netherlands and UK (Scotland) that aims to improve understanding of the individual stock components of herring in 6.a and 7.b, c. The work will continue the time-series of data on the spawning components of herring stocks in 6.a.N and 6.a.S and 7.b, c. Abundance and biomass indices for horse mackerel will also be generated as per WGIPS protocols. Samples from spawning herring fish may also be used for morphometric studies, ageing, genetic analyses and otolith microstructure, if required outside of the fishery in 6.a.S.

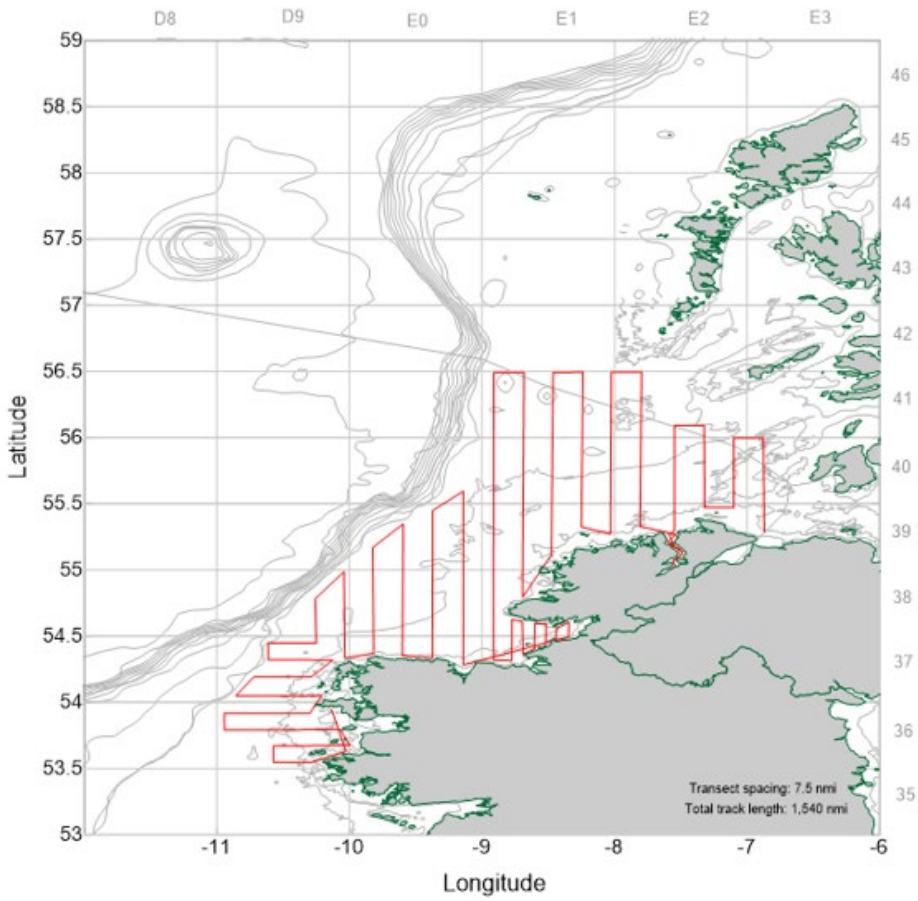


Figure A16.11. Acoustic survey area for 6aS and 7b, c. The example transect lengths shown is 1,540 nmi (start 55˚17N and 6˚52W, progress west). This survey distance is short of the 1,730 nmi allocated, therefore allowing for some intense surveys in areas where fish are observed and also in areas of known to contain herring from the fleet (e.g. Bananas, Lough Swilly, Glen Head/Rathlin O'Beirne, Bruckless Bay, Inver Bay, etc.).

PELACUS

PELACUS-IBWSS started in 2018 covering the Porcupine Sea bight. The survey is performed by the Spanish Institute of Oceanography (IEO) on board R/V Miguel Oliver. Although promising results (100 kt of blue whiting, with mean length located at 25 cm), concerns about the blue whiting stock identity are still present as pointed out by Pointin and Payne (2014). In order to get insights on this question, in 2019 IEO will perform a survey in which together with the coverage of the Porcupine Sea bight area, another two regions, located in north and central slope of the French area, will be also surveyed. This survey, together with the normal PELACUS carried out off the Spanish coast will provide increased coverage of the area to the south of the main spawning area.

The survey is expected to start on 15th March, arriving at the Porcupine Sea bight on 18th earlier in the morning, and covering this area until 25th March.

References

Pointin F, Payne MR (2014). A Resolution to the Blue Whiting (*Micromesistius poutassou*) Population Paradox? PLoS ONE 9(9): e106237. https://doi.org/10.1371/journal.pone.0106237