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Ecosystem Observation Steering Group

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Report of the Working Group on International Pelagic Surveys (WGIPS)

15–19 January 2018

Den Helder, the Netherlands

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

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Executive summary

The Working Group of International Pelagic Surveys (WGIPS) met in Den Helder, Netherlands on 15–19 January 2018, under the chairmanship of Matthias Schaber, Germany, and Bram Couperus, Netherlands. This was the third and last meeting within a 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 Northeast Atlantic, Norwegian Sea, North Sea, and Western Baltic; and to coordinate timing, coverage and methodologies for the upcoming 2018 surveys.

Additionally, progress, developments and experiences with the survey analysis software StoX as well as with the ICES acoustic database repository were analysed and discussed among users and developers during the meeting and the intention to further consolidate both the software and the database as common tools to be utilised 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.

Results from the WGIPS surveys in 2017 as well as coordination plans for the 2018 individual and multinational pelagic acoustic surveys in Northeast Atlantic waters (Multinational surveys: IBWSS, IESNS, IESSNS, HERAS, and individual surveys: CSHAS, WESPAS, ISAS, PELTIC, GERAS, Industry Acoustic 6a/7b Survey) are given in Annexes 5, 6, and 7 of this final report.

1 Administrative details

Working Group name

Working Group of International Pelagic Surveys (WGIPS)

Year of Appointment within the current three-year cycle

Third

Reporting year concluding the current three-year cycle

Third

Chair(s)

Matthias Schaber, Germany

Bram Couperus, Netherlands

Meeting venue(s) and dates

18–22 January 2016, Dublin, Ireland, (16)

16–20 January 2017, Reykjavik, Iceland, (17)

15–19 January2018, Den Helder, Netherlands, (19)

2 Terms of Reference

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

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

c) Adopt standardized analysis methodology and data storage formats utilizing the ICES pelagic 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.

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

g) Develop alternative analysis methods (e.g. using geostatistics) to monitor the pelagic ecosystem by extracting metrics from the collected survey data other than those required for single-species stock assessments.

h) Assess auxiliary pelagic ecosystem surveying technology (e.g. optical technology, multibeam and wideband acoustics) to: (i) achieve monitoring of different ecosystem components, and/or (ii) derive ecosystem indicators from surveys covered by WGIPS.

i) Develop and refine methods to derive stock or spawning component-specific survey indices for herring based on biological criteria (e.g. otolith shape analysis or morphometric measurements).

3 Summary of Work plan

Year 1

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

Workshop to evaluate and develop joint methods from current participant-specific acoustic abundance estimation methods used in the HERAS surveys (WKEVAL).

Workshop to standardize scrutinisation procedures for pelagic ecosystem surveys covered by the WG (WKSCRUT).

Session to familiarise WG members with the use of the new standardized acoustic survey analysis tool (StoX) and data storage format from the ICES pelagic database repository.

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 review and provide possible updates for the WGIPS acoustic survey manual.

Session to: (i) explore alternative analysis methods (e.g. geostatistics); and (ii) assess and document auxiliary pelagic ecosystem surveying methodology (e.g. optical technology, multibeam and wideband acoustics), in order to monitor components of the wider ecosystem and derive ecosystem indicators from surveys covered by WGIPS.

Session to review and adapt stock and spawning component splitting methods applicable to herring in the North Sea, and areas IIIa and VIa; and plan methods used on surveys in Year 2 accordingly.

Contributing to Session C "Ecosystem Monitoring in Practice" at the 2015 ICES ASC through active involvement of WG members as session convener and presenters.

Contributing a paper analysing the HERAS survey time-series to the ICES Symposium on "Marine Ecosystem Acoustics (SOMEACOUSTICS).

Submission of a manuscript on blue whiting distribution from the WGIPS survey time-series to a peer reviewed Journal.

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.

Session to exchange experiences and analyse progress with the use of the new standardized acoustic survey analysis tool (StoX) and data storage format from the ICES pelagic database repository.

Session to compare and evaluate scrutinisation of Year 2 survey databased on the standardized procedures developed in WKSCRUT.

Session to review and provide possible updates for the WGIPS acoustic survey manual.

Session to review and adapt stock and spawning component splitting methods applicable to herring in the North Sea, and areas 3a and 6a; and plan methods used on surveys in Year 3 accordingly.

Session to draft a manuscript on an example of alternative analysis methods (e.g. geostatistics) used with WGIPS survey data.

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

Session to draft a list of potential ecosystem indicators to be measured during WGIPS surveys.

Year 3

General meeting, preceded by 3 post-cruise meetings which collate data of multinational surveys. Session to review and evaluate survey designs across all WGIPS coordinated surveys done in Year 3.

Session to analyse progress with the use of the new standardized acoustic survey analysis tool (StoX) and data storage format from the ICES pelagic database repository.

Session to review and provide possible updates for the WGIPS acoustic survey manual.

Session to review and adapt stock and spawning component splitting methods applicable to herring in the North Sea, and areas 3a and 6a used on surveys in Years 1–3.

Session to evaluate progress to draft a manuscript on an example of alternative analysis methods (e.g. geostatistics) used with WGIPS survey data.

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

Session to evaluate progress in listing potential ecosystem indicators to be measured during WGIPS surveys.

4 Summary of Achievements of the WG during 3-year term

The following outcomes and achievements were obtained during this delivery period and the 3-year term:

- Indices for the stocks of herring, sprat, mackerel, boarfish, and blue whiting in Northeast Atlantic waters from annual ecosystem surveys as fishery-independent data for analytical assessment purposes in HAWG (Herring Assessment Working Group)and WGWIDE (Working Group on Widely Distributed Stocks):

  - 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 proportion, 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 6aN-S, 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 3a 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 7a), autumn spawning herring, numbers, biomass, distribution, maturity proportion, mean weight, and length-at-age.
  - 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).
- Review of herring larvae surveys conducted prior to or ongoing during the meeting (International Herring Larvae Surveys, IHLS) (no longer reported to the group from 2018 on. Will in future be reported to WKSINS).
- Review and advise on 6a, 7bc industry acoustic survey for autumn spawning herring

- Other ecosystem survey-derived operational products:
    - 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 (ESAS) during Irish CSHAS, IBWSS and WESPAS surveys

- Other outcomes and achievements:
    - WKEVAL (Workshop on evaluating current national acoustic abundance estimation methods for HERAS surveys), 24-28 August 2015
    - WKSCRUT (Workshop on scrutinisation procedures for pelagic ecosystem surveys), 7-11 September 2015
    - Contribution to ICES ASC Session
    - 2016-2018 survey plans (see Annex 7 for 2018 survey plans).
    - Overview of currently applied auxiliary pelagic ecosystem sampling technology/Ecosystem index overview table (see Annex 8).
    - Input to the development of the ICES acoustic database repository.
    - 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 in the HERAS survey.
    - Recalculation of IESSNS mackerel abundance with StoX.
    - StoX comparison Working Document
    - 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)
    - Further version of 'SISP 9 Manual for International Pelagic Surveys (IPS)'.

Published manuscript on blue whiting distribution (http://www.sciencedirect.com/science/article/pii/S0165783616301497).

5 Final report on ToRs, workplan and Science Implementation Plan

5.1 Progress and Fulfilments by ToR

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

IBWSS

In 2015, a total of 6,891 nmi (nautical miles) of survey transects were completed and the total area of all the subareas covered was 123,840 nmi^2. This represented a reduction of 16% in total surveyed transects and 1% in surveyed areas compared to last year. Coverage was considered sufficient and still takes into account expected distributions on the Rockall and Porcupine Banks.

The estimated total abundance of blue whiting for the 2015 international survey was 1.38 million tonnes, representing an abundance of 16.6x10^9 individuals (Figure 6, Tables 3 and 4). Spawning stock was estimated at 1.1 million tonnes and 11.2x10^9 individuals. In comparison to the 2014 survey estimate, this represents a decrease of -58% in the observed stock biomass and a related decrease in stock numbers of 47%.

The 12th International Blue Whiting Spawning stock Survey 2015 shows a marked decrease in total stock biomass of 58% with a corresponding reduction in abundance by 47% when compared to the 2014 estimate.

In 2016, 6,257 nmi (nautical miles) in total of survey transects were completed areas across six strata relating to an overall geographical coverage of 134,429 nmi^2. This represented a reduction of 16% in total survey mileage (acoustic sampling effort) but an increase of 9% in surveyed area compared to last year. Containment in western extremes of the survey was considered sufficient. Weather conditions were good for the main body of the survey with approximately 24 hrs of downtime recorded. Towards the end of the survey, when only one vessel was surveying (M. Heinason) a further two days were lost.

The 13th International Blue Whiting Spawning stock Survey 2016 shows an increase in total stock biomass of 108% with a corresponding increase in abundance of 109% when compared to the 2015 estimate. However, the 2015 estimate was considered as an under representation of the stock in the time-series due to the missing dominant age classes and reduced biomass observed.

In 2017, a total 6,105 nmi (nautical miles) of survey transects were completed areas across six strata relating to an overall geographical coverage of 135,085 nmi^2. This represented a slight reduction of 3% in total survey mileage (acoustic sampling effort) a even slighter increase of 0.4 % in surveyed area compared to last year. Containment in western extremes of the survey was considered sufficient.

Overall weather conditions were mixed with periods of poor and good weather. All vessels, with the exception of Kings Bay experienced some downtime due to conditions with the Faroes experiencing the most prolonged period of bad weather at the end of the survey period.

From the survey in 2016 StoX was used instead of the former BEAM software for calculating the stock indices of blue whiting. The stock index was recalculated using StoX back to 2004 and the point estimates showed good agreement with the previously used method (WGIPS, 2016 - Annex 8). The blue whiting time-series from this survey has been and is the most important fisheries independent input to the assessment of this stock.

Details of the 2017 survey and findings are reported in Annex 5a.

IESNS

The survey has been considered to contain the distribution area of NSS herring, although in 2016 the most northwesterly transects were not surveyed due to time constraints induced by rudder problems on one of the vessels. NSS herring has mainly been concentrated in the southwestern part of the survey area since 2005, although in 2016 and 2017 aggregations of mainly the 2013 year class have been observed in the northwestern part and in 2017 the largest biomass on record of 1-year old herring was observed in the Barents Sea.

Since 2015 the Norwegian vessel has surveyed two cross-basin transects in order to sample environmental data, currently not sampled by the other vessels. This has also enabled comparison on e.g. acoustics and biological sampling among vessels in the same region, which is considered as a strength in quality checking data.

In 2016 StoX was used for the first time for calculating the stock indices of NSS herring and blue whiting. The stock index of NSS herring was recalculated using StoX back to 2008 and the point estimates showed good agreement with the previously used method (WGIPS, 2016 - Annex 8).

Details of the 2017 survey and findings are reported in Annex 5b.

HERAS

The HERAS survey is carried out annually and provides abundance indices by age for North Sea autumn spawning herring (NSAS), western Baltic spring spawning herring (WBSS), Malin Shelf herring (MSH), sprat in the North Sea, and sprat in Skagerrak-Kattegat.

Up to 2015, the survey was designed to be analysed using rectangle based estimation with ICES rectangles as the analysis unit. Tracks were planned to ensure a minimum of one length of track in each ICES rectangle covered. StoX was used for the first time for the 2015 survey, although the survey was designed for rectangle based estimation. In 2016 and 2017 the survey design was changed to be in accordance with the StoX method for estimation.

The introduction of StoX required delivering disaggregated biological and acoustic data instead of aggregated data, thus introducing a common ground for discussing survey practice and analysis practice as the indices were estimated from raw data at the post-cruise meeting. The use of StoX has continued, but the strata covered by Denmark has been analysed using the Danish national calculation method used up to 2014 (WKEVAL: ICES 2015) and combined with StoX calculated estimates for the relevant stocks.

The survey has all three years covered the entire survey area (North Sea, Skagerrak-Kattegat and Malin Shelf), but there have been discussions whether the survey covers the stocks properly in the northern part (NSAS) as other surveys claim to see this stock north of 62°N, and if there might be herring from the west of Scotland stock in the North Sea within the survey area. For sprat, there is no indication that the limit of the sprat stock distribution is reached at the southern limit (52°N) of the survey area.

Several herring stocks might occur in the survey area. Currently, there is a procedure for splitting into NSAS and WBSS used in the strata covered by Denmark and Norway. The splitting method used for the two countries differ. In November 2017, there was a workshop (WKSIDAC 2017) where one of the aims were to establish a common method for splitting. This is work in progress, and more material and data are needed to reach this goal.

Details of the 2017 survey and findings are reported in Annex 5c.

IESSNS

The survey strata south of Iceland has now been changed from a dynamic stratum to smaller permanent strata, but with lower sampling intensity between 60 and 62°N than on the Icelandic shelf edge where sampling intensity is higher. Greenland has been participating in the survey since 2016 with a chartered vessel conducting the survey simultaneously with the other vessels, which has led to improved temporal progression.

In 2017 StoX was accepted for calculating the stock index of Northeast Atlantic mackerel. This procedure was accepted at the benchmark assessment in 2017.

Details of the 2017 survey and findings are reported in Annex 5d.

GERAS

The German Autumn Acoustic Survey (GERAS) is coordinated by ICES WGIPS and the ICES Baltic International Fish Survey Working Group (WGBIFS). During the current reporting cycle, the survey provided the Herring Assessment Working Group (HAWG) and the Baltic Fisheries Assessment Working Group (WGBFAS) with index values for stock sizes of herring and sprat in the Western Baltic area (ICES Subdivisions 21-24). In 2017, a significant decrease in stock biomass and abundance was estimated from survey results, among others driven by the absence of the usual dense aggregations of old pre-spawning Western Baltic Spring Spawning herring in the Sound (SD 23).

Details of the 2017 survey and findings are reported in Annex 6a.

ISAS

The Agri-Food and Biosciences Institute (AFBI), continues to provide age stratified data for herring to the HAWG by conducting acoustic surveys of the northern Irish Sea (ICES Area 7aN) throughout the term of the current reporting cycle (2015-2017). A survey design of systematic, parallel transects covers approximately 620 nmi, widely-spaced (8-10 nmi) transects are surveyed around the periphery of the Irish Sea with transect spacing reduced to 2 nmi in strata around the Isle of Man to improve precision of estimates of adult herring biomass. Transect positioning is randomized within +/- 4 nmi of a baseline position each year.

Details of the 2017 survey and findings are reported in Annex 6b.

CSHAS

The Celtic Sea herring acoustic survey continues to provide age stratified data for herring to the HAWG. Changes in the behaviour of the stock prompted a review of the survey design in 2016. The survey now delivers replicate surveys of the core broad-scale area accompanied by high intensity focused adaptive surveys on high abundance areas.

Details of the 2017 survey and findings are reported in Annex 6c.

WESPAS

In 2016 the boarfish survey was carried out onboard the RV *Celtic Explorer* for the first time and run in conjunction the Malin Shelf herring survey forming the WESPAS survey (Western European Shelf Pelagic Acoustic Survey). The WESPAS survey is carried out annually and provides age stratified data for herring, horse mackerel and boarfish. These data are submitted annually to HAWG and WGWIDE.

Moving to a dedicated research platform has allowed this survey to develop into a large-scale multidisciplinary survey far greater than its original remit (See Annex 8).

In 2016 the survey adopted StoX as the primary biomass computational tool after evaluation with existing national method was within acceptable tolerances (<1%). All acoustic and biological data are uploaded and stored within the ICES database. The future plan is to develop this survey further to provide a second index for Celtic Sea herring to compliment the CSHAS time-series.

Details of the 2017 survey and findings are reported in Annex 6d.

PELTIC

The 5th Pelagic ecosystem survey in western Channel and eastern Celtic Sea (PELTIC), expanded its coverage northwards in the Celtic Sea and southwards to include French waters of the English Channel. More than 2000 nautical miles of survey transects were completed. Sprat biomass from Lyme Bay, English Channel will feed into HAWG to underpin its assessment. A sixfold increase in sprat biomass in Lyme Bay from the 2016 low, was recorded (34,109 t). Age disaggregated sardine biomass extends the existing time-series (to five years) and will be presented in combination with other biological parameters collected during the survey, to WGHANSA. This represents the only fisheries independent data on sardine in ICES area 7, which, since 2017, has been considered as a separated stock from sardine from ICES area 8. In 2017, EchoR was used to process the acoustic data and provide abundance estimates. Distribution and abundance of other pelagic fish species (anchovy, horse mackerel and mackerel) as well information on top predators, lower trophic levels and physical oceanography were collected.

Details of the 2017 survey and findings are reported in Annex 6e.

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

IBWSS

Faroese scientists have coordinated the IBWSS survey the last three years. In 2016 and 2017 4 vessels participated in the survey, leading to coarser sampling intensity as compared to the previous years, when 5 vessels participated, but reallocation of survey effort has ensured coverage of the distribution area of blue whiting. The survey will be planned using 4 vessels covering the area since it is no indications that a fifth vessel will participate in the nearest future. The responsibility of coordinating the survey is given to Norway from 2018.

IESNS

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

IESSNS

Norwegian scientists have coordinated the IESSNS survey in 2015 and 2016, whereas Icelandic scientists coordinated the 2017 survey. In general timing and temporal progression have been improving in the later years and were good in 2016 and 2017. The core strata remained unchanged, whereas some of the peripheral strata have been changed – some strata have been divided in two, as well as some strata have been expanded.

HERAS

Scottish scientists have coordinated the HERAS survey in 2015-2017. In general, the timing and progression of vessels have been good, and methodology has been according to the survey standard. The survey design has changed from a rectangle based survey design used up to 2015, to a strata based design optimal for estimation by StoX in 2016-2017. The responsibility of coordinating the survey is taken over by Norway from 2018.

WESPAS

The 2018 WESPAS survey will be carried out during the same time slot as in 2017 running over 42 days beginning on the 9th June (break 29-2nd July) and finishing 24th July. The direction of survey operations (south to north) adopted in 2017 will be retained going forward to provide closer temporal and geographical alignment with surveys to the south (PELGAS) and north (Scottish HERAS).

CSHAS

The 2018 CSHAS will run over 21 days beginning on the 7th October. The survey will use the same survey design adopted in 2016 of a laddered approach for broadscale areas and high intensity mini surveys of high abundance areas. The summer feeding phase survey will be developed during WESPAS to provide an alternative measure of stock abundance. Industry driven surveys may be carried out to supplement seasonal observations.

ISAS

The 2018 Irish Sea acoustic survey (ISAS) will be carried out onboard the RV Corystes between August 27th and September 14th 2018. A survey design of systematic, parallel transects will cover approximately 620 nmi and be divided into two parts. Transects around the periphery of the Irish Sea are randomized within +/- 4 nmi of a baseline position each year with spacing set between 8-10 nmi. Transect spacing is reduced to 2 nmi in strata around the Isle of Man to improve precision of estimates of adult herring biomass.

PELTIC

The 2018 Pelagic ecosystem survey in western Channel and eastern Celtic Sea (PELTIC) is scheduled to commence on the 5th of October and will finish on the 8th of November 2018. The survey will use the same, expanded survey design adopted for the first time in 2017. It will cover the waters of the eastern Celtic Sea, from south Wales to the French coast of the western English Channel (ICES areas 7f, e and parts of g and h). Where possible PELTIC will be coordinated with CSHAS (to the north and west) and JUVENA (to the south), to achieve best possible widescale coverage.

GERAS

GERAS as a national survey represents a part of the ICES Baltic International Acoustic Survey (BIAS) that is coordinated through the ICES Baltic International Fish Survey Working Group (WGBIFS). As GERAS also covers the distribution area of Western Baltic Spring Spawning herring that is also contained in other WGIPS coordinated surveys, both the survey coordination and the presentation of results are conducted under the auspices of both WGIPS and WGBIFS. GERAS was coordinated by scientists from the Thünen Institutes of Baltic Sea Fisheries and of Sea Fisheries TI-OF and TI-SF) and followed a stratified systematic design. Survey timing and effort was comparable throughout the reporting period.

The 2018 survey designs and proposed/planned cruise schedules are provided in detail in Annex 7.

TOR c: Adopt standardized analysis methodology and data storage formats utilizing the ICES pelagic database repository for all acoustically derived abundance estimates of WGIPS coordinated surveys.

Over the term of the current reporting cycle (2015-2017) the group has progressed and completed a critical review of survey design and methods initiated in 2015. Survey design and analysis methods for both national and internationally coordinated surveys were evaluated and updated as required to adhere to international best practice. This process was carried out through a series of dedicated workshops (WKEVALandWKSCRUT) and culminated in the publication of a dedicated WGIPS survey manual (SISP #9).

As part of this process the group adopted a new computational tool for the calculation of acoustic survey abundance (StoX). Old and new abundance calculation methods were compared by various survey groups (HERAS, IBWSS, IESNS) and close agreement was reached with each method. All surveys coordinated by WGIPS now use StoX as the primary abundance calculation tool allowing reproducible results in a common format. The group was formative in the development of the new ICES Acoustic survey database and the majority have adopted this as a repository for aggregated biological and acoustic survey data.

As it stands, all WGIPS coordinated surveys (national and international) are conducted following methods and protocols as laid out in the SISP survey manual. This is a live document updated annually during WGIPS meetings. All surveys use StoX as the primary computational tool and data (acoustic and biological) are stored in the ICES acoustic database (and PGNAPES database where applicable) and available for download. Surveys now provide a measure of precision (CV) for age stratified abundance estimates and are fully reproducible and available as StoX project files. Overall this relates to 29 vessel surveys carried out by 9 nations.

For multi-vessel acoustic surveys it is critical that surveys carried out in common areas adhere to the same methods and design in order to not compromise the validity of the global estimate. It is therefore recommended that nations/surveys not adhering to common and agreed methods (WKEVAL) provide supporting evidence to justify these decisions to the group for review in 2019.

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

Work progressed on drafting a further version of the 'SISP 9 Manual for International Pelagic Surveys (IPS)', to add updated information and detail on: the new ICES database, the data formats in use, details on scrutiny methods, the new survey analysis software StoX method, and applied ecosystem monitoring techniques.

The following parts of the acoustic survey manual have been reviewed and updated:

The collection of zooplankton samples has been divided into a general part applicable to all surveys and assessing (possible) differences between the national surveys, and more detailed protocol descriptions in the chapters covering the coordinated surveys.

In an attempt to cover experimental work going on during the national surveys, short chapters on "integrated ecosystem monitoring", "alternative ground truthing methods" and "Jellyfish monitoring" have been added.

Under "4.1.1 Acoustic equipment requirements for wider ecosystem surveys" a section on multibeam has been added.

In its current state the survey manual needs a thorough update. Changes in operation and analysis have progressed rapidly during the last three years. The group has not been able to incorporate these changes into the manual, partly due to time constraints. This is further aggravated by the fact that during meetings, changes are discussed and goals set, while no clear mechanism has been employed to apply these changes. Under these circumstances it is very difficult to keep the manual up to date at the meeting.

In the 2018 meeting the group has concluded that keeping the manual up to date should be carried out intersessionally. The annual meeting can then be used to set tasks to the participants and review the work.

During the coming three years cycle, the update and review of the acoustic survey manual needs to be given a higher priority.

TOR e: Review and evaluate survey designs across all WGIPS coordinated surveys to ensure the integrity of survey deliverables.

Results of the Workshop on evaluating current national acoustic abundance estimation methods for HERAS surveys (WKEVAL) 2015 were presented in 2016. Work was done to provide quantitative differences between previous and new methods and evaluate performance of new sampling designs. The group was satisfied with the results generated using the new method, as the estimates derived from the methodology previously applied were contained within the uncertainty range (95% confidence interval) of the StoX estimates. StoX, which was developed to provide common code for survey analysis, and to format, quality check, and plot data from acoustic surveys, was adopted by all WGIPS coordinated surveys.In HERAS a change was made from a stat square to a stratum based analysis using parallel transects. Designs and plans of the different surveys were established and agreed for 2016 and 2017 across all WGIPS surveys within survey subgroups. For 2016, 25 individual surveys were planned in total(26 in 2017), including 4 multinational surveys in both years. Survey plans for 2018 are provided in Annex 7.

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

In order to compare, evaluate and harmonize echogram scrutinisation and post-processing procedures currently applied by different participants of pelagic surveys coordinated by WGIPS, the group recommended in 2014 that a corresponding workshop be held in 2015. Accordingly, a Workshop on scrutinisation procedures for pelagic ecosystem surveys (WKSCRUT) was held in September 2015. Additional aims of the workshop were to document recommended methods to be followed by survey participants, to produce acoustic density values by species and sampling units from raw acoustic energy data, and implement data requirements needed for a move to a new database for the storage of disaggregated survey data; to update the WGIPS survey manual with the recommended methods.

During the workshop, example datasets based on acoustic raw data collected during HERAS (GER, NL, IE, SCO), IBWSS (NL) and IESNS (NOR) surveys were scrutinized and post-processed by the participants. The example datasets were provided after a data call scheduled prior to the meeting and were classified into "typical" and "challenging" situations encountered during the corresponding surveys. Additional trawl catch data had been made available to specifically allocate species aggregations and echotraces. The scrutinisation exercises revealed that even across surveys and with post-processors unfamiliar with individual surveys, there was a very high degree of consensus on how to identify and categorize echotraces from acoustic raw data. This was also observed across software platforms utilized for post-processing. Causes for variance and deviation in results in most cases could be identified and discussed and were further specified and addressed in resulting recommendations.

The harmonized scrutinisation procedures were applied to larger exemplary datasets during later WGIPS meetings and showed high consistency among post-processors. The process of updating the SISP manual with results from this workshop and following exercises is ongoing.

TOR g: Develop alternative analysis methods (e.g. using geostatistics) to monitor the pelagic ecosystem by extracting metrics from the collected survey data other than those required for single-species stock assessments.

Geostatistics has been considered a useful alternative tool to characterize the spatial distribution pattern of fish from acoustic survey data. Geostatistical indices such as center of gravity, isotropy, spatial patches and colocation have been investigated using RGeoStats (Renard *et al.*) package for HERAS and IBWSS surveys. Outputs were evaluated in a way to evaluate the survey design. Some of the results were presented in the SOMEACOUSTICS symposium 2015 and a paper was published on this (Gastauer et al., 2016). It would be beneficial to further investigate the potential use of geostatistics to improve spatial structuring of the stocks within the survey area. However, due to the departure of members with relevant expertise, the group currently lacks the necessary capacity to further develop this task. One way to ensure the continuity of this task is to discuss with StoX software developers on the possibility to integrate necessary geostatistical tools into the software, as has partially been accomplished for e.g. EchoR.

References:

Gastauer, S., Fässler, S. M., O'Donnell, C., Høines, Å., Jakobsen, J. A., Krysov, A. I., Smith, L., Tangen, Ø., Anthonypillai, V., Mortensen, E., Armstrong, E., Schaber, M., Scoulding, B. (2016). The distribution of blue whiting west of the British Isles and Ireland. *Fisheries Research*, *183*, 32-43.

Renard, D., Bez, N., Desassis, N., Beucher, H., Ors, F., Freulon, X. RGeostats: The Geostatistical R package. MINES ParisTech / ARMINES. http://cg.ensmp.fr./rgeostats

TOR h: Assess auxiliary pelagic ecosystem surveying technology (e.g. optical technology, multibeam and wideband acoustics) to: (i) achieve monitoring of different ecosystem components, and/or (ii) derive ecosystem indicators from surveys covered by WGIPS.

In the last three years, the group has continued to contribute significantly to the application and development of methodologies to collect auxiliary data which may be used to monitor the ecosystem and/or improve the understanding of the ecological processes which drive the small pelagic fish community. The group acknowledges that integrated assessment receives increased focus and ecosystem based management is expected to be more important in future years. The table in Annex 8 provides, for each survey, a summary of data routinely collected on the various components of the ecosystem. Case studies expanding on several topics within the table have been provided during the last three years, the details of which are included in the annual reports; a summary is provided here.

There is an increasing demand for a better understanding of the zooplankton community and its interactions with other parts of ecosystems. In addition, a fishery targeting zooplankton is under development in several areas and increased sampling of zooplankton is therefore supported within the group. Different types of gear are used for sampling zooplankton aboard several surveys and include Mocness, which is able to get depth-stratified samples of the zooplankton community, Dyedi nets, and, more commonly, WP2 and ringnets, small nets which are hauled vertically from the seabed (or a fixed depth) to the surface. Net avoidance and deployment complexity affect the choice of most appropriate gears on each survey. More recently, more automated, often continuous plankton sampling methods have been explored including Cefas Autonomous Litter and Plankton Sampler (CALPS; Pitois et al., 2016). Processing the zooplankton catch also varies and includes microscopic analysis of fixed samples, dried weight and optical methods (Zooscan), with objective and budget being the main drivers determining the chosen method.

Jellyfish is another trophic group, which is of interest due to its presumed predatory role in the marine ecosystem. It is regularly caught in the trawl catches, however, due to the opportunistic nature of trawl deployments (when fish schools require groundtruthing), these trawl-caught jellyfish do not provide a reliable measurement of their abundance and distribution. Acoustic methods currently have limited routine application in quantifying these gelatinous organisms during these surveys, due to complexities of their acoustic reflection. DTU-Aqua developed new jellyfish monitoring trials by deploying a GoPro camera (Hero3) on a towed body at 3-5m depth, deployed from the foredeck of the vessel. Manual and automated processing of the video proved successful in yielding quantitative information on the concentration of jellyfish. This work is in progress, a corresponding section in the SISP manual has been updated (Chapter 9), and further results will be disseminated through the working group. Ireland is also developing methods to better quantify jellyfish distribution and abundance using biological sampling and optical techniques as part of the WESPAS survey.

Ongoing efforts by the Netherlands aim to explore the use of acoustic equipment on board RV Tridens to collect additional data on seabed type and use geostatistical methods to quantify the links between seabed types, benthic biomass, abundance/biomass of benthic/demersal fish and relative abundance of pelagic fish groups. The project will thus not only develop methods for surveys and multi-trophic level data analysis but also provide ecological insights into ecosystem connections across trophic levels.

Finally, as illustrated in the table in Annex 8, all surveys coordinated by WGIPS collect CTD profiles throughout their survey areas. Only in some of these surveys (IESNS, IENSS, WESPAS, CSHAS and PELTIC), are these data used for more detailed investigations in relation to the distribution patterns of target species. This year, WGIPS discussed ways to better utilize the CTD data and, because most of these data are already submitted to the ICES hydrographic data suppository, a possible link with the new acoustic database would facilitate and encourage more research.

Reference:

Pitois, SG., Bouch, P., Creach, V., van der Kooij, J. (2016). Comparison of zooplankton data collected by a continuous semi-automatic sampler (CALPS) and a traditional vertical ring net. *Journal of Plankton Research 38 (4)*, 931-943.

TOR i: Develop and refine methods to derive stock or spawning component-specific survey indices for herring based on biological criteria (e.g. otolith shape analysis or morphometric measurements).

WKSIDAC (20–24 November 2017, Galway, Ireland) covered herring in the areas 2.a, 6.a+7.b-c, 4.a-c+7.d, 3.a, SD 22+23+24 and the most common methods used to separate herring in those areas. In the North Sea, currently, herring in the areas between 4°W and 2°E and then south of 56°N are all considered to be NSAS. Identification and allocation between NSAS and WBSS is only undertaken east of 2°E in the Norwegian and Danish Sectors. In the Norwegian area, allocation is based on vertebrate counts (percentage assignment) and in the Danish area, it is undertaken based on a combination of otolith shape and otolith micro structure (individual assignment). There is a need for a standardised method that can provide stock assignment at the individual level. In the workshop several potential methods were presented: otolith shape analyses, otolith microstructure, growth separation, the use of parasites, and a combined approach (morphometric + otolith shape + genetics).

The optimal allocation method for stock assessment purposes (as perceived by the Workshop members) varied by area. Otolith shape analyses appeared the most widely recommended, however, other techniques such as genetics and otolith microstructure and micro-chemistry would be necessary for validating the shape analyses results. For the North Sea area, the otolith shape technique was recommended with validation from otolith micro-structure and micro-chemistry and genetics. In the Baltic, separation based on the growth, through length-at-age was favoured and in Area 6.a a combined approach using genetics and morphology is preferred. Baselines, in all areas, need to be updated on a regular basis.

The Workshop was not able to provide an outline of a manual by method for stock identification of herring for implementation in individual laboratories nor provide guidance on retrospective corrections of herring survey time-series. These topics need to be taken up in some future Workshop/Meeting.

The workshop made a set of recommendations for further sampling and work.

5.2 Science highlights

Gastauer, S., Fässler, S. M., O'Donnell, C., Høines, Å., Jakobsen, J. A., Krysov, A. I., Smith, L., Tangen, Ø., Anthonypillai, V., Mortensen, E., Armstrong, E., Schaber, M., Scoulding, B. (2016). The distribution of blue whiting west of the British Isles and Ireland. *Fisheries Research*, *183*, 32-43.

6 Cooperation

6.1 Cooperation with other Working Groups

WGFAST

Based on the methodology utilized in all of the surveys coordinated by WGIPS, a co-operation with WGFAST in terms of survey technology and protocols applied exists that led to specific workshops initiated by WGIPS and WGFAST (WKSCRUT, WKQUAD).

HAWG

Age-disaggregated indices from three of the WGIPS-coordinated surveys are used by the Herring Assessment Working Group (HAWG). The HERAS survey provides age disaggregated abundance indices used in the assessments of North Sea autumn spawning herring, Western Baltic spring spawning herring, Malin Shelf herring, sprat in the North Sea, and sprat in 3a. The Celtic Sea herring acoustic survey (CSHAS) and HERAS provides the only fisheries independent tuning series for the assessment of Celtic Sea herring and Malin Shelf herring, respectively. The Irish Sea acoustic survey (ISAS) delivers indices for the Irish Sea herring assessment. In HAWG 2016, a list of the features and estimates derived from the existing surveys which are relevant to the interpretation of results and model fitting process and therefore need to be clearly presented in the surveys' group, was provided. WGIPS from 2017 began to include these as a standard in the HERAS report (Annex 5c), and provided a table to HAWG documenting where these are located (Annex 11 in WGIPS 2017).

WGACEGG

The Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas 7, 8 and 9 (WGACEGG) is dealing with acoustic-trawl and ichthyoplankton surveys targeting both species. Besides, the acoustic-trawl surveys are routinely reporting biomass estimates for the most important pelagic species (sprat, mackerel, horse mackerel, boarfish or blue whiting) occurring in Southern European Atlantic waters, together with ancillary information on top predators, oceanographic features (SSS, SST, SSF, CTD and plankton casts), subsurface eggs counts from CUFES among others. Some of the individual surveys such as PELTIC are reported in both WGACEGG and WGIPS, while from 2018 onwards part of the PELACUS survey, carried out by Spain in ICES Sub-Divisions 8c and 9a, will also cover 7hjk and 8ad within IBWSS. The Irish WESPAS and CSHAS cover geographical regions (Celtic Sea and northern Biscay) and stocks (boarfish and horse mackerel) reported to WGACEGG. At present no process exists for data flow between these groups or communication on stock abundance estimates aside from ad hoc exchanges. It would be useful to develop communication between the groups and at the very least link countries co-surveying the same regions namely, Ireland. Given also the similarity in some of the ToR's and activities, a closer cooperation between both WG's would result in an improvement of the acoustic survey-based monitoring of Northeast Atlantic ecosystems. WGIPS members P. Carrera (Spain) and J. van der Kooij (UK) will act as contact persons between WGIPS and WGACEGG.

WGWIDE

Age-disaggregated indices from three of the WGIPS-coordinated surveys are used by the Working Group on Widely Distributed Stocks (WGWIDE). In the blue whiting assessment acoustically derived abundance index by age from the IBWSS survey is used as the only fisheries independent tuning series. In the Northeast Atlantic mackerel assessment the swept-area based abundance index by age from the IESSNS survey is used as one of the fisheries independent tuning series. In the assessment of Norwegian spring spawning herring the acoustically derived abundance index by age from the IESNS survey is used as one of the fisheries independent tuning series.

6.2 Cooperation with Advisory structures

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 workshops, i.e. the Workshop on Evaluating Current National Abundance Estimation Methods for HERAS Surveys (WKEVAL, chaired by Ciaran O`Donnell, Ireland, met at ICES headquarters from 24-28 August 2015) and the Workshop on the Review of the ICES acoustic-trawl survey database design (WKIACTDB, chaired by Neil Holdsworth, Denmark, and Nils Olav Handegard, Norway, met in Copenhagen from 1-2 October 2015). Additional input came from the yearly WGIPS and survey post-cruise meetings.

The acoustic data format consists of two parts – an Acoustic and a Biotic part. The acoustic part of the format is based on the SISP 4 – A metadata convention for processed acoustic data from active acoustic systems developed by the ICES Working Group on Fisheries Acoustics, Science and Technology (WGFAST), while the biotic part of the format is based on the ICES Database of Trawl Surveys (DATRAS).

The database and portal is now in production and actively used by a number of acoustic working groups including WGIPS which have been involved in the development by giving input to the data structure and workflow.

6.3 Cooperation with the pelagic fishing industry

Industry Acoustic Surveys in 6a/7b

In response to ICES advice for zero TAC and calls for a rebuilding plan to be established fishing industry associations representing Scottish, English, Dutch, Irish and German fishery interests (under the auspices of the Pelagic Advisory Council) set about providing evidence required to establish reliable stock assessments for the separate stocks, and develop a rebuilding plan.

2017 was the second industry-led acoustic survey of herring in 6a/7bc, the aim of which is to improve the knowledge base for the spawning components of herring 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.

Four industry vessels were used in the 6aN survey, three vessels had Simrad EK60s mounted on a towed body, and the other vessel used a Simrad EK80 transceiver with the ships transducer. Each vessel was calibrated and dedicated to undertake an acoustic survey in a specific pre-spawning/ spawning area coinciding with the known spawning period. The industry vessels were proven to be stable platforms for acoustic surveys. Herring were aggregated mainly in one area, (different from 2016) so biological samples are spatially limited.

In 6aS/7bc, two pairtrawlers, one with a scientific EK60 transceiver and calibrated towed body-mounted transducer (38kHz) wereused to conduct the survey encompassing the majority of spawning areas in 6aS and 7b. Herring were distributed in hyper-aggregated schools in discrete areas close inshore during the survey and therefore full containment of the stock was difficult and most likely not achieved. Therefore, estimates of abundance and biomass are minimum for the surveyed area. Additional samples were obtained from the monitoring fishery being conducted at the same time in the survey area. Abundance and biomass results were similar to the survey conducted in 2016, including good cohort tracking between the two years. Horse mackerel abundance and biomass for the surveyed area was also estimated, however, this stock was not contained.

Following the rebuilding plan, the 6a industry surveys intend to continue under the coordination of WGIPS until such time as the stock has recovered.

Details of the 2017 surveys and findings are reported in Annex 6f.

6.4 Cooperation with other IGOs

MEDIAS (Mediterranean Acoustic Survey on Small Pelagics)

There is currently no contact person and collaboration, but WGIPS strives to achieve cooperation with this group given the similarity of methods and surveys.

7 Summary of Working Group self-evaluation and conclusions

During the last and preceding terms, WGIPS has produced survey-based indices for many of the most important pelagic fish stocks in the Northeast Atlantic region through a series of internationally coordinated and individual national acoustic surveys. Additionally, the group – in close cooperation with other ICES working groups – established new, common survey- and analysis protocols and participated in transitioning towards the use of a common ICES acoustic database repository. In light of an ecosystem approach to fisheries management, the scope of the surveys coordinated within the framework of the group has broadened towards measuring a wider range of ecosystem metrics and parameters. New advances and applications of fisheries acoustics are being utilised by the group and their common usage in surveys is being aspired. Through a series of workshops and post-survey meetings, the group has continuously updated the current SISP manual and hence provided best practice guidelines for all surveys coordinated within the auspices of WGIPS. Additionally, the group promotes industry-science collaborations to enhance the database for the assessment of some of the stocks monitored.

Accordingly, the Working Group of International Pelagic Surveys is therefore proposing to continue as an ICES working group.

Full details can be found in the comprehensive self-evaluation report in Annex 4.

Annex 1: List of participants

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Annex 2: Recommendations

Recommendations issued in 2017 to WGIPS:

EG: **WKQUAD**

Recommendation	Adressed to
1. Collect data during both calm weather and in inclement weather. Use the opportunity of inclement weather to collect data along a tran-sect in opposite headings (i.e. with and against the seas).	WGIPS, WGBIFS, WGACEGG
2. Compile seabed substrate maps and data for the survey area. These may be useful for decoupling substrate effects from noise or attenua-tion effects on data quality when the seabed backscatter is used as a diagnostic	WGIPS, WGBIFS, WGACEGG
3. Compile information on transducer location and vessel trim, and collect vessel motion (pitch, roll, heave) data at a sampling rate of at least twice the frequency of the vessel motion (<1/2 the period), i.e. Nyquist sampling rate. A typical rate is 3 Hz.	WGIPS, WGBIFS, WGACEGG
4. Collect meteorological data, e.g. windspeed and direction, swell, sea state, wave height during the surveys.	WGIPS, WGBIFS, WGACEGG
5. Collect passive data during inclement weather. Transient and impulse noise will appear in passive data. Compare noise values between good and bad data.	WGIPS, WGBIFS, WGACEGG

Reply:

The group discussed the recommendations from WKQUAD and how the group can provide survey data for further analysis by this focus group. The WGIPS proposed two ways in which data can be provided; opportunistic data collected 'on survey' focusing on biological targets and second a standardised transect approach using insonified seabed data.

The ability to carry out additional work within established survey programs is somewhat limited due to core work commitments. However, the group agrees that opportunist sampling can be carried out when time allows.

On survey data

Collection of 'on survey' acoustic data (reciprocal heading) during inclement weather can be problematic during a monitoring survey due to time constrains. One possibility could be at the end of a transect to turn and complete a short section (5-10 nmi) with reciprocal heading. This sampling cannot be used in the survey calculation. Therefore this sampling can only be done if survey time allows. Standardised transect

A possibility exists to collect insonified seabed data over a standardised transect of known substrate type. It is suggested that an area is chosen close to the vessels home port, and/or survey pathway, that can be frequently crossed while transiting to and from the vessels home port. By choosing a 'close to home' location data could be collected without interrupting routine operations.

As a baseline, a straight line transect area of no less than of 1 nmi (nautical mile) in length should be surveyed over an area of known substrate. Substrate type can be determined using bathymetric multibeam mapping and where possible groundtruthed with grab sampling. As a minimum, grab sampling should be carried out on areas where aggregates predominate (gravel, shell, shale etc). The candidate area should be relatively uniform in terms of relief to reduce the effects of beam scattering, excessive reflectivity and shadowing. The area should also be composed of temporally stable substrate (gravel, shale, rock, and reef) so as to reduce variability between measurements over time.

The area should be surveyed between the same waypoints on each occasion to ensure a consistent line of seabed is insonified. The .raw data files (including motion reference data) and weather data should be provided for analysis by WKQUAD.

By using a standardised transect, focusing on seabed backscatter provides an alternative measure of transducer performance due to the effects of weather as compared to biological based observations due to the effects of temporal and spatial variability.

Collection criteria:

- Standardised waypoints (straight line transect)
- Minimum of 1 nmi in length
- Known and stable substrate type of low relief and relatively uniform (substrate determined using grab sampling and/or bathymetric multibeam)
- Accompanying weather data
- Accompanying CTD data (optional)

EG: **HAWG**

	Recommendation	Adressed to
1.	WGIPS to evaluate age 6 in the HERAS survey in the NSAS area.	WGIPS

Reply:

WGIPS requested further details from HAWG to the nature of the problem, and a spreadsheet with the time-series as used in the North Sea herring assessment was forwarded along with a description of the issue. The concern was centred on a mismatch between very large abundances at ages 5 which were not carried through as large abundances at age 6 the following year, but was then present at age 7 two years later in certain years. Upon inspection of this file, it was not obvious, however, that there was a problem. WGIPS will endeavour to carry out a review of the time-series published in the report to ensure no errors are present.

EG: **JFATB / WGFAST**

	Recommendation	Adressed to
2.	JFATB recommends the development of terms of reference for a joint session of WGFAST and WGFTFB in April/Mayof 2020. The Terms of Reference are to be mutually decided by the Working Group Chairs and new joint session chairs. WGFAST proposes Stéphane Gauthier (Canada) and WGFTFB proposes Michael Pol (USA) as new chairs of JFATB. We recommend that WGFTFB investigate 'improved methods to refine survey gear, and quantify trawl selectivity across a broad range of species and sizes. This may lead to improved survey estimates of species and size distributions, which is a key source of uncertainty in acoustic-trawl surveys. Survey groups WGIPS, WGBIFS, WGACEGG should be included in planning for this session, as establishing survey trawl selectivity is important for these surveys. The joint session should review existing knowledge and recent developments in this area, with a focus on trawls used to sample pelagic organisms, and practical approaches to estimate trawl selectivity. A subset of WGFTFB and WGFAST members and members of survey groups (WGIPS, WGBIFS, WGACEGG) have expertise that is relevant in this area.	WGFTFB, WGFAST, WGIPS

Reply:

WGIPS acknowledges that gear selectivity is one of the key sources of uncertainty in producing abundance and biomass estimates of fish from hydroacoustic surveys. Most partners within the group therefore conduct routine trials to assess and improve fishing gear performance and monitor escaping behaviour of fish, although these tend not to be published in dedicated studies. Examples include the deployment of sensors on the trawl gear which measure flow near the codend to provide information on the optimal towing speed; headline sonar equipment is used, among others, to provide accurate information on fish escaping underneath the footrope; several surveys use cheap forward-facing "action" cameras near the mouth of the codend to study the fish behaviour within the fishing gear. Systematic studies using these cameras were conducted in support of establishing the suitability of the swept-area trawl operations in the new IESSNS surveys. Results of these studies have been presented at ASC, workshops and working groups and focused on the movement, behaviour and catchability and avoidance of mackerel in the Multpelt trawl (see some examples below). WGIPS therefore welcomes the proposed joint session of WGFAST and WGFTFB in April/May of 2020 and the proposed session chairs, as the group acknowledges the significant effect of gear selectivity on the reliability of the partitioned acoustic data.

Valdemarsen, J. W., Nøttestad, L., Jakobsen, J. A.(2013).Standardized swept-area pelagic trawling with Multpelt 832. ICES Annual Science Conference (ASC). Reykjavik, Iceland 23-27 September 2013.

Nøttestad, L., Rosen, S., Valdemarsen, J. W. (2015). Using action cameras to quantify fish behaviour and passages rate inside a trawl. POLSHIFT Poleward shifts in the pelagic complex, and effect of climate change?; Reykjavik, Iceland 14-15 April 2015.

Rosen, S., Valdemarsen, J. W., Nøttestad, L. (2015). Inexpensive action cameras quantify fish behaviour and passage rates inside a survey trawl. ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB); 5-9 may 2015.

Aarbakke, B. (2016). A comparison of abundance, distribution and behavior of Northeast Atlantic mackerel (*Scomber scombrus* L.) during curved and straight forward trawling. Bergen: Universitetet i Bergen 2016. 79 pp.

EG: **WGINOR**

Recommendation	Adressed to
1. In the last two decades, changes and expansions have been seen in feeding locations of the pelagic fish stocks in the Nordic Seas (e.g. NE-Atlantic mackerel, NSS-herring, Icelandic capelin). All information suggests that abundance of pelagic fish in Greenland Sea is currently small. However, climate changes might enhance these observed expansions of pelagic fish further and possibly into Greenland Sea. If and before such changes occur, it is important to record the "original" stage and record potential changes in the ecosystem and environmental variability. Consequently, WGINOR recommends that the International Ecosystem Summer Survey in Nordic Sea in July/August (IESSNS) will be extended into Greenland Sea. Whether this should be done every year or every second year can be discussed.	WGIPS

Reply:

The group is taking this recommendation into consideration. In the preliminary plans for the IESSNS survey 2018 two transects are covering the southernmost part of this area. This part of the survey is not directly related to the recommendation from WGINOR, but may still be regarded as a starting point for surveying the Greenlandic Sea in its current state as part of the IESSNS survey.

Recommendations from WGIPS:

Recommendation	Adressed to
Proposal to undertake a WK to coordinate the development of standardised protocols Aim: To coordinate the development of standardised protocols for the acoustic assessment of resources in the mesopelagic zone. Open ocean acoustic surveys frequently encounter significant biomass within the mesopelagic zone. This zone contains a complex mixture of organisms, visible from acoustic sensors as multi-species scattering layers, DSL (deep scattering layer), diel mixing layers and single species fish schools. Classification of biomass into useful biological groups is no doubt a complex processes, but is nonetheless necessary for reliable measurements. The complexities of such classification are recognised as are the limitations of vessel based acoustic measurements and the collection of biological samples using existing survey trawl designs. Several international surveys coordinated by WGIPS (e.g. IBWSS, IESSNS and IESNS) cover areas where extensive mesopelagic layers are present, providing an opportunity for routine measurement. The recent WKMESO workshop (Workshop on monitoring technologies for the mesopelagic zone) discussed some of the limitations and opportunities afforded from utilising existing survey programs for data collection and developments in wideband acoustics, biological and optical sampling technologies. To improve the understanding within WGIPS it is proposed that a workshop is undertaken under guidance of WGFAST to bring together experts in the field on biology and acoustic properties of assemblages within the DSL. The ubiquitous nature of DSL and its understanding may appeal to the wider community.	WGFAST

Annex 3: Draft WGIPS terms of reference

The **Working Group ofInternational 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	
Year 2020	13–17 January	Bergen, Norway	Final 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	

ToR descriptors[1]

ToR	Description	Background	Science Plan topics addressed	Duration	Expected Deliverables
a	Combine and review annual ecosystem survey data to provide: indices of abundance and spatial distribution for the stocks of herring, sprat, mackerel, boarfish and blue whiting in Northeast Atlantic waters.	a) Advisory Requirements b) Requirements from other EGs	Goal 3	years 1–3	Survey reports containing indices of stock biomass and abundance at age, spatial distributions, zooplankton biomass, and hydrographic conditions. HAWG WGWIDE
b	Coordinate the timing, area and effort allocation and methodologies for individual and multinational acoustic and larvae surveys on pelagic resources in the Northeast Atlantic waters	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs	Goal 1,3	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	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	Goal 3, 4, 5	years 1–3	Progress on the adaption of standardized analysis methodology and data storage format utilizing the ICES pelagic acoustic database repository of WGIPS coordinated surveys.
d	Periodically review and update the WGIPS acoustic survey manual to address and maintain monitoring requirements for pelagic ecosystem surveys	a) Science requirements b) Advisory requirements	Goal 3	years 1–3	Updated WGIPS survey manual.
e	Review and evaluate survey designs across all WGIPS coordinated surveys to ensure the integrity of survey deliverables	a) Science requirements b) Advisory Requirements c) Requirements from other EGs	Goal 3	years 1–3	Optimize and harmonize sampling designs and precision estimates for the different surveys to ensure survey quality. HAWG WGWIDE
f	Assess and compare scrutinisation procedures	a) Science requirements	Goal 3	year 1	Documented standardized scrutinisation recommendations; Update

	employed for the analysis of raw acoustic data from WGIPS coordinated surveys	b) Advisory requirements			of survey manual to adress and maintain monitoring requirements for pelagic ecosystem surveys.
g	Collaborate with groups wishing to utilize available time-series from WGIPS coordinated surveys.	a) Science requirements	Goal 3, 4, 5	Years 1-3	Facilitate testing and developing forecast models provided by WGS2D and other groups.
h	Assess 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	Goal 1 & 3	years 1–3	Update ecosystem metrics that are collectedby 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 scruitinisation 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 discuss and harmonize changes amongst the different surveys. Session (mini symposium) to assess auxilliary pelagic ecosystem surveying technology focusing on the achievement to monitor different ecosystem components. 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 to discuss and harmonize changes amongst the different surveys. Session to assess progress in the implementation of auxilliary pelagic ecosystem surveying technology from 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 to discuss and harmonize changes amongst the different surveys. 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 larval and 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 Groups core task is the standardization, planning, coordination, implementation, and reporting of acoustic and larvae surveys for main pelagic fish species 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	WGWIDE, HAWG

groups under ACOM	
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 4: Working Group self-evaluation

1. Working Group name: Working Group of International Pelagic Surveys (WGIPS)
2. Year of appointment: 2016
3. Current Chairs:

   Matthias Schaber, Germany

   Bram Couperus, Netherlands

4. Venues, dates and number of participants per meeting:

   18–22 January 2016, Dublin, Ireland, (19)

   16–20 January 2017, Reykjavik, Iceland, (17)

   15–19 January 2018, Den Helder, Netherlands, (19)

WG Evaluation

5. If applicable, please indicate the research priorities (and sub priorities) of the Science Plan to which the WG make a significant contribution.
   - Describe and quantify the state of North Atlantic Ocean regional systems: 1. Assess the physical, chemical and biological state of regional seas, and investigate the predominant climatic, hydrological, and biological features and processes that characterize regional ecosystems.
   - Estimate long-term trends of human impacts on marine ecosystems: 10. Develop historical baselines of population and community structure and production to be used as the basis for population and system level reference points.
   - Identify and prioritize ICES monitoring and data collection needs: 25. Identify monitoring requirements for science and advisory needs in collaboration with data product users, including a description of variables and data products, spatial and temporal resolution needs, and the desired quality of data and estimates.
   - Develop further the methodology for the observation and monitoring of marine ecosystems in the ICES area: 27. Identify knowledge and methodological monitoring gaps, and develop strategies to fill these gaps. 28. Promote new technologies and opportunities for observation and monitoring, and assess their capabilities in the ICES context.
   - Implement integrated monitoring programmes in the ICES area: 30. Allocate and coordinate observation and monitoring requests to appropriate expert groups on fishery-independent and fishery-dependent surveys and sampling, and monitor the quality and delivery of data products. 31. Ensure the development of best practices through establishment of guidelines and quality standards for: (a) surveys and other sampling and data collection systems; (b) external peer reviews of data collection programmes; and (c) training and capacity-building for monitoring activities.
6. In bullet form, list the main outcomes and achievements of the WG since their last evaluation. Outcomes including publications, advisory products, modelling outputs, methodological developments, etc. *

- Indices for the stocks of herring, sprat, mackerel, boarfish, and blue whiting in Northeast Atlantic waters from annual ecosystem surveys as fishery-independent data for analytical assessment purposes in HAWG (Herring Assessment Working Group) and WGWIDE (Working Group on Widely Distributed Stocks):
  - 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 proportion, 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 6aN-S, 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 3a 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 7a), autumn spawning herring, numbers, biomass, distribution, maturity proportion, mean weight, and length-at-age
  - 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)
  - Review of herring larvae surveys conducted prior to or ongoing during the meeting (International Herring Larvae Surveys, IHLS) (no longer reported to the group from 2018 on. Will in future be reported to WKSINS)

    - Review and advise on 6a, 7bc industry acoustic survey for autumn spawning herring.
- Other ecosystem survey-derived operational products:
    - 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 (ESAS) during Irish CSHAS, IBWSS and WESPAS surveys.
- Other outcomes and achievements:
    - WKEVAL (Workshop on evaluating current national acoustic abundance estimation methods for HERAS surveys), 24-28 August 2015
    - WKSCRUT (Workshop on scrutinisation procedures for pelagic ecosystem surveys), 7-11 September 2015
    - Contribution to ICES ASC Session
    - 2016-2018 survey plans (see Annex 6 for 2018 survey plans)
    - Overview of currently applied auxiliary pelagic ecosystem sampling technology/Ecosystem index overview table (see Annex 7)
    - Input to the development of the ICES acoustic database repository
    - 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 in the HERAS survey
    - Recalculation of IESSNS mackerel abundance with StoX
    - StoX comparison Working Document
    - 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)
    - Further version of 'SISP 9 Manual for International Pelagic Surveys (IPS)'
    - Published manuscript on blue whiting distribution (http://www.sciencedirect.com/science/article/pii/S0165783616301497).

7. *Has the WG contributed to Advisory needs? If so, please list when, to whom, and what was the essence of the advice.*
   The WG provides age disaggregated abundance indices for many stocks of small pelagic fish in the Northeastern Atlantic region on an annual basis. Corresponding information was provided to e.g. WGWIDE, HAWG, WGHANSA.
8. *Please list any specific outreach activities of the WG outside the ICES network (unless listed in question 6). For example, EC projects directly emanating from the WG discussions, representation of the WG in meetings of outside organizations, contributions to other agencies' activities.*
   none
9. *Please indicate what difficulties, if any, have been encountered in achieving the workplan.*
   Through individual members leaving the group during this term, difficulties emerged in fully accomplishing some ToRs due to a lack of expert knowledge.
   While amendments and updates to the SISP manual based on the adoption of new evaluation tools and preceding dedicated WKs were on the agenda for each preceding meeting of WGIPS, it became evident that the concept of a "living document" was not compatible with the updates required. The group concluded that keeping the manual up to date should be carried out intersessional.

Future plans

10. *Does the group think that a continuation of the WG beyond its current term is required? (If yes, please list the reasons)*
    Yes. WGIPS represents a main group providing indices of a wide range of pelagic species to be utilized in the corresponding advisory process. The group is responsible for coordination, evaluation and standardisation of corresponding surveys and survey products. Additionally, new techniques for data collection are evaluated in the framework of the groups´ tasks.
11. *If you are not requesting an extension, does the group consider that a new WG is required to further develop the science previously addressed by the existing WG.*
    n.a.
12. *What additional expertise would improve the ability of the new (or in case of renewal, existing) WG to fulfil its ToR?*
    The group would like to explore the requirement to provide geostatistical metrics of survey data as a means to improving the evaluation of survey estimates provided by the group. As the group now utilises a common computational and reporting format (StoX) the option exists to also include geostatistical products as a standard annual survey output. It would increase the ability to assess the precision of the abundance estimates provided to stock assessment groups (HAWG, WGWIDE). To achieve this the group recommends that the providers of the ICES Training Course on Geostatisticsl discuss with the developers of StoX the feasibility of a standardised reporting script to the group.
13. *Which conclusions/or knowledge acquired of the WG do you think should be used in the Advisory process, if not already used? (please be specific)*
    Uncertainty estimates are available for the indices provided for several stocks. These estimates could be utilized in the assessment process.

Annex 5:

Annex 5a: International blue whiting spawning survey (IBWSS) survey report 2017

Survey Summary table	
Name of the survey (abbreviation):	International blue whiting spawning survey (IBWSS)
Summary:	**Cruise Report Link:** http://hdl.handle.net/10793/1318

In total 6,105 nmi (nautical miles) of survey transects were completed areas across six strata relating to an overall geographical coverage of 135,085 nmi². This represented a slight reduction of 3% in total survey mileage (acoustic sampling effort) a even slighter increase of 0.4 % in surveyed area compared to last year. Containment in western extremes of the survey was considered sufficient.

Overall weather conditions were mixed with periods of poor and good weather. All vessels, with the exception of Kings Bay experienced some downtime due to conditions with the Faroes experiencing the most prolonged period of bad weather at the end of the survey period.

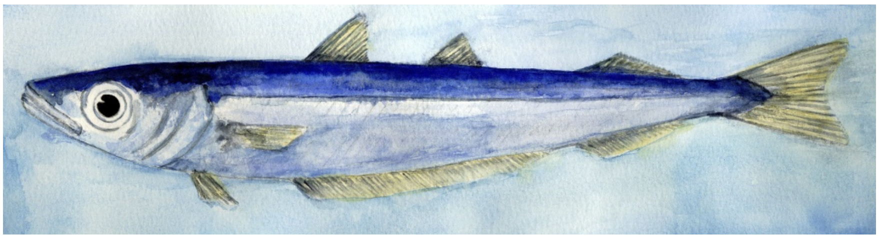
The 14th International Blue Whiting Spawning stock Survey 2017 shows an increase in total stock biomass of 9% with a corresponding increase in total abundance of 2% when compared to the 2016 estimate.

	Description
Survey design	Stratified systematic parallel design (30 & 20 nmi spacing) with randomised start point.
Index Calculation method	StoX (via the PGNAPES database)
Random/systematic error issues	NA, 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	Weather conditions were mixed and some weather induced downtime was recorded. Issues exist with smaller vessels and those without a drop keel.
Extinction (shadowing)	No particular issues
Blind zone	NA
Dead zone	No particular issues
Allocation of backscatter to species	Directed trawling for verification purposes
Target strength	Recommended values for blue whiting
Calibration	All survey vessels and frequencies calibrated and results within recommended tolerances

Working Document

Working Group on International Pelagic Surveys
Amsterdam, Netherlands, January 2018

Working Group on Widely Distributed Stocks
Copenhagen, Denmark, September 2017



INTERNATIONAL BLUE WHITING SPAWNING STOCK SURVEY (IBWSS) SPRING 2017

Ebba Mortensen[4^], 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], Eric Armstrong[6], Søren Eskildsen[8], Felix Muller[7], Ailbhe Kavanagh[11], Gary Kett[11], Bram Couperus[1*]
R/V Tridens

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

Åge Høines[2*], Valantine Anthonypillai[2], Ørjan Sørensen[2], Ståle Kolbeinson[2], Frøydis T. R. Bogetveit[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 BirdWatch, Ireland
10 Irish Whale and Dolphin Group, Ireland
11 University College Cork, Galway, 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 coordinator based on real time observations. Participating vessels together with their effective survey periods are listed below:

Vessel	Institute	Survey period
Celtic Explorer	Marine Institute, Ireland	21/3 – 02/4
Magnus Heinason	Faroe Marine Research Institute, Faroe Islands	1/4 – 10/4
Tridens	Wageningen Marine Research, the Netherlands	22/3 – 2/4
Kings Bay	Institute of Marine Research, Norway	23/3 – 4/4

The survey design applied followed methods described in ICES Survey design Manual (2015) and allowed for a flexible transect design and comprehensive coverage of the spawning aggregations. Overall weather conditions were mixed with periods of poor and good weather. All vessels, with the exception of Kings Bay experienced some downtime due to conditions with the Faroes experiencing the most prolonged period of bad weather at the end of the survey period. The entire survey was undertaken within 20 days and below the 21 day target threshold. The bulk of the survey was temporally consistent with the exception of one transect in the southern Rockall Trough (stratum 3).

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 twice 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 with a standard calibration sphere (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 blue whiting sampling by vessel is shown in Table 3.

Hydrographic sampling

Hydrographic sampling by way of vertical CTD casts was carried out by each participant 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. Norway experienced technical difficulties and therefore no CTD was provided. Equipment specifications are summarised in Table 1.

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

Acoustic scrutiny was based on categorisation by experienced experts aided by 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.6) post-processing software for the previous day's work. Data was partitioned into the following categories: plankton (<120 m depth layer), mesopelagic species 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. 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 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). Pre-determined survey strata, established in 2016, were adjusted within in StoX based on survey effort and observations in 2017. This occurred mainly in the western fringes where some transects were shortened due to zero registrations of blue whiting (Figure 1). The strata and transects used in StoX are shown in Figure 1 and 5. All trawl stations within a given stratum with catches of blue whiting where assigned to all transects within the stratum, and the length distributions where weighted equally within the 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. (exact name: 1_FillMissingData_SuperIndividuals.txt). This table was used to split the total abundance estimate by any combination of population parameters. The StoX project folder for 2017 is available on request.

Estimate of relative sampling error

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

For the baseline run, the user defines which trawl stations should be assigned to the individual acoustic primary samples (typically transects). In simple terms, a total length distribution of the species of interest 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 use the calculated length distribution and a standard target strength equation with user defined parameter values. 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 follows the same principle as in the baseline run. However, for each run, transects within a stratum are selected randomly with replacement, and for each selected transect, the trawl stations which are assigned for the selected transect are randomly sampled with replacement. Thereafter, each run follows the same estimation procedure as described above. 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 6,105 nmi (nautical miles) of survey transects were completed areas across six strata relating to an overall geographical coverage of 135,085 nmi.^{2} (Figure 1, Tables 3). Acoustic sampling effort and area coverage were the same as in 2016 (Table 7). Stock containment was considered sufficient for core abundance areas and peripheral distributions on the Rockall and Porcupine Banks. 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 86% of total biomass (Table 4). The Rockall Bank (strata 5) accounted for 7% of the biomass in 2017 (Table 4). The two northernmost strata (South Faroes strata 4 and Shetland Ch. strata 6) accounted for the remaining 8% of the biomass (Table 4).

The maximum s_A values (top 3) observed in the survey were recorded in northern part of strata 1 (Porcupine Bank) close to the shelf slope (84,756 m^2/nmi^2, 60,520 m^2/nmi^2 and 51,905 m^2/nmi^2 respectively) by Tridens (Figure 8a). Strata 2 (Porcupine Bank) contained numerous high density registrations as observed by the Celtic Explorer in open water (Figure 8b). Low density registrations dominated the Rockall strata. Northern strata (4 and 6) were dominated by numerous low density registrations.

Stock size

The estimated total biomass of blue whiting for the 2017 international survey was 3.13 million tonnes, representing an abundance of 35.2×10^9 individuals (Table 4). Spawning stock was estimated at 3.11 million tonnes and 35.0×10^9 individuals (Table 5).

Stock composition

Individuals of ages 1 to 13 years were observed during the survey.

The main contribution (81%) to the spawning stock biomass were the age groups 3, 4 and 5 in order of importance (Table 5), with 3- and 4-year old fish contributing 40% and 29% to total biomass, respectively.

The Rockall Trough is historically the most productive stratum accounting for upwards of 50% of the SBB in all years with the exception of 2013-2014 (48% and 44% respectively in these years). In 2017 this stratum accounted for nearly 60% of SSB compared to 55% in 2016 (Table 4). Mean weights of the fish caught in the Rockall Trough area were highest in the survey (Figures 9 and 10). Also in the area south of the Faroe Bank some blue whiting were observed among argentines close to the bottom (Figure 10).

The two northern strata (South Faroes; stratum 4 and Faroes/Shetland; stratum 6) were found to contain significantly less proportions of blue whiting in 2017, a decrease from around 25%

to 8% compared to 2016 (Table 4). There was also a shift in the age composition to older fish in 2017. The age groups 3 and 4 dominated in the strata. The 1-year olds were missing in this area in 2017, as compared to 2016 and 2015 when they were well represented.

The bulk of the blue whiting that was observed in 3 strata bordering the shelf edge (Strata 1, 2 and 3) was dominated by 3 to 5 year old fish, and thus represented most of the fish observed in the survey this year (Figures 13). Three year old fish dominated most strata with the exception of strata 2 and 4, where 4 year olds ranked higher and 3 year olds (Figure 12). The proportion of 1 and 2 year old fish was low in all strata and certainly in northern most strata south and east of the Faroes (strata 4 and 6) where young fish were most abudnance in the 2016 estimate.

The proportion of blue whiting in the Rockall Bank and Hatton Bank decreased from 2016 to 2017, from 10.3% to 6.9%, respectively (Table 4). This decrease was accompanied by a decrease in salinity and temperature in the deeper regions in the Rockall Bank area in 2017 as compared to 2017 (Figure 19).

An uncertainty estimate based on a comparison of the abundance estimates by age was calculated for IBWSS for years 2015, 2016 and 2017 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 2015 to 2017 it appears evident that consistency from one year to the next is acceptable for some year classes. For example the one year olds in 2014 (2013 year class) were high and also as two year olds in 2015 and three year olds in 2016. However, the level in the estimates in 2015 was significantly lower than in the 2016 and 2017 estimates. This indicates that the 2015 survey might be biased.

The survey time series (2004-2017) of TSN and TSB has been recalculated using StoX (including uncertainty estimates) and are presented in Figures 14 and 15 respectively and Table 6.

Hydrography

A combined total of 78 CTD casts were undertaken over the course of the survey, excluding those carried out by Norway (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. It seems as the salinity and temperature in the deeper regions in the Rockall Bank area decreased in 2017 as compared to the previous years.

Concluding remarks

Main results

- Weather conditions were mixed with both good and bad periods. All but the Norwegian vessel experienced some weather induced downtime ranging from 24 hrs (Ireland) to 48 hrs (Faroes).
- Total area coverage and acoustic sampling effort was maintained as in 2016. However, both acoustic and biological sampling was lower compared to previous years due to the reduced number of vessels over the last two successive years.
- The 14th International Blue Whiting Spawning stock Survey 2017 shows an increase in total stock biomass of 9% with a corresponding increase in total abundance of 2% when compared to the 2016 estimate.
- The survey was carried out over 21 days and thus within the recommended 21 day time window agreed by the group.

- Estimated uncertainty around the total stock biomass remains low, CV=0.14 which is the same value as in 2016.
- The stock biomass within the survey area was dominated by 3, 4, 5 year old fish contributing over 81% of total stock biomass.
- The age structure of the 2017 estimate is considered representative of the age structure of the stock compared to the 2016 estimate.
- The proportion of immature fish (1 year olds) in the 2017 estimate is significantly lower than in 2016 and is most notable in the northern strata around the Faroes. Immature fish were absent from the Rockall and north Porcupine strata.

Interpretation of the results

- The group considers the 2017 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 is comparable with 2016 (2.9 mt and 3.1 mt respectively). However, the SSB has increased significantly over this time period. This is in part due to the high proportion of one year old fish observed during 2016 that have now recruited to the spawning stock as two year old fish this year.
- The 2017 survey estimate and distribution pattern strengthen the concerns regarding the 2015 survey. The 2017 and the 2016 estimates are similar in abundance and more closely aligned with trends observed in biomass and age structure during the period 2011-2014 making the 2015 estimate an outlier in the time series.
- The bulk of SSB was distributed from north of the Porcupine Bank and continued northwards through the Rockall Trough.
- Although not considered a reliable indicator of emerging year class strength this survey has in the past foreseen strong or weak signals from observations the northern strata, as in 2016. The lack of abundance of one year olds in 2017, although not definitive may indicate a poor emerging 2016 year class.

Recommendations

- The 2017 acoustic sampling intensity within stratum 2 was deemed too high resulting in the temporal mismatch by the vessel covering this block. To address this issue the group recommends a reduced sampling intensity in this block.
- 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 are observed for 15 nmi consistent ‘clear water’ miles. This applies to peripheral regions to the west of the Rockall and Hatton Bank areas.
- 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 2018 and put forward to StoX developers as routine output formats.
- The group requires as a matter of priority that the future contribution of survey effort by Russia is established. If non-participation is on-going then this will require additional survey days by other vessels to meet the shortfall. This will require planning over the

longer term. To that end we ask that the intentions of Russia be clearly laid out in the medium term at WGIPS 2018 or before.

- The group again stresses the need for physical participation of at least one member form each country (vessel) at the post cruise meeting to facilitate the timely delivery of the final report.
- 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.

Achievements

- The entire survey area (135,085 nmi²) was covered in 21 days just over the group recommendation of 21 days, an achievement considering the reduced vessel number.
- The number of aged samples used in the analysis was maintained at a comparable level to 2016. However, the number of trawl stations and transect miles (acoustic sampling) was less than in years when 5 vessels participated.

References

Demer, D. A., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., Domokos, R., *et al*. 2015. Calibration of acoustic instruments. ICES Cooperative Research Report No. 326.

ICES. 2012. Report of the Workshop on implementing a new TS relationship for blue whiting abundance estimates (WKTSBLUES), 23–26 January 2012, ICES Headquarters, Copenhagen, Denmark. ICES CM 2012/SSGESST:01. 27 pp.

ICES. 2015. Manual for International Pelagic Surveys (IPS). Series of ICES Survey Protocols SISP 9 – IPS. 92 pp.

ICES 2016. First Interim Report of the Working Groupof International Pelagic Surveys (WGIPS). ICES CM SSGIEOM/05, 433 pp.

Jolly, G. M., and I. Hampton. 1990. A stratified random transect design for acoustic surveys of fish stocks. Canadian Journal of Fisheries and Aquatic Sciences 47(7): 1282-1291.

Simmonds, J. and MacLennan D. 2007. Fisheries acoustics, theory and practice. Second edition. Blackwell publishing.

Table 1. Country and vessel specific details, IBWSS March-April 2017.

	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	3.0-3.2	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/SAIV SD208
Standard sampling depth (m)	1000	1000	1000	1000

Table 2. Acoustic instruments and settings for the primary frequency, IBWSS March-April 2017.

	Celtic Explorer	Magnus Heinason	Tridens	Kings Bay
Echo sounder	Simrad EK 60	Simrad EK60	Simrad EK 60	Simrad EK 60
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	9.8
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	21.9
2-way beam angle (dB)	-20.6	-20.8	-20.6	-20.6
Sv Transducer gain (dB)				
Ts Transducer gain (dB)	25.90	25.62	26.54	22.94
s_A correction (dB)	-0.67	-0.66	-0.66	-0.64
3 dB beam width (dg)				
alongship:	6.82	7.1	6.87	7.07
athw. ship:	6.88	7.1	6.89	7.08
Maximum range (m)	750	750	750	750
Post processing software	Myriax Echoview	Myriax Echoview	LSSS	LSSS

Table 3. Survey effort by vessel, IBWSS March-April 2017.

Vessel	Effective survey period	Length of cruise track (nmi)	Trawl stations	CTD stations	Plankton sampling WP2-net	Aged fish	Length-measured fish
Celtic Explorer	21/3-2/4	1493	16	27	-	749	2179
Magnus Heinason	1/4-10/4	1,212	6	16	11	400	990
Kings Bay	23/3- 4/4	1,711	12	22*	22	328	1,100
Tridens	22/3-2/4	1689	12	35	-	1,000	1,000
Total	21/3-10/4	6,105	46	100	33	2,477	5,269

* Due to technical difficulties these data were discarded

Table 4. Abundance and biomass estimates of blue whiting by stata in 2017 and 2016. IBWSS March-April 2017.

		2017				2016				% difference 2016 to 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	616	7 367	19.6	20.9	236	2 745	8.2	8.0	139%	163%
2	N Porcupine Bank	177	2 084	5.6	5.9	335	4 078	11.7	11.8	-52%	-50%
3	Rockall Trough	1 871	20 855	59.7	59.3	1 376	14 877	47.9	43.2	25%	37%
4	South Faroes	102	881	3.2	2.5	323	4 321	11.2	12.5	-71%	-80%
5	Rockall Bank	215	2 321	6.9	6.6	295	3 913	10.3	11.4	-33%	-42%
6	Faroe/Shetland Ch.	154	1 670	4.9	4.7	307	4 513	10.7	13.1	-54%	-64%
	Total	3 135	35 178	100	100	2 873	34 447	100	100		

Table 5. Survey stock estimate of blue whiting, IBWSS March-April 2017.

					Age in years (year class)						Number	Biomass	Mean	Prop	SSN
Length	1	2	3	4	5	6	7	8	9	10+			weight	Mature	
(cm)	2016	2015	2014	2013	2012	2011	2010	2009	2008		(10^6)	(10^6 kg)	(g)		(10^6)
18-19	10										10	0.3	29	0	0
19-20	38	50									88	3.8	43	39	35
20-21	89	103									192	9.2	48	83	158
21-22	117	167									284	14.5	51	100	284
22-23	22	187	271	57							537	31.3	58	100	537
23-24		466	1 858	553	60						2 936	187.4	64	100	2928
24-25		558	4 315	1 914	140						6 927	482.9	70	100	6901
25-26		434	4 447	2 058	531						7 470	573.6	77	100	7470
26-27		151	2 816	2 019	415	131	25				5 556	475.9	86	100	5556
27-28		65	1 213	1 563	607	122	107				3 676	351.7	96	100	3676
28-29			739	1 119	677	49	27				2 612	279.6	107	100	2612
29-30			194	469	625	357	104	16			1 765	209.1	118	100	1765
30-31			86	310	238	387	170				1 190	156.3	131	100	1190
31-32				99	158	218	227				701	104.6	149	100	701
32-33				21	126	176	23	2			349	57.0	164	100	349
33-34				8	34	118	65		29	8	262	46.1	176	100	262
34-35					9	51	94			9	162	32.0	197	100	162
35-36						86	5	26		9	126	28.6	228	100	126
36-37				6	2	8	36	10	15	64	141	34.4	245	100	141
37-38						8	18	6	10	41	82	21.4	260	100	82
38-39									12	27	39	10.2	260	100	39
39-40										20	20	6.1	301	100	20
40-41										14	14	4.1	284	100	14
41-42										17	17	6.8	411	100	17
42-43								15			15	5.6	380	100	15
43-44										7	7	2.4	370	100	7
TSN(mill)	275	2 180	15 939	10 196	3 621	1 711	900	75	66	144	35 178				
TSB(1000 t)	13.2	150.2	1 241.2	890.9	381.0	237.4	131.2	17.9	14.3	38.2	3 134.9				
Mean length(cm)	20.6	23.8	25.3	26.2	27.8	30.4	30.9	35.5	35.3						
Mean weight(g)	48	69	78	87	105	139	146	240	219						
% Mature	64	97	100	100	100	100	100	100	100	100					
SSB (1000kg)	8.4	146.3	1239.3	890.5	381.0	237.4	131.2	17.9	14.3	38.2	3104.6				
SSN (mill)											35047				

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

*Survey discarded.

Table 7. Comparable 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

* No Russian vessel in 2016 and 2017.

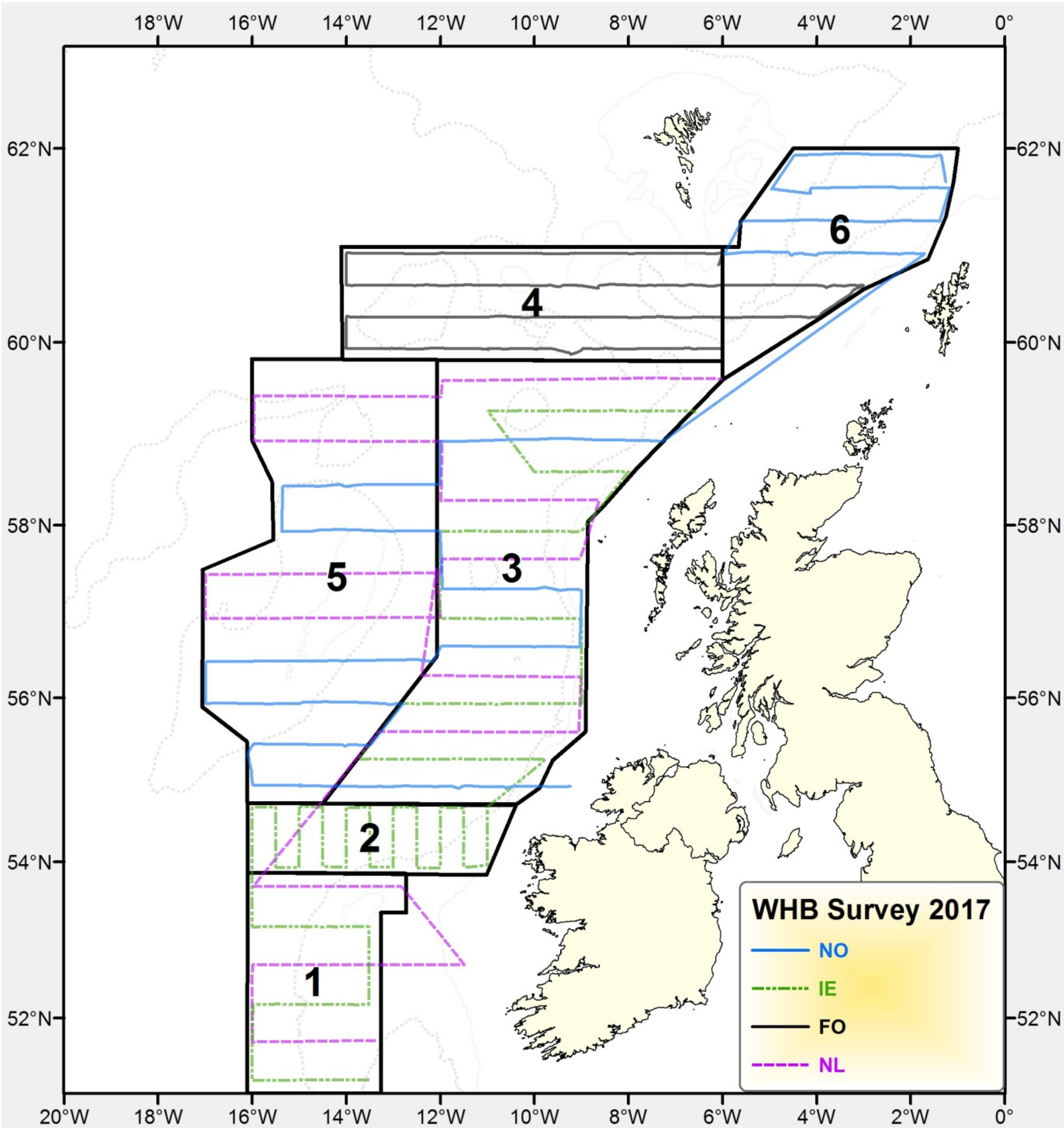


Figure 1. Strata and cruise tracks for the individual vessels (country) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2017.

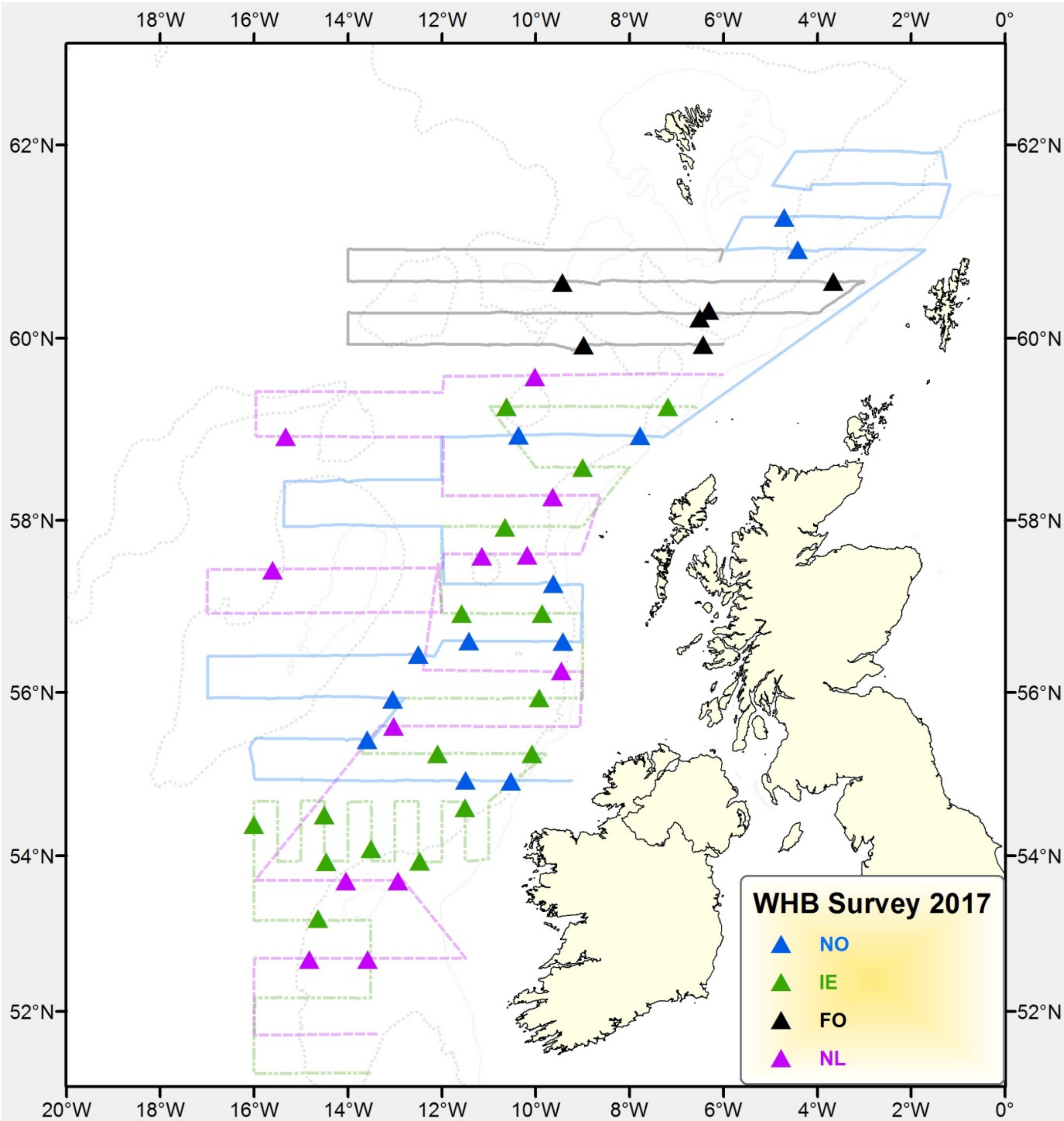


Figure 2. Vessel cruise tracks and trawl stations of the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2017. IE: Ireland (Celtic Explorer); FO: Faroe Islands (Magnus Heinason); NL: Netherlands (Tridens); NO: Norway (Kings Bay).

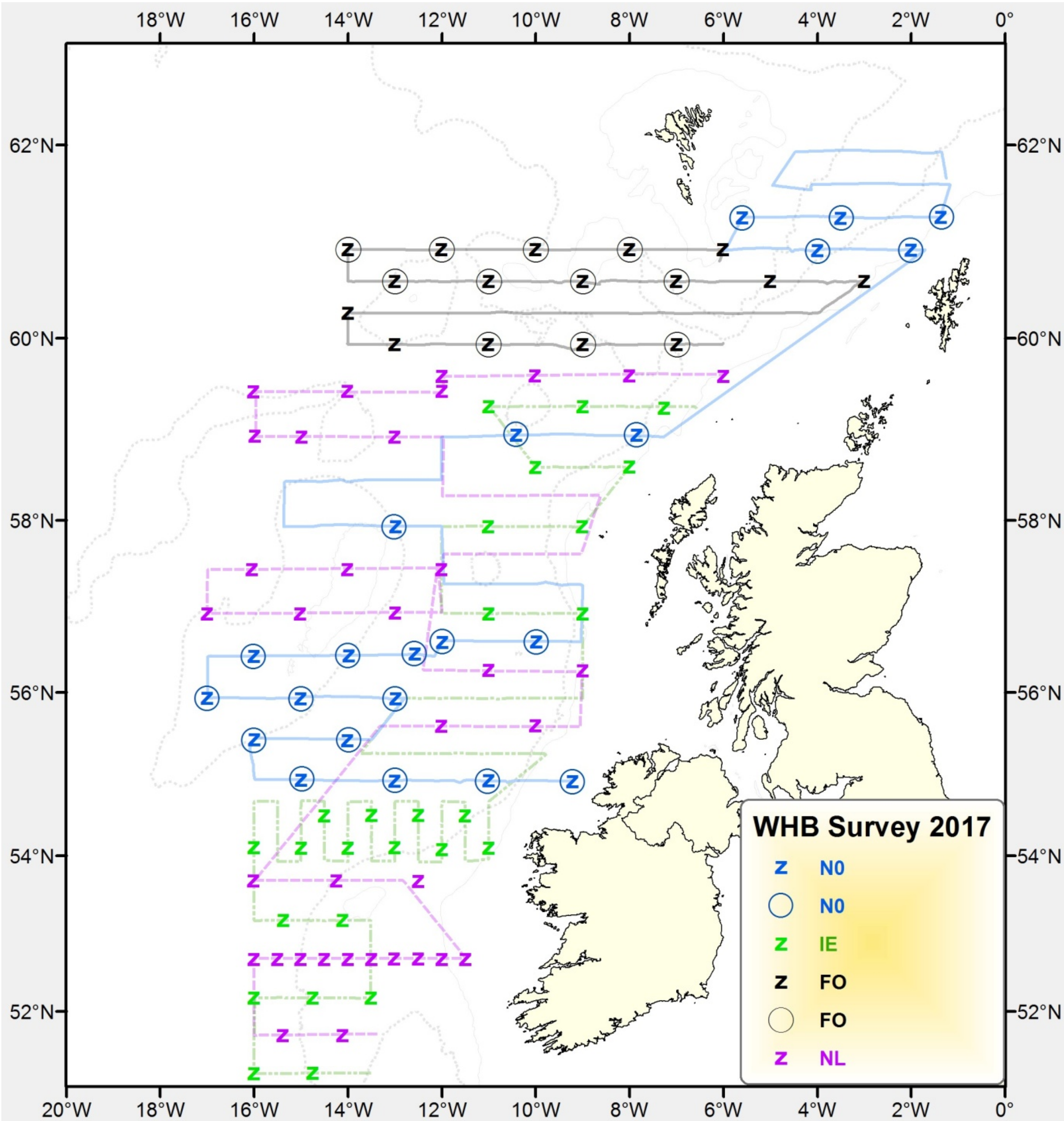


Figure 3. Vessel cruise tracks with hydrographic CTD stations (z) and WP2 plankton net samples (citrcles) during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2017. Colour coded by vessel.

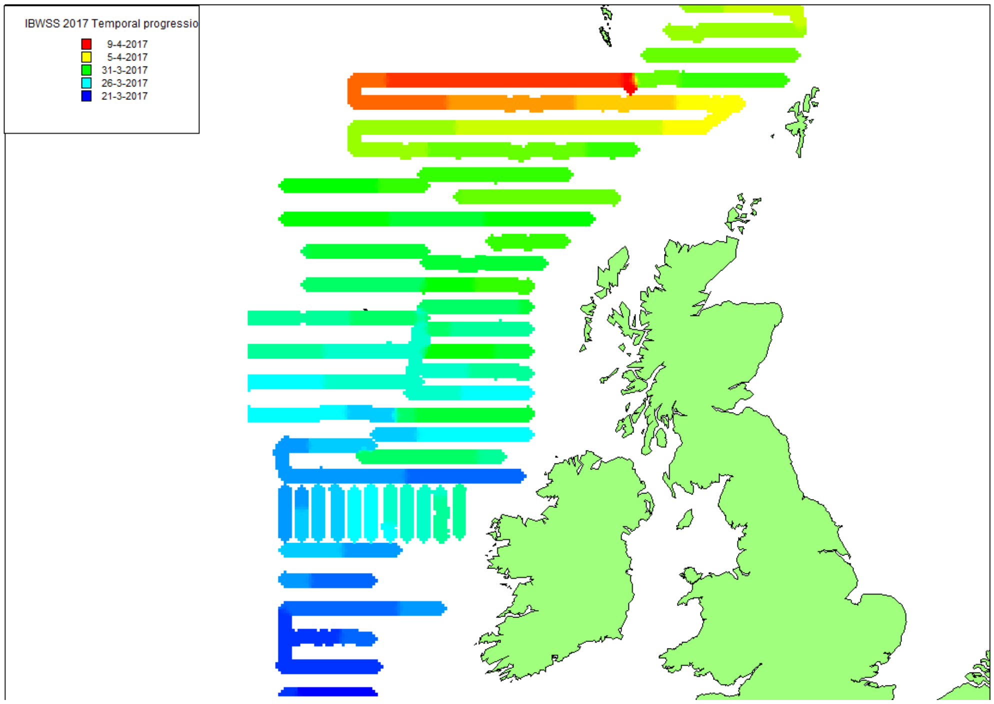


Figure 4. Temporal progression for the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2017.

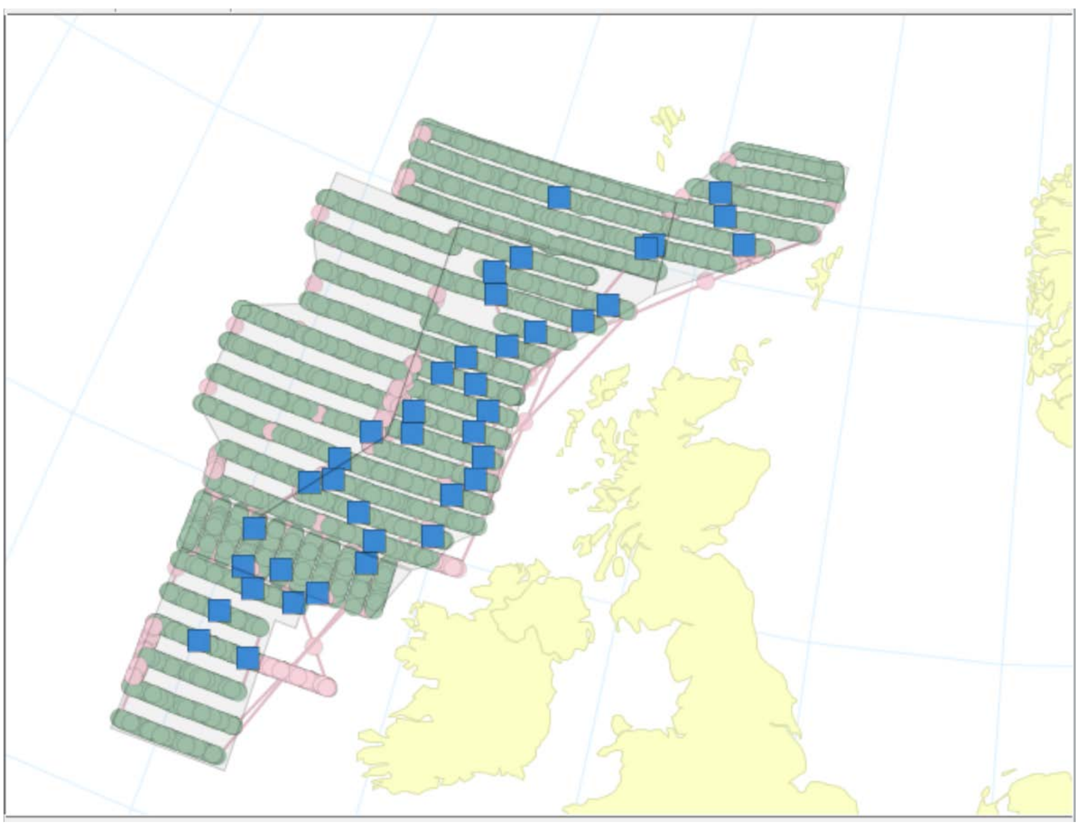


Figure 5. Tagged acoustic transects (green circles) with acociated trawl stations (blue squares) used in the StoX abundance estimation. IBWSS March-April 2017.

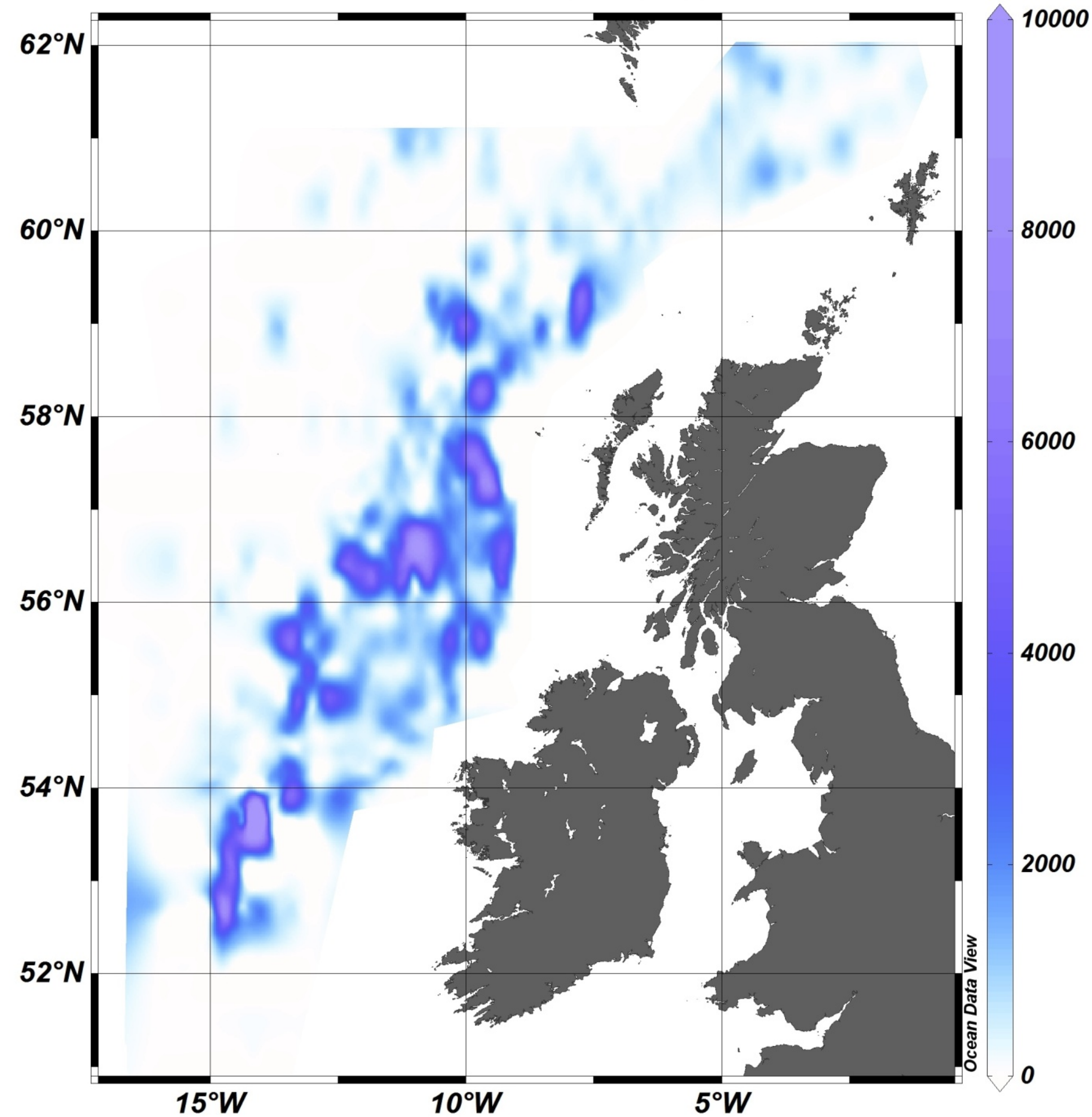


Figure 6. Map of acoustic density (s_A m^2/nmi^2) of blue whiting during the International Blue Whiting Spawning Stock Survey (IBWSS) from March-April 2017.

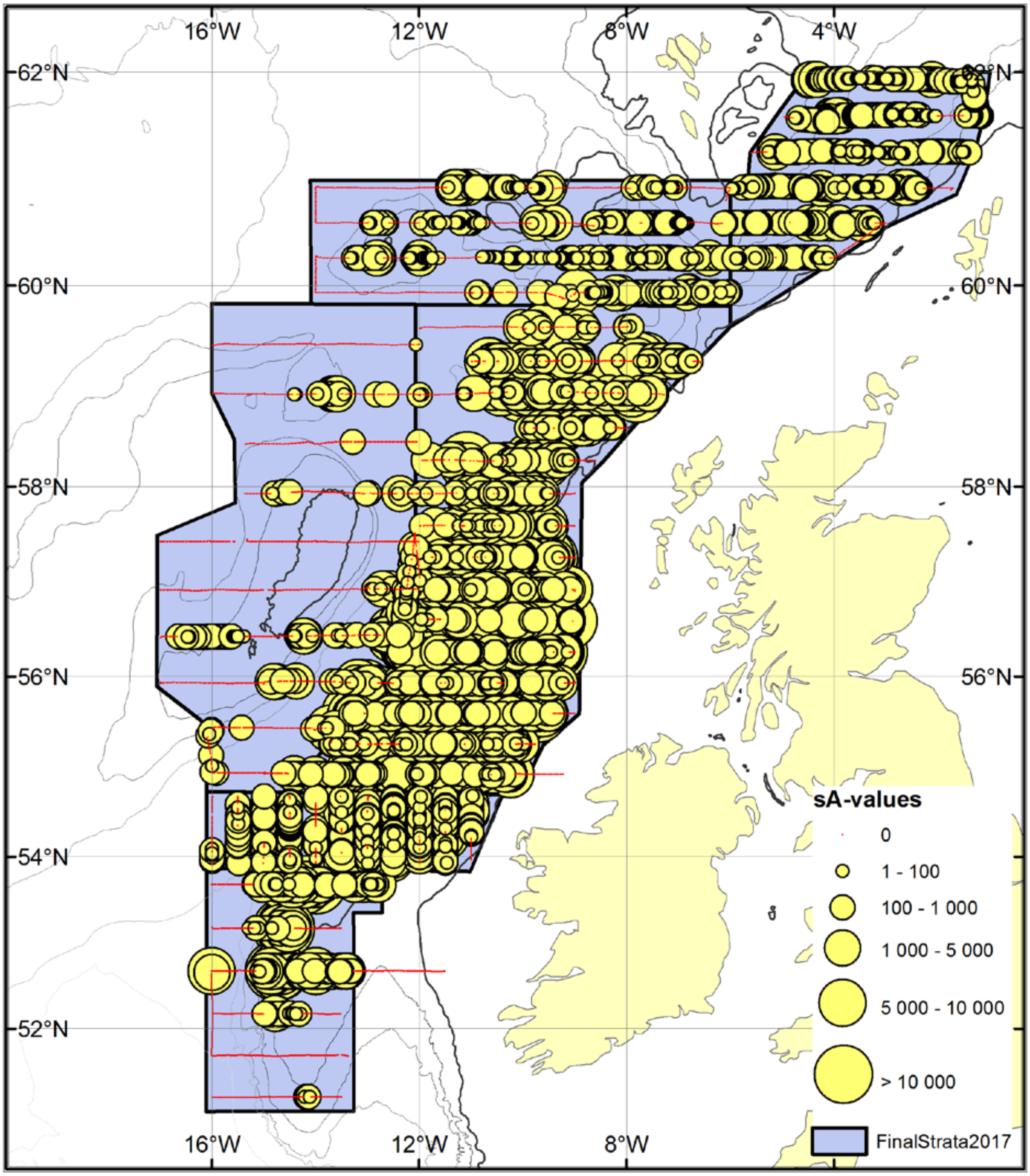
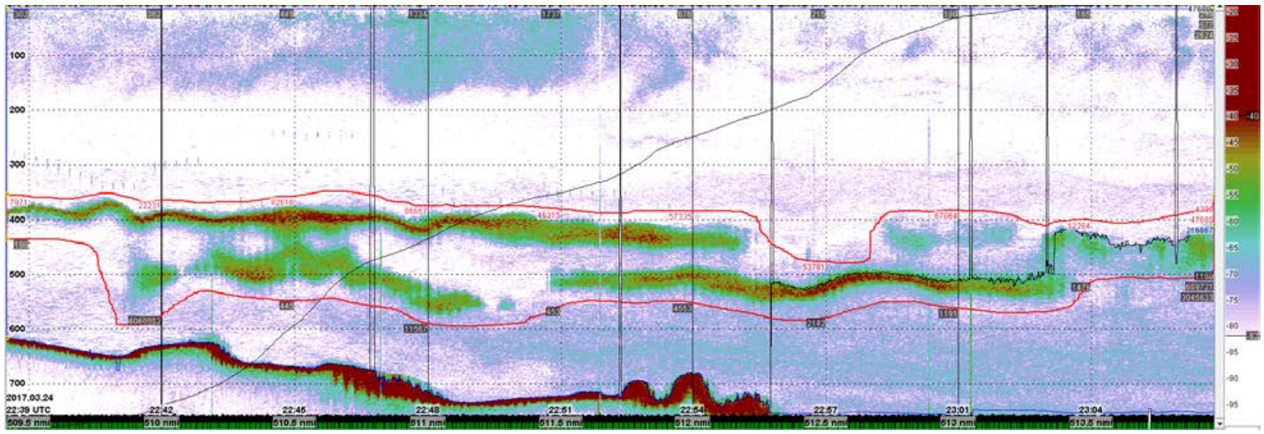
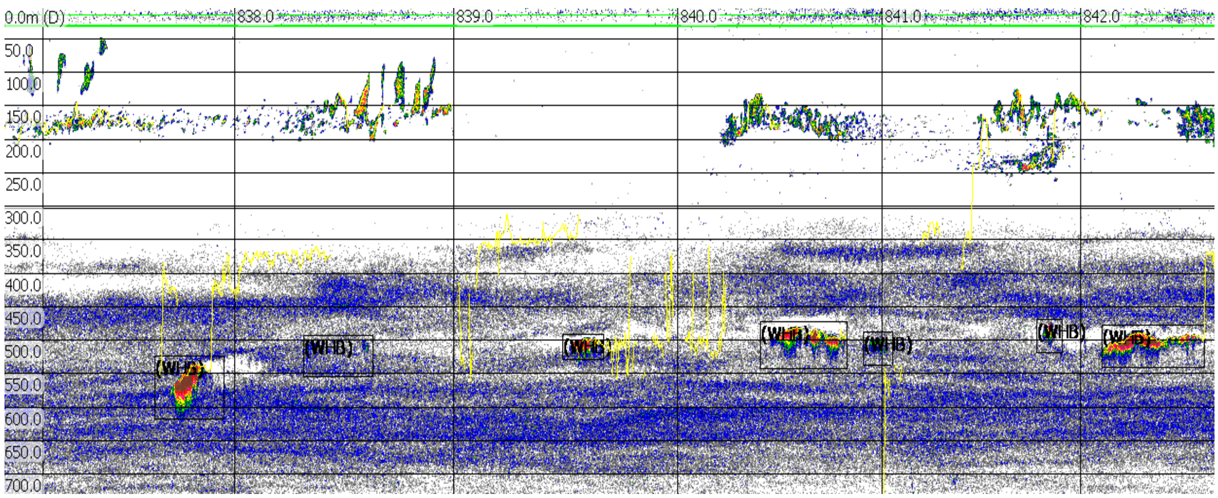


Figure 7. Map of acoustic density (s_A m^2/nmi^2) of blue whiting by 1 nmi (circle scaled by acoustic density). IBWSS March-April 2017.



a) Very high density school of blue whiting registered by Tridens in the Western Porcupine Bank area.



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

Figure 8. Echograms of interest encountered during the IBWSS, March-April 2017: a) Tridens and b) Celtic Explorer.

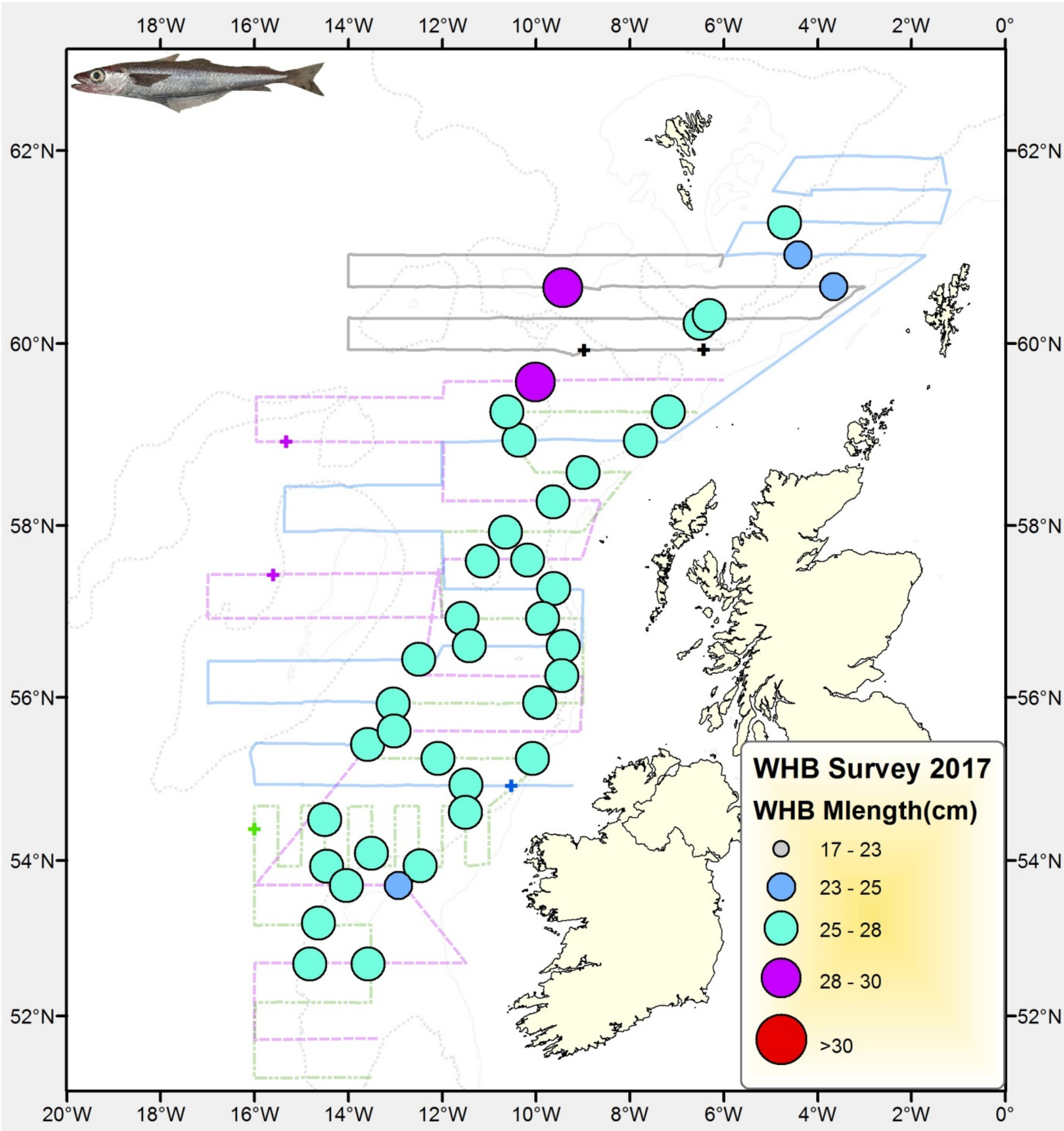


Figure 9. Combined mean length of blue whiting from trawl catches by vessel, IBWSS in March- April 2017. Crosses indicate hauls with zero blue whiting catches.

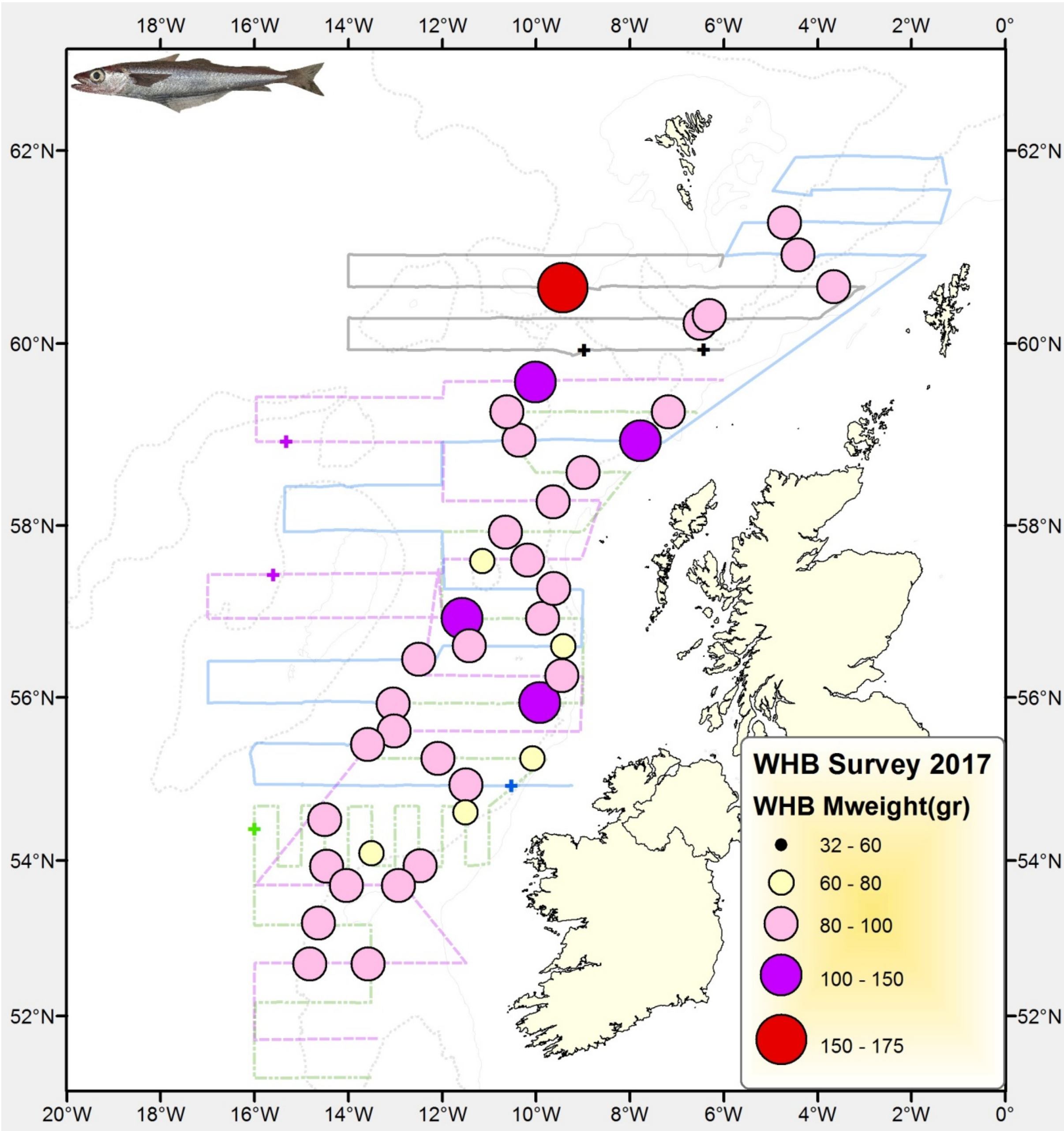


Figure 10. Combined mean weight of blue whiting from trawl catches, IBWSS March- April 2017. Crosses indicate hauls with zero blue whiting catches.

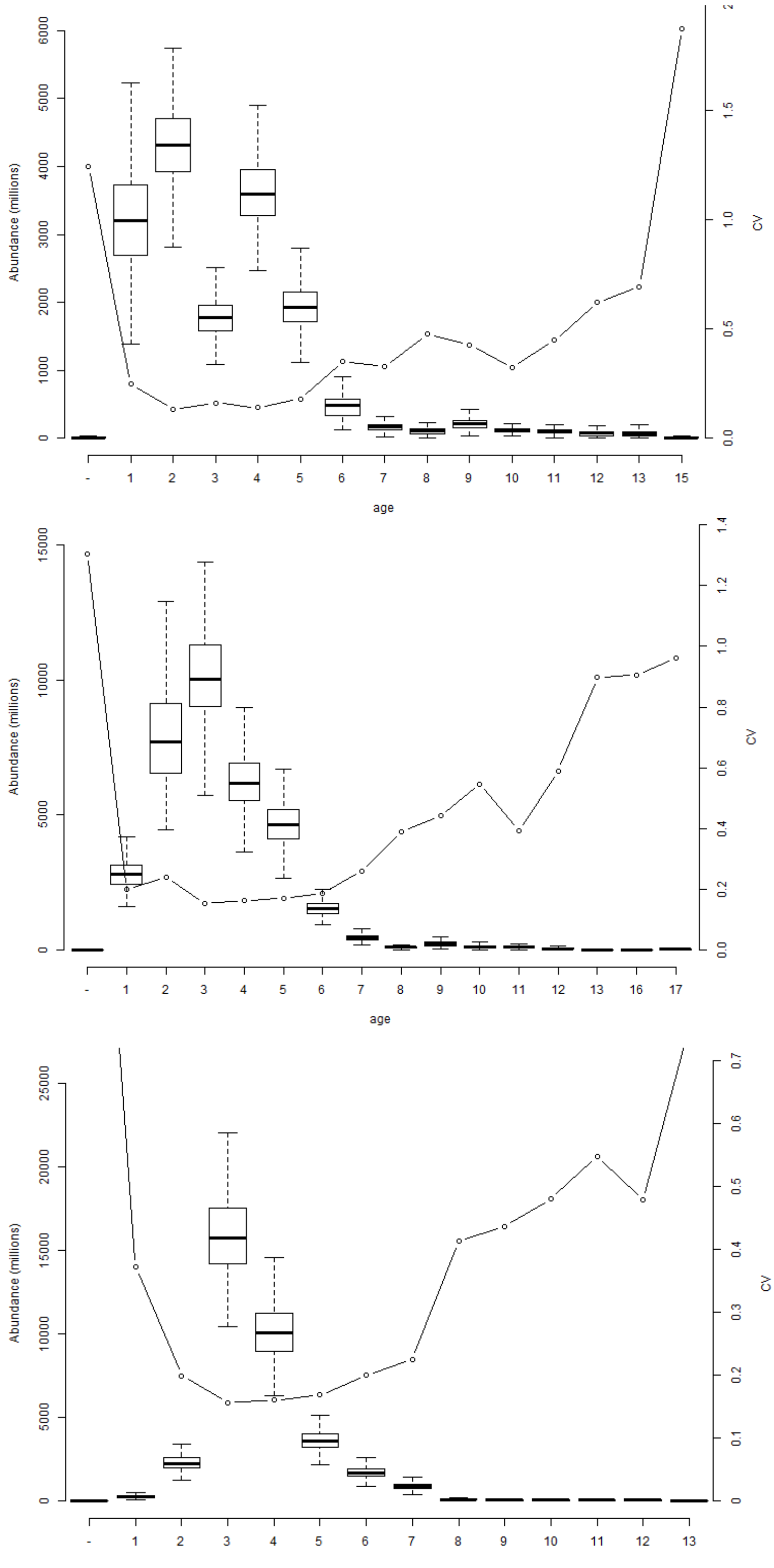


Figure 11. Blue whiting bootstrap abundance (millions) by age (left axis) and acociated CVs (right axis) in 2015 (top panel), 2016 (middle panel) and 2017 (lower panel). From StoX.

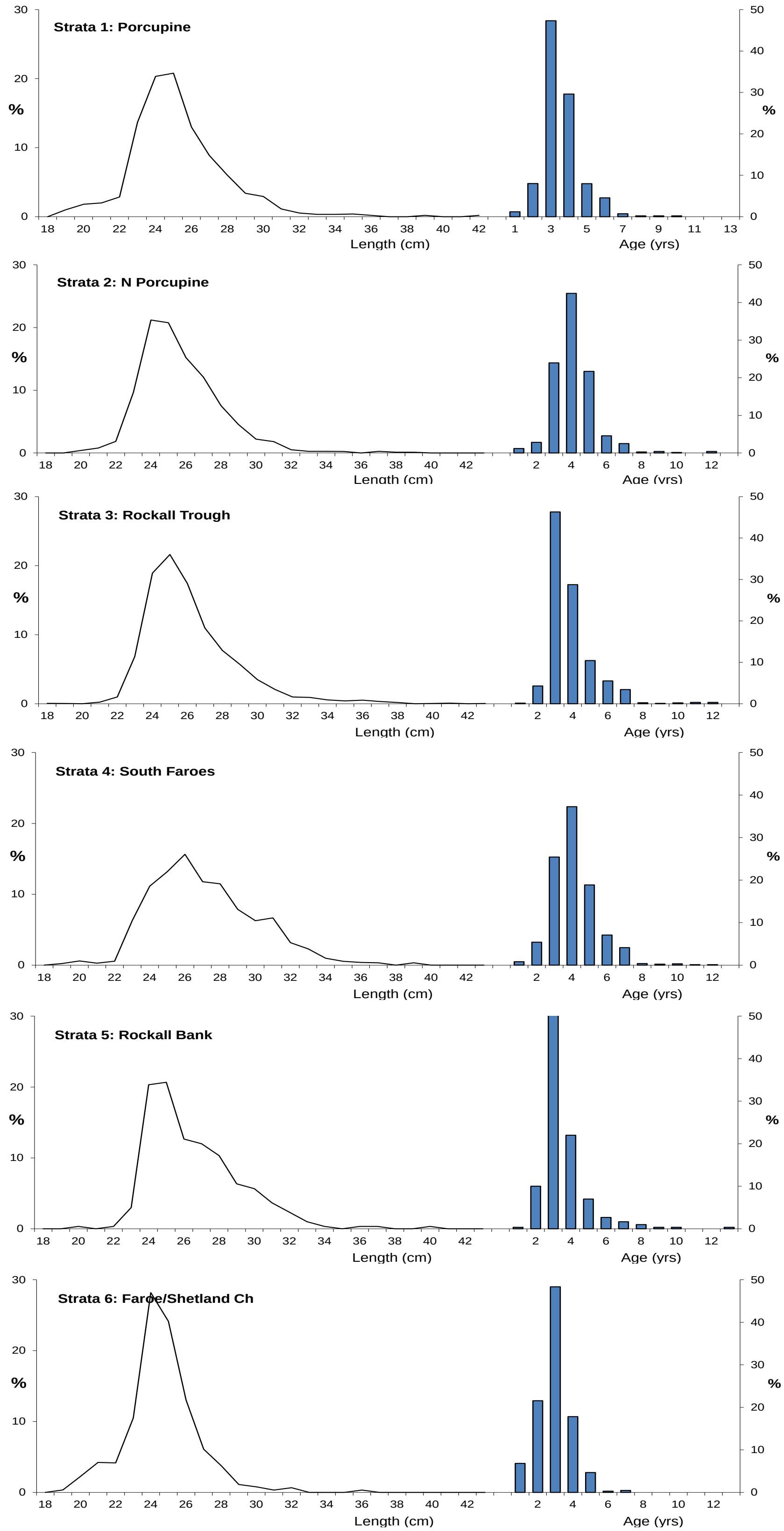


Figure 12. Length and age distribution (numbers) of blue whiting by survey strata. March-April 2017.

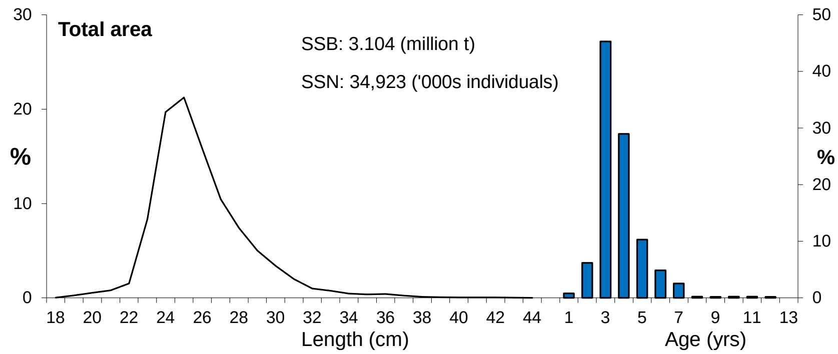


Figure 13. Length and age distribution (numbers) of total stock of blue whiting. March-April 2017.

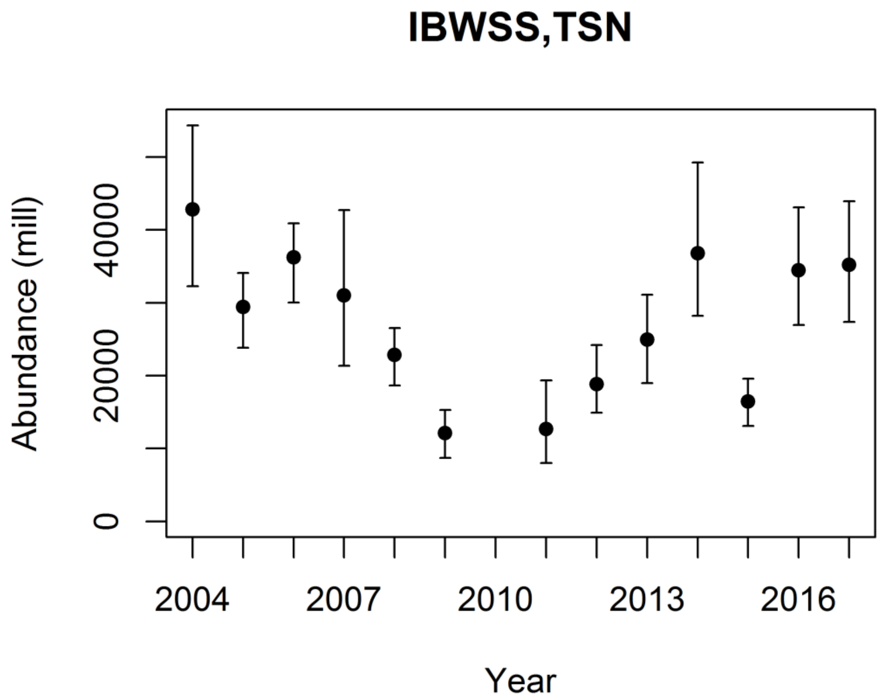


Figure 14. Time series of StoX survey indices of blue whiting abundance.

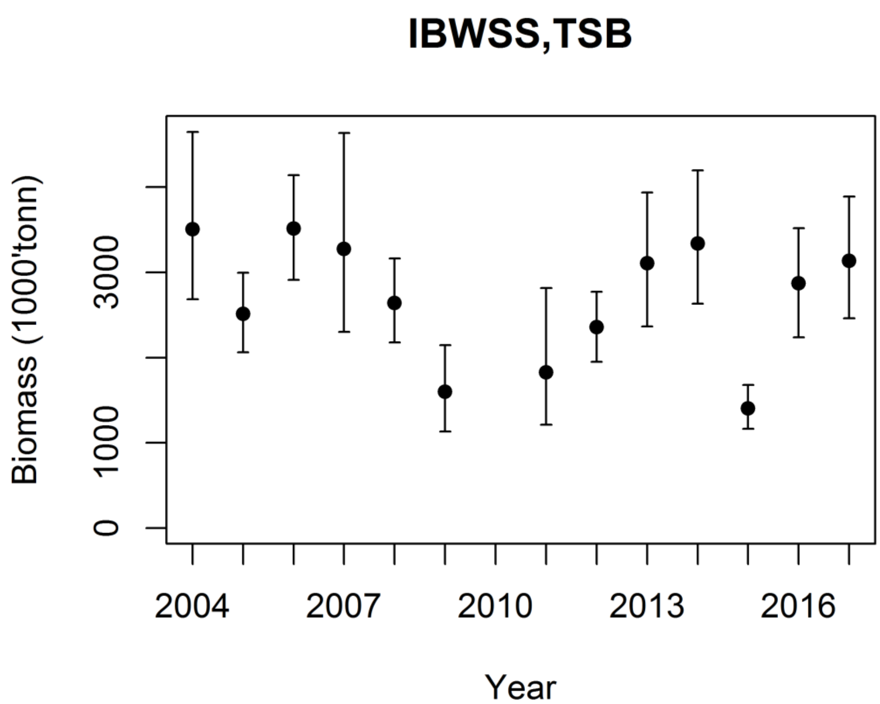


Figure 15. Time series of StoX survey indices of blue whiting biomass.

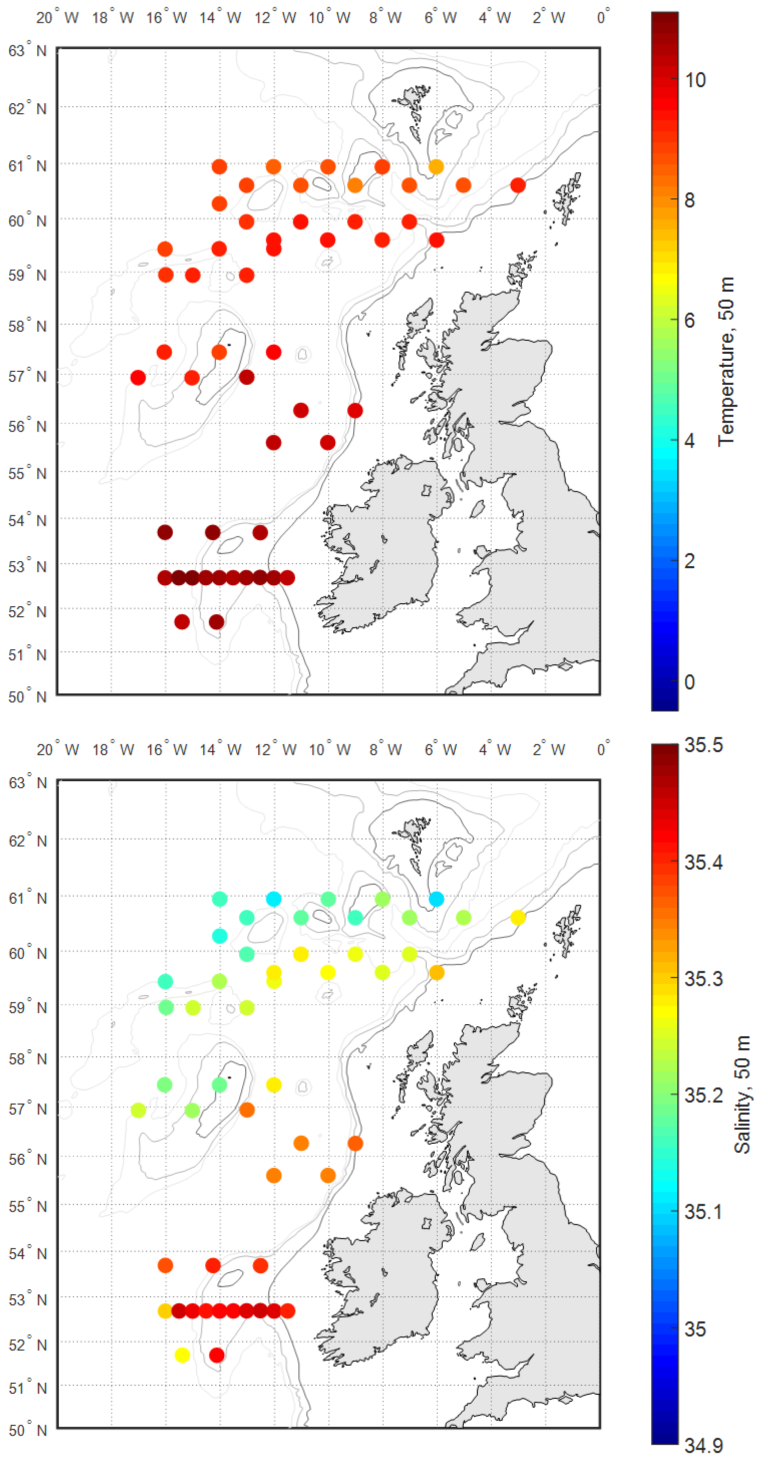


Figure 16. Horizontal temperature (top panel) and salinity (bottom panel) at 50 m subsurface as derived from vertical CTD casts. IBWSS March-April 2017.

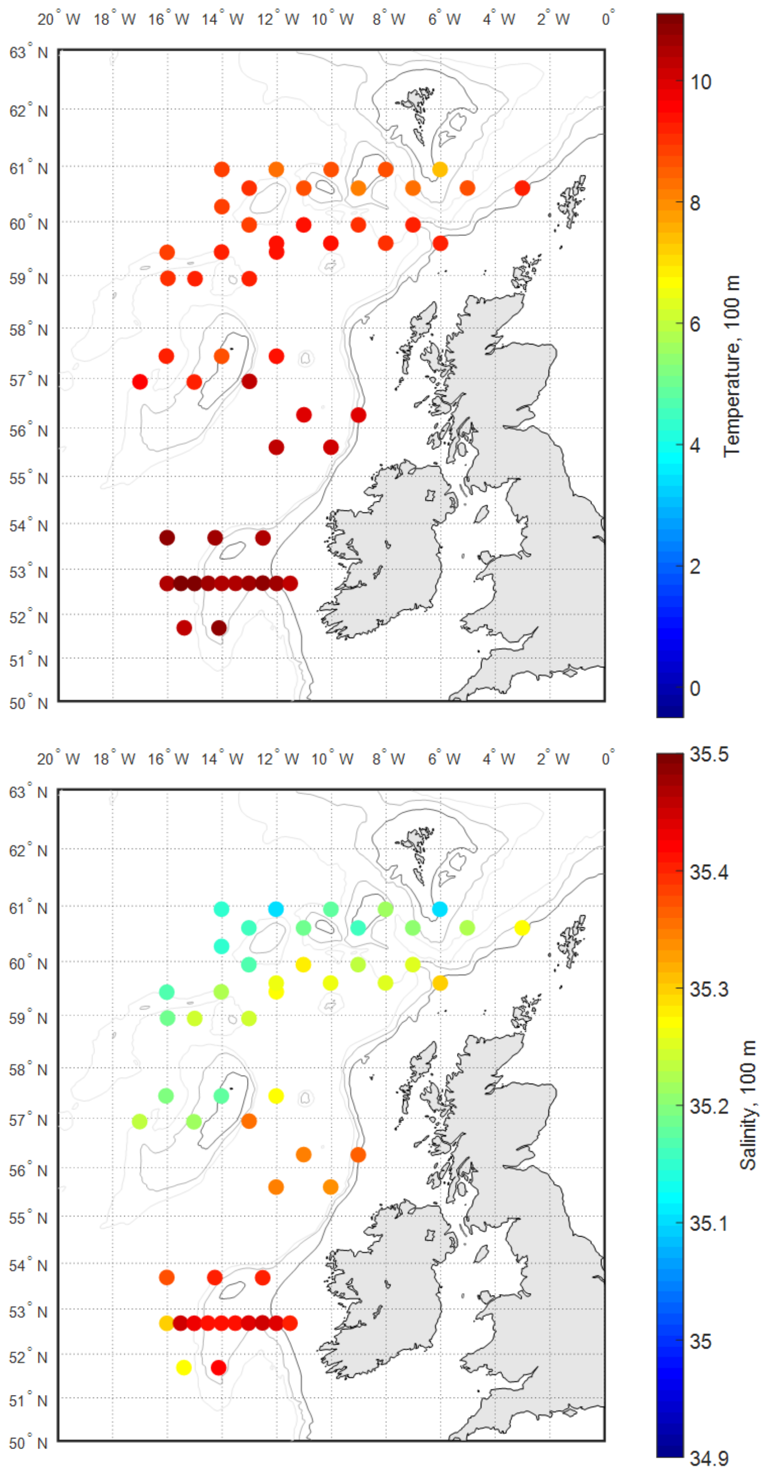


Figure 17. Horizontal temperature (top panel) and salinity (bottom panel) at 100 m subsurface as derived from vertical CTD casts. IBWSS March-April 2017.

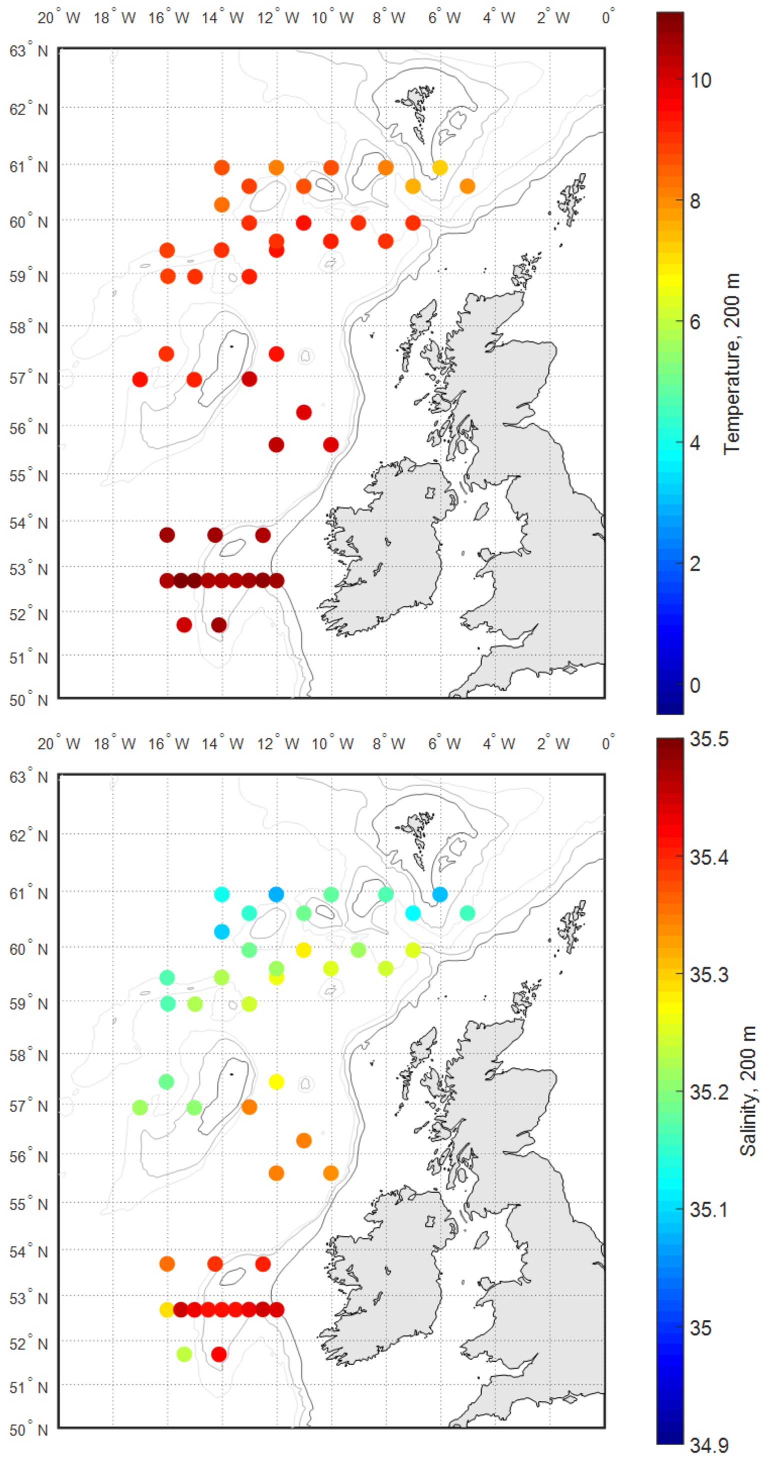


Figure 18. Horizontal temperature (top panel) and salinity (bottom panel) at 200 m subsurface as derived from vertical CTD casts. IBWSS March-April 2017.

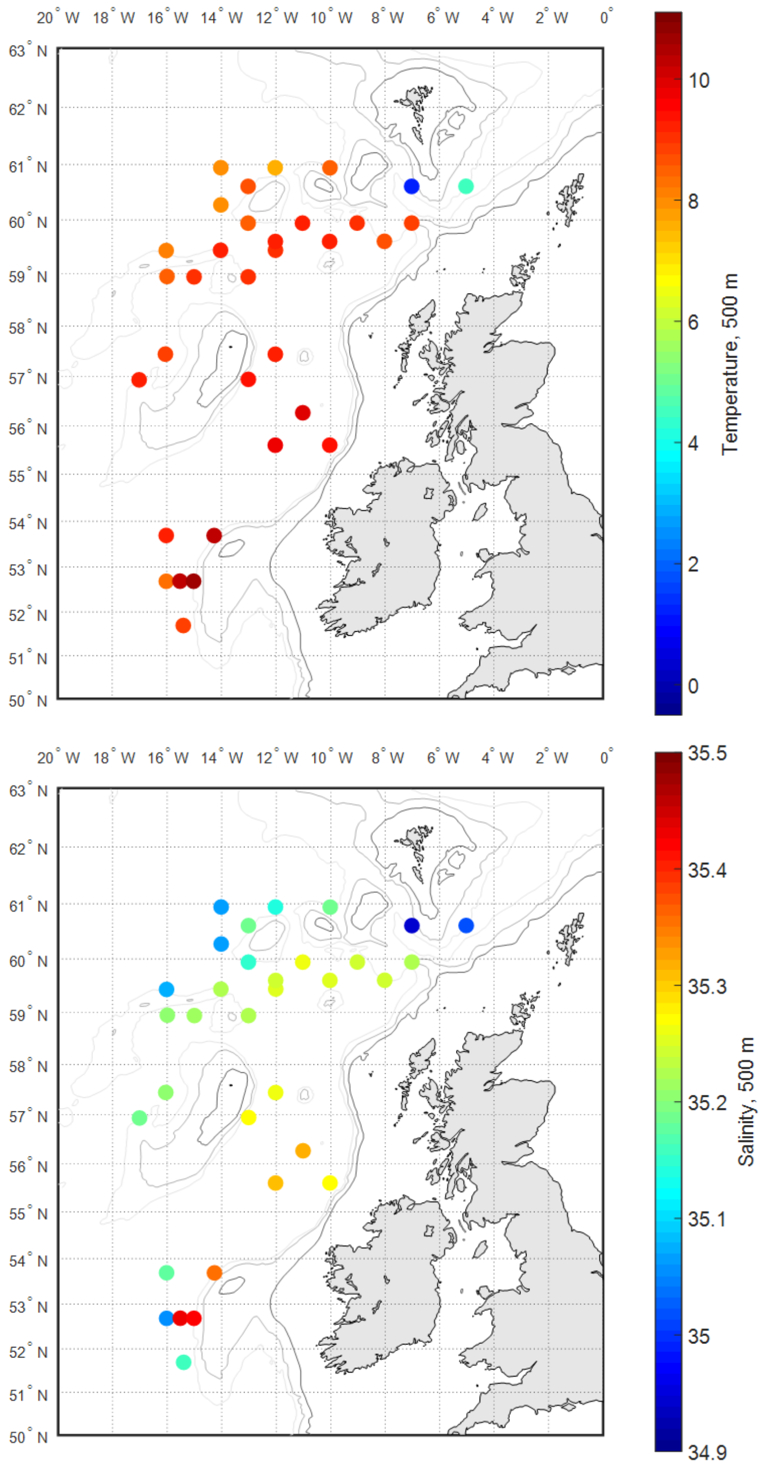


Figure 19. Horizontal temperature (top panel) and salinity (bottom panel) at 500 m subsurface as derived from vertical CTD casts. IBWSS March-April 2017.

Annex 5b: International Ecosystem Survey in Nordic Sea (IESNS) survey report 2017

Survey Summary table

Name of the survey (abbreviation):	IESNS

Summary: CruiseReport Link:http://hdl.handle.net/10793/

Survey coverage was considered adequate in 2017 and in line with previous years. For NSS herring, the zero-line is believed to be reached throughout the survey area, and it is therefore recommended that the results can be used for assessment purpose.

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 sampling at some stations.

The herring was primarily distributed in the western Norwegian Sea, but there were also aggregations off the northern Norwegian coast. In the Barents Sea the main aggregations were observed in the eastern part. Registrations of NSS herring were low in the southeastern part of the survey area.

The total biomass estimate of herring in the Norwegian Sea was 4.2 million tonnes. This estimate is 1.2 million tonnes lower than in 2016. The herring stock is dominated by 3, 7 and 12 years old herring (year classes 2013, 2005 and 2004) in terms of numbers, with the 2013 and 2004 contributing equally to the biomass. In the Barents Sea, the total herring abundance estimate was 14.7 billion individuals of age 1 and 3.3 billion individuals of age 2. The total biomass of blue whiting in the Norwegian Sea was 0.93 million tons, which is a 40% decrease from the biomass estimate in 2016 (1.54) but similar to 2015 (0.96). Age three is dominating the estimate.

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

	Description
Survey design	Stratified transect design with randomised start point in each stratum.
Index Calculation method	StoX (via the PGNAPES database)
Random/systematic error issues	Challenges related to allocation of backscatter to species in areas with mixed registrations of blue whiting and herring. Concern regarding differences in estimated strata specific age distribution between vessels.
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, relatively good weather dominated the survey in 2016
Extinction (shadowing)	NA
Blind zone	Possible occurrence of herring above transducer depth
Dead zone	NA
Allocation of backscatter to species	Directed trawling for verification purposes
Target strength	Blue whiting: TS = 20 log(L) – 65.2 dB Herring: TS = 20.0 log(L) – 71.9 dB
Calibration	All survey frequencies calibrated and results within recommended tolerances

Working Document

Post-cruise meeting of the Working Group on International Pelagic Surveys (WGIPS)
Bergen, Norway, 20 – 22 June 2017

Working Group on Widely distributed Stocks
Copenhagen, Denmark, 30 August - 5 September 2017

INTERNATIONAL ECOSYSTEM SURVEY IN NORDIC SEA (IESNS) in May – June 2017

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9 Cefas, Lowestoft, UK

Introduction

In May-June 2017, six research vessels; R/V Dana, Denmark (joined survey by Denmark, Germany, Ireland, The Netherlands, Sweden and UK), R/V Magnus Heinason, Faroe Islands, R/V Arni Friðriksson, Island, R/V G.O. Sars Norway and R/V Fridtjof Nansen, 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 2016, Magnus Heinason: Homrum, Smith, FAMRI 1718-2017, Árni Friðriksson: Óskarsson et al. 2017, Fridtjof Nansen: Rybakov PINRO 2017.

Material and methods

Coordination of the survey was done during the WGIPS meeting in January 2017. 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	28/04-23/05
G.O. Sars	Institute of Marine Research, Bergen, Norway	02/5-5/6
Fridtjof Nansen	PINRO, Russia	24/5–17/6
Magnus Heinason	Faroe Marine Research Institute, Faroe Islands	04/5- 15/5
Arni Friðriksson	Marine and Freshwater Research Institute, Iceland	10/5-23/5

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.

In general, the weather condition did not affect the survey even if there were some days that were not favourable and prevented for example WP2 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	Fridtjof Nansen
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)	3	8.5	8	3	5.2
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	-20.8	-20.81	-20.8	-20.7
Sv Transducer gain (dB)					
Ts Transducer gain (dB)	25.32	25.34	24.28	25.62	25.57
s_A correction (dB)	-0.56	-0.66	-0.61	-0.66	-0.59
3 dB beam width (dg)					
alongship:	6.8	7.06	7.31	7.1	6.89
athw. ship:	6.8	7.03	6.95	7.1	6.92
Maximum range (m)	500	500	500	500	450
Post processing software	LSSS	LSSS	LSSS	Sonardata Echoview 7.1	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 with the different software (see table above) 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	Fridtjof Nansen
Circumference (m)		832	832	640	500
Vertical opening (m)	25-35	45–50	30–35	45–55	50
Mesh size in codend (mm)		40	40	40	16
Typical towing speed (kn)	3.0-4.0	4.0–4.5	3.0–5.1	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 estimates of herring and blue whiting abundance were obtained during the surveys. This was carried out by visual scrutiny of the echo recordings using post-processing systems. The allocation of NASC-values to herring, blue whiting and other acoustic targets were based on the composition of the trawl catches and the appearance of echo recordings according to the agreed scrutinizing procedures (ICES 2009 and Annex 4 in ICES 2015).
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 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.

Some preliminary results from ongoing work with sonar were presented at the meeting, and some of these are presented as appendices to this report (Appendix 1 and 2).

Results

Hydrography

Temperature distribution for April-June 2017

The temperature and salinity distributions in the ocean at 5m, 50m, 100, 200m and 400m depth are shown in Figures 4 and 5. The temperature distributions in the ocean, averaged over selected depth intervals; 0-50 m, 50-200 m, and 200-500 m, are shown in Figures 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 (Figure 6). The Arctic front was encountered slightly below 65°N east of Iceland extending eastwards towards 4-5° West where it turned almost straight northwards up 70°N. The front was visible 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 nearly 70° N in the surface layers.

Relative to a 21 years long-term mean, from 1995 to 2015, the temperatures at all depths over the most of the Norwegian Sea and in the eastern part of the Iceland Sea were considerable higher in 2017 compared to the long-term mean (Figures 6-8). Relative warmest water was in the southern Norwegian and Iceland Sea where the temperatures in some regions were more than 1 °C higher than the mean. In the eastern area of the Norwegian Sea, along the continental shelf, the temperatures were closer to the long-term average.

The temperature in the upper 800 m at the Svinøy section in May 2017 is shown in Figures 9. Atlantic water is lying over the colder intermediate layer and reach down to 500 m at the shelf edge and down to 200 m depth further west. The warmest water is located near the shelf edge where the core of the inflowing Atlantic Water is located. Westward temperature is reduced due to mixing with colder water. Relative to a long-term mean the temperatures on the shelf were higher in 2017 while it was lower at the shelf edge where the main northward transport of Atlantic Water is located. In the western part of the section the temperatures in the upper 300 m were about 1°C higher than the long-term mean.

Zooplankton

Zooplankton biomass (g dry weight m^{-2}) at 0-200m at the sampling stations is shown in Figure 10. Sampling stations were evenly spread over the area, and most oceanographic regions were covered. Highest zooplankton biomass was observed north of Lofoten/Vesterålen, in the Norwegian Sea basin, and along the Mohn ridge separating the Norwegian and Greenland Seas.

The index for zooplankton biomass for the Norwegian Sea calculated using the objective analysis with a Gaussian correlation function was 10.9 g dry weight m^{-2}, which is an increase from last year's value (Figure 11). All four sub-areas showed the same trends with a period of high zooplankton biomass from mid-1990s to the beginning of 2000, followed by a period of lower zooplankton biomass. The last years, a tendency of an increase can be noted. The zooplankton biomass east of Iceland was in general higher compared with the other sub-areas throughout the time-series period. In the Barents Sea (east of 20°E), the mean zooplankton biomass was 1.9 g dry weight m^{-2} in 2017 compared to 1.6 in 2016. It was 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.

Norwegian Spring-spawning herring

Survey coverage in the Norwegian Sea was considered adequate in 2017 and in line with previous years. The zero-line was believed to be reached for 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 western Norwegian Sea (Figure 12), but there were also aggregations off the northern Norwegian coast. In the Barents Sea the main aggregations were observed in the eastern part. Registrations of NSS herring were low in the southeastern part of the survey area.

As in previous years the smallest fish were found in the eastern area of the Norwegian Sea. As last year, young NSS herring were also caught in and near the Jan Mayen area. Size and age were found to increase to the west and south (Figure 13). Correspondingly, it was mainly older herring that appeared in the southwestern areas. The 2013 year class (age 4) was observed widely in the northern survey area. Its number at age 4 (Table 2) is comparable to the 2009 year class at same age (Figure 14), which indicates that it is larger than the most recent year classes but not a large one like e.g. the 2004 year class.

The herring stock was dominated by 4, 12 and 13 year old herring (year classes 2013, 2005 and 2004) in terms of numbers, with the 2013 and 2004 year classes contributing equally to the biomass (Table 2). The three year classes from 2004, 2005 and 2013 contribute 13%, 13%, and 17%, respectively, to the total biomass in the Norwegian Sea. The total number of herring recorded in the Norwegian Sea was 17.7 billion in 2017. Uncertainty estimates for numbers at age based on bootstrapping within StoX are shown in Figure 15.

The total biomass estimate of herring in the Norwegian Sea from the 2017 survey was 4.2 million tonnes. This estimate is 1.2 million tonnes (23%) lower than in 2016. The biomass decreased from 2009 to 2012, and has then fluctuated from 4.2 to 5.9 million tonnes in the years 2013-2016 (Figure 16), with the lowest abundance occurring in 2017.

The abundance estimates of herring by age and length in the Barents Sea (Stratum 6) are shown in Table 3. The investigations of herring in the Barents Sea covered the area from 40°E to the 20°00´ E. The total abundance estimate was 14.7 billion individuals of age 1 (mean length of 12.7 cm and weight of 12.2 g) and 3.3 billion individuals of age 2 (mean length of

17.1 cm and mean weight of 29.9 g). No older herring were observed. StoX estimates of age 1 from the period 2009-2017 are shown in Figure 17, and these indicate a high index estimate for 2017.

Blue whiting

The spatial distribution of blue whiting in 2017 was similar to the years before, with high 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 and in the open sea in the southern part of the Norwegian Sea (Figure 18). 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 of blue whiting registered during the IESNS survey in 2017 was 0.93 million tons (Table 4), which is a 40% decrease from the biomass estimate in 2016 (1.54) but similar to 2015 (0.96). The total number for 2017 was 9.7 billion, which is about 50% lower than in 2016. Age 3 (2014 year class) is dominating the estimate (44% of the biomass and 44% by number). Uncertainty estimates for numbers at age based on bootstrapping with StoX are shown in Figure 20.

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 or 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 2017 where mackerel was caught over a wide area in the 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 1 (mean length 18.1 cm) was most numerous in the combined samples (not weighed by catch size), and amounted to 32%, followed by age 3 (21%) and age 5 (14%).

Discussion

Hydrography

Discussions related to the oceanographic condition in April/June 2017 are provided in the results section above, while more general patterns are introduced in this section.

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

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

Plankton

The zooplankton biomass index for the Norwegian Sea in May has been estimated since 1995 (Figure 11). 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 2003-2017). A tendency of an increase can be noted in the last part of the low-biomass period. The index for 2017 (10.9 g) is closer in value to the high-biomass period than the low-biomass period. This general pattern applies more or less to all the different sub-areas within the Norwegian Sea (Figure 11).

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. The zooplankton biomass index in the Barents Sea (east of 20°E) was 1.9 g dry weight m^{-2}, which is higher than the previous years 2012-2016 where the biomass was within 0.8-1.7g. As stated above, the biomass estimates for the Barents Sea taken with the Djedi net are not directly comparable to the other areas taken by WP2 nets, but are comparable among years within the Barents Sea.

Summing up, the reason for the observed changes in zooplankton biomass is not clear to us and more ecological and environmental research to reveal this 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

The Norwegian spring-spawning herring is characterized by large dynamics with regard to migration pattern. This applies to wintering, spawning and feeding area. The following discussion will mainly concentrate on the distribution and situation in the feeding areas in May, but no attempt was done to draw up the likely feeding migration, but it is believed to be comparable to recent years.

The total biomass of herring measured in the 2017 survey in the Norwegian Sea was 23% lower than in 2016 (Figure 16). When considering the addition of the 2013 year class to the biomass in 2017 (constituted to 17% of the biomass in 2017), the decrease in the estimates between 2016 and 2017 in the adult stock is even more pronounced. This biomass estimate in 2017 is comparable to the estimates from 2012 and 2014, which had also similar confidence interval.

The estimate on number of age 1 in the Barents Sea in 2017 is higher than seen for the most recent years (Figure 17). It is for example two times higher than the estimates of the 2013 year class in 2014. 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 (e.g. only two samples that were large enough behind the 2017 estimate, taken close to each other).

In the last three years (2014-2016) 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 is in progress at the moment, where scales and otoliths for the same fish have been sampled. It is recommended that a workshop based on this exchange will take place before next year’s survey.

With respect to age-reading concerns in the recent years, the comparison between the nations in this year’s survey showed some different results (Figure 23). The 2004 year class was in higher proportion by the Icelandic and Norwegian readers than the Faroese readers in Stratum 3.

In the 2017 IESNS there were no apparent discrepancies in the acoustic scrutinizing results between any neighbouring vessels. Hence, there was no reason to revisit the acoustic data and the scrutinizing work during the post-cruise meeting.

Blue whiting

The abundance estimate of blue whiting in the IESNS survey 2017 showed a significant decrease from 2016. The biomass estimate decreased as well but not as much as the abundance. A positive sign in development of the stock size was observed in the 2011 survey when blue whiting at age 1 and 2 were in higher numbers than the previous years. In 2017, the number of 1 year old blue whiting was lower than the last three years, indicating a small 2016 year class. The result from the last years showing a strong 2014 year class was confirmed with the three year olds as the most dominant year class in this year's survey in both abundance and biomass (Table 4).

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

Next years post-cruise meeting

19-21 June 2017. Location will be decided at the next WGIPS meeting.

Concluding remarks

- Relative to a 21 years long-term mean, the temperatures at all depths over most of the Norwegian Sea and adjacent waters were considerable higher in 2017, especially in the south and west.
- The 2017 index of meso-zooplankton biomass in the Norwegian Sea and adjoining waters increased from last year and is now comparable to the mean of the earlier high-biomass period, but is still relatively low in the westernmost areas.
- The biomass estimate of NSSH in 2017 was 23% lower compared to last year. The survey in the Norwegian Sea followed the pre-planned protocol and there are no obvious methodological reasons for the decrease in the biomass estimate of NSS-herring from the 2016 survey. The biomass is comparable in size to the estimates from 2012 and to 2014. The survey group recommends using this estimate in the assessment.
- The 2013 year class was most numerous for NSSH followed by six year classes at similar levels – representing relatively equal and wide age distribution in the stock.
- The 2013 year class appears to be around the level of the 2009 year class, i.e. not a strong year class.
- Number of age 1 of NSSH in the Barents Sea was higher than in recent years, which might indicate improved recruitment, but the uncertainty around the estimate is high.
- The biomass of blue whiting measured in the 2017 survey decreased by 40% from last year's survey and by 50% in number.
- Age 3 (2014 ycl) blue whiting is dominating the acoustic estimate (44% of the biomass and by numbers), while the 2016 year class appears to be small.

References

Foote, K. G., Knudsen, H. P., Vestnes, G., MacLennan, D. N., and Simmonds, E. J. 1987. Calibration of acoustic instruments for fish density estimation: a practical guide. ICES Coop. Res. Rep. 144: 1–57.

ICES 2009. Report of the PGNAPES Scrutiny of Echogram Workshop (WKCHOSCRU) 17–19 February 2009, Bergen, Norway ICES CM 2009/RMC

ICES. 2012. Report of the Workshop on implementing a new TS relationship for blue whiting abundance estimates (WKTSBLUES), 23–26 January 2012, ICES Headquarters, Copenhagen, Denmark. ICES CM 2012/SSGESST:01. 27 pp.

ICES. 2015. Report of the Workshop on scrutinisation procedures for pelagic ecosystem surveys (WKSCRUT), 7-11 September 2015, Hamburg, Germany. ICES CM 2015/SSGIEOM:18. 107pp.

ICES. 2016. Report of the Working Group on the Integrated Assessments of the Norwegian Sea (WGINOR), 7-11 December 2015, Reykjavik, Iceland. ICES CM 2015/SSGIEA:10. 150 pp.

Jolly, G. M., and I. Hampton. 1990. A stratified random transect design for acoustic surveys of fish stocks. Can.J. Fish. Aquat. Sci. 47: 1282-1291.

Skjoldal, H.R., Dalpadado, P., and Dommasnes, A. 2004. Food web and trophic interactions. *In* The Norwegian Sea ecosystem. Ed. by H.R. Skjoldal. Tapir Academic Press, Trondheim, Norway: 447-506

Tables

Table 1. Survey effort by vessel for the International ecosystem survey in the Nordic Seas in May - June 2017.

Vessel	Effective survey period	Effective acoustic cruise track (nm)	Trawl stations	Ctd stations	Aged fish (HER)	Length fish (HER)	Plankton stations
Dana	28/04-23/05	1895	38	33	539	2094	33
Magnus heinason	4/5-15/5	1312	13	19	220	249	19
Árni Fridriksson	10/5-23/5	2633	22	33	1167	4611	30
G.O.Sars	3/5-4/6	3397	64	73	535	1586	84
Fridtjof Nansen	24/5-14/6	2441	32	42	108	536	42
Total		**10956**	**169**	**200**	**2567**	**8648**	**208**

Table 2. IESNS 2017 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring.

	age																				
LenGrp	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)
15-16	15177	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15177	394.6	26.00
16-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4052	4052	194.5	48.00
19-20	-	22251	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22251	1162.6	52.25
20-21	-	19229	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19229	1184.5	61.60
21-22	-	17168	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17168	1150.3	67.00
22-23	-	27042	55740	13521	-	-	-	-	-	-	-	-	-	-	-	-	-	-	96304	8004.8	83.12
23-24	-	14104	57586	14104	9403	-	-	-	-	-	-	-	-	-	-	-	-	-	95196	8927.3	93.78
24-25	-	-	71211	8901	-	-	-	-	-	-	-	-	-	-	-	-	-	-	80112	8763.4	109.39
25-26	-	-	58204	8315	-	-	-	-	-	-	-	-	-	-	-	-	-	-	66519	8028.0	120.69
26-27	-	-	80848	134646	-	-	-	-	-	-	-	-	-	-	-	-	-	-	215494	28942.6	134.31
27-28	-	3859	58256	655062	175367	3859	-	-	15993	-	-	-	-	-	-	-	-	-	912396	136634.4	149.75
28-29	-	-	124515	1587403	266718	103829	39342	16801	8401	-	40573	-	-	-	-	-	-	-	2187581	363199.7	166.03
29-30	-	48752	123836	1292518	466835	144089	255304	100936	107742	7210	14419	-	-	-	-	-	-	-	2561640	467762.9	182.60
30-31	-	-	25275	375838	322900	482681	396049	300700	32109	16055	8027	4247	-	-	-	-	-	-	1963883	388336.2	197.74
31-32	-	-	55075	91341	205455	306798	139438	193542	9918	94249	39895	19920	-	-	-	-	-	-	1155631	247578.9	214.24
32-33	-	-	-	39423	67657	161887	167789	77472	39659	52978	-	8133	16266	-	-	-	-	-	631265	150063.3	237.72
33-34	-	-	-	27011	25779	261891	60042	133604	-	47003	30361	-	-	12554	-	-	-	-	598246	159406.0	266.46
34-35	-	-	-	2523	3784	146352	169525	302871	53578	98219	144700	121888	58517	-	-	-	-	-	1101958	320351.3	290.71
35-36	-	-	-	-	-	16766	114851	421072	100574	288085	385833	488082	364027	67044	2579	-	-	-	2248913	684408.7	304.33
36-37	-	-	-	761	-	7142	-	108500	48347	195272	275787	737466	711932	170005	47211	-	-	-	2302422	732145.3	317.99
37-38	-	-	-	-	-	-	-	32997	13294	32783	69313	341930	375002	171728	50671	11693	-	-	1099411	367395.0	334.17
38-39	-	-	-	-	-	-	-	-	-	56	7441	32246	138962	69453	16123	12402	8682	-	285366	101572.2	355.94
39-40	-	-	-	-	-	-	-	-	-	-	-	30308	4849	-	-	-	-	-	35158	12737.9	362.31
40-41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1169	1169	-	-
TSN(1000)	15177	152404	710547	4251368	1543898	1635293	1342340	1688494	429616	831909	1016351	1784220	1669556	490783	116584	24096	8682	5221	17716540	-	-
TSB(1000 kg)	394.6	16365.5	104963.0	726324.7	285624.0	363304.7	299412.4	439230.6	110400.6	241048.7	299872.1	561357.4	536599.2	161452.7	39804.4	8642.5	3352.8	194.5	-	4198344.3	-
Mean length (cm)	15.50	23.89	26.89	28.59	29.50	31.25	31.37	32.99	32.56	34.44	34.74	35.84	36.10	36.46	36.76	37.51	38.00	22.93	-	-	-
Mean weight (g)	26.00	107.38	147.72	170.84	185.00	222.16	223.05	260.13	256.98	289.75	295.05	314.62	321.40	328.97	341.42	358.67	386.20	48.00	-	-	236.99

Table 3. IESNS 2017 in the Barents Sea. Estimates of abundance, mean weight and mean length of Norwegian spring-spawning herring.

LenGrp	age 1	2	Number (1E3)	Biomass (1E3kg)	Mean W (g)
9-10	179234	-	179234	806.6	4.50
10-11	437156	-	437156	2295.1	5.25
11-12	834968	-	834968	7410.3	8.88
12-13	6959522	-	6959522	77066.5	11.07
13-14	4555164	-	4555164	61989.8	13.61
14-15	1512559	-	1512559	25146.3	16.63
15-16	179234	358468	537702	11560.6	21.50
16-17	-	935514	935514	23762.0	25.40
17-18	-	1254637	1254637	38983.4	31.07
18-19	-	537702	537702	19715.7	36.67
19-20	-	179234	179234	6990.1	39.00
TSN(1000)	14657837	3265555	17923392	-	-
TSB(1000 kg)	178209.6	97516.8	-	275726.4	-
Mean length (cm)	12.68	17.10	-	-	-
Mean weight (g)	12.16	29.86	-	-	15.38

Table 4. IESNS 2017 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	14	Number (1E3)	Biomass (1E3kg)	Mean W (g)
17-18	888	-	-	-	-	-	-	-	-	-	-	-	-	-	888	24.9	28.00
18-19	10673	-	-	-	-	-	-	-	-	-	-	-	-	-	10673	371.5	34.81
19-20	153892	-	-	-	-	-	-	-	-	-	-	-	-	-	153892	6065.6	39.41
20-21	489175	11555	1050	2101	-	-	-	-	-	-	-	-	-	-	503881	22873.0	45.39
21-22	426936	100999	29146	-	-	-	-	-	-	-	-	-	-	-	557081	29544.5	53.03
22-23	132310	299671	159889	11743	-	-	-	-	-	-	-	-	-	-	603614	38007.7	62.97
23-24	1416	547747	384647	43969	-	-	-	-	-	-	-	-	-	-	977779	71838.0	73.47
24-25	-	533293	768481	95421	11362	-	-	-	-	-	-	-	-	-	1408558	117529.1	83.44
25-26	-	352916	1187677	197584	27080	-	-	-	-	-	-	-	-	-	1765258	164992.9	93.47
26-27	-	127464	1070151	291865	29068	-	889	-	-	-	-	-	-	-	1519436	157785.8	103.84
27-28	-	28728	456905	334981	55334	17098	1937	-	-	-	-	-	-	-	894982	103290.4	115.41
28-29	4172	11918	135333	154586	91713	23408	9383	-	-	-	-	-	-	-	430513	56328.5	130.84
29-30	-	-	41130	76079	46520	30785	14436	-	-	1110	-	-	-	-	210061	30838.6	146.81
30-31	-	-	11669	13784	54593	35082	42643	-	-	-	-	-	-	-	157771	25319.1	160.48
31-32	-	-	2783	-	85213	16542	7505	1251	-	-	-	-	-	-	113294	20019.9	176.71
32-33	-	-	-	2772	7718	18121	8316	12183	-	5544	9805	-	-	5544	70003	14774.5	211.06
33-34	-	-	-	2350	10246	17297	12596	9402	-	11752	4701	4701	2350	2350	77746	16124.1	207.39
34-35	-	-	-	1891	2811	11245	2811	7713	2811	8433	2811	14825	-	2811	58163	14472.9	248.83
35-36	-	-	-	-	-	-	19464	9278	13917	13917	9278	-	-	-	65856	17896.9	271.76
36-37	-	-	-	-	2897	-	2897	2897	8690	5793	2897	-	-	-	26070	7815.2	299.78
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)	1219462	2014292	4248861	1229126	424555	169578	126523	42723	29968	51100	29492	22807	32000	10706	9651193	-	-
TSB(1000 kg)	59301.3	159034.9	404116.7	136270.4	61391.6	29216.4	23616.6	10193.2	8102.7	13254.8	7350.7	5945.3	9774.4	2445.9	-	930014.8	-
Mean length (cm)	20.50	23.71	25.24	26.51	28.90	30.33	31.60	33.71	35.75	34.40	33.78	34.51	38.13	32.87	-	-	-
Mean weight (g)	48.63	78.95	95.11	110.87	144.60	172.29	186.66	238.59	270.38	259.39	249.24	260.68	305.45	228.47	-	-	96.36

Figures

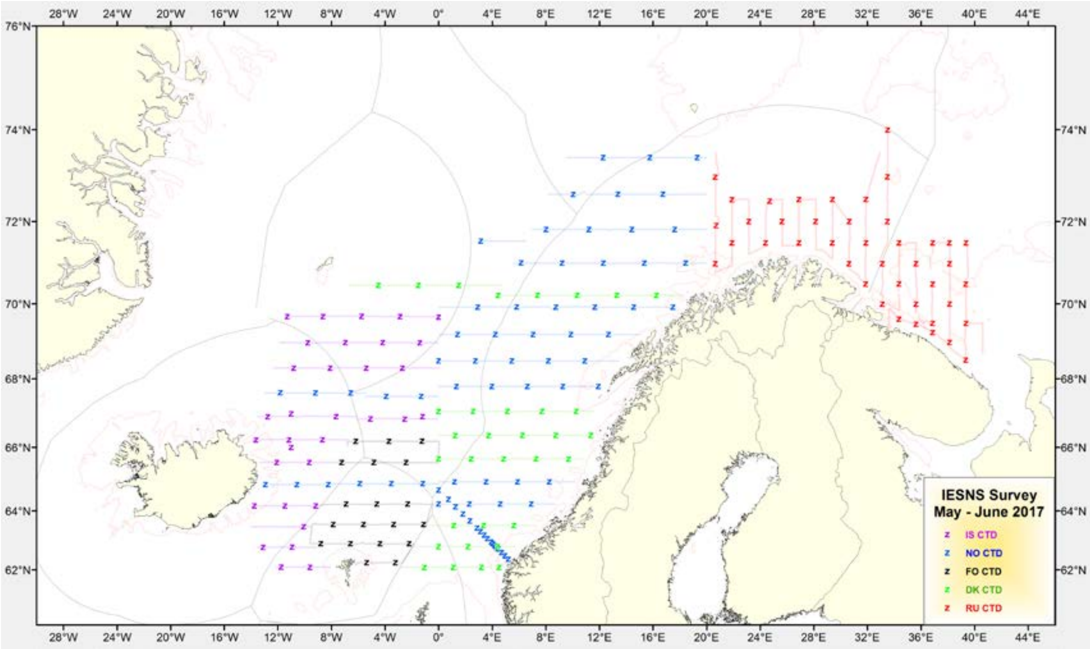


Figure 1. Cruise tracks and CTD stations by country for the IESNS survey in May-June 2017.

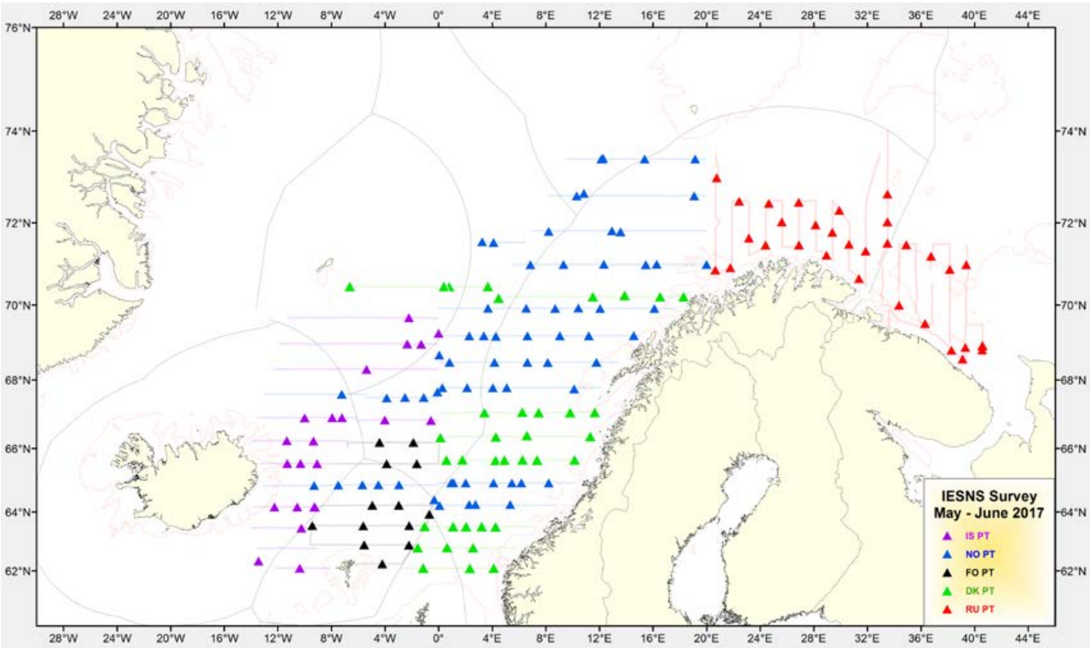


Figure 2. Cruise tracks during the IESNS survey in May-June 2017 and location of trawl stations.

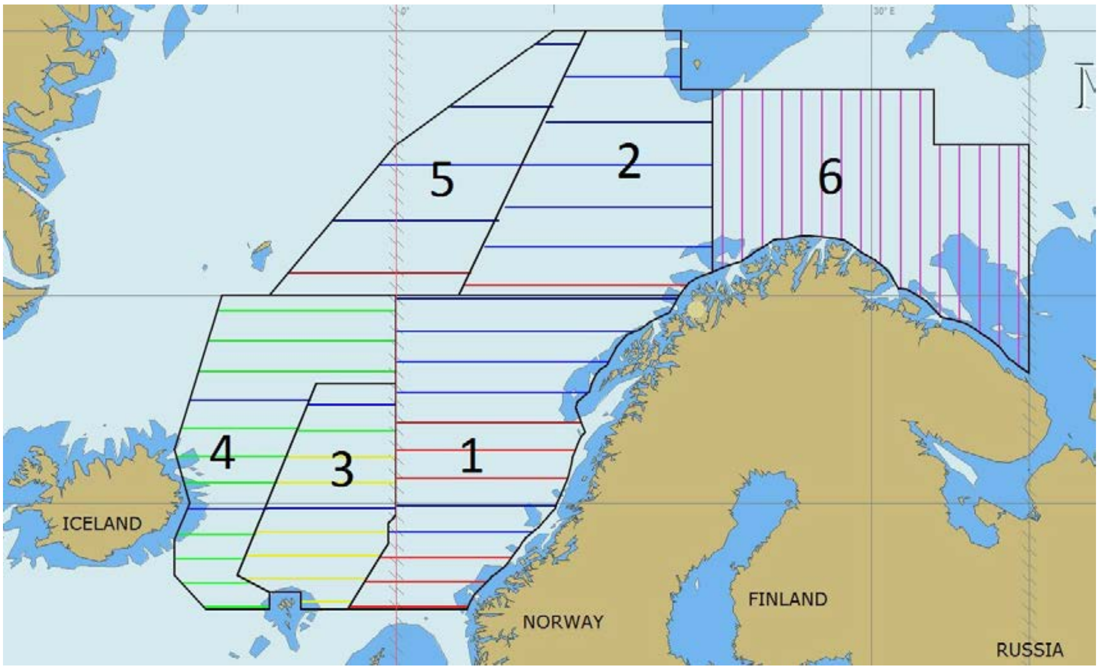


Figure 3. The pre-planned strata and transects for the IESNS survey in 2017 (red: EU, dark blue: Norway, yellow: Faroes Islands, violet: Russia, green: Iceland).

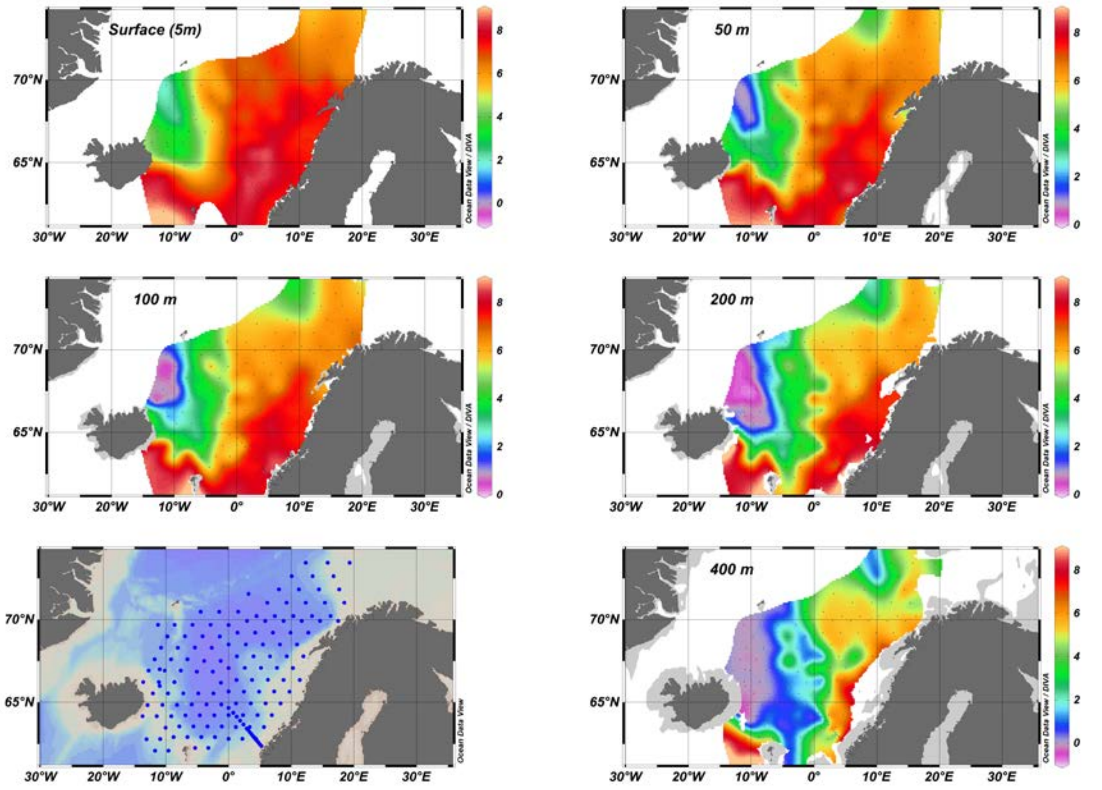


Figure 4. The horizontal distribution of temperatures (°C) at 5 m (surface), 50m, 100m, 200m and 400m depth in IESNS in May-June 2017.

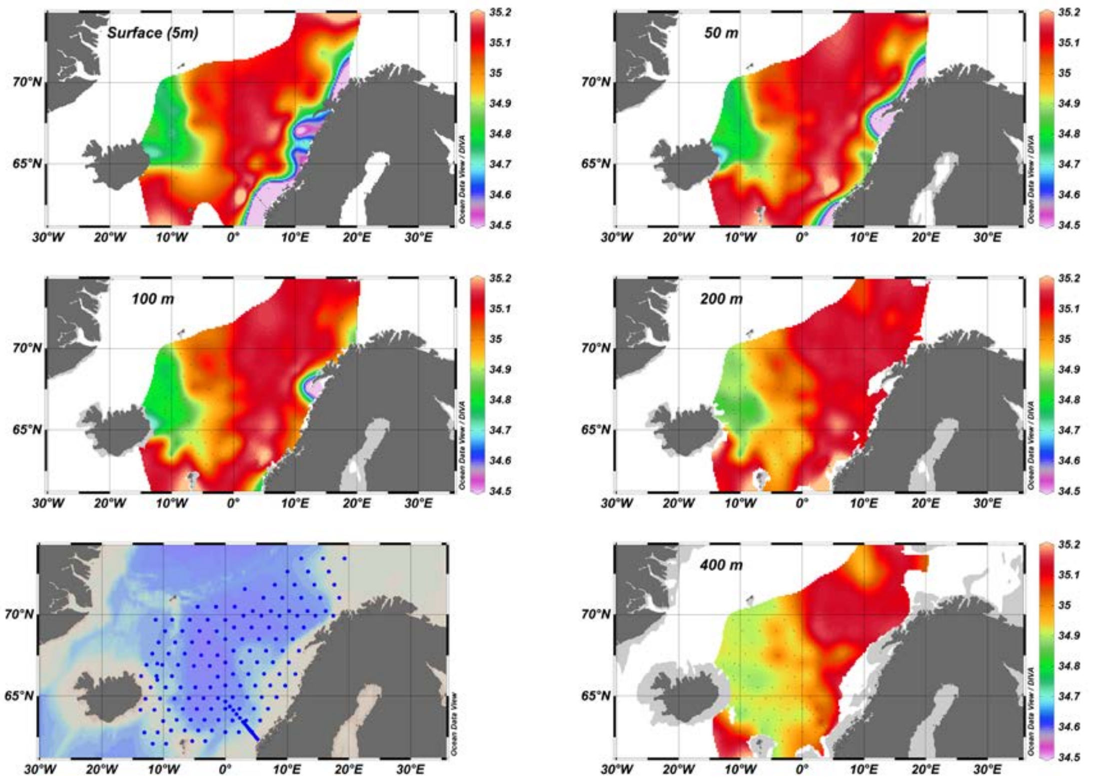


Figure 5. The horizontal distribution of salinity at 5 m (surface), 50m, 100m, 200m and 400m depth in IESNS in May-June 2017.

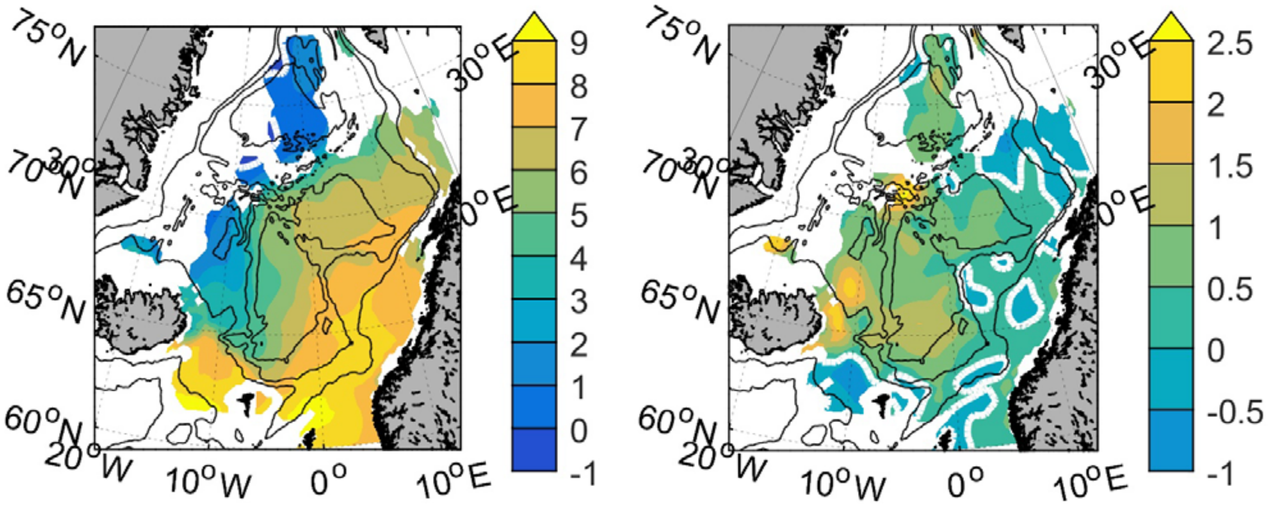


Figure 6. Temperature (left) and temperature anomaly (right) averaged over 0-50 m depth in May 2017. Anomaly is relative to the 1995-2015 mean.

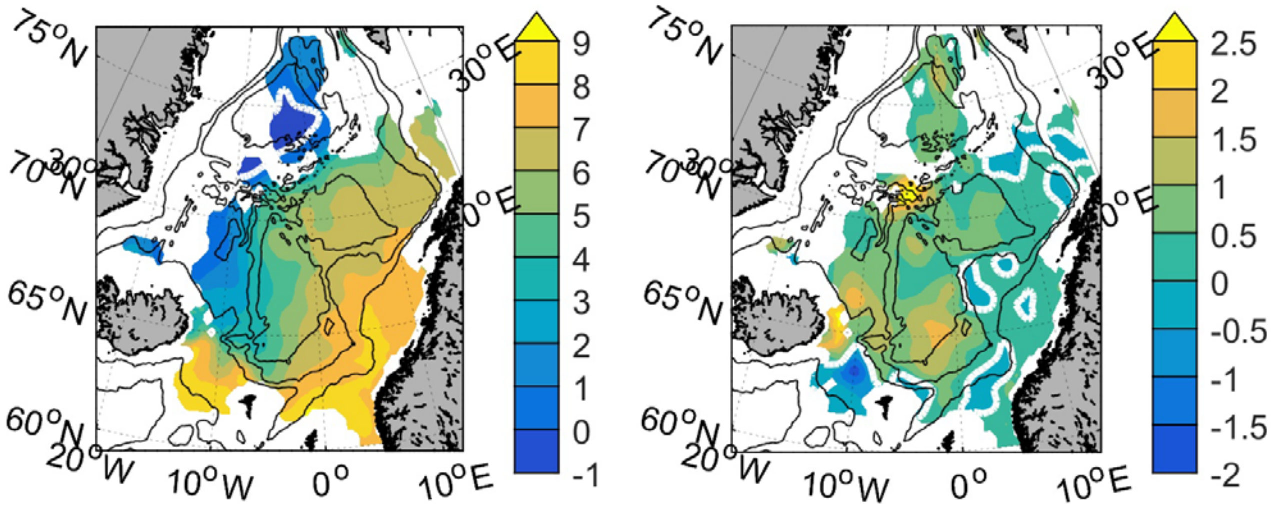


Figure 7. Temperature (left) and temperature anomaly (right) averaged over 50-200 m depth in May 2017. Anomaly is relative to the 1995-2015 mean.

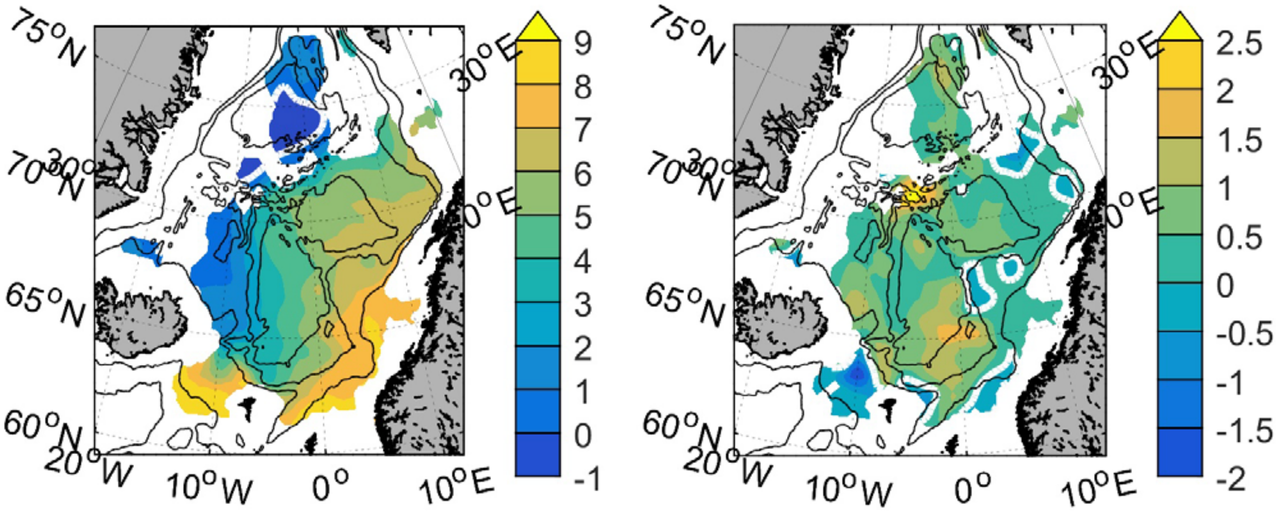


Figure 8. Temperature (left) and temperature anomaly (right) averaged over 200-500 m depth in May 2017. Anomaly is relative to the 1995-2015 mean.

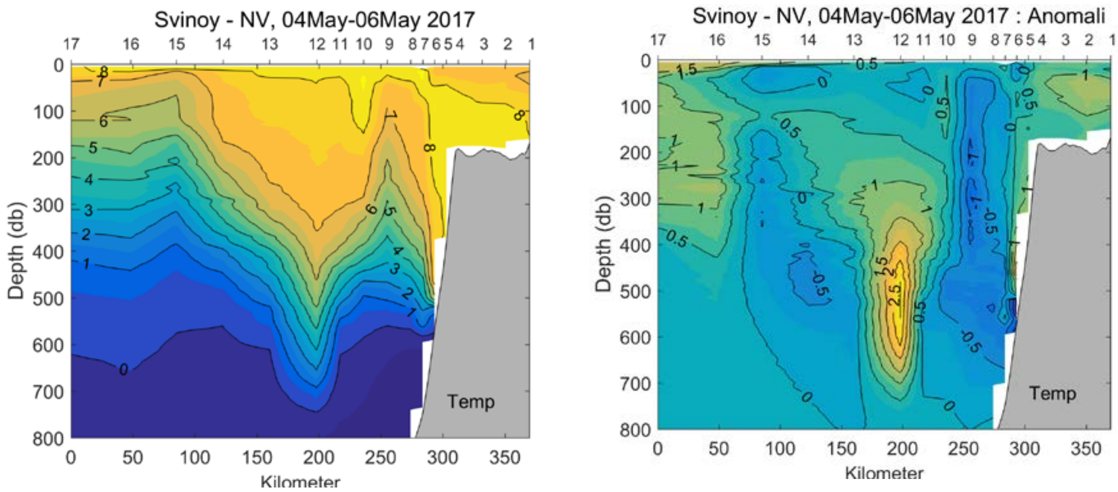


Figure 9. Temparature (left) and temperature anomaly (right) in the Svinøy section, May 2017. Anomalies are relative to a 30 years long-term mean (1978-2007).

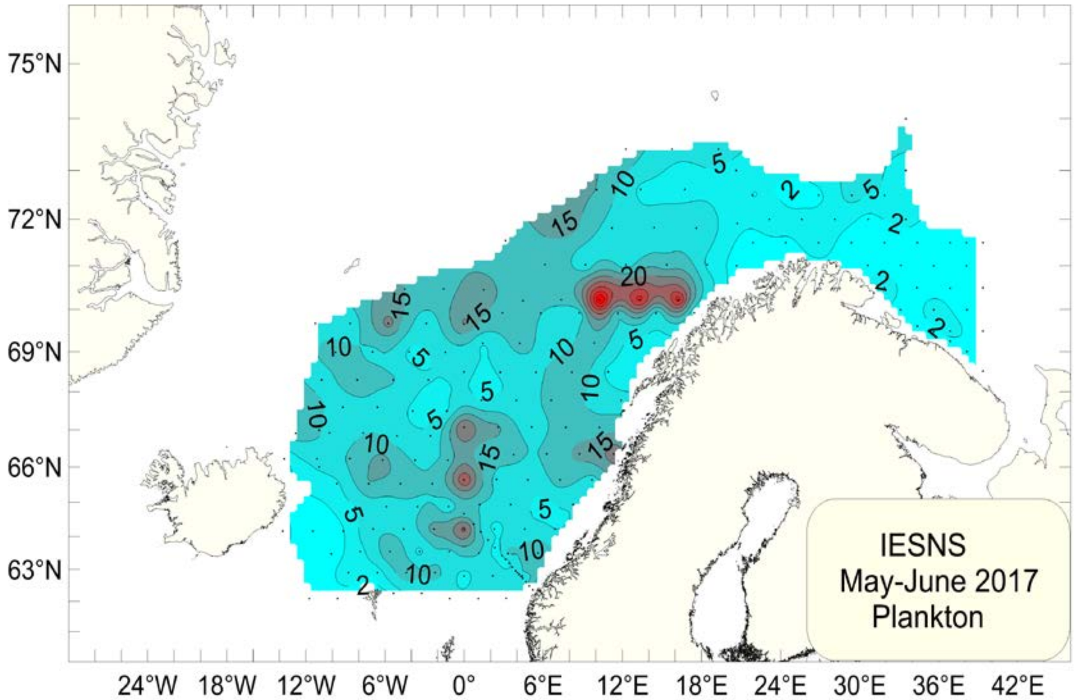


Figure 10. Representation of zooplankton biomass (g dry weight m-2; at 0-200 m depth) in May-June 2017.

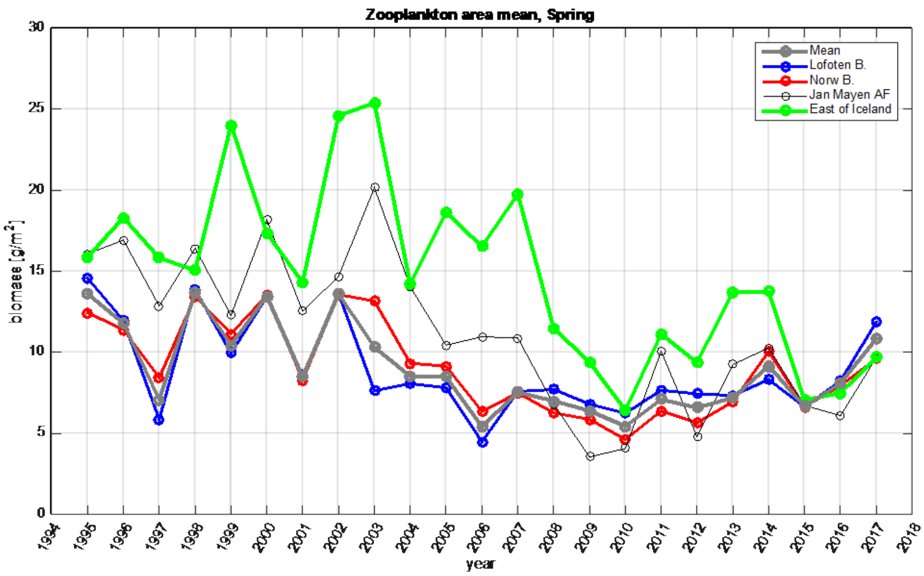
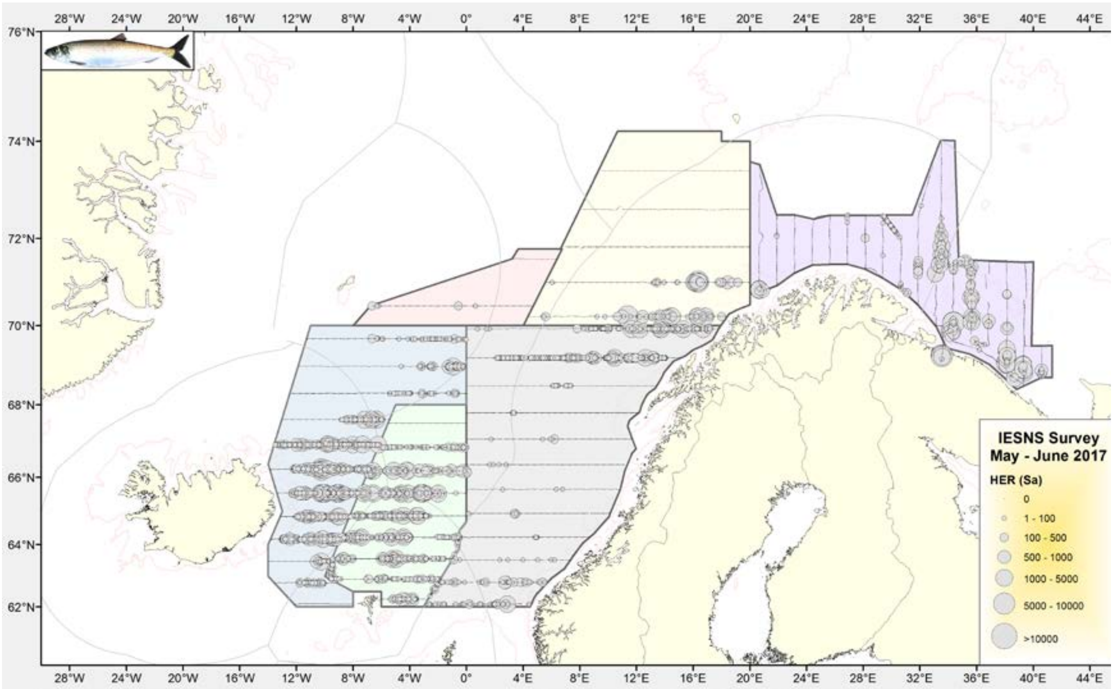


Figure 11. Indices of zooplankton dry weight (g m-2) sampled by WP2 in May in (a) the different areas in and near Norwegian Sea from 1997 to 2017 as derived from interpolation using objective analysis utilizing a Gaussian correlation function (see details on methods and areas in ICES 2016).

(a)



(b)

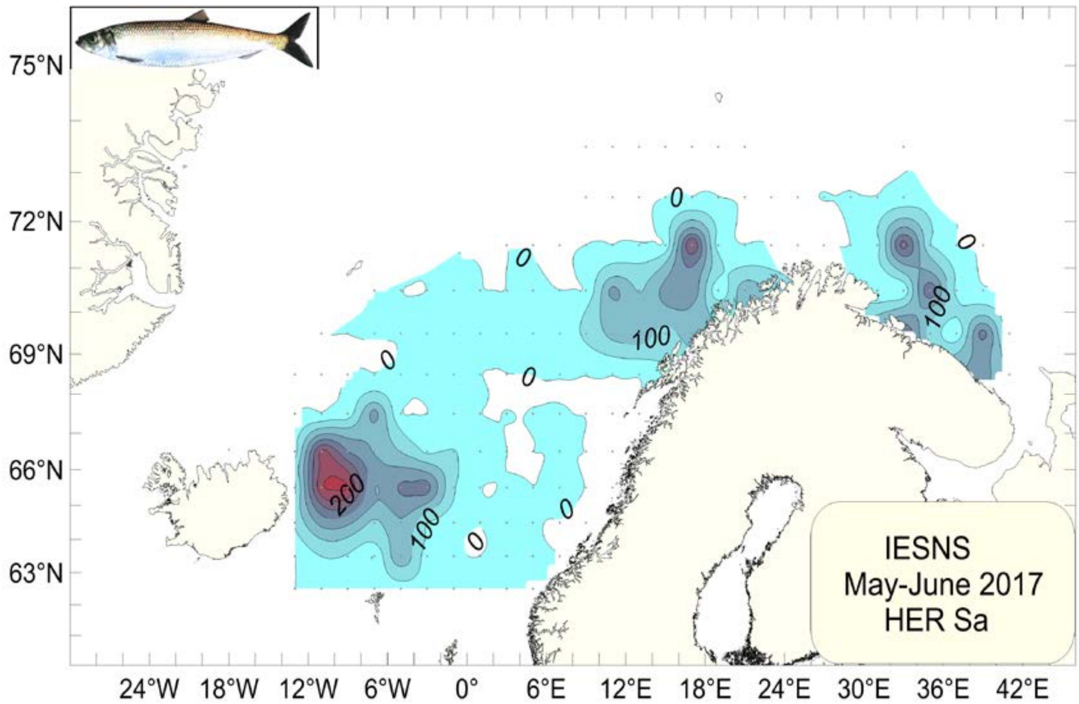


Figure 12. Distribution of Norwegian spring-spawning herring as measured during the IESNS survey in April-June 2017 in terms of NASC values (m²/nm²) (a) averaged for every 1 nautical mile and (b) represented by a contour plot. The stratification of the survey area is shown on the upper map.

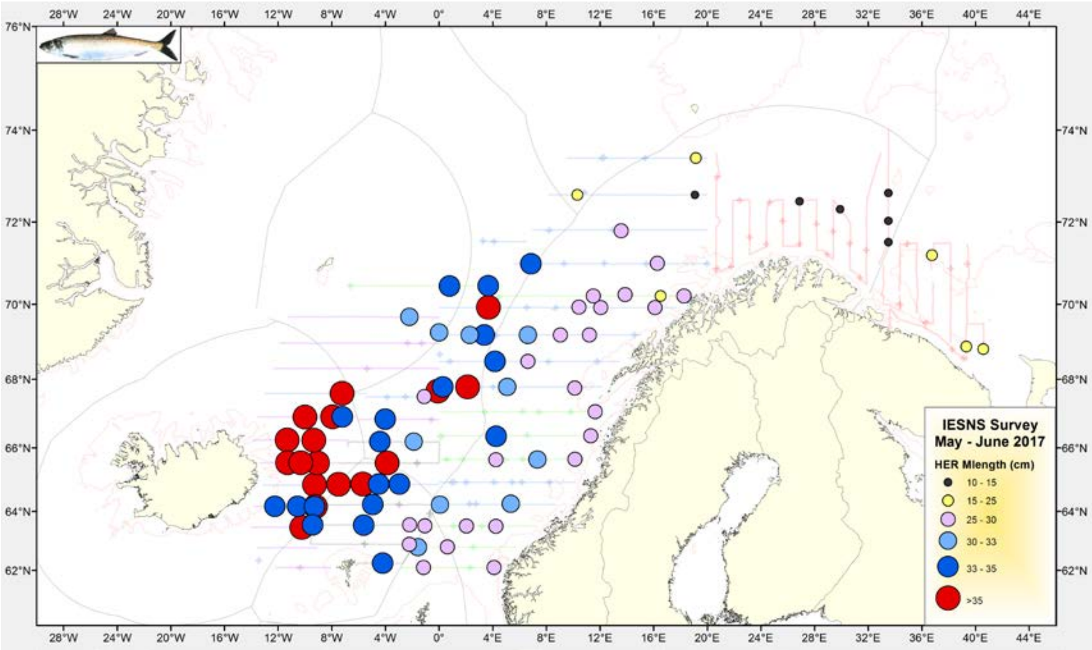


Figure 13. Mean length of Norwegian spring-spawning herring in all hauls in April-June 2017.

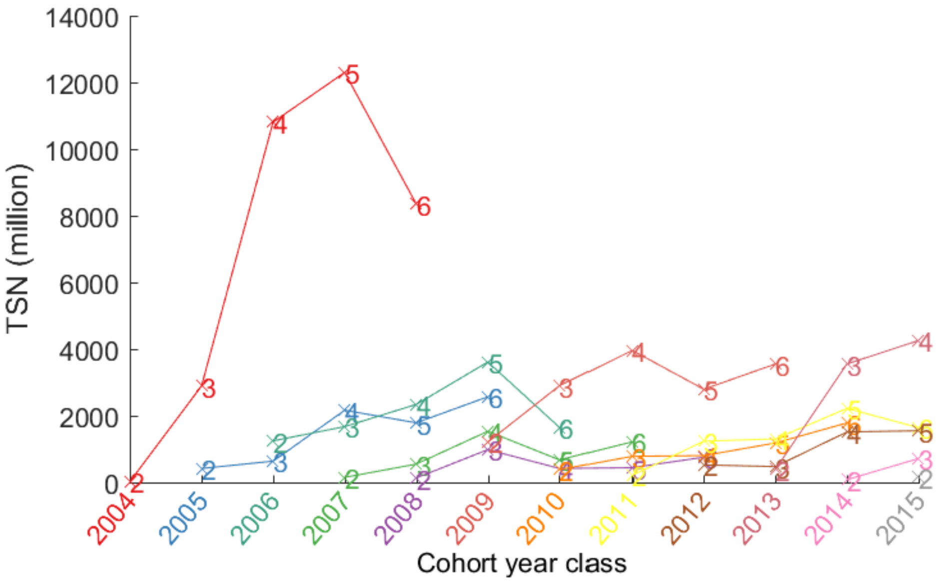


Figure 14. Tracking of the Total Stock Number (TSN, in millions) of Norwegian spring-spawning herring for each cohort since 2004 from age 2 to age 6. From 2008, stock is estimated using the StoX software. Prior to 2008, stock was estimated using BEAM.

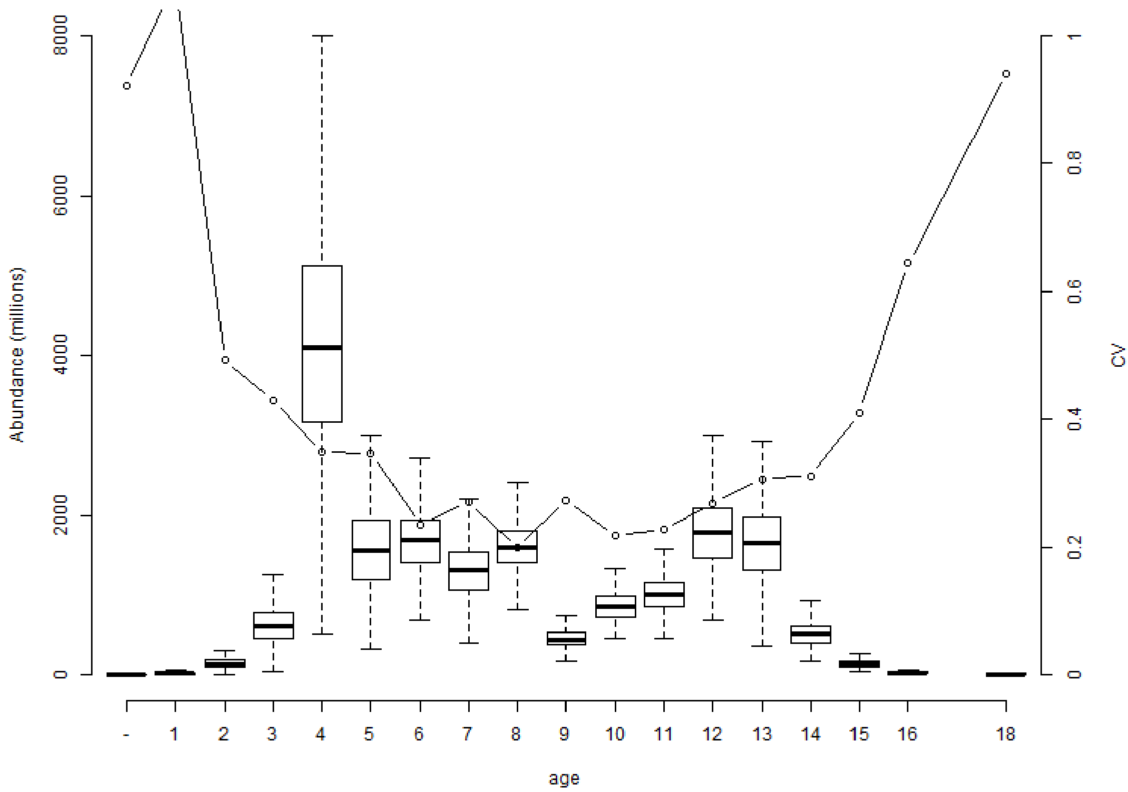


Figure 15. Norwegian spring-spawning herring in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

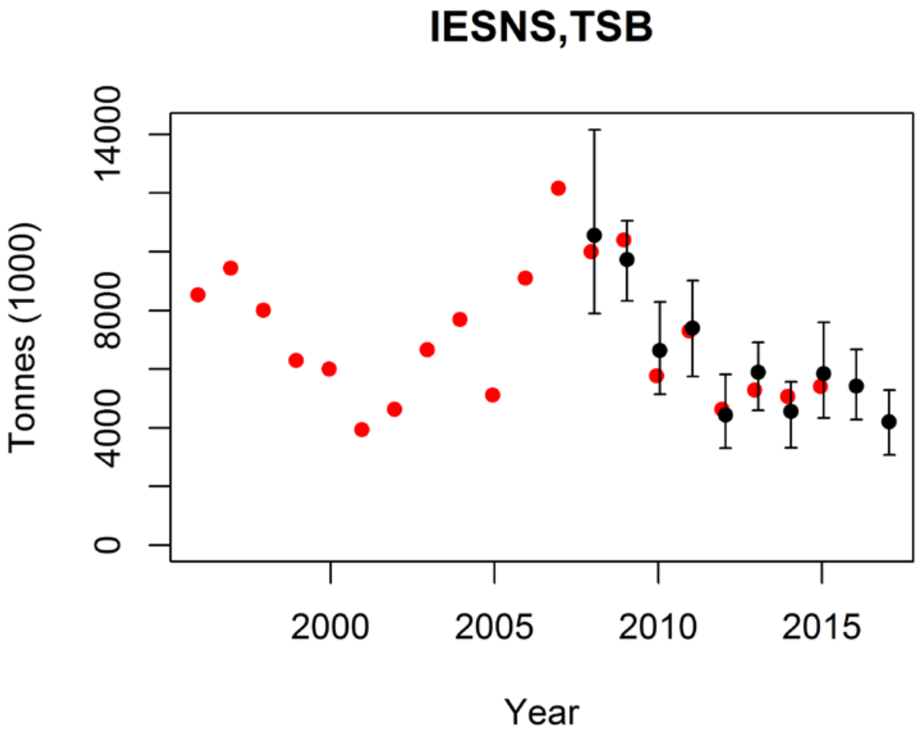


Figure 16. The annual biomass index of Norwegian-spring spawning herring in the IESNS survey (Barents Sea, east of 20°E, is excluded) from 1996 to 2017 as estimated using BEAM (red dots; calculated on basis of rectangles) and as estimated with the software StoX (black dots with 90% confidence interval; calculated on basis of standard stratified transect design).

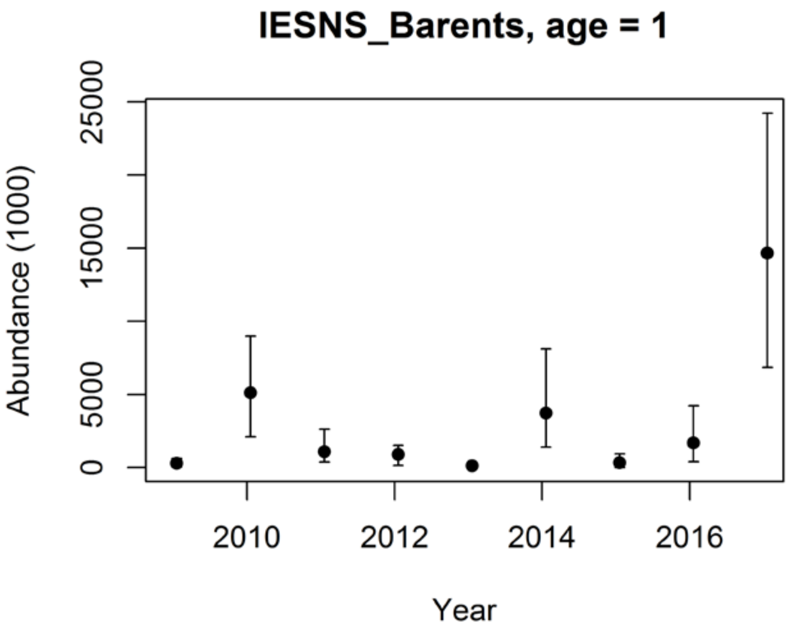
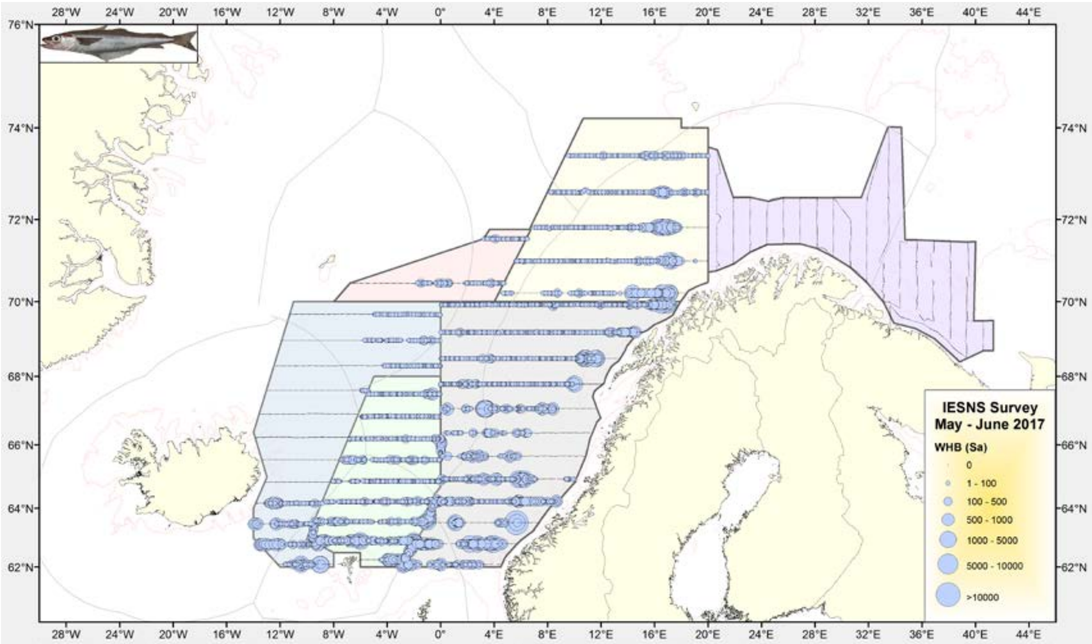


Figure 17. Numbers of one year old herring in the Barents Sea in April-June as estimated with the software StoX (black dots with 90% confidence interval; calculated on basis of standard stratified transect design).

(a)



(b)

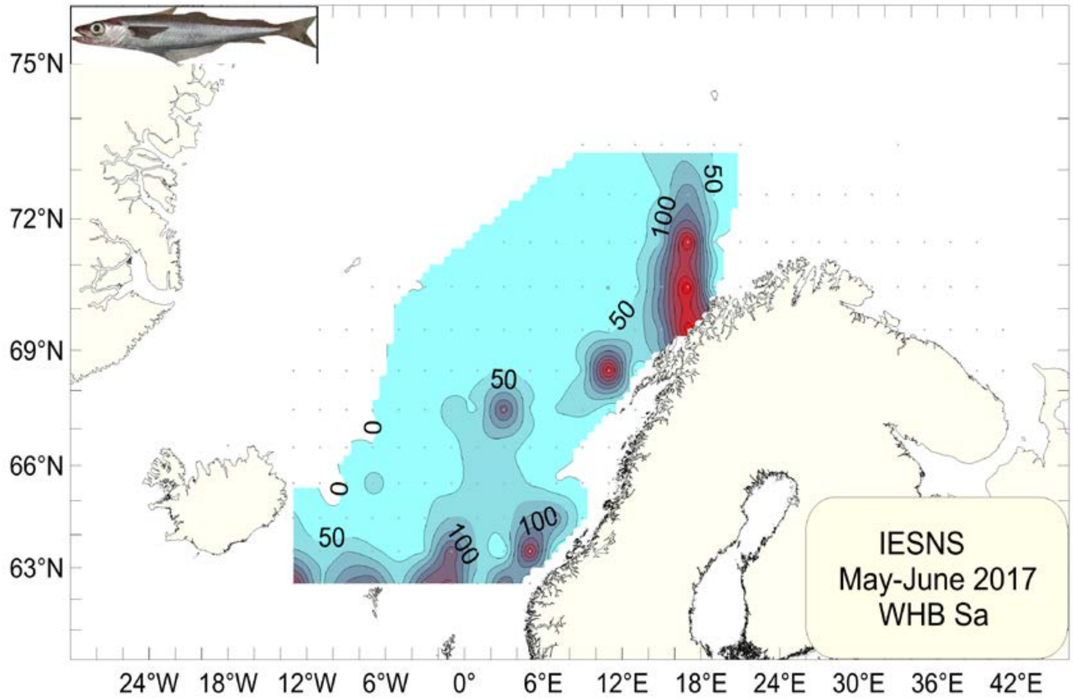


Figure 18. Distribution of blue whiting as measured during the IESNS survey in April-June 2017 in terms of NASC values (m²/nm²) (a) averaged for every 1 nautical mile and (b) represented by a contour plot. The stratification of the survey area is shown on the upper map.

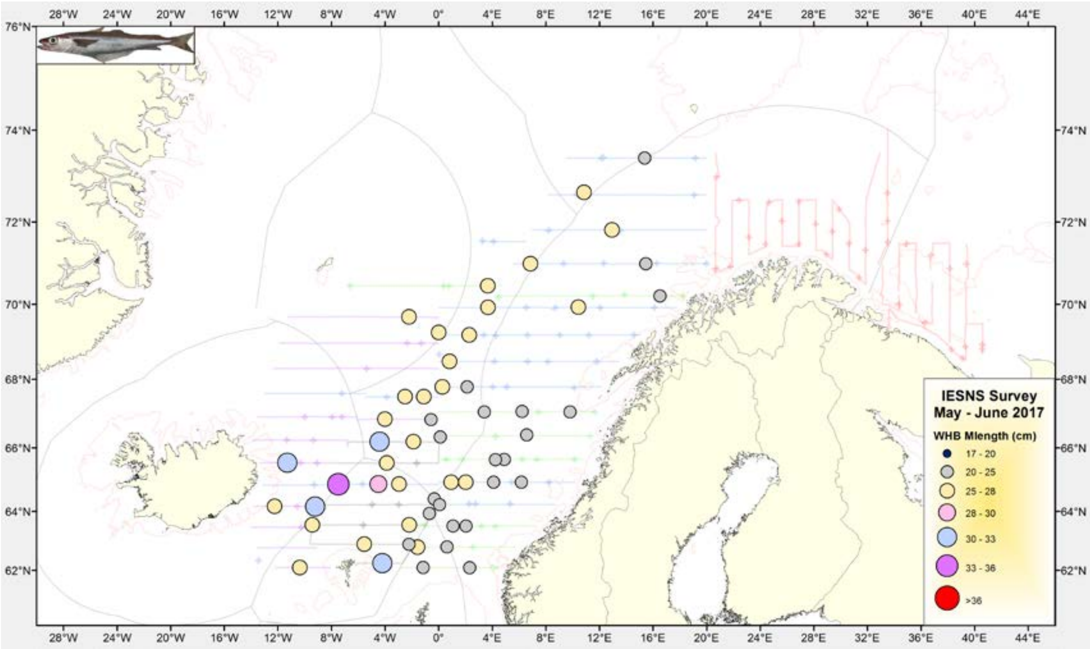


Figure 19. Mean length of blue whiting in all hauls in IESNS 2017.

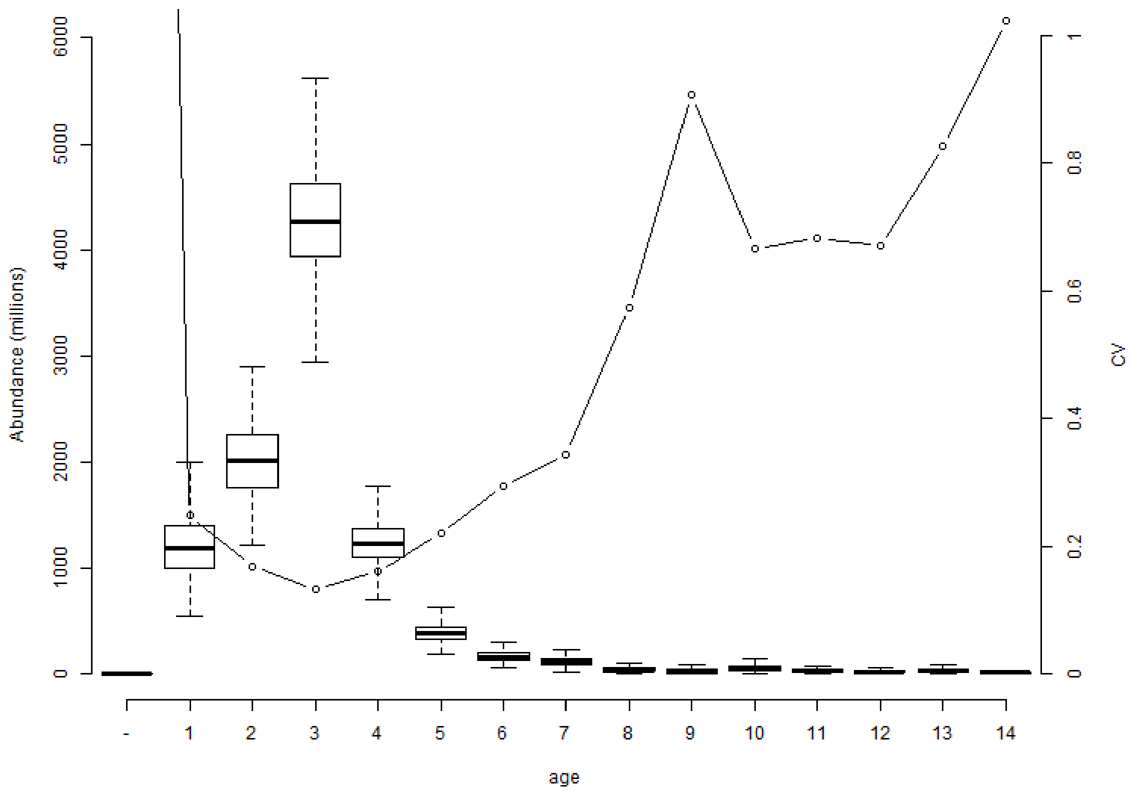


Figure 20. Blue whiting in the Norwegian Sea: R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

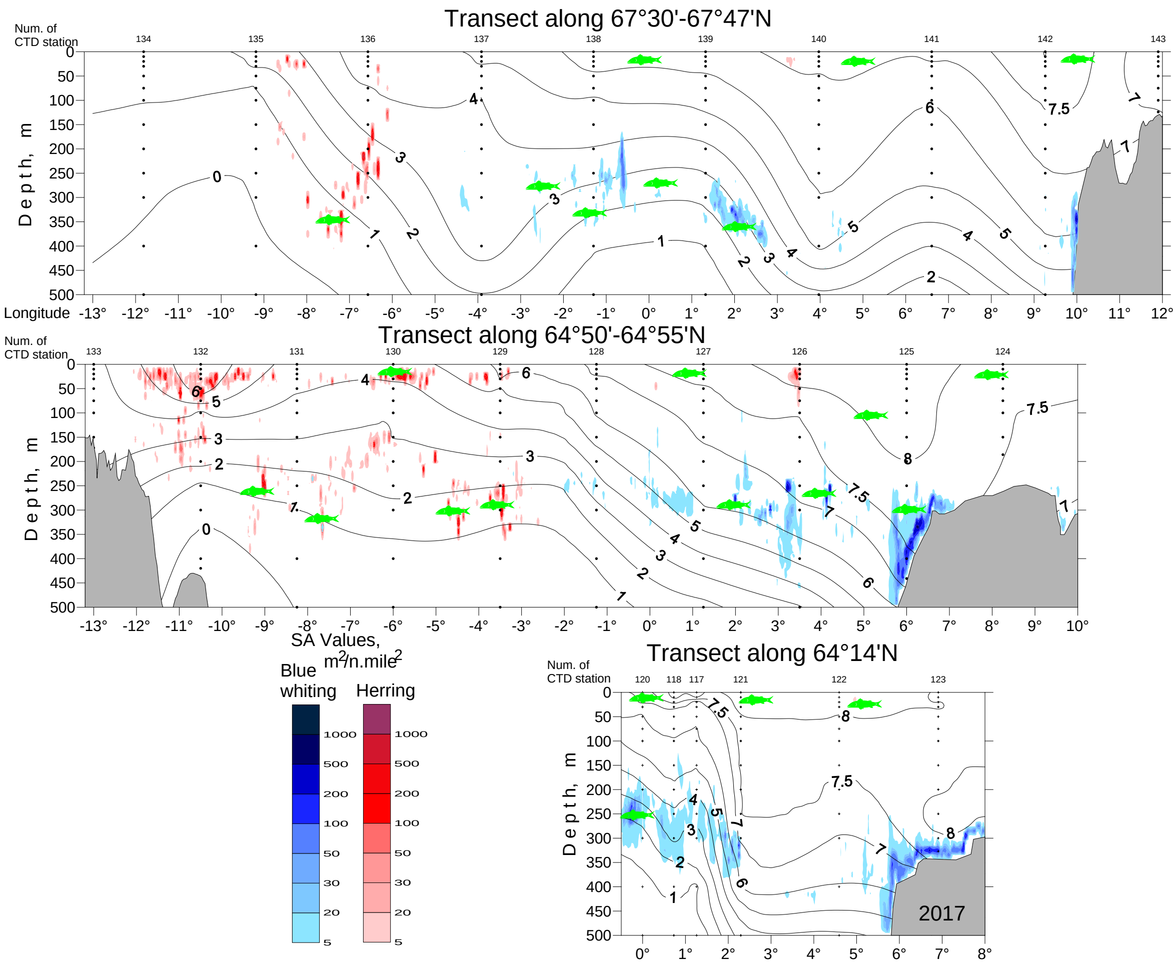


Figure 21. Acoustic values of NSS-herring (red) and blue whiting (blue), location of trawl stations (green fish) and temperature profile (black lines) along two transects across the whole Norwegian Sea in May 2017, and one short transect in close to the Norwegian coast covered by "G.O. Sars".

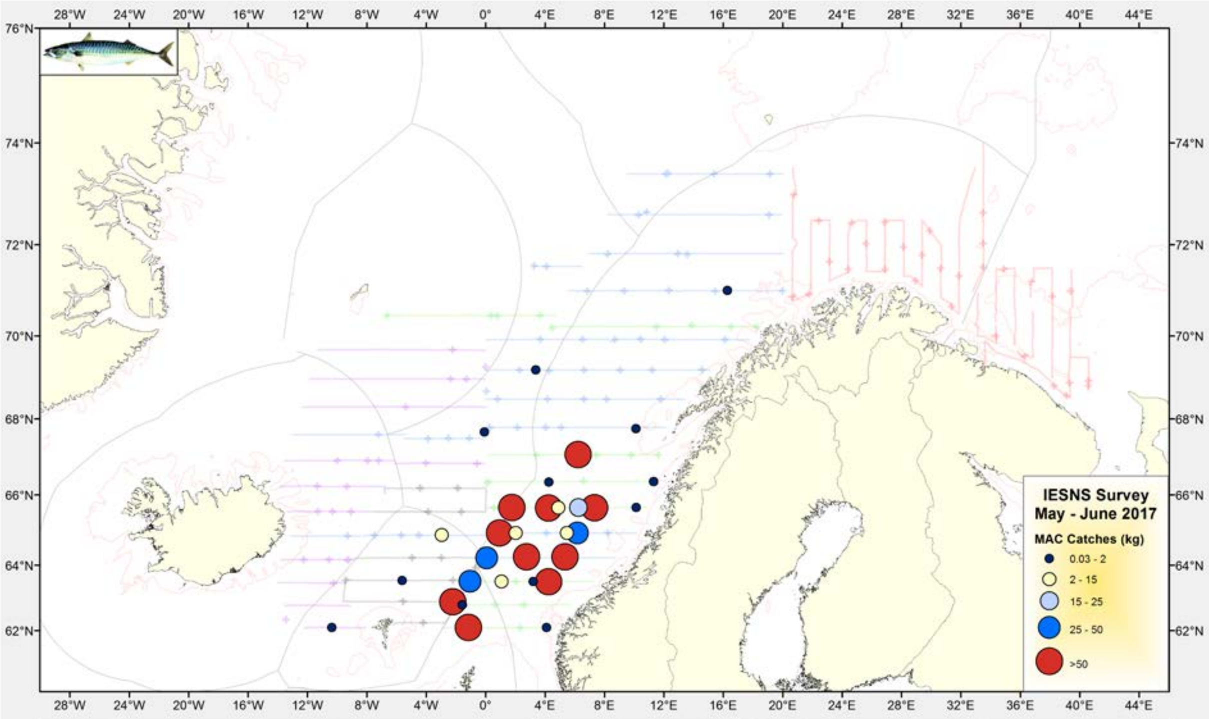


Figure 22. Distribution of hauls containing mackerel and the catch size in the 2017 IESNS.

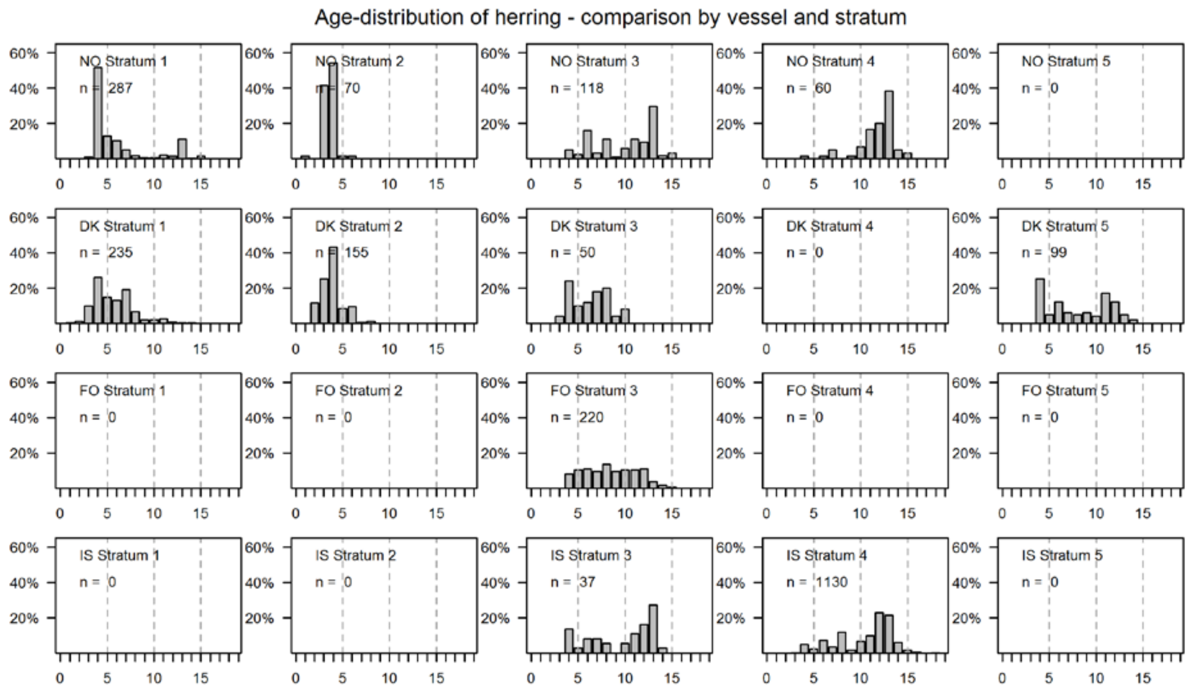


Figure 23. Comparison of the age distributions of NSS-herring by stratum and country in IESNS 2017. The strata are shown in Figure 3.

Appendix 1

School observations using omni directional fisheries sonar during international ecosystem survey in Nordic SEA (IESNS) in May – June 2017

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Introduction

In acoustic trawl surveys on pelagic schooling species, the down-looking narrow beam echosounder is the standard tool used for estimation of fish abundance. An important bias in this method is occurs when fish are distributed in the acoustic blind zone of the echosounder, i.e. between the sea surface and the far field of the transducer. When transducers are mounted in a drop keel below the vessels hull, the blind zone can extend up to 15 m below sea surface. Another source of bias, is the avoidance of the fish aggregations to the approaching surveying vessel, either by swimming away from the vessel track or by diving (De Robertis and Handegard, 2012).

Omni directional fisheries sonar are 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 fanpointing in any direction,in most cases 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, make omni sonars a potential tool to investigate the blind zone and avoidance bias of the echo sounder sampling.

Efforts from the Norwegian Institute of Marine Research, over last 5 years have allowed the development of calibrationmethods and data processing of omni sonars for single school investigations and from systematic surveys for abundance estimation. In this report, we present the results of an investigation looking at the use of the omni sonars as a tool to identify and quantify the level of bias of the echosounder estimates.

The objectives of the present work are: i) present a new methodology using vertical beams from omni sonars to investigate the presence of schools in the echo sounder blind zone, ii) compare sonar and echo sounder measurementsin the blind zone, and use results as an indicator of bias in echo sounder estimates.

Methods

Data preparation

Low frequencyomni sonar Simard SU90 onboard R/V "G. O. Sars" was calibrated following in Macaulay et al.'s guidelines(2016) prior the start of the survey, on May 3 in Bergen'sharbor. Calibration parameters were computed and applied to the stored data during post-processing. Data was collected continuously all throughout the survey and Raw files where stored in external USB hard drives.

Sonar operating at 26 kHz was synchronized with the SIMRAD EK80 echo sounders to avoid acoustic interference, with the latter set as the master. Sonar settings were optimized for sampling the surface layers between surface and 80 m, with alternated horizontal and vertical beams, at higher ping rate possible of ca. 1 Hz. The 64 horizontal beams were set to a 7 deg tilt, with a range from 0 to 450 m. The 64 vertical beams were set in direction perpendicular to the vessel track, with a 180 deg fan, with a range of 450 m from the vessel. In addition, the noise filter was disabled during the data collection because it affects the raw data.

Data recorded withthe vertical beam number 3 (counting from surface) on both port side and starboard side were converted to echo sounder EK80 raw file format in LSSS (Korneliussen et al,. 2016) using the module Processing system for omni directional fisheries sonar (Profos).

The data between 5 and 80 m range from the vessel were individually scrutinized by beamusing the standard echo sounder postprocessing tools in LSSS. A threshold of -60 dB was used to keep only scatters which correspond to schools. Note that all schools from sonar data were not categorized as species, allocation that was done during the data analysis based in the pelagic trawl data and personal communication with the cruise leader.Data was stored into LSSS database at range channels of 10 m and 1 nmi distance along the vessel track by beam.

The data from the vertical beams was converted from range from the vessel to a depth range below sea surface, by using sonar transducer depth, sonar beam tilt angle and beam width. A schematic representation of one vertical beam and the parameters considered are presented in Figure 1.

The data from the echosounder correspond to the scrutinized EK80 data at 38 kHz done onboard during the survey. In the scrutinized echosounder data, the acoustic category herring was used, but no allocation of acoustic data was done to mackerel. Data was stored in channels of 10 m and 1 nmi distance along the vessel track

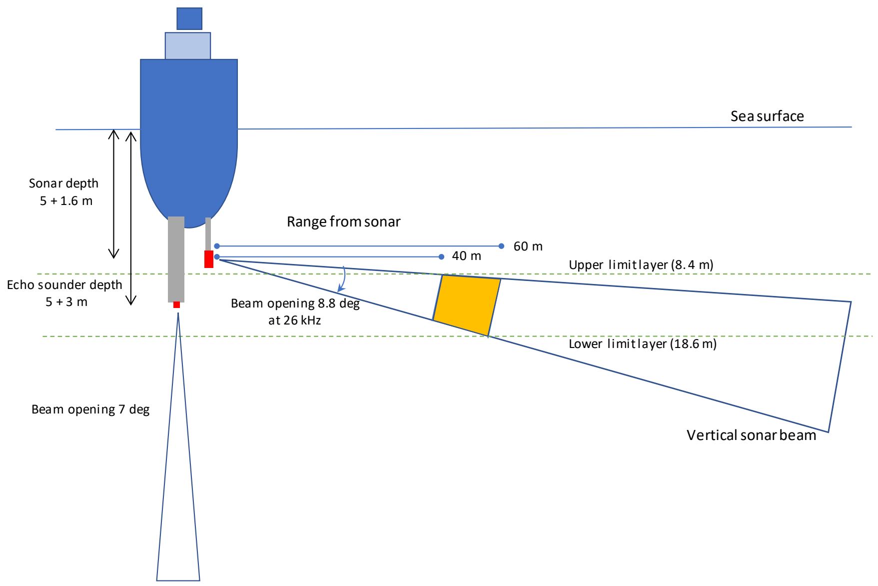


Figure 1. Section view of vessel with schematic description of one vertical beam from SU90 sonar. During operation sonar transducer is lowered 1.6 m below the vessel hull (at 5 m). Also, is included the drop keel where the echosounder transducers are mounted 3 me below vessel hull.

Sonar vertical beam data is displayed in Profos as a half circle with the vessel in the center, with upper beam (at both sides) pointing straight along the depth of the sonar transducer, i.e. 6.6. m for R/V "G.O. Sars"(Figure 2).

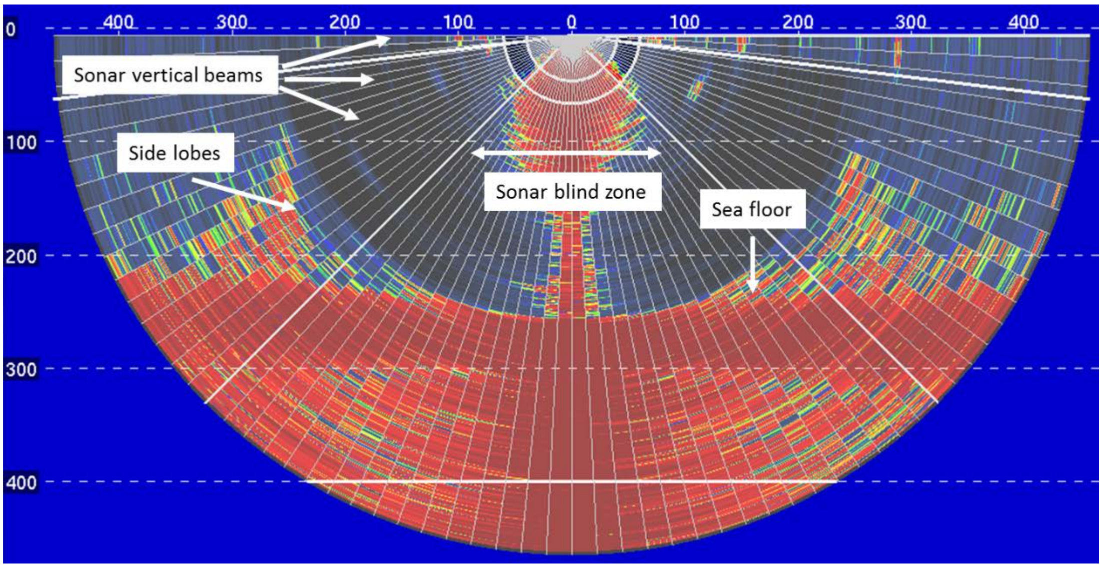


Figure 2. Image of one ping of the complete fan of the vertical beams of the SU90 sonar. A total of 64 beams are displayed up to a range from 0 to 450 m (vessel in 0 m range). This sonar has a cylindrical transducer without acoustic elements pointing directly downwards, therefore, no beams are pointing in that direction generating a sonar blind zone.

Acoustic data from beam 3 from (port and starboard side) was selected from a range between 40 to 60 m from the vessel, which corresponds to a depth range between 8.4 and 18.6 m. This depth range is inside the echosounder blind zone (Figure 3). A comparison between the area scattering NASC from this depth layer from the vertical beam and the EK80 echo sounder data was computed for both transects.

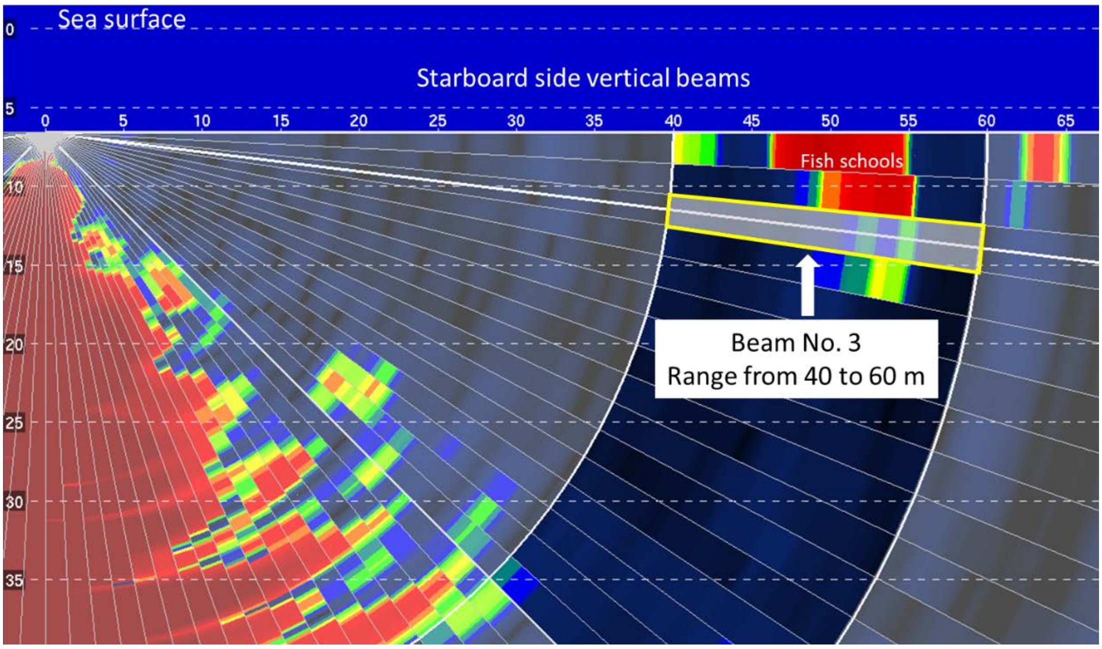


Figure 3. Detail of the vertical beams directed to starboard side. Beam 3 is indicated with a yellow polygon, with upper and lower borders derived from ideal beam shape, and proximal and distal borders by the 40 and 60 m ranges, respectively. Inside this range from the vessel, is possible to observe a fish school (squares colored between yellow and red) distributed from the surface up to beam 4.

A detailed inspection of the echo sounder and sonar data was done to identify those periods when weather conditions were adverse, and large amount of air bubbles were swept below the sea surface reaching up to 20 m. Sonar acoustic data from these periods were excluded from both single schools and vertical beams processing.

Due to time constrains, two transects were processed at the time the submission of the current report, and the results are presented here. Transect centered in latitude 65°N from the coast of Norway to Iceland at the beginning of the survey from 8 to 13 of May, and transect centered in 70°N off the coast of Tromsø, from 22 to 26 May, both transects with sailing direction East to West.

Analyses

To investigate the presence of fish in the echo sounder blind zone, a combined analysis of the data from the sonar vertical beams and the scrutinized data from the EK80 echo sounder was conducted.

Area scattering (NASC) from the sonar and echosounder data were exported as LSSS database outputsand processed in software R (R Core Team, 2015). First, an analysis of the consistency between NASC measurements of beam 3 from port and starboard side, by t-test and linear correlation. For comparing the sonar and echosounder, data were split by transects and plot along the vessel track.

Results

Sonar data storing during most of the survey was adequate, with only reduced periods when the sonar stopped operating and some data was lost before the system was restarted. Data storing rate was 2 GB per hour, with a total of 1.3 TB for the whole survey for R/V “G. O. Sars”. A sonar log was completed indicating the more relevant features encounter, i.e. presence of school, bad weather conditions, etc. Also, a daily quality control of the raw data was done loading some files into the post processing system Profos ensuring that all basic information was stored in the files (i.e. navigation, transmission power, etc.).
An example of echo sounder and sonar data along a transect is presented in Figure 4. As both sources of acoustic data contain GPS and synchronized time, simultaneous visualization is possible, and facilitates the interpretation of the sonar data and the school segmentation process.

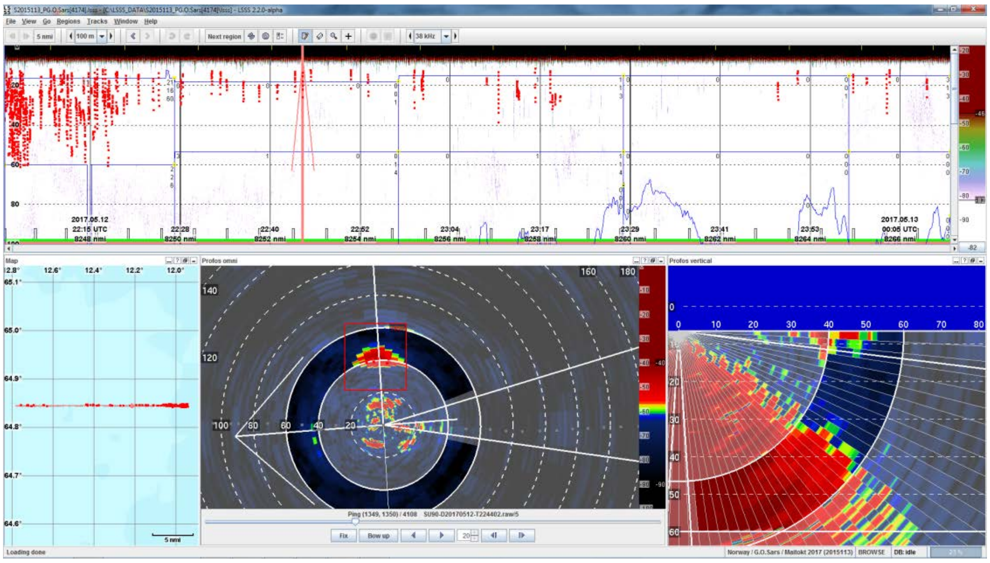


Figure 4. Screen dump from post processing system LSSS, showing ca. 18 nmi of EK80 data from 38 kHz (upper panel) and a map with the position of the transect (bottom left panel). The horizontal beams of the SU90 sonar from one ping zoomed to a range of 180 m with the vessel in the center and an arrow pointing West in sailing direction (center bottom panel). In the same panel and up from the vessel position is observed a colored oval shape (green to red) which correspond to a school in a range between 35 to 50 m from the vessel, marked with a red square. The vertical beams from the starboard side of the vessel, set as a fan across the vessel track, show the same school detected for at least 4 vertical beams at 40 m range, from the surface up to a depth of ca. 15 m.

Sonar data quality

During adverse weather conditions, sonar data is also affected by the large amount of bubbles present in the upper 30 m. As the primary objective of tis report was to investigate the echo sounder blind zone, data from both horizontal and vertical beams was discarded during these periods, because of the inability to discriminate between school and bubble scatters, in the uppermost beams. An example of this adverse conditions is showed in Figure 5.

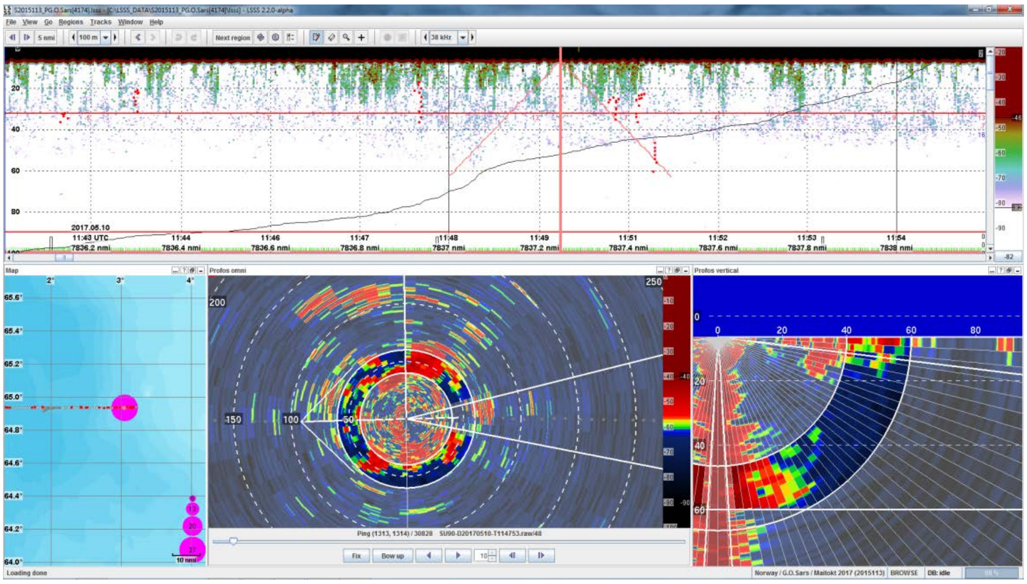


Figure 5. Figure showing acoustic data during adverse weather conditions. EK80 data show rather strong backscatters from the surface up to 30 m product of air bubbles swept down the sea surface (top panel). In the horizontal sonar beams, these bubbles are observed as strong scatters (colors orange to red) almost homogenously distributed up to a range of 150 m from the vessel (central bottom panel). In a zoom of the vertical beams display, the bubble layers are observed as a continuous strong echoes from the surface up to 20 m depth, from the vessel up to 60 m range (right bottom panel).

Consistency between sonar beams

A comparison between area scattering values of beam 3 from port and starboard side for both transects was analyzed (Figure 6). The aggregated transect data showed higher values from port side (p-value = 1.02e-05, mean NASC port = 17.8 m^2 nmi^{-2}, mean NASC starboard = 27.2 m^2 nmi^{-2}). A priori was expected similar NASC values from both sides, and the difference encountered can be explained by the sailing direction East to West in both transects. Although the sonar beams are electronically stabilized, results indicates that beams at both sides of the vessel are not sampling the same depth ranges, and a prevalent vessel roll angle occurs that is not compensated. A comparison of the same beams at different sailing directions will be done later.

Although this difference, measurements from both sides are highly correlated and provide an indication of the presence and relative abundance of school scatters in this layer. We have chosen arbitrary the data from starboard side to be compared with the echo soundermeasurements.

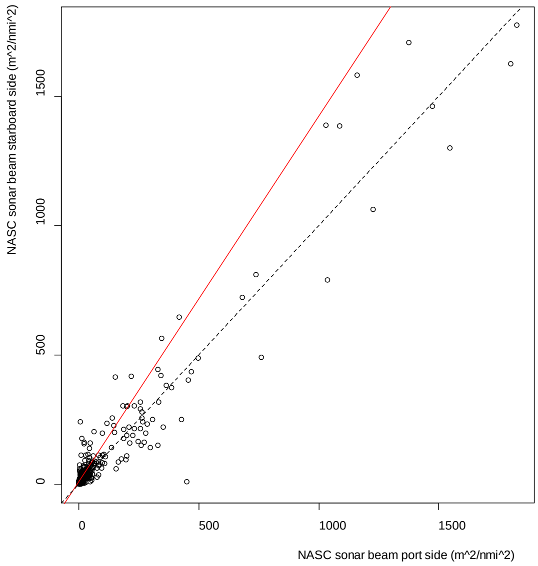


Figure 6. Area scattering NASC values of beam 3 from port and starboard side, for a depth layer between 8.4 and 18.6 m. Red line indicates the linear regression and the black dashed line, the 1:1 curve.

Echosounder and sonar data comparison

The NASC values,in the upper layer between 8 and 19 m depth, along transect at 65°N showed almost continuous school scatters from 10°E to 4°E (Figure 7). To the East no data was available due to bad weather conditions. Around 0°and up to 3°W, more and stronger NASC values were found. Along this sailed distance two surface pelagic trawls confirmed that scatters observed in the sonar data correspond to mackerel. In this same region, no herring was allocated to the EK80 data, except for a few data points around 4°E, which matches the slight increase in the NASC values from the sonar. West from 5°W, another two pelagic trawl indicated the presence of herring in the surface layer above 50 m. From 9°W to about 7°W, high NASC values were measured both by sonar and echosounder. However, in the last part of the transect,close to Iceland, no herring was allocated in the echosounder data, while high values were measured in the sonar.

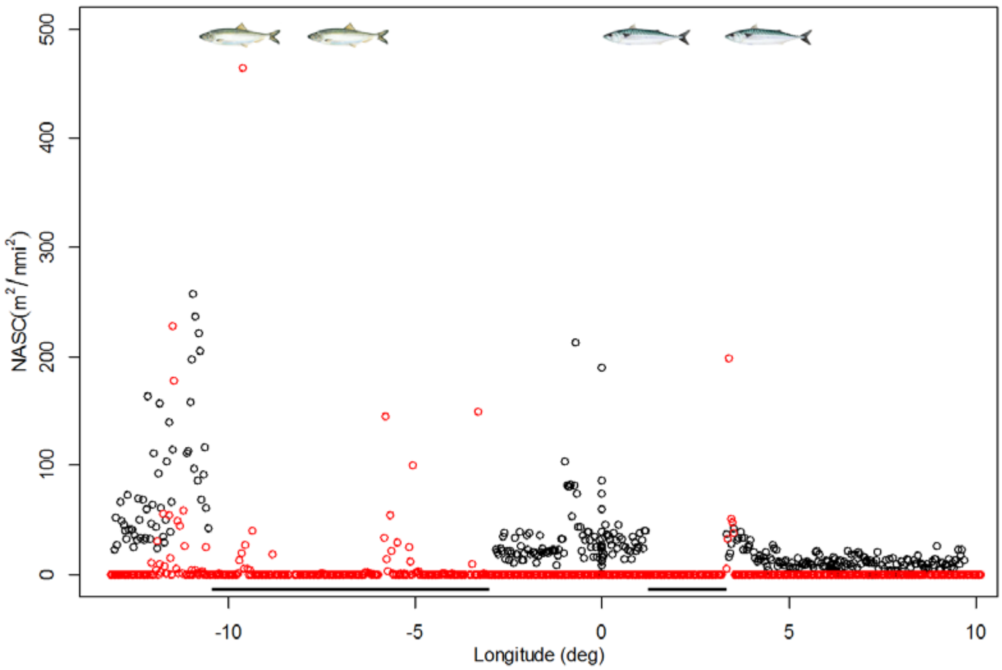


Figure 7.Area scattering along transect centered in 65°N. NASC values from sonar vertical beam (red circles) and echosounder data (black circles). Also indicated the longitude where pelagic trawl stations were made and predominant species (i.e. mackerel and herring). Black continuous line above the X axis indicate periods where sonar data was excluded from the analysis due to bad weather conditions.

Along the transect in the northern region, centered in 70°N, three pelagic trawls indicated the dominance of herring in the surface layer (Figure 8). From the East until about 12°E, high values of NASC were measured by sonar and echosounder in the upper layer between 8 and 17 m depth, reflecting the presence of herring schools in this region. From about 8°E to the East, sonar measurements indicated the presence of herring schools in the upper layer, but no NASC allocation for this species was done in the echo sounder data, except for 1 value (i.e. 1 nmi integrated value) close to the end of the transect.

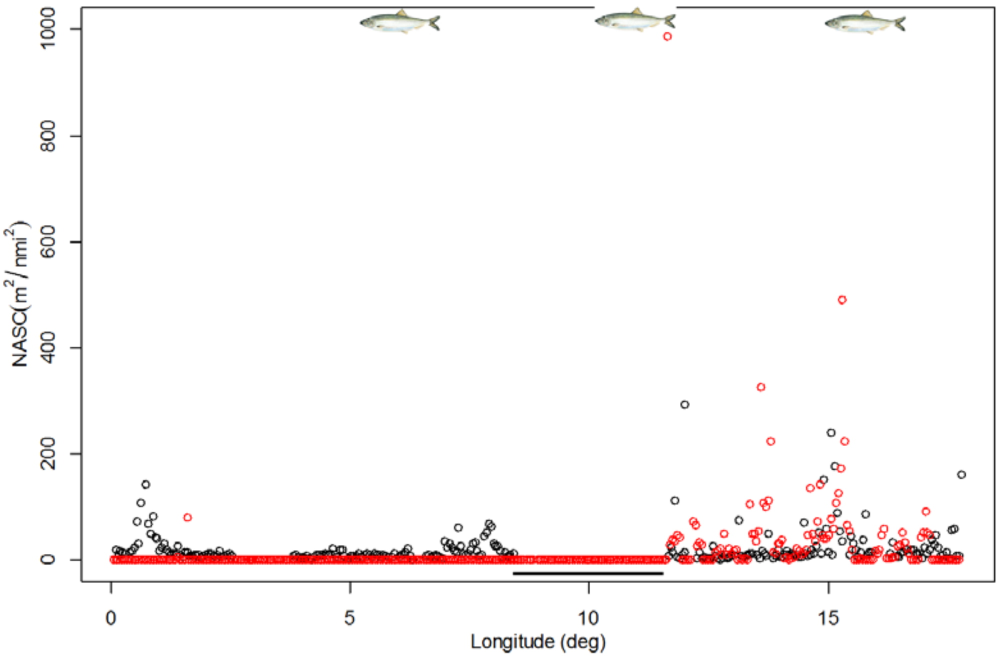


Figure 8. Area scattering along transect centered in 70°N. NASC values from sonar vertical beam (red circles) and echosounder data (black circles). Also indicated longitude where pelagic trawl stations were made and predominant species (i.e. herring). Black continuous line above the X axis indicate periods where sonar data was excluded from the analysis due to bad weather conditions.

Discussion

This report presents a rather simple and fast approach to process vertical beams from sonar data, comparable to the amount of time required to process the echosounder data.

In the present work, sonar data from vertical Beam 3 was analyzed. Beams with a higher tilt (i.e. Beam 1 and 2) were not used because of presence of surface reflection scatters during part of the survey with adverse weather conditions. However, in days with calm seas, the upper beams provided valuable data that will be analyzed later.

The transformation of the sonar data from range along a vertical beam to depth was done using theoretical computations based in transducer location and beam geometry. At the rather short ranges of the sonar data (40 to 60 m), is not expected any ray bending, therefore we estimate that the depth computed is accurate.

Unexpected higher NASC values from the vertical beam pointing to starboard side may indicate a non-random vessel roll when sailing East to West, with the consequent sampling of different depth layerswith respect to the beam pointing to port side. More work is needed to confirm this hypothesis.

The comparison between the sonar and the echosounder data for a depth interval between 8 and 18 m, indicated a general good agreement in some periods of the two transects analyzed. However, in the western end of transect along 65°N close to Iceland, no herring was allocated to the echosounder data, when the sonar measurements indicated the contrary. More dramatic is the difference found in the northern transect, centered in 65°N, where in about 8 deg in longitude (ca. 150 nmi) no herring was allocated to the depth layer analyzed. These results may indicate an underestimation of the herring abundance from the echo sounder measurements, in the specific regions where data was processed. The next step is to investigate methods for the quantification of this underestimation.

References

De Robertis, A. and Handegard N. O., 2012. Fish avoidance of research vessels and the efficacy of noise-reduced vessels: a review- ICES Journal of Marine Science, 70: 34–45.

Korneliussen, R. J., Heggelund, Y., Macaulay, G. J., Patel, D., Johnsen, E., & Eliassen, I. K. (2016). Acoustic identification of marine species using a feature library. Methods in Oceanography, 17, 187-205.

Macaulay, G. J., Vatnehol, S., Gammelsæter, O. B., Peña, H and Ona, E. 2016. Practical calibration of ship-mounted omni-directional fisheries sonars. Methods in Oceanography, 17: 206-220

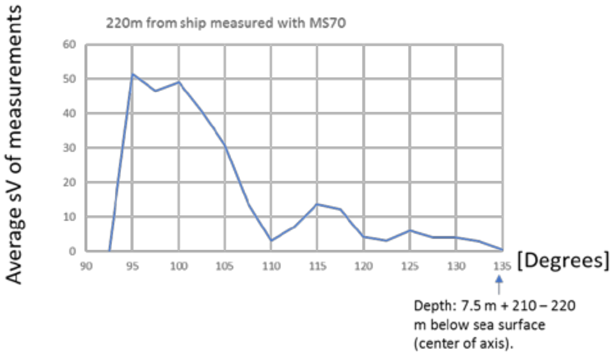
Peña, H., Handegard, N. O. and Ona, E. 2013. Feeding herring schools do not react to seismic air gun surveys. – ICES Journal of Marine Science, 70: 1174–1180.

R Core Team (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Appendix 2

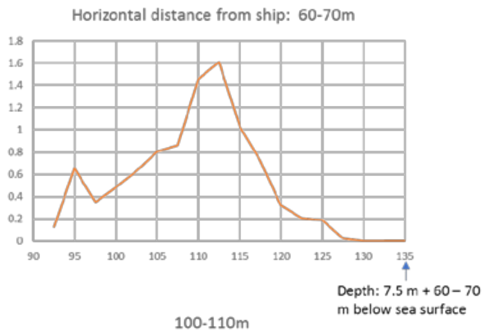
School observations using scientific multibeam sonar during international ecosystem survey in Nordic SEA (IESNS) in May – June 2017

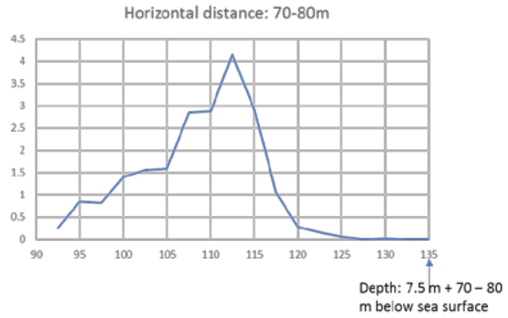
Rolf Korneliussen
Marine ecosystem acoustic group
Institute of Marine research, Bergen, Norway

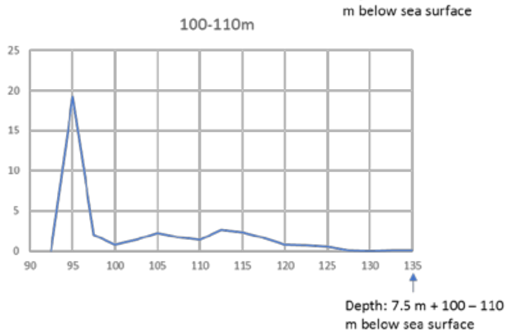


90 degrees means that center of upper fan is horizontal. Center of MS70 transducer is 7.5 m below surface. The three uppermost fans will hit the surface at varying ranges in calm weather, and even more in bad weather. Average all days until 2017.05.23, the weather was mostly good. At 210 – 220 m, the two uppermost beams has hit the surface already, and the upper edge of the third uppermost beam is approaching the surface, while its centre is pointing 5 degrees down. Note that Data was only stored with MS70 down to 180 m

Thus, it is measured fish that may be «at» the surface, but the sonar resolution cannot tell if the fish is on the surface or 40 m below the surface. The center of the beam is 25 m below the surface.

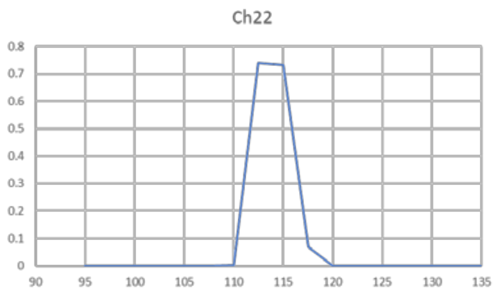




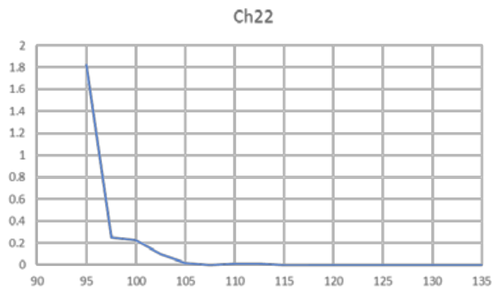


Notice that the s_V is larger at larger distances

All days until 2017.05.23, herring



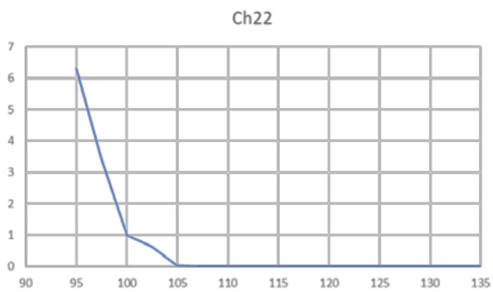
2017.05.07



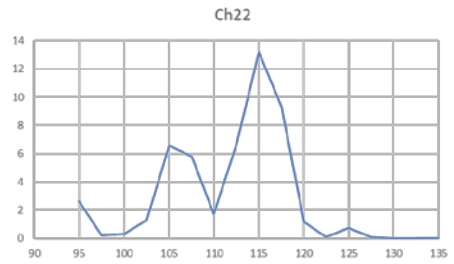
2017.05.08

2017.05.09: Essentially no herring

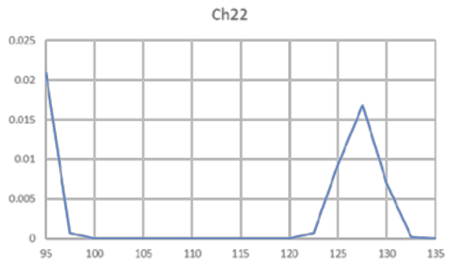
2017.05.10: Essentially no herring



2017.05.11

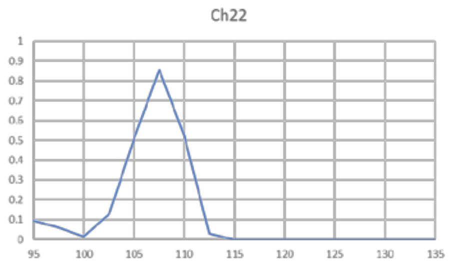


2017.05.12

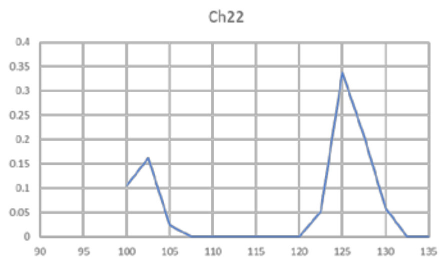


2017.05.14

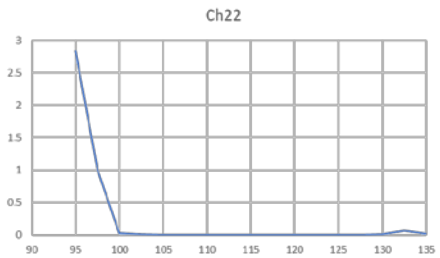
2017.05.15 no PROMUS data



2017.05.16

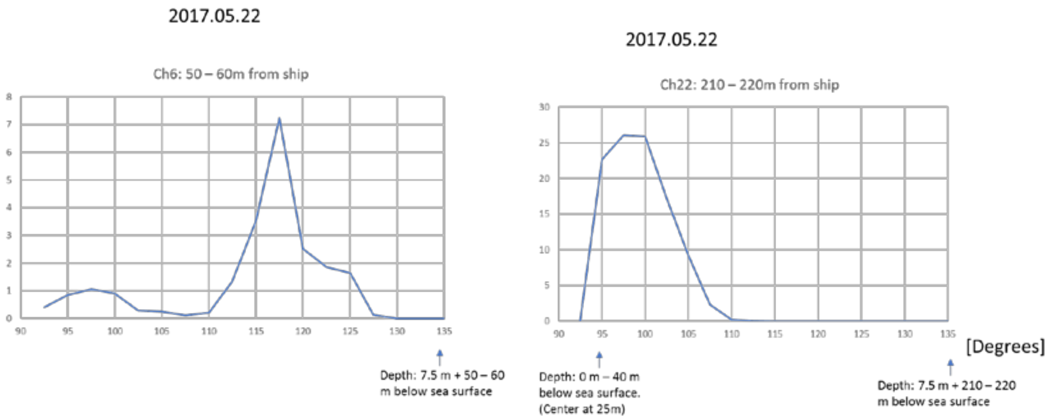


2017.05.17



2017.05.20

2017.05.21



2017.05.22 is the part of the stock close to the Norwegian coast. The depth distribution here is representative for herring close to the Norwegian coast.

Annex 5c: HERAS survey report 2017

Survey Summary table

Name of the survey (abbreviation):	HERAS
Summary:	

The 2017 survey covered all planned strata and survey effort, timing and coverage were comparable to previous years and all main aggregations of sprat and herring are considered to have been sampled sufficiently.
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 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. 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). Abundance of herring was largely comparable to recent surveys in the North Sea area. In the Malin Shelf area abundance was significantly higher than the previous 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 below the long-term average; in Div. 3.a well below.

The estimates derived from the 2017 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 strata.
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	Not generally an issue. During severe weather survey effort was paused in most strata until conditions improved.
Extinction (shadowing)	NA, Target species not thought to aggregate in dense enough schools to produce extinction effects.
Blind zone	NA, Target species typically not found in large quantities near the surface in this area (herring and sprat).
Dead zone	NA, Target species typically not distributed tight to seabed (herring and sprat).
Allocation of backscatter to species	Species composition verified by directed trawling. Allocation of backscatter to species mainly using multifrequency algorithms in LSSS and Echoview.
Target strength	Standard agreed
Calibration	Survey frequencies calibrated according to SISP and results within recommended tolerances.

The 2017 ICES Coordinated Acoustic Survey in the Skagerrak and Kattegat, the North Sea, West of Scotland and the Malin Shelf area

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[2] Wageningen Marine Research, IJmuiden, The Netherlands
[3] Marine Institute, Galway, Ireland
[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 slightly lower than previous year at 1.9 million tonnes largely due to a decrease in the number of fish in the stock (2016: 17 499mill. fish, 2017: 11 621mill. fish). The stock is dominated by young fish of age 3 and 4-wr.

The 2017 estimate of Western Baltic spring-spawning herring 3+ group is 221 000 tonnes and 1 353 million. This is an increase of more than 126% compared to the 2016 estimates of 78 000 tonnes and 600 million fish and a return to stock levels observed prior to 2009.

The West of Scotland estimate (6.a.N) of SSB is 139,000 tonnes and 765 million individuals, a considerable increase compared to the 88,000 tonnes and 486 million herring estimate in 2016

The 2017 SSB estimate for the Malin Shelf area (6.a and 7.b,c) is 145,000 tonnes and 798 million individuals. This is a significant increase compared to the 2016 estimates (88 000 tonnes and 486 million herring). In 2016, the estimates for the Malin Shelf and West of Scotland (6.a.N) were the same as no herring were observed south of the 56°N line of latitude. There was some herring distribution south of 56°N in 2017; this resulted in a slightly higher estimate for the Malin Shelf compared to the West of Scotland.

The total abundance of North Sea sprat (Subarea 4) in 2017 was estimated at 45 956 million individuals and the biomass at 354 000 tonnes (Table 5.10). This is below the long-term average of the time series, in terms of both abundance (2% below) and biomass (16%). The stock is dominated by 1-year-old sprat. The estimate also included 0-gr sprat (6% in numbers, and less than 1% in biomass), which only occasionally is observed in the HERAS survey.

In Division 3.a, the sprat abundance is estimated at 248 million individuals and the biomass at 4 100 tonnes. This is well below the long-term average both in terms of abundance (86% below) and biomass (83%). The stock is dominated by 2- and 3+-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 2017 herring acoustic surveys.

VESSEL	PERIOD	CONTRIBUTING TO STOCKS	STRATA
Celtic Explorer (IRL) EIGB	06 June – 21 July	MSHAS, WoS	2, 3, 4, 5, 6
Scotia (SCO) MXHR6	30 June – 19 July	MSHAS,WoS, NSAS, Sprat NS	1, 91 (north of 58°30′N), 101, 111, 121
Scottish Charter (SCO)	30 June – 7 July	NSAS	91 (north of 58°30′N), 111
Johan Hjort (NOR) LDGJ	2 July – 18 July	NSAS, WBSS	11, 141
Tridens (NED) PBVO	26 June – 20 July	NSAS, Sprat NS	81, 91 (south of 58°30′N)
Solea (GER) DBFH	28 June – 18 July	NSAS, Sprat NS	51, 61, 71, 131
Dana (DEN) OXBH	21 June – 5 July	NSAS, WBSS, Sprat NS, Sprat IIIa	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 2015a) 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 9717 n.mi of track covered during the survey was used in the acoustic analysis, achieving good coverage of the entire survey area. 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 2017 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. Data for strata covered by Denmark (21, 31, 41, 42, 151 and 152) were analysed using the Danish national calculation method used up to 2014 (WKEVAL: ICES 2015b) and combined with StoX calculated estimates for the relevant stocks.

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 North Sea sprat and sprat in 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. 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 sprat (Sprat NS)

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

Div. 3.a Sprat (Sprat 3.a)

Sprat in 3.a is also a geographically delimited stock. All sprats in strata 21, 31, 41 and 42 are included in this index. The border between ICES Div. 3.a and Div. 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 2017

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, North Sea sprat and Div. 3.a sprat) 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 decreased from 2.6 million tonnes in 2016 to 1.9 million tonnes this year (Table 5.6, Figure 5.11).

The abundance of mature fish has decreased from 17 499 million in 2016 to 11 621 this year (Table 5.2) and is largely responsible for the decrease in SSB. The mean weight of mature fish has increased again from 151.3 g last year to 167.2 g and is more in line with the longer time series. This is largely due to the large amount of 2 and 3 winter ring fish entering the SSB last year driving the mean weight down in 2016 and the lower abundance and low maturity level of 2-wr this year. All age groups decreased in mean weight compared to last year but the effect of this on the overall mean weight is offset by the much smaller proportion of small 2wr fish contributing to the average. The large numbers of 2 and 3 winter ring fish last year were encountered as large numbers of 3 and 4 winter ring fish in this years' survey.

The abundance of immature fish in the stock has decreased from 34 187 million in 2016 to 18 434 million this year. This is mainly due to the very low numbers of 1 and 2 winter ring fish which were both some of the lowest in the survey series (Table 5.6, Figure 5.5).

Maturities for 2 winter ringers was very low at 55%. Maturities for ages 3 and above were comparable to last year, with 96% of 3 winter ringers and 97% or higher maturity for all ages 4 and above. 100% maturity was only reported above age 6 (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 strong 2012 and 2013 year classes (3 and 4-winter ringers this year) are now fully recruited to the spawning stock and dominates the stock (Table 5.6, Figure 5.5). The 2007 year class (9-winter rings this year) continues to grow very slow and mean weight continues to be below that of the following year class (Table 5.2). This year class is now in the plus-group.

The distribution of adult herring in the North Sea is still concentrated in the areas east and north of Scotland (Figure 5.3). Similarly to last year the distribution is stretching south in the western North Sea although not quite as far as in 2016.

The 2017 estimate of Western Baltic spring-spawning herring 3+ group is 221 000 tonnes and 1 353 million herring (Table 5.3). This is the highest level observed since 2008 and comparable to the stock size prior to the low levels observed after 2009. The increase was driven by an increase in numbers of all ages. The stock is dominated by 3 and 4 winter ring fish (Table 5.7, Figure 5.6). The numbers of older herring (3+ group) in the stock has returned to the levels seen prior to 2009, and comprise a large proportion of the total stock compared to recent period (55% as compared to an average of 31% for 2009 to 2016). Mean weights at age were significantly increased for ages 1-3 winter ringers this year (up by an average of 20%).

The Malin Shelf herring estimate of SSB is 145 000 tonnes and 798 million individuals (Table 5.4), a significant increase compared to the 88 000 tonnes and 486 million herring estimate in 2016. The estimate is still however very low in the time series (Table 5.9, Figure 5.14). In 2017, 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 139 000 tonnes and 765 million individuals (Table 5.4), an increase compared to the 88 000 tonnes and 486 million herring estimate in 2016. Long-term indices of abundance per age class for West of Scotland herring are provided in Table 5.8 and Figure 5.7. In 2017, the biomass of herring in 6.a.S and 7.b,c was 6 000 tonnes.

Although there was an increase in the 2017 estimates for the Malin Shelf and West of Scotland compared to 2016, the estimates are still among the lowest in the time series. The distribution of herring schools expanded slightly compared to 2016 and were more spatially heterogeneous; there was some herring distributed south of 56°N line of latitude (Figure 5.3a) in 2017. There were some strong herring marks found to the west and northwest of the Outer Hebrides and around St. Kilda in 2017, with marks occurring in deeper water on a contour towards the edge of the survey area in the northwest. Herring are also often 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 was less evidence in 2017 that herring distributions in this area influenced the Malin Shelf/West of Scotland estimates. It appears that the increase in the 2017 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 2016 the estimate was dominated by 5,3, and 4 winter ringed fish and ranked accordingly. In 2017, 3 to 6 winter ringed fish dominated representing 89% of total biomass and 89% of total abundance. Immature fish represented a very small proportion of TSB in 2017 (0.3%; 384 tonnes) and TSN 0.3% (3 338 individuals). 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 Division 3.a

In the North Sea, sprat data were available from strata 51, 61, 71, 81, 101, 131, 151 and 152 (Table 5.17). As in 2015-2016, no sprats were observed in the northern part of the North Sea in strata 11, 111, 121 and 141. In strata 101, sprats were mostly found in coastal areas, as in 2015 and 2016. In 2014, no sprats were found in this part of the survey, and the coastal distribution of sprats probably explains some of the high variability in abundances between years. In strata 51, 61, 71, 81 and 131, 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). In the 2017-2015 acoustic surveys, sprats were found further north than in 2014, but 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 sprats can be found even further south in the English Channel. The sprat distribution in the North Sea and Division 3.a in terms of abundance and biomass per strata 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 2017 was estimated at 45 956 million individuals and the biomass at 354 000 tonnes (Table 5.10). This is at average in the time series in terms of abundance, and 16% below average in terms of biomass. Compared to the historic high of the time series (the 2016 estimate), abundance and biomass have decreased by 63 and 68%, respectively (Table 5.11, Figure 5.9). The stock was dominated by 1-year-old sprat (79% of biomass), and most of the sprat were found to be mature (78%) (Table 5.10). The 2014-2016 sprat biomass estimates are all well above the long-term average for the survey time series, whereas the 2017 estimate was 16% 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 Division 3.a, sprats were mostly found in the Kattegat (strata 21) and, in very small amounts, in the Skagerrak area (strata 151), as in 2014-2016. This contrasts with 2013, when sprats were only seen in the Kattegat. The abundance is estimated at 248 million individuals, a decrease by 74% compared to the 957 million individuals in 2016 (Tables 5.12-5.13). The biomass has decreased by 70% to 4100 tonnes. 2-year-old sprat dominate the stock (59% in numbers and 56% in biomass), while also the 3+ group was a large proportion of the stock. The age-disaggregated time-series of sprat abundance and biomass in Division 3.a are given in Table 5.13 and Figure 5.10. The sprat distribution in the North Sea and Division 3.a in terms of abundance and biomass per strata is shown in Table 5.17. The NASC values attributed to sprat in the survey are shown in Figure 5.4.

Quality considerations

The 2017 HERAS global survey estimates of abundance were calculated using StoX, with input files (XML) 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 this will also be uploaded from 2018.

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 (strata 11, 21, 31, 41, 42, 141, 151 and 152) 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).

In addition, 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 a number of 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 taken into account 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-occur 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 strata 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.

Recommendations:

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

2) Include an exploratory strata covered by NORACCU to the North of strata 11 and 111 to monitor stock containment to the north and investigate whether it is necessary to expand the survey area further north..

3) Norwegian data should also be uploaded to the ICES database in 2018.

References

Demer DA, Andersen LN, Bassett C, Berger L, Chu D, Condiotty J, Cutter GR, Hutton B, Korneliussen R, Le Bouffant N, Macaulay G, Michaels WL, Murfin D, Pobitzer A, Renfree J.S, Sessions TS, Stierhoff KL, Thompson CH 2017. "2016 USA–Norway EK80 Workshop Report: Evaluation of a wideband echosounder for fisheries and marine ecosystem science," ICES Cooperative Research Report, 336, p. 69.

Demer DA, Berger L, Bernasconi M, Bethke E, Boswell K, Chu D, Domokos R, Dunford A, Fassler SMM, Gauthier S, Hufnagle L, Jech M, Le Bouffant N, Lebourges-Dhaussy A, Lurton X, Macaulay GJ, Perrot Y, Ryan T, Parker-Stetter S, Stienessen S, Weber T, Williamson N 2015. “Calibration of acoustic instruments,” ICES Cooperative Research Report 326, p. 133.

Foote KG, Francis DTI, Atkins PR 2007, “Calibration sphere for low-frequency parametric sonars,” J. Acoust. Soc. Am., 121(3), p. 1482.

ICES 2015a. Manual for International Pelagic Surveys (IPS). Series of ICES Survey Protocols SISP 9 – IPS. 92 pp.

ICES 2015b. Report of the Workshop on evaluating current national acoustic abundance estimation methods for HERAS surveys (WKEVAL), 24-28 August 2015, ICES Headquarters, Copenhagen, Denmark. ICES CM 2015/SSGIEOM:16. 48 pp.

ICES 2017a. “Interim Report of the Working Group on Fisheries, Acoustics, Science and Technology,” in WGFAST 2017. p. 40.

ICES 2017b. Workshop on Stock Identification and Allocation of Catches of Herring to Stocks (WKSIDAC). 20–24 November 2017. Galway, Ireland. 99 p.

StoX (2015) StoX: An open source approach to acoustic and swept area survey calculations. Institute of Marine Research, Bergen, Norway. URL: http://www.imr.no/stox

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 2017. Mean weights, mean length and fraction mature by age winter ring.

Age (ring)	Numbers	Biomass	Maturity	Weight(g)	Length (cm)
0	14,260	50	0.00	3.5	8.0
1	3,054	130	0.02	42.6	17.3
2	1,761	175	0.55	99.6	22.6
3	6,095	948	0.96	155.5	25.9
4	3,142	559	0.97	177.9	27.0
5	787	156	0.98	198.3	28.0
6	365	82	0.98	224.6	29.3
7	298	70	1.00	233.2	29.6
8	153	36	1.00	237.3	29.9
9+	140	32	1.00	230.5	29.9
Immature	**18,434**	**295**		**16.0**	**10.4**
Mature	**11,621**	**1,943**		**167.2**	**26.4**
Total	**30,055**	**2,238**	**0.39**	**74.5**	**16.6**

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 2017. Numbers, biomass, mean weights and mean length and by winter ring.

Age (ring)	Numbers	Biomass	Weight (g)	Length (cm)
0	1	0	23.0	15.5
1	696	31	45.0	17.8
2	424	41	97.1	22.5
3	661	101	153.4	25.9
4	401	63	157.3	26.3
5	94	16	173.4	27.1
6	53	10	182.0	28.0
7	52	11	202.7	28.5
8+	92	20	221.2	29.7
3+	**1 353**	**221**	**163.6**	**26.6**
Total	**2 474**	**294**	**118.8**	**23.4**

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 2017. Mean weights, mean lengths and fraction mature by winter ring.

Age (ring)	Numbers	Biomass	Maturity	Weight (g)	Length (cm)
0	**0**	**0**	**-**	**-**	**-**
1	**0**	**0**	**-**	**-**	**-**
2	**22**	**3**	**0.89**	**134.5**	**24.9**
3	**324**	**55**	**1.00**	**170.4**	**26.8**
4	**144**	**26**	**1.00**	**180.6**	**27.5**
5	**97**	**19**	**1.00**	**197.9**	**28.5**
6	**109**	**22**	**1.00**	**199.0**	**28.8**
7	**44**	**9**	**1.00**	**213.7**	**29.4**
8	**18**	**4**	**1**	**223.1**	**29.7**
9+	**5**	**1**	**1**	**235.7**	**30.5**
Immature	**4**	**1**		**115.2**	**23.2**
Mature	**761**	**139**		**183.1**	**27.6**
Total	**765**	**140**	**1.00**	**182.8**	**27.6**

Table 5.5. Total numbers (millions) and biomass (thousands of tonnes) of Malin Shelf herring (6.a.N-S, 7.b,c) June-July 2017. Mean weights, mean lengths and fraction mature by winter ring.

Age (ring)	Numbers	Biomass	Maturity	Weight (g)	Length (cm)
0	0	0	-	-	-
1	0	0	-	-	-
2	25	3	0.95	128.8	24.9
3	339	58	1.00	169.9	26.8
4	155	28	1.00	179.0	27.4
5	106	21	1.00	196.2	28.5
6	110	22	1.00	198.3	28.8
7	47	10	1.00	212.3	29.4
8	13	3	1.00	222.4	29.8
9+	5	1	1.00	231.9	30.3
Immature	**3**	**0.4**		**120.0**	**25.5**
Mature	**798**	**145**		**181.7**	**27.5**
Total	**800**	**145**	**1.00**	**181.5**	**27.5**

Table 5.6. Estimates of North Sea autumn spawners (millions) at age and SSB from acoustic surveys, 1986–2017. For 1986 the estimates are the sum of those from the Division 4.a summer survey, the Division 4.b autumn survey, and the Divisions 4.c, 7.d winter survey. The 1987 to 2017 estimates are from summer surveys in Divisions 4.a,b,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

Table 5.7. Numbers at age (millions) of Western Baltic spring spawning herring at age (winter rings) from acoustic surveys 1992 to 2017. 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

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 2017. In 1997 the survey was carried out one month early in June as opposed to July when all the other surveys were carried out.

Year/Age	1	2	3	4	5	6	7	8	9+	SSB:
1993	3	750	681	653	544	865	284	152	156	866
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	577	803	329	95	61	77	78	115	370
1997	792	642	286	167	66	50	16	29	24	141
1998	1,221	795	667	471	179	79	28	14	37	376
1999	534	322	1,389	432	308	139	87	28	35	460
2000	448	316	337	900	393	248	200	95	65	500
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	168
2006	112	835	388	285	582	415	227	22	59	472
2007	0	126	294	202	145	347	243	163	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

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 2017.

Year/Age	1	2	3	4	5	6	7	8	9+	SSB:
2008	312	290	998	720	363	331	744	386	274	842
2009	928	265	274	444	380	225	193	500	456	593
2010	300	376	374	242	173	146	102	100	297	366
2011	63	257	900	485	213	228	205	113	264	494
2012	796	548	832	518	249	115	111	57	105	427
2013	0	212	435	672	195	71	61	29	37	282
2014	1031	281	243	502	534	148	33	19	13	285
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

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 2017 North Sea acoustic survey (HERAS).

Age	Abundance (million)	Biomass (1000 t)	Mean weight (g)	Mean length (cm)
0i	2 941	2.4	0.8	4.8
1i	14 397	76.8	5.3	8.8
1m	23 727	203	8.6	10.3
2i	14	0.1	8.9	10.4
2m	3 504	48	13.8	12.0
3i	0	0		
3m	1 230	21	16.9	12.9
4m	144	3	17.8	13.3
5m	0	0		
6m	0	0		
Immature	**17 351**	**79**	**4.6**	**8.1**
Mature	**28 605**	**275**	**9.6**	**10.6**
Total	**45 956**	**354**	**7.7**	**9.7**

Table 5.11. Sprat in the North Sea (ICES Subarea 4): Time-series of abundance and biomass as obtained from the summer North Sea acoustic survey (HERAS) time series 2000-2017. 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
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 Division 3.a: Abundance, biomass, mean weight and length by age and maturity from the summer 2017 North Sea acoustic survey (HERAS).

Age	Abundance (million)	Biomass (tonnes)	Mean weight (g)	Mean length (cm)
0i	0	0		
1i	0	0		
1m	11	118	10.8	11.1
2i	0	0		
2m	146	2301	15.7	12.8
3m+	91	1672	18.5	13.6
Immature	0	0		
Mature	248	4090	16.5	13.0
Total	248	4090	16.5	13.0

Table 5.13. Sprat in ICES Division 3.a: Time-series of sprat abundance and biomass as obtained from the summer North Sea acoustic survey (HERAS) time series 2006-2017.

	Abundance (million)					Biomass (kt)				
Year/Age	0	1	2	3+	Sum	0	1	2	3+	Sum
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 strata, last year and present survey. Strata numbers corresponds to numbering in Figure 5.1.

	2016				2017			
Strata	Abundance (mill)	Biomass (kt)	Mean weight (g)	% Mature	Abundance (mill)	Biomass (kt)	Mean weight (g)	% Mature
11	800	136	170.4	72	1 186	194	163.2	76
21	640	3	4.3	0	125	4	31.9	0
31	182	12	64.3	2	110	6	57.0	2
41	270	21	76.3	6	142	9	64.1	2
42	[a]	[a]	[a]	[a]	50	3	51.7	1
51	10 495	40	3.8	0	3 325	10	3.1	0
61	3 959	31	7.9	0	10 603	37	3.5	0
71	1 748	12	7.0	0	285	5	18.2	0
81	943	44	46.4	15	715	54	75.5	48
91	12 970	1 658	127.8	77	6 871	950	138.2	85
101	692	58	84.4	47	155	9	57.5	6
111	3 049	625	205.0	83	3 093	602	194.6	98
121	1 583	266	168.0	82	1 301	250	192.5	99
131	12 486	438	35.1	17	1 289	32	25.1	0
141	1 798	162	90.1	24	586	64	108.7	39
151	70	4	50.8	6	135	4	30	0
152	[b]	[b]	[b]	[b]	82	5	62.2	4

[a] New strata in 2017, was part of strata 41 in 2016. [b] New strata in 2017, was part of 151 in 2016.

Table 5.15. Western Baltic spring spawning herring. Total abundance, biomass and mean weight by strata. Strata numbers corresponds to numbering in Figure 5.1.

	2016			2017		
Strata	Abundance (mill)	Biomass (kt)	Mean weight (g)	Abundance (mill)	Biomass (kt)	Mean weight (g)
11	221	40	180.1	265	46	174.8
21	223	1.6	7.0	98	4	37.4
31	179	12.3	68.4	100	6	63.6
41	400	35.1	87.9	135	9	70.1
42a	-	-	-	46	2	52.8
141	178	26	145.8	251	38	150.0
151	282	10.7	37.8	213	6	30.2
152b	-	-	-	112	8	74.9

[a] New strata in 2017, was part of strata 41 in 2016. [b] New strata in 2017, was part of 151 in 2016.

Table 5.16. Malin shelf and 6.a.N herring. Total abundance, biomass, mean weight and percent mature by strata. Strata numbers corresponds to numbering in Figure 5.1. The 6.a.N herring geographic subset is comprised of strata marked with *.

		2016					2017				
Strata		Abundance (mill)	Biomass (kt)	CV	Mean weight (g)	% Mature	Abundance (mill)	Biomass (kt)	CV	Mean weight (g)	% Mature
1*	a	68	12	0.7	177.0	99%	304	57	-	188.6	100
	b	55	9	0.4	161.0	98%					
	2*	0	0	-	-	-	0	0	-	-	-
	3*	283	53	0.3	186.0	100%	293	54	-	185.6	100
	4*	79	14	0.4	182.1	100%	168	28	-	165.0	100
	5	0	0	-	-	-	36	6	-	165.0	100
	6	0	0	-	-	-	0	0	-	-	-

Table 5.17. North Sea sprat and Div. 3.a sprat. Total abundance, biomass, mean weight and percent mature by strata. Strata numbers corresponds to numbering in Figure 5.1.

		2016				2017			
Stock	Strata	Abundance (mill)	Biomass (t)	Mean Weight (g)	% Mature	Abundance (mill)	Biomass (t)	Mean Weight (g)	% Mature
Div. IIIa sprat	21	957	13 516	14.1	29	256	4 223	16.5	100%
	31	0	0	-	-	0	0	-	-
	41	0.001	0.017	12.3	0	0	0	-	-
	42a	-	-	-	-	0	0	-	-
North Sea sprat	11	0	0	-	-	0	0	-	-
	51	55 722	441 419	7.9	47	27 874	191 881	6.9	51%
	61	20 147	238 440	11.8	69	9 540	65 232	6.8	65%
	71	11 875	103 375	8.7	67	1 583	15 234	9.6	88%
	81	17 418	221 690	12.7	84	768	11 492	15.0	100%
	91	1 477	16 337	11.1	93	0	0	-	-
	101	508	4169	8.2	100	113	1 206	10.6	85%
	111	0	0	-	-	0	0	-	-

121	0	0	-	-	0	0	-	-
131	16 758	82 289	4.9	36	6 025	68 315	11.3	98%
141	0	0	-	-	0	0	-	-
151	817	11 164	13.7	12.3	52	706	13.5	100%
152b	-	-	-	-	0	0	-	-

[a] New strata in 2017, was part of strata 41 in 2016. [b] New strata in 2017, was part of 151 in 2016.

Table 5.18. Length of track used in analysis, number of fish ages used in estimates and transect spacing for each strata in the 2016 and 2017 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.

	2016				2017			
Strata	Total transect length (nmi.)	Herring ages	Sprat ages	Transect spacing (nmi.)	Total transect length (nmi.)	Herring ages	Sprat ages	Transect spacing (nmi.)
1	396	260	-	15	518	297	-	15
2	218	0	-	-	90	0	-	-
3	139	483	-	15	167	150	-	15
4	131	241	-	15	125	100	-	15
5	385	0	-	15	153	100	-	15
6	401	0	-	15	124	100	-	15
11	859	677	-	15	907	1026	-	15
51	353	312	672	25	595	393	676	25
61	119	160	236	-	248	239	338	23
71	263	207	184	15	328	421	343	17.5
81	462	133	227	35	575	125	88	30
91	1614	2447	-	15	1532	1367	22	15
101	90	116	31	15	96	45	21	15
111	1114	1060	-	7.5	1042	1196	-	10
121	661	790	-	7.5	413	344	-	15
131	428	395	414	37.5	614	415	345	30
141	1128	489	-	15	1243	497	0	15
21	192	3264	930	10	190	635	391	13
31	92			10	138	357	-	10

41	215	17.5	141	697	-	17.5
42	a	-	70	355	-	17.5
151	411	15	328	720	71	15
152	b	-	80	362	0	15

[a] New strata in 2017, was part of strata 41 in 2016. [b] New strata in 2017, was part of 151 in 2016.

Table 5.19. Results from the calibration procedure using the standard sphere method for the EK80 CW at 38 kHz by the RV Solea (GER) and RV Johan Hjort (NOR).

	GER	NOR
Number of target detection (#)	644	526
rms error (dB)	0.1825	0.0698
Gain (dB)	26.89	26.5
S_a correction (dB)	-0.0883	0.0220

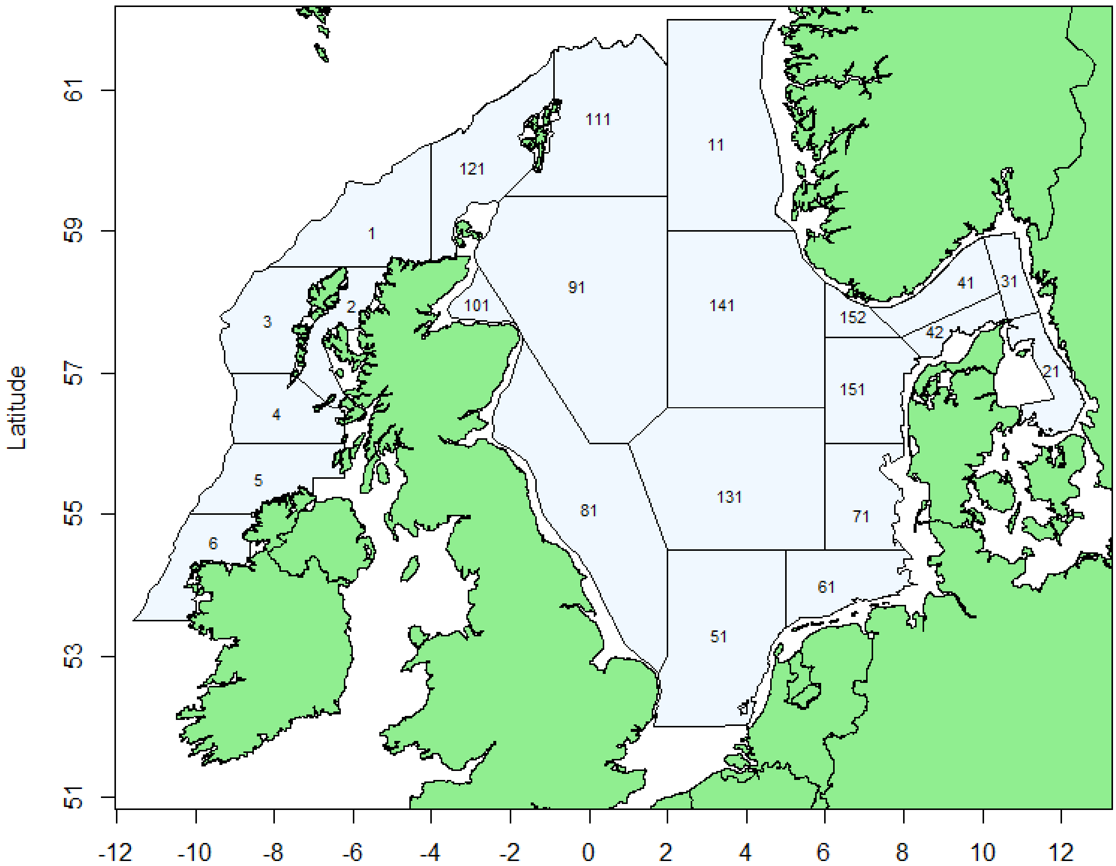

Figure 5.1. Strata used in the HERAS survey 2017.

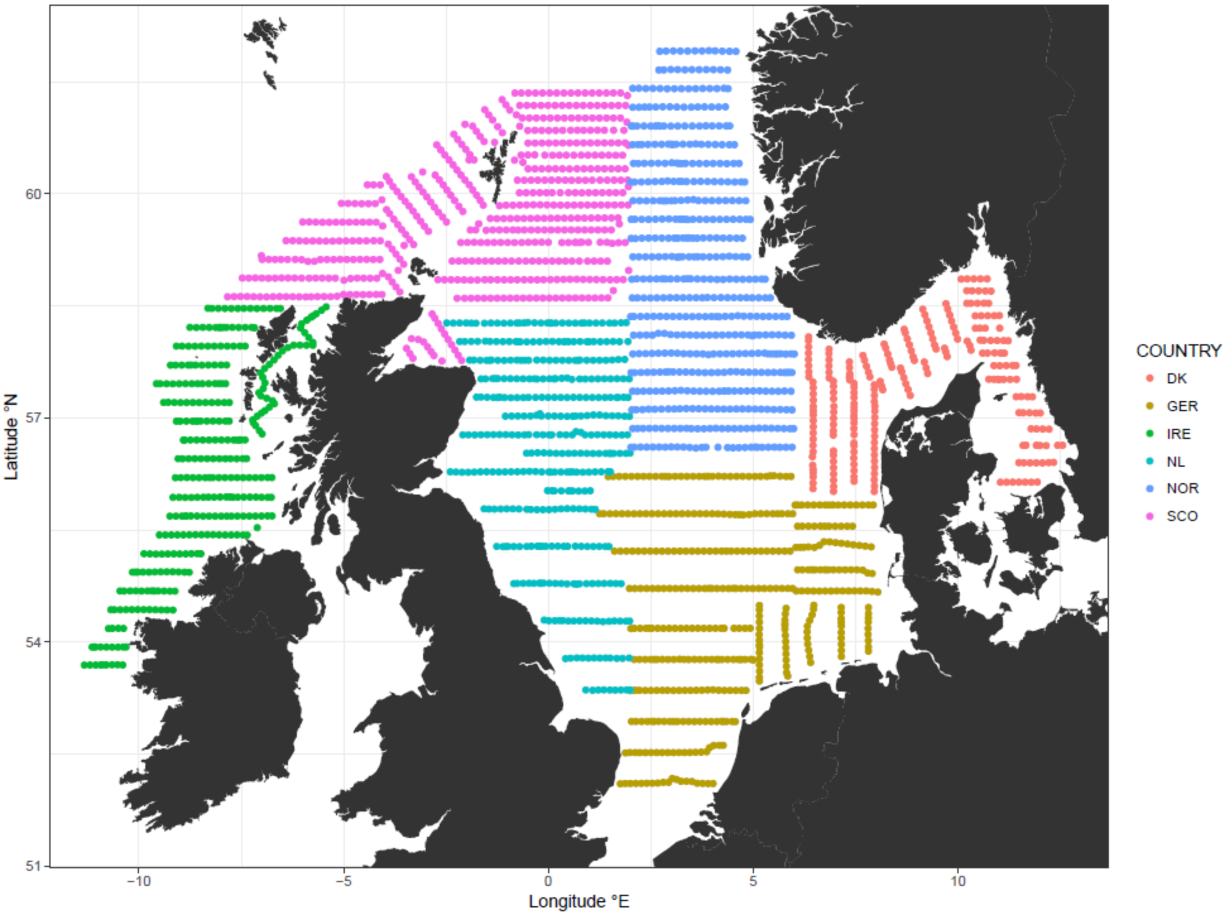

Figure 5.2. Survey area coverage in the HERAS survey in 2017 and individual vessel tracks by nation.

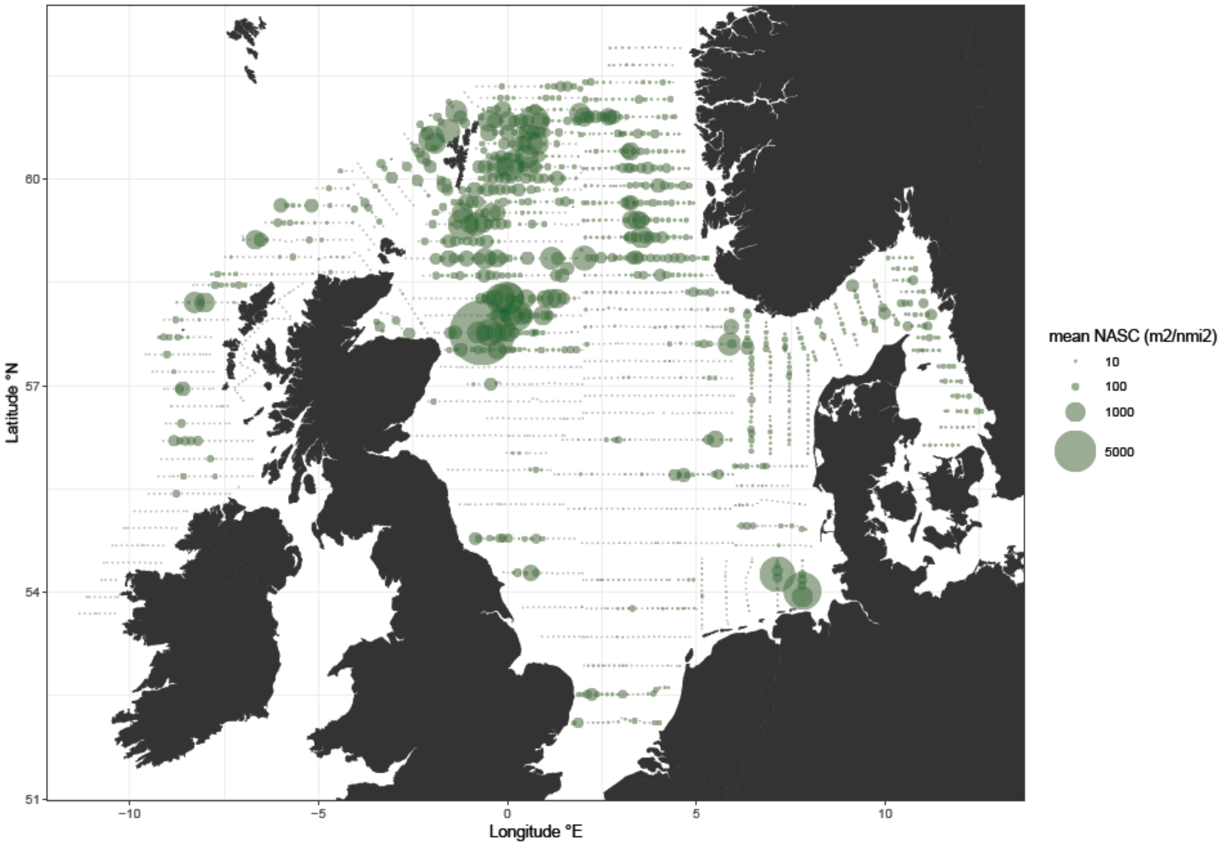

Figure 5.3. Distribution of NASC attributed to herring in HERAS in 2017. Acoustic intervals represented by light grey dot with green circles representing size and location of herring aggregations. NASC values are resampled at 5 nmi. intervals along the cruise track.

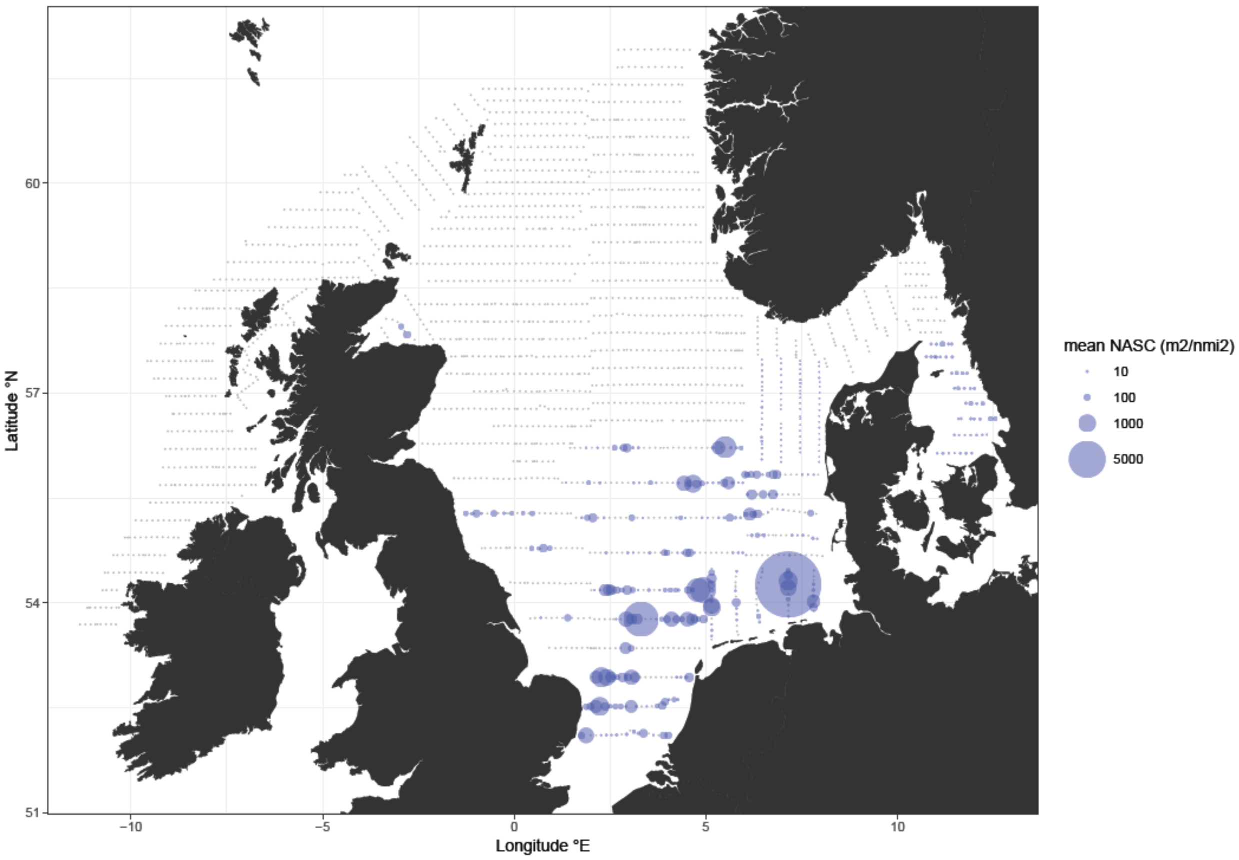

Figure 5.4. Distribution of NASC attributed to sprat in HERAS in 2017. Acoustic intervals represented by light grey dot with blue circles representing size and location of sprat aggregations. NASC values are resampled at 5 nmi. intervals along the cruise track.

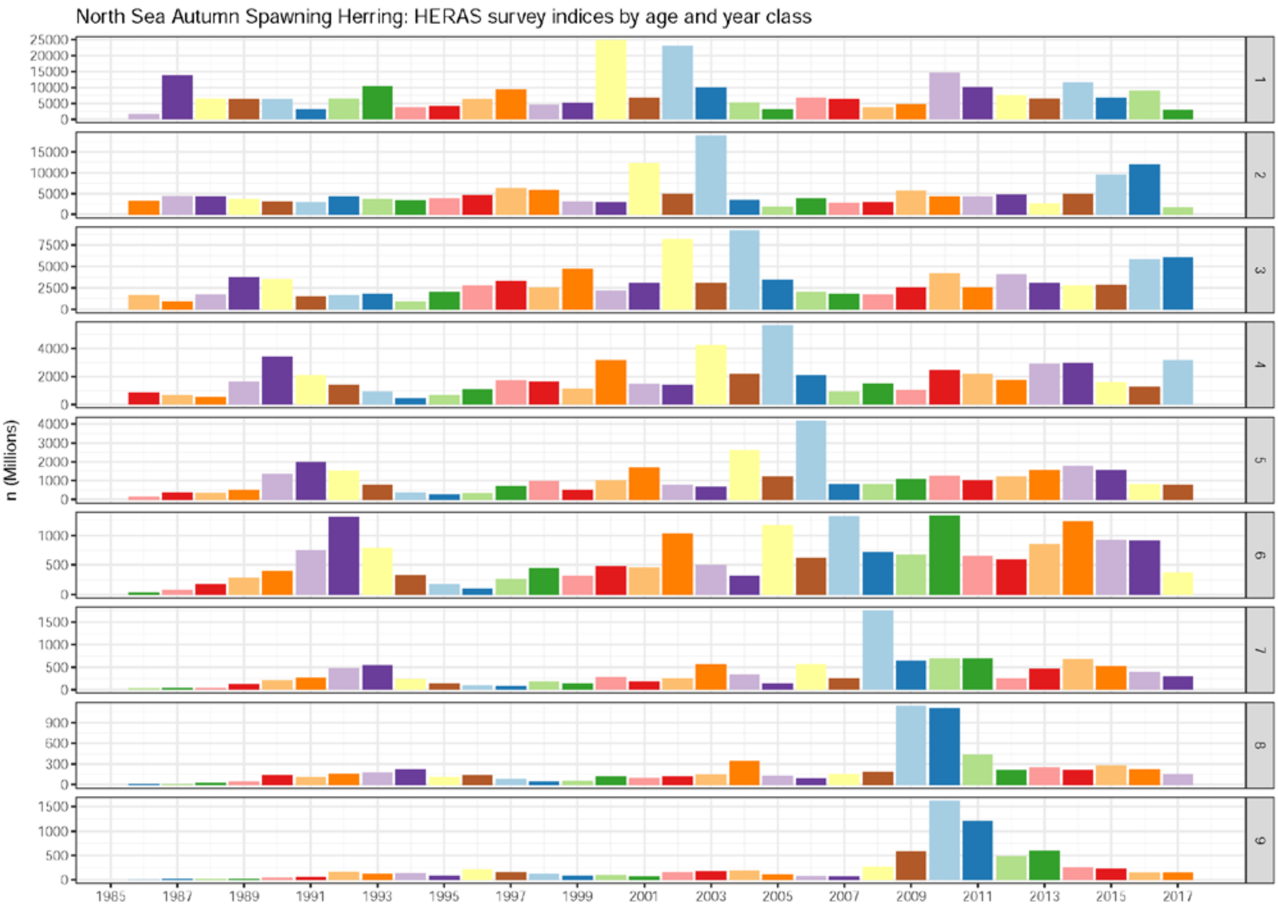

Figure 5.5. North Sea autumn spawning Herring: HERAS indices (millions) by age (winter rings) and year from the acoustic surveys 1986-2017. Age 9 includes ages 9 and older. Note diverging scales of abundance between ages.

Figure 5.6. Western Baltic spring spawning Herring: HERAS indices (millions) by age (winter rings) and year from the acoustic surveys 1992-2017. Age 8 includes ages 8 and older. Note diverging scales of abundance between ages.

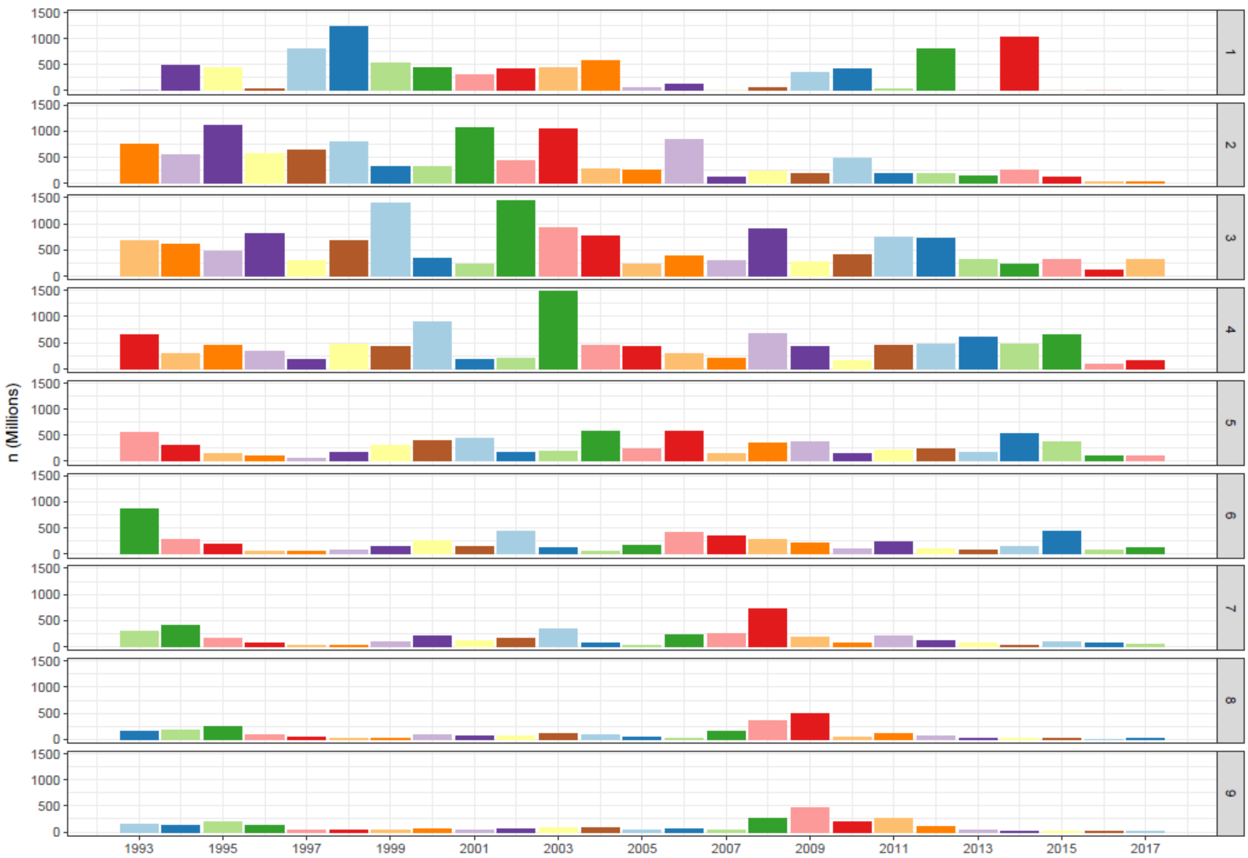

Figure 5.7. West of Scotland (6.a.N) autumn spawning herring: HERAS indices (millions) by age (winter rings) and year from the acoustic surveys 1993-2017. Age 9 includes ages 9 and older.

Figure 5.8. Malin Shelf Herring (6.a.N-S, 7.b,c): HERAS indices (millions) by age (winter rings) and year from the acoustic surveys 2008-2017. Age 9 includes ages 9 and older.

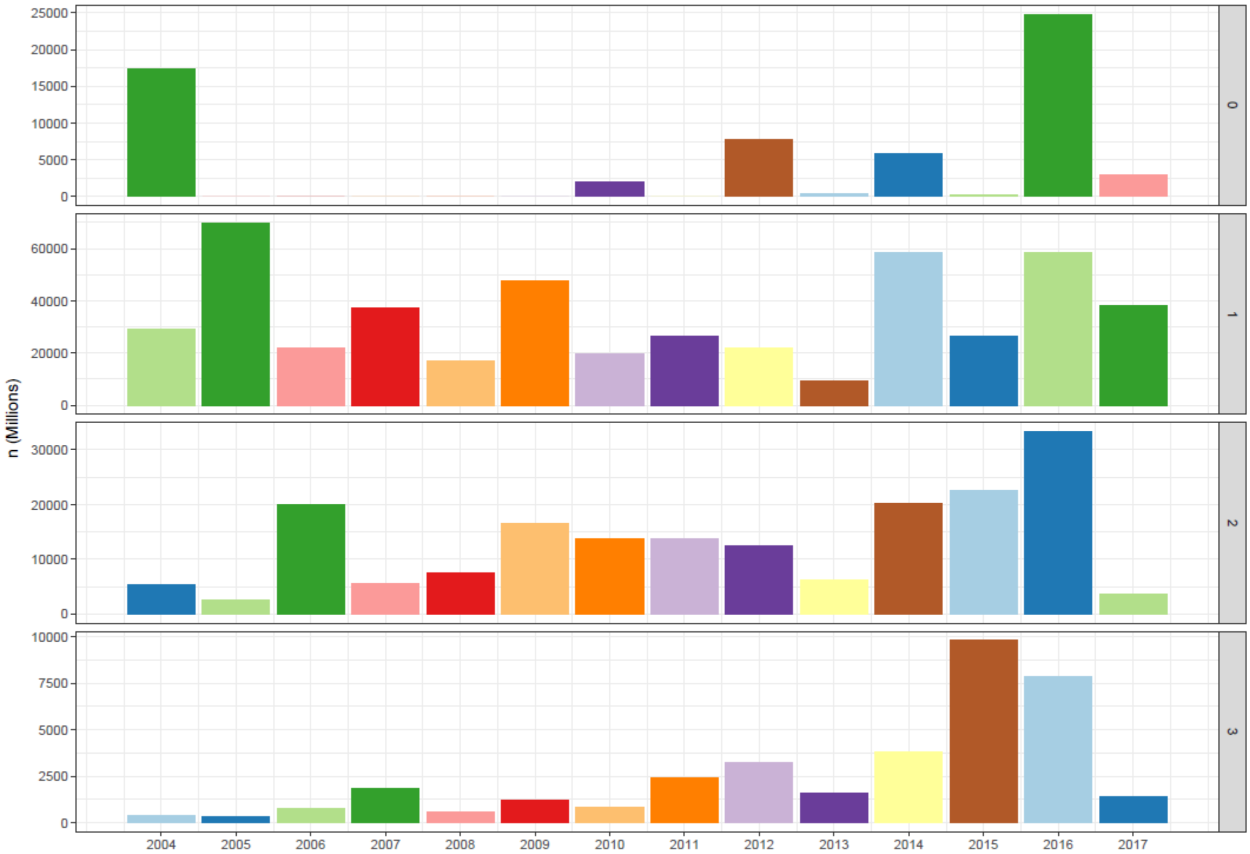

Figure 5.9. North Sea Sprat: HERAS indices (millions) by age (winter rings) and year from the acoustic surveys 2004-2017. Age 3 includes ages 3 and older. Note diverging scales of abundance between ages.

Figure 5.10. Sprat in Division 3.a: HERAS indices (millions) by age (winter rings) and year from the acoustic surveys 2006-2017. Age 3 includes ages 3 and older. Note diverging scales of abundance between ages.

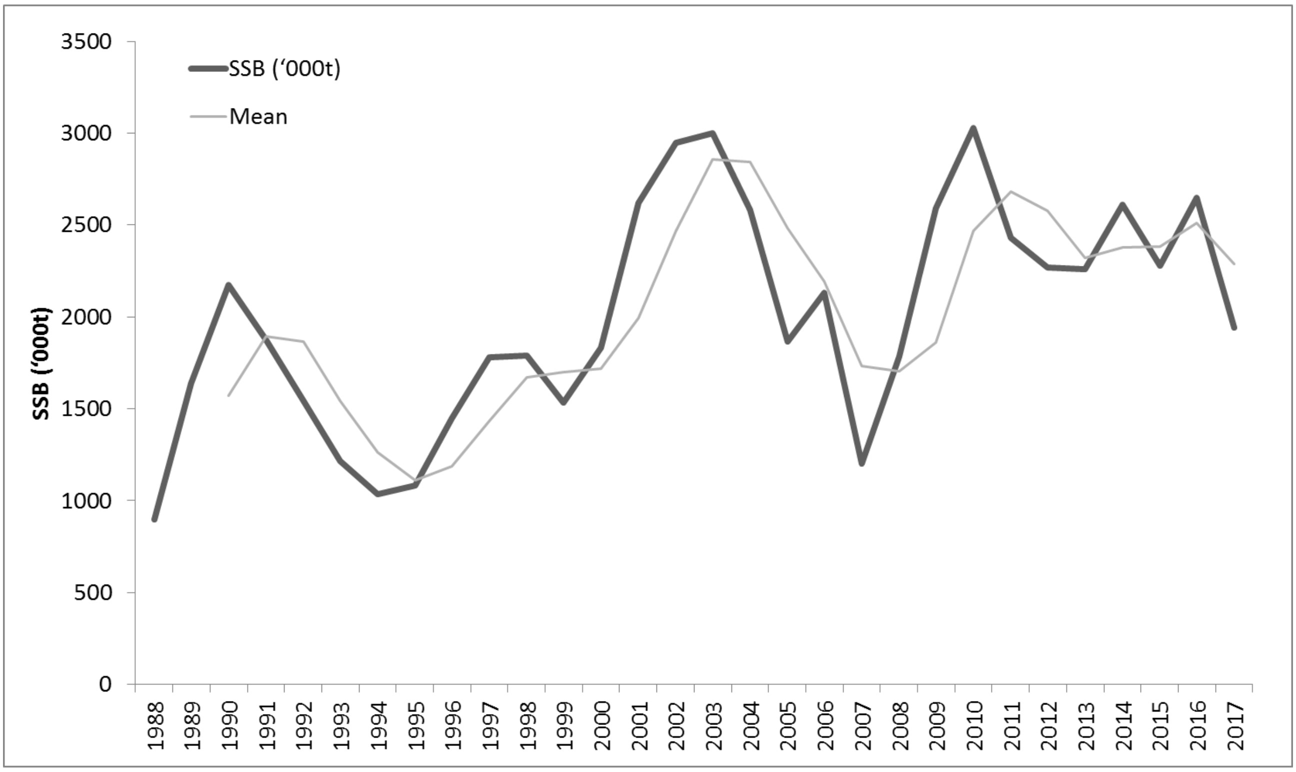

Figure 5.11. Time series of SSB of North Sea autumn spawning herring with three year running mean.

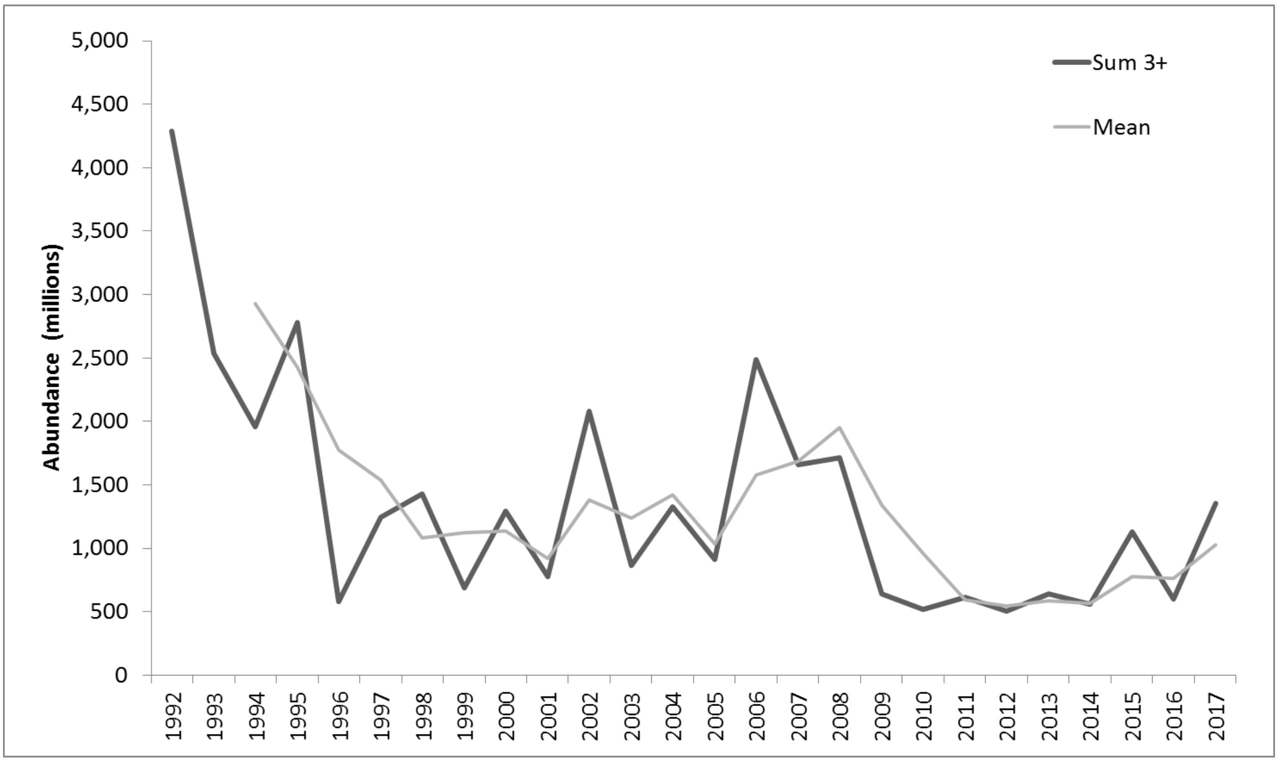

Figure 5.12. Time series of 3+ abundance of Western Baltic spring-spawning herring with three year running mean.

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

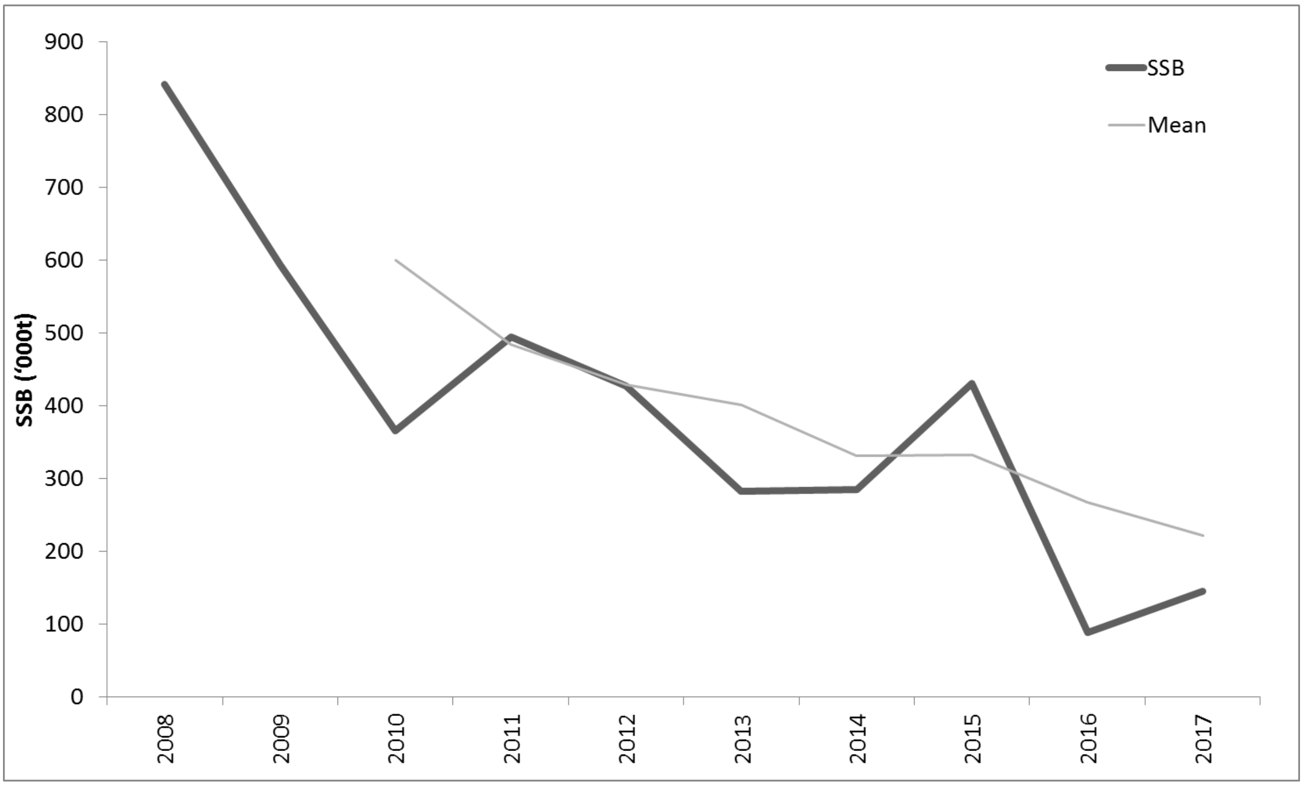

Figure 5.14. Time series of SSB of Malin Shelf herring with three year running mean.

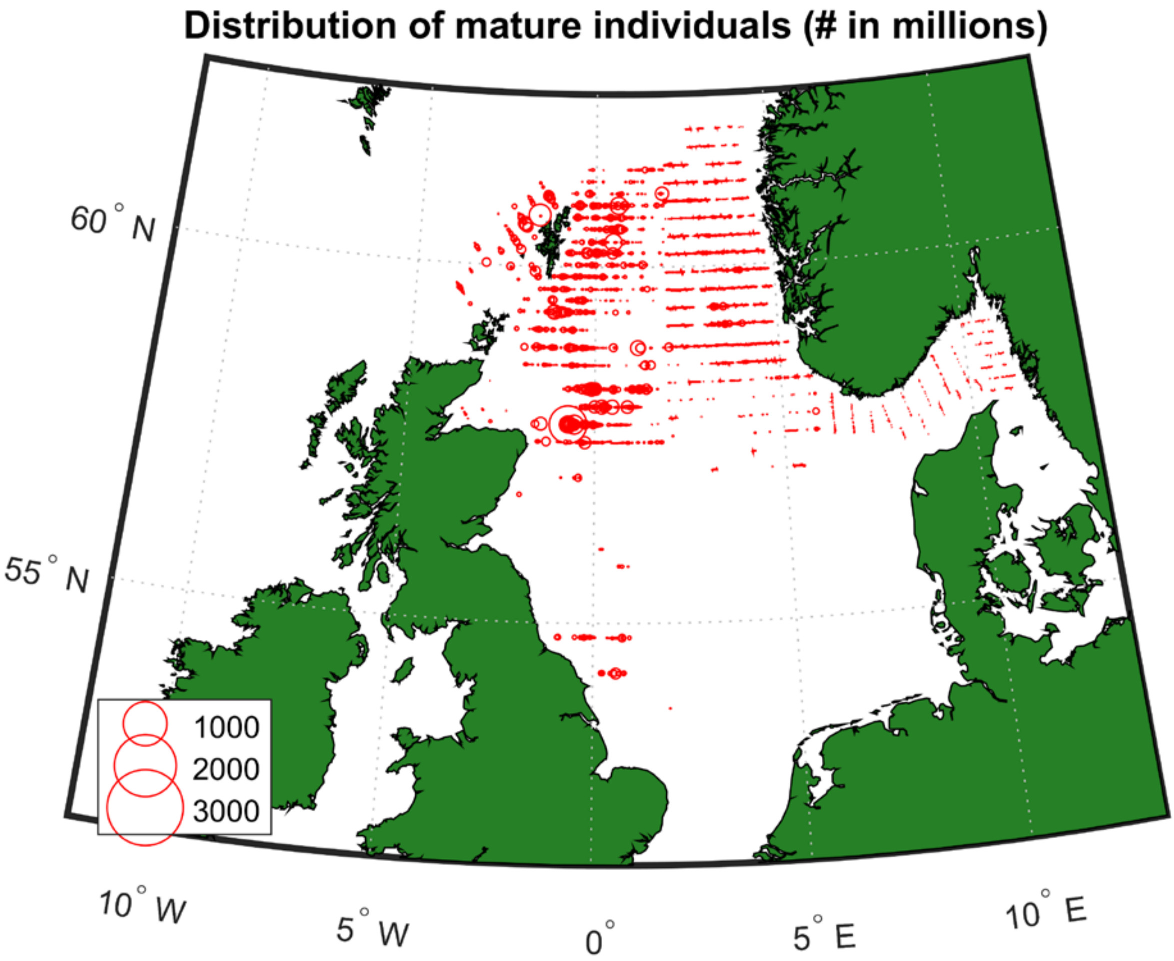

Figure 5.16. Distribution of mature North Sea autumn spawning herring in 2017. The NASC values per interval within each stratum were split into mature and immature following the proportion mature for the stratum.

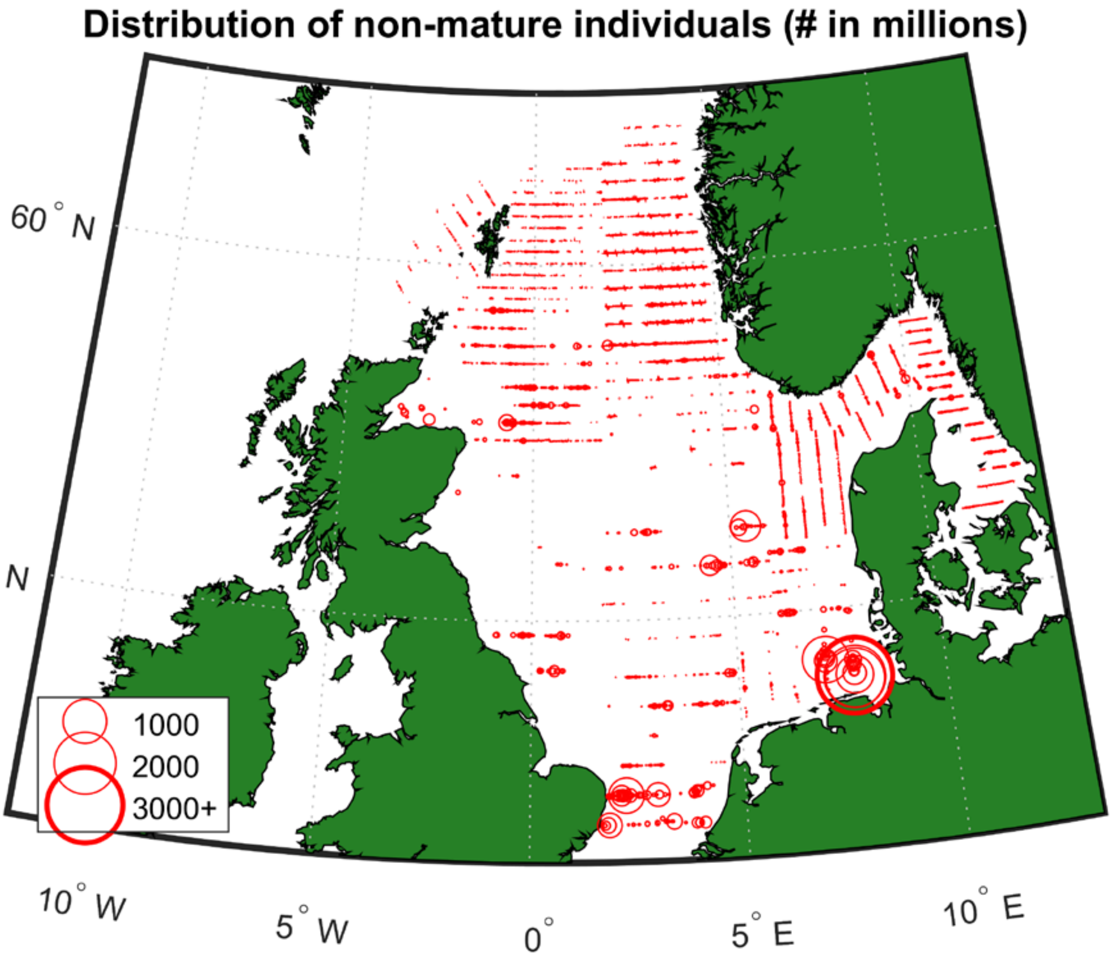

Figure 5.17. Distribution of immature North Sea autumn spawning herring in 2017. The NASC values per interval within each stratum were split into mature and immature following the calculated proportion mature for the stratum.

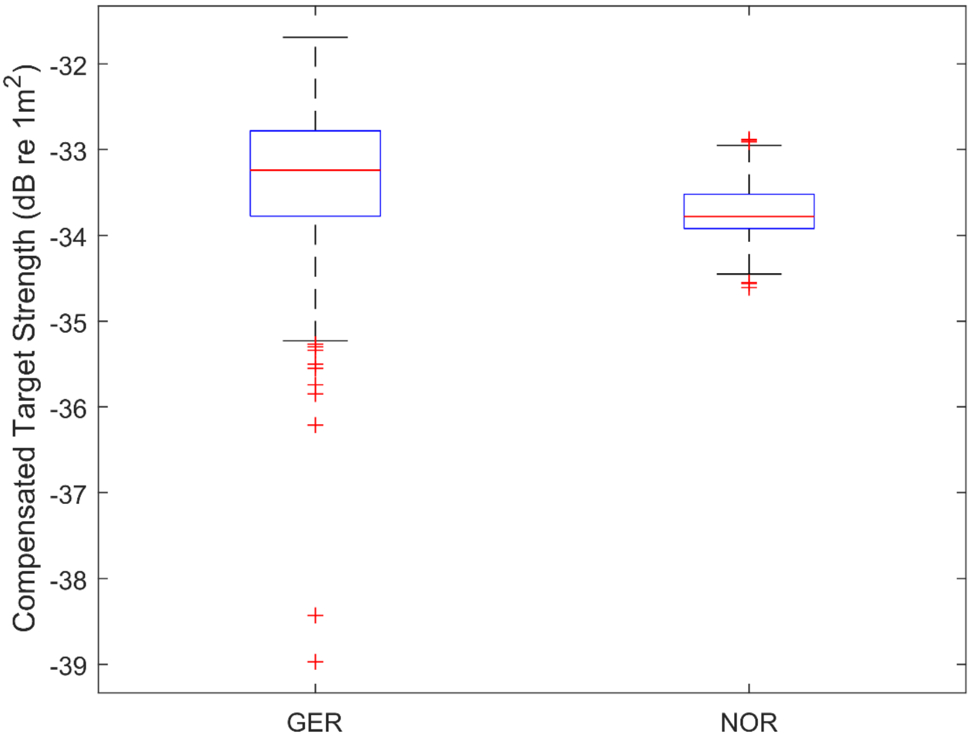

Figure 5.18. Results from the calibration procedure undertaken for the EK80 CW at 38 kHz by the RV Solea (GER) and RV Johan Hjort (NOR). For each vessel, a box plot represents the distribution of the compensated target strength for each target detection during the calibration procedure. The central red mark indicate the median while the bottom and top edge of each box indicate the 25th and 75th percentiles respectively. The whiskers extend to the most extreme data points not considered outliers, and the outliers are plotted as the red crosses.

Annex 5d: International Ecosystem Summer Survey in the Nordic Seas (IESSNS) survey report 2017

Survey Summary table	
Name of the survey (abbreviation):	IESSNS
Summary:	
In 2017, the survey included five vessels (1 research vessel and 4 commercial vessels) from four nations surveying more than 3 million km² in Nordic seas during the period from July 3 – August 4 2017. The weather was good and did not cause any problems. All vessels used a standardized trawl, including rigging, and trawl operation procedures. Acoustic data are analysed with regards to presence and abundance of herring and blue whiting only, from the surface to 500m depth.	

	Description
Survey design	Stratified design with 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 density index is calculated using stratified approach. The survey area is split into 10 strata, for each stratum the average density (kg km^{-2}) is calculated and multiplied by stratum area.
Random/systematic error issues	Not an issue.
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	The weather was good and no incidences of degraded echogram quality by bubble sweep down. No corrections made.
Extinction (shadowing)	Not an issue.
Blind zone	This is an issue for herring in the surface 10 m – 15 m. No attempts made to correct for loss of herring in the blind zone.
Dead zone	Not an issue.
Allocation of backscatter to species	Only allocated backscatter identified as herring or blue whiting. Identification according to standard procedure of echogram footprint, target strength, backscatter strength, position in water column, geographical location, and biological sampling.
Target strength	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

Calibration	Done according to standard procedure by all vessels prior to survey.

Working Document to

ICES Working Group on Widely Distributed Stocks (WGWIDE), ICES HQ, Copenhagen, Denmark, 30. August – 5. September 2017

Cruise report from the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) with M/V ”Kings Bay”, M/V “Vendla”, M/V “Tróndur í Gøtu”, M/V “Finnur Fríði” and R/V “Árni Friðriksson”, 3rd of July – 4th of August 2017

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Contents

1 Executive summary

The International Ecosystem Summer Survey in the Nordic Seas (IESSNS) was performed within approximately 4 weeks from July 3rd to August 4th in 2017 using five vessels from Norway (2), Iceland (1), Faroe Islands (1) and Greenland (1). The main objective is to provide annual age-disaggregated abundance index, with an uncertainty estimate, for the NEA 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 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 (NSS) herring (*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 mackerel index 2017 increased 13% for biomass and decreased 2 % for abundance (numbers of individuals) compared to the mackerel index in 2016. The most abundant year classes were 2010, 2011, 2012 and 2014 with 19 %, 19 %, 14 % and 15 % (in numbers). The incoming 2016-year class appears abundant and is larger than the 2015-year class. Mackerel cohort internal consistency has improved by adding the 2017 survey data to the time series. 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 6-7 years old mackerel. The survey coverage area was 2.8 million square kilometres in 2017 which is 7% smaller than in 2016. Mackerel was observed in most of the survey area. Distribution zero boundaries were found in westward areas, in Icelandic and Greenlandic waters, in northward areas near Jan Mayen and Bear Island, and also in northeast areas in the southern Barents Sea.

The NSS herring index in 2017 increased by 2% in numbers, but the biomass declined 10.5% compared to 2016. The acoustic measurements of Norwegian spring-spawning (NSS) herring was dominated by 4 years old (2013-year class) in terms of numbers and biomass. Distribution is age segregated with mature individuals (> 5 years) located at frontal areas north of Iceland, and in the areas east of Iceland and north of Faroe Islands. The recruiting year class (4 years old) was mainly distributed in the north-eastern part of the Norwegian Sea and it contributed with 19% of the total biomass index. The blue whiting index in 2017 decreased by 19 % in numbers and increased by 3.5 % in biomass, compared to 2016 (when excluding the 0-group). The acoustic measurements of blue whiting were dominated by 3-year olds (2014-year class) in terms of both numbers and biomass. Blue whiting was found in the whole survey area that was dominated by warm Atlantic waters, i.e. the Norwegian Sea, east, south and west of Iceland. The spatio-temporal overlap between NEA mackerel and NSS herring in July-August 2017 was highest in the south-eastern, southern and south-western parts of the Norwegian Sea. There was practically no overlap between NEA mackerel and NSS herring in the central and northern part of the Norwegian Sea. Herring was most densely aggregated in areas where zooplankton concentrations where high compared to other regions. Mackerel, on the other hand, was distributed in most of the surveyed area, and in areas with more varying zooplankton concentrations.

Other fish species also monitored are lumpfish and Atlantic salmon. Lumpfish of all sizes were caught in the upper 30 m of the water column. They were practically distributed everywhere within the total surveyed area from west of Cape Farwell in Greenland to western part of the Barents Sea. The largest individuals were consistently found in the north-western and northernmost part of the surveyed area. A total of 36 North Atlantic salmon were caught, mainly in central northern and north-western part of the Norwegian Sea.

Environmental conditions showed moderate changes when comparing 2017 to 2016. Sea surface temperature (SST) in July 2017 was similar to temperatures in July 2016 throughout most of the survey area. The 2017, SST was 1-2 °C higher than the long-term average (20-year mean) in central and northern part of the Norwegian Sea, but similar or colder in southern part of the Norwegian Sea and in southern Icelandic and Greenland waters. In 2017, the average zooplankton index for the Norwegian Sea was slightly lower

(7.6 g m^{-2}; n=158), while the index was approximately 100% higher in Icelandic waters (8.4 g m^{-2}; n=50) and Greenlandic waters (16.5 g m^{-2}; n=25), compared to in 2016.

Opportunistic whale observations were done by M/V "Kings Bay" and M/V "Vendla" from Norway in addition onboard R/V "Árni Friðriksson" from Iceland. Overall >700 marine mammals and 8 species were observed, representing a substantially higher number of sightings compared to previous years.

2 Introduction

During approximately four weeks of survey in 2017, five 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, and the M/V "Finnur Fridi" operating in Greenland waters, participated in the International Ecosystem Summer Survey in the Nordic Seas (IESSNS). The highly coordinated IESSNS survey in space and time was successfully conducted with altogether five vessels participating from 3rd of July to 4th of August 2017.

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 their summer feeding migration phase in the Nordic Seas, to be used as input to the abundance estimation of mackerel at ICES. Since 2016 we have also conducted systematic acoustic abundance estimation of both Norwegian spring-spawning herring (*Clupea harengus*) and blue whiting (*Micromesistius poutassou*). 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, WGWIDE 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 and Greenland since 2013.

Opportunistic whale observations were conducted onboard the Norwegian vessels Kings Bay and Vendla, and the Icelandic R/V Arni Fridriksson in order 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.*, 2016a).

3 Material and methods

Coordination of the IESSNS survey was done during WGWIDE 2016 meeting in August-September 2016 in Copenhagen, Denmark, WGIPS meeting in January 2017 in Reykjavik, Iceland, and by correspondence in spring and summer 2017. 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 the five vessels for oceanographic monitoring, plankton sampling, acoustic registrations and pelagic trawling. The weather in Iceland waters had predominantly foggy conditions, with up to 7 days of stormy weather. The weather in Faroese waters were good with exception of one day. The weather in Greenland waters was fairly good only with a few days of windy conditions. The weather was exceptionally good and calm for the two Norwegian vessels operating in the central and northern part of the Norwegian Sea.

During the IESSNS survey 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, and has been the standard for six years now (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 coming out of the mackerel benchmark in January-February 2017, were carefully considered and implemented during the IESSNS survey in July-August 2017.

Table 1. Survey effort by each of the five vessels in the IESSNS survey in 2017. *) 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)	Trawl stations/ Fixed stations*)	CTD stations	Plankton stations
Árni Friðriksson	3/7-3/8	5616	91/74	75	72
Tróndur í Gøtu	3/7- 19/7	3167	47/43	31	43
Finnur Fríði	21/7-2/8	2500	18/15	15	16
Vendla	5/7-4/8	5735	91/72	72	72
Kings Bay	5/7-4/8	4969	94/75	76	74
Total	3/7-4/8	21987	341/279	281	277

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, and Kings Bay and Vendla were both equipped with SAIV CTD sensors. Finnur Fridi operating in Greenland waters 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.

Some vessels collected and recorded also oceanographic data from the surface either applying a thermosalinograph (temperature and salinity) placed at approximately 6 m depth underneath the surface or a thermograph logging or visualizing temperatures continuously near the surface throughout the survey.

Zooplankton was sampled with a WP2-net on all vessels. 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 2014b).

Not all planned CTD and plankton stations were taken. 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 2014c). Effective trawl width and trawl depth was monitored live by scientific personal 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 3rd of July to 4th of August 2017. 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**	**Tróndur í Gøtu**	**Finnur Fríði**	**Influ-ence**
Trawl producer	Egersund Trawl AS	Hampiðjan new 2017 trawl	Egersund Trawl AS	Vónin	Hampiðjan	0
Warp in front of doors	Dynex–34 mm	Dynex-34 mm	Dynex -34 mm	Dynema – 34mm	Dynex-38 mm	+
Warp length during towing	350	350	350	300-350	350	0
Difference in warp length port/starboard (m)	2-10	3-12	2-10	0-25	10-20	0
Weight at the lower wing ends (kg)	2×400	2×400 kg	2×400	2×400	2×500	0
Weight of the groundrope chain (kg)						

Setback (m)	6 m	6	6 m	6 m	6	+
Type of trawl door	Seaflex 7,5 m^2 adjustable hatches	Jupiter	Seaflex 7,5 m^2 adjustable hatches	Injector F-15	T-20vf Flipper	0
Weight of trawl door (kg)	1700	2200	1700	2300	2000	+
Area trawl door (m^2)	7.5 with 25% hatches (effective 6.5)	7	7.5 with 25% hatches (effective 6.5)	6	7 with 50% hatches (effective 6.5)	+
Towing speed (knots)	4.9 (4.2-5.4)	5.1 (4.6-5.8)	4.9 (4.2-5.7)	4.7 (4.4-4.9)	4.6 (4.5-4.7)	+
Trawl height (m)	30-32	31 (21-39)	24-32	36.5	-	+
Door distance (m)	120-130	122 (110 - 130)	114-131	107.2	107 (100-107)	+
Trawl width (m)-calculated from door distance	69	69	68	61.2	60.7	+
Turn radius	5-10 degrees turn	5-10 degrees turn	5-10 degrees turn	5-10 degrees BB turn	5-10 degrees turn	+
A fish lock in front end of cod-end	Yes	Yes	Yes	Yes	Yes	+
Trawl door depth (port, starboard, m)	5-15, 7-18 m	15-28, 1-23	6-18, 7-19 m	7.4, 8.3	-	+
Headline depth	0 m	0-1 m	0 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	+
Weighing of catch	All weighted	All weighted except 2 stations where the cod end bursted.	All weighted	All weighed – except 3 large catches estimated	All weighted	+

Table 3. Summary of biological sampling in the survey from 3rd of July to 4th of August 2017 by the five participating countries. Numbers denote the maximum number of individuals sampled for each species for the different determinations.

	Species	Faroes	Greenland	Iceland	Norway
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	25	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
	Herring	0		0	30

- *Length measurements / weighed individuals
- **Stomachs sampled at every third station
-

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 in the upper 30 m of the water column. Video recordings were collected at 50 trawl stations. The camera was attached on the trawl in the transition between 200 mm and 400 mm mesh sizes onboard Kings Bay and Vendla. Analyses of the recording material, including behaviour and patchiness of mackerel and NSS herring are underway and will be presented by other means when available.

3.3 Marine mammals

Opportunistic observations of marine mammals were conducted by trained scientific personnel and crew members from the bridge between 3rd of July and 4th of August 2017 onboard M/V "Kings Bay" and M/V "Vendla", respectively. Dedicated marine mammal observations were done onboard R/V "Árni Friðriksson". The priority periods of observing were during the transport stretches from one trawl station to another. Observations were done 24 h per day if the visibility was sufficient for marine mammal sightings. Digital filming and photos were taken whenever possible on each registration from scientists onboard.

3.4 Acoustics

Multifrequency echosounder

The acoustic equipment onboard Kings Bay and Vendla were calibrated 3rd of July 2017 for 18, 38 and 200 kHz. Árni Friðriksson was calibrated on 6th of May 2017 for the frequencies 18, 38, 120 and 200 kHz. Tróndur í Gøtu was calibrated on 28th June 2017 for 38 and 200 kHz. Finnur Fríði was calibrated on the 18th July 2017 for 38 kHz prior to the cruise, and 120 and 200 kHz after the cruise at 2nd of August. 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 from 3rd of July to 4th of August 2017.

	M/V Kings Bay	R/V Árni Friðriksson	M/V Vendla	M/V Tróndur í Gøtu	M/V Finnur Fríði
Echo sounder	Simrad EK60	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)	9.8	10.6	9.9	9.8	9.7
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.43	2.43	2.425	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)	-20.6	-20.81	-20.6	-20.6	-20.7
TS Transducer gain (dB)	23.10	24.28	23.27	24.15	23.75
s_A correction (dB)	-0.64	-0.61	-0.65	-0.65	-0.59
alongship:	6.98	7.20	7.01	7.19	7.17
athw. ship:	7.03	7.22	7.11	7.11	7.01
Maximum range (m)	500	500 (750 in part of the survey)	500	500	500 (750 in part of the survey)
Post processing software	LSSS	LSSS v.2.1.0	LSSS	Sonardata Echoview 8.x	Sonardata Echoview 8.x

Multibeam sonar

M/V "Kings Bay" and M/V "Vendla" were equipped with the Simrad fisheries sonar SH90 (frequency range: 111.5-115.5 kHz), with a scientific output incorporated which allow the storing of the beam data for post-processing. Acoustic multibeam sonar data was stored continuously onboard Kings Bay and Vendla for the entire survey from 5th of July to 4th of August 2017. The main objective for the continuous sonar recordings was to study the vertical distribution, school geometry and patchiness of the mackerel and herring in the upper 30-40 m of the water column.

Cruise tracks

The five participating vessels followed predetermined survey lines with pre-selected surface trawl stations (Figure 1). An adaptive survey design was also adopted although to a small extent, due to uncertain geographical distribution of mackerel, herring and blue whiting. The main adaptation was in the Icelandic-south stratum where it was shortened southwards as the zero line of mackerel distribution had been reached. Furthermore, northwest of Iceland, one station and one transect could not be surveyed due to sea ice. Temporal survey progression by vessel along the cruise tracks in July-August 2017 is shown in Figure 2. The cruising speed was between 10-13 knots if the weather permitted otherwise the cruising speed was adapted to the weather situation.

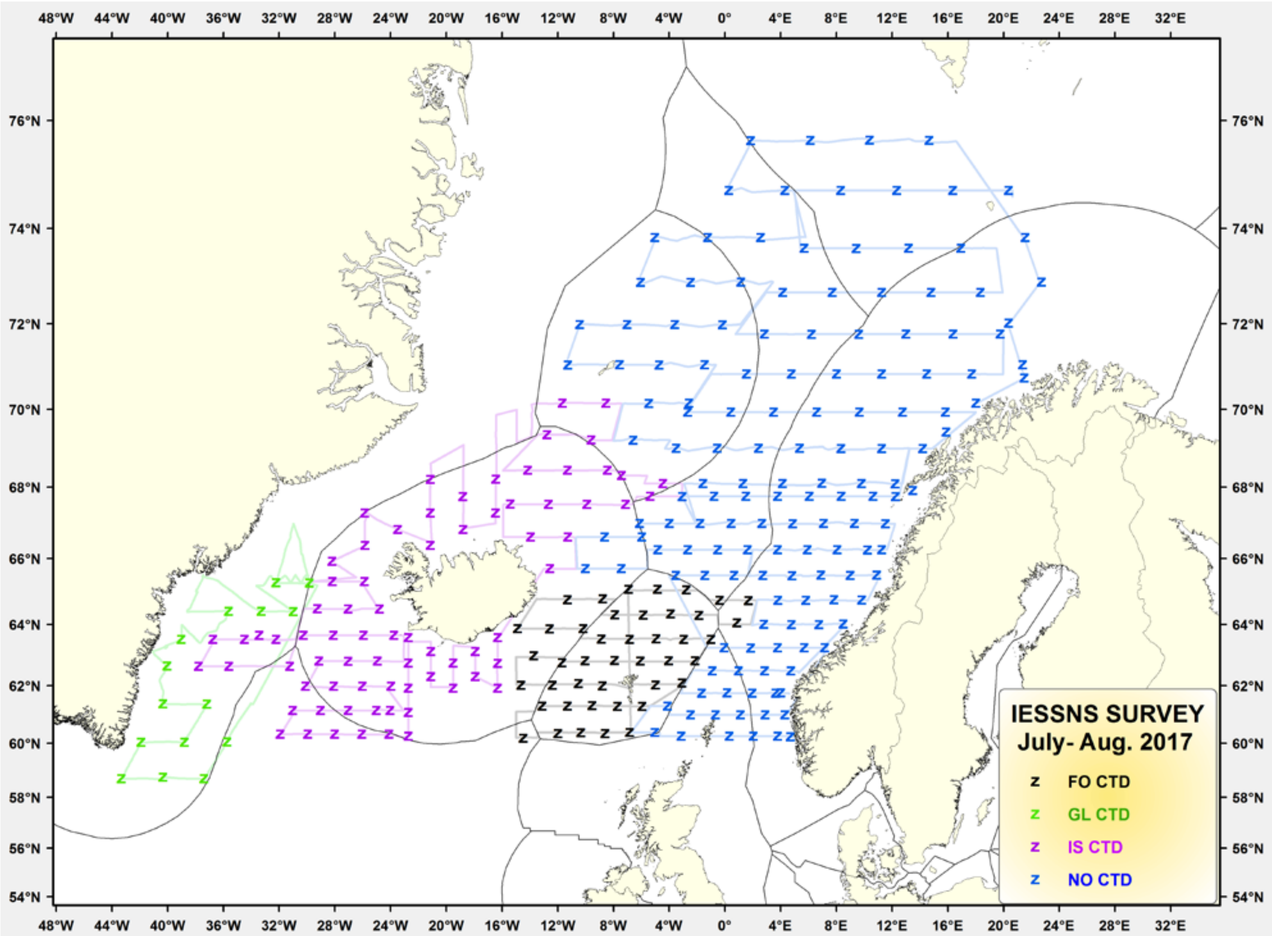


Figure 1. Fixed predetermined trawl stations included in the IESSNS 3rd of July – 4th of August 2017. At each station a 30 min surface trawl haul, a CTD station (0-500 m) and WP2 plankton net samples (0-200 m depth) was performed. The colour codes, Árni Friðriksson (purple), Tróndur í Gøtu (black), Kings Bay and Vendla (blue) and Finnur Fríði (green).

In relation to calculating the abundance of NEA mackerel based on the swept area approach, we have designed the survey in different strata (permanent and dynamic strata), (Figure 2). The survey design using different strata is done in order to be able to calculate abundance indices with uncertainty estimates both overall and from each stratum in the software program StoX (see Salthaug et al. 2017).

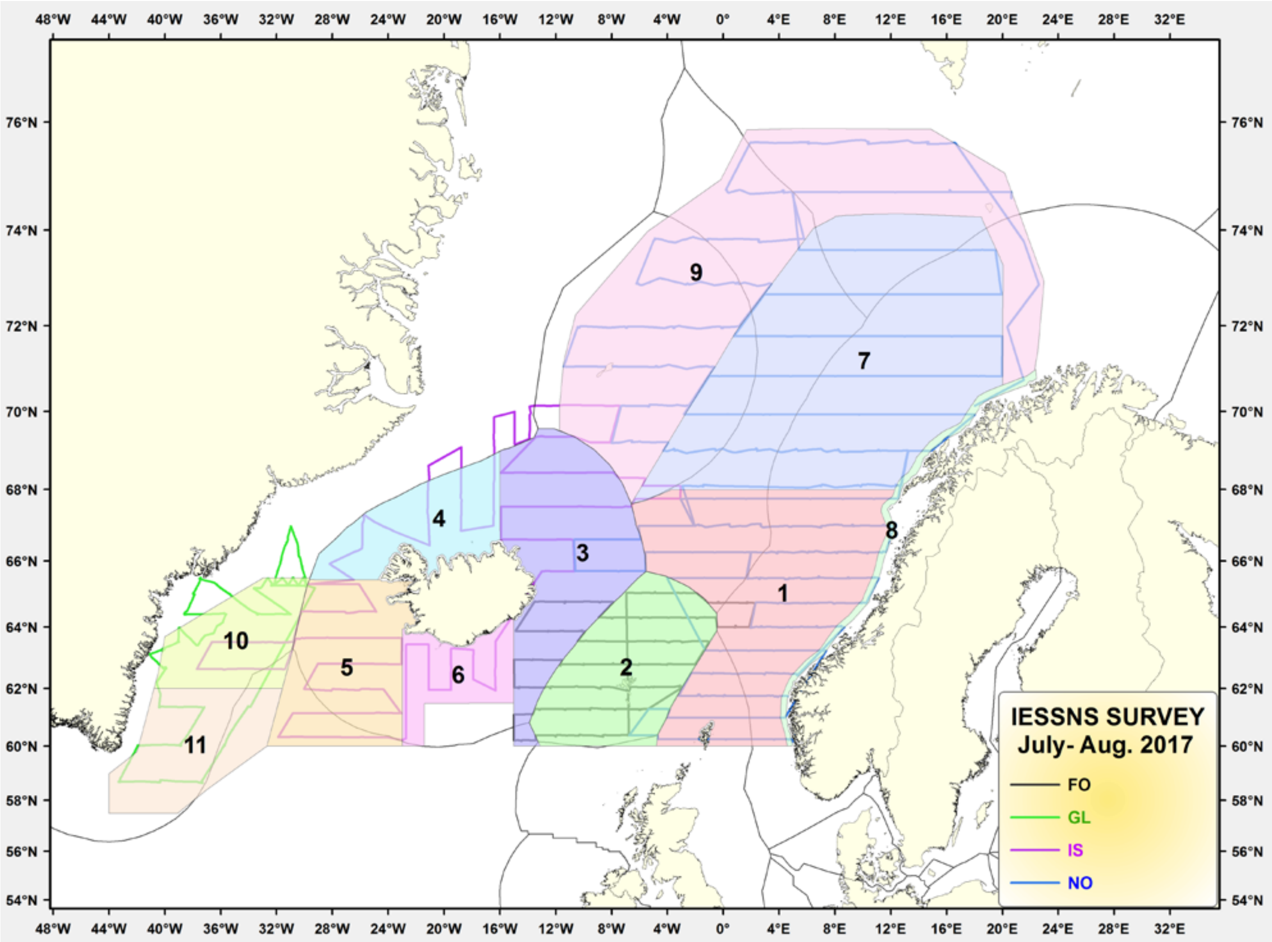


Figure 2. Permanent and dynamic strata used in StoX for the IESSNS 2017 survey. The dynamic strata are: 4, 9 and 11.

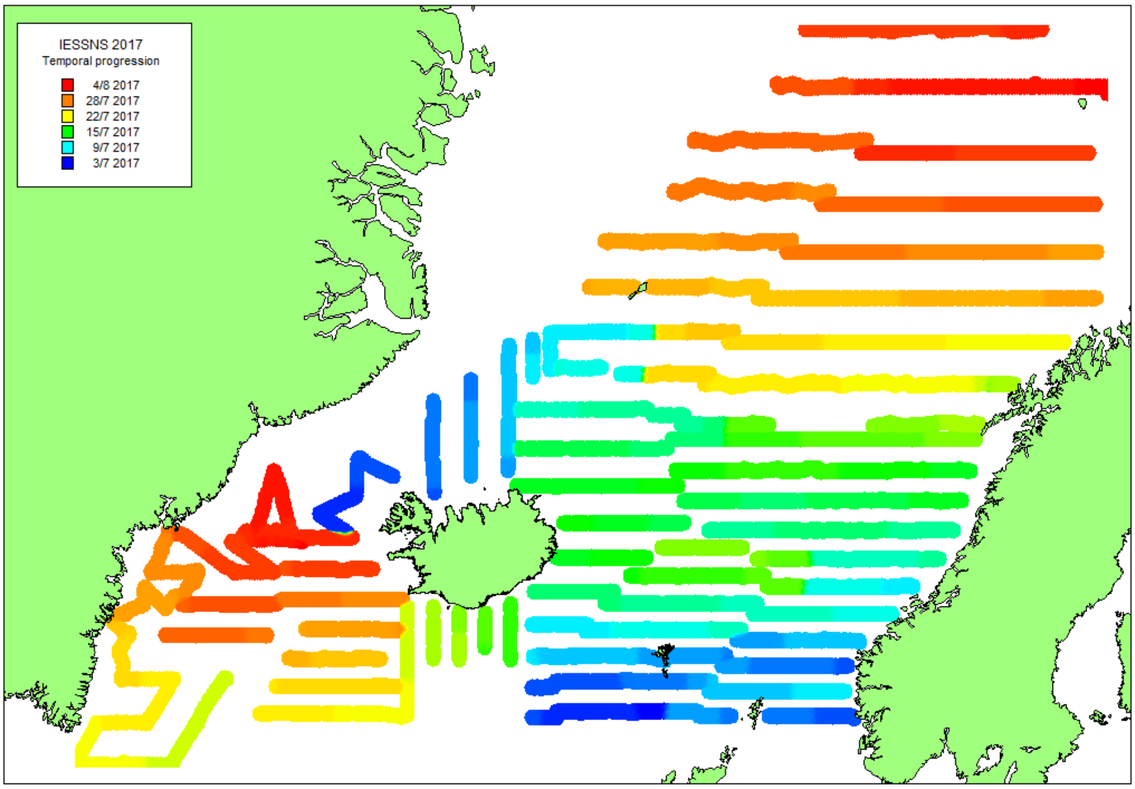


Figure 3. Temporal survey progression by vessel along the cruise tracks in July-August 2017: blue represents survey start (3 July) progressing to red representing the end of the survey (4 August).

3.5 StoX

StoX is open source software developed at IMR, Norway to calculate survey estimates from acoustic and swept area surveys. The software, examples and documentation can be found at: http://www.imr.no/forskning/prosjekter/stox/nb-no. The program is a stand-alone application build 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.

3.6 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 by 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. Two different kinds of data were analyzed, manually reported values from log books (one value per station) and digitally recorded data from trawl sensors (*). Digitally recorded data were filtered prior to calculations and outliers were excluded. Next, average door spread and vertical opening was calculated for each station, then the average values per station were used to calculate overall mean, maximum (max), minimum (min) and standard deviation (st.dev.) 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
Trawl doors horizontal spread (m)					
Number of stations	39	73	75	72	16
Mean	107.2	122	120	114	107
max	113.0	130	130	131	114
min	98.0	110	125	122	100
st. dev.	3.9	5	10.5	7.8	4.5
Vertical trawl opening (m)					
Number of stations	40	72	75	72	-
Mean	36.5	31	30	28	-
max	39.9	39	32	32	-
min	33.0	21	30	24	-
st. dev.	1.9	3	2	4.5	-
Horizontal trawl opening (m)					
mean	61.2	69	69	68	60.7
Speed (over ground, nmi)					
Number of stations	43	73	75	72	16
mean	4.7	5.1	4.9	4.9	4.6
max	4.9	5.8	5.4	5.7	4.7
min	4.4	4.6	4.2	4.2	4.5
st. dev.	0.11	0.2	0.7	0.8	0.1

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. This year the towing speed range was extended from 5.0 to 5.2.

Door spread(m)	Towing speed 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

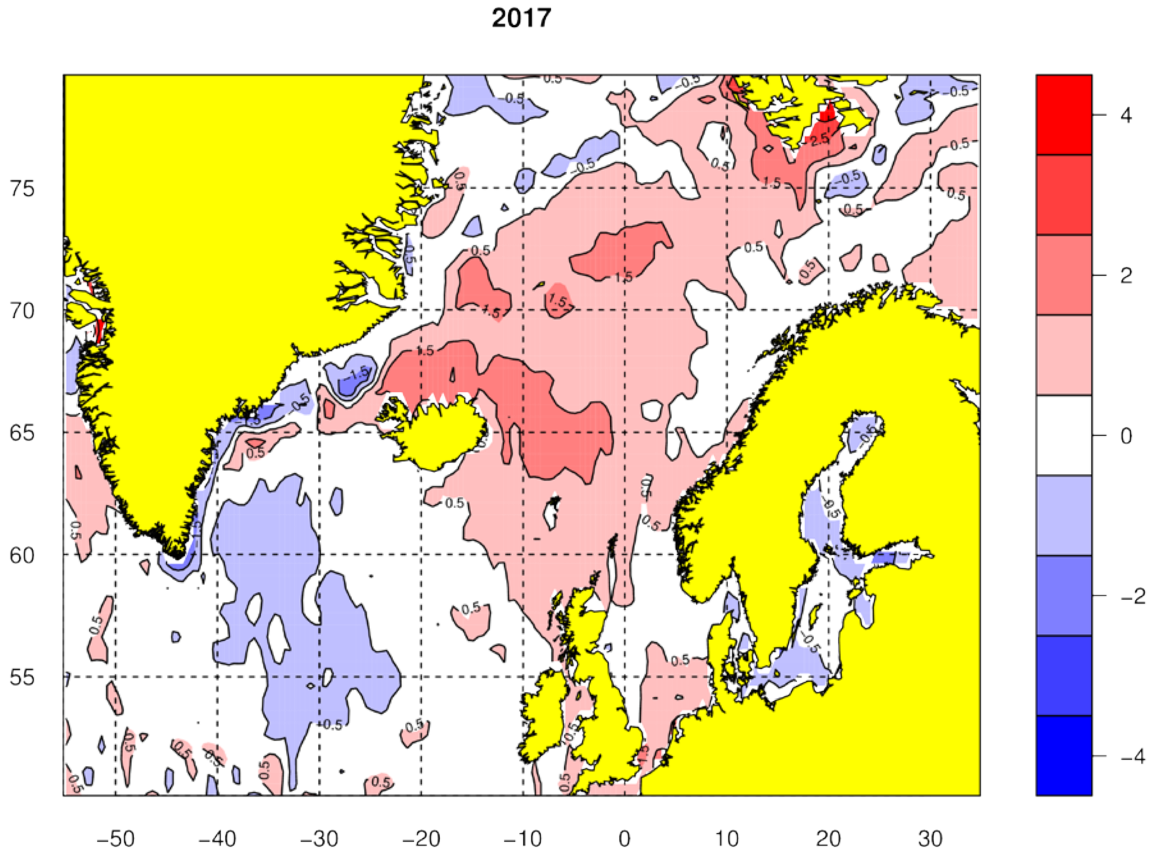
Overall the surface temperatures were generally 1-2°C warmer in the NE part of the Northeast Atlantic in July 2017 compared to the average for 1990-2009 based on Sea Surface Temperature (SST) anomaly plot (Figure 4a). On the other hand, to the SW of the Greenland-Scotland ridge the SST was generally closer to or colder than average especially in the central Irminger Sea.

The surface temperatures were similar in July 2017 compared to July 2016 (Figure 4a or 4b), although not as warm as found in July 2014.

The surface temperatures were generally 0.5-1.5°C warmer in the northern part of the Northeast Atlantic in July 2017 compared to the average for the last 20 years based on Sea Surface Temperature (SST) anomaly plot (Figure 4). The temperature in the surface layer in southern and southeastern part of Greenland waters in the west it was between 0.5-1.5°C colder in July 2017 than the average for the last 20 years (Figure 4). In the eastern part of the Norwegian Sea and along the Norwegian coast the SST was more or less the same as the 20 years average on SST anomaly. Overall in the Northeast Atlantic, the SST was quite similar between July 2016 and July 2017 (Figures 5a, b).

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 features of SSTs between years (Figures 4a, b and 5a, b). 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 (< 30 m depth) was 0.5-1.0°C colder in 2017 compared to 2016 in the northern and north-western part of the surveyed area (Figures 5a and b). The temperature in the upper layer was higher than 6°C in more or less throughout the surveyed area covering approximately 2.8 million km², 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), the hydrographical features in the area were similar to 2015 and 2016. At all depths there were a clear signal from the cold East Icelandic Current, which originates from the East Greenland Current.



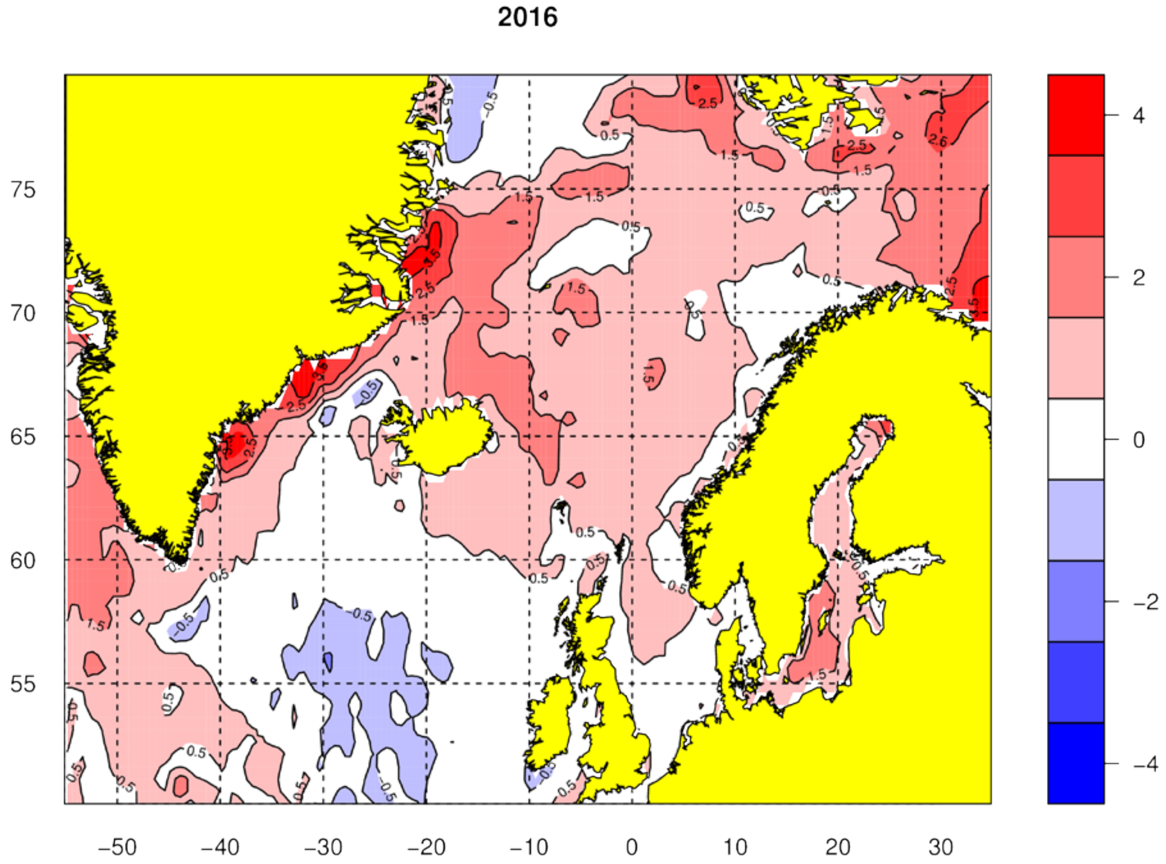
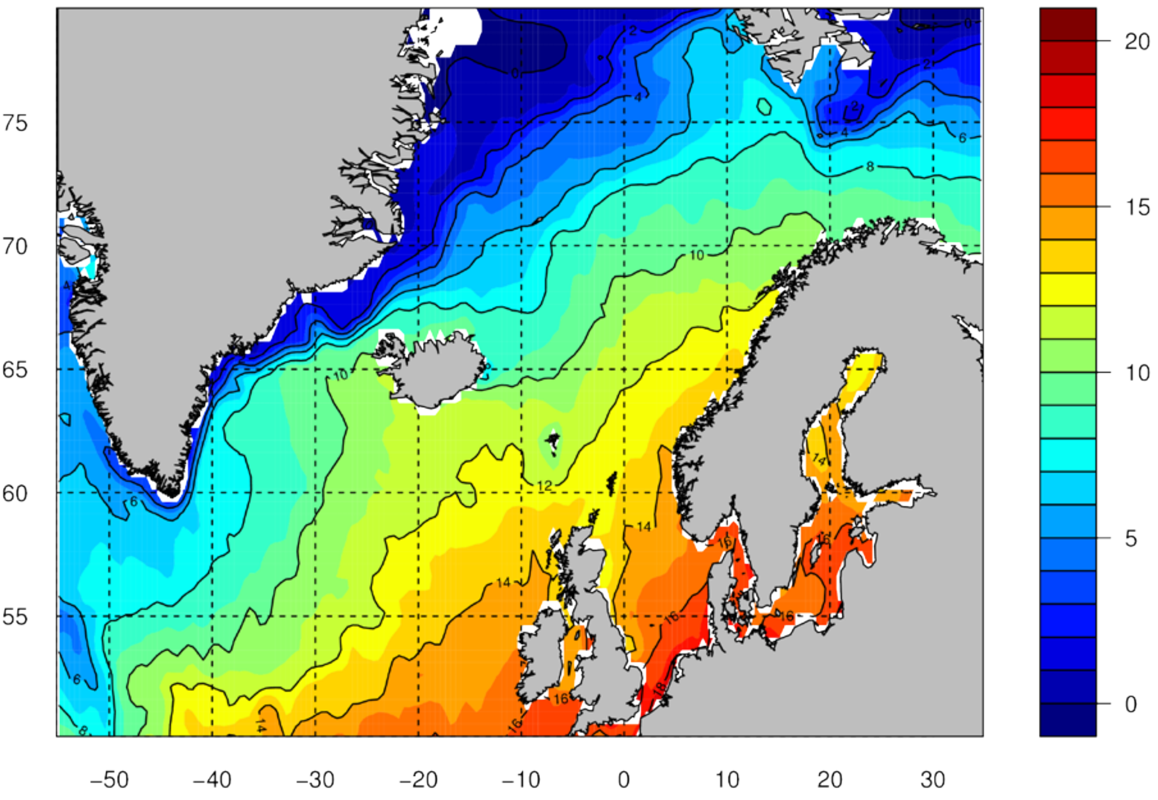


Figure 4. Sea surface temperature anomaly in the North Atlantic for July 2017 (a) and 2016 (b) (°C) showing warm and cold conditions in comparison to the average for July 1990-2009. Based on monthly averages of daily Optimum Interpolation Sea Surface Temperature (OISST, AVHRR-only, Banzon et al. 2016, https://www.ncdc.noaa.gov/oisst).

2017



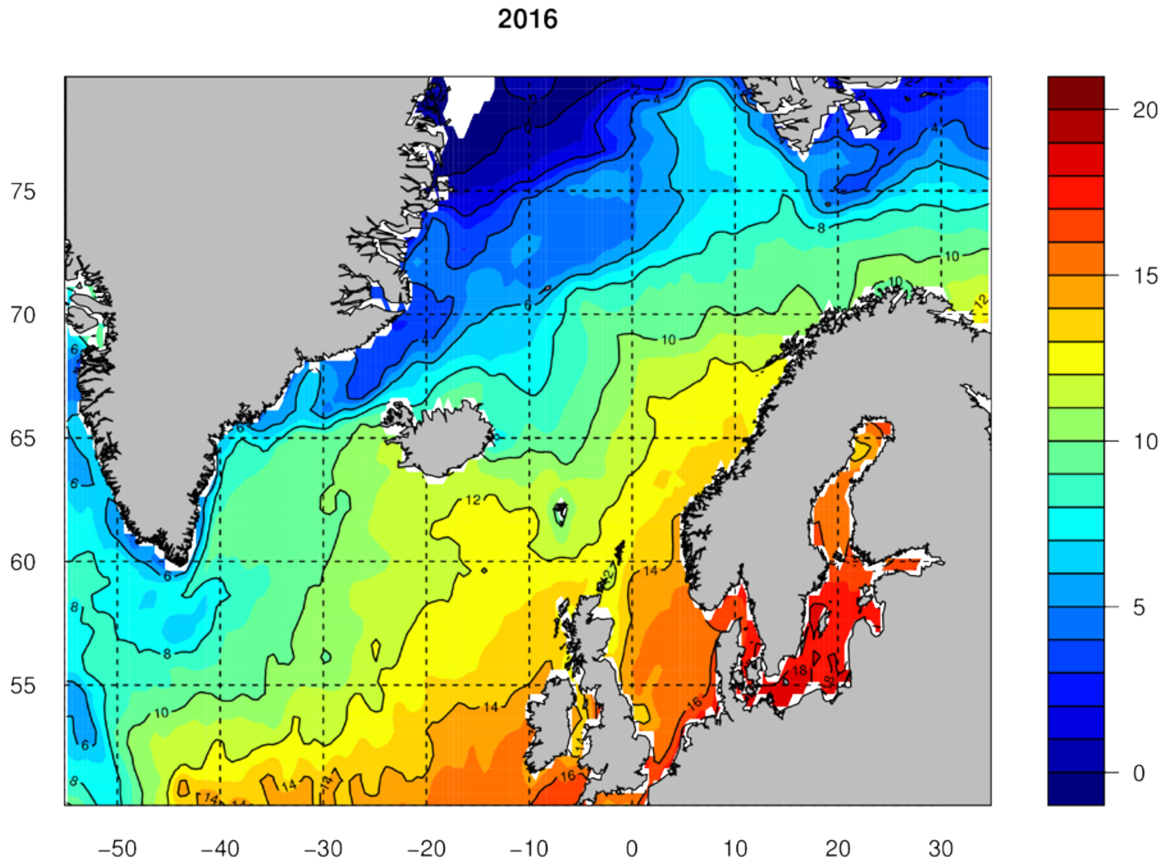


Figure 5. Average sea surface temperature in the North Atlantic for a) July 2017 (°C) and b) July 2016 (°C). Based on daily Optimum Interpolation Sea Surface Temperature (OISST, AVHRR-only, Banzon et al. 2016, https://www.ncdc.noaa.gov/oisst).

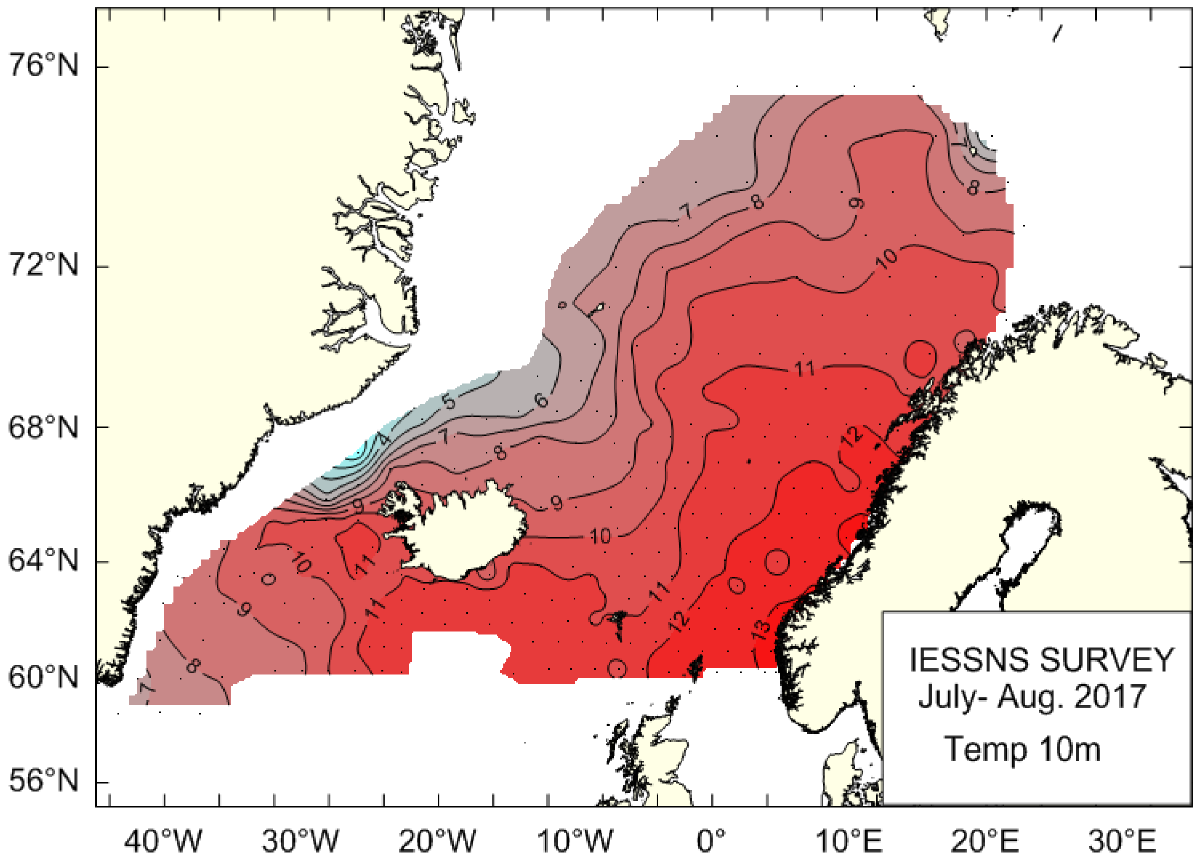

IESSNS SURVEY
July- Aug. 2017
Temp 10m
76°N
72°N
68°N
64°N
60°N
56°N
40°W
30°W
20°W
10°W
0°
10°E
20°E
30°E

Figure 6. Temperature (°C) at 10 m depth in the Norwegian Sea and surrounding waters in July-August 2017.

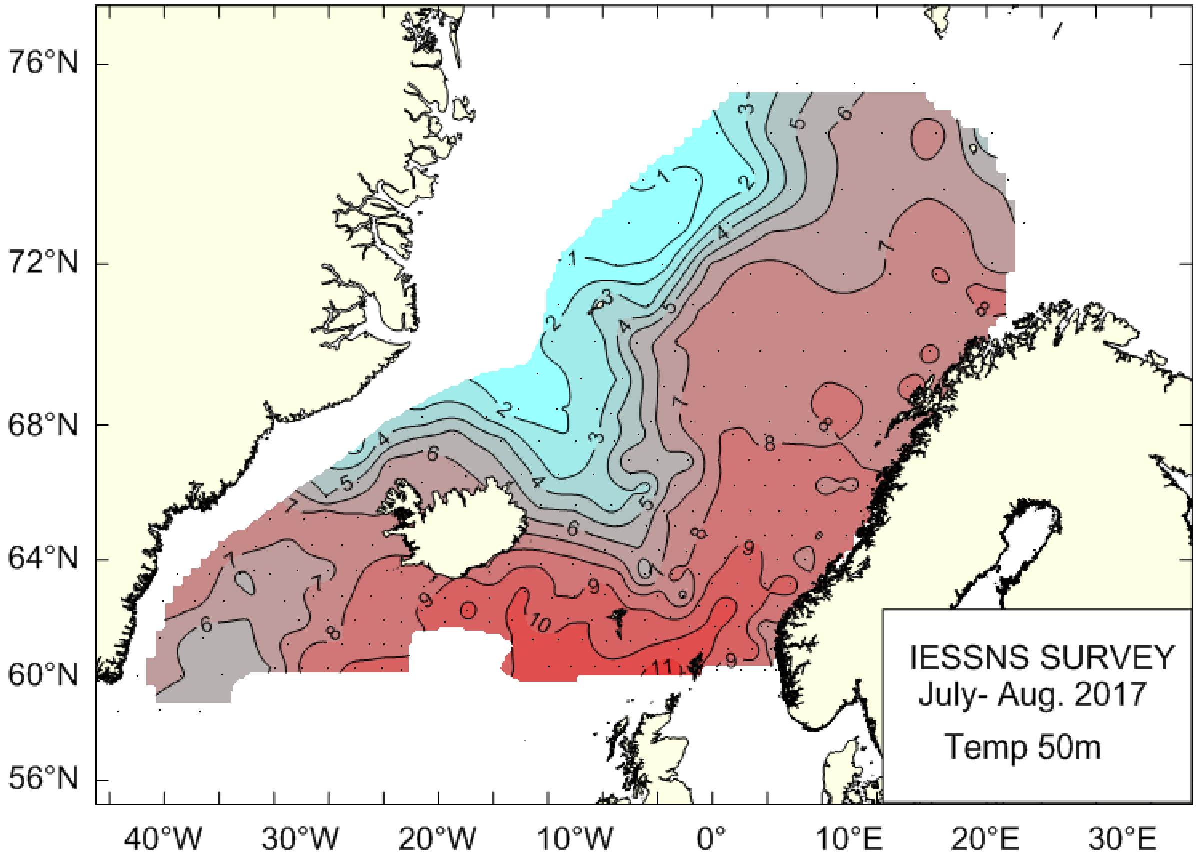


Figure 7. Temperature (°C) at 50 m depth in the Norwegian Sea and surrounding waters in July-August 2017.

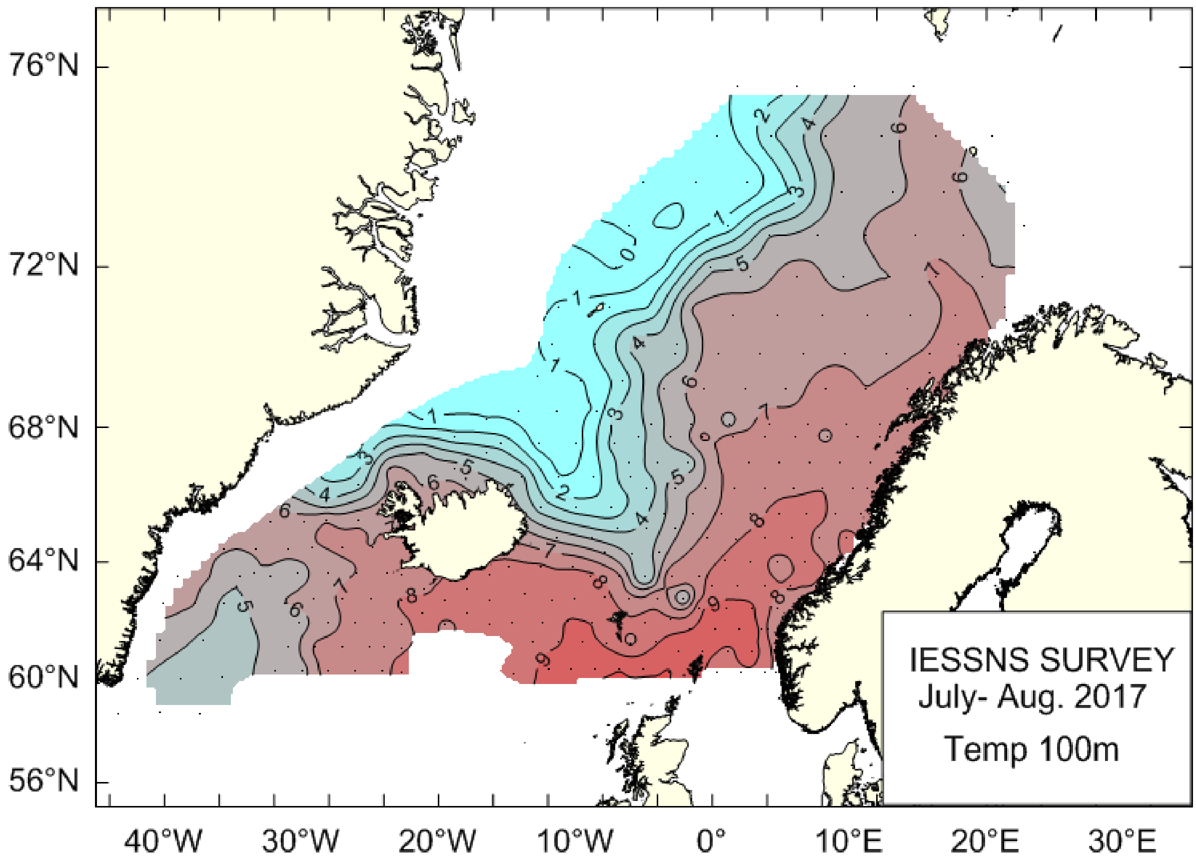

IESSNS SURVEY
July- Aug. 2017
Temp 100m
76°N
72°N
68°N
64°N
60°N
56°N
40°W
30°W
20°W
10°W
0°
10°E
20°E
30°E

Figure 8. Temperature (°C) at 100 m depth in the Norwegian Sea and surrounding waters in July-August 2017.

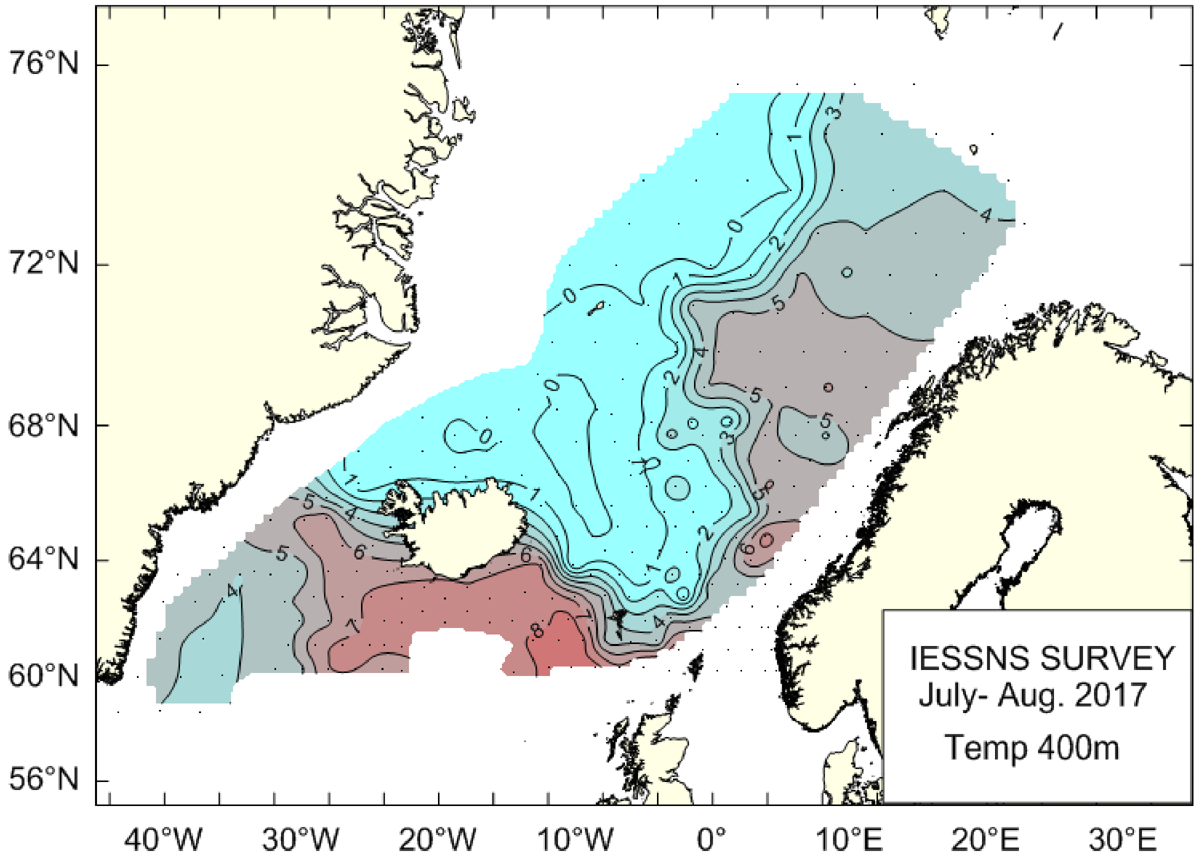
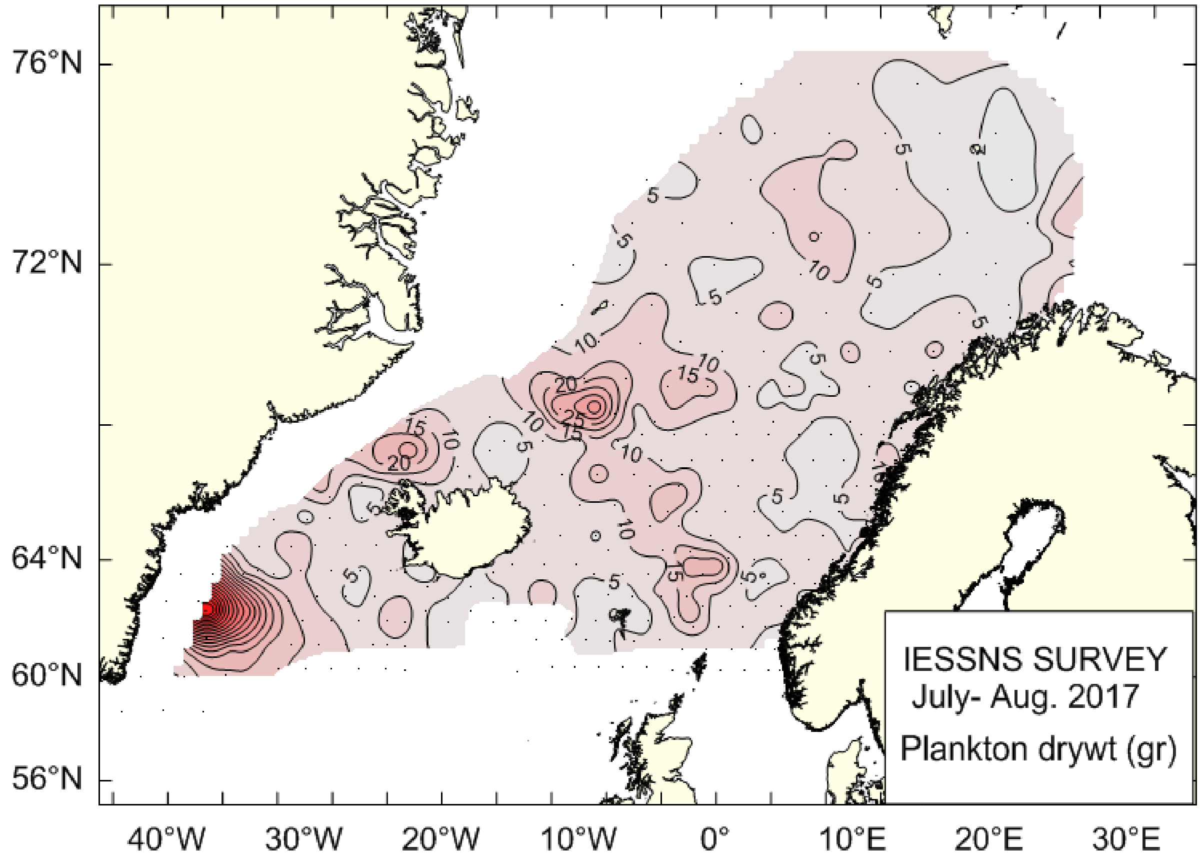


Figure 9. Temperature (°C) at 400 m depth in the Norwegian Sea and surrounding waters in July-August 2017.

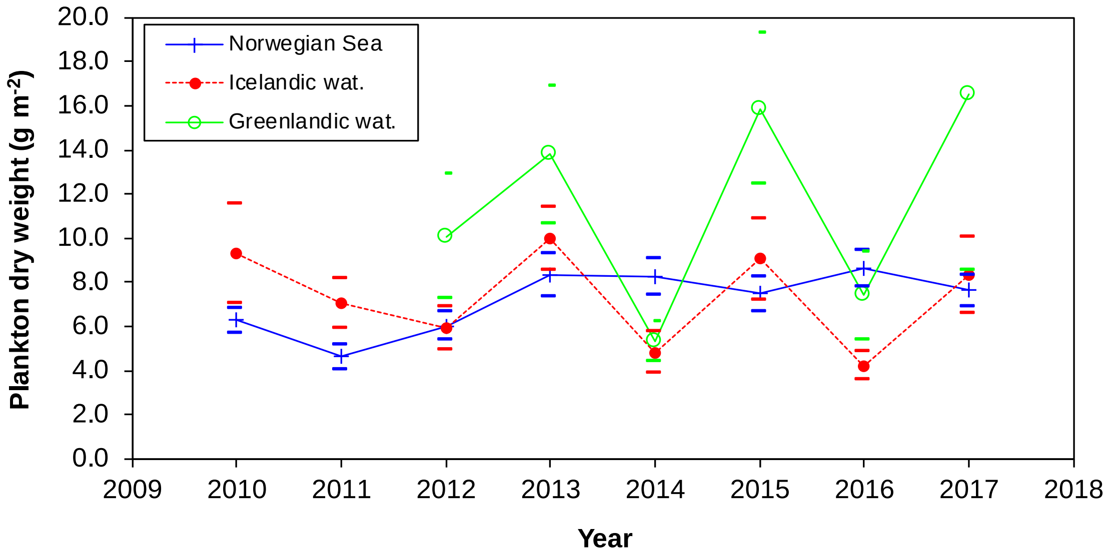
4.2 Zooplankton

The zooplankton biomass was relatively uniform over the whole survey area. Biomasses between 1-10 g m^{-2} dominated the picture in the Norwegian Sea, whereas Iceland waters had higher biomasses 5-15 g m^{-2} and Greenland waters with the highest plankton biomasses 5- > 40 g m^{-2}. Some areas had very high densities, especially in eastern Greenland waters off the coast, according to the dry weight measurements from the WP2 samples (Figure 10a). The average index for the Norwegian Sea was slightly lower in 2017 (7.6 g m^{-2}; n=179), than in 2016 (GIVE THE 2016 VALUE HERE) while approximately 100% higher in Icelandic waters (8.4 g m^{-2}; n=50) and Greenlandic waters (16.5 g m^{-2}; n=25) (Figure 10b). This relatively short time-series show much more pronounced fluctuations and year-to-year variability (cyclical patterns) in Icelandic and Greenlandic waters compared to in the Norwegian Sea. This might in part be explained by both more homogeneous oceanographic conditions in the area defined as Norwegian Sea and more sampling stations. Iceland and Greenland waters fluctuate a lot, however, they fluctuate in the same way from one year to the next (Figure 10b).

The zooplankton samples for species identification have not been examined in detail.



(a)



(b)

Figure 10. Zooplankton biomass indices (g dw/m², 0-200 m) (a) in the Norwegian Sea and surrounding waters in July-August 2017 and (b) time-series for three areas or Norwegian Sea (between 17°E and 14°W and north of 61°N), Icelandic waters (between 14°W and 30°W) and Greenlandic waters (west of 30°W).

4.3 Mackerel

The mackerel catch rates by trawl station (kg/km^2) measured with the Multpelt 832 is presented in Figure 11 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 30 tonnes, corresponding to 94 tonnes/km^2 on average. The mackerel occupied a very wide spatial distribution of 2.8 million km^2. High density areas were found in the central and north-eastern part of the Norwegian Sea as well as in south-eastward and westward of Iceland and further west into the adjacent part of Greenland waters.

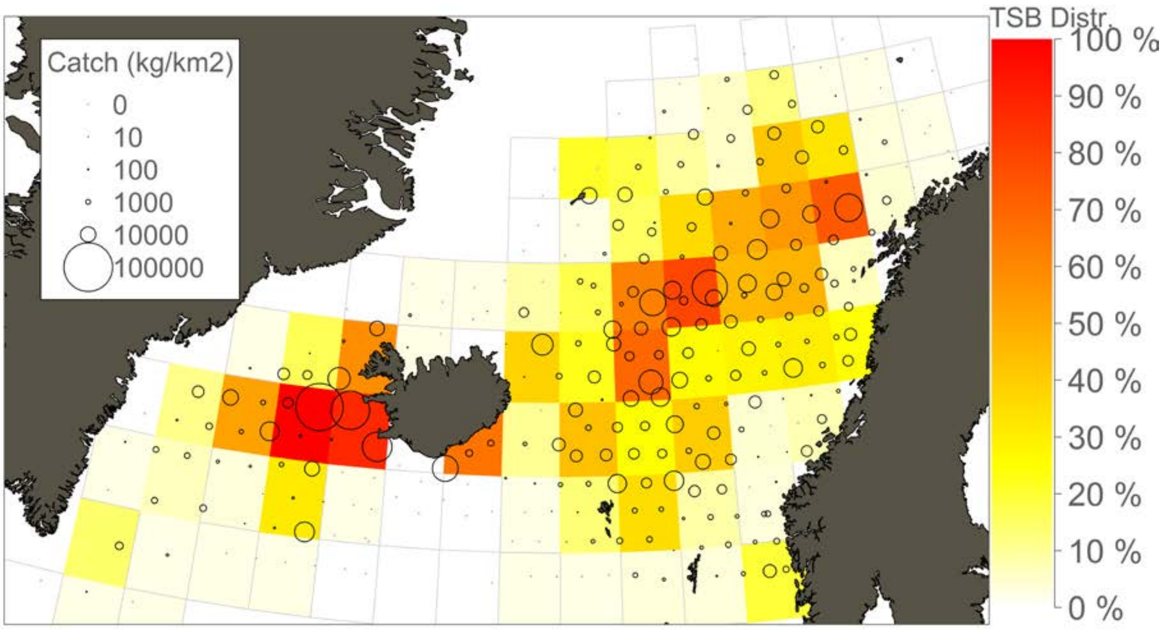


Figure 11. Mackerel catch rates by Multpelt 832 pelagic trawl haul (circle areas represent catch rates in kg/km^2) overlaid on mean catch rates per standardized rectangles (1° lat. x 2° lon.). White rectangles indicate zero-observations and yellow-red colour scale represent the biomass distribution (illustrated as cumulative fractions, e.g. the sum of all areas with the colour corresponding up to 40% represents 40% of the total biomass in the entire survey).

The length distribution of NEA mackerel during the IESSNS 2017 showed a pronounced length- dependent distribution pattern both with regards to latitude and longitude. The largest mackerel on average were found in the northernmost (39 cm in length) including northeast in the entrance to the Barents Sea, and westernmost (38 cm in length) part of the covered area (Figure 12).

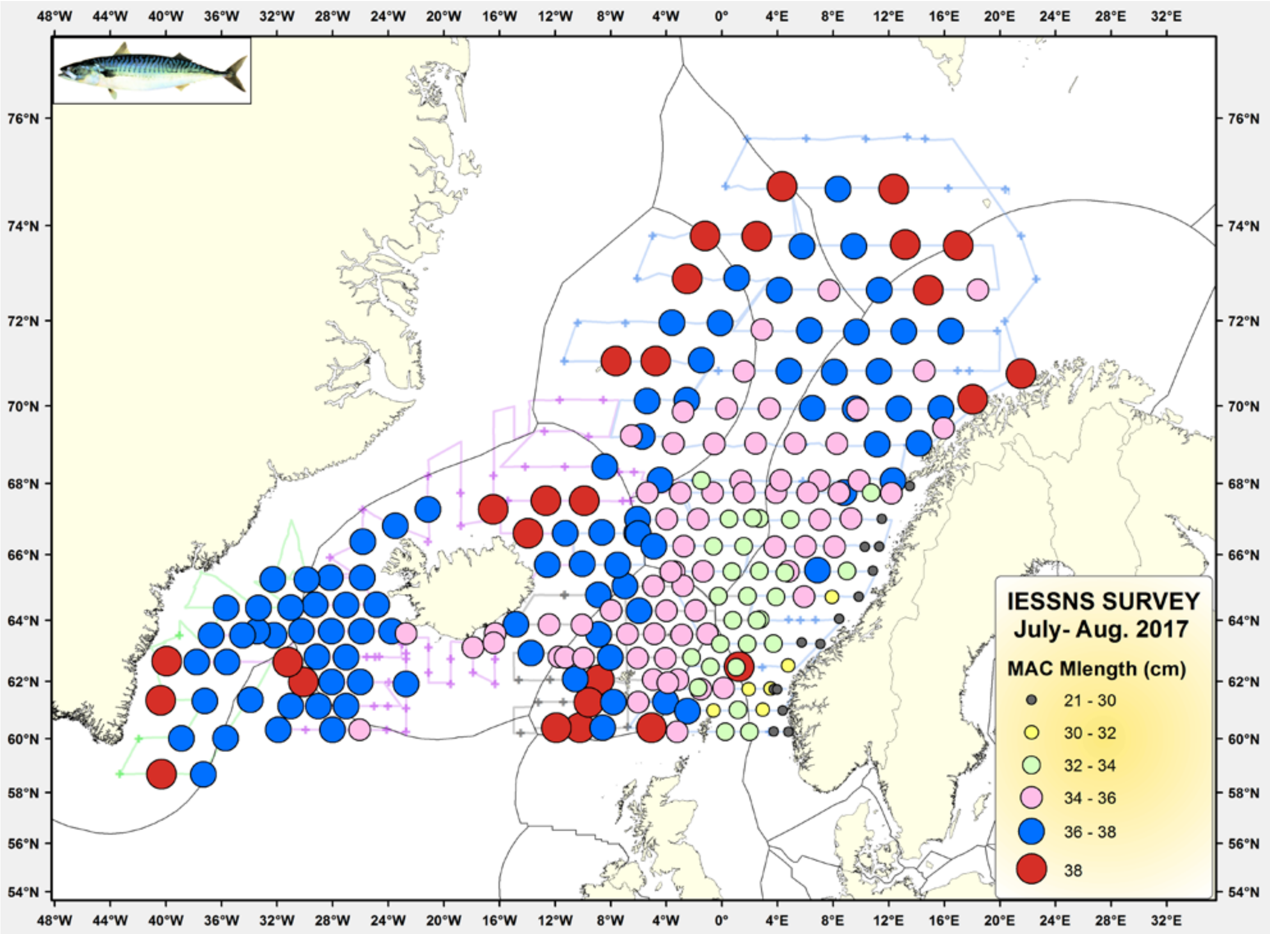


Figure 12. Average length distribution of NEA mackerel from the joint ecosystem survey with the five involved vessels M/V "Kings Bay", M/V "Vendla", M/V "Trøndur i Gøtu", R/V "Árni Friðriksson" and M/V "Finnur Fridi" in the Nordic Seas between 3rd of July and 4th of August 2017.

Mackerel caught in the pelagic trawl hauls onboard the five vessels varied from 21.7 to 40.1 cm in length. The average length was 35.1 cm. The individuals between 28-30 cm and 33-38 cm dominated in numbers and biomass. The mackerel weight (g) varied between 89 to 599 g and was 418 g on average. The 2016-year class (1-year old) dominated among juvenile mackerel caught. The 2016 year-class was dominating the catches along the Norwegian coast from Bergen in south to Lofoten area in the north. The spatial distribution and overlap between the major pelagic fish species (mackerel, herring, blue whiting, salmon, lumpsucker) from the joint ecosystem IESSNS survey 2017 in the Nordic Seas according to the catches are shown in Figure 13.

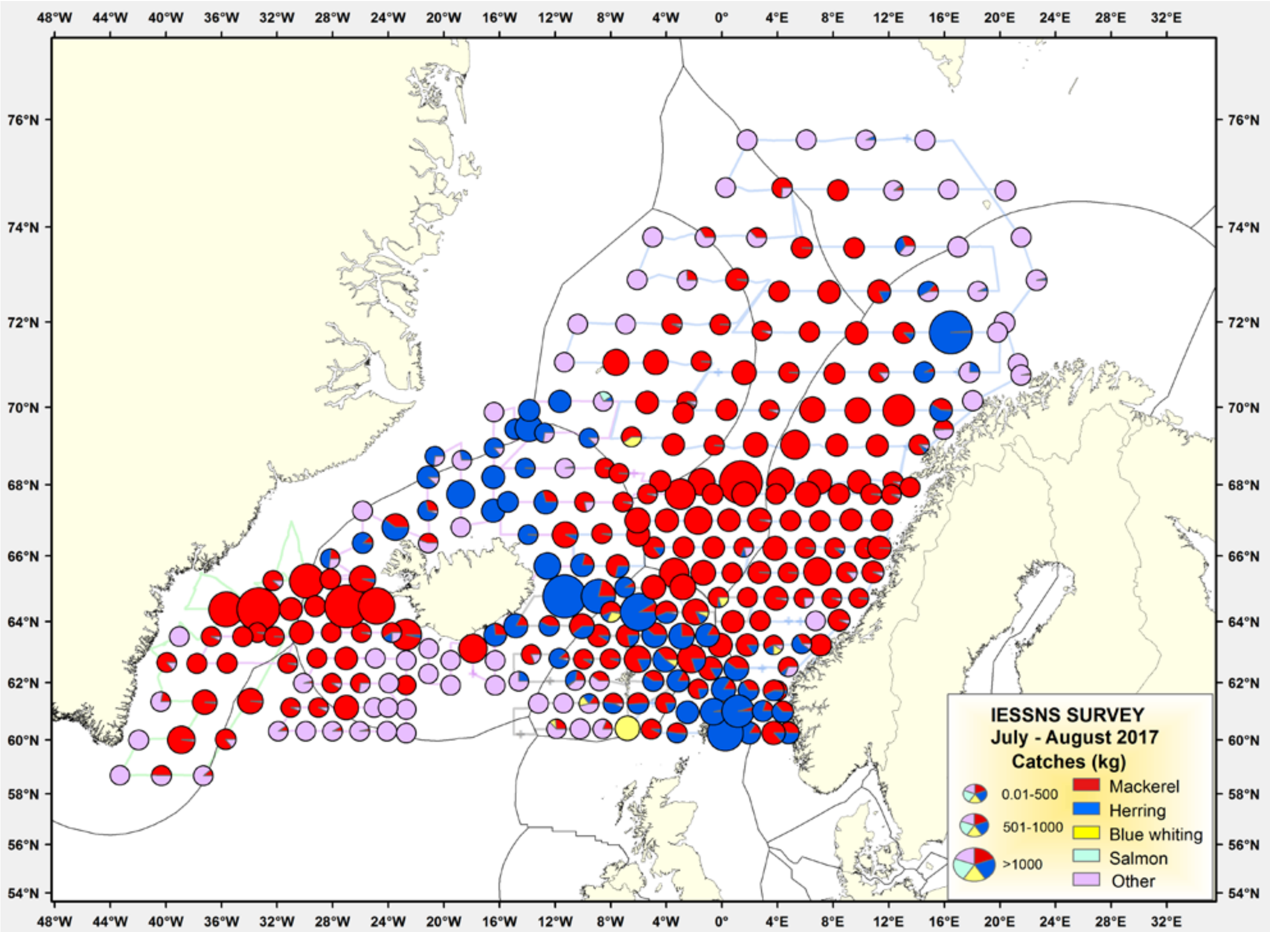


Figure 13. Distribution and spatial overlap between mackerel (red), herring (blue), blue whiting (yellow) and salmon (turquoise) from joint ecosystem surveys conducted onboard M/V "Kings Bay" and M/V "Vendla" (Norway), M/V "Trøndur i Gøtu" (Faroe Islands), R/V "Árni Friðriksson" (Iceland) and M/V "Finnur Fridi" (chartered to Greenland) in the Norwegian Sea and surrounding waters between 3rd of July and 4th of August 2017. Vessel tracks are shown as continuous lines.

Swept area analyses from standardized pelagic trawling with Multpelt 832

The swept area estimates of mackerel biomass in July 2017 were based on abundance of mackerel per stratum (see strata definition in Figure 2) and calculated in StoX (version 2.4). Mackerel were horizontally distributed over more or less the entire survey area. The total swept area biomass index of NEA mackerel in summer 2017 is the highest biomass index in the time series and increased with 13% compared to in summer 2016, whereas the abundance index in 2017 was 2 % lower than in 2016. The survey coverage area was 2.8 million square kilometres in 2017. The most abundant year classes were 2010, 2011, 2012 and 2014 with 19, 19, 14 and 15 % (in numbers). The incoming 2016-year class appear promising and are higher than the 2015-year class.

The total survey index for number-at-age is 24 billion individuals. The dominating age groups are 3, 6 and 7 years old, which are the 2014, 2012, 2011 and 2010-year classes (Figure 14) and they contributed to 67% of the total abundance estimate.

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

The internal consistency plot for age-disaggregated year classes has improved since the benchmark in 2017 by the inclusion of one more survey year (Figure 15). This is especially apparent for 5 to 11 years 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.

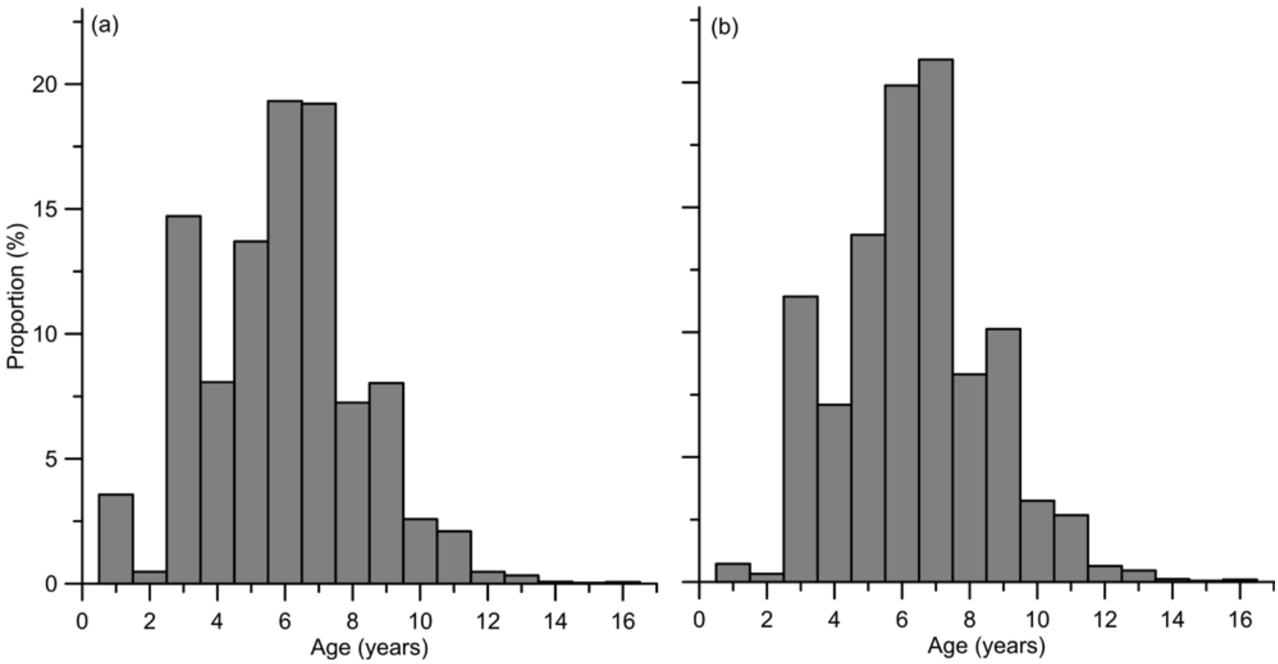


Figure 14. Age distribution in proportion represented as a) % in numbers and b) % in biomass of Northeast Atlantic mackerel in the IESSNS 2017.

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).

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
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
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

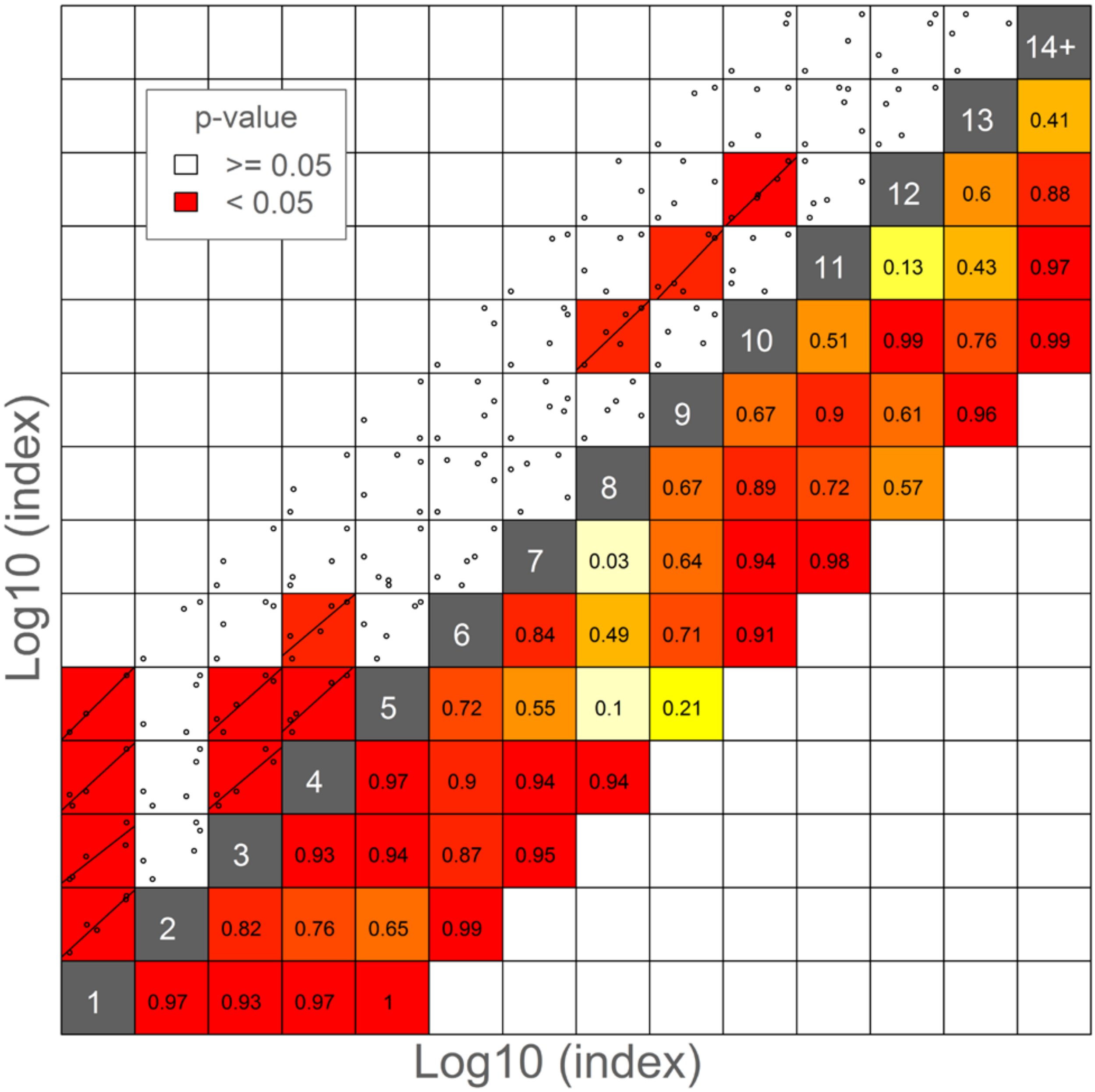


Figure 15. Internal consistency of mackerel density index. Ages indicated by white numbers in grey diagonal cells. Statistically significant positive correlations (*p<0.05*) are indicated by regression lines and red cells in upper left half. Correlation coefficients (r) are given in the lower right half.

Multibeam sonar recordings

Multibeam sonar recordings were conducted and recorded continuously onboard the two Norwegian vessels M/V "Kings Bay" and M/V "Vendla". The mackerel schools detected were of variable size predominantly with medium density. In some areas, the mackerel schools appeared more as individual fish or loose aggregations, where they were not visible neither on the multibeam sonars (Simrad SH90 and Simrad SX90), nor the echosounder frequencies. They were detected swimming in the upper 5-40 m of the water column throughout the day. Some school were detected below the vertical depth of the Multpelt 832 trawl to approximately 30 m depth. Even if we maximized the ping rate on both the multibeam sonars and multi-frequency echosounders including an array of frequencies from 18 to 333 kHz, the mackerel were practically invisible for the multibeam sonars as well as for the multifrequency echosounders. The main reason is probably due to very loose aggregations/shoals close to the surface thereby providing extremely low detection probability on any acoustic instrumentation. Sometimes nothing or very little was detected on the sonars but still medium to high catches of mackerel were caught, suggesting very dispersed mackerel concentrations. In 2017 we also had several situations where we could observe large amount of schools at the surface with sonars and visual means, but only caught small amounts of mackerel, due to active avoidance of the mackerel.

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 16). 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 northeastern 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 NSS herring was considered to be reached in all directions.

The NSS herring stock is dominated by 4-years old herring (year classes 2013) in terms of numbers and biomass (Table 8). This year class is mainly distributed in the northeastern part of the Norwegian Sea and it contributes 19% to the total biomass. The total number of herring recorded in the Norwegian Sea was 20.6 billion in 2017 and the total biomass was 5.88 million tonnes. Number by age, with uncertainty estimates, for NSS herring during IESSNS in July 2017 is shown in Figure 17.

Table 8. IESSNS 2017 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of Norwegian Spring Spawning herring based on calculation in StoX.

Variable: Abundance
EstLayer: 1
Stratum: TOTAL
SpecCat: SILDG03

LenGrp	age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	21	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
3-4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	201	201	-	-
4-5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5-6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	68397	68397	-	-
6-7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	256490	256490	-	-
7-8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	170993	170993	-	-
8-9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9-10	59147	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	59147	315.4	5.33
10-11	50457	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50457	378.4	7.50
11-12	136402	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	136402	1307.9	9.59
12-13	355553	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	355553	4816.1	13.55
13-14	383473	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	383473	6319.9	16.48
14-15	159167	17685	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	176852	3590.1	20.30
15-16	37338	56007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	93345	2259.0	24.20
16-17	9751	58506	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	68257	2106.2	30.86
17-18	15389	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15389	528.4	34.33
18-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19-20	-	7920	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7920	448.5	56.62
20-21	-	18629	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18629	1345.2	72.21
21-22	9699	28394	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38093	3550.3	93.20
22-23	-	40368	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40368	3950.5	97.86
23-24	-	10173	19574	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29747	3214.1	108.05
24-25	-	1611	260359	1074	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	263045	30927.3	117.57
25-26	-	-	212385	1939	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	214324	27947.5	130.40
26-27	-	8370	285480	20073	899	1798	-	-	-	-	-	-	-	-	-	-	-	-	-	316620	46643.9	147.32
27-28	-	-	239377	209150	6589	37718	879	879	-	-	21705	-	-	-	-	-	-	-	-	516297	91045.9	176.34
28-29	-	-	128662	468655	8769	51785	2192	-	26683	6671	-	11674	-	-	-	-	-	-	-	705092	149805.2	212.46
29-30	-	-	68123	1217364	213716	52681	16915	43955	21459	2844	5060	-	-	2174	-	-	-	-	-	1644293	385292.3	234.32
30-31	-	-	48004	1711722	257960	163748	105431	146789	36047	91958	24954	14247	37430	-	-	-	-	-	-	2638289	683813.8	259.19
31-32	-	-	14999	669782	240701	276164	75237	187041	236224	64046	14396	1803	1353	-	-	-	-	-	-	1781746	512964.5	287.90
32-33	-	-	-	179778	164262	244784	211815	199898	164359	70227	63012	64904	-	-	-	-	-	-	-	1363039	438313.1	321.57
33-34	-	-	-	26330	120602	199942	102097	117456	26704	112389	68228	69281	88365	-	26704	-	-	-	-	958098	339260.5	354.10
34-35	-	-	-	38835	42105	114423	160181	291473	111608	103202	83554	125169	145045	19253	-	-	-	-	-	1234849	449380.7	363.92
35-36	-	-	-	31075	-	30272	82236	479029	159563	287383	450808	264361	221082	49526	1109	-	-	-	-	2056442	754143.0	366.72
36-37	-	-	7799	-	-	15124	58784	274260	206195	349368	648398	461976	655694	112215	5619	3989	-	5199	-	2804621	1069276.8	381.26
37-38	-	-	-	-	-	-	-	53288	33303	28907	255151	342890	780999	31985	105920	1259	21452	-	-	1655152	663213.4	400.70
38-39	-	-	-	-	-	-	-	-	-	14365	17534	36788	258188	56554	400	-	-	-	-	383829	165573.5	431.37
39-40	-	-	-	10008	-	-	-	-	-	-	-	5679	19035	22733	26910	-	5679	-	-	90046	36754.7	408.18
40-41	-	-	-	-	-	-	-	-	-	-	-	2315	4629	-	-	-	6944	-	-	13888	6437.3	463.52
TSN(1000)	1216376	247662	1284763	4585786	1055603	1188440	815767	1794067	1022146	1131359	1652800	1401088	2211822	294441	166662	5248	34075	5199	496081	20609383	-	-
TSB(1000 kg)	19003.1	14609.2	202903.9	1114380.3	296986.4	368022.2	272000.6	629533.8	346447.9	403868.4	616834.9	528783.6	870327.9	115766.5	68530.8	1989.5	12682.4	2252.1	-	-	5884923.3	-
Mean length (cm)	12.66	18.44	26.45	29.95	31.07	31.73	32.91	33.79	33.41	34.35	35.37	35.57	36.22	36.43	36.70	36.30	38.10	36.00	6.43	-	-	-
Mean weight (g)	15.62	58.99	157.93	243.01	281.34	309.67	333.43	350.90	338.94	356.98	373.21	377.41	393.49	393.17	411.20	379.11	372.19	433.15	-	-	-	292.59

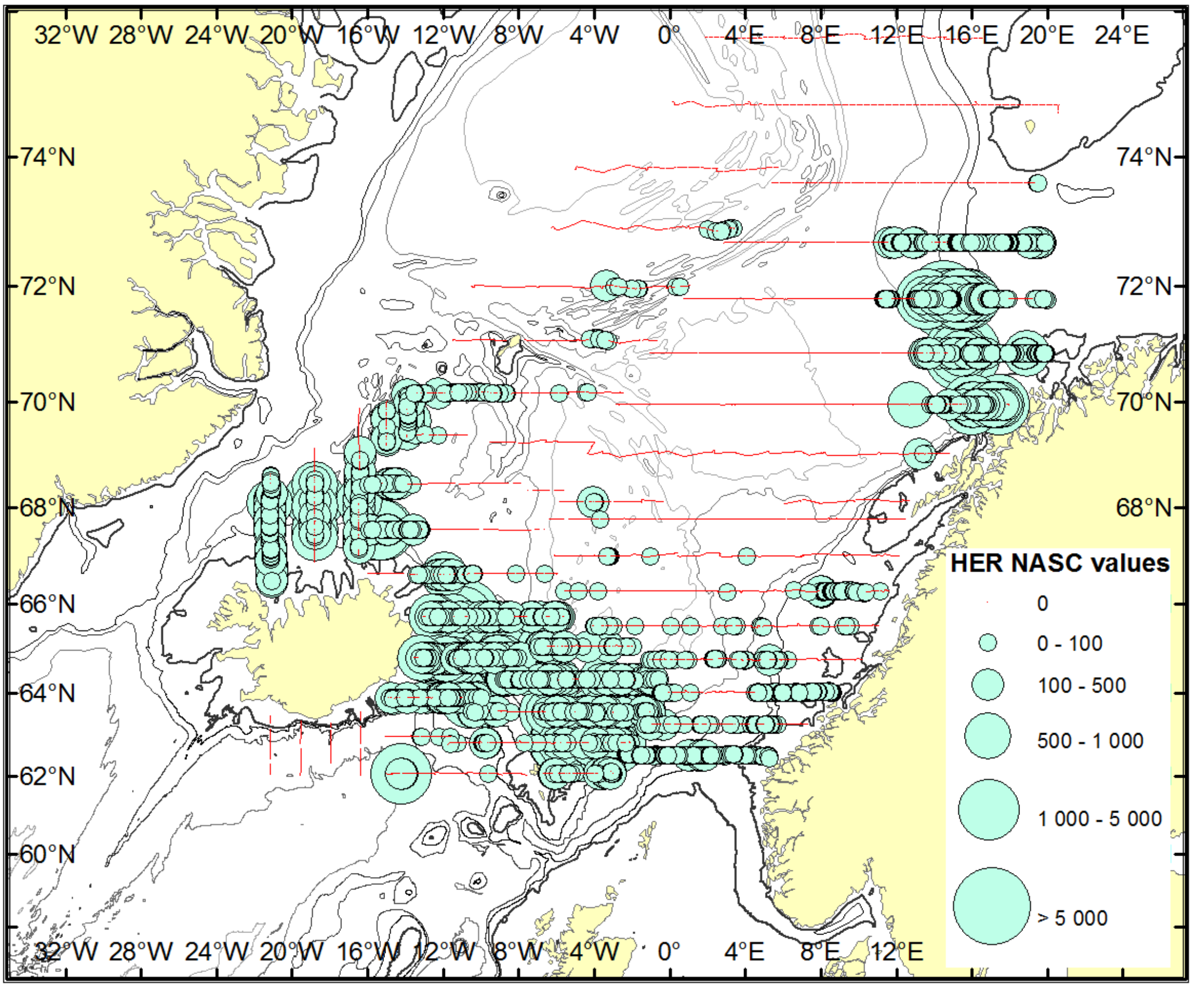


Figure 16. The sA/Nautical Area Scattering Coefficient (NASC) values of Norwegian spring-spawning herring north of 62ºN and east of 22 ºW, along the cruise tracks in IESSNS in July-August 2017. South and west of this area the herring observed are other stocks, i.e. Faroese autumn spawners, North Sea herring and Icelandic summer spawning herring.

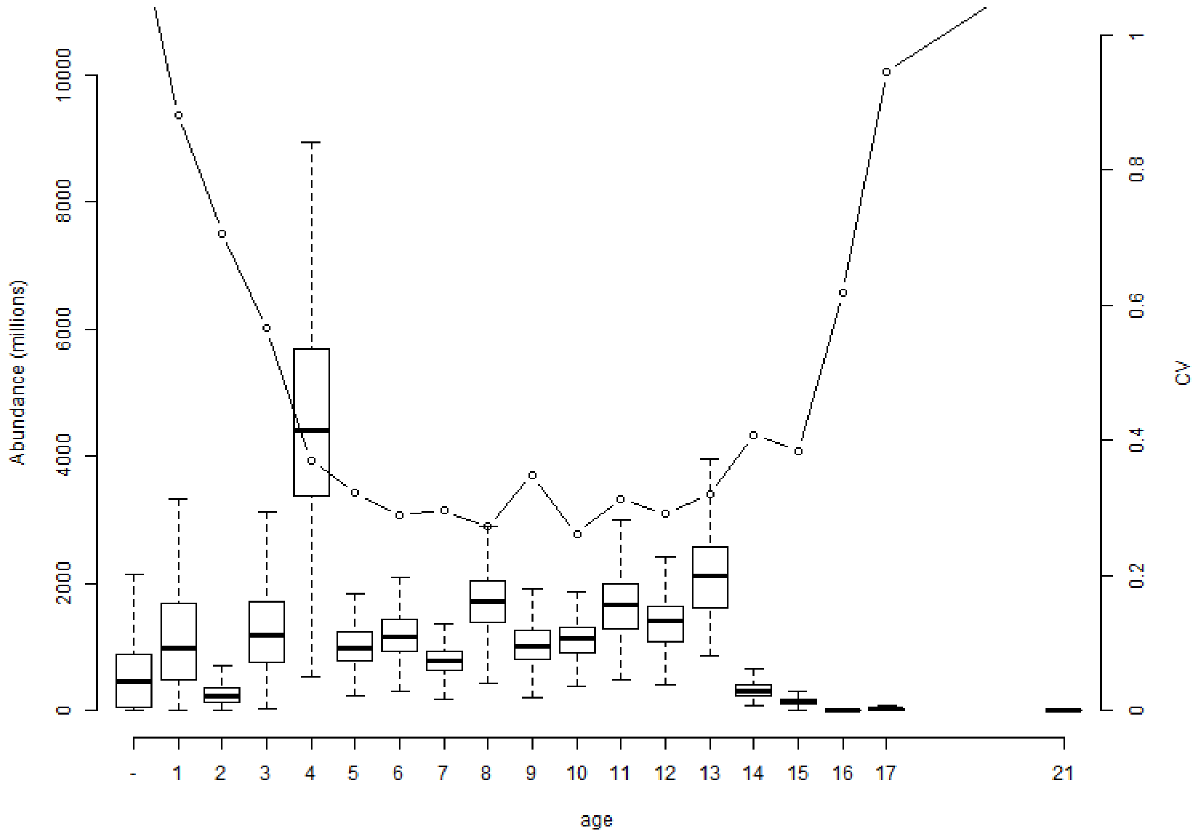


Figure 17. Number by age for NSS herring during IESSNS in July-August 2017. Boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

4.5 Blue whiting

The blue whiting was distributed in the entire survey area with exception of the area north of Iceland and in the southern Greenland area. The highest s_A-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 southwest of Iceland. Some extremely high s_A -values were seen south of the Faroe Islands and samples showed that this was 0-group concentrations. The main concentrations of older fish were observed both in connections with the continental slopes in the eastern and the southern part of the Norwegian Sea (Figure 18). The largest fish were found in the central and northern part of the survey area.

The total biomass of blue whiting registered during the IESSNS survey in 2017 was 2.7 million tons (Table 9), which is an increase compared to 2016 when the estimated index was 2.28 million tons. The stock estimate in number for 2017 is 45.4 billion compared to 29.8 billion in 2016. However, when excluding the 0-group, age three is dominating the estimate (46% of the biomass and 48% by number) and the total abundance index (age 1+) decreased from 25.9 in 2016 to 22.3 billion this year, a decrease of approx. 14%. Number by age, with uncertainty estimates, for blue whiting during IESSNS in July 2017 is shown in Figure 19.

Table 9. IESSNS 2017 in the Norwegian Sea. Estimates of abundance, mean weight and mean length of blue whiting based on calculation in StoX.

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

LenGrp	age 0	1	2	3	4	5	6	7	8	10	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
11-12	-	-	-	-	-	-	-	-	-	-	166730	166730	-	-
12-13	3181768	-	-	-	-	-	-	-	-	-	-	3181768	38929.9	12.24
13-14	4926126	-	-	-	-	-	-	-	-	-	-	4926126	76628.6	15.56
14-15	10924214	-	-	-	-	-	-	-	-	-	-	10924214	202098.0	18.50
15-16	4105096	-	-	-	-	-	-	-	-	-	-	4105096	92091.0	22.43
16-17	-	-	-	-	-	-	-	-	-	-	250096	250096	-	-
17-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19-20	-	29699	-	-	-	-	-	-	-	-	-	29699	1151.8	38.78
20-21	-	78565	34339	-	-	-	-	-	-	-	-	112905	4967.3	44.00
21-22	-	158104	97447	-	-	-	-	-	-	-	-	255551	14176.2	55.47
22-23	-	696065	96499	24905	32951	-	-	-	-	-	-	850420	57980.5	68.18
23-24	-	1210347	709899	261920	10539	-	-	-	-	-	-	2192706	172693.5	78.76
24-25	-	362568	1480435	1080685	129617	5741	-	-	-	-	-	3059046	270135.6	88.31
25-26	-	17327	1482295	2957036	61490	14891	-	-	-	-	-	4533039	436287.1	96.25
26-27	-	3917	1412002	2681029	223971	-	30307	-	-	-	-	4351225	465045.5	106.88
27-28	-	-	356903	1942397	589950	40551	-	-	-	-	-	2929801	348851.3	119.07
28-29	-	1667	55223	924963	420473	83283	23234	-	-	-	-	1508844	195848.3	129.80
29-30	-	-	26894	248806	395101	97077	24473	-	-	-	-	792351	113468.6	143.20
30-31	-	-	9511	110677	300411	76606	63386	-	-	-	-	560591	87024.1	155.24
31-32	-	-	2994	66315	123690	102618	35267	-	-	-	-	330883	56797.3	171.65
32-33	-	-	-	4019	-	102820	36524	-	-	-	-	143363	25215.3	175.89
33-34	-	-	-	-	12444	49850	18622	-	-	-	-	80916	15652.8	193.45
34-35	-	-	-	-	-	-	-	-	24668	24693	-	49361	11434.0	231.64
35-36	-	-	-	-	-	-	-	18129	-	-	-	18129	4525.3	249.62
36-37	-	-	-	-	-	-	18179	-	-	-	-	18179	4859.0	267.29
37-38	-	-	-	-	-	-	-	-	-	-	6308	6308	1907.5	302.40
38-39	-	-	-	-	-	-	-	-	-	-	6464	6464	1764.7	273.00
39-40	-	-	-	-	-	-	-	-	-	-	6464	6464	1797.0	278.00
41-42	-	-	-	-	-	-	-	-	-	-	6076	6076	2236.1	368.00
TSN(1000)	23137203	2558261	5764440	10302753	2300636	573437	249991	18129	24668	24693	442138	45396350	-	-
TSB(1000 kg)	409747.4	183222.4	548339.6	1111371.3	299418.8	87941.5	39860.4	4525.3	5853.5	5580.6	7705.2	-	2703566.0	-
Mean length (cm)	13.98	22.90	24.99	26.13	27.93	30.12	30.49	35.33	34.12	34.00	15.51	-	-	-
Mean weight (g)	17.71	71.62	95.12	107.87	130.15	153.36	159.45	249.62	237.29	226.00	304.41	-	-	60.11

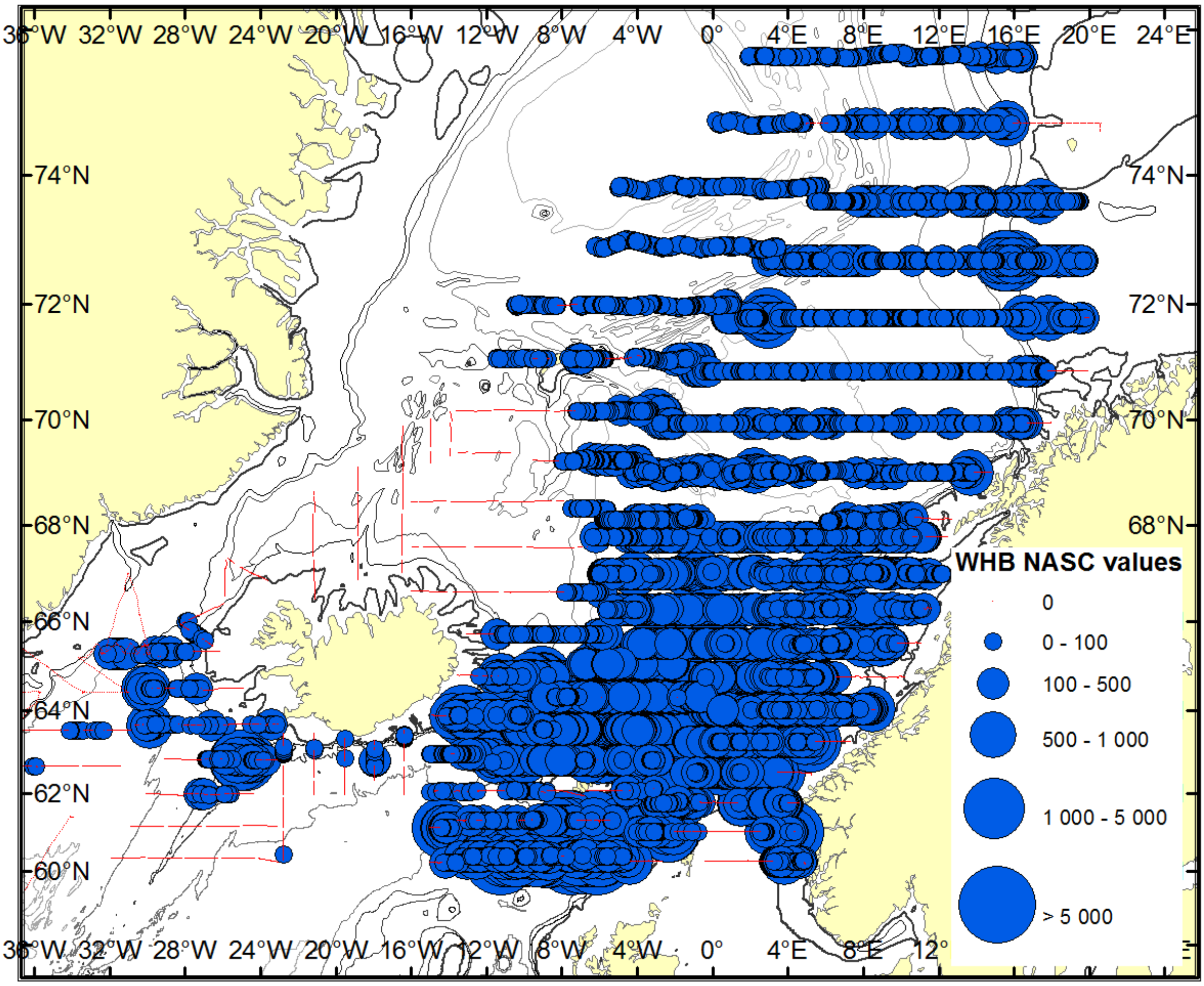


Figure 18. The sA/Nautical Area Scattering Coefficient (NASC) values of blue whiting along the cruise tracks in IESSNS in July-August 2017.

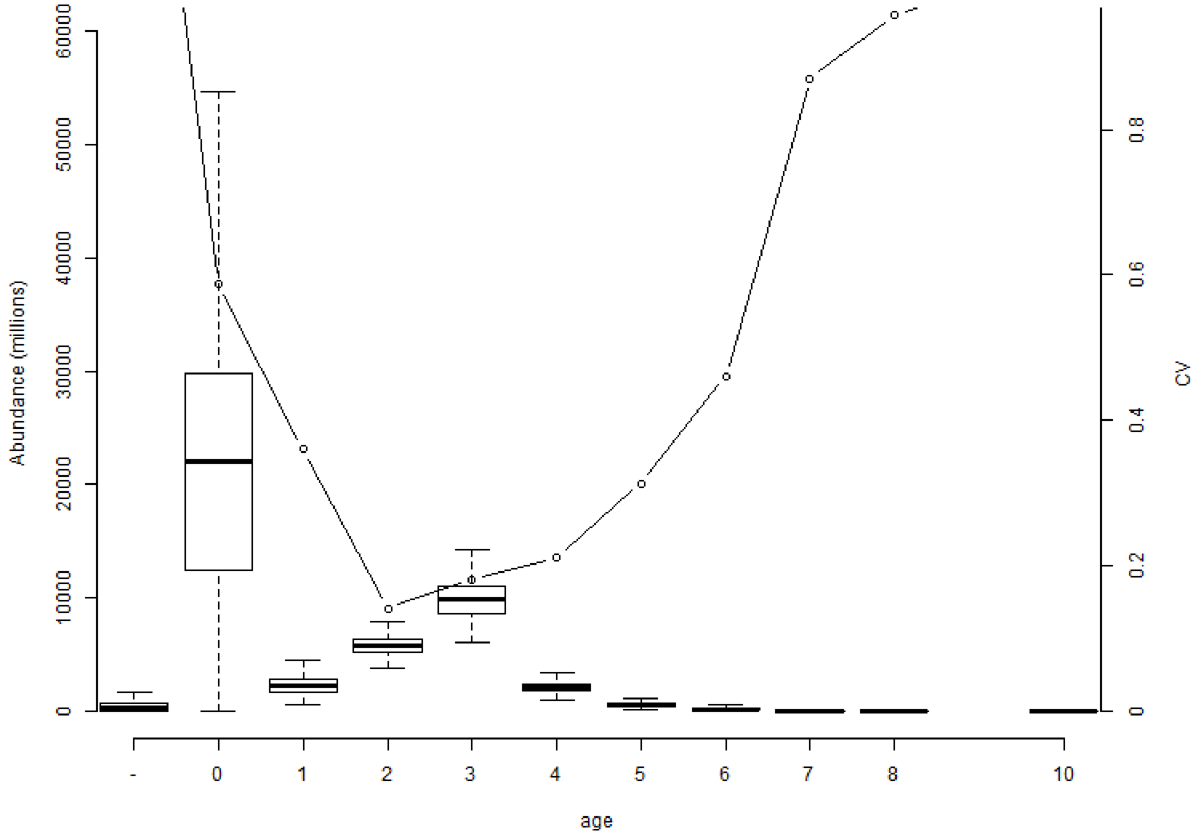


Figure 19. Number by age with uncertainty for blue whiting during IESSNS in July-August 2017. R boxplot of abundance and relative standard error (CV) obtained by bootstrapping with 500 replicates using the StoX software.

4.6 Other species

Lumpfish (*Cyclopterus lumpus*)

Lumpfish was caught in approximately 70% of trawl stations in July 2017 (Figure 20) and where lumpfish was caught, 70% 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 Árni Friðriksson, Kings Bay, Vendla and Finnur Fríði, whereas a subsample of 100 kg to 200 kg was processed onboard Trøndur i Gøtu in Faroese waters. Therefore, small catches (< 10 kg) of lumpfish might be missing from the survey track of Trøndur i Gøtu (black crosses in Figure 20).

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 5 to 57 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. 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.

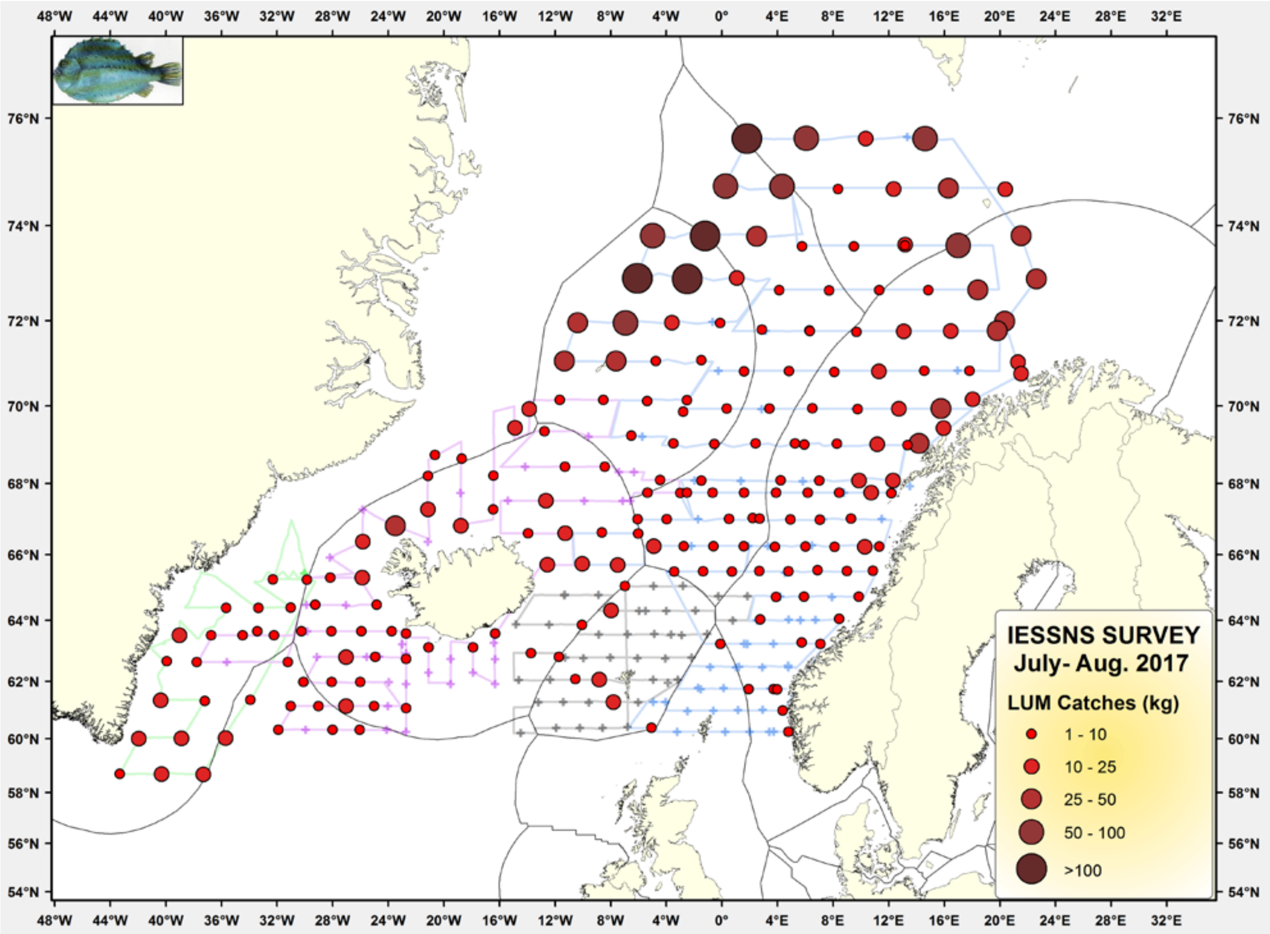


Figure 20. Lumpfish catches at surface trawl stations during the IESSNS survey in July-August 2017.

Salmon (*Salmo salar*)

A total of 36 North Atlantic salmon (*Salmo salar*) were caught in 21 stations both in coastal and offshore areas in the upper 30 m of the water column during the 2017 IESSNS survey (Figure 21). The salmon ranged from 0.11 kg to 5.25 kg in weight, dominated by salmon weighing between 110 gram and 1 kg. The length of the salmon ranged from 24 cm to 61 cm, with a large majority of the salmon <30 cm in length.

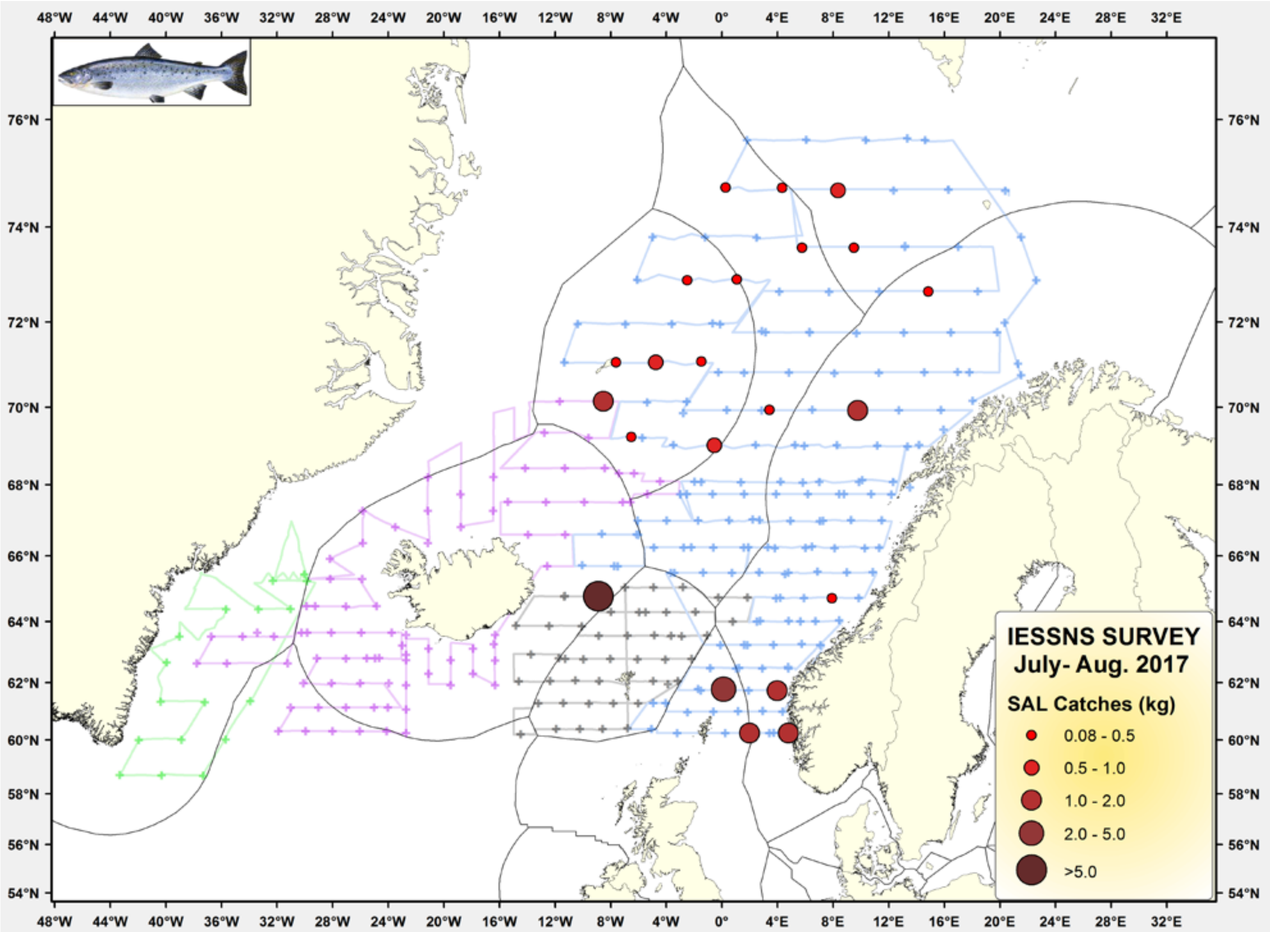


Figure 21. Catches of salmon at surface trawl stations during the IESSNS survey in July-August 2017.

Capelin (*Mallotus villosus*)

Capelin was caught in the trawl on 22 stations from along the cold front at the edge of the mackerel distribution from Cape Farewell, via Denmark Strait, North of Jan Mayen to the Barents Sea around Bear Island (Figure 22).

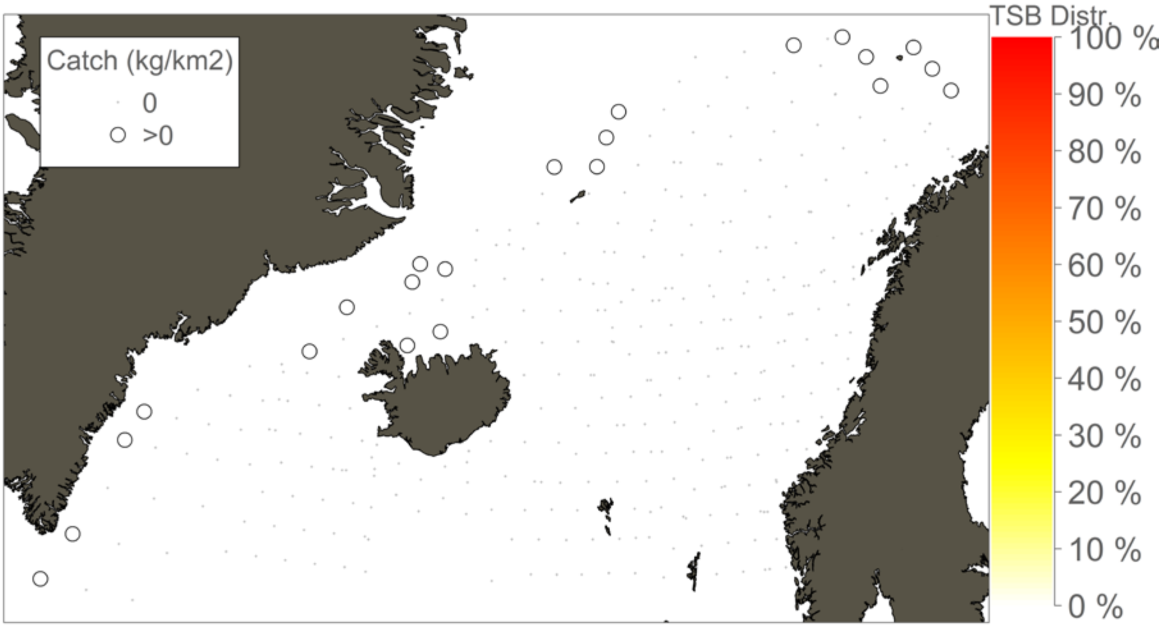


Figure 22. Presence of capelin in surface trawl stations during the IESSNS survey in July-August 2017.

4.7Marine 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 during 3rd of July - 4th of August 2017 (Figure 23). Overall >700 marine mammals and 8 species were observed. Altogether 174 individuals were observed onboard R/V "Árni Friðriksson" whereas >500 individuals were observed onboard M/V "Kings Bay" and M/V "Vendla". We had substantially higher number of sightings in 2017 than previous years, both due to the inclusion of Icelandic data, but also due to more sightings onboard the two Norwegian vessels. The Icelandic sightings were dominated of humpback whales (27), pilot whales (24), sperm whales (14), fin whales (13) and minke whales (12). Only one single small pod of two killer whales was observed during the survey. It has to be mentioned that there were long periods with rather thick fog and thereby low visibility, reducing the sighting probability for marine mammals in Iceland waters during most of the survey period. The opposite situation was evident for the two Norwegian vessels with practically flat sea and excellent visibility during the entire survey period. The species found in the Norwegian part of the survey in the Norwegian Sea and along the Norwegian coast included; fin whales, minke whales, humpback whales, pilot whales, killer whales, sperm whales, white-sided dolphins and white beaked dolphins. Altogether 15 pods consisting of 115 individual killer whales were found, mostly in the central and western part of the Norwegian Sea in close association with mackerel onboard the two Norwegian vessels. High densities of especially large groups of white beaked and white sided dolphins were observed in the northern part of the Norwegian Sea (Figure 23). Small groups of fin whales as well as some humpback whales were also dominating in northern part of the Norwegian Sea feeding on juvenile fish and capelin. Few marine mammals were sighted in the southern and central part of the Norwegian Sea (Figure 23).

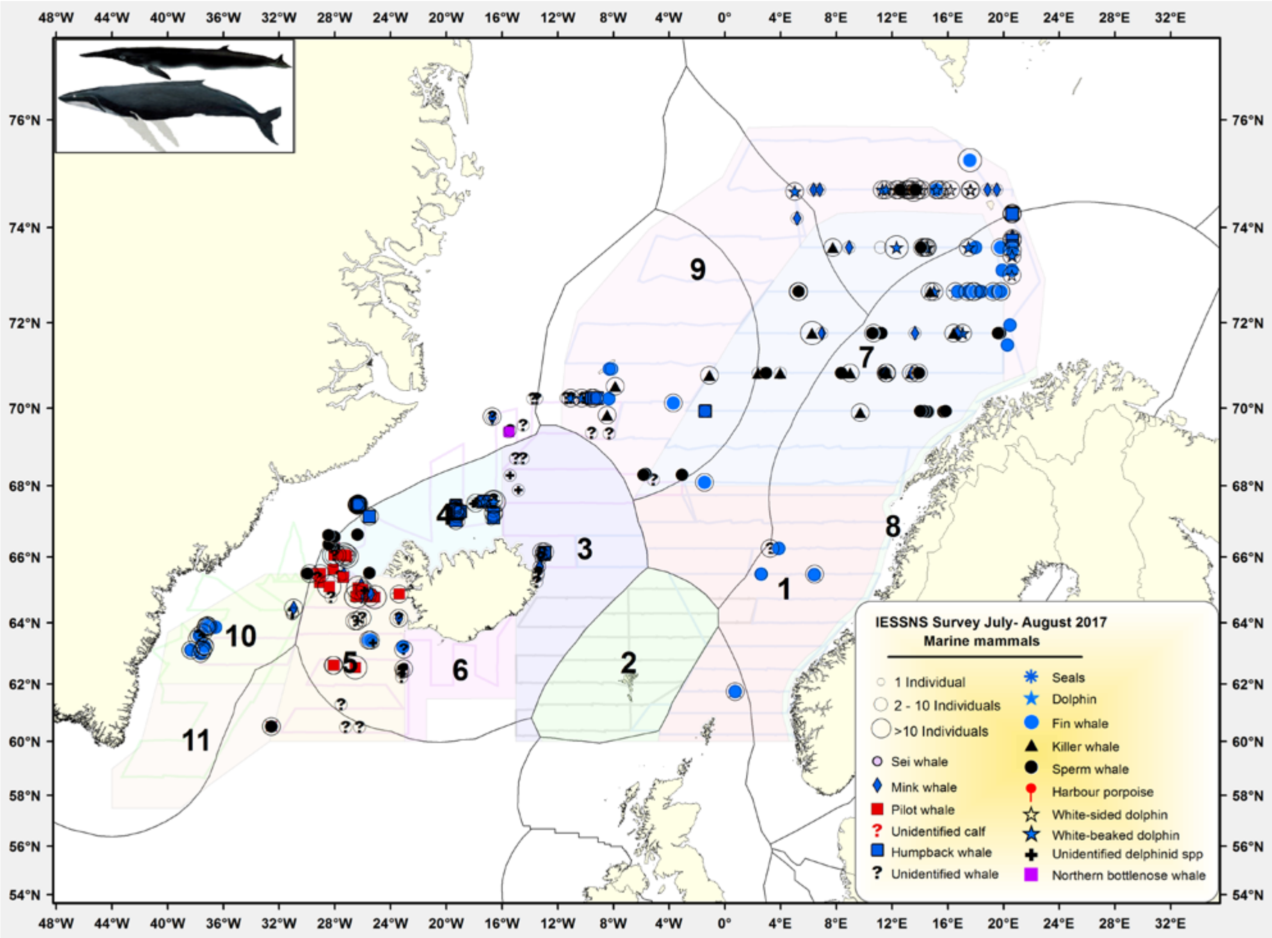


Figure 23. Overview of all marine mammals sighted onboard M/V "Vendla", M/V "Kings Bay" and R/V "Árni Friðriksson" in the Norwegian Sea and surrounding waters in July-August 2017.

5 Discussion

The international coordinated ecosystem survey in the Norwegian Sea and adjacent areas (IESSNS) was performed during 3rd of July – 4th of August 2017 by five vessels from Norway (2), Iceland (1), Faroes (1), and Greenland (1). The survey coverage slightly smaller than in previous year. A major part of the survey is a standardised surface trawling at predefined locations, which has been used for a swept area abundance estimation of NEA mackerel since 2007, although not in all 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 for the second time in the 2017 IESSNS survey to identify species and size distribution for acoustic estimation of blue whiting and Norwegian spring-spawning herring. The attempts have been considered successful both in 2016 and 2017, so we are now creating a new time series for abundance estimation and biomass indices for blue whiting (north of 60°N) and Norwegian spring-spawning herring. The IESSNS therefore provides abundance indices of three pelagic fish stocks, i.e. NEA mackerel, blue whiting and Norwegian spring-spawning herring.

The total swept area biomass index of mackerel in 2017 was the highest in the time-series, and was 13 % higher than in 2016, whereas number of individuals was lower in 2017 compared to 2016 by 2 %. The mackerel was distributed over an area of approximately 2.6 million km^2, which gives an average density of 3.9 tonnes/km^2. The average density is the highest in the entire time series. The 13 % increase in biomass indices from 2016 to 2017 can partly be explained by addition of the strong 2014-year class (15 % of the biomass).

The results seem to confirm the observation from the IESSNS 2016 that the 2014-year class is strong (Table 7). The size of the year class is still poorly determined but could be, according to these results, at similar level as the big 2010 and 2011-year classes. The 2016-year class also look promising.

The internal consistency plot for age-disaggregated year classes has improved since the benchmark in 2017 by the inclusion of one more survey year. This is especially apparent for 5 to 11 years 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.

The spatio-temporal overlap between mackerel and herring in 2017 was similar to that in both 2015 and 2016. However, the overlap in 2017 was highest in the south-eastern, southern and south-western part of the Norwegian Sea. There was practically no overlap between NEA mackerel and NSS herring in the central and northern part of the Norwegian Sea, mainly because of very limited amounts of herring in this area (Figure 15). Herring concentrations were highest in areas where zooplankton concentrations where high. Mackerel, on the other hand, was distributed in most of the surveyed area, also in areas with more varying zooplankton concentrations. In the areas where herring and mackerel overlap an inter-specific competition for food between the species can be expected. According to Langøy *et al.* (2012), Debes *et al.* (2012), and Oskarsson *et al.* (2015) the herring may suffer in this competition, the mackerel had higher stomach fullness index than herring and the herring stomach composition is different from previous periods. Langøy et al. (2012) and Debes et al. (2012) also found that mackerel target more prey species compared to herring and mackerel may thus be a stronger competitor and more robust in periods with low zooplankton abundances. Mackerel is known to utilize the dominating Atlantic currents for transportation norhtward (Nøttestad et al. 2016a).

This year's survey was very well synchronized in time and was conducted over a relatively short period given the large spatial coverage (Figure 1). This was in harmony to recommendations put forward in last year's report 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.

The acoustic abundance index of Norwegian spring-spawning herring was 20.6 billion corresponding to 5.88 million tonnes (Table 8). The abundance estimate of herring from the 2016 survey was 20.2 billion corresponding to 6.75 million tonnes, i.e. a reduction of approx. 10.5% in terms of biomass this year. However, the abundance (number of individuals) increased by approx. 2% due to the immigration of the 2013-year class. The distribution of this year class differs from the older fish since most of them are found in the northeastern part of the survey area. Older fish dominates in the western and southwestern part and the 2004-year class is still the most dominant year class in this area. Over all the 2004-year class is second most abundant both in terms of biomass and numbers.

The acoustic abundance index of blue whiting was 45.4 billion corresponding to 2.7 million tonnes (Table 9). The abundance estimate of blue whiting from the 2016 survey was 29.8 billion corresponding to 2.3 million tonnes, i.e. an increase of approx. 17% in terms of biomass. The abundance increased with approx. 52% and this is due to some strong registrations of 0-group south of the Faroe Islands. Some concentrations of 0-group were also seen in the same area last year and it seemed that these schools were mainly fish concentrated by fin whales feeding. The biomass index was close to threefold the estimate from May indicating that blue whiting are moving back to the Norwegian Sea to feed after the spawning migration in the spring.

The group considered the two acoustic biomass estimates of herring and blue whiting to be of good quality in the 2017 IESSNS.

The overall obtained zooplankton biomass indices in this year's survey (Figure 9) were in line with the results of the IESNS survey in May (ICES, 2017). There were, nevertheless, differences in areas where the high-density of plankton biomasses were located from May to July 2017. There was a substantial increase in zooplankton biomasses in parts of Icelandic and Greenland waters from July 2016 to July 2017. In the central and northern Norwegian Sea a slight decrease in zooplankton biomasses was observed from July 2016 to July 2017. These plankton indices, however, needs to be treated with some care due to various amounts of phytoplankton species/groups available to the zooplankton between years and areas. Further, the zooplankton estimate 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 from 61 to 69 m; Table 5), assuming that a constant fraction of the mackerel inside the horizontal trawl opening are caught. Further, that if mackerel is distributed below the depth of the trawl (footrope), this fraction is assumed constant from year to year.

6 Recommendations

Recommendation	**To whom**
Perform statistical power analyses of the historic data, to optimize the survey (station distance vs. patchiness in different areas).	Norway, Faroe Islands, Iceland, Greenland, EU
Encourage EU to join the IESSNS survey in order to obtain an even better synoptic and to include the southern part of the mackerel distribution during summer. Develop a method that can sample the mackerel representatively in the North West European shelf Seas south of the present survey area. Investigate the horizontal distribution and abundance of mackerel and if standardized trawling in the surface (0-30 m) can be used to measure the abundance of mackerel in the North West European shelf Seas south of the present survey area.	EU
We recommend that observers collect sighting information of marine mammals and birds on all vessels.	Norway, Faroe Islands, Iceland, Greenland, EU
In planning for IESSNS 2018, all vessels should aim for planning surface trawls in a straight path in addition to the predefined curved path surface trawl stations, to get enough replicates to evaluate if there are differences in catchability between straight and curved tows. The needed number of extra trawls should be calculated in a power analysis.	Norway, Faroe Islands, Iceland, Greenland, EU
The guidelines for trawl performance should be revised to reflect realistic values.	Norway, Faroe Islands, Iceland, Greenland, EU
Criteria should be established for discarding trawl stations when trawl performance is not good enough.	Norway, Faroe Islands, Iceland, Greenland, EU
A scrutinizing workshop to train all participant in analysing blue whiting and herring backscatter.	Norway, Faroe Islands, Iceland, Greenland.

Scientific personal should observe all surface trawling live from the bridge and specifically observe that headline is in surface, door spread is optimal and that trawl speed is recorded.	Norway, Faroe Islands, Iceland, Greenland.
The stratum south of Iceland (number 6 is not dynamic, it is permanent and the whole stratum should be surveyed.	Iceland

7 Survey participants

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9 References

Banzon, V., Smith, T. M., Chin, T. M., Liu, C., and Hankins, W., 2016: A long-term record of blended satellite and in situ sea-surface temperature for climate monitoring, modeling and environmental studies. Earth Syst. Sci. Data, 8, 165–176, doi:10.5194/essd-8-165-2016.

Debes, H., Homrum, E., Jacobsen, J.A., Hátún, H., Danielsen, J. 2012. The feeding ecology of pelagic fish in the southwestern Norwegian Sea –Inter species food competition between Herring (*Clupea harengus*) and mackerel (*Scomber scombrus*). ICES CM 2012/M:07. 19 pp.

Eydna í Homrum, E., Óskarsson, G.J., Slotte, A., 2016. Spatial, seasonal and interannual variations in growth and condition of Norwegian spring spawning herring during 1994-2015. WD to ICES Benchmark Workshop on Pelagic stocks (WKPELA), 29 February–4 March 2016, ICES Headquarters, Copenhagen, Denmark. 41 pp.

Foote, K. G., 1987. Fish target strengths for use in echo integrator surveys. J. Acoust. Soc. Am. 82: 981-987.

ICES 2013a. Report of the Workshop on Northeast Atlantic Mackerel monitoring and methodologies including science and industry involvement (WKNAMMM), 25–28 February 2013, ICES Headquarters, Copenhagen and Hirtshals, Denmark. ICES CM 2013/SSGESST:18. 33 pp.

ICES 2013b. Working group on Improving use of Survey Data for Assessment and Advice (WGISDAA). Dublin, Ireland, May 2013.

ICES 2014b. Manual for international pelagic surveys (IPS). Working document of Working Group of International Surveys (WGIPS), Version 1.02 [available at ICES WGIPS sharepoint] 98 pp.

ICES 2014c. Report of the Benchmark Workshop on Pelagic Stocks (WKPELA), 17–21 February 2014, Copenhagen, Denmark. ICES CM 2014/ACOM: 43. 341 pp

ICES 2015. International ecosystem survey in the Nordic Sea (IESNS) in April-June 2015. Working document to Working Group on International Pelagic Surveys (WGIPS). Copenhagen, Denmark, 16 – 18 of June 2015. 35 pp.

ICES. 2016. Report of the Working Group on Widely Distributed Stocks (WGWIDE), 31 August – 5 September 2016, Copenhagen, Denmark. ICES CM 2016/ACOM:16. 500 pp.

ICES. 2017. Report of the Benchmark Workshop on Widely Distributed Stocks (WKWIDE), 30 January-3 February 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:36. 196 pp.

Jolly, G. M., and I. Hampton. 1990. A stratified random transect design for acoustic surveys of fish stocks. Can.J. Fish. Aquat. Sci. 47: 1282-1291.

Langøy, H., Nøttestad, L., Skaret, G., Broms, C., & Fernö, A. (2012). Overlap in distribution and diets of Atlantic mackerel (*Scomber scombrus*), Norwegian spring- spawning herring (*Clupea harengus*) and blue whiting (*Micromesistius poutassou*) in the Norwegian Sea during late summer. Marine biology research, 8(5-6), 442-460.

Nøttestad L. and J.A. Jacobsen 2009. Coordinated Norwegian-Faroese ecosystem survey with M/V "Libas", M/V "Eros", and M/V "Finnur Fríði" in the Norwegian Sea, 15 July – 6 August 2009. Working Document to WGWIDE, ICES 2-8 Sept. 2009. 32 p.

Nøttestad, L., Diaz, J. E., Penã, H., Søiland, H., Huse, G., and Fernö, A. 2016a. The feeding strategy of mackerel in the Norwegian Sea in relation to currents, temperature and prey. ICES Journal of Marine Science; 73(4): 1127-1137, doi:10.1093/icesjms/fsv239.

Nøttestad, L., Utne, K.R., Óskarsson, G. J., Jónsson, S. Þ., Jacobsen, J. A., Tangen, Ø., Anthonypillai, V., Aanes, S., Vølstad, J.H., Bernasconi, M., Debes, H., Smith, L., Sveinbjörnsson, S., Holst, J.C., Jansen, T. and Slotte, A. 2016b. Quantifying changes in abundance, biomass and spatial distribution of Northeast Atlantic (NEA) mackerel (*Scomber scombrus*) in the Nordic Seas from 2007 to 2014. ICES Journal of Marine Science 73(2): 359-373. doi:10.1093/icesjms/fsv218.

Olafsdottir, A.H, Kjell R. Utne, Leif Nøttestad, Jan Arge Jacobsen, Teunis Jansen, Guðmundur J. Óskarsson, Sigurður Þ. Jónsson, Leon Smith, Are Salthaug, Eydna í Hömrum, and Aril Slotte 2017. Preparation of data from the International Ecosystem Summer Survey in Nordic Seas (IESSNS) for use as an annual tuning series in the assessment of the Northeast Atlantic mackerel (*Scomber scombrus L.)* stock. Working Document (WD) for WGIPS 2017 and WKWIDE 2017. 36 p.

Óskarsson, G.J., A. Gudmundsdottir, S. Sveinbjörnsson & Þ. Sigurðsson 2016. Feeding ecology of mackerel and dietary overlap with herring in Icelandic waters. Marine Biology Research, 12: 16-29.

Pampoulie, C., Slotte, A., Óskarsson, G.J., Helyar, S.J., Jónsson, Á., Ólafsdóttir, G., Skírnisdóttir, S., Libungan, L.A., Jacobsen, J.A. Joensen, H., Nielsen, H.H. Sigurðsson, S.K., Daníelsdóttir, A.K. 2015. Stock structure of Atlantic herring *Clupea harengus* in the Norwegian Sea and adjacent waters. Marine Ecology Progress Series. 522: 219-230.

Salthaug, A., Aanes, S., Johnsen, E., Utne, K. R., Nøttestad, L., and Slotte, A. 2017. Estimating Northeast Atlantic mackerel abundance from IESSNS with StoX. Working Document (WD) for WGIPS 2017 and WKWIDE 2017. 103 pp.

Trenkel, V.M., G. Huse, B.R. MacKenzie, P. Alvarez, H. Arrizabalaga, M. Castonguay, N. Goñi, F. Grégoire, H. Hátún, T. Jansen, J.A. Jacobsen, P. Lehodey, M. Lutcavage, P. Mariani, G.D. Melvin, J.D. Neilson, L. Nøttestad, Guðmundur J. Óskarsson, M.R. Payne, D.E. Richardson, I. Senina, D.C. Speirs 2014. Comparative ecology of widely distributed pelagic fish species in the North Atlantic: implications for modelling climate and fisheries impacts. Progress in Oceanography 129: 219-243.

Utne, K.R. Huse G., Ottersen G., Holst J.C., Zabavnikov V., Jacobsen J.A., Óskarsson G.J., and Nøttestad L. 2012. Horizontal distribution and overlap of planktivorous fish stocks in the Norwegian Sea during summers 1995-2006. Marine Biology Research. 8 (5-6): 420-441.

Valdemarsen, J.W., J.A. Jacobsen, G.J. Óskarsson, K.R. Utne, H.A. Einarsson, S. Sveinbjörnsson, L. Smith, K. Zachariassen and L. Nøttestad 2014. Swept area estimation of the North East Atlantic mackerel stock using a standardized surface trawling technique. Working Document (WD) to ICES WKPELA. 14 pp.

Annex 6:

Annex 6a: GERAS survey report 2017

Survey Summary table	
Name of the survey (abbreviation):	GERAS / BIAS (GER)
Summary:	
The objectives of the survey were carried out successfully and as planned in all of the covered ICES Subdivisions. Adverse weather conditions in the northern part of SD 21 (Kattegat) required shortening of the transects in the two northernmost statistical rectangles that nevertheless were covered with lesser transect mileage. Altogether, 57 trawl hauls were carried out during the survey providing biological data for age stratified abundance estimation of target species herring and sprat. Measured NASC values per 1 nmi EDSU allocated to clupeids were distinctly lower in most parts of the survey area in comparison to previous years (and also in comparison to the long-term survey mean). A significant decrease in both abundance (ca. 40%) and biomass (ca. 20%) of Western Baltic Spring Spawning herring was evident in comparison to the already low levels measured in 2016. In sprat, abundance and biomass in the survey area declined by ca. 50% and ca. 70% respectively. As in the previous year, dense aggregations of large, mature herring seemed to be absent from their overwintering area in SD23. Survey effort, timing and coverage were comparable to previous years.	

	Description
Survey design	Stratified systematic (parallel where applicable) design. Start point not randomized.
Index Calculation method	GERIBAS 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.
Extinction (shadowing)	No particular issues as targets are scattered throughout the water column in loose aggregations in most of the surveyed areas.
Blind zone	Night-time distribution of clupeids in surface layers (i.e. within blind zone and near-field) is assumed to occur but is not quantified.
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.
Calibration	All survey frequencies calibrated and results within recommended tolerances.

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Survey Report FRV Solea

German Acoustic Autumn Survey (GERAS)

04 – 23 October 2017

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 30th 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, 1167 nmi (plus 132 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 lower than the values measured in 2016 and also often lower than the long-time mean values. Only in altogether seven rectangles in ICES SD 21, 22 and 24, mean NASC values were occasionally distinctly higher than in the previous year (and in 3 cases than the long-time mean). In SD 23, as in 2016, unusually low NASC values (even significantly lower 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. It has to be mentioned, that during a repetition of the transect in SD 23 during daytime for comparison, NASC values measured and echorecordings clearly showed presence of a significant amount of clupeids in the area.

For species allocation and identification, altogether 57 fishery hauls were conducted. Vertical hydrography profiles were measured on 87 stations.

2 SURVEY DESCRIPTION & METHODS APPLIED

2.1 Cruise narrative

The 740th cruise of FRV Solea represents the 30th 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 4th in Kiel harbor. On the same afternoon, Solea left port for the calibration of scientific echosounders. A calibration site off Strande was chosen according to prevailing weather conditions providing acceptable conditions deteriorating towards the evening. 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 5th.

Hydroacoustic survey operations commenced October 5st at 06:50 PM in SD 22 southeast of Langeland Island.

Generally, survey operations were conducted during nighttime to account for the more pelagic distribution of clupeids during that time. Adverse weather conditions at the start of the survey required to start survey operations in the comparatively sheltered western Baltic SD 22. After finishing SD 22, FRV Solea steamed to Warnemünde port to allow disembarking of a scientific crew member on October 10th. Survey operations commenced the same evening in SD 24. Due to expected severe weather conditions during the following evening and afterwards, a cruise track waypoint southwest of Bornholm Island was approached the following day and survey operations commenced in an opposing direction to be able to enter Sassnitz harbor for an interruption of survey work the following morning. Accordingly, the survey had to be suspended for one night on October 12th due to bad weather. On October 13th, survey operations commenced on the waypoint near Bornholm Island in westerly directions according to the cruise plan. The rest of SD 24 as well as SD 23 were covered as planned due to favorable weather conditions. In SD 21 (Kattegat), the cruise track in the northernmost rectangles to be covered had to be shortened due to adverse weather conditions but was finished as planned in the remaining subdivision. After accomplishing the regular survey work, a comparative sampling (hydroacoustics and fishery) of the SD 23 (Sound) was conducted to validate weak registrations recorded during the regular, initial passage. Afterwards, Solea entered Copenhagen port on October 21st to switch survey operations back to day time. On October 22nd, a third passage of the Sound (SD 23) transect was conducted (hydroacoustics and fishery) to identify drivers for variable registrations of clupeids in that area. The scientific program was finished on October 22th, 05:15 PM. The ship arrived at Marienehe port on October 23rd, 07:00 AM.

Altogether, the following survey schedule was accomplished:

Belt Sea	(SD 22)	05. - 09.10.
Arkona Sea	(SD 24)	10. - 15.10.
Sound	(SD 23)	16.10.
Kattegat	(SD 21)	17. - 19.10.
Sound (comp.)	(SD 23)	20.10.
Sound (day)	(SD 23)	22.10.

Total survey time	15 nights (+ 1 night / 1 day comparison in SD 23)
Fishery hauls	57
CTD-casts	87
Hydroacoustic transects	1167 nmi (+ 132 nmi transects for comparison)

Overall hydroacoustic transect length was 1167 nmi (2016: 1179 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 characterised 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 1 167 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 8 software (Echoview Software Pty Ltd, 2017). Mean volume back scattering values (sv) 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 but increasingly inclement weather conditions from a drifting vessel in Strande Bay/Kiel Bight. 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 57 fishery hauls were conducted (Figure 1), out of which 54 (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, while water samples for Winkler titration and calibration of oxygen measurements were taken and processed at least once per day. Altogether, 87 CTD-profiles were measured (Figure 6).

2.7 Data analysis

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 (sA) 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:

Fish species considered:

Herring	(*Clupea harengus*)
Crystal goby	(*Crystallogobius linearis*)
Cod	(*Gadus morhua*)
Three-spined stickleback	(*Gasterosteus aculeatus*)
Whiting	(*Merlangius merlangus*)
Saithe	(*Pollachius pollachius*)
Mackerel	(*Scomber scombrus*)
Sprat	(*Sprattus sprattus*)
Horse mackerel	(*Trachurus trachurus*)
Norway pout	(*Trisopterus esmarckii*)

Exclusion of trawl hauls with very low catches:

Haul No.	Rectangle	Subdivision (SD)
3	39G0	22
36, 52	40G2	23
37	41G2	23
43	41G1	21
48	41G2	21

Exclusion of day time trawl hauls:

Haul No.	Rectangle	Subdivision (SD)
55-57	40G2	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)
1	39G1	22
4	40G1	22
5	41G0	22
6, 7	40G0	22
9	39G0	22
13	38G1	22
17	37G2	24
38, 53	41G2	23
49	42G2	21
50	43G1	21
39, 51	41G2	23

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	49 and 50	42G2 and 43G1/21
39F9/22	8 and 9	40F9 and 39G0/22
39G2/23	29, 35	39G2/24
37G4/24	21, 24, 25	38G4/24

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 2017, the majority of which can be allocated to clupeids. In almost all rectangles surveyed, mean NASC values were significantly lower than those recorded in 2016, and often also well below the long-time survey average. On ICES subdivision scale, mean NASC values were lower than in the previous year in all subdivisions covered.

In SD 21, overall NASC values measured were low. Only in 2 rectangles (41G1 and 42G1), mean NASC NASC per 1 nmi EDSU was marginally higher in almost all rectangles observed than in the previous year, but still lower than the long-time survey average, as in all rectangles surveyed.

In SD 22, mean NASC values recorded were lower than the previous year in 9 out of 11 rectangles surveyed. In comparison to the long-term survey mean of rectangles in SD 24, the NASC measured was lower in all but one rectangles. Increased aggregations of clupeids were measured in Kiel Bight and Mecklenburg Bight as well as near the northern entrance to the Little Belt, where mean NASC was almost 10fold higher than in the previous year. This area however contains only a short transect distance and is usually characterized by extremely low NASC levels.

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 2017. NASC values were significantly lower than the already low levels measured in 2016 as well as the long-term survey mean. A replicate measurement of the transect in SD 23 during night time a few days later corroborated these findings. It has to be mentioned however, that on another replicate measurement 2 days later during daytime, significant NASC values were measured and dense aggregations of clupeids were detected on the echosounder (see Figure 7).

In SD 24, mean NASC values were significantly lower than the values measured in 2016 in 3 out of 6 rectangles surveyed. In rectangle 38G4 and 39G4 (eastern part of Arkona Basin) however, mean NASC levels were around twice as high as the levels measured during the previous survey in 2016. As in the years before, higher aggregations were also detected north of Rügen Island.

3.2 Biological data (T. Gröhsler)

Fishery hauls according to ICES Subdivision:

SD	Hauls (n)
21	11
22	16
23	11 (incl. 3 daytime hauls)
24	19

Altogether, 1 701 individual herring, 757 sprat, 12 European anchovies and 5 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, 39 different species were recorded. Herring were caught in 49, sprat in 51 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 2016, when sardines (*Sardina pilchardus*) were caught in SD 22-24, this species only appeared in catches from SD21 in 2017. As in previous years, anchovy (*Engraulis encrasicolus*) were present in in the whole survey area, albeit in a lower frequency of occurrence (41 of 55 hauls in 2016; 7 of 57 hauls in 2017).

Altogether, the following species were sampled and processed:

Species	Length measurements (n)	Prevalence (n of hauls)
Clupea harengus	11 021	49
Crystallogobius linearis	224	23
Ctenolabrus rupestris	7	3
Cyclopterus lumpus	7	6
Engraulis encrasicolus	15	7
Eutrigla gurnardus	40	8
Gadus morhua	269	23
Gasterosteus aculeatus	366	26
Limanda limanda	108	22
Merlangius merlangus	378	37
Mullus surmuletus	3	3
Platichthys flesus	47	20
Pleuronectes platessa	8	5
Pomatoschistus minutus	193	27
Sardina pilchardus	5	4
Scomber scombrus	255	12
Sprattus sprattus	8 624	51
Trachinus draco	233	20
Trachurus trachurus	84	21
Trisopterus esmarckii	5	4
Others	798	-

Figures 3 and 4 show relative length-frequency distributions of herring and sprat in ICES subdivisions 21, 22, 23 and 24 for the years 2016 and 2017. Compared to results from the previous survey in 2016, the following conclusions for **herring** can be drawn (Figure 3):

- In contrast to 2016, catches in SD 21 showed a less pronounced bimodal distribution characterized by the presence of the incoming year class (ca. ≤15 cm) and older herring (>15 cm). The fraction of the incoming year class dominated in 2016, whereas in 2017 older herring accounted for the largest share.
- The catches in SD 22 showed a multimodal distribution with two modes at 11.25 cm and 15.26 cm corresponding to the incoming year class (ca. ≤15 cm) and one mode of 18.75 cm for older herring (>15 cm). This was in contrast to the dominant contribution of herring <10 cm (mode at 9.75 cm) in 2016.
- In contrast to the years before, larger herring (>20 cm) were more or less absent from night time catches conducted in SD 23. The catches in 2017 were dominated by the contribution of the incoming year class (ca. ≤15 cm).
- In SD 24, the herring length-frequency distribution was characterized by a similar contribution of the incoming year class (≤15 cm) and older herring (>15 cm) in both years. However, the bimodal distribution in 2017 showed more lager herring (≤15 cm: mode 2016/9.75 cm and mode 2017/11.75 cm; >15 cm: mode 2016/17.75 cm and mode 2017/18.25 cm).
- Altogether, the present contribution of the incoming year class (ca. <15 cm) seemed to be rather low.

Relative length-frequency distributions of **sprat** in the years 2016 and 2017 (Figure 4) can be characterized as follows:

- In SD 21 catch numbers of the incoming year class (ca. ≤10 cm) were virtually absent in both years. The catches were dominated by the contribution of larger sprat (>10 cm).

- In SD 22 - 24 catch numbers of the incoming year class (ca. ≤10 cm) dominated in 2016, whereas the catches now show a larger contribution of larger sprat (>10 cm) in 2017.
- Altogether, as for herring the present contribution of the incoming year class (ca. ≤10 cm) seemed to be rather low.

3.3 Biomass and abundance estimates

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 2011-2016 and in 2017 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 in prep.). 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 Sa values.

The age-length distribution of herring in SD 22 in 2017 indicated a low contribution of older fish of CBH origin. Thus, the SF was not applied in 2017 in SD 22.

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.

3.3.1 Estimates incl. Central Baltic Herring (CBH)

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 summarised in Table 9 and Table 12.

The herring stock in Subdivisions 21-24 was estimated to be 2.8 x 10^9 fish (Table 7) or 111.7 x 10^3 tonnes (Table 9). For the included area of Subdivisions 22-24 the number of herring was calculated to be 2.5 x 10^9 fish or 100.9 x 10^3 tonnes.

The estimated sprat stock in Subdivisions 21-24 was 7.5 x 10^9 fish (Table 10) or 99.5 x 10^3 tonnes (Table 12). For the included area of Subdivisions 22-24 the number of sprat was calculated to be 7.1 x 10^9 fish or 93.3 x 10^3 tonnes. The overall abundance estimate in 2017 was dominated by on year old sprat (year class 2016, Figure 4 and Table 10).

3.3.2 Estimates excl. Central Baltic Herring in SDs 22&24

Estimated numbers of herring excluding CBH in 39G2/SD 23 and SD 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 summarised in Table 15. Removal of the CBH fraction in SDs 22 and 24 from herring GERAS index in 2017 resulted in biomass reductions of 15.8 % with corresponding reductions in numbers of 12.7 % (-29.4 % and -18.7 %, respectively in 2016; Figure 5).

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, 87 CTD casts were conducted during this survey.

Surface temperatures ranged from ca. 11°C in the eastern Arkona Basin and ca. 13 °C in the Kattegat area to around 14°C in the Kiel Bight and southern Belt Sea (Figure 6). Bottom temperatures were also mostly around 14°C in the largest part of the survey area except for the deeper western parts of the Bornholm Basin, where temperatures near the seafloor were below 7°C.

Surface salinities showed a large gradient from ca. 7 PSU in the eastern Arkona Sea to ca. 15 PSU in the Kiel Bight and over 20 PSU in the Kattegat. Salinity near the seafloor ranged from 8 PSU in the Arkona Sea to ca. 33 PSU in the Kattegat. Especially in the Sound, a very strong stratification with steep salinity gradients was observed.

Surface waters were well oxygenated throughout the survey area. Near the seafloor, low oxygen levels were measured in the central eastern parts of the Arkona Basin. Anoxic conditions above the seafloor were observed in the southern part of the Little Belt and the inner Mecklenburg Bight.

4 DISCUSSION

Compared to 2016, the present estimates of herring (incl. CBH) show a significant decrease in stock biomass and abundance:

Herring	Difference compared to 2016	
Area	Numbers (%)	Biomass (%)
Subdivisions 22-24	-42	-22
Subdivisions 21-24	-44	-20

The significant decrease in 2017 was mainly driven by lower numbers or biomass estimates in SD 23 (-83 % in numbers and -93 % in biomass). The present herring abundance and biomass estimates in SD 23 represent the 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 2017 as in 2016 for the second time since many years almost absent. This complete absence could be explained by delayed immigration of WBSSH from the feeding areas in the Skagerrak in 2016. The exceptionally low numbers in 2016 and even further decreased numbers in 2017 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 disappearance of older herring in time. The strong correlation of N20 with the 1-age group (Polte and Gröhsler, 2018) of GERAS index supports this assumption. It has to be mentioned, however, that also methodological biases could lead to the low numbers observed: While during recurrent measurements along the transect during night time both S_A values and catches were low, significant and massive schools of presumably large herring were detected in a following recording conducted during daytime. While diurnal differences in distribution can be ruled out based on the long-term observations, other factors affecting the presence or absence of the large schools/aggregations in the deeper (surveyed) parts of SD 23 should be investigated.

Older and bigger herring were in 2017 only detected in SD 24. In contrast to last year's results, the exclusion of CHB in SD 24 did not lead to a virtual elimination of older and bigger herring in this area. This is in accordance with the results in 2015, when some older and bigger herring already had started to migrate out of the Sound (SD 23). It is assumed that these migrations are 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 2017, such migration of big herring was already partially detected during the survey period, indicating that according hydrographic conditions were met driving herring out of the Sound.

In SD 21 and 23 some herring were observed that according to their age and length (e.g. age 3, total length 15 cm) could be allocated to CBH with a high degree of probability. This immigration has been observed in past years, albeit only in single individuals. Analyses of 2016-2017 data validating the SF indicate that a further reduction of big herring together with immigration of CBH in SD 21 and SD 23, when being used as basis sample for WBSSH, can lead to problems with estimating SF parameters and their utilization.

5 SURVEY PARTICIPANTS

Name	Function	Institute
Dr. M. Schaber	Hydroacoustics, Cruise leader	TI-SF
B. Stefanowitsch	Hydroacoustics	TI-SF (student assistant)
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S.-E. Levinsky	Fishery biology	DTU Aqua, Kgs. Lyngby, (DK)
F. Müller	Fishery biology	TI-SF (student assistant)
M. Püts	Fishery biology	TI-SF
L. Wietrzynski	Fishery biology	TI-OF (04.- 10.10.)

6 REFERENCES

Echoview Software Pty Ltd (2017) Echoview software, version 8. Echoview Software Pty Ltd, Hobart, Australia.

Foote, K.G., Aglen, A. and Nakken, O. (1986) Measurement of fish target strength with a split-beam echosounder. Journal of the Acoustical Society of America, 80(2): 612-621.

Gröhsler, T., Oeberst, R., Schaber, M., Larson, N. and Kornilovs, G. (2013) Discrimination of western Baltic spring-spawning and central Baltic herring (*Clupea harengus* L.) based on growth vs. natural tag information. ICES Journal of Marine Science, 70 (6): 1108-1117. doi:19.1093/icesjms/fst064.

Gröhsler, T., Schaber, M., Larson, N. and Oeberst, R. (2016) Separating two herring stocks from growth data: long-term changes in survey indices for Western Baltic Spring Spawning Herring (Clupea harengus) after application of a stock separation function. Journal of Applied Ichthyology 32: 40-45; doi: 10.1111/jai.12924

Gröhsler, T. and Schaber, M. (2018, in prep.). Applicability of the Separation Function (SF) in 2017. WD for WGBIFS 2018.

ICES (2017) SISP Manual of International Baltic Acoustic Surveys (IBAS). Series of ICES Survey Protocols SISP 8 – IBAS. 47pp.

ICES (2015) Report of the Workshop on scrutinisation procedures for pelagic ecosystem surveys (WKSCRUT). ICES CM 2015 / SSGIEOM: 18

ICES (2013) Report of the Benchmark Workshop on Pelagic Stocks (WKPELA 2013). ICES Document CM 2013/ACOM: 46

ICES (1983) Report of the Planning Group on ICES coordinated herring and sprat acoustic surveys. ICES Document CM 1983/H:12.

Miethe, T., Gröhsler, T., Böttcher, U. and von Dorrien, C. (2014) The effects of periodic marine inflow into the Baltic Sea on the migration patterns of Western Baltic spring-spawning herring. ICES Journal of Marine Science, 71(3): 519-527.

Nielsen, J. R. (1996) Acoustic monitoring of herring related to the establishment of a fixed link across the Sound between Copenhagen and Malmö. DFU-rapport Nr. 11-96, ISSN 1395-8216, 93pp.

Oeberst, R., Gröhsler, T., Schaber, M. and Larsen, N. (2013) Applicability of the Separation Function (SF) in 2011 and 2012. WD 01 for HAWG. ICES Document CM 2013/ACOM06: Sec 14: 819-825 & WD for WGBIFS. ICES Document CM 2013/SSGESST:08: Annex 9: 399-405.

Oeberst, R., Gröhsler, T. and Schaber, M. (2014) Applicability of the Separation Function (SF) in 2013. WD for WGIPS 2014.

Oeberst, R., Gröhsler, T. and Schaber, M. (2015) Applicability of the Separation Function (SF) in 2014. WD for WGIPS 2015.

Oeberst, R., Gröhsler, T. and Schaber, M. (2016) Applicability of the Separation Function (SF) in 2015. WD for WGBIFS 2016.

Polte, P., and Gröhsler, T. (2018) Western Baltic spring spawning herring recruitment monitored by the Rügen Herring Larvae Survey. WD in prep. for ICES HAWG 2018.

7 FIGURES

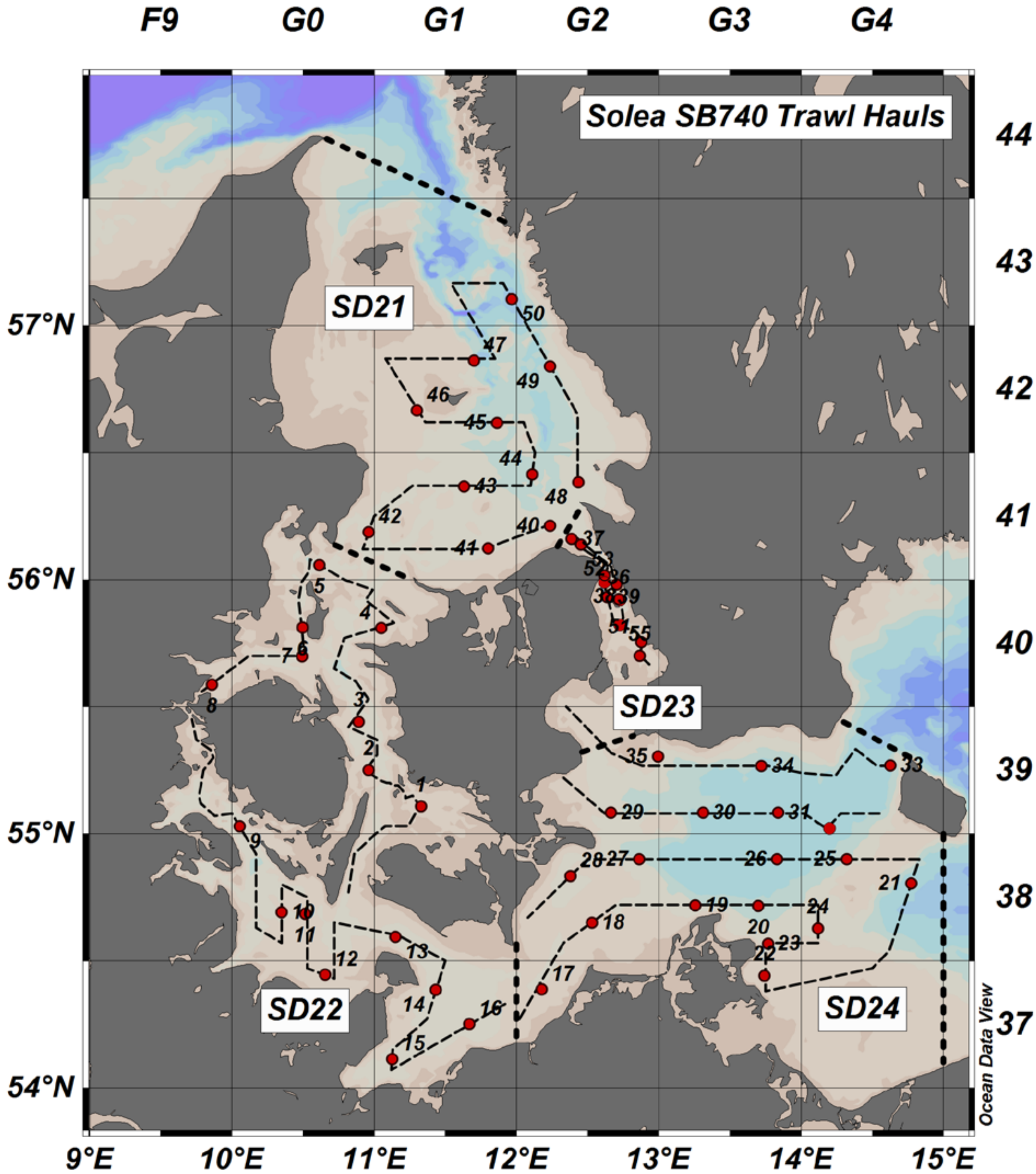


Figure 1: FRV Solea cruise 740/2017. Cruise track (thin dashed lines) and fishery hauls (red dots). ICES statistical rectangles are indicated in the top and right axis. Thick dashed lines separate ICES subdivisions (SD).

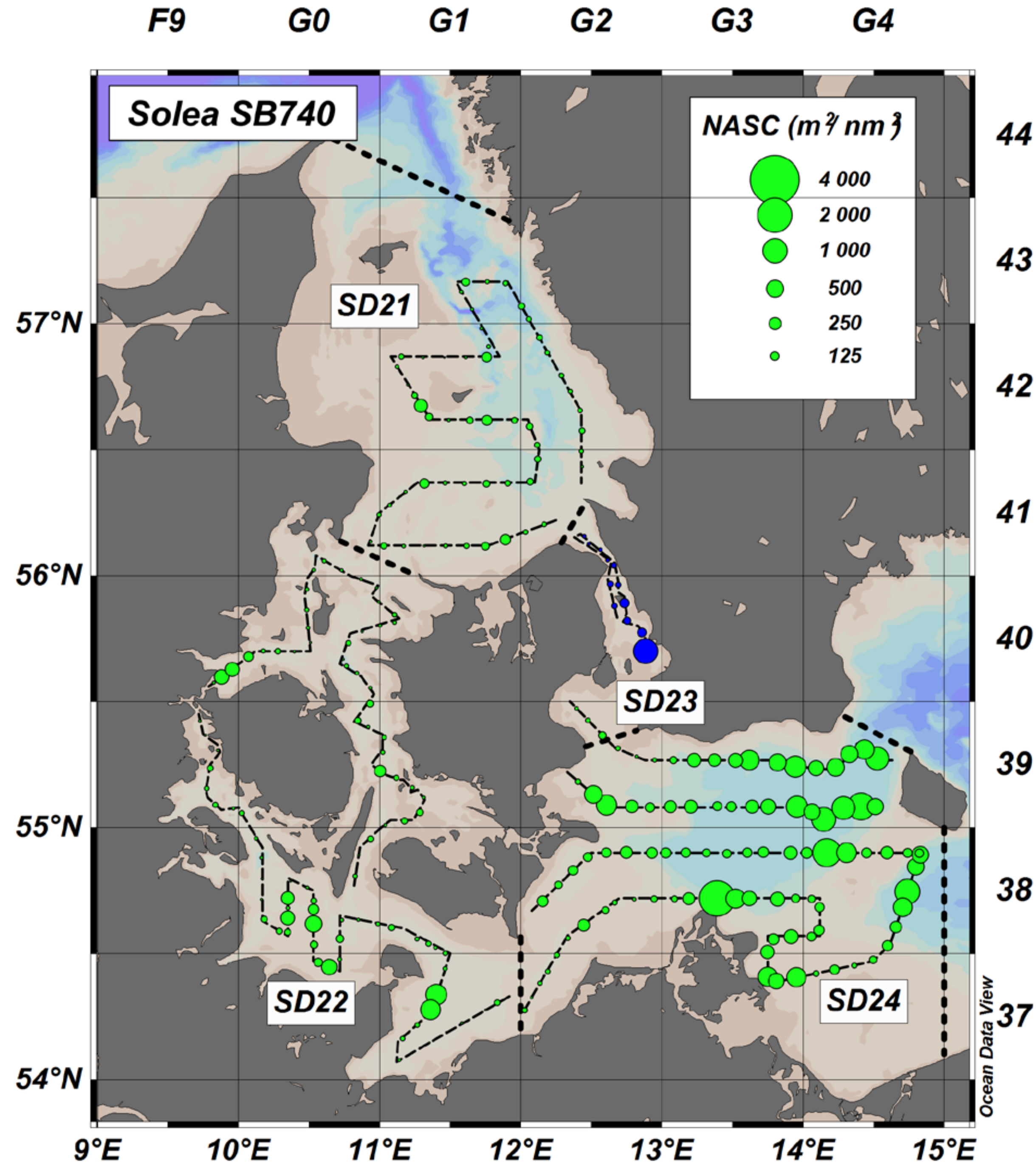


Figure 2: FRV Solea cruise 740/2017. Cruise track (thin dashed lines) and mean NASC (5 nmi intervals, dots). ICES statistical rectangles are indicated in the top and right axis. Thick dashed lines separate ICES subdivisions (SD). Blue NASC values in Subdivision 23 (Sound) represent mean of two (night time) recordings.

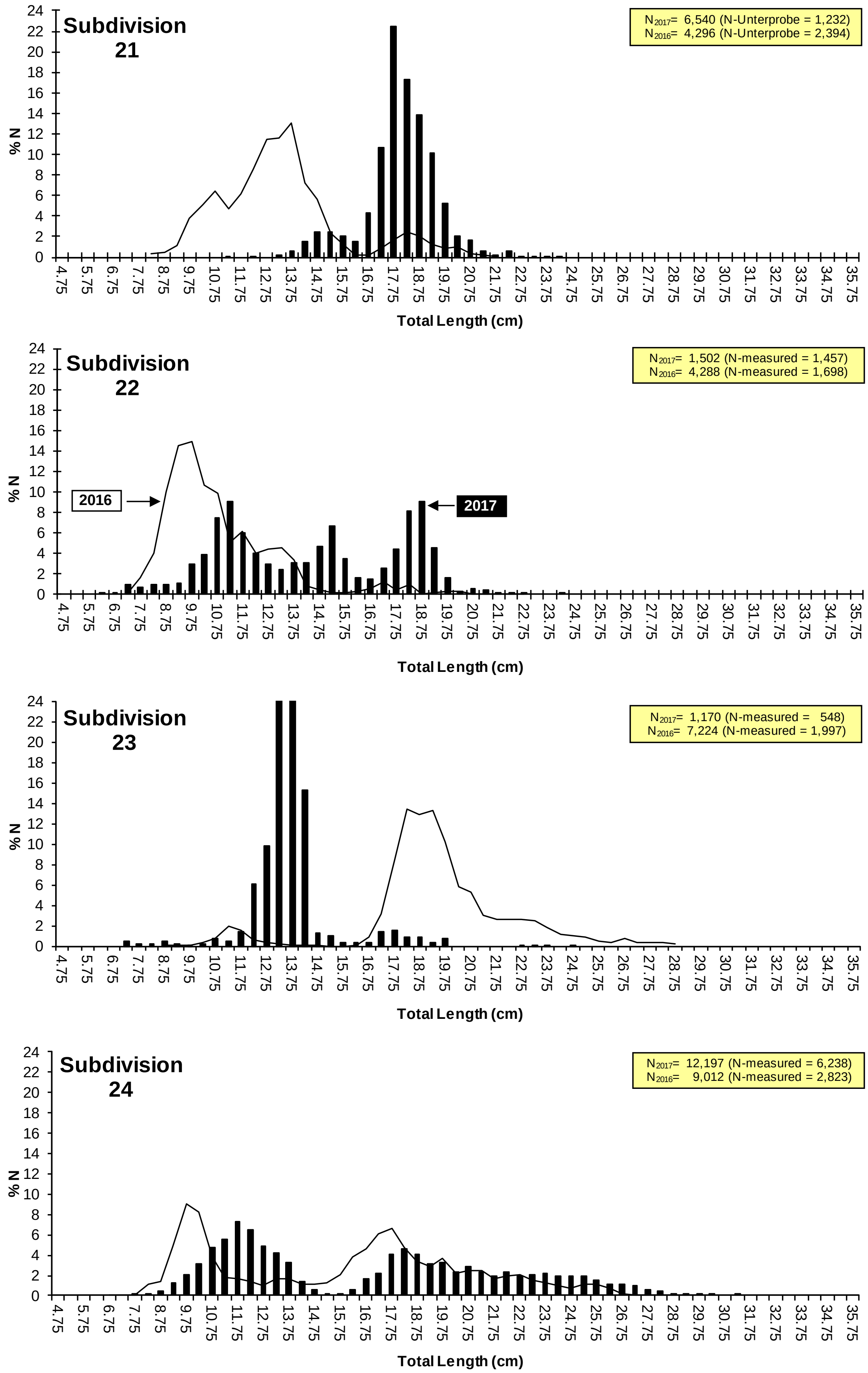


Figure 3: FRV Solea cruise 740/2017. Herring (*Clupea harengus*) length-frequency distribution compared to previous year (cruise 726/2016).

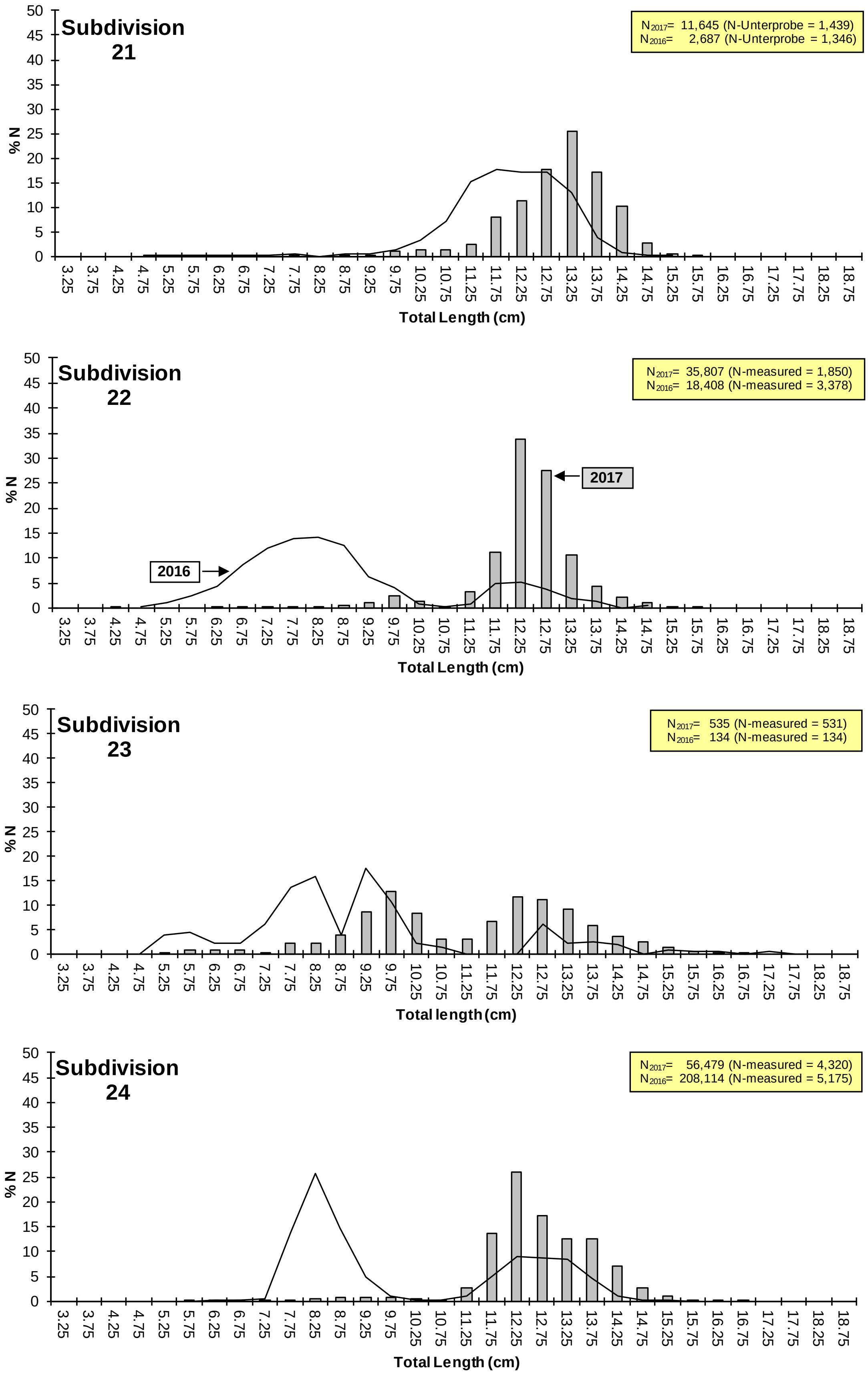


Figure 4: FRV Solea cruise 740/2017. Sprat (*Sprattus sprattus*) length-frequency distribution compared to previous year (cruise 726/2016).

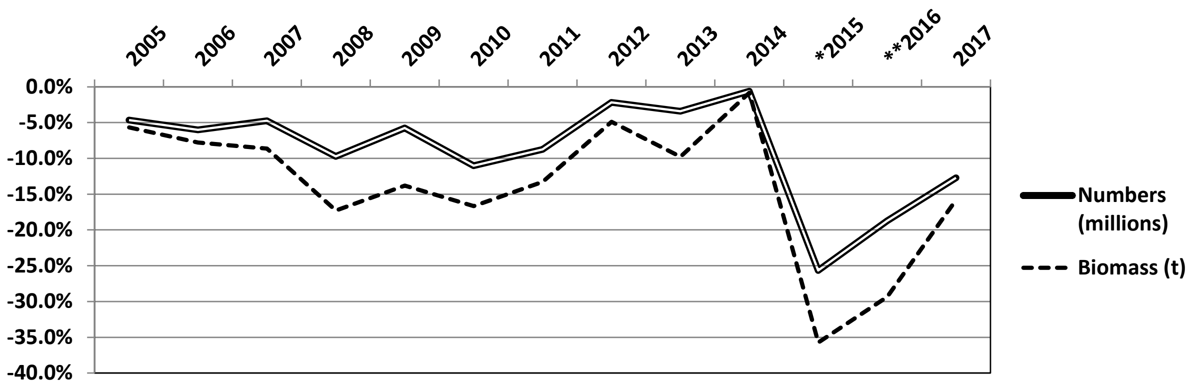


Figure 5: Relative changes in abundance and biomass of Western Baltic Spring Spawning herring in ICES Subdivisions 21-24 (2005-2017) after application of the stock separation function (SF, Gröhsler et al., 2013) to the abundance and biomass index generated from German acoustic survey data (GERAS). **2015= excl. CBH also in SD 22 and mature herring (stages ≥6) in SD 23;*
***2016= excl. CBH also in SD 22).*

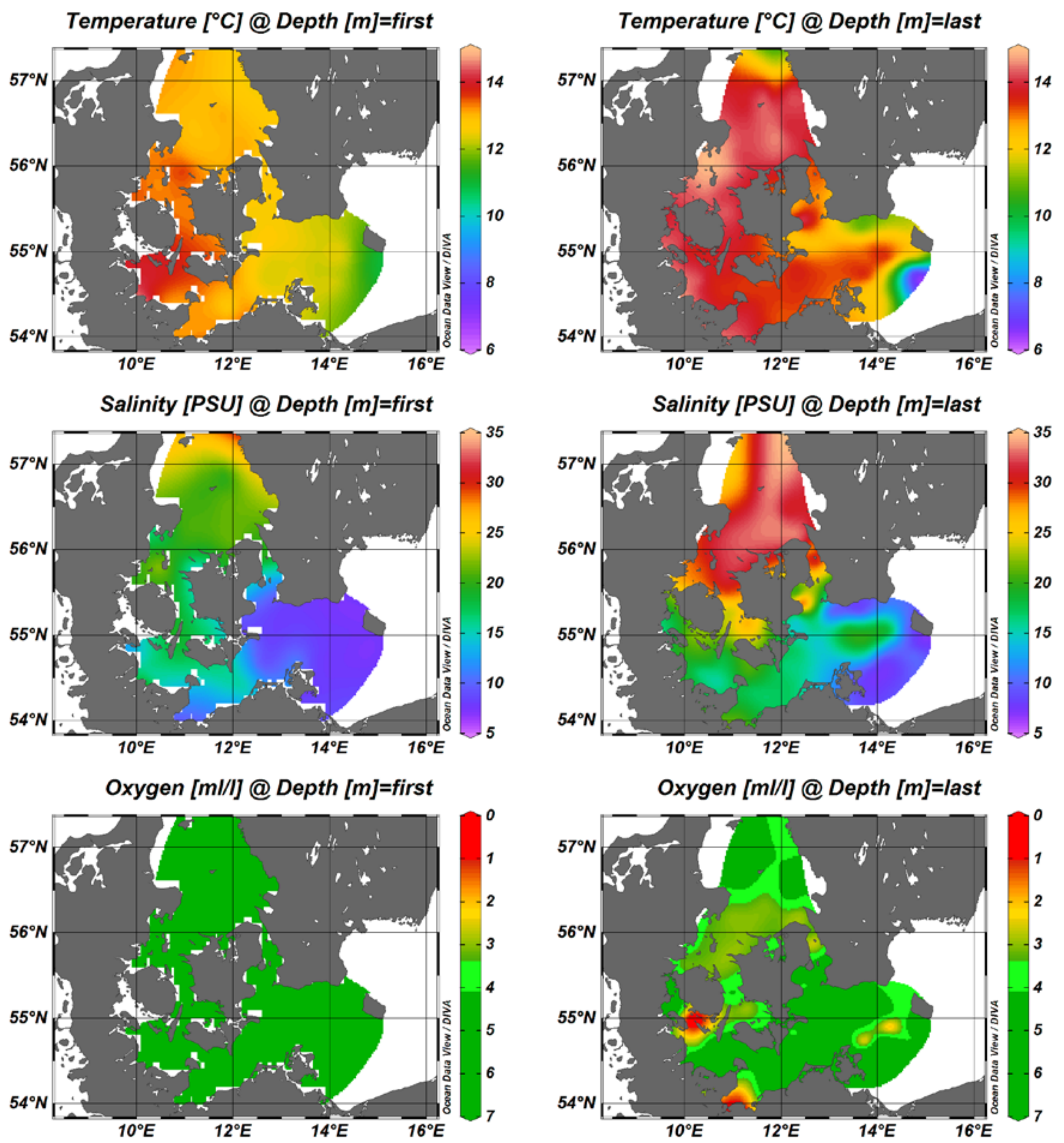


Figure 6: FRV Solea cruise 740/2017: Hydrography. CTD stations are depicted as blue dots in the area map (lower panel). Temperature (°C, top panels), salinity (PSU, middle panels and oxygen concentration (ml/l, lower panels) at the surface (left) and near the seafloor (right).

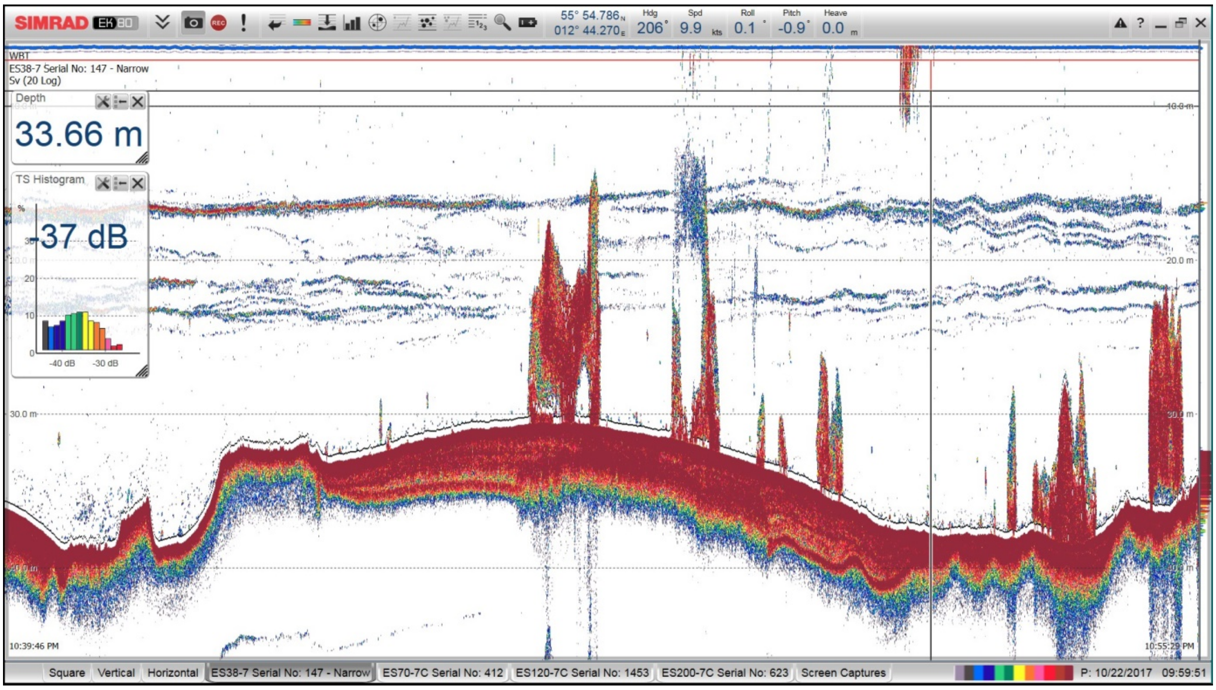


Figure 7: FRV Solea cruise 740/2017. Echosounder EK80 screenshot (38 kHz) of large clupeid schools measured during a day time sampling of the SD23 transect in the Sound for comparison with the virtually absent detections recorded during night time during two preceding recordings.

8 TABLES

Table 1: FRV Solea cruise 740/2017: Simrad EK80 calibration report (38 kHz Transducer).

Date:	04.10.2017		
Transceiver Type:	WBT		
Software Version:	EK80 1.10.3.0		
Reference Target:	Tungsten (WC-Co) 38.1 mm		
Transducer:	ES38-7 Serial No. 147		
Frequency:	38000 Hz	Beamtype:	Split/Narrow
Gain:	27.33 dB	Equivalent Beam Angle:	-20.7 dB
Beamwidth Athw.:	6.79 deg	Beamwidth Along.:	6.67 deg
Offset Athw.:	0.33 deg	Offset Along.:	-0.23 deg
Depth:	4.20 m		
Pulse Duration:	0.256 ms		
Power:	1000 W		
TS Detection:			
Min. Value:	-49.0 dB	Min. Spacing:	0.0
Max. Gain Comp.:	3.0 dB	Min. Echolength:	0.8
Max. Echolength:	1.8		
Environment:			
Absorption Coeff.:	0.005295	Sound Velocity:	1486.2 m/s
Calibration results:			
Transducer Gain:	27.41 dB	SaCorrection:	-0.30 dB
Beamwidth Athw.:	6.52 deg	Beamwidth Along.:	6.69 deg
Offset Athw.:	-0.30 deg	Offset Along.:	0.13 deg
RMS-Error:	0.08		

Table 2: FRV Solea cruise 740/2017: Catch composition (kg 0.5 h^{-1}) by haul in SD 21.

Haul No.	40	41	42	43	44	45	46	47	48	49	50	Total
Species / ICES Rectangle	**41G2**	**41G1**	**41G0**	**41G1**	**41G2**	**42G1**	**42G1**	**42G1**	**41G2**	**42G2**	**43G1**	
ALLOTEUTHIS SUBULATA						0.03				0.02	0.01	**0.06**
CANCER PAGURUS											0.47	**0.47**
CARCINUS											0.01	**0.01**
CLUPEA HARENGUS	0.19	139.22	2.06		8.41	77.54	8.10	10.79		0.42		**246.73**
CRANGON CRANGON											0.03	**0.03**
CRYSTALLOGOBIUS LINEARIS	+			+	+	+			+	+	+	**+**
CTENOLABRUS RUPESTRIS				+								**+**
ENGRAULIS ENCRASICOLUS						0.03			0.01	0.02		**0.06**
EUTRIGLA GURNARDUS						0.83		0.02		0.12	0.03	**1.00**
GASTEROSTEUS ACULEATUS				0.02								**0.02**
HIPPOGLOSSOIDES PLATESSOIDES										0.01		**0.01**
LEANDER											+	**+**
LIMANDA LIMANDA		0.24	0.44		0.20	1.29		0.22		0.08		**2.47**
LOLIGO FORBESI	0.04	0.01	0.07	0.07	0.01	0.22	0.01	0.09	0.01	0.17	0.12	**0.82**
MERLANGIUS MERLANGUS	0.06	0.84	0.03			0.74	+	0.10	0.05	0.67	0.02	**2.51**
MERLUCCIUS MERLUCCIUS						0.07						**0.07**
MYSIDACEA											+	**+**
NEPHROPS NORVEGICUS									0.57			**0.57**
PLEURONECTES PLATESSA											0.10	**0.10**
POMATOSCHISTUS MINUTUS			+	+		+					+	**+**
SARDINA PILCHARDUS	+	0.04			0.01				+			**0.05**
SCOMBER SCOMBRUS	2.50	7.16	0.05		1.12	0.37		5.16		0.14	9.68	**26.18**
SEPIOLA			+					0.00			0.04	**0.04**
SPRATTUS SPRATTUS	2.47	72.82	6.66		0.71	85.66	0.05	16.76	0.10	0.98		**186.21**
SYNGNATHUS TYPHLE	+											**+**
TRACHINUS DRACO		1.67	1.38	0.36	0.59	1.83	0.10	5.18		0.49	0.40	**12.00**
TRACHURUS TRACHURUS	0.06	0.27		+	+	0.01		0.02	0.01		0.01	**0.38**
TRISOPTERUS ESMARKI						+				0.01	+	**0.01**
Total	**5.32**	**222.27**	**10.69**	**0.45**	**11.05**	**168.62**	**8.26**	**38.34**	**0.75**	**3.13**	**10.92**	**479.80**
Medusae	1.19	0.22	0.75	6.45	0.91	0.15	33.90	6.20	2.29	1.51	3.01	56.59

+ = < 0.01 kg

Table 3: FRV Solea cruise 740/2017: 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	**39G1**	**39G0**	**39G0**	**40G1**	**41G0**	**40G0**	**40G0**	**40F9**	**39G0**	**38G0**	**38G0**	**37G0**	**38G1**
CLUPEA HARENGUS	0.72	10.47	0.38	1.24				11.28		0.68	0.65	0.31	0.24
CRANGON CRANGON						+							
CRYSTALLOGOBIUS LINEARIS	0.01		+		+	+					+		
CYCLOPTERUS LUMPUS			0.10										0.10
ENGRAULIS ENCRASICOLUS	+												
GASTEROSTEUS ACULEATUS	+			+			+	0.01	0.42	+		0.01	+
GOBIUS NIGER	+												0.02
LIMANDA LIMANDA		0.06	0.04		0.04						0.44	0.11	0.16
LOLIGO FORBESI	0.01		+	+	0.06	0.01							
MERLANGIUS MERLANGUS			+	0.07	0.01		+	+	+		0.29		+
MULLUS SURMULETUS			0.01	0.01									
PLATICHTHYS FLESUS													
POMATOSCHISTUS MINUTUS	+				+						0.01		
SCOMBER SCOMBRUS						11.80	0.31						
SOLEA VULGARIS						0.01							
SPRATTUS SPRATTUS	0.07	64.18	0.03	0.16		0.03	0.02	8.78		6.36	3.15	29.96	
SYNGNATHUS TYPHLE			+										
TRACHINUS DRACO			0.05	0.10	0.49								
TRACHURUS TRACHURUS		0.01	0.01	+	0.03	0.01	+	0.03	+				
TRISOPTERUS ESMARKI	+												
Total	**0.81**	**74.72**	**0.62**	**1.58**	**0.63**	**11.86**	**0.33**	**20.10**	**0.42**	**7.04**	**4.54**	**30.39**	**0.52**
Medusae	1.11	1.19	4.15	2.00	2.11	3.56	29.26	26.90	22.59	8.72	9.63	11.63	7.32

Haul No.	**14**	**15**	**16**	**Total**
Species / ICES Rectangle	**37G1**	**37G1**	**37G1**	
CLUPEA HARENGUS	2.00	3.31	1.10	**32.38**
CRANGON CRANGON				**+**
CRYSTALLOGOBIUS LINEARIS	0.01	+		**0.02**
CYCLOPTERUS LUMPUS				**0.20**
ENGRAULIS ENCRASICOLUS				**+**
GASTEROSTEUS ACULEATUS	0.01	0.05	0.02	**0.52**
GOBIUS NIGER				**0.02**
LIMANDA LIMANDA	0.19			**1.04**
LOLIGO FORBESI				**0.08**
MERLANGIUS MERLANGUS	0.14			**0.51**
MULLUS SURMULETUS				**0.02**
PLATICHTHYS FLESUS		0.15	0.23	**0.38**
POMATOSCHISTUS MINUTUS	+			**0.01**
SCOMBER SCOMBRUS				**12.11**
SOLEA VULGARIS				**0.01**
SPRATTUS SPRATTUS	56.18	0.40	338.71	**508.03**
SYNGNATHUS TYPHLE				**+**
TRACHINUS DRACO		0.07		**0.71**
TRACHURUS TRACHURUS				**0.09**
TRISOPTERUS ESMARKI				**+**
Total	**58.53**	**3.98**	**340.06**	**556.13**
Medusae	1.23	0.78	13.38	145.55

+ = < 0.01 kg

Table 4: FRV Solea cruise 740/2017: Catch composition (kg 0.5 h^{-1}) by haul in SD 23.

Haul No.	36	37	38	39	51	52	53	54	*55	*56	*57	Total
Species / ICES Rectangle	40G2	41G2	41G2	40G2	40G2	40G2	41G2	40G2	40G2	40G2	40G2	
ALLOTEUTHIS SUBULATA				0.04	0.01		0.01					**0.06**
CARCINUS					0.04							**0.04**
CLUPEA HARENGUS	0.54		1.42	1.19	1.49	0.34	0.77	12.74	858.51	22.53	30.87	**930.40**
CRANGON CRANGON	0.02				+	+						**0.02**
CRYSTALLOGOBIUS LINEARIS	+	+	+	+			+	+				**0.00**
CTENOLABRUS RUPESTRIS	0.03		+									**0.03**
ENGRAULIS ENCRASICOLUS							+	0.01				**0.01**
EUTRIGLA GURNARDUS	0.21		+	0.21				0.16				**0.58**
GADUS MORHUA	6.35		10.96	18.96	88.34	8.28	3.19	1.85		19.52	18.84	**176.29**
GASTEROSTEUS ACULEATUS	+						+	+				**0.00**
HIPPOGLOSSOIDES PLATESSOIDES					+							**0.00**
LIMANDA LIMANDA	0.50	0.05	0.09	0.06			0.87	0.40				**1.97**
LOLIGO FORBESI	0.07	0.05	0.02	0.02	0.02	0.15	0.18	0.01			+	**0.52**
MELANOGRAMMUS AEGLEFINUS	1.71					7.26						**8.97**
MERLANGIUS MERLANGUS	0.16	0.05	0.08		0.47		0.10	0.83			0.17	**1.86**
MULLUS SURMULETUS				+								**0.00**
MYSIDACEA	+											**0.00**
PLATICHTHYS FLESUS	0.22					0.47	0.51					**1.20**
POLLACHIUS POLLACHIUS								0.03				**0.03**
POMATOSCHISTUS MINUTUS	0.05	+	0.01	0.03		0.01		+				**0.10**
SCOMBER SCOMBRUS			0.62								0.69	**1.31**
SEPIOLA	0.03				+	0.04	0.03					**0.10**
SPRATTUS SPRATTUS	0.02	+	0.06	0.07	4.81	0.02	0.28	0.54	4.41	5.32		**15.53**
TRACHINUS DRACO	0.04	0.05	0.05		0.02	0.04	0.02	0.05				**0.27**
TRACHURUS TRACHURUS		+	+	0.01				0.01				**0.02**
Total	**9.95**	**0.20**	**13.31**	**20.59**	**95.20**	**16.61**	**5.96**	**16.63**	**862.92**	**47.37**	**50.57**	**1139.31**
Medusae	2.79	3.49	2.84	13.64	0.77	1.22	0.08	4.94	1.80	1.16	0.59	**33.32**

* = recording during daytime   + = < 0.01 kg

Table 5: FRV Solea cruise 740/2017: Catch composition (kg 0.5 h^{-1}) by haul in SD 24.

Haul No.	17	18	19	20	21	22	23	24	25	26	27	28	29
Species / ICES Rectangle	37G2	38G2	38G3	38G3	38G4	37G3	38G3	38G4	38G4	38G3	38G2	38G2	39G2
BELONE BELONE	0.03												
CLUPEA HARENGUS	0.81	4.10	7.14	23.12	25.78	45.10	22.37	21.11	17.89	11.85	55.40	4.51	12.08
CRYSTALLOGOBIUS LINEARIS		+							+				+
CYCLOPTERUS LUMPUS	0.27				0.30				0.41				
ENGRAULIS ENCRASICOLUS	+												
GADUS MORHUA				4.02	+	21.66	5.17	2.38	13.24	0.64			2.25
GASTEROSTEUS ACULEATUS	0.04	0.06	+		+					+	0.03	0.03	0.05
LAMPETRA FLUVIATILIS				0.16									
LIMANDA LIMANDA	0.30	0.01											
MERLANGIUS MERLANGUS	+			20.77		4.03	8.56		0.56	3.85		+	
OSMERUS EPERLANUS						0.01	0.01						
PLATICHTHYS FLESUS	1.08		0.46	0.62		0.41	0.59		2.02	0.16	0.58	0.99	
PLEURONECTES PLATESSA	0.17			0.46									
POMATOSCHISTUS MINUTUS	+	+	+	+	+				+	+	+	+	+
SPRATTUS SPRATTUS	0.05	1.59	14.87	40.22	2.01	6.85	11.15	46.40	7.49	42.34	1.62	3.79	0.83
TRACHURUS TRACHURUS													+
Total	**2.75**	**5.76**	**22.47**	**89.37**	**28.09**	**78.06**	**47.85**	**69.89**	**41.61**	**58.84**	**57.63**	**9.32**	**15.21**
Medusae	4.55	6.38	7.99	1.42	5.59	18.19	9.05	2.14	1.28	2.01	15.10	17.00	8.04

Haul No.	30	31	32	33	34	35	Total
Species / ICES Rectangle	39G3	39G3	39G4	39G4	39G3	39G2	
BELONE BELONE							**0.03**
CLUPEA HARENGUS	6.18	31.50	26.33	5.19	166.67	15.27	**502.40**
CRYSTALLOGOBIUS LINEARIS							**+**
CYCLOPTERUS LUMPUS			0.19				**1.17**
ENGRAULIS ENCRASICOLUS							**+**
GADUS MORHUA	0.00	1.46	+	0.54	11.92	4.08	**67.36**
GASTEROSTEUS ACULEATUS	0.11	0.04			0.04		**0.40**
LAMPETRA FLUVIATILIS							**0.16**
LIMANDA LIMANDA	0.03						**0.34**
MERLANGIUS MERLANGUS	0.16	1.54	6.88		6.48	0.16	**52.99**
OSMERUS EPERLANUS							**0.02**
PLATICHTHYS FLESUS	0.70	0.24	0.99	0.15	0.53	0.28	**9.80**
PLEURONECTES PLATESSA	0.85				0.20		**1.68**
POMATOSCHISTUS MINUTUS	0.01	+				0.01	**0.02**
SPRATTUS SPRATTUS	17.30	154.48	229.05	14.03	137.36	11.06	**742.49**
TRACHURUS TRACHURUS							**+**
Total	**25.34**	**189.26**	**263.44**	**19.91**	**323.20**	**30.86**	**1378.86**
Medusae	6.58	2.34	2.58	4.99	0.57	3.76	**119.54**

+ = < 0.01 kg

Table 6: FRV Solea, cruise 740/2017. 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	16.8	1.770	10.26	11.59	87.37	1.19	8.96
21	41G1	946.8	62.4	2.177	271.38	42.53	55.48	115.41	150.55
21	41G2	432.3	48.0	1.798	115.41	40.12	51.48	46.30	59.41
21	42G1	884.2	56.6	2.595	192.85	48.94	49.95	94.39	96.32
21	42G2	606.8	49.6	2.312	130.18	11.88	57.43	15.47	74.76
21	43G1	699.0	46.0	0.192	1674.69	0.00	0.00	0.00	0.00
21	43G2	107.0	39.2	1.112	37.72	5.94	28.71	2.24	10.83
21	**Total**	**3,784.2**			**2432.49**			**275.00**	**400.83**
22	37G0	209.9	117.2	1.445	170.24	0.74	98.98	1.26	168.51
22	37G1	723.3	127.4	1.257	733.08	27.30	70.10	200.10	513.85
22	38G0	735.3	90.1	1.626	407.44	9.14	86.15	37.23	351.02
22	38G1	173.2	37.2	2.362	27.28	70.00	0.00	19.10	0.00
22	39F9	159.3	29.7	1.215	38.94	18.17	31.45	7.07	12.25
22	39G0	201.7	76.2	0.944	162.81	4.22	45.76	6.88	74.50
22	39G1	250.0	56.9	1.021	139.32	27.78	9.72	38.70	13.55
22	40F9	51.3	254.1	2.077	62.76	36.33	62.90	22.80	39.47
22	40G0	538.1	36.2	0.474	410.95	0.00	10.48	0.00	43.05
22	40G1	174.5	26.2	2.444	18.71	71.43	16.07	13.36	3.01
22	41G0	173.1	22.4	0.472	82.15	0.00	0.00	0.00	0.00
22	**Total**	**3,389.7**			**2253.68**			**346.50**	**1219.21**
23	39G2	130.9	53.3	2.238	31.18	64.80	32.21	20.21	10.04
23	40G2	164.0	235.5	6.166	62.64	61.10	30.24	38.27	18.94
23	41G2	72.3	30.8	3.866	5.76	62.19	23.75	3.58	1.37
23	**Total**	**367.2**			**99.58**			**62.06**	**30.35**
24	37G2	192.4	31.4	1.289	46.87	59.21	6.58	27.75	3.08
24	37G3	167.7	509.5	3.635	235.06	39.12	54.60	91.97	128.35
24	37G4	875.1	103.7	3.055	297.05	35.50	62.75	105.46	186.41
24	38G2	832.9	128.6	1.289	830.96	64.30	33.53	534.31	278.60
24	38G3	865.7	341.3	1.902	1553.44	21.05	77.36	326.94	1201.72
24	38G4	1034.8	385.9	3.055	1307.13	35.50	62.75	464.08	820.28
24	39G2	406.1	203.4	2.238	369.08	64.80	32.21	239.17	118.89
24	39G3	765.0	355.1	1.902	1428.24	14.75	83.78	210.60	1196.55
24	39G4	524.8	668.9	1.737	2020.95	3.61	96.14	73.04	1942.95
24	**Total**	**5,664.5**			**8,088.78**			**2073.32**	**5876.83**
22-24	**Total**	**9,421.4**			**10,442.04**			**2481.88**	**7126.39**
21-24	**Total**	**13,205.6**			**12,874.53**			**2756.88**	**7527.22**

Table 7: FRV Solea, cruise 740/2017. 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	0.24	0.95								1.19
21	41G1	10.64	103.91	0.65	0.21						115.41
21	41G2	14.20	31.73	0.27	0.09	0.01					46.30
21	42G1	4.10	79.10	9.20	1.68	0.30					94.38
21	42G2	2.29	13.18								15.47
21	43G1										0.00
21	43G2	0.33	1.91								2.24
21	Total	31.80	230.78	10.12	1.98	0.31	0.00	0.00	0.00	0.00	274.99
22	37G0	1.00	0.25								1.25
22	37G1	188.33	11.32	0.22	0.19	0.04					200.10
22	38G0	18.32	18.61		0.31						37.24
22	38G1	0.00	18.21	0.55	0.34						19.10
22	39F9	1.62	5.05	0.22	0.13	0.04					7.06
22	39G0	4.57	2.11	0.12	0.07	0.01					6.88
22	39G1	10.47	22.21	4.68	1.13	0.22					38.71
22	40F9	5.23	16.30	0.72	0.42	0.14					22.81
22	40G0										0.00
22	40G1	4.47	8.40	0.25	0.21	0.04					13.37
22	41G0										0.00
22	Total	234.01	102.46	6.76	2.80	0.49	0.00	0.00	0.00	0.00	346.52
23	39G2	13.71	1.59	0.97	1.63	1.01	1.04	0.18	0.07	0.02	20.22
23	40G2	34.16	3.33	0.22	0.31	0.18	0.07				38.27
23	41G2	3.42	0.11	0.03	0.01						3.57
23	Total	51.29	5.03	1.22	1.95	1.19	1.11	0.18	0.07	0.02	62.06
24	37G2	22.20	2.48	0.55	0.89	0.89	0.67	0.07			27.75
24	37G3	16.62	4.45	13.76	20.01	22.01	9.31	3.32	1.78	0.71	91.97
24	37G4	20.65	5.92	13.08	19.81	26.02	13.01	4.96	1.36	0.67	105.48
24	38G2	459.90	28.42	5.04	16.33	11.68	11.55	1.39			534.31
24	38G3	168.28	24.98	30.55	40.44	30.91	23.20	4.83	2.43	1.33	326.95
24	38G4	90.86	26.04	57.55	87.19	114.48	57.24	21.81	5.97	2.95	464.09
24	39G2	162.21	18.77	11.52	19.29	11.94	12.28	2.09	0.83	0.24	239.17
24	39G3	67.57	23.00	23.85	36.93	31.78	19.76	4.85	1.73	1.13	210.60
24	39G4	2.86	3.89	12.82	18.93	19.78	9.35	2.88	1.94	0.59	73.04
24	Total	1,011.15	137.95	168.72	259.82	269.49	156.37	46.20	16.04	7.62	2,073.36
22-24	Total	1,296.45	245.44	176.70	264.57	271.17	157.48	46.38	16.11	7.64	2,481.94
21-24	Total	1,328.25	476.22	186.82	266.55	271.48	157.48	46.38	16.11	7.64	2,756.93

Table 8: FRV Solea, cruise 740/2017. 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	14.50	43.15								37.37
21	41G1	19.68	38.70	65.58	61.71						37.14
21	41G2	15.98	36.84	62.51	60.33	66.29					30.64
21	42G1	19.68	44.24	70.92	69.87	66.29					46.30
21	42G2	16.82	39.57								36.20
21	43G1										0.00
21	43G2	16.82	39.57								36.22
21	Total	17.75	40.42	70.35	68.57	66.29					39.13
22	37G0	15.10	33.84		38.83						18.85
22	37G1	10.49	40.03	45.27	38.83	48.32					12.23
22	38G0	15.26	35.74		38.83						25.69
22	38G1		39.28	45.27	38.83						39.44
22	39F9	18.67	40.40	54.40	55.46	48.32					36.17
22	39G0	17.40	38.85	59.08	46.30	48.32					25.04
22	39G1	17.59	38.82	62.92	56.21	48.32					36.55
22	40F9	18.67	40.40	54.40	55.46	48.32					36.19
22	40G0										0.00
22	40G1	16.15	38.68	60.38	43.14	48.32					31.65
22	41G0										0.00
22	Total	11.68	38.78	59.56	49.62	48.32					20.99
23	39G2	13.31	37.17	57.52	47.87	55.71	44.33	52.21	78.40	70.19	24.43
23	40G2	13.58	38.00	51.59	34.09	34.97	33.77				16.23
23	41G2	13.37	34.76	94.58	76.63	36.76	33.77				14.89
23	Total	13.49	37.67	57.36	45.83	52.57	43.66	52.21	78.40	70.19	18.82
24	37G2	11.77	37.57	48.48	42.63	39.54	38.41	40.21			17.40
24	37G3	8.23	40.02	71.93	84.73	105.66	81.07	106.34	91.56	82.33	72.36
24	37G4	11.28	39.27	69.39	85.42	116.95	110.39	127.88	91.37	78.25	79.21
24	38G2	8.98	36.27	41.26	35.80	36.71	38.88	43.85			12.90
24	38G3	9.04	37.88	65.66	60.91	70.91	57.28	73.78	84.58	74.19	34.00
24	38G4	11.28	39.27	69.39	85.42	116.95	110.39	127.88	91.37	78.25	79.21
24	39G2	13.31	37.17	57.52	47.87	55.71	44.33	52.21	78.40	70.19	24.43
24	39G3	11.26	37.54	66.32	66.22	82.33	61.33	84.72	88.27	79.18	48.11
24	39G4	10.82	37.67	75.98	84.62	107.16	87.81	112.66	87.45	88.23	85.44
24	Total	10.14	37.77	67.27	72.71	99.50	82.44	109.11	88.88	78.58	44.60
22-24	Total	10.55	38.19	66.91	72.27	99.20	82.16	108.89	88.84	78.56	40.66
21-24	Total	10.73	39.27	67.09	72.24	99.16	82.16	108.89	88.84	78.56	40.51

Table 9: FRV Solea, cruise 740/2017. 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	3.5	41.0								44.5
21	41G1	209.4	4,021.3	42.6	13.0						4,286.3
21	41G2	226.9	1,168.9	16.9	5.4	0.7					1,418.8
21	42G1	80.7	3,499.4	652.5	117.4	19.9					4,369.8
21	42G2	38.5	521.5								560.1
21	43G1										0.0
21	43G2	5.6	75.6								81.1
21	Total	564.6	9,327.7	712.0	135.8	20.6	0.0	0.0	0.0	0.0	10,760.6
22	37G0	15.1	8.5								23.6
22	37G1	1,975.6	453.1	10.0	7.4	1.9					2,448.0
22	38G0	279.6	665.1		12.0						956.7
22	38G1	0.0	715.3	24.9	13.2						753.4
22	39F9	30.3	204.0	12.0	7.2	1.9					255.4
22	39G0	79.5	82.0	7.1	3.2	0.5					172.3
22	39G1	184.2	862.2	294.5	63.5	10.6					1,415.0
22	40F9	97.6	658.5	39.2	23.3	6.8					825.4
22	40G0										0.0
22	40G1	72.2	324.9	15.1	9.1	1.9					423.2
22	41G0	0.0	0.0	0.0	0.0	0.0					0.0
22	Total	2,734.0	3,973.6	402.7	138.94	23.7	0.0	0.00	0.00	0.0	7,272.9
23	39G2	182.5	59.1	55.8	78.03	56.3	46.1	9.40	5.49	1.4	494.1
23	40G2	463.9	126.5	11.4	10.6	6.3	2.4				621.0
23	41G2	45.7	3.8	2.8	0.8						53.2
23	Total	692.1	189.5	70.0	89.4	62.6	48.5	9.4	5.5	1.4	1,168.2
24	37G2	261.3	93.2	26.7	37.9	35.2	25.7	2.8			482.8
24	37G3	136.8	178.1	989.8	1,695.5	2,325.6	754.8	353.1	163.0	58.5	6,654.9
24	37G4	232.9	232.5	907.6	1,692.2	3,043.0	1,436.2	634.3	124.3	52.4	8,355.4
24	38G2	4,129.9	1,030.8	208.0	584.6	428.8	449.1	61.0			6,892.0
24	38G3	1,521.3	946.2	2,005.9	2,463.2	2,191.8	1,328.9	356.4	205.5	98.7	11,117.9
24	38G4	1,024.9	1,022.6	3,993.4	7,447.8	13,388.4	6,318.7	2,789.1	545.5	230.8	36,761.2
24	39G2	2,159.0	697.7	662.6	923.4	665.2	544.4	109.1	65.1	16.9	5,843.3
24	39G3	760.8	863.4	1,581.7	2,445.5	2,616.5	1,211.9	410.9	152.7	89.5	10,132.9
24	39G4	31.0	146.5	974.1	1,601.9	2,119.6	821.0	324.5	169.7	52.1	6,240.2
24	Total	10,257.9	5,211.0	11,349.7	18,891.9	26,814.1	12,890.6	5,041.0	1,425.7	598.8	92,480.6
22-24	Total	13,684.0	9,374.1	11,822.4	19,120.2	26,900.3	12,939.1	5,050.4	1,431.2	600.2	100,921.7
21-24	Total	14,248.5	18,701.8	12,534.3	19,256.0	26,920.9	12,939.1	5,050.4	1,431.2	600.2	111,682.3

Table 10: FRV Solea, cruise 740/2017. Numbers (millions) of sprat by age and area.

Sub-division	Rectangle/ Age group	0	1	2	3	4	5	6	7	8+	Total
21	41G0	0.04	2.80	3.98	2.10	0.04					8.96
21	41G1	4.96	56.30	56.93	29.92	2.45					150.56
21	41G2	30.22	4.92	10.79	12.26	1.22					59.41
21	42G1	0.14	19.26	39.74	34.50	2.68					96.32
21	42G2	2.34	15.99	26.47	26.54	3.42					74.76
21	43G1										0.00
21	43G2	0.34	2.32	3.83	3.84	0.49					10.82
21	Total	38.04	101.59	141.74	109.16	10.30	0.00	0.00	0.00	0.00	400.83
22	37G0	1.60	131.76	13.57	19.22	0.60	1.59	0.18			168.52
22	37G1	215.28	213.26	31.73	46.97	2.08	4.01	0.52			513.85
22	38G0	2.33	221.40	43.40	73.82	4.08	4.56	1.42			351.01
22	38G1										0.00
22	39F9	0.33	6.63	1.93	3.03	0.12	0.19	0.01			12.24
22	39G0	8.26	42.59	8.78	12.98	0.61	1.05	0.22			74.49
22	39G1	7.57	3.86	0.00	1.15	0.97					13.55
22	40F9	1.08	21.37	6.22	9.77	0.39	0.62	0.02			39.47
22	40G0	16.14	6.83	3.91	15.19	0.98					43.05
22	40G1		0.78	0.59	1.50	0.09	0.03	0.03			3.02
22	41G0										0.00
22	Total	252.59	648.48	110.13	183.63	9.92	12.05	2.40	0.00	0.00	1,219.20
23	39G2	0.27	2.73	2.81	2.71	1.05	0.19	0.17	0.02	0.09	10.04
23	40G2	9.15	5.84	1.66	1.55	0.52	0.16	0.05	0.01		18.94
23	41G2	0.98	0.28	0.07	0.03	0.01					1.37
23	Total	10.40	8.85	4.54	4.29	1.58	0.35	0.22	0.03	0.09	30.35
24	37G2	1.23	0.73	0.47	0.50	0.06	0.03	0.03		0.03	3.08
24	37G3	63.72	55.75	4.64	3.42	0.55	0.14	0.11	0.01	0.02	128.36
24	37G4	0.85	70.47	46.06	46.07	15.84	2.83	2.54	0.20	1.53	186.39
24	38G2	183.63	63.40	14.10	13.13	2.65	0.65	0.65		0.39	278.60
24	38G3	198.23	715.35	124.48	123.53	25.97	6.08	5.50	0.29	2.29	1,201.72
24	38G4	3.73	310.10	202.70	202.73	69.72	12.47	11.20	0.89	6.74	820.28
24	39G2	3.21	32.28	33.30	32.14	12.43	2.28	1.96	0.20	1.09	118.89
24	39G3	7.81	588.02	249.17	247.73	63.67	15.74	15.01	0.78	8.62	1,196.55
24	39G4		1,082.39	364.24	360.24	83.24	21.13	20.77	0.18	10.76	1,942.95
24	Total	462.41	2,918.49	1,039.16	1,029.49	274.13	61.35	57.77	2.55	31.47	5,876.82
22-24	Total	725.40	3,575.82	1,153.83	1,217.41	285.63	73.75	60.39	2.58	31.56	7,126.37
21-24	Total	763.44	3,677.41	1,295.57	1,326.57	295.93	73.75	60.39	2.58	31.56	7,527.20

Table 11: FRV Solea, cruise 740/2017. 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	7.95	14.61	15.90	17.27	20.23					15.80
21	41G1	8.98	13.23	15.10	18.02	20.71					14.87
21	41G2	7.35	13.49	17.17	18.90	20.55					12.30
21	42G1	9.83	15.08	16.82	18.37	20.55					17.12
21	42G2	8.87	14.00	16.53	19.22	21.03					16.91
21	43G1										0.00
21	43G2	8.87	14.00	16.53	19.22	21.03					16.91
21	Total	7.68	13.77	16.07	18.55	20.77					15.49
22	37G0	7.85	13.56	15.94	16.02	18.16	15.96	19.85			14.02
22	37G1	6.10	13.83	16.06	16.46	18.34	16.51	20.02			11.02
22	38G0	6.71	13.93	16.57	17.12	18.96	16.51	21.32			15.00
22	38G1										0.00
22	39F9	4.73	14.78	16.11	16.64	17.30	15.74	19.65			15.22
22	39G0	5.37	14.20	16.25	16.81	18.27	16.49	21.41			14.00
22	39G1	4.78	12.16	0.00	23.66	25.50					9.97
22	40F9	4.73	14.78	16.11	16.64	17.30	15.74	19.65			15.22
22	40G0	3.46	15.08	17.75	17.62	17.75					11.92
22	40G1	0.00	15.73	17.98	17.74	18.10	16.70	19.65			17.29
22	41G0										0.00
22	Total	5.88	13.88	16.34	16.87	19.17	16.38	20.89			12.98
23	39G2	6.8	13.11	16.29	16.48	17.58	16.77	16.33	19.67	15.9	15.37
23	40G2	5.69	12.61	14.63	18.07	18.77	22.77	21.58	26.09		10.18
23	41G2	5.01	11.89	13.14	16.12	15.97					7.15
23	Total	5.65	12.74	15.63	17.05	17.96	19.51	17.52	21.81	15.90	11.76
24	37G2	4.25	12.90	15.22	14.78	15.90	14.60	14.60	0.00	15.90	10.23
24	37G3	5.68	10.92	12.34	13.35	16.29	16.28	15.35	19.67	15.90	8.47
24	37G4	5.17	12.87	16.05	16.10	17.32	16.58	16.28	19.67	15.90	14.93
24	38G2	4.53	12.02	14.55	14.46	15.69	15.47	15.47		15.90	7.38
24	38G3	5.13	11.74	14.26	14.50	16.58	15.92	15.52	19.67	15.90	11.35
24	38G4	5.17	12.87	16.05	16.10	17.32	16.58	16.28	19.67	15.90	14.93
24	39G2	6.80	13.11	16.29	16.48	17.58	16.77	16.33	19.67	15.90	15.37
24	39G3	5.66	12.58	15.41	15.35	16.74	15.92	15.80	19.67	15.90	14.03
24	39G4		12.49	15.24	14.97	16.25	15.62	15.55	19.67	15.90	13.71
24	Total	4.99	12.34	15.37	15.31	16.78	16.01	15.81	19.67	15.90	13.12
22-24	Total	5.31	12.62	15.46	15.55	16.87	16.09	16.02	19.69	15.90	13.09
21-24	Total	5.42	12.65	15.53	15.80	17.01	16.09	16.02	19.69	15.90	13.22

Table 12: FRV Solea, cruise 740/2017. 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	0.3	40.9	63.3	36.3	0.8					141.6
21	41G1	44.5	744.9	859.6	539.2	50.7					2,238.9
21	41G2	222.1	66.4	185.3	231.7	25.1					730.5
21	42G1	1.4	290.4	668.4	633.8	55.1					1,649.1
21	42G2	20.8	223.9	437.6	510.1	71.9					1,264.2
21	43G1										0.0
21	43G2	3.0	32.5	63.3	73.8	10.3					182.9
21	Total	292.1	1,398.9	2,277.5	2,024.8	213.9	0.0	0.0	0.0	0.0	6,207.2
22	37G0	12.6	1,786.7	216.3	307.9	10.9	25.4	3.6			2,363.3
22	37G1	1,313.2	2,949.4	509.6	773.1	38.2	66.2	10.4			5,660.1
22	38G0	15.6	3,084.1	719.1	1,263.8	77.4	75.3	30.3			5,265.6
22	38G1										0.0
22	39F9	1.6	98.0	31.1	50.4	2.1	3.0	0.2			186.3
22	39G0	44.4	604.8	142.7	218.2	11.1	17.3	4.7			1,043.2
22	39G1	36.2	46.9	0.0	27.2	24.7					135.1
22	40F9	5.1	315.9	100.2	162.6	6.8	9.8	0.4			600.6
22	40G0	55.8	103.0	69.4	267.7	17.4					513.3
22	40G1		12.3	10.6	26.6	1.6	0.5	0.6			52.2
22	41G0										0.0
22	Total	1,484.5	9,001.0	1,799.0	3,097.5	190.2	197.4	50.1	0.0	0.0	15,819.7
23	39G2	1.8	35.8	45.8	44.7	18.5	3.2	2.8	0.4	1.4	154.3
23	40G2	52.1	73.6	24.3	28.0	9.8	3.6	1.1	0.3		192.7
23	41G2	4.9	3.3	0.9	0.5	0.2					9.8
23	Total	58.8	112.8	71.0	73.2	28.4	6.8	3.9	0.7	1.4	356.9
24	37G2	5.2	9.4	7.2	7.4	1.0	0.4	0.4		0.5	31.5
24	37G3	361.9	608.8	57.3	45.7	9.0	2.3	1.7	0.2	0.3	1,087.1
24	37G4	4.4	907.0	739.3	741.7	274.4	46.9	41.4	3.9	24.3	2,783.2
24	38G2	831.8	762.1	205.2	189.9	41.6	10.1	10.1		6.2	2,056.8
24	38G3	1,016.9	8,398.2	1,775.1	1,791.2	430.6	96.8	85.4	5.7	36.4	13,636.2
24	38G4	19.3	3,991.0	3,253.3	3,264.0	1,207.6	206.8	182.3	17.5	107.2	12,248.9
24	39G2	21.8	423.2	542.5	529.7	218.5	38.2	32.0	3.9	17.3	1,827.2
24	39G3	44.2	7,397.3	3,839.7	3,802.7	1,065.8	250.6	237.2	15.3	137.1	16,789.8
24	39G4		13,519.1	5,551.0	5,392.8	1,352.7	330.1	323.0	3.5	171.1	26,643.2
24	Total	2,305.6	36,016.0	15,970.4	15,764.9	4,601.0	982.1	913.4	50.2	500.4	77,103.9
22-24	Total	3,848.9	45,129.7	17,840.4	18,935.5	4,819.5	1,186.4	967.4	50.8	501.8	93,280.4
21-24	Total	4,141.0	46,528.6	20,117.9	20,960.3	5,033.4	1,186.4	967.4	50.8	501.8	99,487.7

Table 13: FRV Solea, cruise 740/2017. Numbers (m) of herring excl. CBH by age/W-rings and area.

Sub-division	Rectangle/ W-rings	0	1	2	3	4	5	6	7	8+	Total	
21	41G0	0.24	0.95								1.19	
21	41G1	10.64	103.91	0.65	0.21						115.41	
21	41G2	14.20	31.73	0.27	0.09	0.01					46.30	
21	42G1	4.10	79.10	9.20	1.68	0.30					94.38	
21	42G2	2.29	13.18								15.47	
21	43G1										0.00	
21	43G2	0.33	1.91								2.24	
21	Total	31.80	230.78	10.12	1.98	0.31	0.00	0.00	0.00	0.00	274.99	
22	37G0	1.00	0.25								1.25	
22	37G1	188.33	11.32	0.22	0.19	0.04					200.10	
22	38G0	18.32	18.61		0.31						37.24	
22	38G1	0.00	18.21	0.55	0.34						19.10	
22	39F9	1.62	5.05	0.22	0.13	0.04					7.06	
22	39G0	4.57	2.11	0.12	0.07	0.01					6.88	
22	39G1	10.47	22.21	4.68	1.13	0.22					38.71	
22	40F9	5.23	16.30	0.72	0.42	0.14					22.81	
22	40G0										0.00	
22	40G1	4.47	8.40	0.25	0.21	0.04					13.37	
22	41G0										0.00	
22	Total	234.01	102.46	6.76	2.80	0.49	0.00	0.00	0.00	0.00	346.52	
23	39G2	13.71	1.59	0.76	0.33	0.23	0.03	0.01			16.66	excl. CBH
23	40G2	34.16	3.33	0.22	0.31	0.18	0.07				38.27	
23	41G2	3.42	0.11	0.03	0.01						3.57	
23	Total	51.29	5.03	1.01	0.65	0.41	0.10	0.01	0.00	0.00	58.50	
24	37G2	22.20	2.48	0.25	0.22	0.00	0.00	0.00	0.00	0.00	25.15	
24	37G3	16.62	4.45	13.31	14.71	16.65	3.86	2.02	0.37	0.28	72.27	
24	37G4	20.65	5.92	12.37	14.37	20.46	7.49	3.66	0.26	0.19	85.37	
24	38G2	459.90	28.42	2.33	0.15	0.00	0.00	0.00	0.00	0.00	490.80	
24	38G3	168.28	24.98	27.86	18.04	11.88	3.86	1.17	0.27	0.25	256.59	excl. CBH
24	38G4	90.86	26.04	54.45	63.22	90.02	32.96	16.10	1.16	0.84	375.65	
24	39G2	162.21	18.77	9.02	3.90	2.71	0.40	0.16	0.02	0.02	197.21	
24	39G3	67.57	23.00	21.20	18.01	15.98	4.17	1.87	0.36	0.36	152.52	
24	39G4	2.86	3.89	12.36	14.26	15.70	5.06	1.92	0.32	0.32	56.69	
24	Total	1,011.15	137.95	153.15	146.88	173.40	57.80	26.90	2.76	2.26	1,712.25	
22-24	Total	1,296.45	245.44	160.92	150.33	174.30	57.90	26.91	2.76	2.26	2,117.27	
21-24	Total	1,328.25	476.22	171.04	152.31	174.61	57.90	26.91	2.76	2.26	2,392.26	

Table 14: FRV Solea, cruise 740/2017. Mean weight (g) of herring excl. CBH by age/W-rings and area.

Sub-division	Rectangle/ W-rings	0	1	2	3	4	5	6	7	8+	Total	
21	41G0	14.50	43.15								37.37	
21	41G1	19.68	38.70	65.58	61.71						37.14	
21	41G2	15.98	36.84	62.51	60.33	66.29					30.64	
21	42G1	19.68	44.24	70.92	69.87	66.29					46.30	
21	42G2	16.82	39.57								36.20	
21	43G1										0.00	
21	43G2	16.82	39.57								36.22	
21	Total	17.75	40.42	70.35	68.57	66.29					39.13	
22	37G0	15.10	33.84		38.83						18.85	
22	37G1	10.49	40.03	45.27	38.83	48.32					12.23	
22	38G0	15.26	35.74		38.83						25.69	
22	38G1		39.28	45.27	38.83						39.44	
22	39F9	18.67	40.40	54.40	55.46	48.32					36.17	
22	39G0	17.40	38.85	59.08	46.30	48.32					25.04	
22	39G1	17.59	38.82	62.92	56.21	48.32					36.55	
22	40F9	18.67	40.40	54.40	55.46	48.32					36.19	
22	40G0										0.00	
22	40G1	16.15	38.68	60.38	43.14	48.32					31.65	
22	41G0										0.00	
22	Total	11.68	38.78	59.56	49.62	48.32					20.99	
23	39G2	13.10	37.80	64.34	82.12	96.88	99.95	121.96	106.38	106.38	20.54	excl. CBH
23	40G2	13.58	38.00	51.59	34.09	34.97	33.77				16.23	
23	41G2	13.37	34.76	94.58	76.63	36.76	33.77				14.89	
23	Total	13.44	37.87	62.46	59.13	69.70	53.62	121.96			17.38	
24	37G2	11.54	38.09	60.15	60.15						15.07	
24	37G3	7.97	40.75	73.56	97.72	122.05	124.91	138.27	127.52	106.38	77.50	
24	37G4	10.97	39.98	71.73	99.92	133.66	155.62	152.98	130.43	106.38	85.52	
24	38G2	8.73	36.80	47.43	60.15						10.55	
24	38G3	8.76	38.53	68.94	83.41	107.91	112.29	140.99	114.30	106.38	30.40	excl. CBH
24	38G4	10.97	39.98	71.73	99.92	133.66	155.62	152.98	130.43	106.38	85.52	
24	39G2	13.10	37.80	64.34	82.12	96.88	99.95	121.96	106.38	106.37	20.59	
24	39G3	11.00	38.13	70.45	91.79	117.73	118.83	137.50	106.37	106.37	49.03	
24	39G4	10.57	38.34	77.33	96.84	120.76	120.09	140.05	106.38	106.38	94.49	
24	Total	9.89	38.40	70.83	95.80	127.57	144.53	149.17	122.36	106.38	43.97	
22-24	Total	10.35	38.55	70.31	94.78	127.21	144.37	149.16	122.36	106.38	39.47	
21-24	Total	10.53	39.46	70.31	94.44	127.10	144.37	149.16	122.36	106.38	39.43	

Table 15: FRV Solea, cruise 740/2017. Total biomass (t) of herring excl. CBH herring by age/W-rings and area.

Sub-division	Rectangle/ W-rings	0	1	2	3	4	5	6	7	8+	Total	
21	41G0	3.5	41.0								44.5	
21	41G1	209.4	4,021.3	42.6	13.0						4,286.3	
21	41G2	226.9	1,168.9	16.9	5.4	0.7					1,418.8	
21	42G1	80.7	3,499.4	652.5	117.4	19.9					4,369.8	
21	42G2	38.5	521.5								560.1	
21	43G1										0.0	
21	43G2	5.6	75.6								81.1	
21	Total	564.6	9,327.7	712.0	135.8	20.6	0.0	0.0	0.0	0.0	10,760.6	
22	37G0	15.1	8.5								23.6	
22	37G1	1,975.6	453.1	10.0	7.4	1.9					2,448.0	
22	38G0	279.6	665.1		12.0						956.7	
22	38G1	0.0	715.3	24.9	13.2						753.4	
22	39F9	30.3	204.0	12.0	7.2	1.9					255.4	
22	39G0	79.5	82.0	7.1	3.2	0.5					172.3	
22	39G1	184.2	862.2	294.5	63.5	10.6					1,415.0	
22	40F9	97.6	658.5	39.2	23.3	6.8					825.4	
22	40G0										0.0	
22	40G1	72.2	324.9	15.1	9.1	1.9					423.2	
22	41G0	0.0	0.0	0.0	0.0	0.0					0.0	
22	Total	2,734.0	3,973.6	402.7	138.94	23.7	0.0	0.00	0.00	0.0	7,272.9	
23	39G2	179.6	60.1	48.9	27.10	22.3	3.0	1.22	0.00	0.0	342.2	excl. CBH
23	40G2	463.9	126.5	11.4	10.6	6.3	2.4				621.0	
23	41G2	45.7	3.8	2.8	0.8						53.2	
23	Total	689.2	190.5	63.1	38.4	28.6	5.4	1.2	0.0	0.0	1,016.4	
24	37G2	256.2	94.5	15.0	13.2	0.0	0.0	0.0	0.0	0.0	378.9	
24	37G3	132.5	181.3	979.1	1,437.5	2,032.1	482.2	279.3	47.2	29.8	5,600.9	
24	37G4	226.5	236.7	887.3	1,435.9	2,734.7	1,165.6	559.9	33.9	20.2	7,300.7	
24	38G2	4,014.9	1,045.9	110.5	9.0	0.0	0.0	0.0	0.0	0.0	5,180.3	
24	38G3	1,474.1	962.5	1,920.7	1,504.7	1,282.0	433.4	165.0	30.9	26.6	7,799.8	excl. CBH
24	38G4	996.7	1,041.1	3,905.7	6,316.9	12,032.1	5,129.2	2,463.0	151.3	89.4	32,125.4	
24	39G2	2,125.0	709.5	580.4	320.3	262.5	40.0	19.5	2.1	2.1	4,061.4	
24	39G3	743.3	877.0	1,493.5	1,653.1	1,881.3	495.5	257.1	38.3	38.3	7,477.5	
24	39G4	30.2	149.1	955.8	1,380.9	1,895.9	607.7	268.9	34.0	34.0	5,356.7	
24	Total	9,999.4	5,297.5	10,848.0	14,071.6	22,120.7	8,353.6	4,012.7	337.7	240.4	75,281.6	
22-24	Total	13,422.7	9,461.6	11,313.7	14,249.0	22,172.9	8,358.9	4,013.9	337.7	240.4	83,570.8	
21-24	Total	13,987.2	18,789.4	12,025.7	14,384.7	22,193.4	8,358.9	4,013.9	337.7	240.4	94,331.4	

Annex 6b: ISAS survey report 2017

Survey Summary table

Name of the survey (abbreviation):	ISAS

Summary:

The vessel departed Belfast at 2100 on the 29th August and proceeded to the east coast of the Isle of Man for acoustic calibration off Laxey on the 30th August. The survey started on the peripheral Irish Sea transects to the west of the Solway Firth at 05:30 on the 31st August. Phase one of the survey ended on transect 94 on 07th Sept at which time a mid-survey break in Belfast was required to facilitate staff and crew changes.

The survey recommenced on 10th September and concluded on the 17th September during which, 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 Rig Bank were conducted on 06th September.

Sea conditions were reasonably good during the survey; particularly poor weather between the 01st and 02nd September resulted in a temporary cessation of the survey.

The herring were fairly widely distributed within mixed schools at low abundance, with a few distinct high abundance areas. The largest herring aggregations were found northwest of the Isle of Man and off the Northern Ireland coast.

	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	NA Sea conditions were reasonably good during the survey; particularly poor weather between the 01st and 02nd 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 38 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 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.

ANNEX 6B: Irish Sea acoustic survey (Northern Ireland)

Survey report for RV Corystes

29th August – 15th September 2016

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
William Clarke
Victoria Poppleton
Donal Griffin
Adam Butler
Tim Whitton
Suzanne Beck

2.2 Narrative

The vessel departed Belfast at 2100 on the 29th August and proceeded to the east coast of the Isle of Man for acoustic calibration off Laxey on the 30th August. The survey started on the peripheral Irish Sea transects to the west of the Solway Firth at 05:30 on the 31st August and continued to the completion of transect 101 to the north of Angelsey on the 1st September. A short steam to the northeast of the Isle of Man saw the survey recommence at the start of transect 1 on the 02nd Sept and end on transect 63 to the northwest of the Isle of Man on 05th 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. c. Phase one of the survey ended on transect 94 on 07th Sept at which time a mid-survey break in Belfast was required to facilitate staff and crew changes.

The survey recommenced on 10th September and concluded on the 17th 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 01st and 02nd September resulted in a temporary cessation of the survey.

Survey design

The survey design of systematic, parallel transects covers approximately 620 nm (Figure 6B.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 30th 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 6B.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 6B.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 6B.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 2016 survey with 38 successful trawls completed. Table 6B.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 6B.2. 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 $W = 0.00298*L^{3.321}$ (length measured in cm). The preliminary age length key (Table 6B.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 6B.3 and for herring only in Figure 6B.4. The highest abundance of herring was north west 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 6B.4. The total number estimate comprises of ~46% age 0, ~7% age 1, ~24% age 2, ~14% age 3, ~6% age 4 and 3% age 5+.

4. DISCUSSION

The herring stock estimate in the survey area (Irish Sea/North Channel) was estimated to be 107,762t 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 2016 were observed northwest 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 6B.1&4), with a fairly scattered lower abundance observed throughout the Irish Sea (Figure 6B.4). The length frequencies generated from these trawls highlight the spatial heterogeneous nature of herring age groups in the Irish Sea (Figure 6B.2). The estimate of herring SSB of 91,331t is the second highest observed during the time series whilst the biomass estimate of 102,839t for 1+ ringers for 2016 is the highest observed since 2011 and significantly higher than the 2015 estimates. The survey estimates are influenced by the timing of the spawning migration. The highest proportion of the 1+ biomass estimates was to the northwest of the Isle of Man (strata 5, 33%) and off the Irish coast (strata 3; 28%), 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 northeast. The biomass estimate for sprat and 0-group herring is similar to that observed in 2015 but a significant decrease of the 0-gp herring component was observed.

5 TABLES AND FIGURES

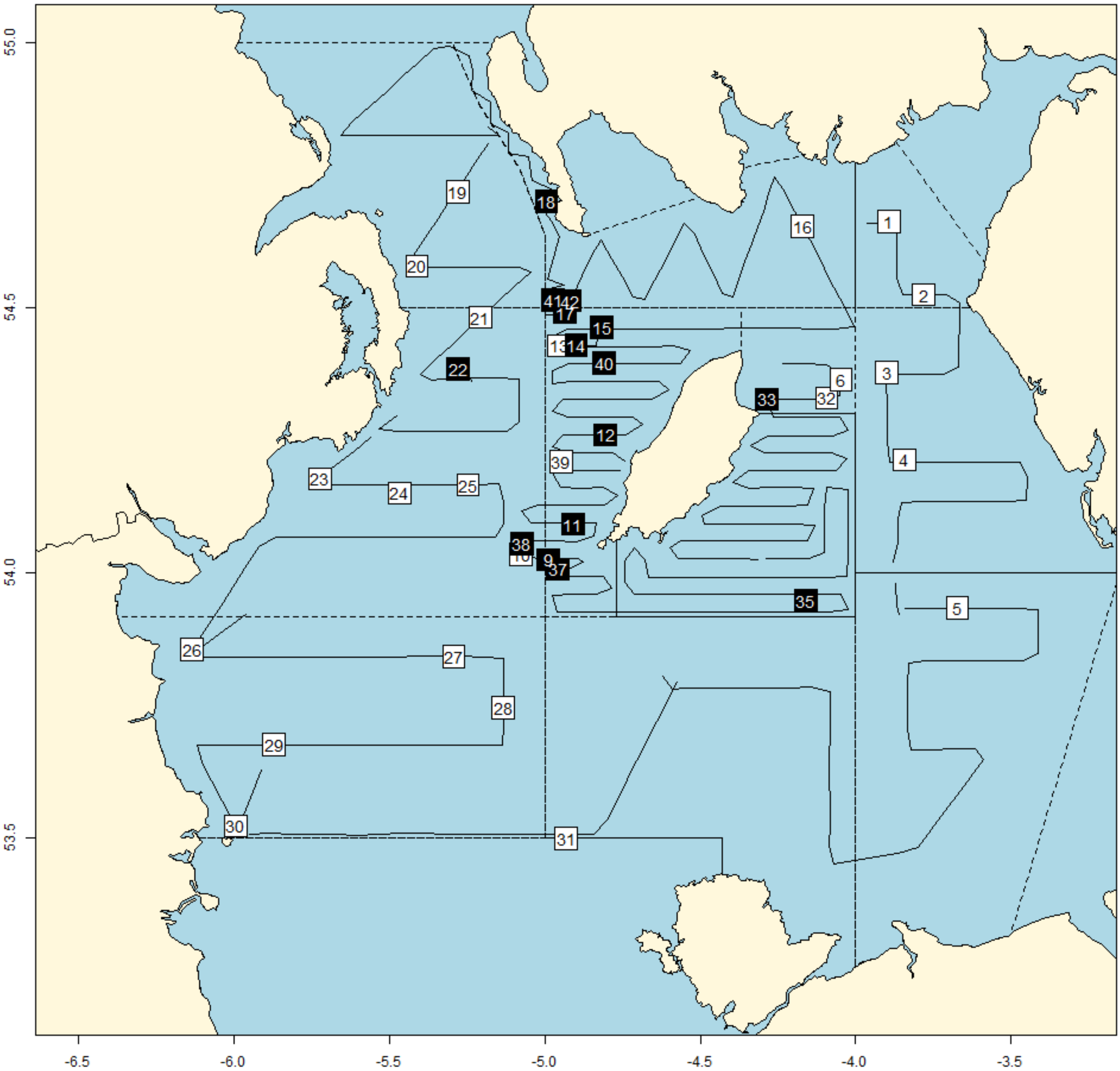
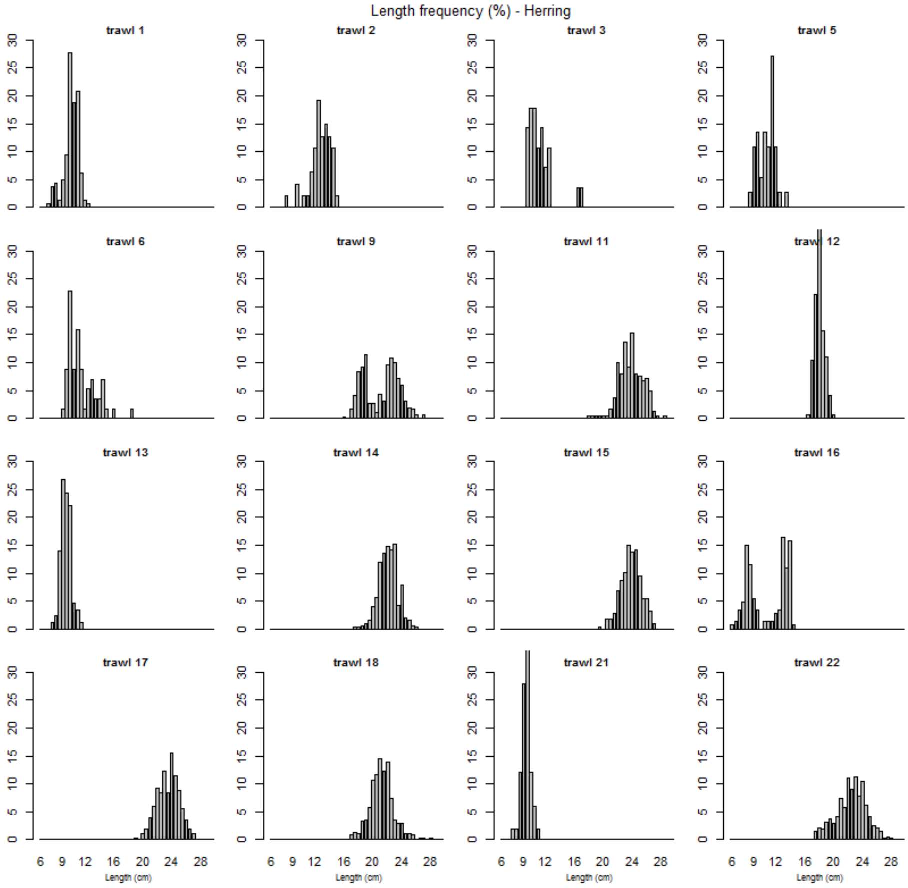


Figure 6B.1: Acoustic survey tracks with trawl positions of the 2016 Irish Sea and North Channel survey on RV "Corystes". Filled squares indicate trawls in which significant numbers of herring were caught or trawls with a high proportion of herring, while open squares indicate trawls with few or no herring.



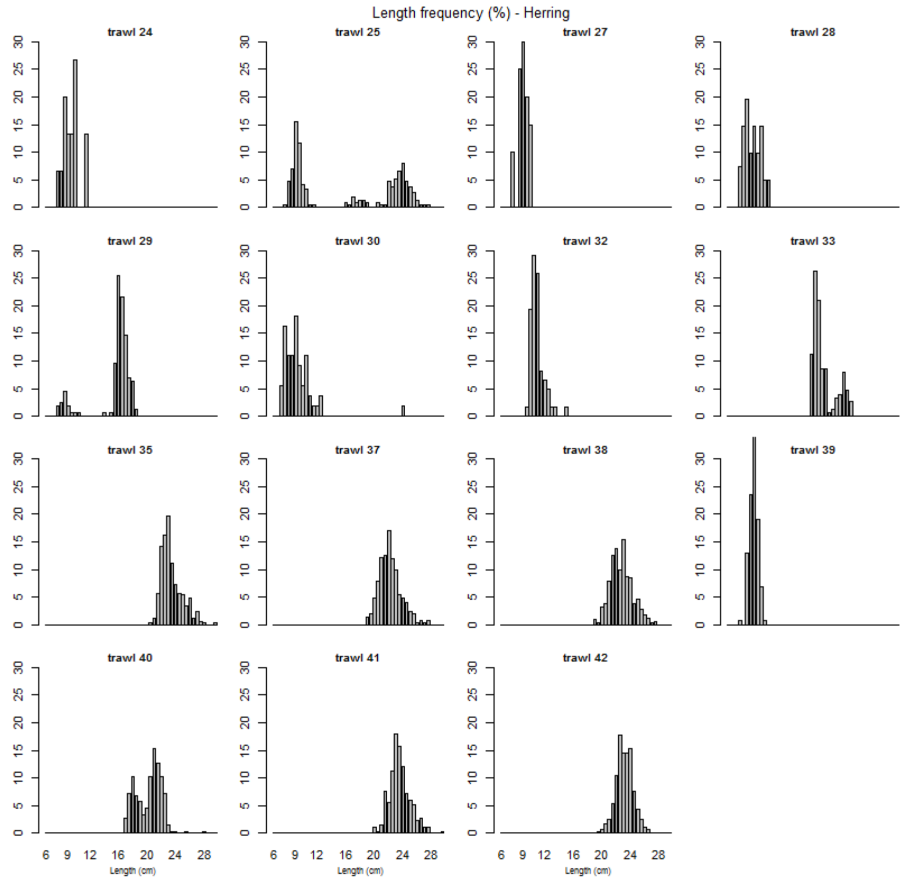


Figure 6B.2: Percentage length compositions of herring in each trawl sample in the September 2016 Irish Sea and North Channel acoustic survey on RV "Corystes".

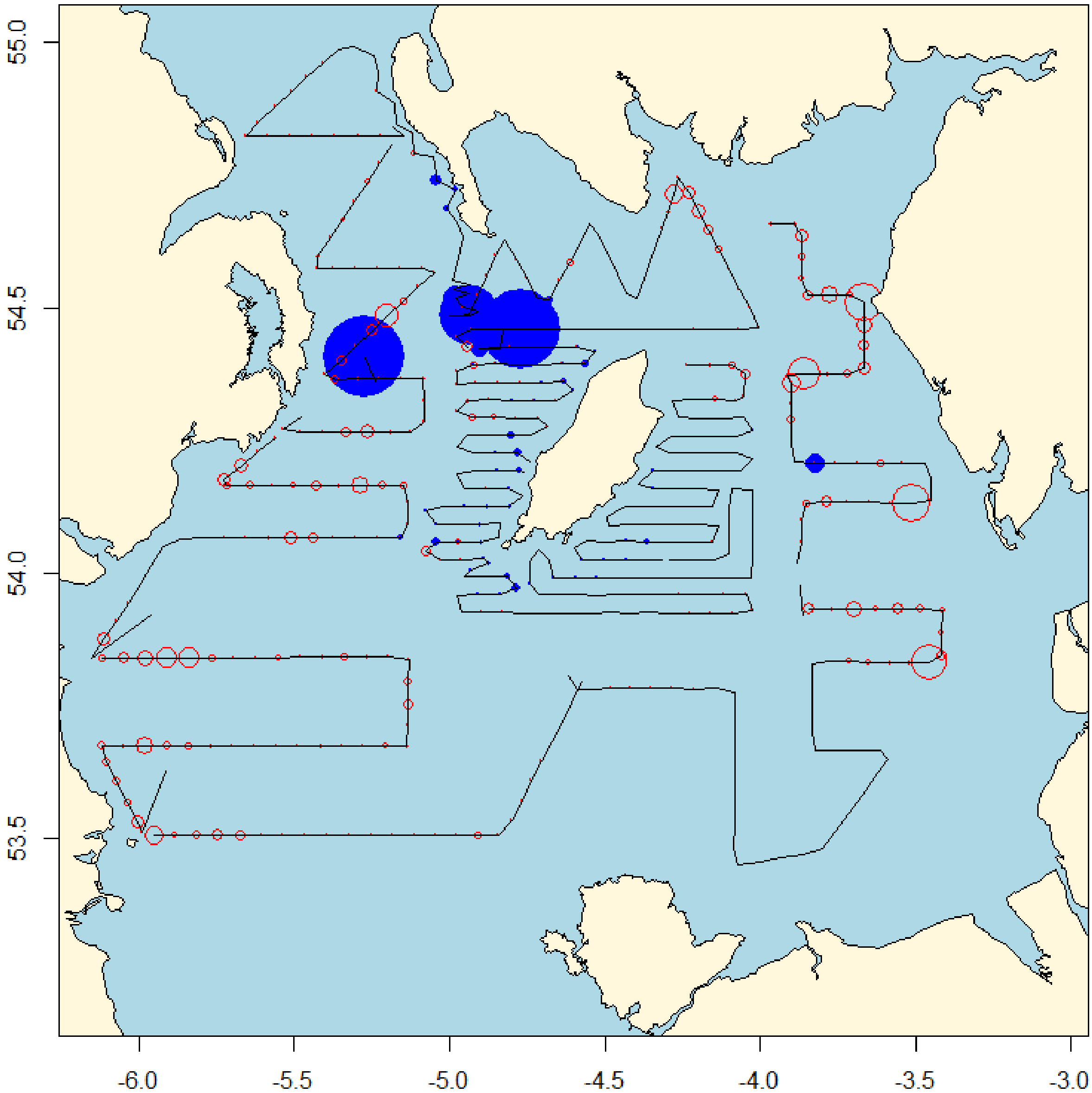


Figure 6B.3: Map of the Irish Sea and North Channel with a post plot showing the distribution of NASC values (size of elipses is proportional to square root of the NASC value per 15-minute interval) obtained during the 2016 acoustic survey on RV "Corystes". (a) Solid circles are for herring NASC values (maximum value was 15675) and (b) open circles are for clupeoid mix NASC, which include juvenile herring and sprat (maximum value was 7355).

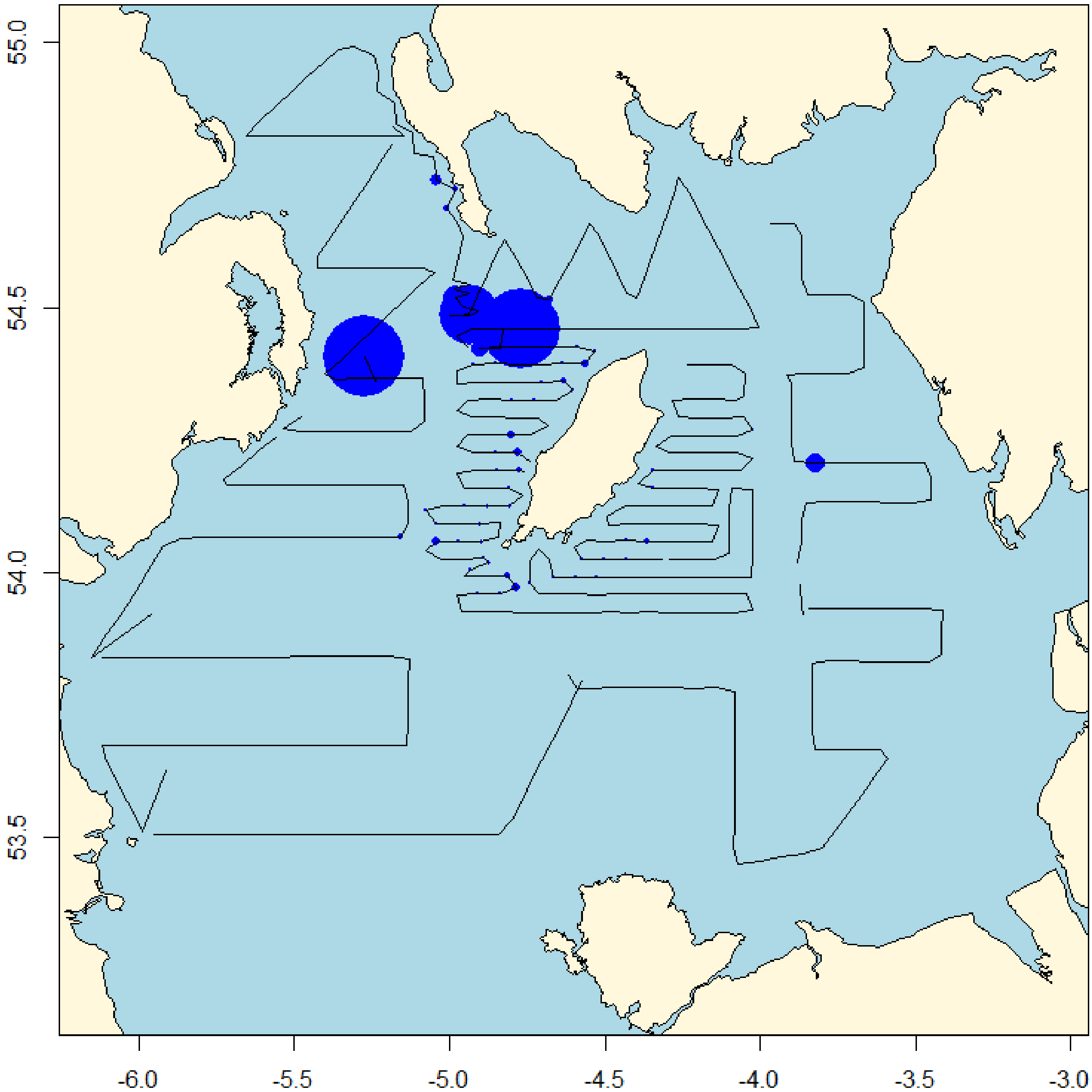


Figure 7B.4: Map of the Irish Sea and North Channel with a post plot showing the distribution of NASC values for assigned herring only (size of ellipses is proportional to square root of the NASC value per 15-minute interval) obtained during the 2016 acoustic survey on RV "Corystes" (maximum value was 15675).

Table 6B.1: Simrad EK60 and analysis settings used on the 2015 and 2016 Irish Sea and North Channel herring acoustic survey on RV "Corystes"

TRANSCEIVER MENU		
Year	2015	2016
Frequency	38 kHz	38 kHz
Sound speed	1510.1m.s^{-1}	1513.3.s^{-1}
Max. Power	2000 W	2000 W
Default Transducer Sv gain	24.80 dB	24.86 dB
Athw. Beam Angle	6.88 deg	6.89 deg
Athw. Offset Angle	0.05 deg	0.04 deg
Along. Beam Angle	6.96 deg	6.97 deg
Along. Offset Angle	0.11 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 6B.2: Catch composition and position of hauls undertaken by the RV *Corystes* during the Irish Sea/North Channel survey, August/September 2016.

Tow	Date	Shooting details						Total fish	percentage composition of fish by weight							Mean length (cm)	
		Time	Lat.		Long.		depth (m)	catch kg.	sprat	herring	mackerel	scad	anchovy	whiting	other fish	sprat	herring
1	31/08/2016	07:15	54	39.69	3	53.58	25	10	66.3	15.56	18.14	0	0	0	0	5	10
2	31/08/2016	09:34	54	31.44	3	46.9	23	131	84.41	1.43	14.16	0	0	0	0	10.5	12.5
3	31/08/2016	11:55	54	22.61	3	53.96	41	438	98.62	0.32	1.01	0	0	0.15	0.06	9.5	10.5
4	31/08/2016	14:57	54	12.76	3	50.6	19	124	92.99	0	6.99	0	0	0	0.02	11	
5	01/09/2016	07:12	53	55.99	3	40.39	27	28	87.18	1.11	10.59	0	1.1	0.02	0	5.5	11.5
6	02/09/2016	07:02	54	21.87	4	2.85	34	235	96.67	1.28	2.01	0	0	0	0.04	10	10
9	03/09/2016	16:32	54	1.49	4	59.3	65	156	5.15	92.72	2.11	0	0.02	0	0	11.5	19
10	03/09/2016	18:17	54	2.03	5	4.59	70	53	97.03	0.08	2.86	0	0	0.03	0	10	
11	03/09/2016	21:53	54	5.5	4	54.62	45	1500	0	100	0	0	0	0	0		24
12	04/09/2016	03:33	54	15.61	4	48.35	38	80	0	99.58	0.4	0	0	0.02	0		18
13	04/09/2016	14:05	54	25.67	4	57.24	118	141	95.91	0.95	3.12	0	0	0	0.02	7	9
14	04/09/2016	15:48	54	25.77	4	54	62	300	0	95.55	3.83	0	0	0.47	0.14		23
15	05/09/2016	02:32	54	27.73	4	49.03	57	62	0	100	0	0	0	0	0		23.5
16	05/09/2016	09:33	54	39.16	4	10.25	45	65	75.36	13.19	11.43	0	0	0	0.02	6	13
17	05/09/2016	17:08	54	29.41	4	56.09	87	1114	0	97.31	1.46	0	0	0	1.22		24
18	05/09/2016	23:54	54	42.01	4	59.72	34	554	0	99.26	0.74	0	0	0	0		21
19	06/09/2016	09:55	54	43.06	5	16.82	141	92	98.02	0	1.92	0	0	0.01	0	7	
20	06/09/2016	12:00	54	34.7	5	24.7	48	84	97.99	0	1.94	0	0	0.07	0.07	7.5	
21	06/09/2016	16:15	54	28.89	5	12.48	141	32	97.66	0.79	0.92	0	0	0	0.63	7.5	9.5
22	06/09/2016	23:17	54	23.01	5	16.77	74	373	0	96.67	0.97	0.04	0	0	2.32		23
23	07/09/2016	06:11	54	10.62	5	43.43	21	126	84.37	0	15.6	0	0	0	0.02	11	
24	07/09/2016	08:14	54	9.02	5	28.1	46	42	97.81	0.21	1.95	0	0	0	0.03	10	10
25	07/09/2016	10:23	54	9.94	5	14.85	86	37	57.76	35.58	1.06	0.02	0	5.35	0.25	6.5	9
26	07/09/2016	17:25	53	51.31	6	8.09	24	48	97.09	0	2.91	0	0	0	0	6.5	
27	10/09/2016	08:46	53	50.52	5	17.59	73	40	89.31	0.25	6.13	0	0	0	4.32	6.5	9
28	10/09/2016	11:05	53	44.7	5	8.02	70	67	95.09	0.34	0.18	0	0	0.01	4.38	5.5	8.5
29	10/09/2016	15:02	53	40.56	5	52.31	53	172	86.43	8.18	3.84	0.02	0	0.01	1.52	9	16

30	10/09/2016	18:03	53	31.37	5	59.74	23	46	94.22	0.88	4.68	0.18	0	0.04	0	9.5	9
31	11/09/2016	09:36	53	29.9	4	55.88	89	14	89.97	0.13	2.53	0.08	0.16	1.46	5.68	6	
32	12/09/2016	19:43	54	19.77	4	5.59	21	62	96.39	0.91	2.2	0	0.03	0.45	0.02	7.5	10.5
33	12/09/2016	20:59	54	19.63	4	17.11	20	191	0	94.52	0.86	0	0	0	4.62		18
35	13/09/2016	20:47	53	56.84	4	9.63	45	132	0	99.37	0.63	0	0	0	0		23
37	14/09/2016	03:22	54	0.4	4	57.52	51	127	0	91.34	2.96	0	0	0.19	5.51		22
38	14/09/2016	05:36	54	3.3	5	4.44	59	2014	0	99.3	0.59	0	0	0	0.1		23
39	14/09/2016	11:25	54	12.55	4	56.86	83	49	94.58	1.3	0.38	0	0	0.01	3.73	6.5	9.5
40	14/09/2016	21:13	54	23.7	4	48.57	38	36	0	88.82	4.63	0	0	0	6.55		21
41	15/09/2016	03:22	54	30.89	4	58.44	113	566	0	86.59	0.05	0	0	0.05	13.32		23
42	15/09/2016	12:59	54	30.76	4	55.09	83	291	0	99.7	0.15	0	0	0.12	0.02		22.5

Table 6B.3: Preliminary age-length key for herring from which otoliths were removed at sea during the Irish Sea/North Channel survey 2016. Data are numbers of fish at age in each length class in samples collected from each trawl.

Length (cm)	Age class (rings, or ages assuming 1 January birthdate) 0	1	2	3	4	5	6	7	8+	Total
6	1									1
6.5	1									1
7	3									3
7.5	9									9
8	10									10
8.5	12									12
9	13									13
9.5	16									16
10	13									13
10.5	14									14
11	12									12
11.5	13									13
12	8									8
12.5	8									8
13	4									4
13.5	5									5
14	4									4
14.5	3									3
15		4								4
15.5		2								2
16		7								7
16.5		6								6
17		15								15
17.5		25								25
18		15								15
18.5		24								24
19		20	5							25
19.5		19	5							24
20		8	18							26
20.5		9	19							28
21		1	37	2						40
21.5		4	38							42
22			44	4						48
22.5			36	14	1					51
23			30	22	2					54
23.5			30	25	3					58
24			4	23	17	1				45
24.5			6	33	9	2				50
25			2	22	16	6	2	1	1	50
25.5				9	17	10	7		1	44
26				2	12	8	4	5	2	33
26.5					13	7	6	4	1	31
27					1	5	6	1	3	16
27.5						2	4	2	2	10
28							1		2	3
28.5						1				1
29									1	1
29.5										
30										
Total	149	159	274	156	91	42	30	13	13	927

Table 6B.4: Acoustic survey estimates of biomass (t) and numbers ('000) of herring and sprat by survey stratum from the AFBI acoustic surveys in 2016.

Stratum	No. sprat	Biomass sprat	No. Her	Biomass Her
1	2716833	7022	3271	18
2	202663	529	52933	4297
3	13660789	32276	134090	7733
4	28780401	61752	47791	700
5	2655769	8494	593245	36078
6	5800447	23702	139674	953
7	1103924	2693	305038	29605
8	721104	3258	10770	76
9	47603	177	24831	2685
10	11294220	54961	98231	8245
11	4243215	6496	10269	57
12	10768347	34638	284397	1633
13	0	0	158684	15676
Total	81995321	236003	1863229	107762

Annex 6c: Celtic Sea Herring Acoustic Survey (CSHAS) summary of survey report 2017

Survey Summary table

Name of the survey (abbreviation):	2017 Celtic Sea Herring Acoustic Survey (CSHAS)

Summary: **Cruise Report Link:** http://hdl.handle.net/10793/1338

The objectives of the survey were carried out successfully and as planned. Approximately 48 hours of weather induced downtime was recorded due to storms *Ophelia* and *Brian*.

Geographical coverage extended southwards in 2017 as part of an adaptive stratum and based on observations of herring during the summer WESPAS survey. Overall the survey was considered to have contained the stock within the survey area as in 2014 to 2016. Distribution can be split into two areas, mature and migratory stock component offshore and inshore component composed of smaller and juvenile fish. The total abundance of herring was significantly lower in 2017 for the increased amount of survey effort and area coverage. Total biomass was 3,600t (CV = na due to low number of bio samples).

Timing of the survey was two weeks later than in previous years. Realistically this not thought to have been a significant factor in the low abundance observed. The co-occurring offshore fishery also saw low catches relative to searching effort offshore before the focus of the fishery moved inshore targeting aggregations of containing a higher proportion of small and juvenile fish.

	Description
Survey design	Stratified systematic parallel design (8 nmi spacing) with randomised start point for broad scale survey (two replicates, laddered approach). Non-random high intensity stratified adaptive surveys (1 nmi spacing) on highly localised offshore aggregations.
Index Calculation method	StoX (via the ICES database)
Random / systematic error issues	Majority of the mature stock has been aggregated into a highly localised and discreet area offshore over the last number of years during the survey. A second component of the stock is composed of smaller and juvenile fish located close inshore. Offshore component is highly aggregated in this way school behaviour inhibits accurate measurements acoustically as fish are located tight on the seabed and within the acoustic deadzone (ADZ).
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, poor weather dominated the survey including two large storm events.
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

Annex 6d: Western European Pelagic Acoustic Survey (WESPAS) summary of survey report 2017

Survey Summary table

Name of the survey (abbreviation):	2017 Western European Pelagic Acoustic Survey (WESPAS)

Summary: **Cruise Report Link:** http://hdl.handle.net/10793/1326

The objectives of the survey were carried out successfully and as planned. Good weather conditions dominated for the majority of the survey resulting in less than 12 hours downtime over the 42 day survey period. 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).

Malin Shelf herring distribution was concentrated in an area to the west of the Hebrides in 6aN and in the western Stanton Bank area (Figure 3). There were no herring observed south of 55°N in 6aS or 7b, c. This was similar to 2016, but this was not the case in years previous to that. Total biomass was 107.9 Kt (CV 45.5) compared to 70.7 Kt in 2016. Boarfish distribution was comparable within the time series. Biomass was higher than 2016 (228.1 Kt in 2017 (CV 21.9) vs. 69.7 Kt in 2016) but more comparable with the medium term time series. The age profile of the stock was comparable. Horse mackerel distribution was similar to 2016 but the biomass was higher (228 Kt (CV 25.5) vs. 69.2 Kt in 2016).

Survey effort and coverage were comparable to previous years as was the vessel and sampling equipment (transducers and trawl) were used. However, in 2017 the rotation of the survey was changed, beginning in the south and working northwards. This led to a temporal offset of in the order of 5 weeks.

	Description
Survey design	Stratified systematic parallel design (15 nmi spacing) with randomised start point.
Index Calculation method	StoX (via the ICES database)
Random / systematic error issues	NA, 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	NA, good weather dominated the survey
Extinction (shadowing)	No particular issues as target schools primarily located in the lower water column.
Blind zone	NA
Dead zone	Possibility of issue with species tight on the seabed, namely horse mackerel
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

Annex 6e: Pelagic ecosystem survey in western Channel and eastern Celtic Sea (PELTIC) summary of survey report 2017

Survey Summary table	
Name of the survey (abbreviation):	2017 Pelagic ecosystem survey in western Channel and eastern Celtic Sea (PELTIC)
Summary:	**Cruise Report Link:** Pending
The objectives of the survey were carried out successfully and as planned. Approximately 36 hours of weather induced downtime was recorded due to storms *Ophelia* and *Brian*. Geographical coverage extended southwards in 2017 to include French waters in the western Channel. Scheduled coverage to the north of the survey area was only partially covered due to weather issues and temporal loss of net sonde. Start date of the survey was very similar to previous years but duration extended to 42 days. In reversal to previous years, the survey commenced in the Bristol Channel and finished in the western Channel. Timing of coverage of the different strata was therefore not necessarily the same as in previous years. The 2000 nautical miles of effective acoustic coverage were supplemented with 38 valid trawls which provided details on species composition and biological information. A mix of pelagic species were found in newly sampled French waters generally consisting of sardine with smaller contribution of anchovy and sprat. The size of these specimens was generally smaller than those found in the northern waters of the Channel. Compared to 2016, low sardine biomass was found north of the Cornish Peninsula (7,124 t) and higher numbers in the English Channel (170,725t). This may be a consequence of the timing of coverage. Anchovy biomass decreased compared to 2017. Sprat biomass had increased in Lyme Bay (English Channel: 34,109 t) compared to the low biomass estimate from 2016. Sardine egg- and larval maps showed similar geographical areas of sardine spawning compared to previous years with particularly the waters at the mouth of the English Channel being most important. Few eggs were observed north of the Cornish Peninsula. Of particular note were the approximately 40 separate observations of feeding Atlantic Bluefin Tuna. Oceanographic conditions were comparable to the average values of the time series.	
	Description
Survey design	Stratified systematic parallel design with variable spacing (5, 10 and 15 nmi) depending on variability in different areas.
Index Calculation method	EchoR
Random / systematic error issues	The 5 nmi spaced transects in Lyme Bay were surveyed twice, once shortly after storm Brian and once after a spell of fine weather, to test the possible effects of weather to behaviour of coastal sprat.
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	We use a filter removed “empty” pings during spells of bad weather.
Extinction (shadowing)	Not dealt with as generally schools not too dense to be an issue
Blind zone	12 m (with drop keel down to 3m below hull 3+4 m + 5m nearfield); during daylight not thought to be a massive issue apart from some mackerel schools right at the surface. At night several species move to surface (hence daylight survey only)
Dead zone	1m –possible issues with horse mackerel; other species thought to be above 1m
Allocation of backscatter to species	Backscatter allocated to several echotypes, each of which may be a single species or mixed species, the identity of which is determined by the acoustic equivalent of the directed trawl catches (sensu Mathieu Doray)
Target strength	@ 38kHz: Herring, sprat, sardine and anchovy: -71.2; boarfish = -66.2; horse mackerel = -68.9; gadoids = -67.4 @200 kHz: mackerel = -81.9 (under review)
Calibration	Successfully completed 10 days prior to the survey in the Isle of Man

Annex 6f: The 2017 industry-science acoustic survey of herring in the Western British Isles (ICES DIV 6A, 7BC)

THE 2017 INDUSTRY-SCIENCE ACOUSTIC SURVEY OF HERRING IN THE WESTERN BRITISH ISLES (ICES DIV 6A, 7BC)

Steven Mackinson[1], Martin Pastoors[2], Susan Lusseau[3], Eric Armstrong[3], Steven O'Connell[3], Dick de Haan[4], Dirk Burgraaf[4], Benoit Berges[4], Alexander McClean[5], Bruce Langlands[5], Andrew Scott, Alex Wiseman[1], Michael O'Malley[6], Maurice Clarke[6]

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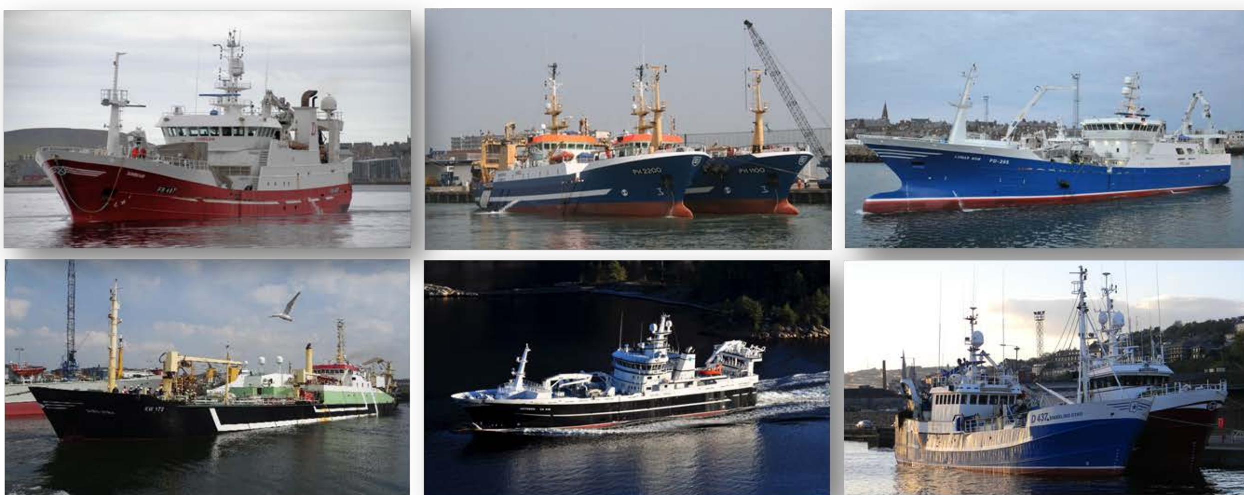
[2] Pelagic Freezer Trawler Association, Netherlands
[3] Marine Scotland, Scotland
[4] Wageningen Marine Research, Netherlands
[5] Scottish Fishermen's Federation, Scotland
[6] Marine Institute, Ireland



Sunbeam (James Duthie), Wiron 5&6 (Jan Melis/ Adrie Hoek), Lunar Bow (AJ Buchan & Alex Buchan), Dirk Dirk (Jaco van Duijvenvoorde), Antares (Lowrie Irvine), Sparkling Star (Donal O'Neill) and Eilean Croine (Eric Murphy)

(Version: 1: 16/02/2018)

Contents

Summary

Overview of this year's survey

2017 was the second industry-led acoustic survey of herring in 6a/7bc. Four industry vessels were used in the 6aN, three vessels had Simrad EK60's mounted on a towed body, the other vessel used a Simrad EK80 transceiver with the ships transducer. Each vessel was calibrated and dedicated to undertake an acoustic survey in a specific pre-spawning/ spawning area coinciding with the known spawning period. Each area was surveyed twice. 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 in this regard. Herring were aggregated mainly in one area, (different from the previous year) so biological samples are spatially limited. Sprat were found distributed throughout the area in surface schools and close attention was given to distinguishing these from herring schools. The distribution of herring aggregations were found in one area.

In 6aS/7b, two industry vessels (pair trawlers), one with a scientific EK60 transceiver and calibrated tow-body mounted transducer (38kHz) were used to conduct the survey encompassing the majority of herring spawning areas in 6aS and some in 7b. A full report of the 6aS/7b survey can be found in http://hdl.handle.net/10793/1341. In this area, similar to the corresponding survey in 2016, the herring were distributed close inshore during the survey and therefore full containment of the stock was most likely not fully achieved. The overall estimate of herring was dominated by distributions of herring in a few discreet areas, resulting in a high CV estimate (~0.50) for the herring survey. In 2017, the acoustic survey in 6aS/7b also looked at horse mackerel. 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. Horse mackerel were distributed mainly in an area to the north west of Tory Island, Co. Donegal. There appeared to be a difference between day time and night time distributions; horse mackerel showed better on the echograms during the daylight. The overall estimate of horse mackerel was dominated by two transects in particular, resulting in a high CV estimate (~0.62) for the horse mackerel survey. Sea state was generally rough, however acoustic data were successfully recorded. , Biological data was obtained from sample hauls and the monitoring fishery. Due to the weather conditions, the survey area was reduced slightly and the survey speed was reduced to between 8 and 10 knots.

Survey component	6aN	6aS/7bc
Survey design	3nmi spacing, covering predefined spawning areas. Calibrated sounders on industry vessels	7.5nmi spacing, covering the main 6aS/7b spawning areas. Calibrated sounder on industry vessel using a transducer mounted on a towed body
Index calculation method	Age dis-aggregated using StoX software	Age dis-aggregated using StoX software
Random/Systematic error issues		
Specific survey error issues (acoustic):		Inshore containment of the stock was most likely not achieved. Estimates rely strongly on a few large schools (e.g. Lough Swilly, Bruckless Bay and Inver Bay)
Bias considerations		
• **Bubble sweep down**	NA	NA
• **Extinction (shadowing)**	NA	Particularly on large schools (e.g. Lough Swilly where school was >3km long and > 200m wide)
• **Blind zone**	NA	NA
• **Dead zone**	Some schools were close to the bottom	Some schools were close to bottom, however schools displayed typical pelagic/mid-water behaviour
• **Allocation of backscatter to species**	Following scrutinisation procedure	Following scrutinisation procedure
• **Target strength**	Using ICES published TS for herring at 38KHz. TS(L) = 20log10(L) -71.2	Using ICES published TS for herring at 38KHz TS(L) = 20log10(L) -71.2 and TS(L) = 20log10(L) -67.5 for horse mackerel
• **Calibration**	Calibrated following standard procedures. (SIMRAD 2003).	Calibrated following standard procedures (SIMRAD 2003).

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 2017/127) made the same provision, enabling the second survey to take place.

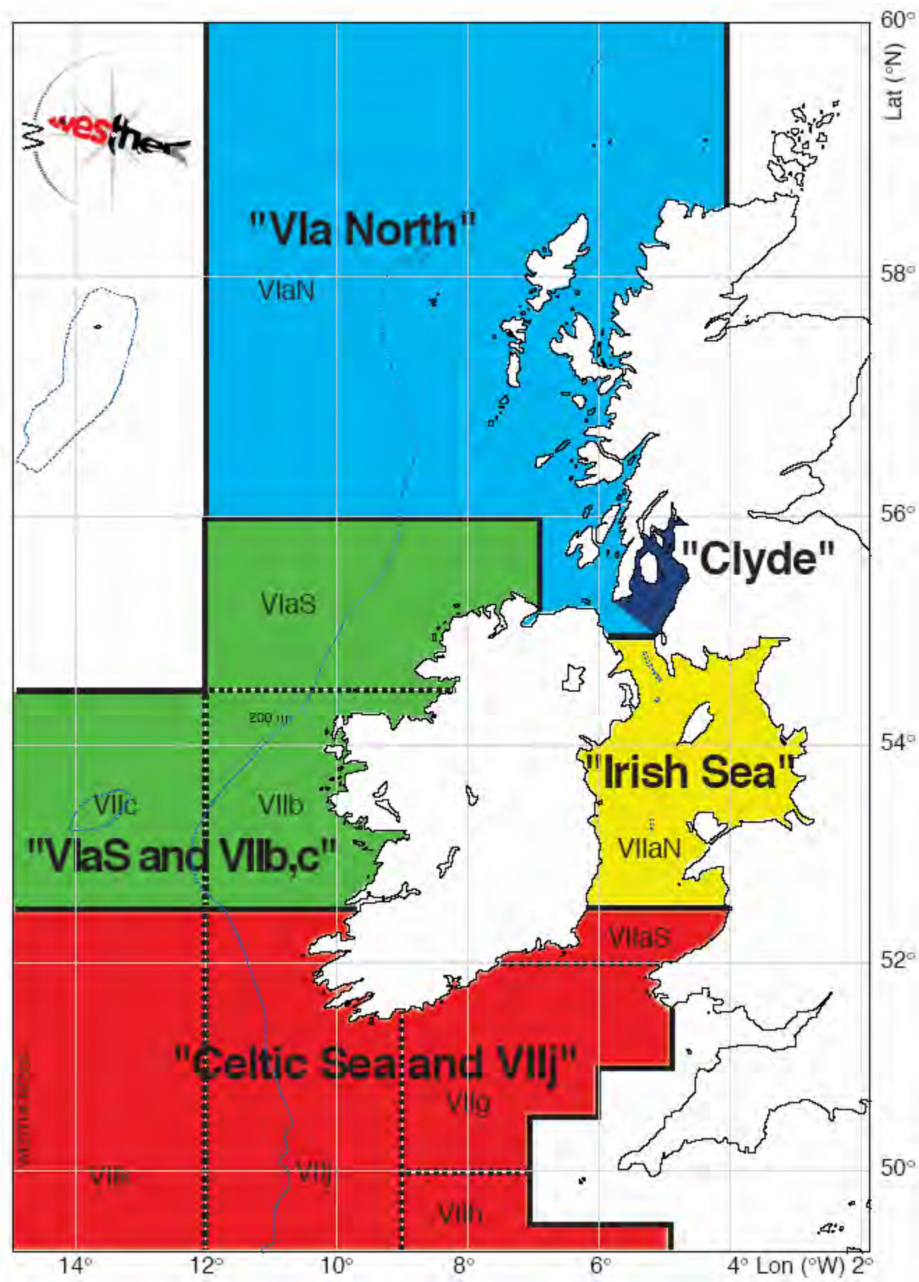


Figure 1.1. Herring stock assessment areas.

1.2 Overall Aim

To improve the knowledge base for the spawning components of herring in 6aN and 6aS,7bc, 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 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 of a scientific monitoring fishery in 2018, and design of future surveys.
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.

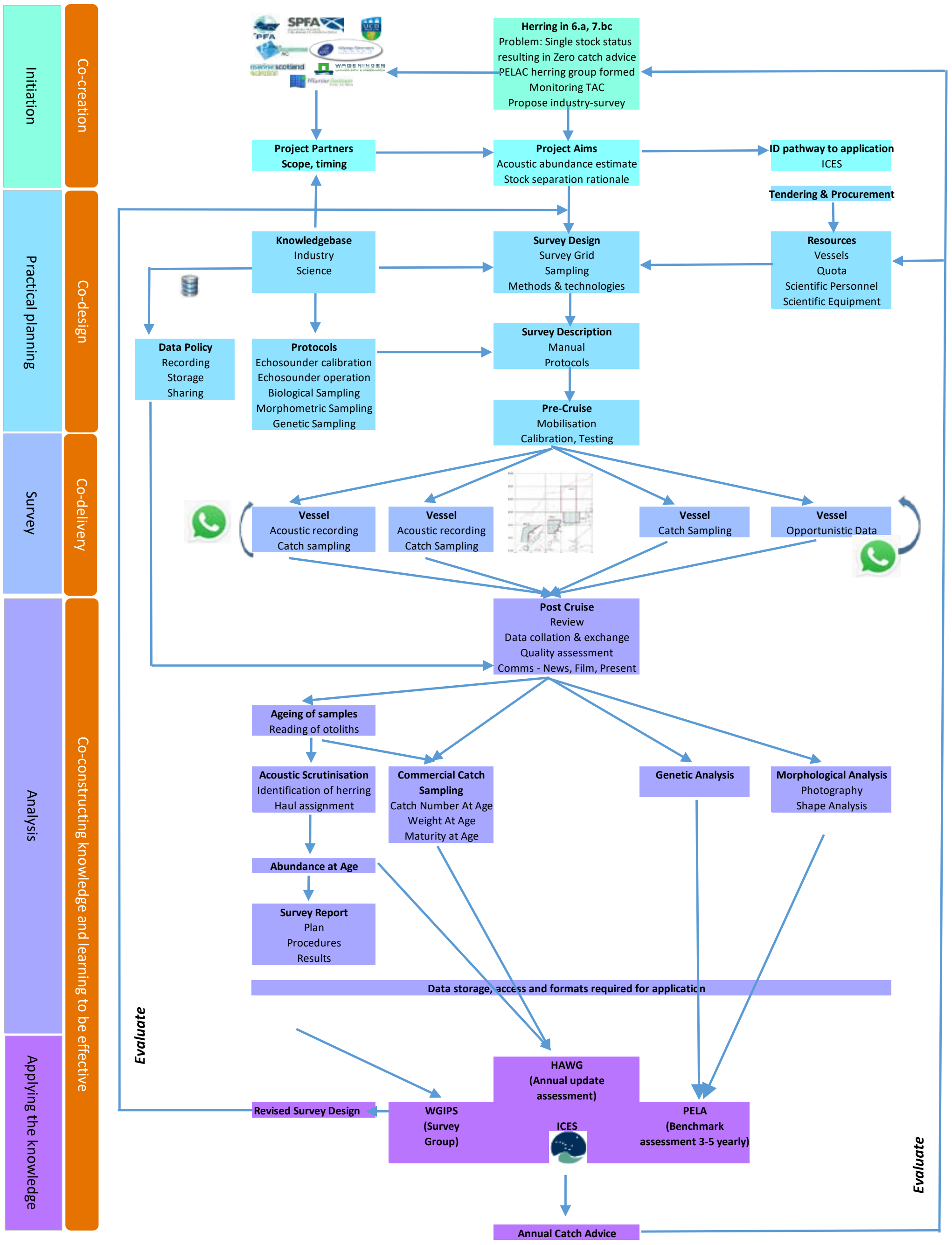


Figure 2.1. Overview of the planning, implementation and analysis stages in the Western herring surveys.

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 survey manual describing the aims, methods and protocols (example in Annex 1 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 2016, a review of spawning areas and timing (Mackinson 2017) and discussions with fishing skippers (21 June 2017), four 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 2016) 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). Systematic acoustic surveys (see section 2.2) were conducted only in areas 2-4 in 6aN, but ad-hoc acoustic data was collected from all vessels.

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).

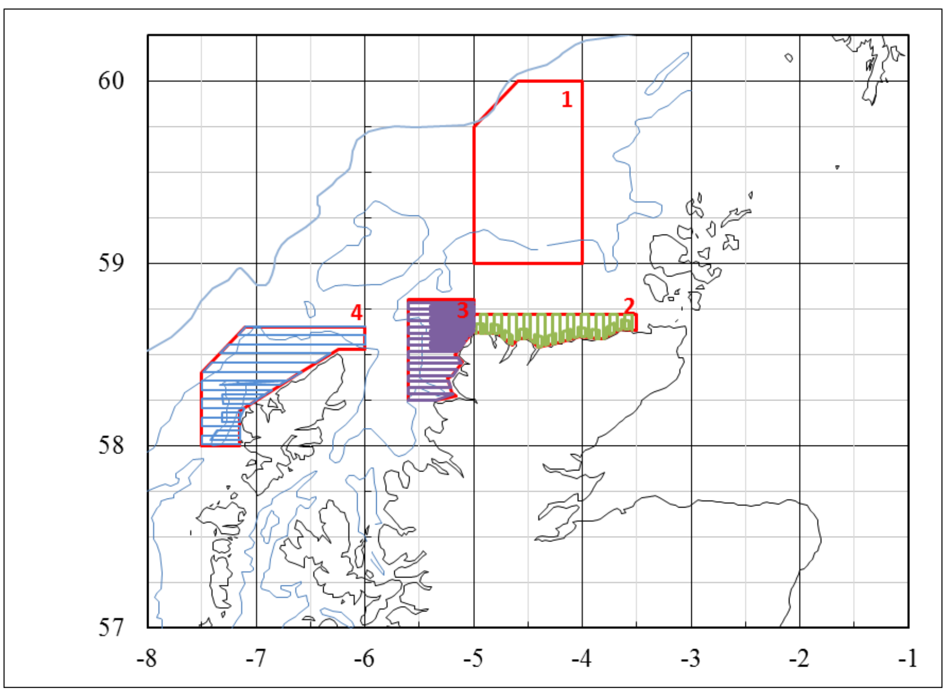


Figure 2.2. Planned survey areas used in the 6aNorth surveys. Area 1- North pre-spawning mixing area, Area 2 -East of cape Wrath, Area 3 – The Minch, Area 4 – Outer Hebrides.

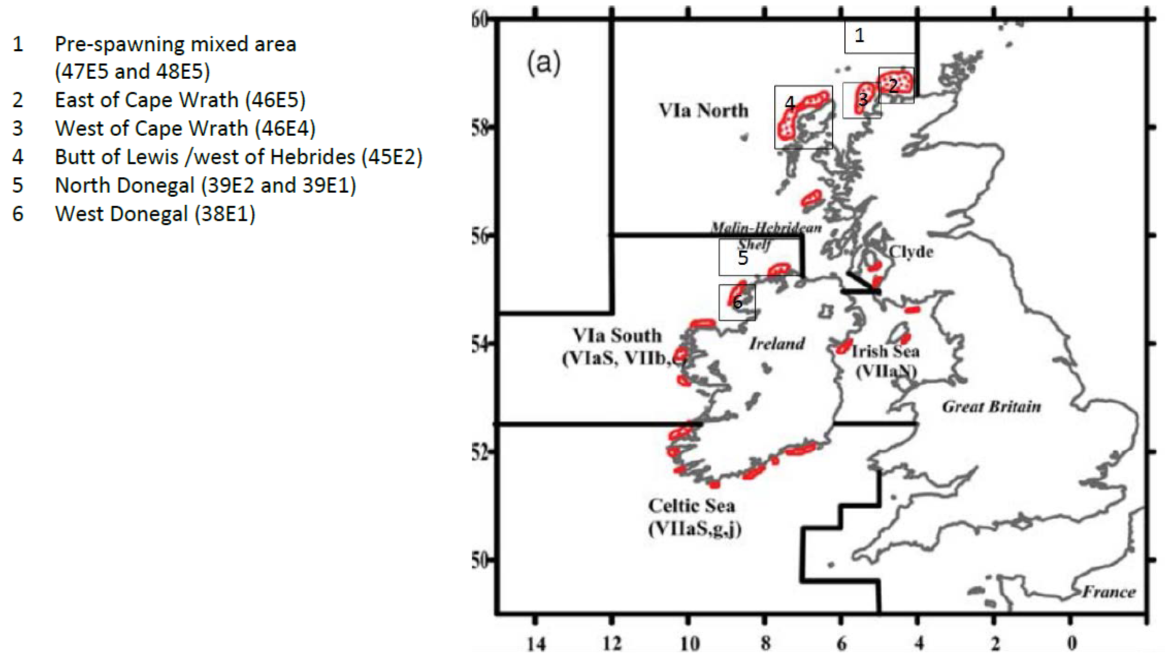


Figure 2.3. Spawning areas for herring in ICES subareas 6 and 7, with currently active spawning areas and pre-spawning aggregation areas for each stock indicated by black rectangles. Used in ICES 2016, redrawn from Geffen *et al.* (2011).

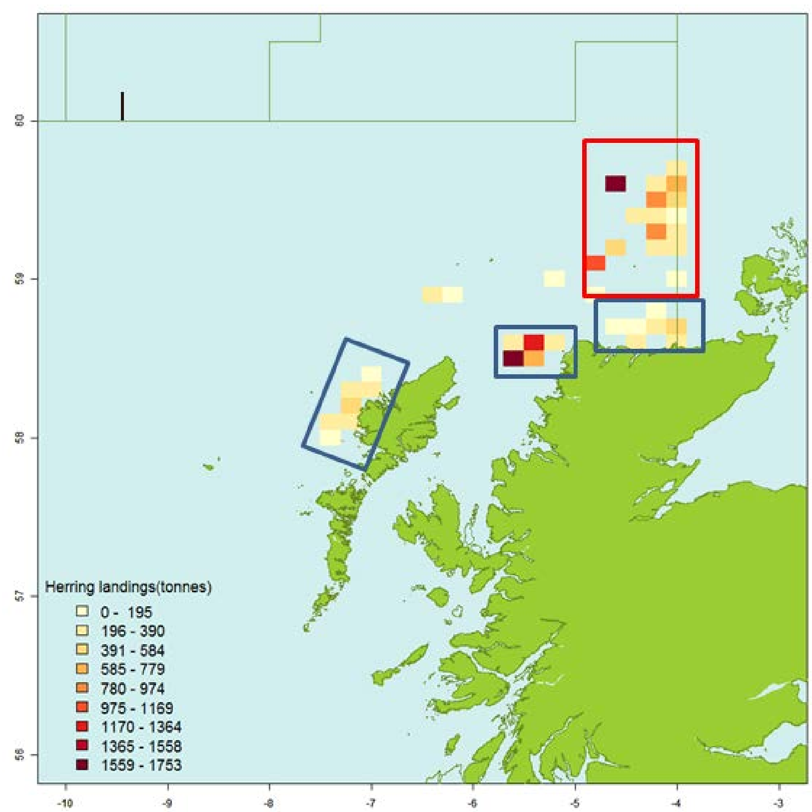


Figure 2.4. Distribution of commercial catches reported in 6aN.

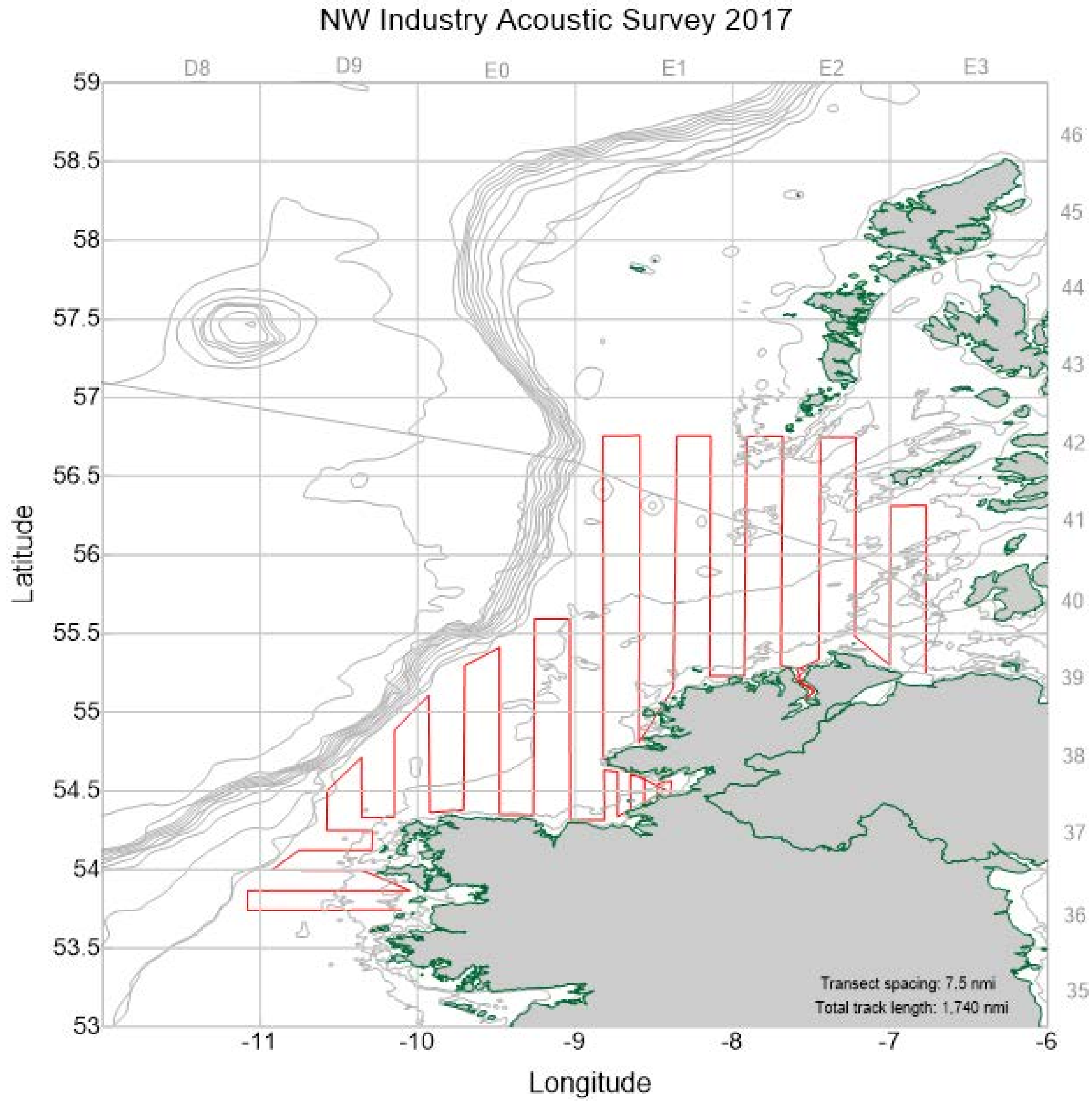


Figure 2.5. Planned acoustic survey area and transects for 6aS/7b, in 2017. The survey was conducted in Irish and UK waters, approximately up to the 56.75˚N line in the north and 7˚W line in the east. To the west, the survey was bounded approximately by the 200m depth contour. The total transect length was 1740nmi (start 55˚24N and 7.2˚W, progress west) with 7.5nmi separation between transects and 3.5nmi in Donegal Bay. An additional zig-zag survey track was completed in Lough Swilly, using the deepest part of the channel as the centreline for the strata area. 250m either side of this centre line was delineated as the boundary area; zig-zag transects were then placed within the strata boundaries.

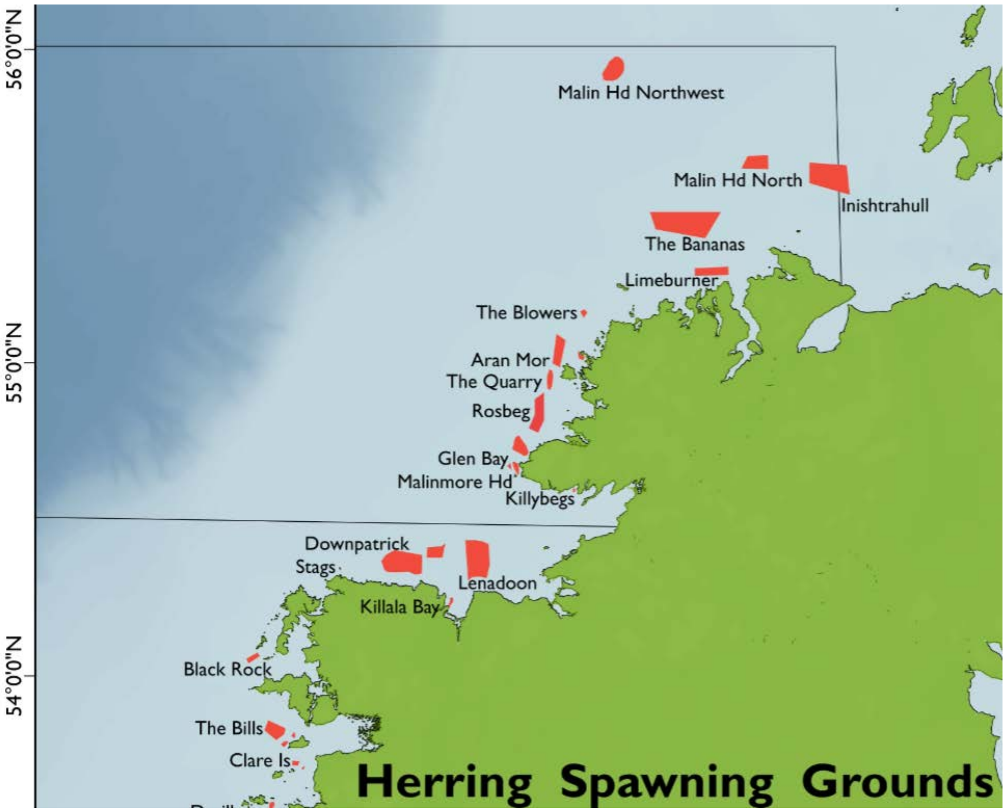


Figure 2.6. Herring Spawning grounds in 6aS/7b,c (from O'Sullivan, 2013).

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

2.1.3 **Timing, vessels and areas for each of the survey vessels (Table 2). Vessels undertaking acoustic work in shaded rows.**

Table 2.2a. Deployment in 6aN. Vessels undertaking acoustic survey work highlighted in bold.

Timing and area coverage	Sun 20-Aug	Mon 21-Aug	Tue 22-Aug	Wed 23-Aug	Thu 24-Aug	Fri 25-Aug	Sat 26-Aug	Sun 27-Aug	Mon 28-Aug	Tue 29-Aug	Wed 30-Aug	Thu 31-Aug	Fri 01-Sep	Sat 02-Sep	Sun 03-Sep	Mon 04-Sep	Tue 05-Sep	Wed 06-Sep	Thu 07-Sep	Fri 08-Sep	Sat 09-Sep	Sun 10-Sep	Mon 11-Sep	Tue 12-Sep
Area 1																								
Dirk Dirk (Catch sampling)																								
Antares (Biol / Gen / Morphometrics)																								
Area 2																								
Sunbeam (Acoustics)																								
Dirk Dirk (Biol / Gen / Morphometrics)													C											
Wirons (Acoustics)													C											
Antares (Biol / Gen / Morphometrics)																								
Area 3																								
Sunbeam (Acoustics)										F						F	F				F	F		F
Lunar Bow (Acoustics)					C													F						
Dirk Dirk (Biol / Gen / Morphometrics)																			F					
Antares (Biol / Gen / Morphometrics)																						F		
Area 4																								
Sunbeam (Acoustics)		C																						
Dirk Dirk (Biol / Gen / Morphometrics)													C											
Antares (Biol / Gen / Morphometrics)																								

Different colour for each vessel

Total period of coverage

F= Fishing
C=Calibration

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)	18-Nov	27 Nov	18-Nov	1500 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 2-4 (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. Replicate acoustic surveys were conducted in each of the areas in 6aN to try and capture the peak time of spawning abundance. 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 fish aggregations, or undertaking finer scale observations in high density locations (e.g. Area 3 shortening westward transects but extending them east to get coverage over key areas where herring were found). 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 the echosounders deployed on each of the vessels. Echomaster Marine successfully performed the calibration of Lunar Bow, 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 Lunar Bow at Peterhead Harbour.

The towed body units deployed on Sunbeam and the Wirons were calibrated in Scapa flow by the onboard acoustic technicians from Marine Scotland and WMR. WMR staff also undertook a successful calibration of the hull mounted transducer on Dirk Dirk in Scapa flow, immediately following the calibration of the Wirons.

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).

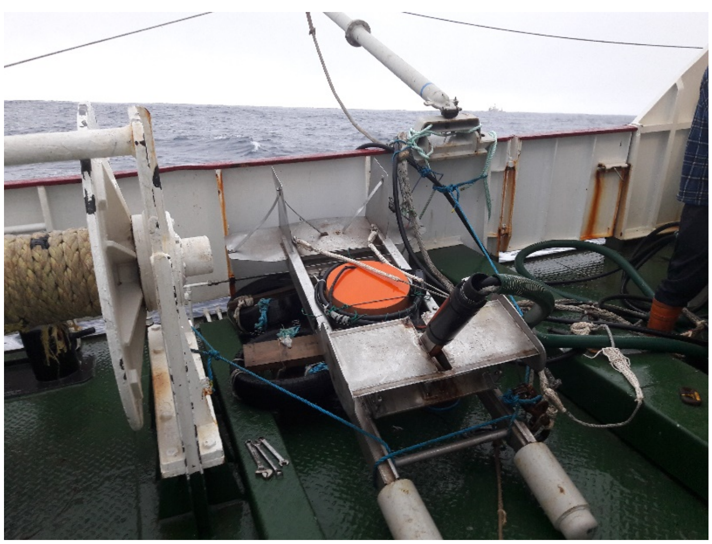


Figure 2.8. Towed-body mounted 38kHz transducer (Eilean Croine S238) were calibrated in Lough Swilly.

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, FV Lunar Bow took on board ballast water to aid stability of the vessel and minimise cavitation. The vessel proved to be a very stable platform in all the conditions experienced and at no time was the quality of acoustic data compromised. All other acoustic equipment was turned off to eliminate interference with the EK80. Only during fishing operations were other acoustic instruments used. A motion reference unit was installed to compensate for pitch and roll.

Raw acoustic data were recorded and stored on the PC and backed up each day on a 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.

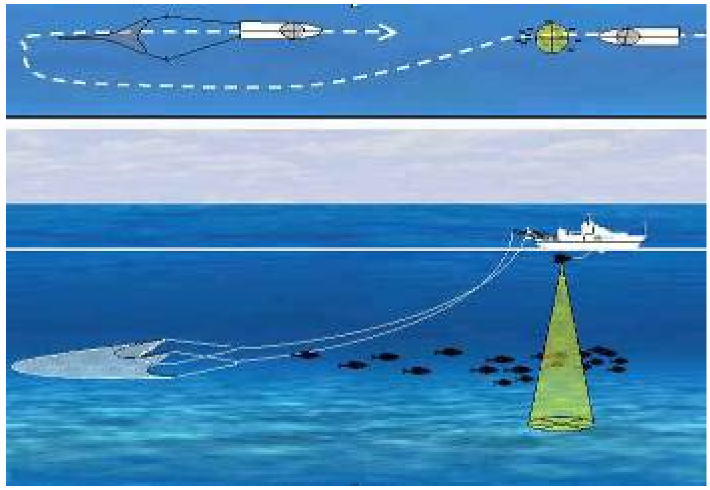


Figure 2.9. Schematic description of fishing operation to collect a biological catch sample during an acoustic survey.

Table 2.3. Acoustic survey summary

Area	Vessel	Transducer and Frequency	Echo-sounder	Power Pulse duration Ping interval	Environment	Calibration Location/ date	Survey area changes
2 - East of Cape Wrath	Wiron 5 & 6 PH1100 (6), PH2200 (5)	Towed body, split beam ES38B (38Khz).	SIMRAD EK60	Power: 2000W Pulse duration: 512µs Ping rate: 2 Hz (interval = 0.5 seconds)		Scapa flow 01-Sep	
3 - The Minch	Lunar Bow (PD 265)	Hull mounted split beam ES38B (38Khz), draft 5.1m With heave compensation.	SIMRAD EK80	Power: 2000W Pulse duration: 1.024ms Ping interval = 0.5 sec	Temp = 10C, Salinity =35, Sound speed 1491.5 m/s	Peterhead breakwater 23 Aug	Extended survey northern and western boundary to cover fish marks. Additional fine scale surveying on identified herring aggregation in northern part of the area.
4 – Outer Hebrides	Sunbeam (FR487)	Towed body, split beam ES38B	SIMRAD EK60	Pulse type = CW Power: 2000W Pulse duration: 1.024ms Ping interval = 0.5 sec	Temp = 10C, Salinity =35, Sound speed 1491.5 m/s	Scapa flow, 27 Aug	Sunbeam also did quick survey grid passes over north end Area 3 and a 3nmi spacing single pass of Area 2.
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. Additional searching conducted with the sonar in the Glen head area and around the coast of Mayo.

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 dumps (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, 200 herring). This subsample was used determine lengths, weight, age and for genetic samples. (see below). (Figure 2.11)

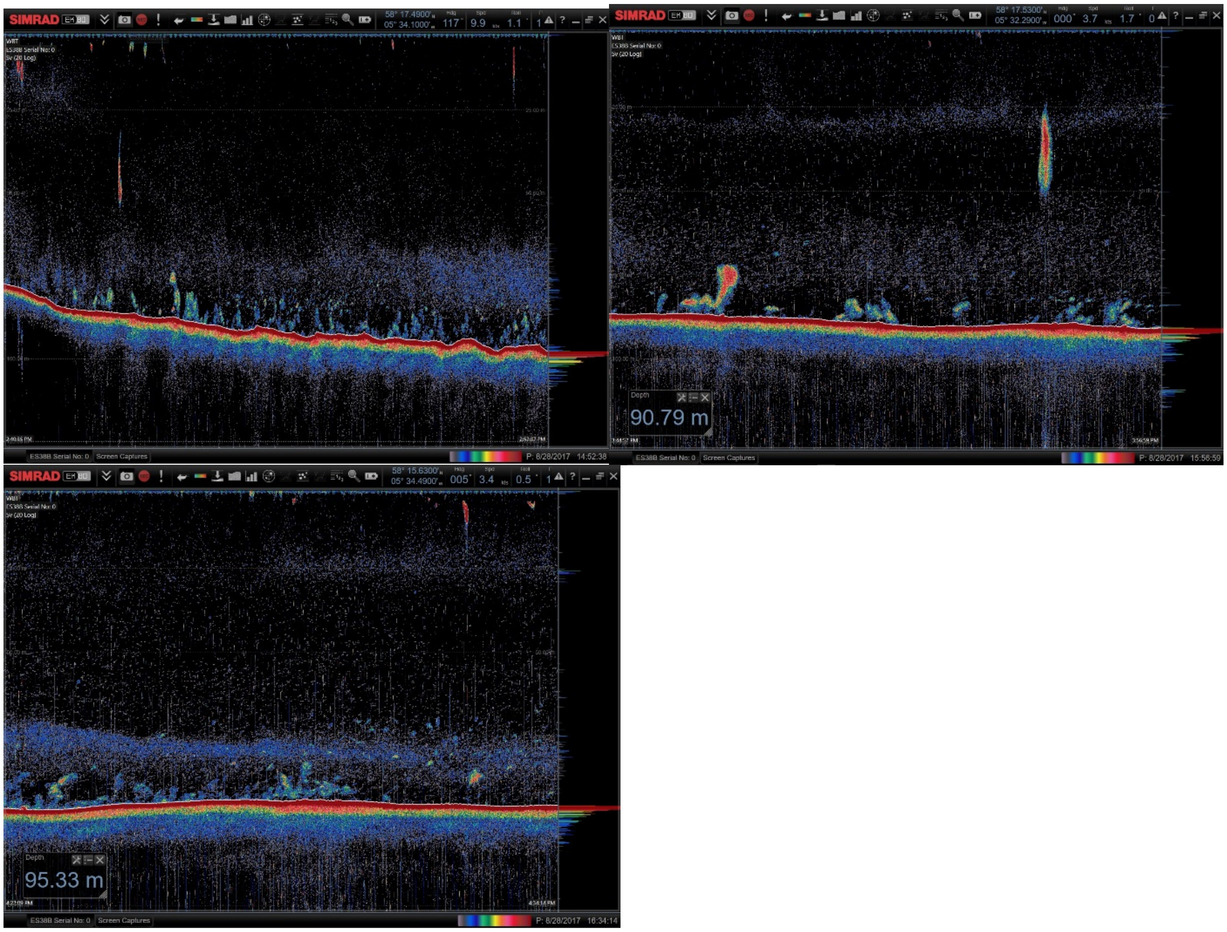


Figure 2.10. Example screen shots of targeted marks (first panel) and those trawled on.

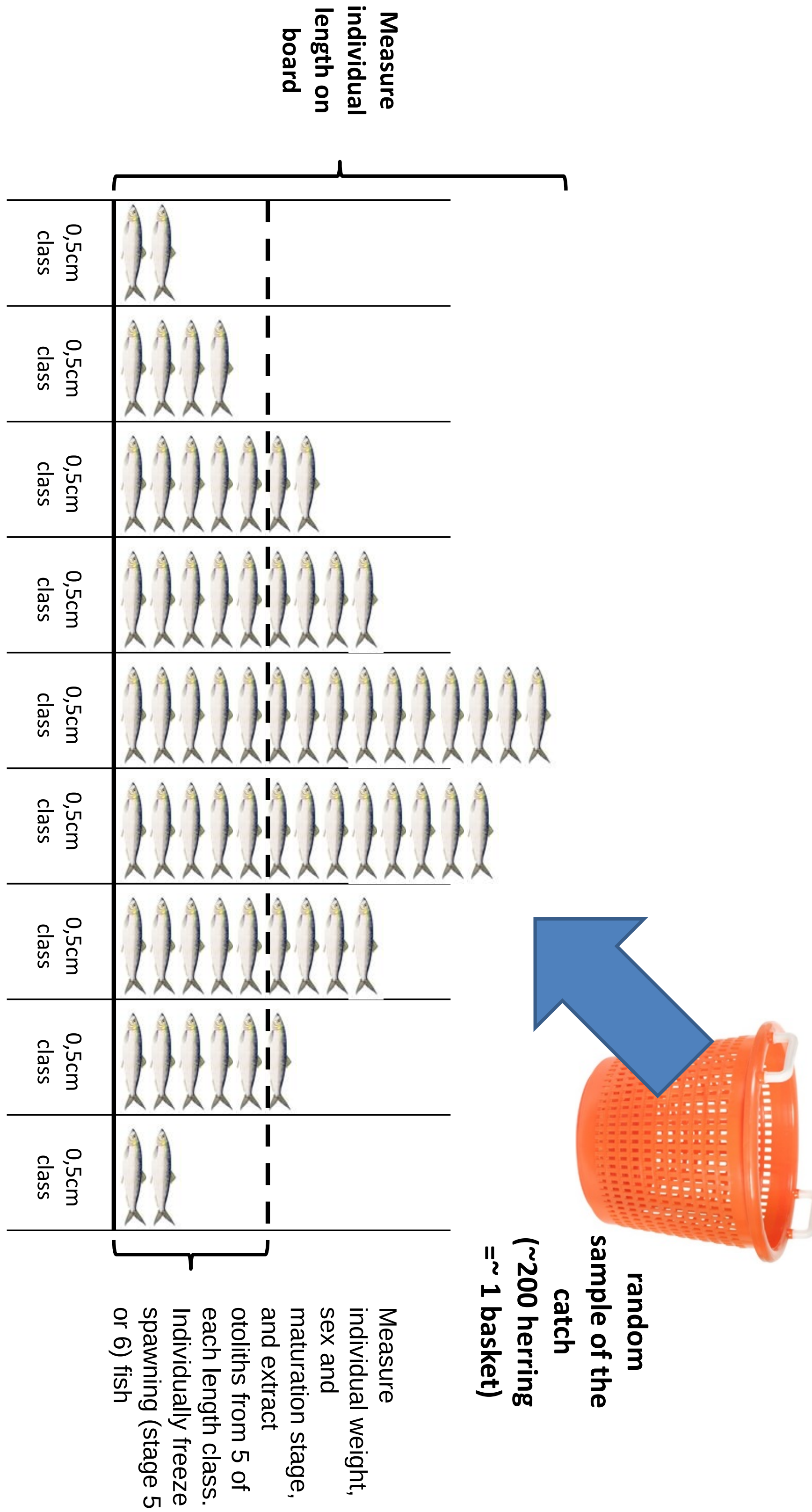


Figure 2.11. Illustration of the required catch sampling procedure.

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 (section 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 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 (ICES 2005) were used to determine the age of fish sampled. This age data was used to create an age-length key (ALK).
- If the fish was in spawning condition, it was bagged, labelled and frozen for later genetic analysis.

When spawning fish were encountered, an additional random 50 herring were collected, bagged, labelled and frozen for biological and genetic sampling. These were collected as 'backup' to the samples taken on board and for the purpose of being able to quality check assessment of length and maturity stages made at sea with those determined at the lab.

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):

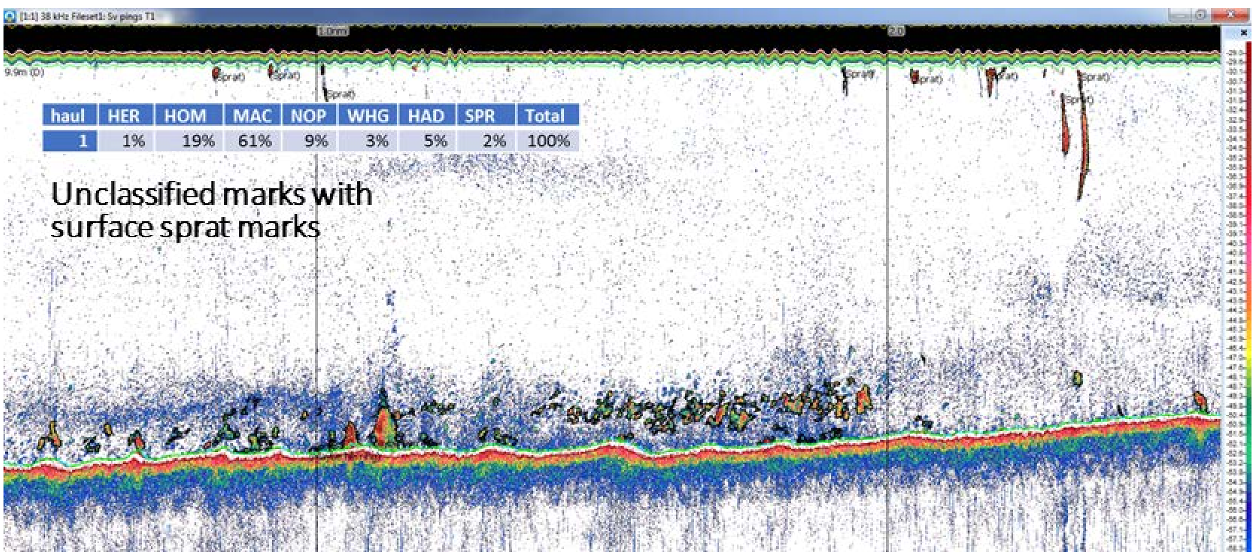
- **Herring** – confident that the marks were herring based on either evidence from a targeted haul or proximity and similarity to other schools known to be herring.
- **Maybe herring** - concentrations of fish tightly associated with prominent outcroppings on the seabed. Believed to be herring, but 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. Additional analysis of the acoustic properties compared to herring-classified marks show a clear difference (Figure 2.13).
- **Unclassified –** confident that the marks were not herring or sprat based on either evidence from a targeted haul or proximity and similarity to other

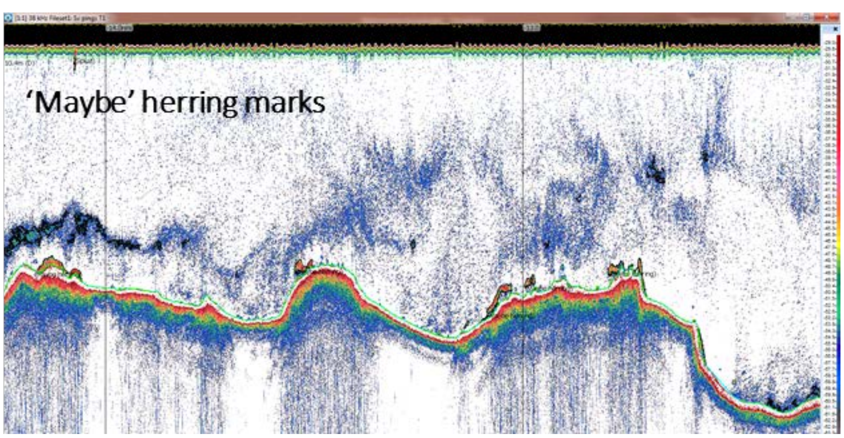
schools known to not to be herring, or characteristic atypical of herring schools.

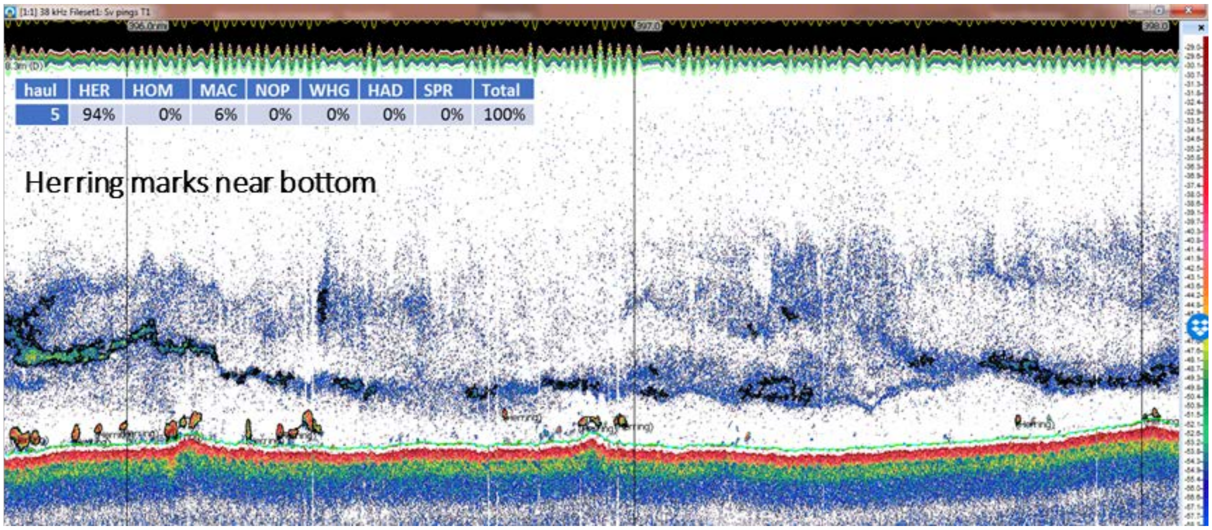
- **Horse mackerel –** a lot of horse mackerel marks were observed through 6aS,7b. Marks were verified with numerous trawls.

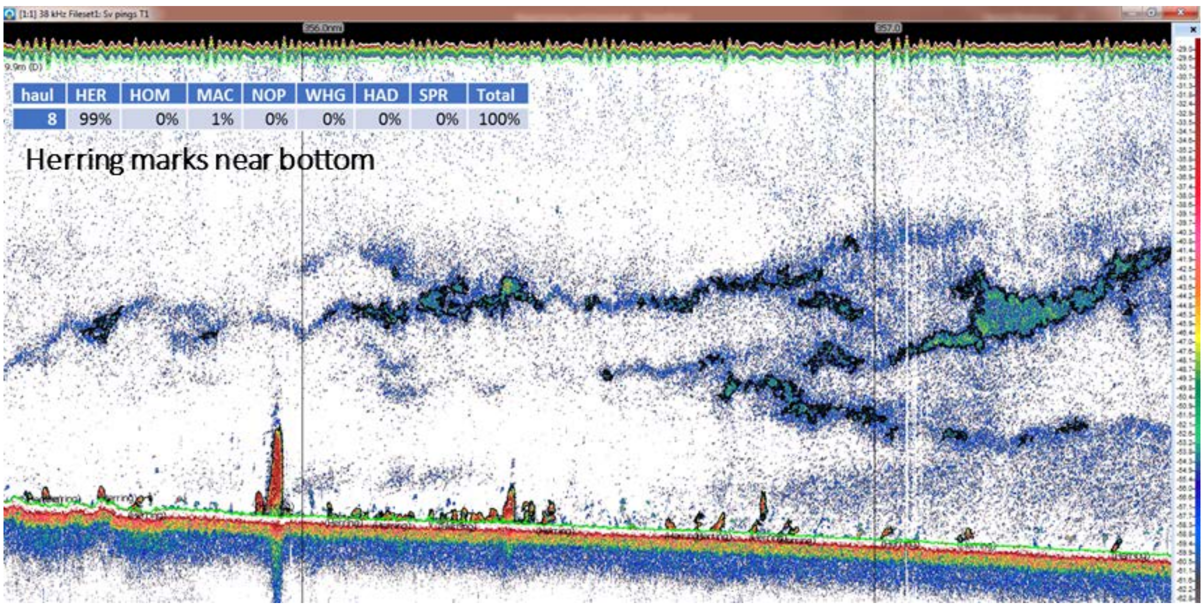
How strongly the acoustic marks are displayed on the screen (backscatter threshold) can have a bearing on the interpreters classification of the acoustic marks and their selection using school detection algorithms. While it is desirable to be consistent in the setting of this parameter, in practice the setting is determined largely by the need to filter out fish schools from other acoustic signals that create noisy backscatter data.

For Lunar Bow, the backscatter threshold used in automated school detection was -60dB. Every school was manually scrutinised thereafter to ensure that it was appropriately delineated. This was particularly important for schools close to/ touching the bottom.

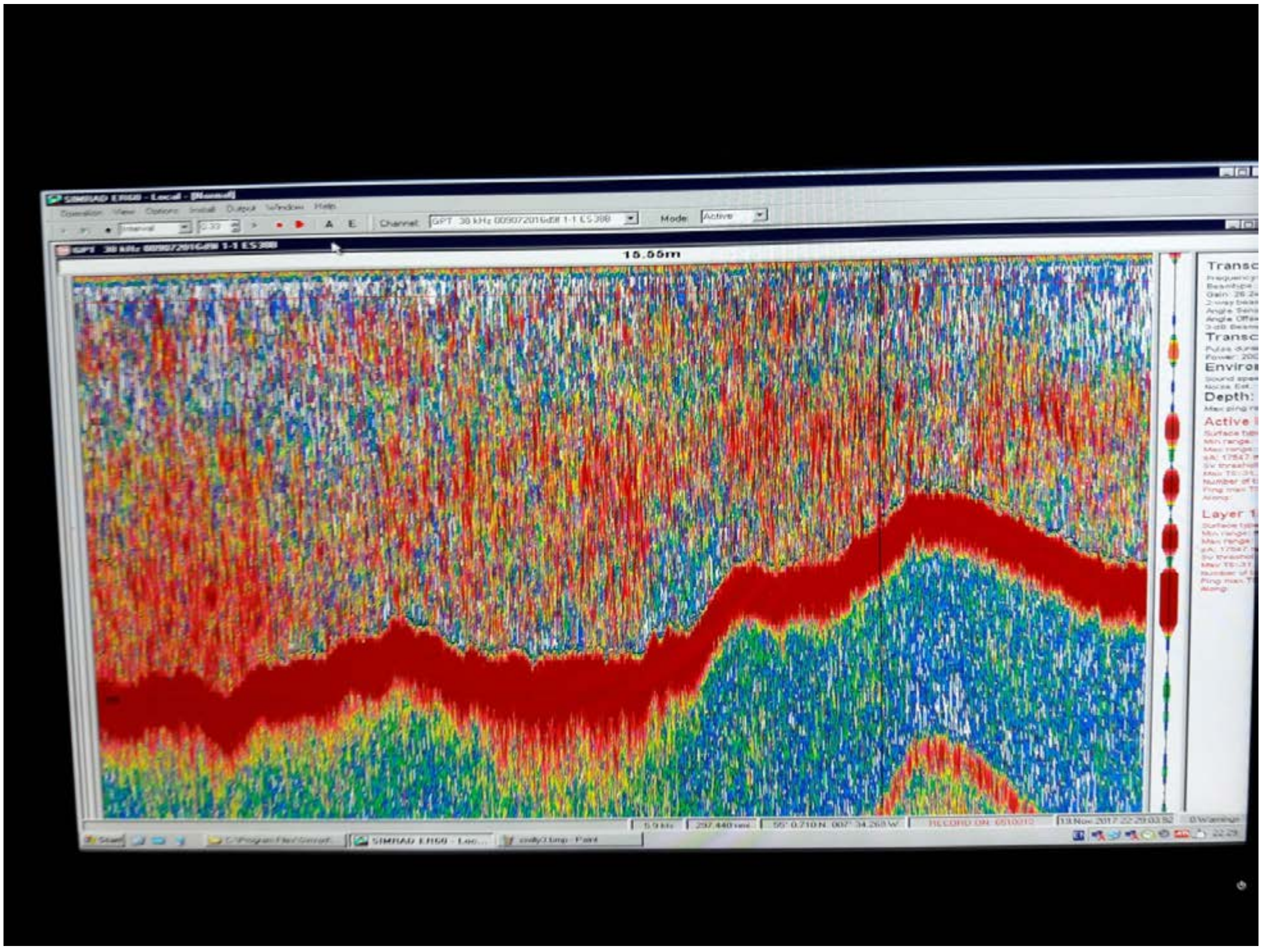




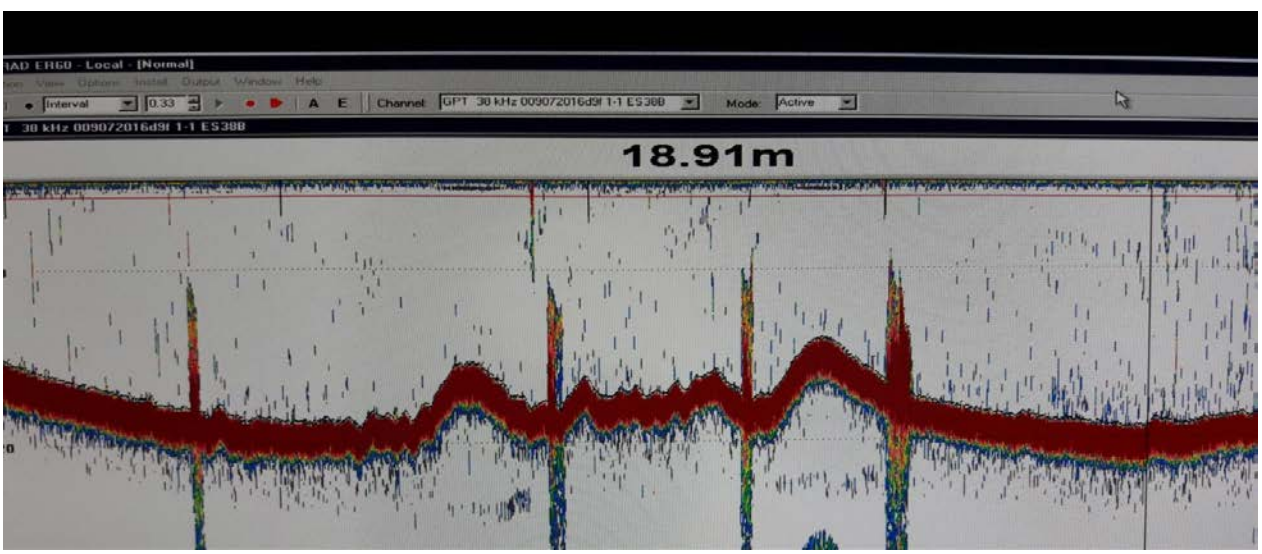




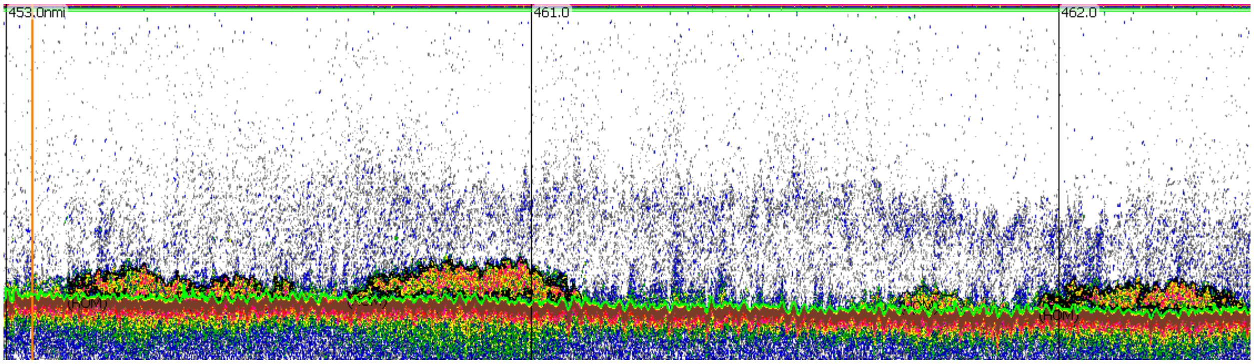
6aN Area 3: Minch acoustic marks



Large herring mark in Lough Swilly, Co. Donegal (6aS) 21/11/17



Series of herring marks in Inver Bay, Donegal (7b) 23/11/17



Horse mackerel marks obsereved throughout Tory Bank area (6aS)

Figure 2.12. Examples of acoustic marks and their identification.

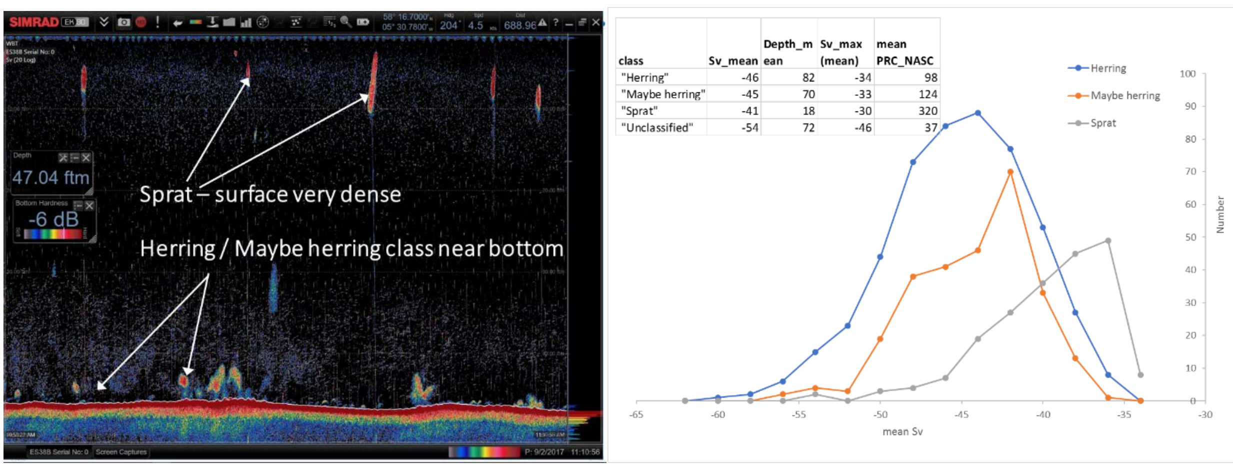


Figure 2.13. Comparison of acoustic properties of different school classes in 6aN Area 3.

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.

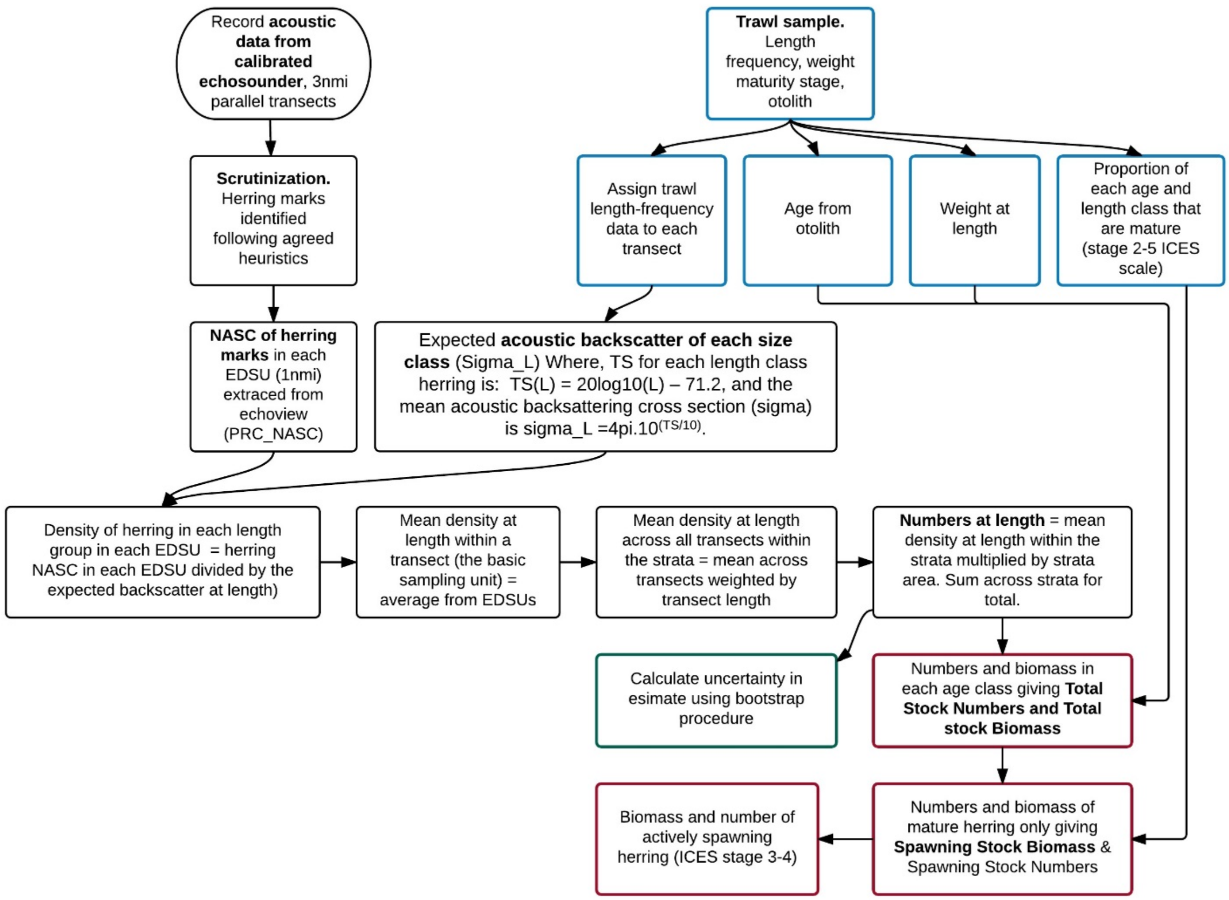


Figure 2.14. Flow diagram of the analysis methods to estimate abundance and biomass. Blue boxes – biological data; black boxes – treatment of acoustic data; red boxes- derived abundances indices; green box – uncertainty estimates

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 scrutinization of the echograms and export of the Nautical Area Scattering Coefficient assigned to herring marks (PRC_NASC from Echoview software), the calculation of age disaggregated abundance was as follows:

1. **Define survey strata.** In 6aN, each of the 3 areas surveyed and any fine-scale detailed grid searches within them was assigned as a strata (Figure 16). In 6aS,7b 3 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.
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).
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:

$$TS = 20\log10(L) - 71.2 \qquad \text{[at 38kHz]} \textit{ for herring}$$

$$TS = 20\log10(L) - 67.5 \qquad \text{[at 38kHz]} \textit{ for horse mackerel}$$

   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 σbs (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, 2 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 will be stored using Marine Scotland Science data base following established procedures. 6aS,7bc raw and processed data will be stored at the Marine Institute, Ireland. Estimates of abundance made from the surveys will be stored in the ICES WGIPS acoustic database.

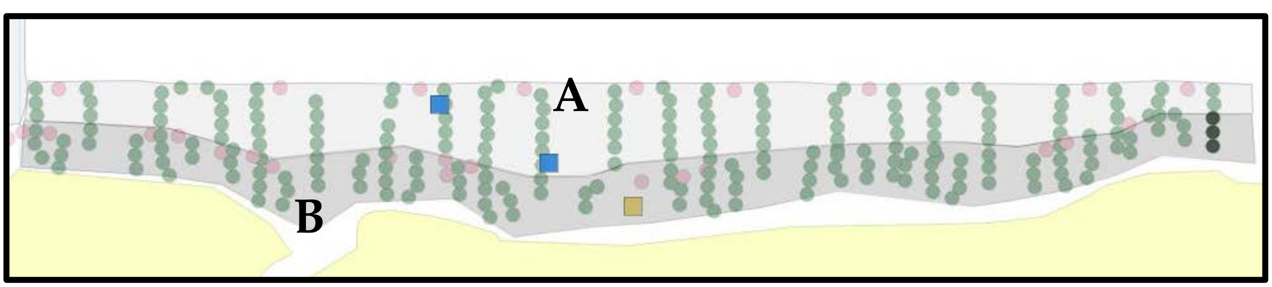


Figure 2.15a. Acoustic survey in 6aN, Area 2 North mainland. Transects and strata used in the analysis of the acoustic survey in area 2 conducted by Wiron (3rd run, 5-6 September). Hauls in blue were allocated to all transects in strata A (lighter colour). The hauls in yellow colour were allocated to all transects within strata B (darker colour). EDSU = 0.5nmi.

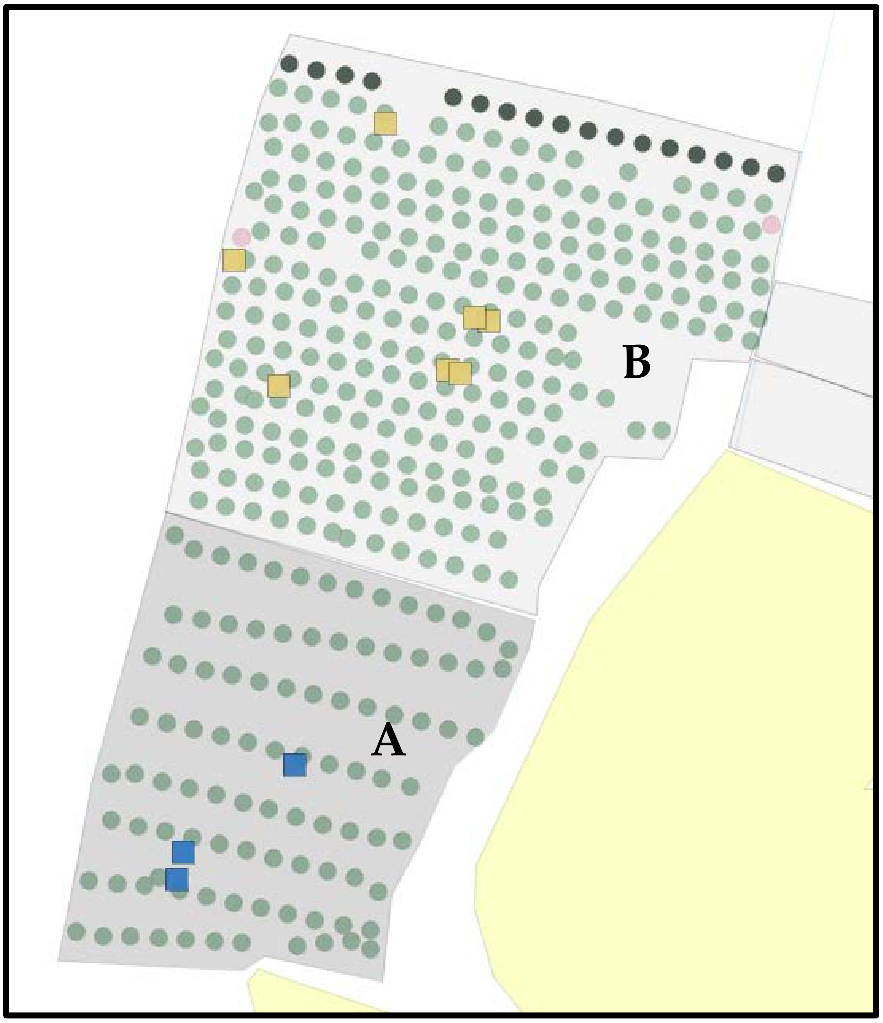


Figure 2.15b. Acoustic survey in 6aN, Area 3 The Minch. Lunar Bow survey track run 2 (1-5 September). Hauls marked in yellow were allocated to all transects in strata B. The hauls in blue were allocated to all transects in strata A. EDSU = 1nmi.

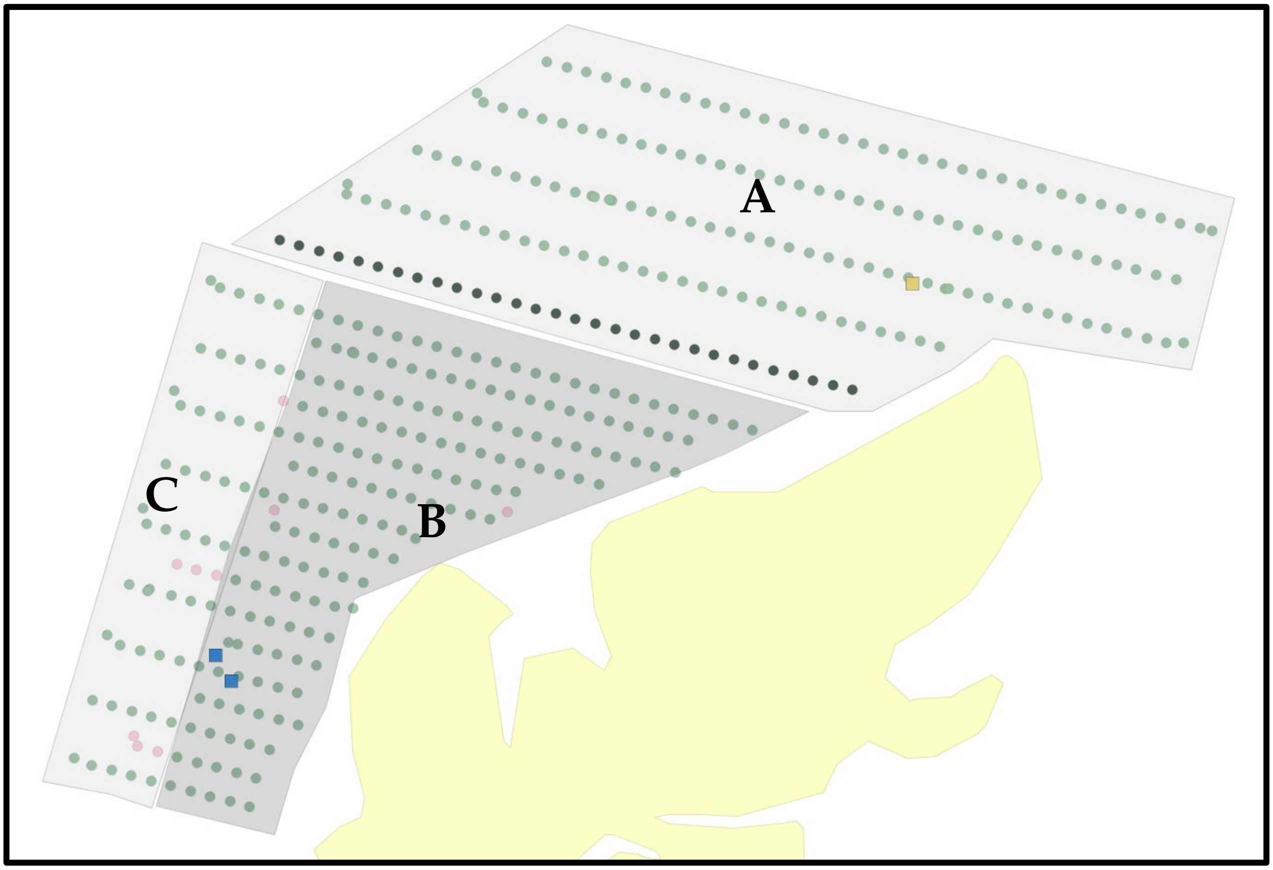


Figure 2.15c. Acoustic survey in 6aN, Area 4 Hebrides. Transects and strata used in the analysis of the acoustic survey in area 4 conducted by Sunbeam (22-25 August). Hauls in yellow were allocated to transects in strata A. The hauls in blue colour were allocated to all transects within strata B and C. EDSU = 1nmi.

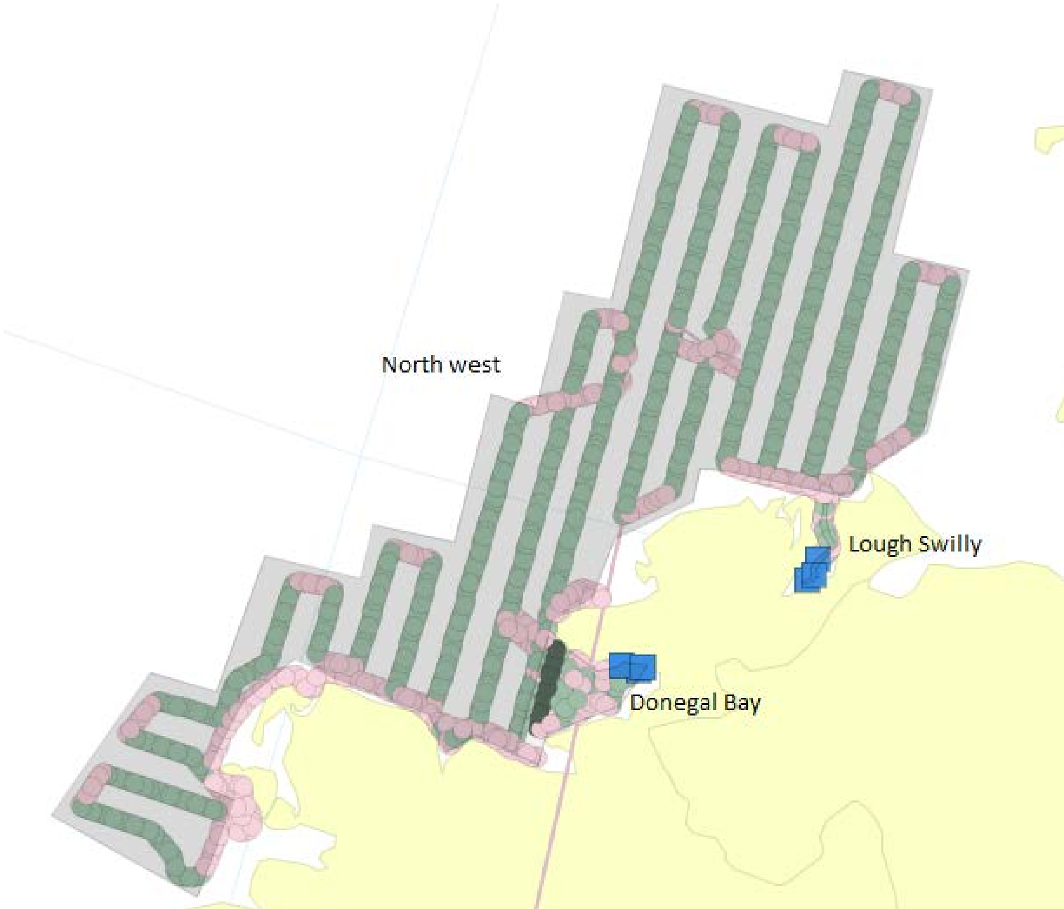


Figure 2.15d. 6aS/7b industry acoustic survey in 2017: StoX strata delineated for the 3 scrutiny areas for herring (Lough Swilly, Northwest, and Donegal Bay). The Northwest strata was also used in the horse mackerel abundance and biomass estimation. The 8 haul/sample stations where herring were obtained for length frequency analysis are also shown. EDSU = 1nmi.

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 Material and methods

3.1 Sampling summary

3.1.1 Sampling statistics 6aN

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 3.1 – 3.5, Table 3.1.

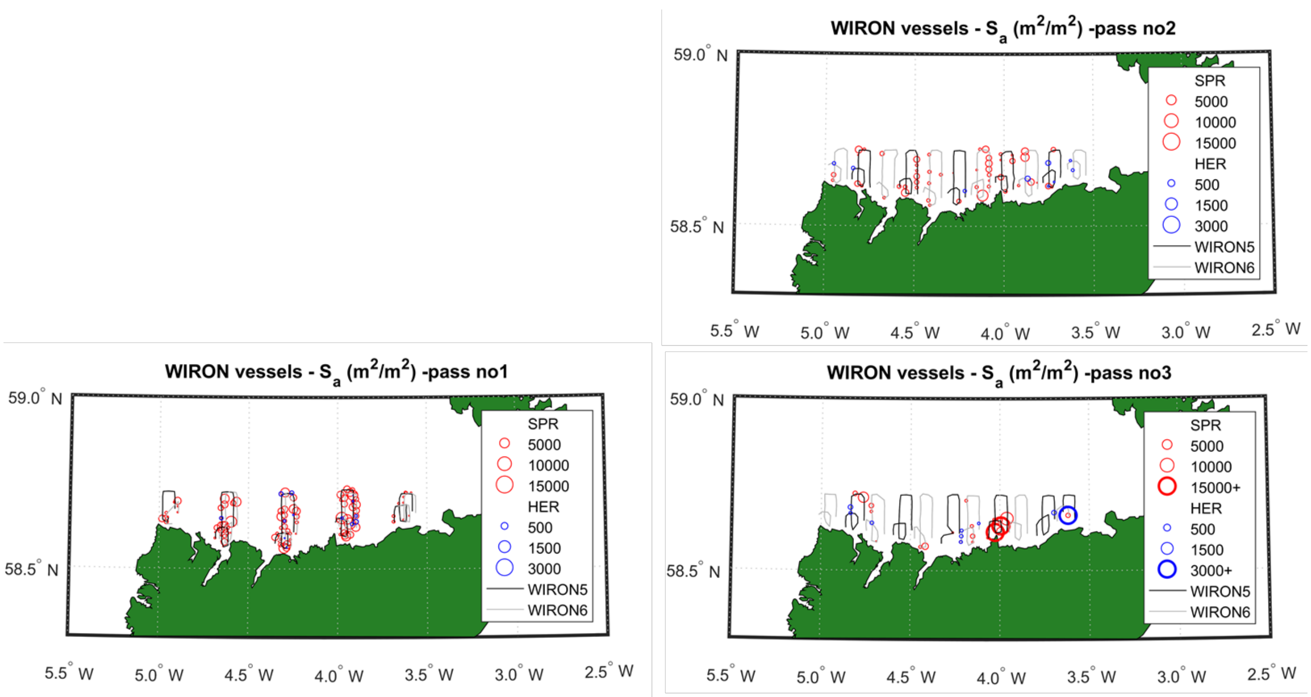


Figure 3.1a. Area 2 East of Cape Wrath, relative acoustic density (NASC m²/mn²). 0.5nmi EDSU. Surveyd by Wiron 5&6

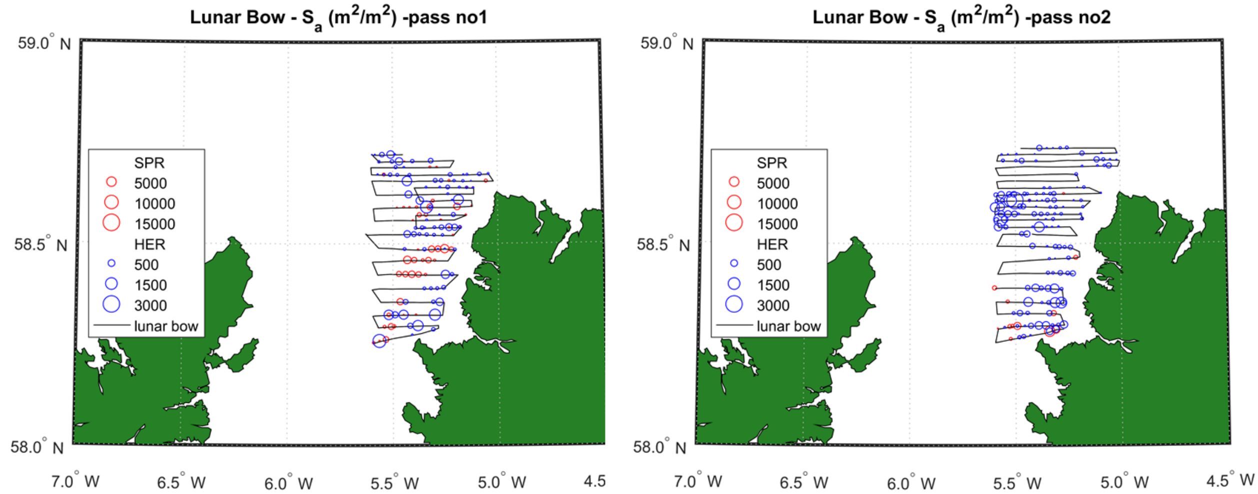


Figure 3.1b. Area 3 The Minch, relative acoustic density (NASC m²/mn²). 1nmi EDSU. Surveyed by Lunar Bow.

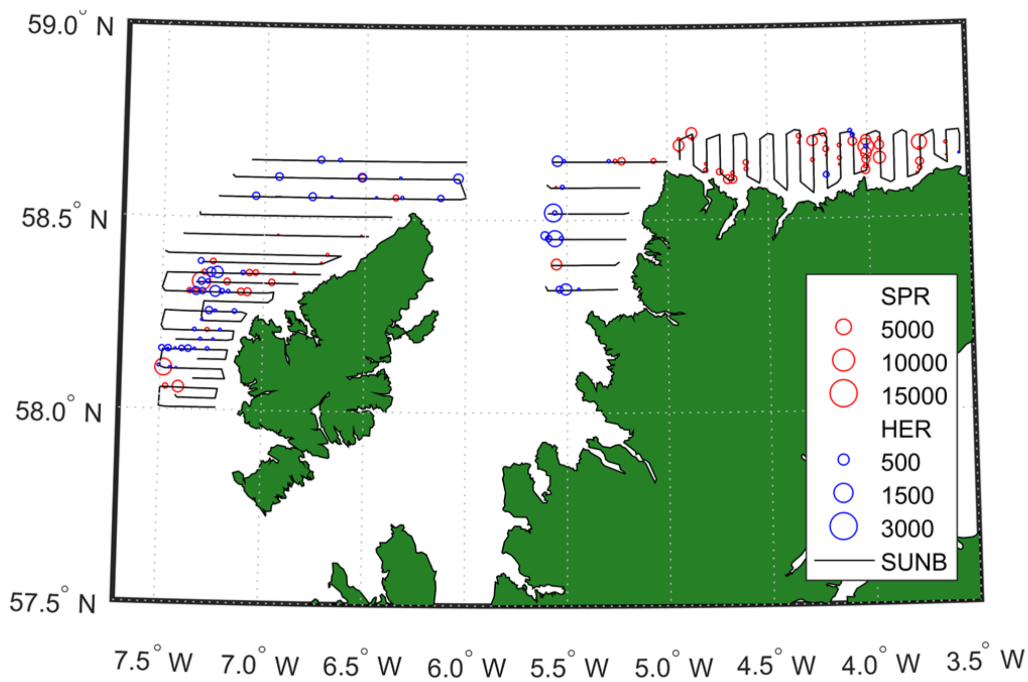


Figure 3.1c. Area 4 Outer Hebrides (and passes of Area 3 and 2) relative acoustic density (NASC m²/mn²). 1nmi EDSU. Surveyed by Sunbeam.

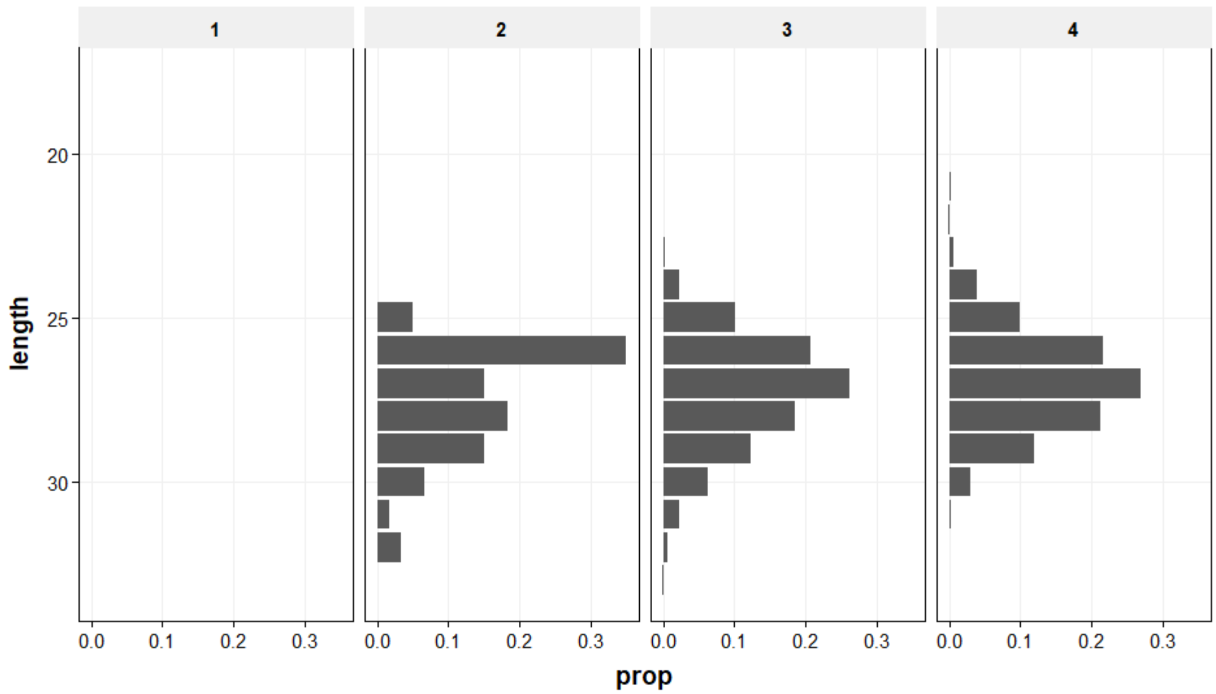


Figure 3.2. Length (cm) frequency distributions of herring in each survey area. Note: no length samples have been taken in area 1 as the (small) catches were taken prior to the survey period.

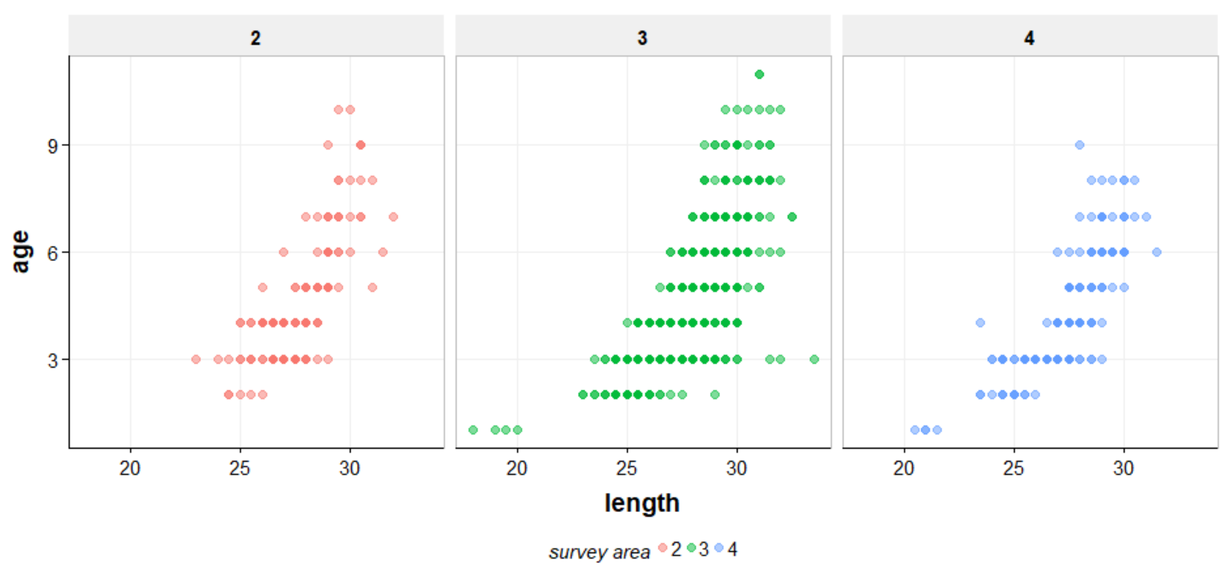


Figure 3.3. Age at length in each survey area

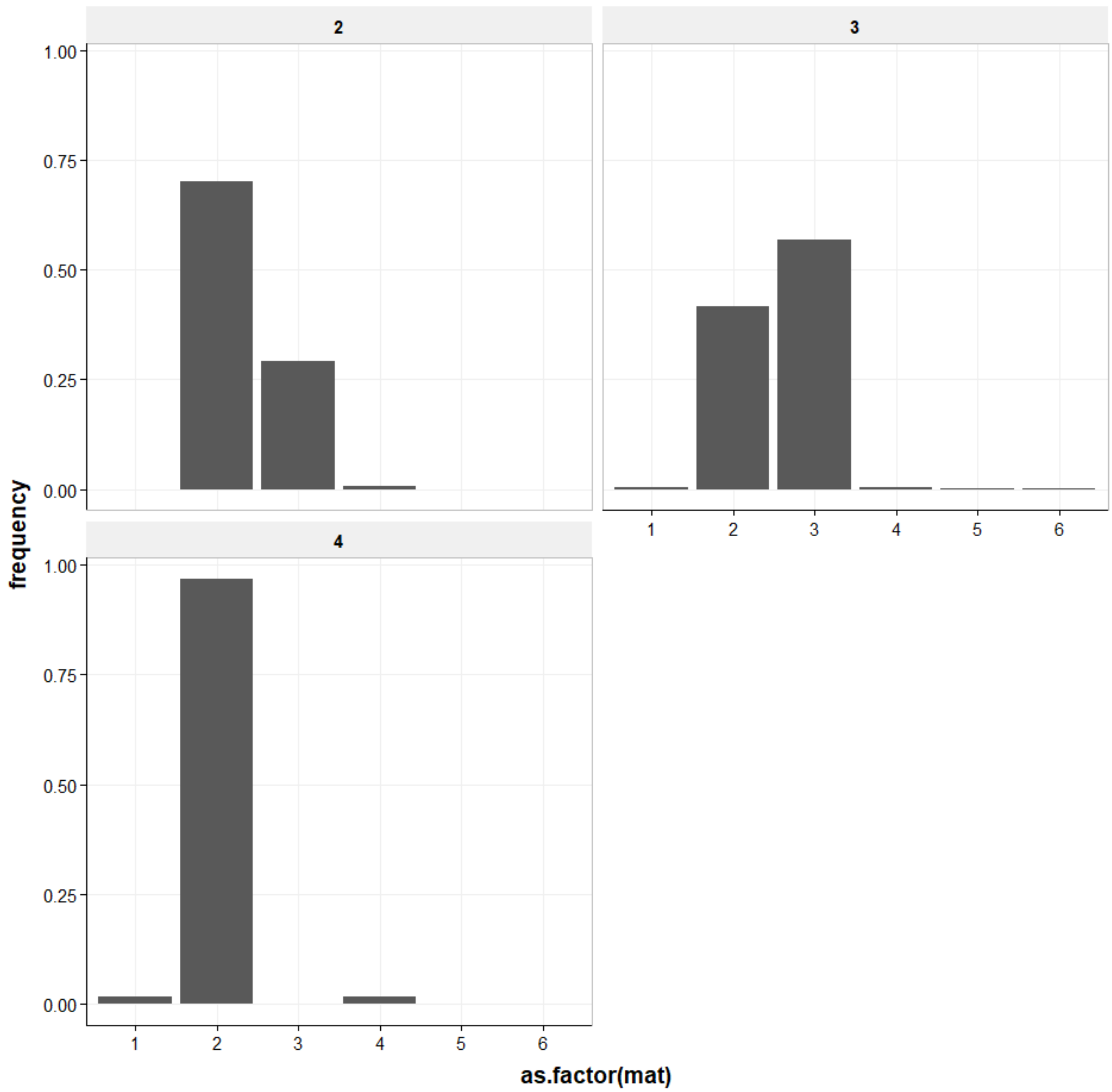


Figure 3.4. Maturity stage distribution in each survey area.

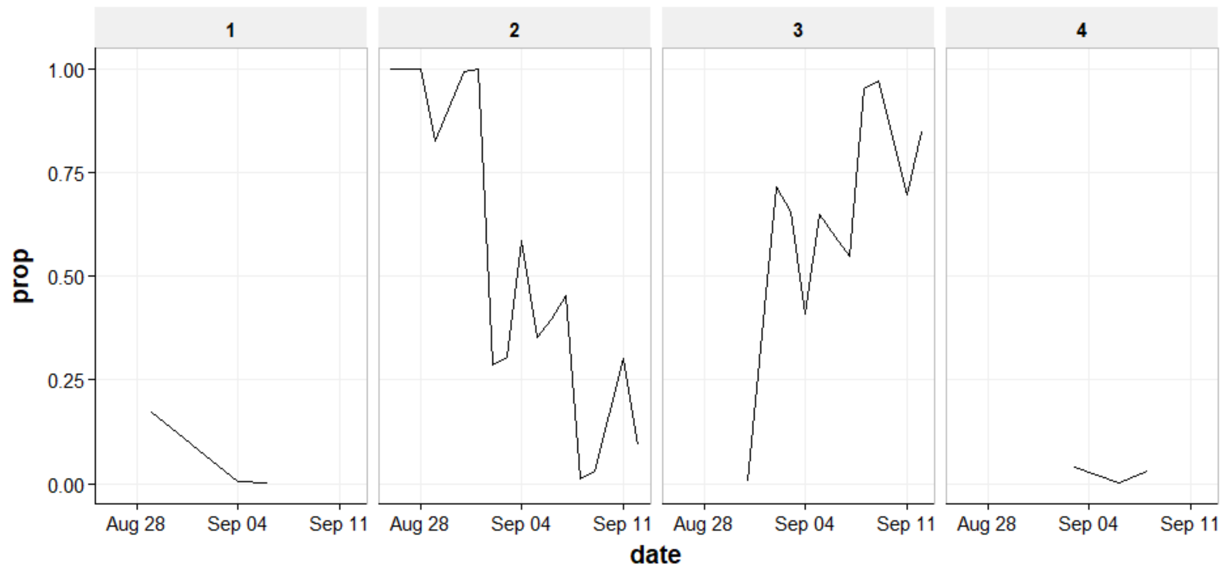


Figure 3.5. Maturation timing in area 3 (International scale). From Maturing (stage 2) to Spawning ready or Spawning (stage 3) to Spent (stage 4) in two weeks. Spawning started around September 1st and that there was still a large amount of spawning activity by the end of the survey on September 11th.

Table 3.1. Haul information and catch composition for hauls relevant to the analysis of the acoustic surveys in 6a North in 2017 (Only hauls catching over 29 herring and used in the analysis included in this table).

Vessel	Haul no.	Date	Time (UTC)	Position	Used in analysis area	Catch (kg)			
						Herring	Sprat	Mackerel	Horse Mackerel
Wiron 6	2	01/09/2017	20:20	58°38' N, 004°22' W	2	48	0	43	4
Wiron 6	9	06/09/2017	09:30	58°35' N, 004°16' W	2	1069	0	1931	0
Sunbeam	2	25/08/2017	08:11	58°33' N, 006°26' W	4	7.9	1	2	0
Lunar Bow	1	28/08/2017	15:30	58°15' N, 005°35' W	3	5	7	274	84
Lunar Bow	2	29/08/2017	09:15	58°23' N, 005°24' W	3	21	5	81	0
Lunar Bow	4	31/08/2017	14:25	58°40' N, 005°36' W	3	814	0	86	0
Lunar Bow	5	01/09/2017	09:40	58°46' N, 005°28' W	3	897	0	53	0
Lunar Bow	7	02/09/2017	12:10	58°18' N, 005°30' W	3	24	0	134	0
Lunar Bow	8	04/09/2017	11:25	58°36' N, 005°31' W	3	4958	0	42	0
Lunar Bow	9	06/09/2017	07:20	58°40' N, 005°18' W	3	160000	0	0	0
Lunar Bow	10	06/09/2017	10:20	58°40' N, 005°19' W	3	500000	0	0	0
Lunar Bow	11	06/09/2017	14:00	58°39' N, 005°17' W	3	90000	0	0	0
Dirk Dirk	2	29/08/2017	16:40	58°39' N, 004°28' W	2	18	28	8	0
Dirk Dirk	3	30/08/2017	23:00	58°07' N, 007°15' W	4	6328	0	25	0

3.1.2 Sampling statistics 6aS/7bc

After calibration of the towed body mounted transducer at Rathmullan in Lough Swilly, approximately 1,500nmi of transects were completed successfully. A total of four hauls were completed, however, only three were landed on deck as the net was torn during haul 2. In some areas where marks of herring were observed, the vessel was unable to fish due to the shallow water depth (e.g. <20m in Lough Swilly) and size of gear available. The monitoring fishery was being conducted at the same time as the survey, on smaller boats in the same areas. Biological samples from some of these vessels were used to augment the sample from the survey. Samples were taken from boats fishing in Lough Swilly, Bruckless Bay and Inver Bay as close spatially and temporally as possible to the survey in these areas.

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 3.6-3.9, Table 3.2 & 3.3.

The location of survey hauls and samples from the fishery is shown in Figure 3.6. 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.

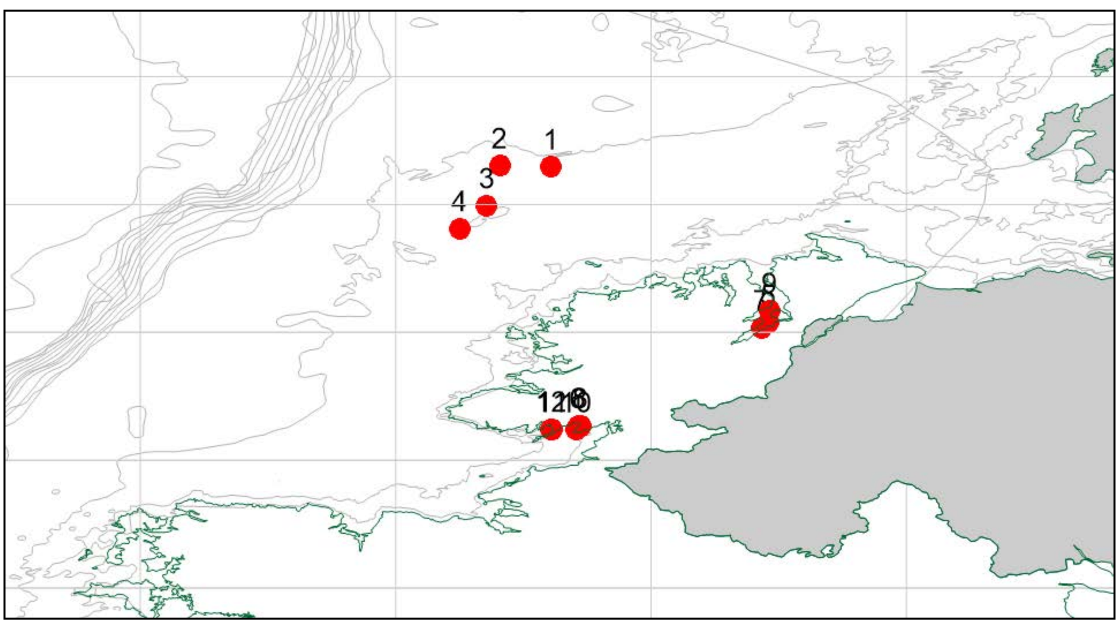


Figure 3.6. Distribution of biological samples obtained in 6aS,7b - all samples from the survey and the monitoring fishery.

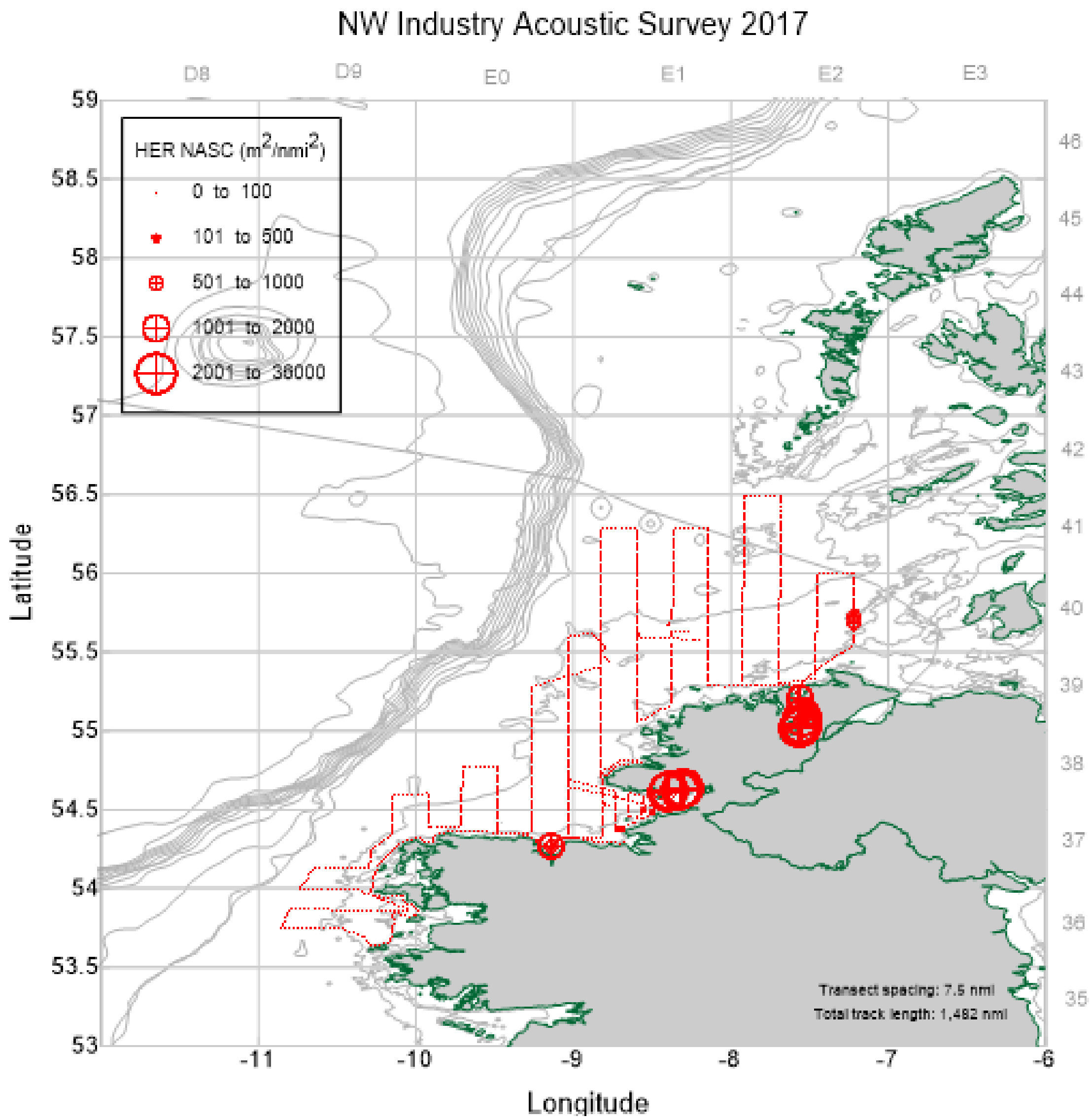


Figure 3.7a. 6aS,7b industry acoustic survey in 2017: distribution of NASC allocated to herring.

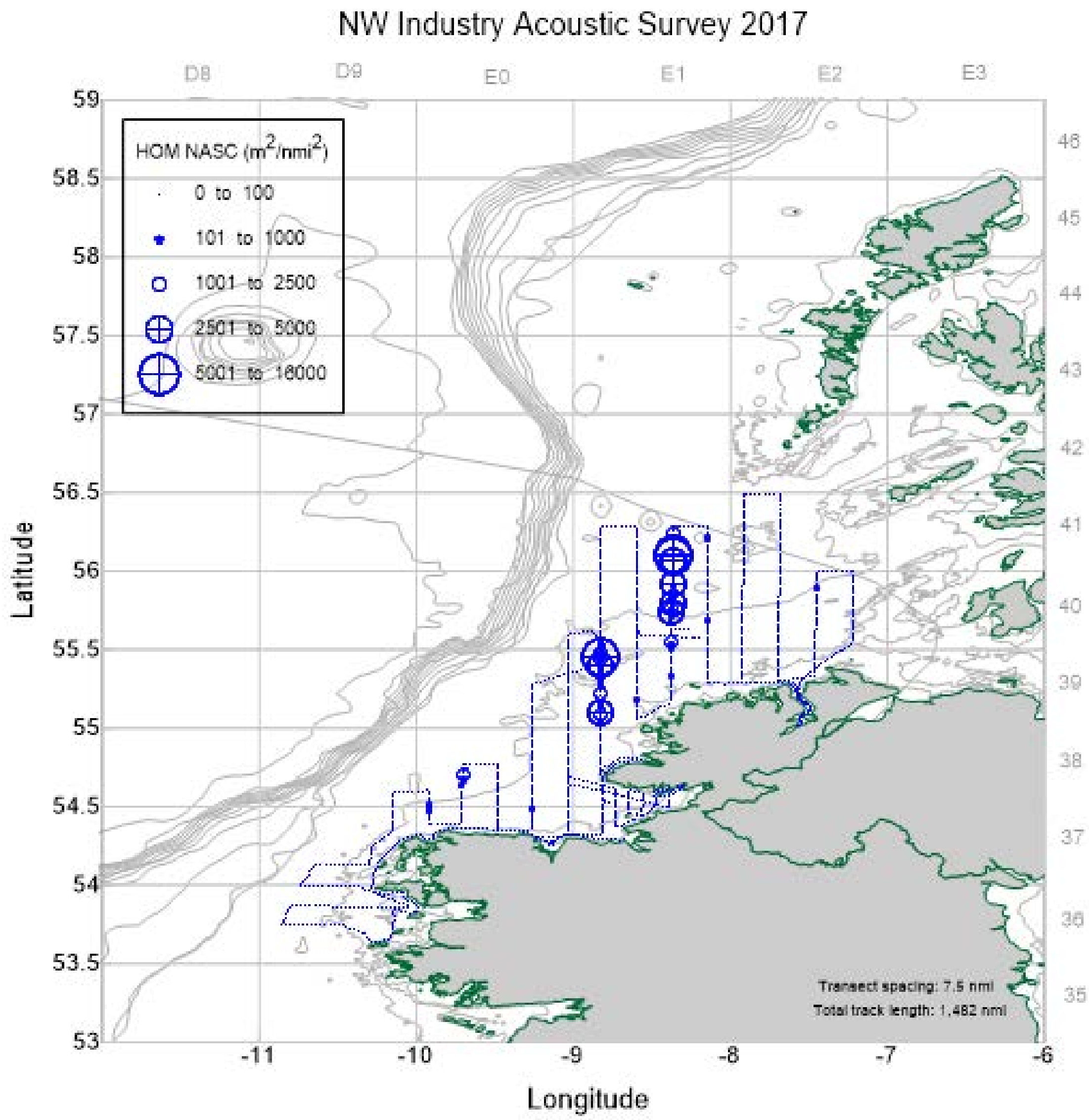


Figure 3.7b. 6aS,7b industry acoustic survey in 2017: distribution of NASC allocated to horse mackerel.

Table 3.2. Biological sampling summary statistics from survey hauls and samples from the fishery in 6aS,7b in 2017.

Haul/Station	Date	Location	Fish (measured/lengths)		Ages/maturity/sex
			Clupea Harengus	*Trachurus trachurus*	
1	20/11/2017	NW Tory Is.		259	50
2	21/11/2017	NW Tory Is.	n/a	n/a	n/a
3	21/11/2017	NW Tory Is.		294	50
4	24/11/2017	NW Tory Is.		232	50
5	14/11/2017	Lough Swilly	338		338
6	20/11/2017	Inver Bay	124		124
7	21/11/2017	Lough Swilly	211		211
8	04/12/2017	Inver Bay	165		165
9	01/12/2017	Lough Swilly	64		64
10	24/11/2017	Inver Bay	54		54
11	30/11/2017	Bruckless Bay	125		125
12	12/04/2017	Bruckless Bay	118		118

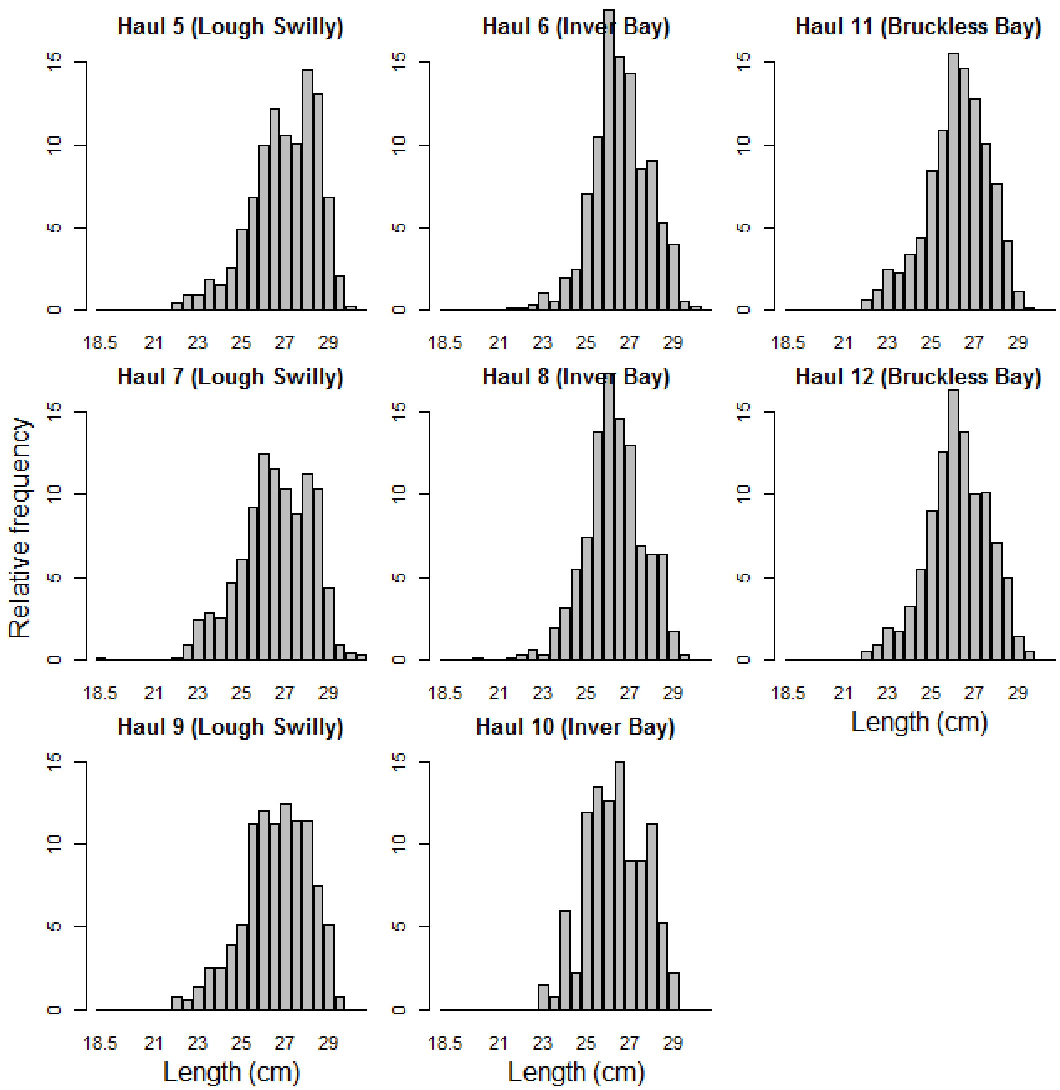


Figure 3.8a. Length (cm) frequency distributions of herring in each haul in 6aS/7b.

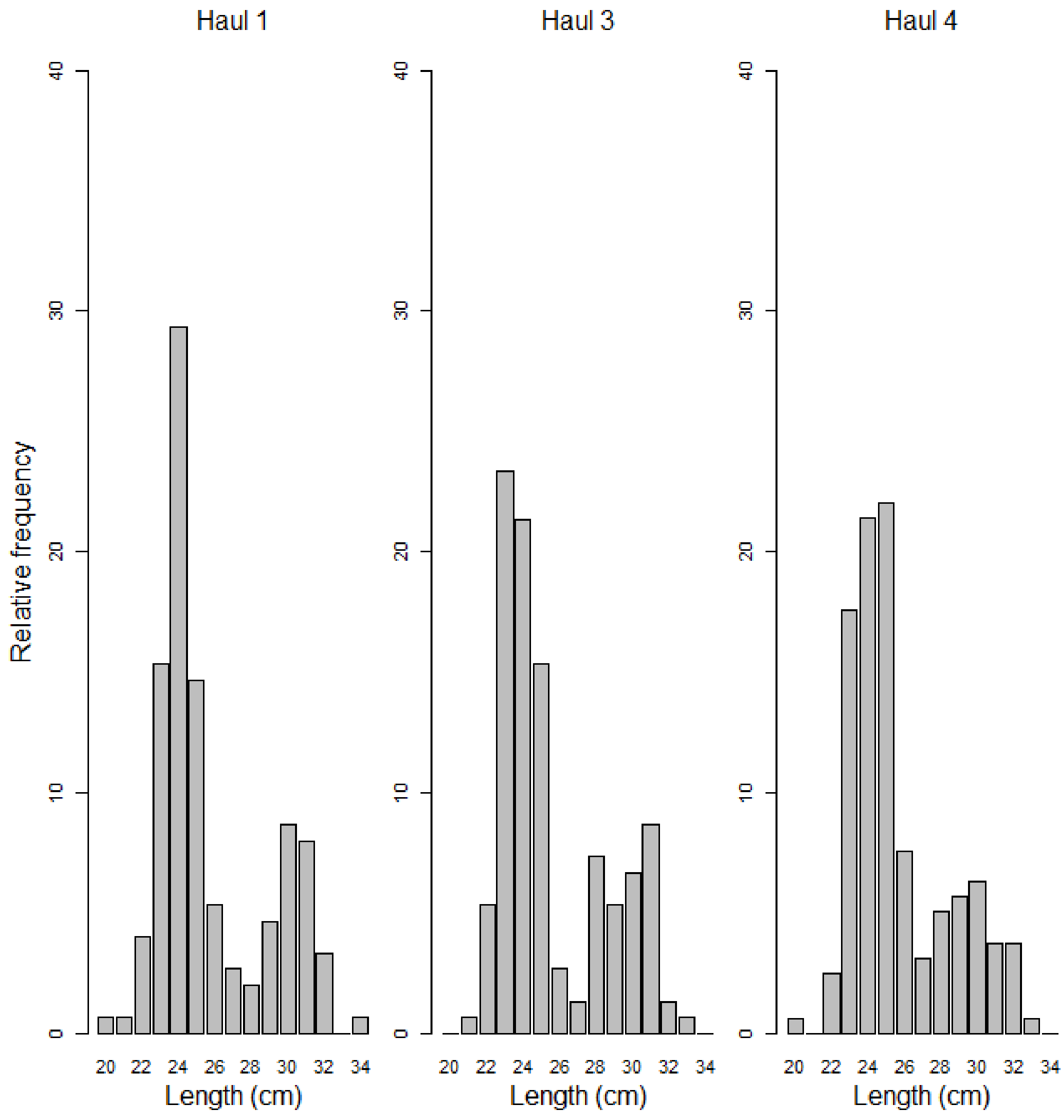


Figure 3.8b. Length (cm) frequency distributions of horse mackerel in each haul in 6aS,7b.

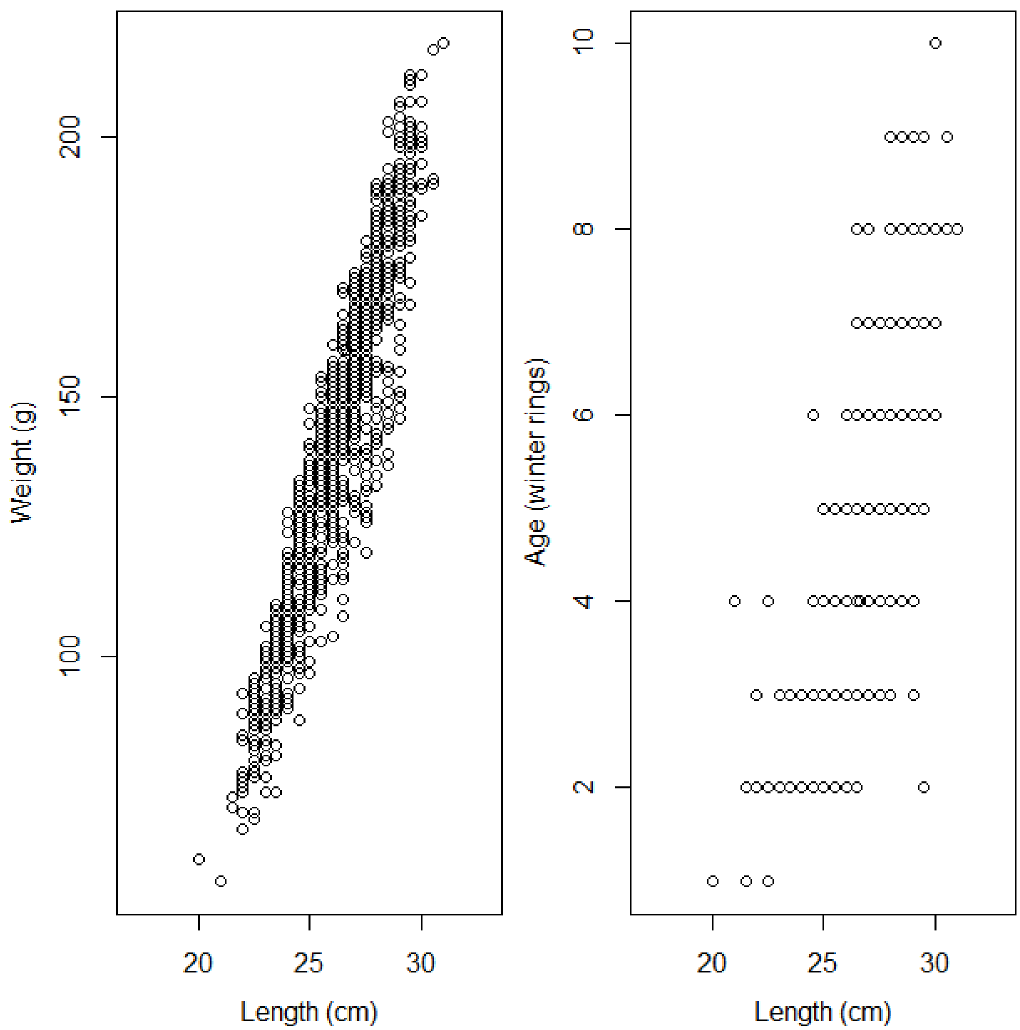


Figure 3.9. 6aS,7b industry acoustic survey in 2017: weight at length and age at length of herring.

Maturity at age for 6aS,7bc herring is shown in Table 7. 66% of 1-wr herring were immature, and 6.7% of 2-wr herring were immature.

Table 3.3. Maturity at age for 6aS,7bc herring in 2017.

Age (winter rings)	Immature	Mature
1	66%	33%
2	6.7%	93.3%
3	1.3%	98.7%

4	0.4	99.6
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. In each section, the summary table for each area is followed by the details for each strata.

3.2.1 6aN (Tables 3.4 to 3.8)

Table 3.4. Total Abundance and overall biological composition of herring in 6a North from the acoustic survey. *Spawning herring is a subset of the mature herring.

Age	Abundance ('000s)	Mature	Spawning	Biomass (t)	Mean length (cm)	Mean weight (g)
1	3454	0%	0%	198	19.1	57.3
2	14252	98%	3%	1918	25.5	134.6
3	57465	99%	31%	9335	26.7	162.4
4	18576	97%	27%	3366	27.9	181.2
5	8360	100%	40%	1764	28.8	210.9
6	7806	98%	37%	1676	29.4	214.7
7	5307	99%	35%	1215	29.6	229.0
8	1895	100%	54%	447	30.1	235.6
9	593	100%	60%	126	29.0	211.8
10	225	100%	40%	60	31.2	266.7
Immature	4958	-	-	425	21.5	85.7
Mature	112980	-	-	19679	27.3	174.2
Spawning*	33063	-	-	6149	27.8	186.0
TOTAL	117937			20104	27.1	170.5

Table 3.5a. Overall length and age distribution for Area 2 East of Cape Wrath.

LenGrp	age 2	3	4	5	6	7	8	9	10	Number (1E3)	Biomass (1E3kg)	Mean W (g)
23.0-23.5	12	-	-	-	-	-	-	-	-	12	1.3	103.00
23.5-24.0	-	-	-	-	-	-	-	-	-	-	-	-
24.0-24.5	12	-	-	-	-	-	-	-	-	12	1.3	105.00
24.5-25.0	19	-	-	-	-	-	-	-	-	19	2.3	124.33
25.0-25.5	14	14	7	-	-	-	-	-	-	34	4.6	132.20
25.5-26.0	14	516	-	-	-	-	-	-	-	530	67.5	127.44
26.0-26.5	6	2007	502	-	-	-	-	-	-	2515	369.5	146.92
26.5-27.0	-	2043	6	-	-	-	-	-	-	2048	313.6	153.09
27.0-27.5	-	1065	16	5	-	-	-	-	-	1086	179.2	165.03
27.5-28.0	-	1045	9	4	-	-	-	-	-	1058	181.2	171.20
28.0-28.5	-	1014	514	14	5	-	-	-	-	1547	277.1	179.12
28.5-29.0	-	995	4	18	9	-	-	-	-	1026	196.7	191.72
29.0-29.5	-	4	495	512	512	8	4	-	-	1535	299.8	195.31
29.5-30.0	-	-	-	500	4	18	4	-	4	531	115.3	217.16
30.0-30.5	-	-	-	-	502	-	6	6	-	514	114.2	222.06
30.5-31.0	-	-	-	-	-	10	506	5	-	521	125.0	240.01
31.0-31.5	-	-	-	3	-	-	3	-	-	7	1.7	254.00
31.5-32.0	-	-	-	-	3	-	-	-	-	3	0.9	274.00
32.0-32.5	-	-	-	-	495	-	-	-	-	495	144.2	291.00
TSN(1000)	77	8703	1553	1056	1530	36	524	11	4	13495	-	-
TSB(1000 kg)	9.1	1410.1	267.8	218.7	352.6	7.9	125.6	2.5	1.0	-	2395.4	-
Mean length (cm)	24.57	26.91	27.64	29.20	30.30	29.67	30.48	30.22	29.50	-	-	-
Mean weight (g)	118.13	162.02	172.42	207.09	230.49	218.88	239.80	221.84	230.00	-	-	177.50

Table 3.5b. Biological composition of herring in Area 2 East of Cape Wrath from the acoustic survey. *Is a subset of the mature herring.

Age	Abundance ('000s)	Mature	Spawning	Biomass (t)	Mean length (cm)	Mean weight (g)
1	0	-	-	0	-	-
2	77	100%	34%	9	24.6	118
3	8703	100%	86%	1410	26.9	162
4	1553	100%	96%	268	27.6	172
5	1056	100%	47%	219	29.2	207
6	1530	100%	98%	353	30.3	230
7	36	100%	25%	8	29.7	219
8	524	100%	95%	126	30.5	240
9	11	100%	55%	3	30.2	222
10	4	100%	0%	1	29.5	230
Immature	0	-	-	0	-	-
Mature	13495	-	-	2395	27.7	178
Spawning*	11510	-	-	2042	27.7	177
TOTAL	13495	100%	85%	2395	27.7	178

Figure 3.6a. Overall length and age distribution for Area 3 The Minch**.** Fish in the unknown age category were assumed to be in the age 10 category given the length and given this is the oldest age seen otherwise.

LenGrp	age 1	2	3	4	5	6	7	8	9	10	Unknown	Number (1E3)	Biomass (1E3kg)	Mean W (g)
18.0-18.5	864	-	-	-	-	-	-	-	-	-	-	864	38.9	45.00
18.5-19.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19.0-19.5	864	-	-	-	-	-	-	-	-	-	-	864	47.5	55.00
19.5-20.0	864	-	-	-	-	-	-	-	-	-	-	864	51.8	60.00
20.0-20.5	864	-	-	-	-	-	-	-	-	-	-	864	59.6	69.00
20.5-21.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21.0-21.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21.5-22.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22.0-22.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22.5-23.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23.0-23.5	-	50	-	-	-	-	-	-	-	-	-	50	5.2	103.00
23.5-24.0	-	89	-	-	-	-	-	-	-	-	-	89	10.4	117.00
24.0-24.5	-	92	137	-	-	-	-	-	-	-	-	229	28.2	123.20
24.5-25.0	-	999	270	-	-	-	-	-	-	-	-	1269	154.3	121.57
25.0-25.5	-	1661	2926	-	-	-	-	-	-	-	-	4587	572.7	124.85
25.5-26.0	-	4736	2328	132	-	-	-	-	-	-	-	7196	989.5	137.51
26.0-26.5	-	4895	6594	-	-	-	-	-	-	-	-	11489	1711.6	148.98
26.5-27.0	-	522	10392	261	-	-	-	-	-	-	-	11175	1739.5	155.66
27.0-27.5	-	-	9589	2282	-	-	-	-	-	-	-	11871	2000.6	168.53
27.5-28.0	-	44	6360	3574	221	-	-	-	-	-	-	10200	1778.4	174.36
28.0-28.5	-	-	2825	2201	1293	535	-	-	-	-	-	6854	1284.5	187.40
28.5-29.0	-	-	437	3849	393	306	306	219	219	-	-	5729	1112.1	194.12
29.0-29.5	-	-	838	1555	2393	529	794	-	-	-	-	6109	1265.8	207.20
29.5-30.0	-	-	218	262	393	524	1004	87	87	-	-	2576	555.8	215.73
30.0-30.5	-	-	89	224	268	537	716	-	89	45	-	1969	444.4	225.70
30.5-31.0	-	-	-	-	134	45	672	90	-	45	-	986	235.5	238.82
31.0-31.5	-	-	-	-	137	91	137	137	-	46	-	549	139.8	254.83
31.5-32.0	-	-	-	-	-	43	-	216	43	-	-	303	76.9	254.00
32.0-32.5	-	-	-	-	-	86	-	43	-	43	-	172	48.0	279.50
32.5-33.0	-	-	-	-	-	-	87	-	-	-	-	87	24.8	285.00
33.0-33.5	-	-	-	-	-	-	-	-	-	-	43	43	11.6	268.00
TSN(1000)	3454	13087	43005	14340	5233	2696	3717	792	439	178	43	86986	-	-
TSB(1000 kg)	197.8	1762.5	6956.8	2589.3	1124.3	572.5	847.1	186.2	91.9	47.4	11.6	-	14387.3	-
Mean length (cm)	19.13	25.56	26.70	27.97	28.83	29.27	29.71	30.28	29.30	30.86	33.00	-	-	-
Mean weight (g)	57.25	134.68	161.77	180.56	214.83	212.30	227.91	235.15	209.52	266.00	268.00	-	-	165.40

Table 3.6b. Biological composition of herring in Area 3 The Minch, from the acoustic survey. *Is a subset of the mature herring.

Age	Abundance ('000s)	Mature	Spawning	Biomass (t)	Mean length (cm)	Mean weight (g)
1	3454	0%	0%	198	19.1	57.3
2	13087	98%	3%	1763	25.6	134.7
3	43005	99%	24%	6957	26.7	161.8
4	14340	96%	24%	2589	28.0	180.6
5	5233	100%	54%	1124	28.8	214.8
6	2696	93%	52%	573	29.3	212.3
7	3717	99%	49%	847	29.7	227.9
8	792	100%	67%	186	30.3	235.2
9	439	100%	80%	92	29.3	209.5
10	221	100%	40%	59	31.3	266.4
Immature	4958			424.7	21.5	85.7
Mature	82029			13963	27.1	170.2

Spawning*	21324			4072	27.8	191.0
TOTAL	86986	94%	25%	14387	26.8	165.4

Figure 3.7a. Length and age distribution for Area 4 Hebrides.

LenGrp	age 2	3	4	5	6	7	8	9	Number (1E3)	Biomass (1E3kg)	Mean W (g)
23.5-24.0	152	-	76	-	-	-	-	-	229	31.3	137.00
24.0-24.5	76	152	-	-	-	-	-	-	229	29.7	130.00
24.5-25.0	229	457	-	-	-	-	-	-	686	94.5	137.78
25.0-25.5	269	113	-	-	-	-	-	-	381	53.1	139.45
25.5-26.0	219	838	-	-	-	-	-	-	1058	162.9	154.07
26.0-26.5	143	753	-	-	-	-	-	-	896	144.3	161.06
26.5-27.0	-	1134	76	-	-	-	-	-	1210	213.4	176.39
27.0-27.5	-	811	591	-	76	-	-	-	1478	254.7	172.32
27.5-28.0	-	1051	528	737	143	-	-	-	2459	462.9	188.23
28.0-28.5	-	152	829	305	286	76	-	143	1792	354.9	198.07
28.5-29.0	-	219	439	372	658	76	76	-	1841	358.7	194.87
29.0-29.5	-	76	143	296	680	667	131	-	1993	420.5	211.01
29.5-30.0	-	-	-	286	792	76	76	-	1231	277.9	225.75
30.0-30.5	-	-	-	76	868	439	152	-	1536	349.9	227.85
30.5-31.0	-	-	-	-	-	143	143	-	286	73.9	258.00
31.0-31.5	-	-	-	-	-	76	-	-	76	18.6	244.00
31.5-32.0	-	-	-	-	76	-	-	-	76	19.6	257.00
TSN(1000)	1088	5757	2683	2071	3580	1554	579	143	17456	-	-
TSB(1000 kg)	146.1	968.1	509.0	420.5	751.2	360.1	134.7	31.2	-	3320.9	-
Mean length (cm)	24.85	26.44	27.65	28.34	29.13	29.47	29.63	28.00	-	-	-
Mean weight (g)	134.22	168.16	189.73	202.99	209.82	231.69	232.83	218.00	-	-	190.25

Table 3.7b. Biological composition of herring in Area 4 Hebrides, from the acoustic survey. *Is a subset of the mature herring.

Age	Abundance ('000s)	Mature	Spawning	Biomass (t)	Mean length (cm)	Mean weight (g)
1	0	-	-	0	-	-
2	1088	100%	0%	146	24.9	134.2
3	5757	100%	3%	968	26.4	168.2
4	2683	100%	3%	509	27.7	189.7
5	2071	100%	0%	421	28.3	203.0
6	3580	100%	0%	751	29.1	209.8
7	1554	100%	0%	360	29.5	231.7
8	579	100%	0%	135	29.6	232.8
9	143	100%	0%	31	28.0	218.0
10	0	-	-	0	-	-
Immature	0			0	-	-
Mature	17456			3321	27.7	190.3
Spawning*	229			36	26.8	155.7
TOTAL	17456	100%	1%	3321	27.7	190.3

The results of the uncertainty estimates (CV) for 6aN are shown in Table 12. The CV estimates are high (~0.37) for the survey in 2016.

Table 3.8. 6aNc uncertainty estimates (with CV) by weight and number for the 3 areas

3.2.2 6aS/7b herring (Table 3.9 to 3.13)

The estimated total stock biomass (TSB), number at age, numbers at length class and mean weight of herring found in each of the survey areas is shown in Tables 3.9-3.13. The transects in Lough Swilly were executed 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 two other stratum; NW (parallel transects, 7.5 nmi. spacing) and Donegal Bay (parallel transects with 3.5nmi. spacing). The combined estimated numbers at age and biomass at age over the entire survey area is also shown in Table 9. The TSB estimate for the combined 6aS,7b area was 40,646 tonnes (Lough Swilly = 12,098 tonnes, Donegal Bay = 23,157 tonnes, and the remaining NW area = 5,391 tonnes).

Table 3.9. 6aS,7b industry acoustic survey in 2017: age-disaggregated estimate of mature herring in total survey area. The total estimated TSB for the entire survey area = 40,646 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)
20.0-20.5	168	-	-	-	-	-	-	-	-	-	168	10.2	61.00
20.5-21.0	-	-	-	-	-	-	-	-	-	-	-	-	-
21.0-21.5	-	-	-	281	-	-	-	-	-	-	281	16.0	57.00
21.5-22.0	170	170	-	-	-	-	-	-	-	-	341	24.5	72.00
22.0-22.5	-	1944	561	-	-	-	-	-	-	-	2505	201.7	80.50
22.5-23.0	249	6435	-	249	-	-	-	-	-	-	6933	597.4	86.16
23.0-23.5	-	8581	1079	-	-	-	-	-	-	-	9660	893.3	92.47
23.5-24.0	-	10763	3101	-	-	-	-	-	-	-	13864	1363.3	98.34
24.0-24.5	-	8806	9581	-	-	-	-	-	-	-	18387	1980.7	107.72
24.5-25.0	-	5756	14141	835	-	302	-	-	-	-	21033	2415.7	114.85
25.0-25.5	-	742	17038	4182	776	-	-	-	-	-	22738	2826.2	124.29
25.5-26.0	-	1258	15060	5526	559	-	-	-	-	-	22402	2980.6	133.05
26.0-26.5	-	186	12318	8470	929	667	-	-	-	-	22570	3162.5	140.12
26.5-27.0	-	295	9458	10990	481	852	481	295	-	-	22851	3290.4	144.00
27.0-27.5	-	-	5305	12165	2677	1821	295	187	-	-	22450	3471.3	154.62
27.5-28.0	-	-	2511	6766	2402	6690	3986	-	-	-	22355	3589.0	160.55
28.0-28.5	-	-	662	3682	1802	10636	3677	957	295	-	21711	3700.0	170.42
28.5-29.0	-	-	-	667	3444	8255	5850	3322	481	-	22020	3921.3	178.08
29.0-29.5	-	-	295	479	3205	7075	3987	3575	479	-	19096	3500.8	183.32
29.5-30.0	-	249	-	-	746	2572	1496	3485	497	-	9044	1733.7	191.69
30.0-30.5	-	-	-	-	-	569	1549	1344	-	387	3850	759.0	197.14
30.5-31.0	-	-	-	-	-	-	-	492	246	-	738	147.5	200.00
31.0-31.5	-	-	-	-	-	-	-	281	-	-	281	61.3	218.00
TSN(1000)	587	45184	91109	54292	17021	39439	21321	13938	1998	387	285278	-	-
TSB(1000 kg)	43.1	4490.8	11796.8	7934.1	2802.8	6779.5	3764.3	2600.9	360.1	74.0	-	40646.5	-
Mean length (cm)	21.50	23.56	25.32	26.51	27.76	28.19	28.43	29.05	29.04	30.00	-	-	-
Mean weight (g)	73.39	99.39	129.48	146.14	164.67	171.90	176.55	186.60	180.21	191.00	-	-	142.48

Table 3.10. 6aS,7b industry acoustic survey in 2017: age-disaggregated estimate of mature herring in survey Lough Swilly area. The estimated TSB for the Lough Swilly strata = 12,098 t.

Variable: Abundance
EstLayer: 1
Stratum: Swilly
SpecCat: Clupea herangus

LenGrp	age 1	2	3	4	5	6	7	8	9	Number (1E3)	Biomass (1E3kg)	Mean W (g)
20.0-20.5	138	-	-	-	-	-	-	-	-	138	8.4	61.00
20.5-21.0	-	-	-	-	-	-	-	-	-	-	-	-
21.0-21.5	-	-	-	-	-	-	-	-	-	-	-	-
21.5-22.0	140	140	-	-	-	-	-	-	-	280	20.2	72.00
22.0-22.5	-	432	-	-	-	-	-	-	-	432	31.1	72.00
22.5-23.0	-	1821	-	-	-	-	-	-	-	1821	155.0	85.14
23.0-23.5	-	2456	682	-	-	-	-	-	-	3139	291.5	92.87
23.5-24.0	-	2425	943	-	-	-	-	-	-	3368	325.9	96.76
24.0-24.5	-	1937	4358	-	-	-	-	-	-	6295	678.4	107.77
24.5-25.0	-	1747	4659	437	-	-	-	-	-	6843	769.1	112.38
25.0-25.5	-	613	5055	1991	153	-	-	-	-	7812	941.5	120.53
25.5-26.0	-	308	4152	2615	461	-	-	-	-	7536	979.8	130.02
26.0-26.5	-	153	3837	2609	767	307	-	-	-	7674	1046.1	136.32
26.5-27.0	-	-	2456	4451	153	460	153	-	-	7674	1061.1	138.28
27.0-27.5	-	-	1701	3711	1237	773	-	155	-	7576	1143.3	150.92
27.5-28.0	-	-	612	2907	765	2601	612	-	-	7497	1161.2	154.88
28.0-28.5	-	-	303	606	757	3181	1818	303	-	6968	1161.2	166.65
28.5-29.0	-	-	-	307	1383	2919	2151	307	154	7221	1237.2	171.32
29.0-29.5	-	-	-	153	459	1223	1835	765	153	4587	811.5	176.90
29.5-30.0	-	-	-	-	-	280	420	420	-	1121	216.7	193.25
30.0-30.5	-	-	-	-	-	142	-	142	-	285	58.9	207.00
TSN(1000)	278	12032	28758	19786	6136	11888	6990	2092	307	88267	-	-
TSB(1000 kg)	18.6	1174.3	3615.9	2780.6	946.2	1944.5	1188.8	373.4	55.8	-	12098.1	-
Mean length (cm)	20.76	23.55	25.21	26.44	27.37	28.00	28.43	28.80	28.75	-	-	-
Mean weight (g)	67.05	97.60	125.74	140.53	154.20	163.57	170.09	178.45	182.00	-	-	137.06

Table 3.11. 6aS,7b industry acoustic survey in 2017: age-disaggregated estimate of mature herring in survey Northwest area. The estimated TSB for the Northwest strata = 5,391 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)
20.0-20.5	30	-	-	-	-	-	-	-	-	-	30	1.8	61.00
20.5-21.0	-	-	-	-	-	-	-	-	-	-	-	-	-
21.0-21.5	-	-	-	30	-	-	-	-	-	-	30	1.7	57.00
21.5-22.0	30	30	-	-	-	-	-	-	-	-	61	4.4	72.00
22.0-22.5	-	250	55	-	-	-	-	-	-	-	305	24.1	78.91
22.5-23.0	27	844	-	27	-	-	-	-	-	-	898	77.3	86.00
23.0-23.5	-	1134	170	-	-	-	-	-	-	-	1304	120.6	92.54
23.5-24.0	-	1359	414	-	-	-	-	-	-	-	1773	173.8	98.07
24.0-24.5	-	1119	1390	-	-	-	-	-	-	-	2509	270.3	107.73
24.5-25.0	-	766	1914	128	-	32	-	-	-	-	2839	324.5	114.31
25.0-25.5	-	129	2264	614	97	-	-	-	-	-	3105	383.6	123.55
25.5-26.0	-	162	1976	810	97	-	-	-	-	-	3045	403.4	132.47
26.0-26.5	-	32	1651	1133	162	97	-	-	-	-	3075	428.6	139.38
26.5-27.0	-	32	1229	1552	65	129	65	32	-	-	3105	443.7	142.90
27.0-27.5	-	-	715	1624	390	260	32	32	-	-	3054	470.0	153.91
27.5-28.0	-	-	323	969	323	937	485	-	-	-	3037	484.2	159.45
28.0-28.5	-	-	96	450	257	1413	546	128	32	-	2922	495.9	169.70
28.5-29.0	-	-	-	97	485	1133	809	388	65	-	2977	526.4	176.80
29.0-29.5	-	-	32	64	385	866	577	449	64	-	2437	444.5	182.38
29.5-30.0	-	27	-	-	82	300	191	409	55	-	1063	204.0	191.79
30.0-30.5	-	-	-	-	-	79	159	159	-	40	436	86.4	198.09
30.5-31.0	-	-	-	-	-	-	-	53	26	-	79	15.8	200.00
31.0-31.5	-	-	-	-	-	-	-	30	-	-	30	6.5	218.00
TSN(1000)	87	5884	12229	7499	2343	5246	2863	1681	242	40	38113	-	-
TSB(1000 kg)	6.3	582.8	1575.2	1087.2	380.7	894.2	501.6	312.3	43.6	7.6	-	5391.4	-
Mean length (cm)	21.30	23.56	25.30	26.50	27.68	28.15	28.42	29.02	29.01	30.00	-	-	-
Mean weight (g)	71.71	99.05	128.81	144.98	162.51	170.46	175.19	185.80	180.36	191.00	-	-	141.46

Table 3.12. 6aS,7b industry acoustic survey in 2017: age-disaggregated estimate of mature herring in survey Donegal Bay area. The estimated TSB for the Donegal Bay strata = 23,157 t.

Variable: Abundance
EstLayer: 1
Stratum: Donegal Bay
SpecCat: Clupea herangus

LenGrp	age 1	2	3	4	5	6	7	8	9	10	Number (1E3)	Biomass (1E3kg)	Mean W (g)
20.0-20.5	-	-	-	-	-	-	-	-	-	-	-	-	-
20.5-21.0	-	-	-	-	-	-	-	-	-	-	-	-	-
21.0-21.5	-	-	-	251	-	-	-	-	-	-	251	14.3	57.00
21.5-22.0	-	-	-	-	-	-	-	-	-	-	-	-	-
22.0-22.5	-	1263	505	-	-	-	-	-	-	-	1768	146.5	82.86
22.5-23.0	222	3771	-	222	-	-	-	-	-	-	4214	365.1	86.63
23.0-23.5	-	4991	227	-	-	-	-	-	-	-	5218	481.2	92.22
23.5-24.0	-	6979	1745	-	-	-	-	-	-	-	8723	863.6	99.00
24.0-24.5	-	5750	3833	-	-	-	-	-	-	-	9583	1032.0	107.69
24.5-25.0	-	3243	7567	270	-	270	-	-	-	-	11351	1322.1	116.48
25.0-25.5	-	-	9719	1576	525	-	-	-	-	-	11821	1501.0	126.98
25.5-26.0	-	788	8931	2102	-	-	-	-	-	-	11821	1597.4	135.13
26.0-26.5	-	-	6830	4728	-	263	-	-	-	-	11821	1687.8	142.78
26.5-27.0	-	262	5774	4986	262	262	262	262	-	-	12072	1785.6	147.91
27.0-27.5	-	-	2890	6830	1051	788	263	-	-	-	11821	1858.0	157.18
27.5-28.0	-	-	1576	2890	1313	3152	2890	-	-	-	11821	1943.6	164.42
28.0-28.5	-	-	263	2627	788	6042	1313	525	263	-	11821	2042.9	172.82
28.5-29.0	-	-	-	263	1576	4203	2890	2627	263	-	11821	2157.7	182.53
29.0-29.5	-	-	262	262	2362	4986	1575	2362	262	-	12072	2244.9	185.96
29.5-30.0	-	221	-	-	664	1992	885	2655	443	-	6860	1313.1	191.42
30.0-30.5	-	-	-	-	-	348	1391	1043	-	348	3129	613.7	196.11
30.5-31.0	-	-	-	-	-	-	-	439	220	-	659	131.8	200.00
31.0-31.5	-	-	-	-	-	-	-	251	-	-	251	54.7	218.00
TSN(1000)	222	27268	50122	27007	8542	22306	11468	10165	1450	348	158899	-	-
TSB(1000 kg)	18.2	2733.7	6605.6	4066.4	1476.0	3940.9	2073.9	1915.3	260.7	66.4	-	23157.0	-
Mean length (cm)	22.50	23.56	25.39	26.57	28.05	28.29	28.44	29.10	29.11	30.00	-	-	-
Mean weight (g)	82.00	100.25	131.79	150.57	172.79	176.67	180.83	188.41	179.80	191.00	-	-	145.73

The results of the uncertainty estimates (CV) for herring 6aS/7b are shown in Table 17. The CV estimates on biomass and abundance are high (~0.50) for the survey in 2017. This is most 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.

Table 3.13. 6aS,7b uncertainty estimates for herring (with CV) by weight and number for the Northwest area, Lough Swilly, Donegal Bay and the total survey area.

```
[1] "Ton by stratum"
       Stratum   Ton.5%   Ton.50%  Ton.95%  Ton.mean    Ton.sd    Ton.cv
1: Donegal Bay  118.767 23091.366 73572.28 24878.826 23274.821 0.9355273
2:          NW 2198.340  5370.212 13627.43  6237.623  3901.170 0.6254257
3:      Swilly 3575.446 11567.025 25760.01 12692.914  6986.635 0.5504358
[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: Donegal Bay   819329.6  158898506  498289810   169956545 158258712 0.9311716
2:          NW 15600734.3   37962976   96473163    44105833  27367061 0.6204862
3:      Swilly 26034763.9   83362205  186394088    92292342  50498829 0.5471616
[1] "Ton by survey"
     Ton.5%  Ton.50%  Ton.95% Ton.mean   Ton.sd    Ton.cv
1: 12267.22 39595.01 84213.44 42650.17 22117.12 0.5185706
[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:  88078598  279530401  581915173   298241571 151197768 0.5069641
```

There was good evidence of offshore containment of herring in 6aS/7b again in 2017, 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 in 2017. There are a number of grounds that were known to have spawning in the past (Figure 2.6), however, no herring aggregations were located in these areas apart from a couple of marks in Killala Bay. Spawning is known to occur, but the lack of occurrence of herring marks in these areas suggest that timing of the survey was inadequate, and therefore containment may not have been achieved in these areas in 2017.

3.2.3 6aS/7b horse mackerel (Table 3.14 to 3.15)

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.

Table 3.14. 6aS/7b industry acoustic survey in 2017: age-disaggregated estimate of horse mackerel in total survey area. The total estimated TSB for the entire survey area = 68,079 tonnes.

Variable: Abundance
EstLayer: 1
Stratum: NW
SpecCat: Trachurus trachurus

LenGrp	age 3	4	5	6	7	8	9	10	Number (1E3)	Biomass (1E3kg)	Mean W (g)
20-21	1822	-	-	-	-	-	-	-	1822	185.9	102.00
21-22	1208	-	-	-	-	-	-	-	1208	91.8	76.00
22-23	16952	-	-	-	-	-	-	-	16952	1546.9	91.25
23-24	93298	-	-	-	-	-	-	-	93298	9434.9	101.13
24-25	97558	-	-	3049	-	-	-	-	100607	11391.4	113.23
25-26	74193	11050	6314	-	-	-	-	-	91557	11525.2	125.88
26-27	10012	16686	-	-	-	-	-	-	26697	3784.4	141.75
27-28	3293	-	-	-	8233	-	-	-	11527	1826.1	158.43
28-29	5866	7333	7333	4400	-	2933	-	-	27864	5116.8	183.63
29-30	1533	-	12265	6132	-	3066	-	3066	26063	5520.7	211.82
30-31	7575	-	4545	-	-	-	18180	-	30301	6695.0	220.95
31-32	-	-	8411	-	-	9813	8411	-	26636	6622.6	248.63
32-33	-	-	-	-	-	-	13349	-	13349	3490.7	261.50
33-34	-	-	-	-	-	-	-	3030	3030	846.9	279.50
TSN(1000)	313311	35069	38868	13581	8233	15813	39941	6096	470911	-	-
TSB(1000 kg)	36502.6	5175.4	7725.7	2465.8	1342.0	3574.1	9809.0	1484.7	-	68079.2	-
Mean length (cm)	24.14	26.10	28.71	27.55	27.00	30.06	30.88	30.99	-	-	-
Mean weight (g)	116.51	147.58	198.76	181.56	163.00	226.03	245.59	243.54	-	-	144.57

The results of the uncertainty estimates (CV) for horse mackerel in 6aS/7b are shown in Table 19. The CV estimates on biomass and abundance are high ~ 0.62 for the survey in 2017. For horse mackerel this is most likely caused by and over-reliance of two transects in particular (Figure 3.7b). Bias considerations for the survey are outlined in Table 13. Many of the considerations in Table 11 are common to all acoustic surveys and should be dealt with and reduced if possible at the survey design stage.

Table 3.15. 6aS,7b industry acoustic survey in 2017: uncertainty estimates of horse mackerel (with CV) by weight and number for the total survey area.

```
[1] "Ton by stratum"
   Stratum   Ton.5%  Ton.50%  Ton.95% Ton.mean   Ton.sd    Ton.cv
1:      NW 8525.341 40694.13 106966.6  47212.5 29220.25 0.6189091
[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:      NW  59017570  281485615  739899322   326615007 202194086 0.6190594
[1] "Ton by survey"
     Ton.5%  Ton.50%  Ton.95% Ton.mean   Ton.sd    Ton.cv
1: 8525.341 40694.13 106966.6  47212.5 29220.25 0.6189091
[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:  59017570  281485615  739899322   326615007 202194086 0.6190594
```

3.2.4 Bias considerations

Bias Considerations	Comment
6.1 Directed movement of fish with respect to the survey tracks	No strong directed movement at this time that would make the 'flow' of herring across the strata greater than within. Pre-spawning and spawning aggregations.
6.2 Avoidance effect	unquantified
6.3 Overlapping survey layers	NA
6.4 Shallow water	NA Future design needs to be considered in inshore areas (e.g. Lough Swilly). Currently separate strata. There was good evidence of offshore containment in 6aS/7b, however, stock was not contained inshore due to hyper-aggregating behaviour and shallow distribution inshore (<10m) in some areas.
6.5 Water temperature and the propagation of the sonar beam	No problems?
6.6 Quality of raw material used	Good weather throughout all surveys in 2017. Good quality raw data from calibrated scientific equipment
6.7 Accuracy of calibration constant	Good calibration
6.8 Biomass species composition	Trawl information, results from monitoring fishery and acoustic expert agreement
6.9 The actual accuracy problem of acoustic surveys	See CV estimates

4 Recommendations for data users

4.1 6aN

The acoustic surveys in the three strata surveyed in 6aN are considered to:

1. Contain the principal active spawning areas advised by ICES (29 April 2016) and the locations of reported commercial fishing activity conducted in August-September in recent years.
2. Provide a reliable estimate of
    a. the biomass of all herring at ages observed in the 3 survey areas
    b. the minimum biomass of mature herring at age (Stages 2-5 on the ICES 6 pt maturity scale, ICES 2011)
    c. the minimum biomass of actively spawning herring (those that we are confident are 6aN herring, stages 3-4 on the ICES 6 pt maturity scale, ICES 2011)

The industry survey has particular value in relation to

- Providing an index of 6aN SSB and monitoring changes in the distribution of herring at this time of year, as well as the timing and locations of spawning.
- Providing the catch-at-age data necessary for assessment and evidence for monitoring of a rebuilding plan, which is presently under revision following ICES evaluation (27 Nov 2017)
- Providing a platform to continue work on stock splitting and stock ID in the greater Malin Shelf area and the use of this information to inform the stock assessment of Western herring.
- Map in detail the spawning locations in 6aN, which is useful in relation to marine spatial planning considerations.
- Promoting positive example of industry-science and developing industry's skills to assess pelagic stocks.

4.2 6aS/7b

The acoustic survey in 6aS/7b was considered to:

- Be a minimum estimate of herring in the 6aS/7b survey area at the time of the survey
- Not contain the herring stock inshore due to the inshore distributions observed on the survey and reported in the fishery

- Have high confidence that the herring surveyed were 6aS/7b fish due to the inshore distribution and maturity stages of the fish sampled
- Be a good second data point of a time-series, were the survey to be continued in the future
- Reflect what was experienced in the monitoring fishery for herring at the same time
- 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)

The survey has particular value in relation to

- Being a good proof of concept that Industry/science partnership is a suitable way to survey this stock, including calibration of towed-body mounted transducers (38 kHz) of the industry vessel in Lough Swilly
- Providing a new index of 6aS/7b SSB for the surveyed area
- Providing a platform to continue work on stock splitting and stock ID in the greater Malin Shelf area and the use of this information to inform the stock assessment of Western herring.
- Documenting changes in the timing of spawning and distribution at this time of year and information on pre-spawning behaviour in inshore areas.

5 Recommendations for future surveys

5.1 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.
- Consider in-season evidence for timing based on progress in the North Sea since missing the peak in timing is the biggest risk.
- Allow time for adaptation of survey to map high intensity areas, particularly in the case of active spawning aggregations.
- Maintain the strategy to try and provide continuous coverage in key areas.
- 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

5.2 6aS/7bc

- Survey in 2018 and beyond – funding of the survey is currently uncertain. In 2017, 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 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 (O'Malley et al 2017) and 2017 relied heavily on herring aggregations from a few areas, resulting in a high cv (~0.37 (2016) and ~0.50 (2017))
- Design – stock not contained inshore in 2017,
    - Survey timing
    - better if schools more widely distributed, before inshore aggregating behaviour is apparent, or a design that deals with the inshore behaviour during this time
    - Net/vessel – smaller net needed to fish in shallow areas if this behaviour is evident in future
    - Inshore design/smaller vessel perhaps more appropriate

- Using samples from fishery useful, but not ideal – more trawl samples containing herring is needed during the survey
- Need to develop protocols surrounding mini-surveys, particularly when large aggregations or hyper aggregating behaviour is observed (i.e. in areas like Lough Swilly)

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References

Barbeaux, S. J., Horne, J. K., and Dorn, M. W. 2013. Characterizing walleye pollock (Theragra chalcogramma) winter distribution from opportunistic acoustic data. ICES Journal of Marine Science, 70: 1162-1173.

Campbell, A. 2016. Sampling Precision in the 6.a, 7.b, and 7.c Herring Fishery. ICES CM 2016/ACOM:51. 16 pp.

Demer, D. A., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., Domokos, R. 2015. Calibration of acoustic instruments. ICES Cooperative Research Report No. 326. 133 pp

EU 2016/0203 (NLE). Proposal for a COUNCIL REGULATION amending Regulations (EU) 2016/72 and (EU) 2015/2072 as regards certain fishing opportunities.

EU 2017/127. COUNCIL REGULATION fixing for 2017 the fishing opportunities for certain fish stocks and groups of fish stocks, applicable in Union waters and, for Union fishing vessels, in certain non-Union waters.

FAO. 2012. Fishing vessel execution of acoustic surveys of deep-sea species: main issues and way forward.: No. 1059.

Fassler, S. M. M., Brunel, T., Gastauer, S., and Burggraaf, D. 2013. Using acoustic data from pelagic fishing vessels to monitor pelagic fish stocks and their ecosystem. ICES C.M. 2013 / G:13.

Geffen, A. J., Nash, R. D. M., and Dickey-Collas, M. 2011. Characterization of herring populations west of the British Isles: an investigation of mixing based on otolith microchemistry. ICES Journal of Marine Science, 68: 1447–1458.

Gerlotto, F. 2015. Report Of The 1st Workshop Of The SPRFMO Task Group On “Fishing Vessels As Scientific Platforms”, 8-11 September 2015, Lima. SPRFMO.

Gutierrez, M., Castillo, R., Segura, M. P., S., and Flores, M. 2012. Trends in spatio-temporal distribution of Peruvian anchovy and other small pelagic fish biomass from 1966-2009. Latin American Journal of Aquatic Research, 40: 633-648.

ICES 2005. Report from the herring age reading workshop. http://www.ices.dk/community/Documents/PGCCDBS/her.agewk2005.pdf

ICES. 2007. Collection of Acoustic data from Fishing Vessels. Cooperative Research Report no. 287.

ICES. 2011. Report of the Workshop on Sexual Maturity Staging of Herring and Sprat (WKMSHS), 20-23 June 2011, Charlottenlund, Denmark. ICES CM 2011/ACOM:46. 143pp.

ICES. 2015. Report of the Benchmark Workshop on West of Scotland Herring (WKWEST), 2-6 February 2015, Dublin. ICES C.M. 2015 / ACOM:34.

ICES. 2015b. Herring (Clupea harengus) in divisions VIa and VIIb,c (West of Scotland, West of Ireland). In Report of the ICES Advisory Committee, 2015. ICES Advice 2015, Book 5, Section 5.3.19.

ICES 2016. EU request for advice on a scientific monitoring fishery for herring in ICES divisions 6.a, 7.b, and 7.c. Section 5.4.3 in ICES Special Request Advice Celtic Seas Ecoregion. 29 April 2016.

Jolly, G. M., and Hampton, I. 1990. A stratified random transect design for acoustic surveys of fish stocks. Canadian Journal of Fisheries and Aquatic Sciences, 47: 1282-1291.

Mackinson, S. 2017. Working Document on the location and timing of spawning for herring in 6aN for discussion in survey planning 2017. 21 April 2017.

Marine Scotland Science 2011. Manual to determine gonadal maturity of herring (Clupea harengus L.)

Melvin, G. D., and Power, M. J. 1999. A proposed acoustic survey design for the 4WX herring spawning components. . DFO Can. Stock Assess. Sec. Res. Doc. 99/63. 15 pp. pp.

Nolan, C., O'Donnell, C., Lynch, D., Lyons, K., Keogh, N., McAvoy, S., Cronin, C., et al. 2014. Celtic Sea Herring Acoustic Survey Cruise Report 2014, 06-26 October 2014.

O'Driscoll, R. L., and Macaulay, G. J. 2005. Using fish-processing time to carry out acoustic surveys from commercial vessels. ICES Journal of Marine Science: Journal du Conseil, 62: 295-305.

O'Malley, M., Clarke, M., O'Donnell, C. & Murphy, I. (2017). Atlantic Herring in 6aS/7b, c
Industry Acoustic Survey Cruise Report 28 November – 07 December, 2016.
FEAS Survey Series: Industry Survey: 01/2016. Marine Institute

O'Sullivan, D., E. O'Keeffe, A. Berry, O. Tully and M. Clarke 2013. An Inventory of Irish Herring Spawning Grounds. Irish Fisheries Bulletin No. 42, 2013.

PELAC. 2015. VIa herring meeting, 10 September 2015, Edinburgh.

Pelagic Advisory Council. 2016. Minutes of the Focus Group meeting on herring in area VIa and VII b,c. 27 January 2016, The Hague, The Netherlands.
http://www.pelagic-ac.org/media/pdf/Minutes%20VIa%20herring%2027%2001%202016.pdf

PFA. 2015. Report on the international workshop on the use of acoustic data from fishing vessels, 12 June 2015, Amsterdam. http://www.pelagicfish.eu/media/afbeeldingen/20150612%20International%20workshop%20on%20acoustics%20from%20fisheries%20-%20report.pdf.

Simmonds, J., and MacLennan, D. N. 2008. Fisheries acoustics: theory and practice, John Wiley & Sons.

SIMRAD 2003. EK60 Scientific Echo Sounder System Instruction Manual. www.simrad.com

Singh, R., Melvin, G. D., Clay, A., and Power, M. J. 2014. Summary of 2011 and 2012 Herring Acoustic Surveys in Northwest Atlantic Fisheries Organization (NAFO) Divisions 4VWX. CSAS Research Document 2014/067.

Woillez, M., Rivoirard, J., and Fernandes, P. G. 2009. Evaluating the uncertainty of abundance estimates from acoustic surveys using geostatistical simulations. ICES Journal of Marine Science: Journal du Conseil, 66: 1377-1383.

Appendix 1. 38kHz calibration results for Eilean Croine 18/11/2017

```
Calibration  Version   2.1.0.12

Date:  18.Nov.2017

Comments:Eilean Croine S238 Calibration 2: Rathmullan Pier, Co. Donegal


Reference Target:
  TS                   -42.40 dB       Min. Distance          8.00 m
  TS Deviation           5.0 dB       Max. Distance         10.50 m

Transducer:  ES38B  Serial No.   38
  Frequency             38000 Hz       Beamtype                Split
  Gain                  25.69 dB       Two Way Beam Angle   -20.6 dB
  Athw. Angle Sens.       21.90        Along. Angle Sens.      21.90
  Athw. Beam Angle      6.95 deg       Along. Beam Angle    6.95 deg
  Athw. Offset Angle    0.11 deg       Along. Offset Angle -0.02 deg
  SaCorrection          -0.67 dB       Depth                 1.00  m

Transceiver:  GPT  38 kHz 009072016d9f 1-1 ES38B
  Pulse Duration        1.024 ms       Sample Interval     0.191   m
  Power                  2000  W       Receiver Bandwidth   2.43 kHz

Sounder Type:
  EK60 Version  2.2.1

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

Environment:
  Absorption Coeff.   9.8 dB/km        Sound Velocity     1493.9 m/s

Beam Model results:
  Transducer Gain     = 26.24 dB       SaCorrection        = -0.56 dB
  Athw. Beam Angle    = 6.90 deg       Along. Beam Angle   = 6.77 deg
  Athw. Offset Angle = 0.08 deg        Along. Offset Angle=-0.09 deg

Data deviation from beam model:
  RMS =    0.48 dB
  Max =    1.47 dB  No. =    48  Athw. =  1.3 deg  Along =  0.1 deg
  Min =   -2.33 dB  No. =   165  Athw. =  2.0 deg  Along =  1.8 deg

Data deviation from polynomial model:
  RMS =    0.47 dB
  Max =    1.44 dB  No. =    48  Athw. =  1.3 deg  Along =  0.1 deg
  Min =   -2.40 dB  No. =   165  Athw. =  2.0 deg  Along =  1.8 deg
```

Appendix 2. Example vessel survey manual (Lunar Bow) (available on request)

Annex 7: WGIPS Survey Plans 2018

Annex 7: WGIPS Survey Plans 2018

IBWSS

Four vessels representing the Faroe Islands, the Netherlands (EU), Ireland (EU) and Norway are scheduled to participate in the 2018 blue whiting spawning stock survey. In addition, this year Spain will participate with 5 days of survey time, just prior to the start time of the core survey, investigating the area 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 2017 IBWSS post-cruise and 2018 WGIPS meetings. The group decided that in 2018, the survey design should follow the principle of the one used during the last survey. Last year area 2 was covered by longitudinal transects perpendicular to the slope. This year a zig-zag design will be investigated in this area to save time without losing coverage and the focus will still be on a good coverage of the shelf slope in survey areas 2 and 3 (Figure A7.1.)

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 A7.1.). 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.

It was decided that the Dutch and Irish vessels would start the survey in the southern areas. 3–4 days after beginning their individual surveys, these vessels will be joint by the Norwegian vessel progressing northwards. Once the Norwegian vessel has finished surveying area 3 and 5, it will continue northwards into the Faroese-Shetland channel, area 4, and continue coverage in a northeastern direction. 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. The Rockall area will be covered by the Irish, Dutch and Norwegian vessels, starting in the south, progressing northward. 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 24.-25. March 2018. 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.

Preliminary cruise tracks for the 2018 survey are presented in. Survey coordinator in 2018, Åge Høines (Norway) has been tasked with coordinating contact between participants prior to and during the survey. Detailed cruise lines for each ship are uploaded on the WGPIPS sharepoint (/2018 Meeting docs/Working documents/IBWSS 2018 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 A7.1. Individual vessel dates for the active surveying period in the 2018 International Blue Whiting Spawning stock Survey (IBWSS).

SHIP	NATION	ACTIVE SURVEYING TIME (DAYS)	DEFINITIVE SURVEYING DATES
Celtic Explorer	Ireland (EU)	15	21.3.2018 – 6.4.2018
Kings Bay	Norway	14	23.3.2018 – 5.4.2018
Tridens	Netherlands (EU)	15	20.3.2018 – 3.4.2018
Magnus Heinason	Faroes	9	1.4.2018 –10.4.2018
Miguel Oliver	Spain	5	16.3.2018-21.3.2018

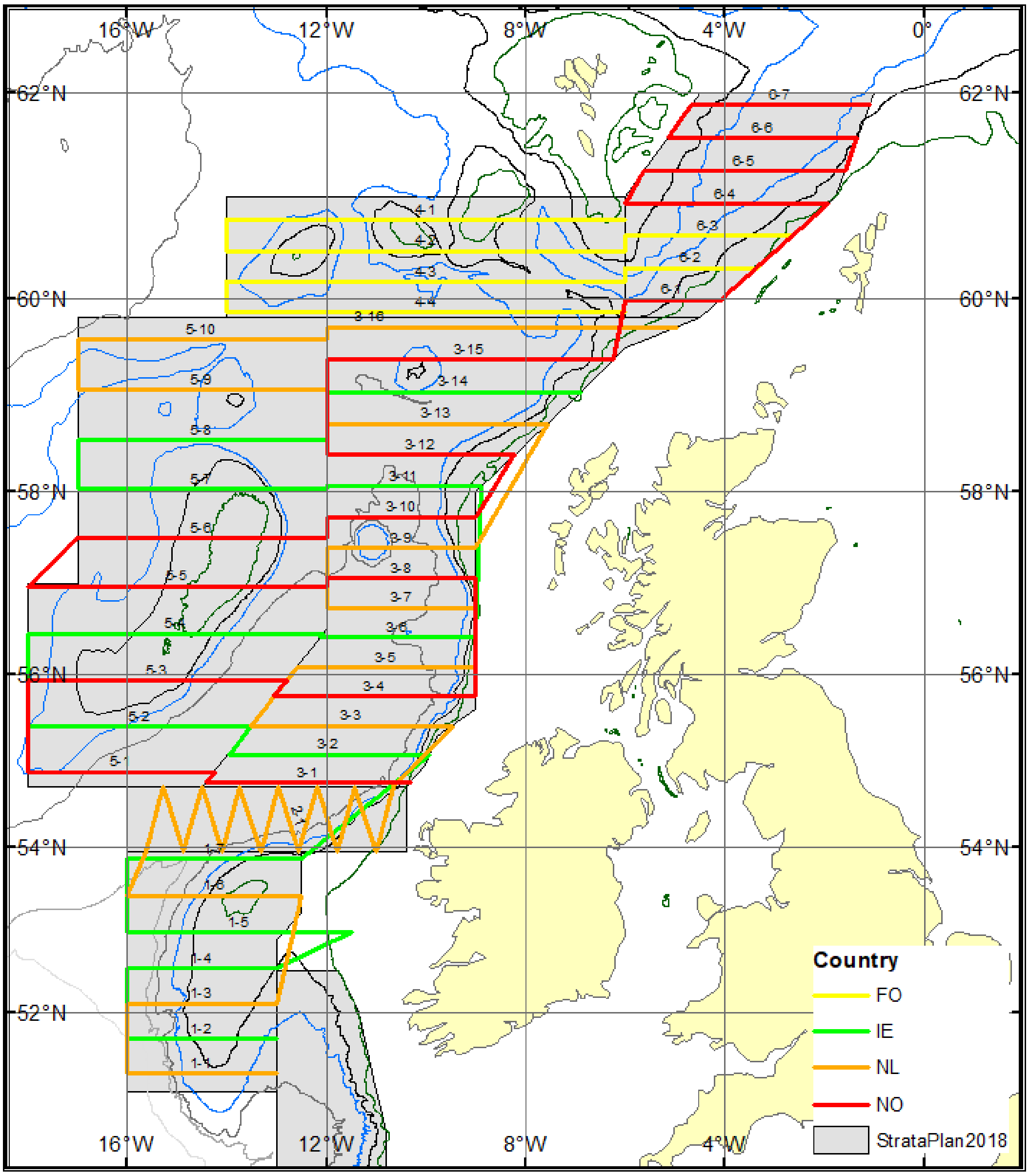

Figure A7.1. Planned survey tracks for the combined 2018 International Blue Whiting Spawning stock Survey (IBWSS).

IESNS

Denmark (EU-coordinator), Faroe Islands, Iceland, Russia and Norway will participate in the IESNS survey in April-June 2018. Ships and preliminary dates are given in Table A7.2. Survey days exclude time for: hydrographic cross sections, coverage outside the IESNS area and crew change. As in the three 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 A7.2. Survey time by stratum is similar to last year. 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 19-21 June 2017 in Copenhagen, Denmark.

Table A7.2. Individual vessel dates for the active surveying period in the 2018 IESNS.

Ship	Nation	Dates (harbour to harbour)	Effective survey days	Crew change
Dana	**Denmark (EU)**	**4 May – 30 May**	**19**	**14-15 May, Bodø**
Magnus Heinason	**Faroe Islands**	**3 May – 16 May**	**11**	
ÁrniFriðriksson	**Iceland**	**3 May – 22 May**	**19**	
G.O. Sars	**Norway**	**30 Apr – 2 June**	**27**	**22-23 May, Tromsø**
Fridtjof Nansen	**Russia**			

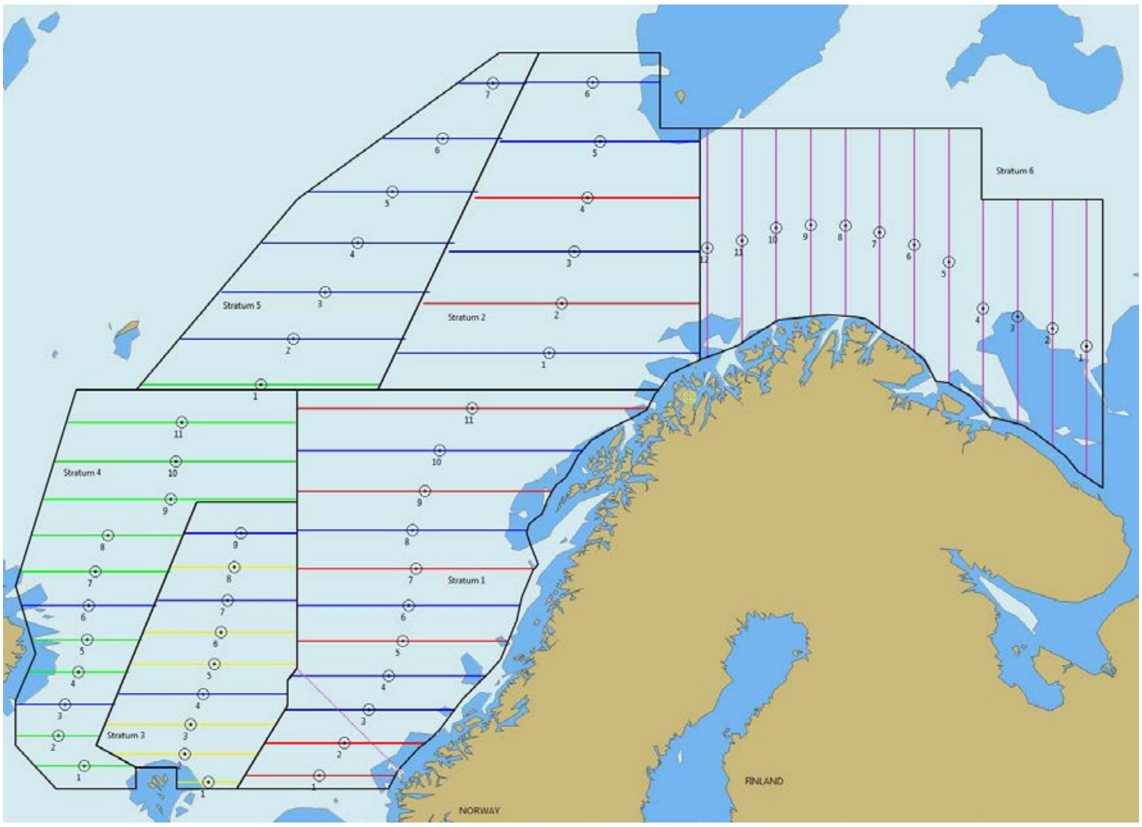

Figure A7.2. Suggested transects for the IESNS survey in 2018. Colors represent the different vessels/nations (yellow: FO, green: IS, dark blue: NO, red: EU, purple: RU).

IESSNS

The International Ecosystem Summer Survey in the Nordic Seas (IESSNS) main priority is standardized surface trawling for mackerel at predetermined locations. Additionally, abundances of Norwegian spring-spawning herring and blue whiting will be recorded using acoustics, from surface to 500 m depth. Stratified random survey design is used to predetermine survey location. Location of the first transect and the first station, in each stratum, is randomized and all other transect/stations located at a set distance from the first transect/station.

There are eleven strata and effort varies between them, from 40 nmi to 80 nmi between stations (Figure A7.3). Effort is higher in stratum with greater abundance and higher expected variability in abundance. In general, each country surveys its exclusive economic zone (EEZ) and international waters are split between participants. In 2018, five vessels from four countries (Norway, Iceland, Faroe Islands, Greenland) contribute 127 vessel days to sample 281 surface stations and cover approximately 22 000 km of survey track. Survey coverage is similar to 2016 and 2017 or roughly 3 million km². At the time of the WGIPS meeting, the planning group was informed of the intention of Denmark to participate in the IESSNS survey 2018, covering the North Sea, but the survey plan for this part of the survey was not yet constructed.

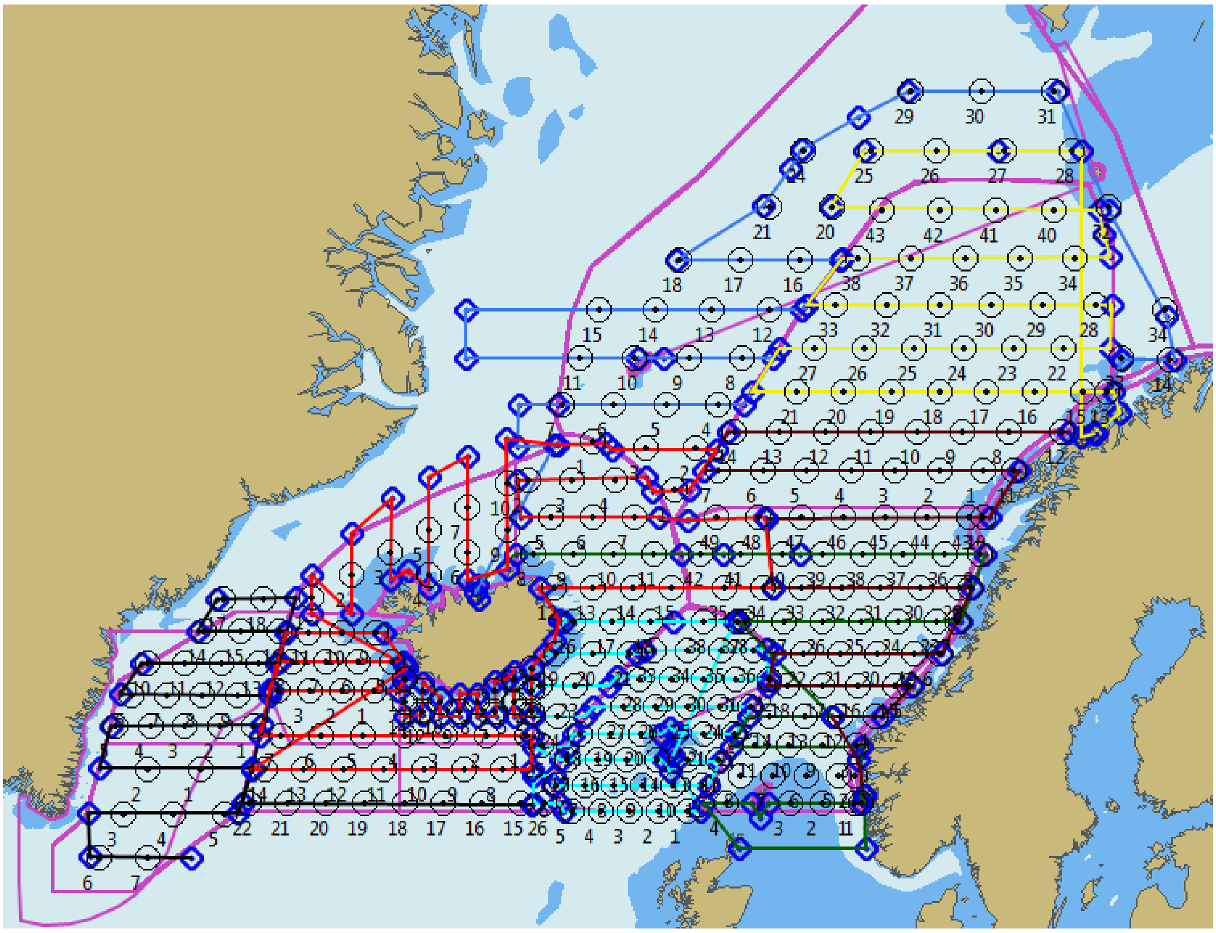

Figure A7.3. Preliminary surface stations (open black circles) and transects (yellow, blue, brown and green = Norway with 2 vessels, turquoise = Faroe Islands, red = Iceland, black = Greenland) for IESSNS from 3. July to 5. August 2018. Strata also delineated (magenta line). NB! Survey plan for Denmark in North Sea not yet constructed at the time of WGIPS meeting – see text.

In 2018, the strata south of Iceland were changed from one dynamic stratum to several permanent strata with varying sampling intensity. The survey begins July 3rd and ends, the latest, August 5th. It is a challenge to coordinate the survey to minimize the possibility for double counting of fish. This specifically applies to the Icelandic strata, which circles the island. To account for this, Iceland will survey clockwise around the island starting in the northwestern region. Norway and Faroe Islands will start in the south and move northwards with east-west transects. The vessels will trade transects between stratum in a similar fashion as performed in 2017.

HERAS

Norway, Denmark, Germany, Netherlands, Scotland and Ireland will participate in the 2018 HERAS and MSHAS surveys. Ships, preliminary dates and preliminary strata allocations are given in Table A7.3 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 2018 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, e.g. transect spacing will be maintained at similar level to 2018. Survey effort should also ensure adequate coverage of the North Sea sprat stock, which requires that the southern boundary of the survey area 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 VIaN and VIaS 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 covered by Denmark and Norway in previous years, 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 vertebrae 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 2018 survey should be continued for this work.

Collection of otoliths for 2018

In addition to the collection of otoliths for shape analyses by MSS and IMR, the following is required.

1. Two samples (25 fish each) of herring otoliths from the vicinity of the German Bight i.e. east of 6 degrees E. The samples are to be from separate statistical rectangles and preferably at least 60 nautical miles apart.
2. One sample (25 fish) of herring otoliths from fish south of 54 degrees North
3. Two samples (25 fish each) of herring otoliths from fish in the central part of the North Sea i.e. 54 to 56.5 degrees N and 0 to 5 degrees East.
4. A set of 25 herring otoliths from 0 or 1 winter ring fish from any location.

In all cases the otoliths are **NOT** to be mounted i.e. stored dry. All standard fish and haul information to be collected.

Analysis and reporting

A post-cruise meeting will be held in Bergen 26 – 30th November 2018. 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 2016-2017 survey is not complete in all cases. This should be rectified in time for the 2018 post cruise meeting. Survey data for 2018 survey is to be uploaded to the ICES Acoustic database in the agreed format no later than **31 October 2018.**

Table A7.3. Time periods, areas and rectangles to be covered in the 2018 acoustic survey.

Vessel	Available days for survey	Period available	Strata to cover
Celtic Explorer (IRE)	22	3 – 24 July	2, 3, 4, 5, 6
Scotia (SCO)	23	tbd	1, 121, 111, 91 (North of 58°30'N)
Johan Hjort (NOR)	18	2– 19 July	11, 141
Dana (DEN)	16	26 June – 10 July	21, 31, 41, 42, 151, 152
Tridens (NED)	17	2 – 22 July	81, 91 (North of 58°30'N), 101
Solea (GER)	21	29 June – 19 July	51, 61, 71, 131

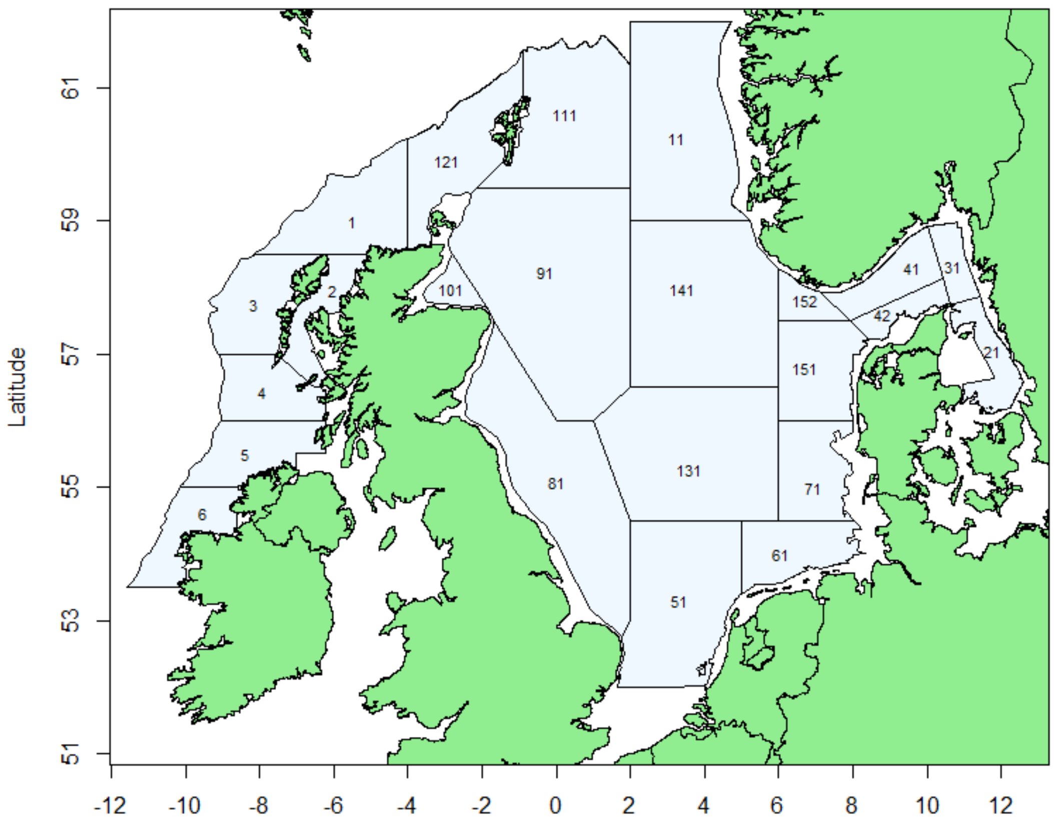

Figure A7.4. Strata for the HERAS 2018 survey.

WESPAS

The 2018 WESPAS (Western European Shelf Pelagic Acoustic Survey) will be carried out on board the RV *Celtic Explorer*. In 2018 the survey will begin in the south (9th June) and work progressively northwards over 46 days ending on the 24 July. The change in survey direction in 2017 has been ratified by WGIPS and will continue in 2018. Changing the survey rotation provides closer temporal and spatial alignment with the PELGAS survey (IFREMER) in the south and the Scottish survey onboard the RV *Scotia* in the north ensuring improved containment overall. The survey will be broken into two 3-week legs, with a 4-day break for Ireland's Sea Fest in Galway.

The scheduled work program will also include marine mammal surveys (visual and passive acoustic), seabird abundance and distribution and plankton sampling.

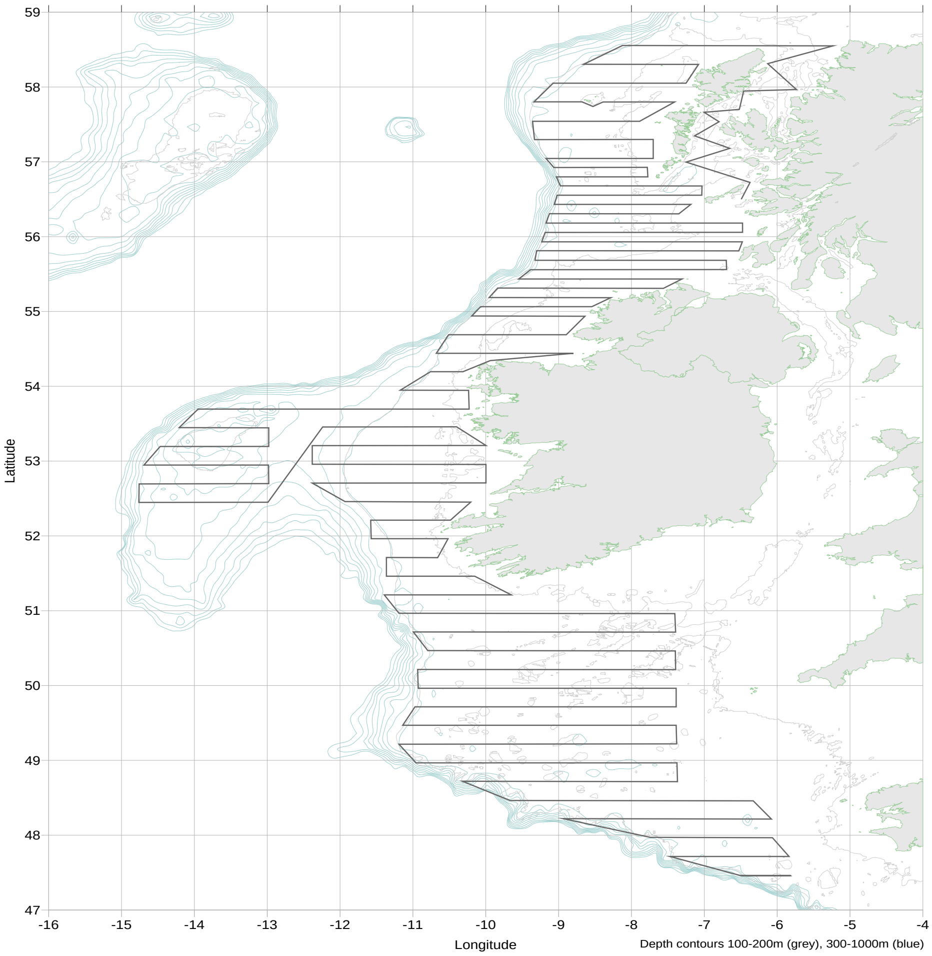

Figure A7.5. Survey transect design for the WESPAS survey in 2017 (a similar design will be in place for 2018).

CSHAS

The Celtic Sea acoustic survey 2018 will be carried out on board the RV *Celtic Explorer* from the 7th – 27th October (21 days). Survey design was modified in 2016 to ensure stock containment. Time continues to be allocated towards adaptive high intensity surveys of hyper aggregations of the remaining offshore component of the stock. Details of the change in survey design have been communicated to HAWG and presented to WGIPS for review.

Hydrographic, seabird and marine mammal surveys will be undertaken in continuation of established programs.

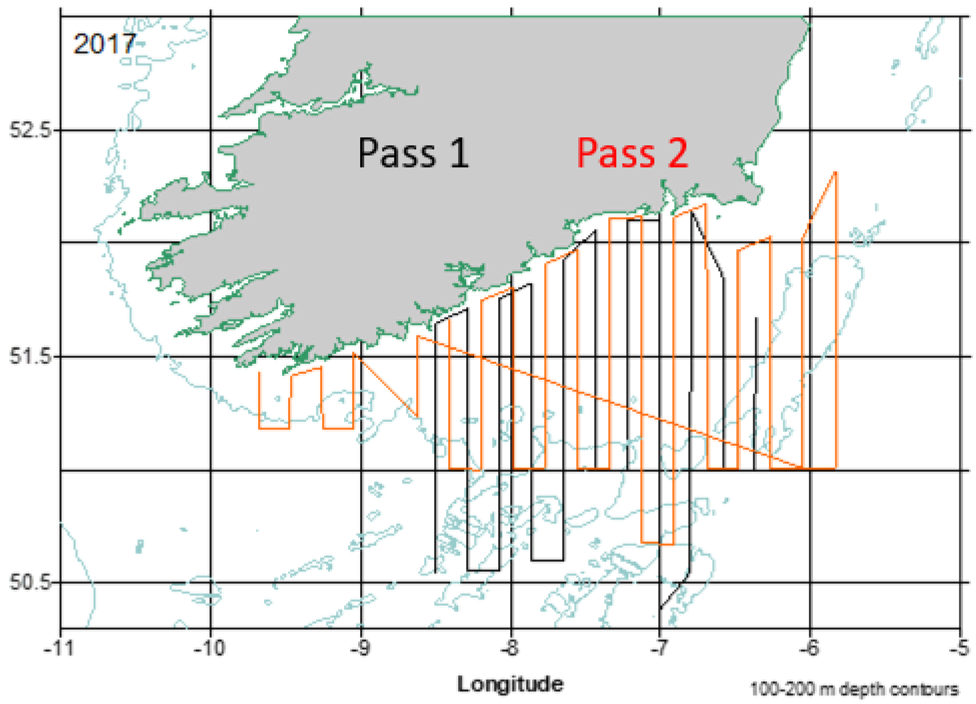

Figure A7.6. Survey effrot in 2017 showing replicate broadscale surveys. High intensity adaptive mini-surveys are conducted in areas where fish are observed, particularly in the Celtic Deep/Smalls area. Proposed track plan for the CSHAS survey 2018 will follow this design.

ISAS

The 2018 Irish Sea acoustic survey (ISAS) will be carried out on board the RV *Corystes* between August 27th and September 14th. Figure A7.7 shows the plan and acoustic tracks for cruise C03518. 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.

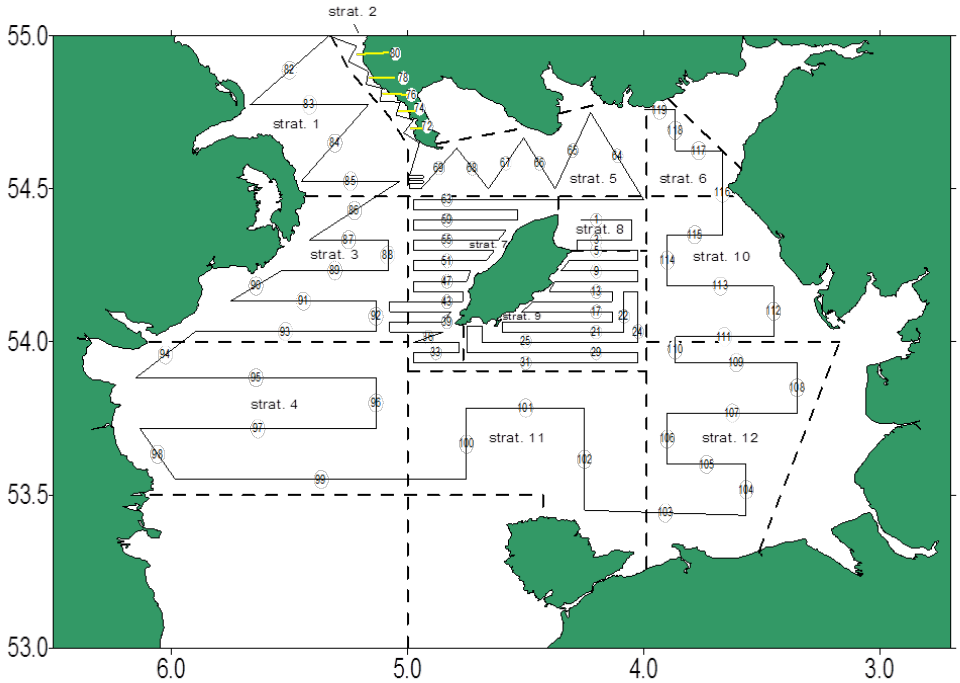

Figure A7.7. Map of Irish Sea and North Channel showing proposed coverage for the 2018 herring acoustic survey C03518.

GERAS

The GERAS acoustic survey 2018 will be carried out on board RV *Solea* from October 1 until October 21. The plan for cruise SB754 and acoustic transects to be covered follow the design adopted for the previous years (figure A7.8) 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.

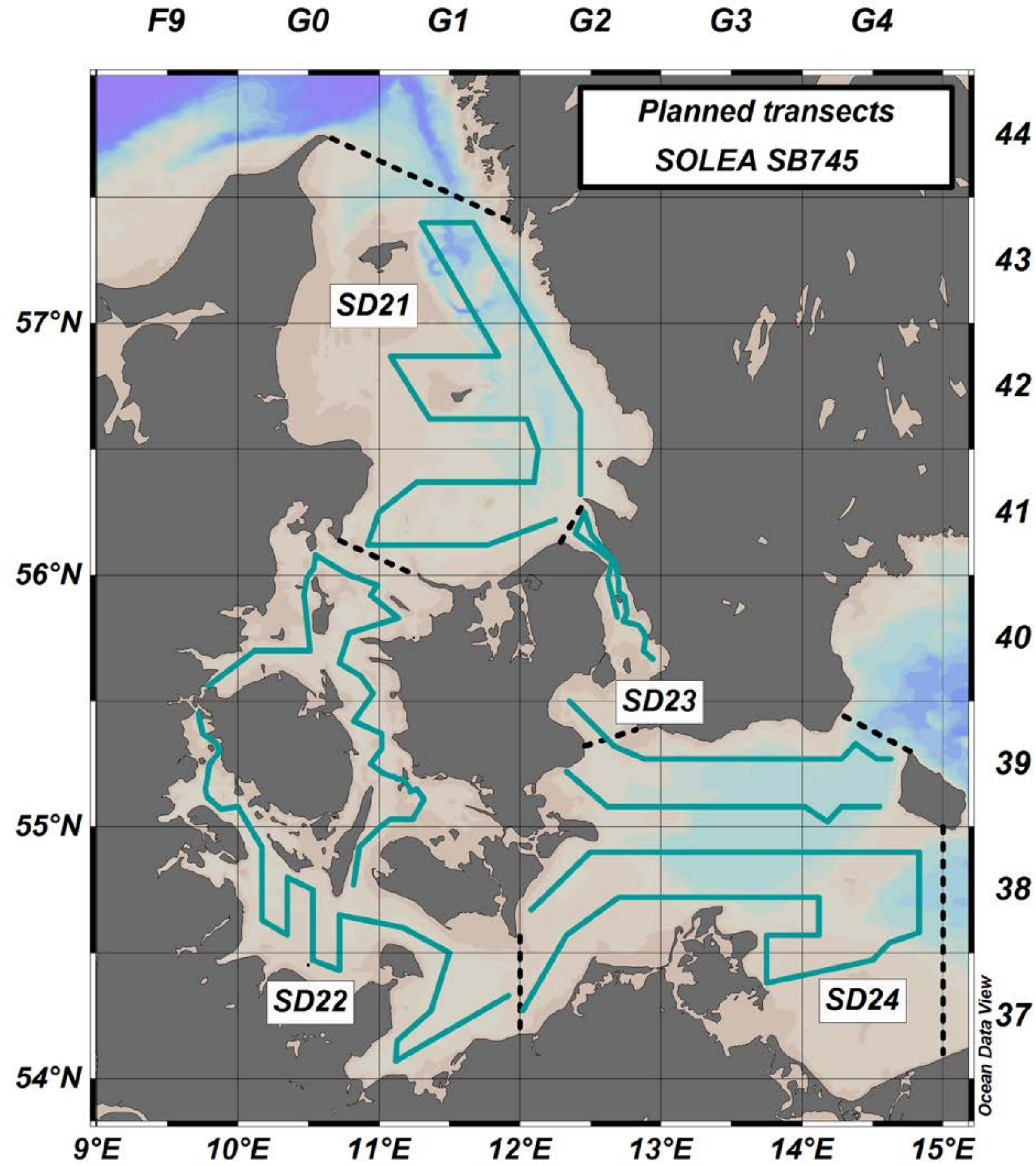

Figure A7.8. Map of the planned coverage in ICES Subdivisions (SD) 21-24 and acoustic transects for the German Acoustic Autumn Survey (GERAS) in 2018.

PELTIC

The 2018 PELTIC survey is scheduled to take place from the 6th of October until the 9th of November focusing again on the small pelagic fish community and their ecosystem in the waters to the SW of the UK. The effective survey duration of 35 days is the same as the extended survey conducted in 2017 and will include a northwards extension in the Celtic Sea and, to the south, French waters of the western Channel (Fig A7.9). The area east of 3° W is a secondary aim and will be covered if time permits. The survey protocol will be the same as in previous years: a series of transects (5, 10 and 15 nmi spaced) will be run during daylight in conjunction with surface oceanographic measurements and marine mammal and bird observations. Pelagic hauls will be made to ground-truth the acoustic marks and collect biological information on the dominant pelagic fish species in the area: sprat, sardine, mackerel and anchovy. At night a series of Zooplankton and CTD stations will be sampled. Where possible, regular communications with the CSHAS survey will be maintained to coordinate coverage in the Celtic Sea. The extra time will be used to conduct more pelagic hauls and conduct a higher resolution survey grid in the coastal waters of Lyme Bay.

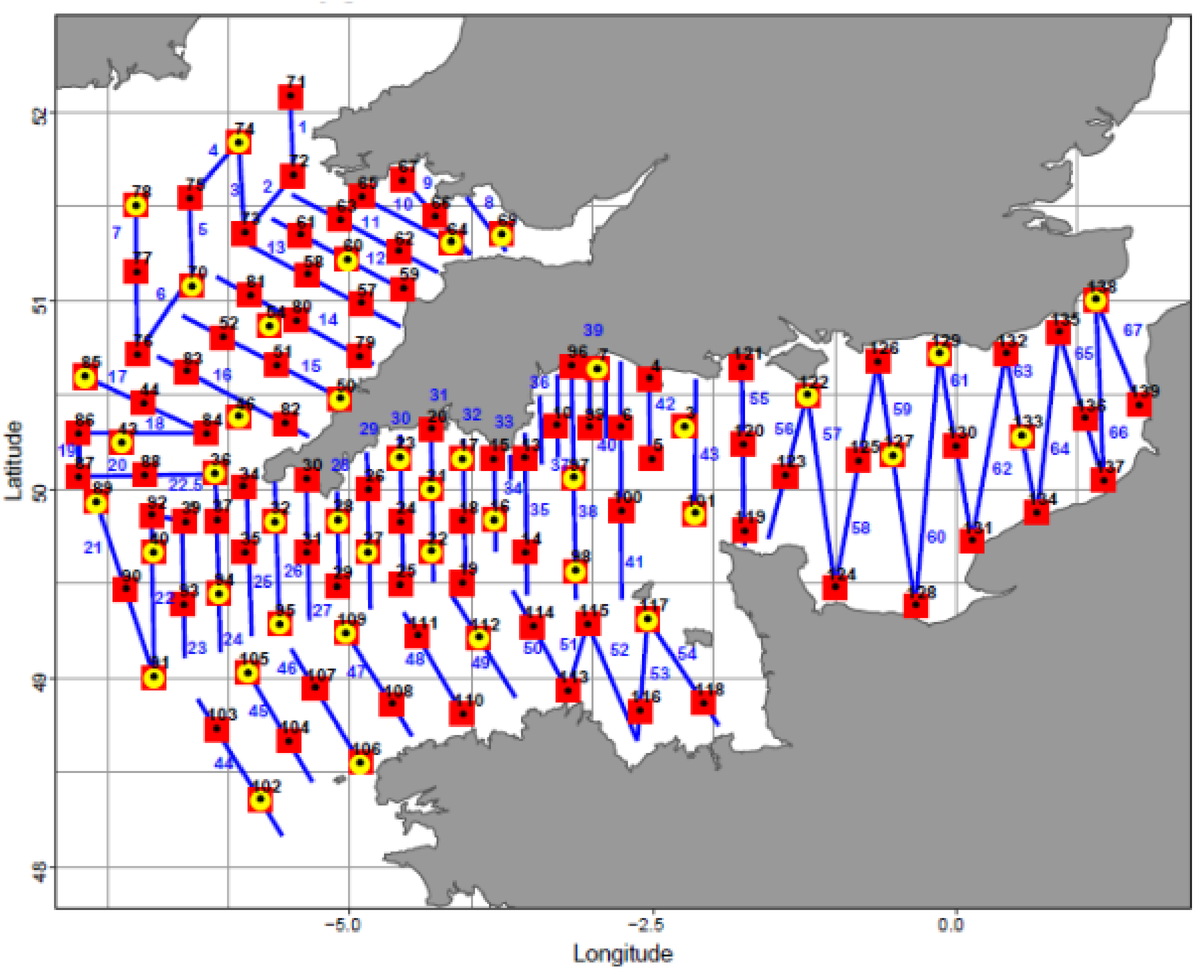

Figure A7.9. Map of the acoustic transects (blue) and plankton (red) and hydrographic (yellow) stations of PELTIC 2018. The waters of the eastern Channel (east of 3° W) are a secondary aim and will be covered if time permits..

Annex 8: 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 observations of pelagic fish	✓		✓			✓					✓	✓					✓				✓	✓		
Tagging																								
Bioactive material																								
Scientific multibeam echosounder for 3D fish school shapes/schools observations in surface 'dead zone'																	✓							
Multifrequency echosounder data for species identification, abundance and biomass estimation (number of frequencies)	5	2	4	2		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	1	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 echosounder			✓			✓						✓									✓	✓		
Physical ground samples																								
Pollution																								
Litter			✓	✓		✓			✓			✓		✓	✓	✓				✓	✓	✓		✓
Pollution in water column																								

Pollution in sediments																								
Pollution in organisms																								
Environmental conditions																								
Weather condition	✓	✓	✓	✓		✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Sea state	✓	✓	✓	✓		✓	✓				✓	✓	✓	✓✓	✓	✓	✓	✓		✓	✓	✓	✓	✓