ICES WKEVAL REPORT 2015

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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
International Council for the Exploration of the Sea
CIEM
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Executive Summary

The Workshop on evaluating current national acoustic abundance estimation methods for HERAS surveys (WKEVAL), chaired by Ciaran O'Donnell, Ireland, met at ICES Headquarters from 24–28 August 2015. The aims of the workshop were to review and evaluate current national acoustic abundance estimation methods for HERAS surveys and to initiate the steps required to implement the move to a new database for the storage of disaggregated survey data, use StoX to calculate 'global' biomass estimates and to populate the database with disaggregated historic survey data.

The International acoustic survey in the North Sea, West of Scotland and Malin Shelf is collectively known as the HERAS survey program. Surveys are carried out annually in June/July to determine the distribution and abundance of herring and sprat in the North Sea region (HERAS) and to the west of Ireland and Scotland. Acoustic estimates are used as a tuning index by ICES to determine the size of the populations of herring and sprat and the results are submitted annually to HAWG. Coordination and planning of the surveys are reported through WGIPS in January each year.

The group is in a transitional phase as the previous calculation and data repository tool (FishFrame) used for HERAS surveys will no longer be maintained or supported into the future. The ICES data centre in partnership with the AtlantOS project is working to develop a new international survey database for acoustic surveys including those currently coordinated by WGIPS. IMR is currently developing an acoustic and swept-area abundance computational tool (StoX) that will replace FishFrame in this regard. In order to ensure a smooth transition from one calculation method to another and to ensure consistency the need for a sensitivity analysis was identified.

Significant progress was made during the meeting towards implementing the new system. This is an ongoing process timetabled over several years involving not only member of this group but also the wider WGIPS group, the ICES data centre and the AtlantOS project. Due to time constraints, it was not possible during the meeting to conduct a 'global' retrospective sensitivity analysis as planned. However, by the end of the meeting members left with the capacity to run StoX using reformatted national datasets. The larger exercise will be rescheduled for a later date. Reformatted historic data, as well as the 2015 dataset can now be read into StoX. The 2015 HERAS 'global' abundance estimate will be produced using StoX in January 2016 during the HERAS post cruise meeting. A lot of time was spent during the meeting discussing and agreeing on the acoustic data reporting structure required to meet the specifics of this group. The ICES data centre now has in place the reporting structure format and group members have an agreed format for submitting acoustic data. Biological data will be submitted to the DATRAS database for upload. The reporting structure will be circulated to the group in readiness for review during WGIPS 2016. The submission structure of biological data will be modified where required to meet the specifics of supporting biological data for use with acoustic datasets.

Some changes to the reporting structure still need to be implemented to ensure the group meets the larger requirements of metadata standards and this will be addressed at a workshop held in October 2015 (WKIACTDB).

1 Introduction

1.1 Terms of Reference 2015

The **Workshop on evaluating current national acoustic abundance estimation methods for HERAS surveys** (WKEVAL), chaired by Ciaran O'Donnell, Ireland, will be established for a single meeting and will meet in ICES, Copenhagen, 24–28 August 2015 to:

a) Review and evaluate current national acoustic abundance estimation methods for HERAS surveys;

b) Initiate the steps required to; implement the move to new database for the storage of disaggregated survey data; a common tool to calculate 'global' biomass estimates and; to populate the database with disaggregated historic survey data from 2003 onwards.

WKEVAL will report by 1 October 2015 (via SSGIEOM) for the attention of SCICOM, ACOM, WGISDAA, WGIPS and HAWG.

1.2 List of participants

Ciaran O'Donnell, (Chair),	Ireland
Sascha Fässler	Netherlands
Cecilie Kvamme	Norway
Espen Johnsen	Norway
Karl-Johan Stæhr	Denmark
Matthias Schaber	Germany
Susan Mærsk Lusseau	Scotland
Carlos Pinto	Denmark (ICES data centre)
Mehdi Abbasi	Denmark (ICES data centre)

A full address list for the participants is provided in Annex 1.

2 HERAS International survey program

2.1 Background

International acoustic surveys in the North Sea, West of Scotland and Malin Shelf are collectively known as the HERAS survey program. Surveys are carried out annually in June/July to determine the distribution and abundance of herring and sprat in the North Sea region (HERAS) and to the west of Ireland and Scotland (Malin Shelf Herring Acoustic Survey- MSHAS; Figure 2.1.1.). Acoustic estimates are used as a tuning index by ICES to estimate the size of the populations of herring and sprat and the results are submitted annually to HAWG. Synoptic surveys are carried out by vessels from Denmark, Germany, Netherlands, Ireland, Norway and Scotland. Coordination and planning of the surveys are reported through WGIPS in January each year.

Further details on the survey including the time-series are available in the latest WGIPS report (WGIPS).

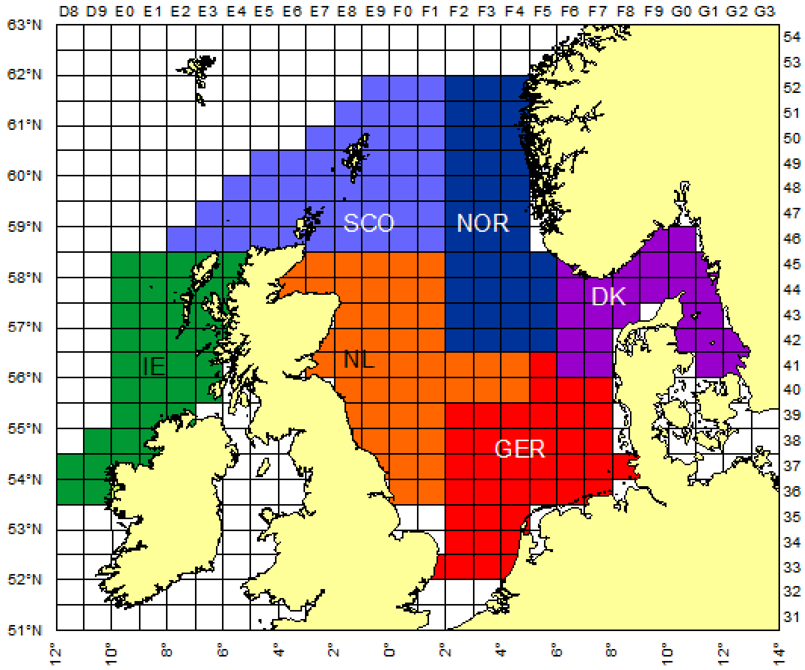

Figure 2.1.1. HERAS area coverage by ICES rectangle in 2014 (IE = Ireland; SCO = Scotland; NOR = Norway; DK = Denmark; NL = Netherlands; GER = Germany).

2.1.1 Survey objectives

The survey aims to provide an annual estimate of the distribution, abundance and population structure to inform the assessment of the following herring and sprat stocks: Western Baltic Spring-spawning herring (in ICES Divisions IV and IIIa), North Sea Autumn Spawning herring (in IV, IIIa and VIId), West of Scotland herring (in VIaN), Malin Shelf herring (west of Scotland/Ireland in VIaN-S and VIIb,c), North Sea sprat (in IV) and Sprat in IIIa (Skagerrak/Kattegat).

The derived estimates and age structure of herring and sprat are used as tuning indices in the respective assessments and are submitted annually to the HAWG.

2.1.2 Survey time-series

The ICES Coordinated acoustic surveys started in 1979 around Orkney and Shetland with the first major coverage in 1984. An index derived from that survey has been used in the assessment of North Sea autumn spawning herring since 1994 with the time-series data extending back to 1989. The survey was extended to IIIa to include the overlapping western Baltic spring-spawning stock in 1989, and the index has been used together with a number of other tuning indices in the assessment of North Sea herring since 1991. The early survey had occasionally covered VIaN during the 1980s and was extended westwards in 1991 to cover the whole of VIaN. Since 1991, this survey provides the only tuning index for West of Scotland (VIaN) herring and from 2008 for the whole of the Malin Shelf area (VIaN-S and VIIb,c). Since 2000, the survey has also provided age disaggregated abundance indices for sprat in the North Sea and since 2006 for sprat in IIIa.

2.2 The current methods for estimating abundance

2.2.1 Background

Abundance estimation is carried out independently and at a national level by each participant for their own individual survey data. These data, aggregated by age and stock (NSAS, WBSS) are then combined within FishFrame to produce 'global' estimates of abundance. Since 2007, WGIPS has been using FishFrame as the groups' standard database for storing and aggregated national data from the HERAS survey.

The need for a change came about through both the need to standardize procedures across nations and also due to the fact that DTU-Aqua does not have the resources to continue hosting and maintaining the acoustic part of FishFrame into the future.

2.2.2 National methods of abundance estimation

2.2.2.1 Ireland– Malin Shelf Herring Acoustic Survey

A full breakdown of the methods employed during the Malin Shelf survey including survey design, biological sampling and analysis methods is provided in Annex 4 of this report.

2.2.2.2 Netherlands

Survey design and area coverage

The Dutch survey area is covered annually within the period from the last week in June to the third week in July. A stratified transect design with random starting points is used in this survey. Survey stratification is based on ICES statistical rectangles with a range of 1 degree in latitude and 2 degrees in longitude. Transect spacing is 15 nm in the two northernmost row of ICES statistical rectangles and 30 nm everywhere else. Ships' speed during the survey is kept at 10 knots. The survey is interrupted during periods of darkness between 23:00–04:00 UTC; and due to working time regulations during weekends between Saturday 15:00 UTC and Monday 06:00 UTC.

Acoustic data collection

Acoustic data are collected using a Simrad EK60 with 38 kHz transducer mounted on a towed body (until 2014) or 18, 38, 70, 120, 200, and 333 kHz transducers mounted on a dropkeel (from 2015). After 2014, Simrad ME70 multibeam data were also collected concurrently. All frequencies are calibrated directly prior to the survey.

Biological data collection

Trawl hauls are collected if considerable echotraces are visible on the echogram to obtain a catch sample from the fish school/layer. The trawl used has a 20mm mesh size in the codend, 25m vertical and 40m horizontal opening.

The fish sample obtained from the trawl catch is divided into species and length measurements are taken to the nearest 0.5 cm below for sprat and herring (and to the whole cm below for other species). For herring and sprat length stratified samples (maximum 5 per 0.5cm length class) are taken for maturity, weight, age (otolith extraction) and weight.

Data analysis and abundance estimation

Echo integration and further data analyses are carried out using MAREC LSSS (Large-scale Survey System) and an R library 'acousaR' (https://code.google.com/p/acousa/). Acoustic data are scrutinised to species level on a regular basis during the survey and acoustic density values (s_A) of herring and sprat exported by 1nm EDSU. Abundance estimation is carried out following the universal principles detailed in Section 6.4 of the survey manual and using the agreed target strength to fish length relationships in Section 6.1 of that manual (ICES, 2015). Abundances and biomass at age of herring and sprat are estimated per ICES statistical rectangle covered according to methods provided in Annex 5 of this report.

2.2.2.3 Norway

Survey design and area coverage

The acoustic survey with Johan Hjort starts in the end of June and ends in mid-July (last couple of years). It runs in systematic parallel E-W transects, and always starts in the southeastern corner of the survey area and runs northward. The transect spacing is 15 nm (some years 30 nm spacing in the two most northern rows of 0.5×1° ICES rectangles). Random start was introduced in 2015. Before 2006, the acoustic survey was a separate survey, but thereafter also other tasks were included, like IBTSQ3, saithe acoustics, marine pollution sampling (every 3rd year) and hydrographic sections. This combined survey lasts for about a month. The last two years the survey design has been improved by doing all the HERAS acoustics at the beginning of the survey, only interrupted by IBTS and saithe target identification trawl hauls.

Acoustic data collection

The acoustics run 24–7. Acoustic data are collected using a Simrad EK60 with 18, 38, 120 and 200 kHz transducers mounted on a drop keel. The speed of the ship during the survey is kept around 10 knots. In 2015, also sonar data were collected.

Biological data collection

The vessel is equipped with several trawls for this survey, but most of the herring samples are collected with a large pelagic trawl (Åkra) with a height around 40 m. A bottom trawl and a smaller pelagic trawl (easier to manoeuvre pelagically near bottom and to avoid very large catches in high-density areas) are also available onboard for taking samples. We aim at two hauls for each rectangle. A lot of these are blind hauls in the surface, as the herring we observe usually is dominated by very small schools in the upper 30–40 m (and such small schools are not easy to target one by one). Trawling speed is kept around 4 knots. All the catch is sorted and weighed. From herring catches, a random sample of 100 individuals is taken. Of these 100, we take all measurements for the first 50 (length, weight, age, vertebrae count (VS), maturity (8 point scale, with 9=abnormal), sex, fat (1–4), stomach fullness (1–6), Icthyophonus (heart, skin)). For the last 50, length and weight is recorded. Age is read during the survey. In 2014–2015, photos of otoliths were taken with the purpose of assigning stock identity (NSAS and WBSS) to individual herring from the shape of the otolith. Currently, stock identity is reported from this survey areas as proportion of WBSS by age (1–4+) within each sample [Prop. WBSS = (56.5-VS)/(56.5–55.8)].

Data analysis and abundance estimation

LSSS (Large-scale Survey System) is used for echo integration and scrutinizing echoes twice every survey day, and the echoes are attributed to herring, sprat, saithe, bottom-fish and plankton. In our survey area, sprat is very seldom observed. N-W transport lags between transects and miles off transects (e.g. trawl hauls) are excluded from the analysis (current resolution 1 nm, for 2016: 0.1 nm). 38 kHz data with a -82 dB threshold are used for reports. During the scrutinizing process in LSSS, however, trawl hauls, frequency response as well as down-thresholding (down to -62 to -55 dB) are all methods used for separating out the herring marks. Large herring schools are boxed. Acoustic density values (s_A) defined as herring are exported by 1nm EDSU. Only herring sample data with age, and a minimum of 20 individuals, are used for estimation. Abundance and biomass for the survey area is calculated by an Excel-sheet, where the mean NASC, sea area, no of nm covered, age distribution, maturity-at-age, mean length-at-age, mean weight-at-age, and proportion of WBSS by age are input values (per rectangle). The samples to use for each rectangle are defined by the biological strata. These are based on the samples' age and length distribution, as well as the proportion of WBSS. The abundance and biomass estimates have, up until now, been delivered by rectangle to FishFrame.

2.2.2.4 Denmark – Skagerrak-Kattegat acoustic survey

A full breakdown of the methods employed during the Skagerrak-Kattegat survey including survey design, biological sampling and analysis methods is provided in Annex 6 of this report.

2.2.2.5 Germany

Survey design and area coverage

The German survey area is covered annually with a 21 days survey conducted in the period last week of June to third week of July. Prior to the 2015 survey, the ICES statistical rectangles allocated by WGIPS covered during the survey were 33F1-F4, 34F2-F4, 35F2-F4, 36F0-F7, 37F2-F8, 38F2-F7, 39F2-F7, 40F6-F7. In the 2015 survey, rectangles 36F0 and 36F1 were allocated to the Dutch survey area whereas rectangles 40F5 and 41F5 were newly allocated to the German survey area leading to a re-design of transects to allow better spatio-temporal coverage of the area (Figure 2.2.2.5.1). In both the former and the latter survey area, a stratified transect design is used with the 20m depth contour as landward limit of the survey area. A randomization of starting points and an according latitudinal shift in transects is not feasible in the area covered due to several traffic separation areas restricting navigation. Stratification is based on ICES rectangles with a transect spacing of 30 nm except for the 4 (formerly 2) rectangles that based on previous fish registrations were allocated higher effort. There, transect spacing is 15 nm. In some parts of the survey area, transect spacing had to be adapted to water depth, which in referring areas is less than 20 m, accordingly requiring a change of transect spacing.

Survey operations are carried out daily between 04:00 and 18:00 UTC and interrupted during periods of darkness.

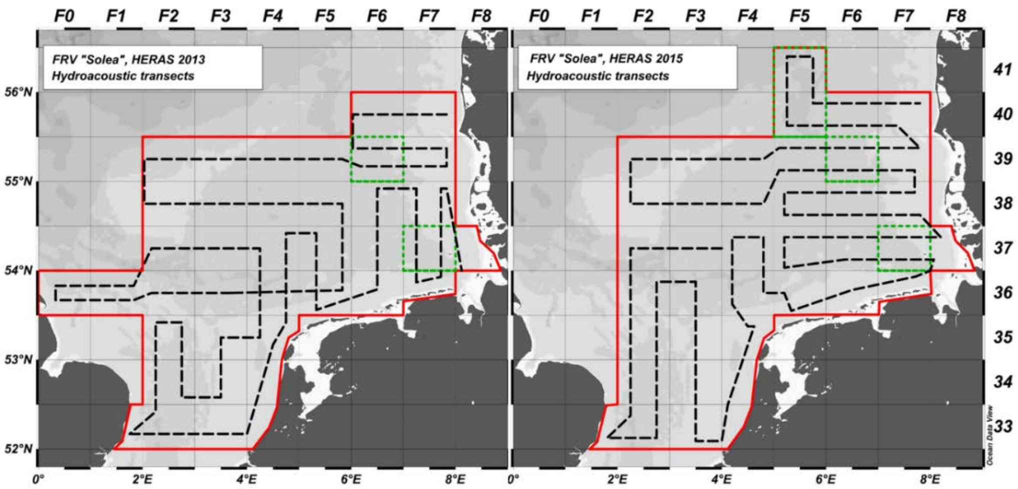

Figure 2.2.2.5.1. Survey area (solid red line) and hydroacoustic transects (dashed black lines) in German HERAS surveys prior to 2015 (left panel) and in 2015 (right panel). Rectangles requiring higher survey effort (transect spacing 15 nm) are indicated with green dotted outlines).

Acoustic data collection

Acoustic data are collected at a ship speed of 10 knots using a Simrad EK60 scientific echosounder with hull mounted 38 kHz and 120 kHz transducers. Both frequencies are calibrated prior to the survey or during the survey with resulting calibration parameters applied for data analysis.

Biological data collection

Based on the rectangle stratification approach, two trawl hauls per rectangle are conducted if noteworthy echotraces are registered on the echograms. The trawlnet employed is a pelagic trawl PSN 388 "Krake" with 10 mm mesh size in the codend.

Samples obtained from the trawl hauls are divided by species and length measurements are taken to the nearest 0.5 cm below for herring, sprat, pilchard and anchovy while other species are measured to the nearest 1 cm below. If necessary, subsamples are taken for length measurements. Subsample weight, subsample count as well as total catch weight then are noted and utilized for raising subsamples to total catch. For each rectangle, 10 specimens of herring and sprat (and, when caught, pilchard and anchovy) per 0.5 cm length class are sampled and either directly processed or frozen for further biological sampling of maturity, weight and otolith extraction (age).

Data analysis and abundance estimation

Post-processing of echograms (integration) is carried out using Echoview software. Acoustic data are scrutinized after the survey is accomplished (previous years) or directly during the survey. A school detection algorithm is applied to detect and classify clupeid schools. As clupeids in the survey area often occur in mixed aggregations and as species-specific scrutinization of schools is not feasible due to identically shaped schools, all aggregations detected and classified are exported as "Clupeids". Then, resulting acoustic density values (S_A) of clupeids are exported by 1 nm EDSU and averaged per rectangle. The average NASC per rectangle then is split up into clupeid species based on calculations derived from mean species-specific length–frequency distributions derived from hauls conducted in or allocated to the corresponding rectangle (i.e. L^2, σ) as well as from relative catch composition of the clupeid species considered for computation of abundance estimates. The general computation principle followed is described in Section 6.4 of the survey manual (ICES, 2015). Resulting abundance and, based on length-at-age and weight-at-age parameters derived from biology samples, biomass at age estimates of herring and sprat (and, where applicable pilchard and anchovy) are computed per ICES statistical rectangle.

2.2.2.6 Scotland

Survey design and area coverage

Marine Scotland Science covers the allocated area over a continuous three-week period between last week of June and the third week of July. A systematic parallel transect design with random starting points is used in this survey (Figure 2.2.2.6.1). The Scottish survey uses a transect spacing of maximum 15 nm but within areas of high abundance registered in previous years a spacing of 7.5 nm is used. In the period, 2011 to 2014 the area allocated to Scotland was covered by two vessels (MRV Scotia and a chartered fishing vessel) running interlaced transects through the area giving an effective spacing of 7.5nm for the entire area. Before 2011, the area east of 4°W was covered exclusively by MRV Scotia and the area to the west of this delineation covered by a chartered fishing vessel.

Ships' speed during the survey is kept at 10 knots. The survey is interrupted during periods of darkness between 23:00–03:00 UTC to avoid surveying when herring migrate to the surface in this area and are dispersed above the depth of the transducers.

Transects are run perpendicular to depth gradients as far as possible, which is expected to be perpendicular to the greatest gradients in fish density. This result in a grid of transects largely running parallel with the lines of latitude. On the administrative boundary at 2°E (and at 4°W in the past), the ends of transects are positioned at half the transect spacing from the area boundary, giving equal transect length in any rectangle within the area: the between transect data can then be included in the data analysis. Transects at the shelf break are continued to the limits of the 200m contour and the transect ends omitted from the analysis as they would otherwise run parallel with the depth contour. Transects terminating at the coast are continued as close inshore as practical, and inter transects running parallel with the coast are excluded from the analysis. The origin of the survey grid is selected randomly within a sampling interval, and the track is laid out with systematic spacing from the random origin.

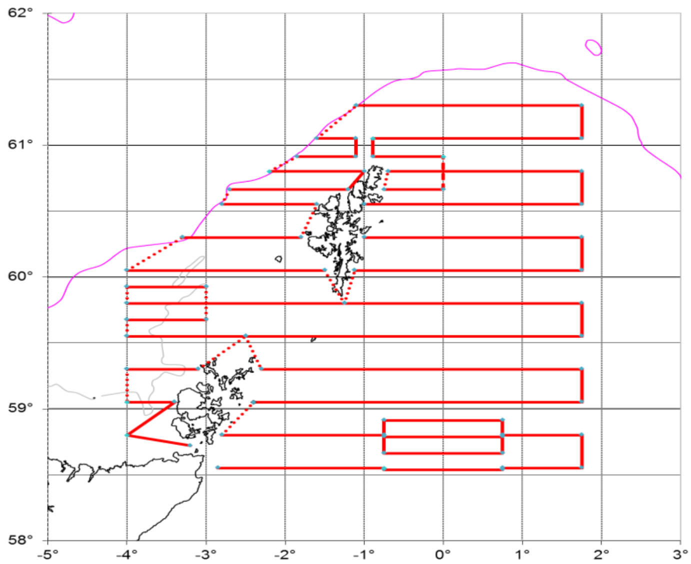

Figure 2.2.2.6.1. Planned survey track for MRV Scotia in 2015. Solid lines are track integrated for analysis; broken lines are omitted from the analysis.

Acoustic data collection

Acoustic data are collected using a Simrad EK60 with 18, 38, 120 and 200kHz transducers mounted on a dropkeel on MRV Scotia. On the chartered fishing vessel 38, 120 and 200kHz transducers are mounted on a towed body. All frequencies are calibrated directly prior to the survey and calibrations are confirmed towards the middle or end of the survey.

Biological data collection

Prior to 2011, directed trawling was carried out from both vessels, but from 2011 onwards trawling has only been carried out from MRV Scotia. Trawls are directed at significant echotraces visible on the echogram to obtain a catch sample from the fish schools/layers. A PT160 trawl is used with a 38 mm mesh size in the codend, 20 m vertical and 20m horizontal opening. Hauls are monitored with a FS70 scanning netsounder mounted on the headline to confirm whether targeted aggregations are sampled.

The fish sample obtained from the trawl catch is divided into species and length measurements are taken to the nearest 0.5 cm below for sprat and herring and to the whole cm below for all other species. For herring a length stratified biological sample (2 per 0.5 cm length class for fish below 22 cm, 5 per 0.5cm length class between 22.5 and 27.5 cm and 10 per 0.5cm length class for fish above 28cm) is taken for maturity, weight, age (otolith extraction) and presence of ichtyophonous infection from each haul.

Data analysis and abundance estimation

Echo integration and further data analyses are carried out using Myriax Echoview and Marine Lab Analysis (MILAP) software. Acoustic data are scrutinised on a regular basis during the survey and acoustic density values (s_A) of herring are exported by 15 min EDSU. Echo integrator data are included in analysis from 12 m below the surface (transducer at 8.5 m depth) to 0.5 m above the seabed. The abundance estimation described below is carried out following the universal principles detailed in Section 6.4

of the survey manual and using the agreed target strength to fish length relationships in Section 6.1 of that manual (ICES, 2015).

Abundance and biomass at age of herring is estimated per ¼ ICES statistical rectangle in the MILAP programme following the workflow summarized below.

Post-stratification of hauls is carried out using the Kolmogorov Smirnov test of similarities among length distributions as described in Simmonds and MacLennan (2005). Homogeneous regions are identified and for each of these, length frequencies from hauls within the region are averaged, giving equal weight to all hauls.

For each rectangle, the arithmetic mean of the s_A values for herring per EDSU in the rectangle is calculated weighted by the size (in minutes) of each EDSU to accommodate the shorter EDSUs.

If there are s_A values assigned to herring in a mixed fish category, the s_A is partitioned to extract the herring s_A first, taking into account the TS of each species present in the mix, their respective size distributions and the relative proportion by number of each species in the mix as described in Simmonds and MacLennan (2005).

Herring density is then calculated from the overall mean s_A for the rectangle using the relevant combined length frequency for the region encompassing the rectangle.

Abundance is calculated for each rectangle by multiplying the density with the total surface area of the rectangle considered habitable by herring (i.e. water deeper than 20m). A single weight length relationship is defined for herring for the entire survey area and is used together with the regional length frequencies to estimate the mean weight of fish in each region. Biomass for each rectangle is then calculated by multiplying total number of fish in the rectangle with the region specific mean weight.

Finally one maturity-age–length key (MALK) is produced for each region by averaging the proportion for each age and maturity category at length in each haul over all hauls in each region again giving equal weight to all hauls. These allocation keys are used to apportion the abundance of herring in each rectangle to numbers-at-age and maturity which is then summed for each region and finally for the entire survey area. The data are uploaded to FishFrame at the aggregated level as abundance for each rectangle and the relevant MALK for each rectangle.

2.2.3 Calculating 'global' abundance using FishFrame

The aggregated national data are reported through a standardized data exchange format and uploaded into the FishFrame database. National estimates are aggregated through FishFrame annually prior to WGIPS to calculate global abundance estimates for the stocks covered by the surveys. The exchange format currently only holds information aggregated to the ICES statistical rectangle level, with at least one entry for each rectangle covered. More flexible strata are accommodated by allowing multiple entries for abundance belonging to different strata. Data submitted consists of the ICES rectangle definition, biological stratum, herring abundance by proportion of autumn spawners (North Sea and VIa North) and spring spawners (western Baltic), age and maturity, and survey weight (survey track length).

Global estimates of numbers-at-age, maturity stage and mean weights-at-age for each stock are calculated as weighted means of individual survey estimates by ICES statistical rectangle. The weighting applied is proportional to the length of survey track for each vessel in each ICES statistical rectangle. The data are combined to provide estimates for the North Sea autumn spawning herring, Western Baltic spring-spawning herring, West of Scotland (VIaN) herring, the combined Malin Shelf herring stock (VIaN-S and VIIb,c), North Sea sprat and sprat in Division IIIa.

3 Calculation of a new survey abundance index using StoX

3.1 HERAS data call

The group identified a need for a workshop to review current HERAS methods during the WGIPS meeting in January 2014 (WGIPS Report 2014)

The data call

The group currently uses FishFrame to store aggregated survey data and as a computational tool to estimate 'global' abundance for HERAS surveys. From 2015, the group working in harmony with the ICES data centre and as part of the larger AtlantOS project will develop a new acoustic database to store survey data from all WGIPS coordinated surveys. The IMR developed StoX computational software will be used and developed through user input by the group as the standardized calculation tool for acoustically derived abundance estimates.

Pre-workshop tasks

Methods review

It is requested that each HERAS participant provide a detailed description of calculation methods employed at national level in advance of the coming WKEVAL workshop. Participants are requested to detail all steps involved in the calculation of acoustic abundance from species allocated NASC data. Echogram scrutinisation will be discussed but a detailed review will be left for consideration at the dedicated workshop (WKSCRUT). Participants should also include details on the stratifying of survey areas, track design, trawl haul allocation and estimates of precision, where applicable. Calculation tools (Excel spreadsheets, R-scripts etc.) and working examples of recent survey datasets should be made available during the meeting.

A SharePoint site has been set up specifically for the WK: WKEVAL SharePoint

The deadline for submissions of methods is the ***Friday 31 July, 2015.***

Data

As the group is preparing to migrate to a new ICES DB format, based on the existing WGNAPES, a number of tasks are required to initiate the process. The StoX program will be adopted as the new computational tool for 'global' estimates of acoustic abundance across WGIPS coordinated surveys.

As an internal sensitivity exercise, a comparative run of historic estimates produced using StoX and FishFrame will be carried out. To that end, participants are asked to reformat current HERAS data for the years 2012–2014 into WGNAPES format for upload to the trial ICES database. Log in details and portal address will be circulated by the ICES data centre as soon as they are ready.

Acoustic data allocated by species should be submitted in 1nmi EDSU and as a single depth channel covering the entire water column. Stock identifiers should be added as an additional column using a pre-agreed naming convention. Additional confirmation is required on the missing meta-data (ICES metadata standards) currently not included as part of the WGNAPES format. This will be provided by Leon Smit in advance of the exercise.

Data format examples, process detail and instructions are available in the WGIPS acoustic survey manual. Support has been volunteered by Leon Smit to help aid the process and this is gratefully appreciated.

The deadline for converted data is the ***Friday 31 July, 2015.***

3.2 StoX application

StoX is 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 with Java for ease of 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 can be accommodated. Despite this complexity, the execution of an index calculation can easily be governed from a user interface and an interactive GIS module, or by accessing the Java function library and parameter set using external software like R.

Accessing StoX from external software may be an efficient way to batch process time-series datasets or to perform bootstrapping on one dataset, where for each run, the content of the parameter dataset is altered. 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.

StoX has been tested alongside existing abundance calculation tools during the 2014 IESNS, IBWSS, IESSNS surveys and the Norwegian acoustic sandeel and cod surveys and has been adopted as the primary method used to calculate abundance going forward. One of the advantages of using StoX is the ability to retrace the steps used in estimating abundance for each run performed. This includes the allocation of hauls used during the analysis, something that is not currently available when using tools such as BEAM (Totland and Godø, 2001).

3.3 New ICES database

To improve the fish survey data availability through the ICES data center there is a need to host interpreted acoustic data (NASC values) and corresponding meta-information, in addition to archiving biotic sampling data. This is important for secure storage and consistency between groups doing acoustic surveys, and for data availability. This is one of the main datasets for fisheries advice on pelagic species, including herring, blue whiting, mackerel and sprat. This is relevant to expert groups that coordinate surveys and feed the ecosystem assessment process in the North Atlantic. This work program has 3 main objectives: 1) to improve the fish survey data availability through the ICES data center for key pelagic fisheries surveys; 2) to prepare the ICES data center to host these data in accordance with ICES and international metadata standards and 3) to modify current processing and analysis software to fit into the new system. The acoustic database will be prepared in accordance with the ICES metadata standards that are currently being implemented throughout the North Atlantic. Software routines will be further developed to utilize the database, including general data preparation, post-processing) and storing of processing parameters. The system will be designed in accordance with the ICES survey groups and all software including database structure will be released under open source licenses. The construction of the new acoustic database forms part of the larger AtlantOS project (www.atlantos-h2020.eu/home).

3.4 Results

One of the primary objectives of the workshop was to retrospectively recalculate HERAS abundance using the StoX application as a sensitivity analysis with existing methods. However, this was not achievable during the meeting due time constraints and will be rescheduled for a later date. The task of reformatting data for the period 2012–2014, although initiated well in advance of the meeting (Section 3.1) was ongoing during the meeting. This was a difficult and complex task especially for those unfamiliar with the format. Members worked tirelessly on this task to ensure data were uploaded in the correct format as per the data call before the end of the meeting (Table 3.4.1). In parallel work was undertaken with ICES data centre to establish the new data formats to meet the groups reporting requirements by modifying the existing WGNAPES format.

This considered the workshop has made considerable progress towards establishing the HERAS data reporting structure for the new ICES Acoustic database, an important milestone for both HERAS and the larger WGIPS group. In addition, the group has put in place the steps required to move to use the new database and the StoX application for calculating abundance for 2015 survey data scheduled for January 2016. By the end of the meeting members left with the capacity to run StoX using reformatted national datasets.

Table 3.4.1. Status of HERAS data call at the end of the workshop. Five file types uploaded =Y (Acoustic, AcousticValues, Catch, Biology, Logbook).

Nation	2012	2013	2014
IRL	Y	Y	Y
SCO	Y	Y	Y
NL	Y	Y	Y
DEN		Y	Y
GER	Y	Y	Y
NOR	Y	Y	Y

4 Evaluation of HERAS survey design and standardization

The process of standardization of survey methods within WGIPS coordinated surveys, including HERAS began in earnest in 2012 resulting in the publication of a dedicated WGIPS survey manual in 2015. Further details on HERAS survey protocols including current methods employed for biological and acoustic data collection are available in the manual (SISP 09).

As part of this ongoing process the need for a dedicated workshop came about to review and evaluate national methods applied during the analysis of acoustic data.

4.1 Current HERAS survey design and analysis

National surveys within HERAS are based on historic programs established prior to the beginning of the "modern" coordinated survey in the late 1980's (i.e. ICES, 1991). Although the overall survey has been coordinated under the WGIPS/PGHERS umbrella, a certain level of autonomy was retained within national institutes with regards to survey design and calculation methods. Survey design and analysis methods have been updated in part over the years at a national level but not in unison. In the current design, effort is based on number of transects within each rectangle. The survey effort is currently distributed to cover all ICES rectangles in the survey area. Selected high density rectangles are covered with higher effort based on historic abundance and distribution prior to 2003 (ICES, 2003). In more recent years, effort allocation has been adjusted to accommodate constraints faced by some participating institutes. The underlying assumptions for the effort allocation have not been verified in recent years.

Abundance estimates are reported by ICES rectangle and in some cases by sub rectangle where the effort is highest. No estimate of precision is currently reported for this time-series.

Biological sampling is carried out by targeted trawling and in some cases, non-targeted surface trawls. Biological sampling routines use both random and random length stratified sampling procedures with both methods considered to be robust and comparable. Temporal daily coverage ranges from 14–24 hours between nations with effort based primarily on fish behaviour (diel vertical migration) as well as logistical constraints.

4.2 Areas where standardization is required across surveys

Implementation of survey strata

Within the areas covered by different national laboratories different choices in terms of survey design and execution have been made over the years to best accommodate local conditions such as fish behaviour (composition of the stock in terms of Mature/immature components, mixing with other fish, diurnal vertical migration, migration patterns, etc.), bathymetry (shallow/deep, steep gradients), biological sampling stratification etc. as described in Section 2.2.

The coordinated survey covers a diverse array of habitats and it was clear from the presentations on national methods that in general the national surveys had adapted to best deal with local conditions. Standardizing all aspects of the survey from design to biological sampling would therefore not be beneficial, but it was recognized that the differences in protocols should not be guided by which nation covers a certain area, but rather be based on how each area can best be surveyed taking into account local constraints.

It was agreed to define a set of survey strata within which a common set of design standards could be defined. These strata do not necessarily coincide with present national survey boundaries but will be based on the specific constraints the survey needs to be sensitive to in the local area.

It was agreed within the group that the survey area is stratified according to biological and/or stock parameters. The formulation of new survey strata not defined by ICES rectangles will facilitate two important developments for the group; 1) Standardization of survey design and effort within co-surveyed strata, 2) Ability to report meaningful precision (CV) of estimates of abundance.

The definition of survey strata is underway and defined survey strata boundary points (Lat/Lon) will be circulated among the group within the defined timelines agreed (15 November, 2015).

Survey design

Systematic parallel transect design (where applicable) with randomized starting points needs to be implemented across all survey strata. The need for separate strata in areas where this is not the best solution due to physical constraints is recognized and will be accommodated. Standardization of transect resolution and design across HERAS defined strata in this way is a requirement to ensure a statistically robust approach (Jolly and Hampton, 1990; Simmonds and Fryer, 1996). Global survey design will be led by the survey coordinator annually during planning at WGIPS and adhering to agreed changes in strata and design. The survey design should take into account the effects of migration, double counting and temporal alignment of co-surveying vessels within common strata. The design for the 2016 survey is scheduled to take place at WGIPS in January 2016.

Temporal coverage

Effort within the 24hr cycle needs to be in line with when target species are most available to acoustic equipment during the diurnal cycle. Standardization of temporal coverage between vessels co-surveying strata is a requirement and will be decided during the planning phase.

Haul allocation

The treatment of haul information when calculating overall abundance and partitioning abundance according to biological characteristics differs among national laboratories. Some use a strict nearest neighbour allocation of hauls to acoustic densities, some average hauls within homogenous regions based on similar length distributions and some average hauls within each ICES rectangle. A comparison to the effect of using nearest neighbour approach vs. homogenous regions on abundance estimation was presented and indicated that between these two approaches there was no significant effect on abundance (Carlson, 2015). The effect on numbers-at-age and maturity were not considered.

It was agreed that standardizing the approach across all strata might not be appropriate but the decisions made should be transparent and ultimately agreed prior to and during the post cruise meeting. The provision of disaggregated data going forward and the use of StoX will enable the group to readily quantify effects of choosing different strategies. This discussion will be continued and guidelines agreed during WGIPS 2016.

Assumption of maturity

For the rare instances where the maturity of herring cannot be determined it was agreed by the group that all herring >4 years shall be assumed to be mature and a component of the spawning stock.

Inclusion of track fragments of <1nmi

It was agreed that track fragments resulting in an EDSU <1 nmi, such as at the end of transects or when trawling has occurred, should be included in the analysis going forward for those who do not currently submit. In StoX such fragments are weighted according to length and are thus valid data points.

Although it is encouraged that tracks be continued to nearest, full 1nmi before breaking off for trawling etc. this is not always possible. sA from these fragments of intervals should be included in the data delivery with the actual distance in nmi specified in the 'LogInt' field in the 'Acoustic' table.

Users of LSSS should be aware that only entire intervals are included in the data export. The inclusion of part intervals can be achieved by changing the storage resolution between 1 nmi to 0.1 nmi intervals.

Treatment of mixed species echotraces

The partitioning of mixed species echotraces is a central part of the analysis process particularly in the Skagerrak-Kattegat area and the southern part of the North Sea where the differentiation of echotraces to individual species level is problematic. It was agreed that although it is possible to partition the proportion of NASC to species level within the most commonly used analysis software (Echoview and LSSS) using the relevant information from trawl catches; it was preferred to allow this step to be carried out within StoX.

To derive a species-specific abundance estimate, survey participants therefore need to supply information related to mixed species echotraces in a standardized way (according to PGNAPES database terminology): 'Acoustic values' not scrutinised to species level need to be labelled as such, using the three letter code 'MIX'; 'Catch' data used to split acoustic densities associated with mixed species need to be labelled in a way to identify the species in the catch that contribute to the related echotraces, using "1" (contributing) and "0" (not contributing).

Data reporting structure

The data reporting structure adopted for use by the group is based on the existing PGNAPES file format but modified to suit our specific needs. Modifications include the inclusion of stock identification parameters, the inclusion of mixed species echotraces and reporting of NASC by high-resolution depth channel. Examples of the new file formats are available on the WKEVAL and WGIPS SharePoint sites with details presented in Annex 1. The finalized reporting structure will be circulated among the group in advance of analysing the 2015 survey and data should be delivered in this new format for the analysis of 2015 survey data.

5 Discussion

The objectives of the workshop were achieved in that a three-year time-series for the HERAS survey was reformatted and ready for use in the sensitivity analysis. Unfortunately, it was not possible to run this analysis during the meeting due to time constraints. However, this exercise will be rescheduled for another as yet to be determined date. By the end of the meeting, an R-script produced by Sascha Fassler (IMARES) was circulated to allow participants to convert reformatted data into the xml file format required by StoX. Each participant now has the capacity to rerun their own national datasets using StoX and compare results.

Having members from the ICES data centre at the meeting was a great help and allowed for discussion on data structure and reporting methods. This led to some important discussion among the group regarding standardization of methods, future stratification and national limitations in operations. The group was also able to identify important metrics within the existing survey program that are a requirement when reporting survey abundance to the HAWG and how to report such using the new data structure.

The group has been able to establish the core reporting structure for the acoustic component of surveys, which will be developed over the course of the project when the metadata requirements are included.

The biological reporting structure, although established at the meeting, may need further development to meet existing structure within DATRAS. This will be communicated to the group through the data centre.

The reporting of other survey components including hydrographic, plankton and egg and larval data will be included into existing databases hosted within the ICES data centre.

The group has identified the need for a training session for new users of both the database and StoX program and this need has been communicated to the ICES training centre.

Achievements:

- Establishment of data structure to meet HERAS reporting requirements for the ICES Acoustic database.
- Three-year dataset reformatted and ready for the rescheduled sensitivity analysis exercise.
- Reporting structure established for 2015 survey data (January 2016).
- Identified where differences exist and initiated process to standardize survey methods within HERAS.

Recommendations:

- The group recommends that the areas identified for standardization to ensure consistency across surveys will be adopted in HERAS surveys carried out in 2016.
- The group also recommends that from 2015 onwards HERAS global estimates of abundance will be carried out using StoX as the primary computational tool.

- The group recommends that members of the ICES data centre along with Espen Johnsen participate in the HERAS post cruise meeting (15–17 January) and if possible WGIPS (18–22 January) to; a) facilitate the production of the HERAS estimate; b) test run the database and StoX using a live dataset; c) update the larger group and to facilitate discussion on future development.
- The group has identified the need to establish the biological reporting structure as soon as possible to allow for planning for surveys scheduled for 2016. To that end, the group recommends that someone from the DATRAS team should attend the WGIPS meeting in January 2016 to update the group.

6 References

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Annex 1: List of participants

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Annex 2: New reporting file structure for HERAS surveys

Reported here are the agreed file types for submission to the ICES Acoustic database. Deviations from existing NAPES format and new additional columns are highlighted. Note: It is envisioned that some minor changes to this reporting structure will take place over the development of the project including the reporting of additional metadata. This includes changes to the biological data format to meet the existing DATRAS structure.

Species identification codes used within ICES and adopted for use here is AphiaID: http://www.marinespecies.org/aphia.php?p=taxlist

Acoustic

RTYPE	A	M
Country	Post code, ISO_3166	M
Vessel	Call sign (ShipC Code)	M
Cruise	Cruise identifier	M
Log	Min 4 digits (nmi)	M
Year	YYYY (4 digits)	M
Month	MM	M
Day	DD	M
Hour	HH, time GMT 0–24	M
Min	MM (integer)	M
AcLat	Decimal degrees The position refers to the beginning of the interval.	M
AcLon	Decimal degrees The position refers to the beginning of the interval.	M
Logint	nmi, Log_end-Log start [EDSU] =1nmi]	M
Frequency	KHz [38 KHz as standard]	M
Sv_threshold	DB [-70 dB as standard]	M

AcousticValues

RTYPE	AV	M
Country	Post code, ISO_3166	M
Vessel	Call sign (ShipC Code)	M
Cruise	Cruise identifier	M
Log	Min 4 digits (nmi)	M
Year	YYYY (4 digits)	M
Month	MM	M
Day	DD	M
SACat	Species code: HER, WHB,…MIX, CLU	M
ChUppDepth	Upper channel depth (m) Rel. to surface	M
ChLowDepth	Lower channel depth (m) Rel. to surface	M
ChRange	Define reporting range [1m]]stdstandard]	M
SA	Acoustic readings (m^2/nm^2)	M
MixHaulID	Identifies the haul allocation to MIX or CLU	See SACat*

Catch

RTYPE	C	M
Country	Post code, ISO_3166	M
Vessel	Call sign (ShipC Code)	M
Cruise	Cruise identifier	M
Station	YYYY (4 digits)	M
StType	PTRAWL= pelagic trawl, BTRAWL= Bottom trawl	M
Year	YYYY (4 digits)	M
Haulvalidity	Valid haul = 1, Not = 0	M
FAOCode	HER, WHB etc	M
Species	Species code: AphiaID The position refers to the beginning of the interval.	M
Sorting_Species	L= large, S=small, C=combined (TBC)	
Sppselect	For MIX, CLU categories 1=clexclude	M
Catch	Weight of total catch (Kg)	M
Subsample	Weight of sub-sample (Kg)	M
Towtime	Trawl duration (mins)	M
Wirelength	Trawl warp length (m)	
TowSpeed	Speed in Knots	
Trawldepth	Mean depth of trawl	

Biology

RType	B	M
Country	Post code, ISO_3166	M
Vessel	Call sign (ShipC Code)	M
Cruise	Cruise identifier	M
Station	Integers	M
StType	PTRAWL= Pel, BTRAWL= Btm trawl	M
Year	YYYY (4 digits)	M
FAOCode	HER, WHB etc	M
Species	Species code: AphiaID The position refers to the beginning of the interval.	M
Sorting_Species	L= large, S=small, C=combined ji(TBC)(TBC)	
Length	Nearest 1cm or 0.5cm below	M
Weight	In grams	
AgeScale	Age years	
AgeOtolith	Age years	
Sex	Female=1, Male=2, 0= undetermined	
Maturation	8 point scale only	
StomFullness	Visual reading 1–5 (ICES scale)	
Icthyophonous	P = present, A= absent	
StockID	NSAS, WBSS, CBH, VIaN, VIaS	
VertCount	XXX	
Recnr		M

Logbook:

RType	L	M
Country	Post code, ISO_3166	M
Vessel	Call sign (ShipC Code)	M
Cruise	Cruise identifier	M
Station	National station number	M
StType	PTRAWL= pel trawl, BTRAWL= Btm trawl, CTD, CC=Course Change, PLK= plankton	M
Year	YYYY (4 digits)	M
Log	Value from the acoustic log (nmi)	
Month	MM	M
Day	DD	M
Hour	HH, time GMT 0–24	M
Min	MM	M
Lat	Decimal degrees	M
Lon	Decimal degrees	M
BottDepth	Mean bottom depth (m)	
WinDir	Compass degrees	
WinSpeed	m/s	

Annex 3: Recommendations to other groups

Recommendation	Adressed to
Confirmation of the biological data reporting structure (DATRAS- pelagic)	ICES Data centre
Confirmation of the additional metadata requirements for all reporting components within WGIPS	ICES Data centre/AtlantOS
Communication between WGNAPES DB hosts (Faroe Islands) that data structure is cross compatible for reporting requirements e.g. IBWSS survey program within WGIPS	ICES Data centre/Faroe Islands
Clarification on the accessibility of data within the ICES Acoustic database	ICES Data centre

Annex 4: Data analysis methods used by Ireland

Malin Shelf Herring Acoustic Survey – Irish Portion, RV Celtic Explorer

Calculation of Acoustic Abundance from Species-allocated NASC Data

Cormac Nolan and Andrew Campbell

Marine Institute, July 2015

This document describes the process used by the Marine Institute to estimate the abundance and biomass of herring (and boarfish) in the Irish portion of the Malin Shelf Herring Acoustic Survey. Full working examples are available at: https://github.com/AndyCampbell/rAco

Detailed yearly survey reports can be found here: http://oar.marine.ie/handle/10793/53

Background

The Malin Shelf Herring Acoustic Survey (MSHAS) covers ICES Divisions VIa and VIIb and is jointly conducted by the Irish Marine Institute and Marine Scotland Science. The Irish portion of the MSHAS (also referred to as the North West Herring Acoustic Survey or NWHAS) takes place annually on the RV Celtic Explorer from late June to mid-July. The time-series of the survey in its current format runs from 2008 – Present. The area covered by the Celtic Explorer (CE) has grown since the start of the time-series (Figure 1). In 2015, the Celtic Explorer covered the entire Malin Shelf area (Figure 2) although shared coverage should revert to normal in 2016.

Survey Design, Strata, and EDSU

A typical example of the CE survey design is shown in Figure 2. Parallel transect spacings of 15 and 7.5 nautical miles are used on the shelf area while zigzag transects are used in the Minch (between the Hebrides and Scottish mainland).The tighter 7.5 nmi spacing is used at latitudes where higher densities of herring have been observed in previous years. However, most years there is sufficient time remaining to fill in many of the 15 nmi spaced transects resulting in 7.5 nmi spacing continuously from 57° N to ≈53.75° N. In 2015 it was planned to reassign some of this extra survey track from low-density areas in the south to the stat rectangles around St Kilda (≈57.75° N), where large herring schools are often observed. This plan changed due to problems with the Scottish charter vessel so it will be addressed in 2016.

Each ICES statistical rectangle is treated as a ‘stratum’ (Estimation with a rectangular grid; Simmonds and McLennan, 2005 p. 351) i.e. an elementary statistical sampling rectangle or ESSR. The boundaries of these strata are adjusted so as not to include land or areas devoid of transects. Surface areas of strata are calculated within the R code described below. Herring biomass and abundance are reported by statistical rectangle, age, maturity and ICES division. An EDSU of 1nmi is used.

The survey begins by zigzagging north through the Minches before progressing to the parallel transects, which are completed from north to south. A random starting point is chosen as the start of the parallel transects each year and zigzag transects are placed haphazardly. The start and endpoints of transects are dictated by the depth: approximately 30m near the shore to 250m at the shelf edge. Data collection is only undertaken during daylight hours (04:00 to 00:00) and a speed of 10 knots is maintained while on transect unless weather conditions intervene.

Fishing Hauls and Their Allocation

As a general rule of thumb, one successful fishing haul is sought in each statistical rectangle where herring are observed, rising to two or three in rectangles with greater herring density. Other hauls for species determination or supplementary samples are conducted as needed. No blind surface hauls are conducted. Roughly, 25 directed hauls using a pelagic trawl are conducted each year. These hauls are not combined into strata by likeness as in other countries. They are treated individually and, using the R code described below, each acoustic mark is assigned to its geographically nearest haul1. The process is fully automated but the assignments are thoroughly checked, particularly around hauls in the Minches. Hauls of herring in the Minches region, if they can be conducted at all in the rough ground, usually contain small 1 WR fish whereas a short distance away, just to the west of the Hebrides, older, larger herring prevail. Care is therefore required that hauls from the Minches are not assigned to marks outside the region.

During scrutinising, the Marine Institute assigns one of four mark types to herring schools: 'Definitely', 'Probably', 'Possibly' and 'Mixed'. A parameter file is used to inform the code which hauls can be used in the analysis and which of those hauls to use for each mark type. Hauls that missed the original target mark or that are thought not to accurately represent the mark for any reason are excluded from further analysis. Hauls that contain herring mixed with other species are labelled as 'herring in a mix'. Such hauls are used to apportion the acoustic values in the nearby 'herring in a mix' marks. For example, the 'Herring In a Mix' parameters from 2012:

Mark Type::Herring In A Mix

NASC Name::Herring In A Mix

Species Common::Herring

Species Scientific::Clupea Harengus

Include::True

Haul Assignment Type::Nearest

Mixed::Scomber Scombrus, Capros Aper

Hauls::6,9,15

In this example the proportions of the weights of herring in haul numbers 6, 9 and 15 were used first to apportion acoustic values in the nearest "herring in a mix" schools to herring, i.e. if 1/3 of the catch in the nearest 'herring in a mix' haul is herring then 1/3 of the NASC of a 'herring in a mix' mark will be counted towards herring. Later in the analysis the biological data (length distribution, ages, maturities, etc.) from these hauls are applied to those same schools when calculating number of herring. The 'Include' variable determines whether this mark type is to be included in the final abundance\biomass estimate.

[1] The R code has the option to combine more than one haul; however, it is rarely put into practice.

Biology

A diagram of the sampling protocol is presented in Figure 3. The following data are collected from a random subsample of the bulk catch.

Length Frequency: Herring measured (to the nearest 0.5cm below) until the most common length class contains 60 measurements.

Length – Weight: 100 random herring weighed and measured.

Aged and Sexed: length, weight, sex, maturity and age (otolith) taken from 120 random herring.

Stock Identification: body and otolith morphology photos taken from the 120 aged herring,

An eight-point scale is used for herring maturity. The stages are detailed below.

Stage	Description	Mature\Immature
1	Juvenile	Immature
2	Developing Virgin	Immature
3	Ripening 1	Mature
4	Ripening 2	Mature
5	Ripe	Mature
6	Running	Mature
7	Recently Spent	Spent
8	Spent-Recovering	Spent

Abundance and Biomass Estimation

All scrutinising is conducted using Echoview (currently version 5.4). Details of the scrutinisation process will be left for WKSCRUT. Once all acoustic registrations have been assigned to species, the integration results (PRC NASC) are exported by regions (marks) by cells (1 nmi X 50m) in spreadsheet format and added to a database alongside the biological sampling, transects, and strata details. The TS-length relationship used is that recommended by the acoustic survey-planning group (ICES, 1994): Herring TS = 20log10L – 71.2 dB per individual (L = length in cm).

For each statistical rectangle, the unit area density of fish (SA) in number per square nautical mile (N* nmi^{-2}) is calculated using standard equations (Dalen and Nakken, 1983, Foote *et al.*, 1987, Toresen *et al.*, 1998; see Annex 1). To estimate the total abundance of fish, the unit area abundance for each statistical rectangle is multiplied by the number of square nautical miles in each statistical square and then summed for all statistical rectangles for the total area. Biomass estimation is calculated by multiplying abundance in numbers by the average weight of the fish in each statistical rectangle and then sum of all squares by rectangle and summed for the total area. The process is further described in the section below 'Overview of the rAco Process' and Annex 1 'Abundance Estimation'

The total and spawning stock abundance and biomass estimates are calculated by statistical rectangle, age (winter rings), length, and maturity using an R package (rAco) and associated scripts that have been developed by Andrew Campbell based on work by Ian Doonin. The package, scripts, and example survey data are available here: https://github.com/AndyCampbell/rAco

A CV (based on strata standard error divided by the strata mean) is estimated for SSB, total abundance and biomass, and abundance by age.

Overview of the rAco Process

The following lines describe, in simplified terms, the flow of the rAco process. The equations behind these steps are included in Annex 1.

Initialization of script: Load libraries (Acoustic functions, GIS) and shapefiles

Begin processing survey:

Load and format hauls, samples, length frequency, biological info, and SA tables.

Load vessel track, hydrographic data, strata boundaries, species details (target strength, maturity codes), and mark types.

Load mark types: details what hauls can be used by each mark type ("Definitely herring", "Possibly Herring", etc.) for the nearest haul assignment. In addition, whether to include that mark type in the final biomass\abundance estimate.

Format SA: Make a list of all SA values. Add details of school position, school length, transect, strata etc. to the elements of the list.

Survey level plots: export plots of transects, CTD positions, haul positions, NASC values by mark type, strata boundaries.

Transect assignment: assign a transect to each mark (acoustic registration) on the basis of its proximity.

Quality control: loop over marks and report any that are closer to an alternative transect to that stored in the database, generate plots containing any such transects in question and the location of the mark.

Set a length-weight relationship for each species.

(For the sake of simplicity, the process for one species is detailed below, although many species can be processed in a loop.)

Create and initialize structures to store the results of the analysis (results by transects -> results by strata -> overall results).

Make an age–length key for the species (can either be made using samples from the current survey or loaded from an external source)

Make maturity key (can either be made using samples from the current survey or loaded from an external source)

Loop through each mark type within the species.

For each mark within that mark type:

- Assign the nearest haul
- Assign the length frequency to the mark
- Calculate the acoustic backscatter cross section

End loop over marks.

For each transect within that mark type:

- Select SA records on that transect
- Calculate the abundance and biomass for those marks (Dalen and Nakken, 1983).
- Calculate the mean abundance and biomass on the transect (per 1 nmi).

- Calculate that abundance and biomass by age, length, and maturity using keys.

End loop over transects

Loop over strata:

- Select the transects in the stratum
- Calculate the mean abundances\biomass by transect
- Calculate the variance by transect
- Weight the variances by transect lengths (detailed below)
- Combine the abundances to stratum level and multiply by cell length

End loop over Strata

End look over mark types

Calculate overall variance\CV (detailed below)

Save results and export tables in appropriate format for Marine Institute survey report.

Survey abundance and biomass variance/cv calculations

Weighting for strata: those strata with fewer transects get a higher weighting and thus contribute proportionally more to the overall variance, also those with a bigger area.

Loop over mark types

Loop over strata

- Get lengths of all transects in stratum
- Weighting factor = sum(all transect lengths ^ 2) / sum(all transect lengths) ^ 2
- Retrieve strata mean abundance and biomass
- Retrieve abundances\biomass variances
- Sum the biomass and abundance variances of all transects within each strata, where:
  - ♦ Variance transect = (var of marks)*(stratum weight)*(stratum area squared)
- ▪ End loop over strata

End loop over mark types

Get CV for abundance and biomass of whole survey where:

- ▪ CV = 100*(square root of total variance) / mean abund or biomass

References

Anon. 1994. Report of the planning group for herring surveys. ICES CM 1994/H:3.

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Toresen, R., Gjøsæter, H., and de Barros, P. 1998. The acoustic method as used in the abundance estimation of capelin (*Mallotus villosus* Müller) and herring (*Clupea harengus* Linné) in the Barents Sea. Fisheries Research 34: 27–38.

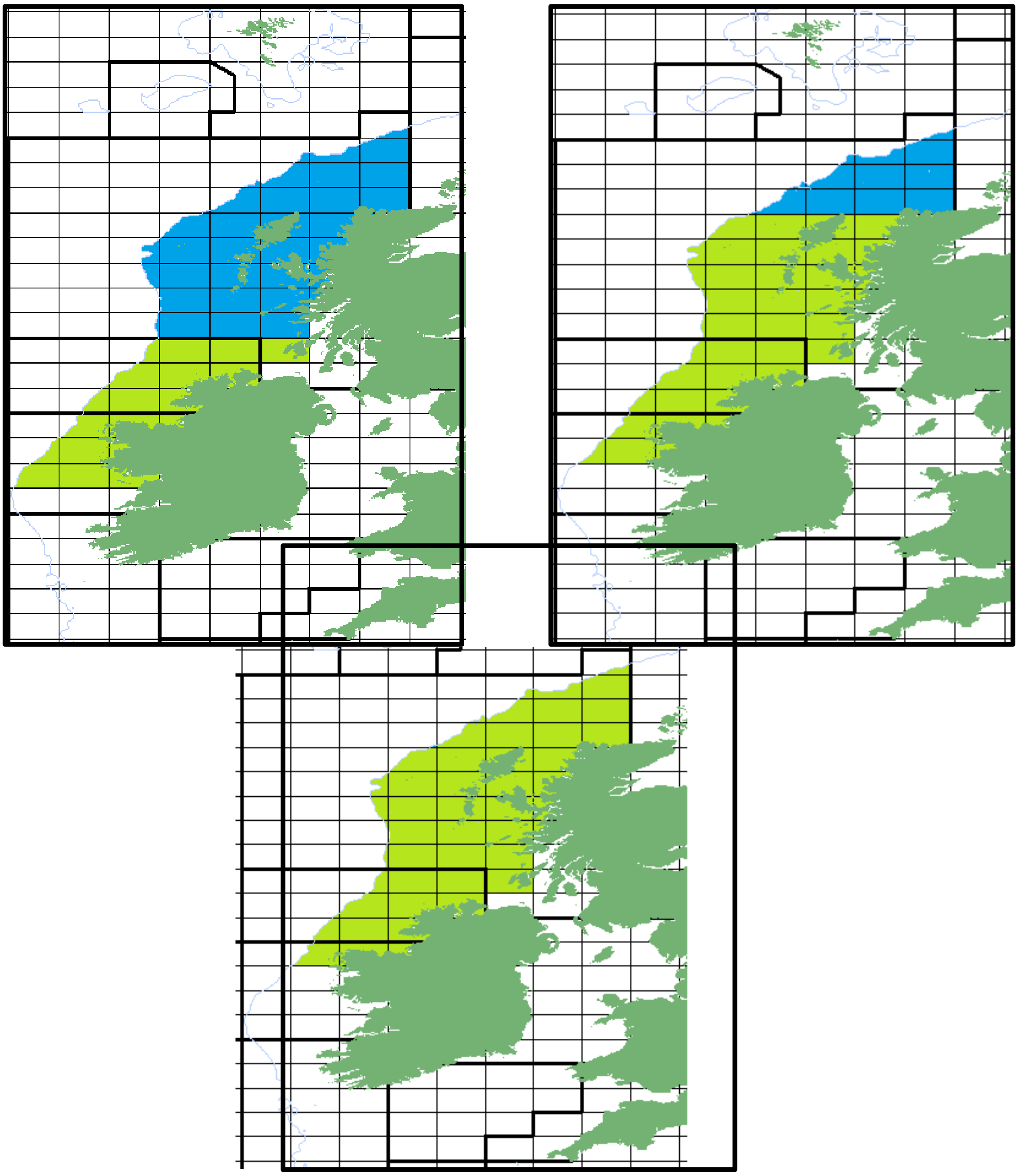


Figure 1. Coverage of the Malin Shelf Herring Acoustic by Scottish (blue) and Irish (green) research vessels from 30m to 250m depth contours (grey lines). 2008–2010 (Top left); 2011–2014 (Top right); 2015 (Bottom). Outlines of ICES Rectangles (black lines) and Divisions (Bold black lines) also shown.

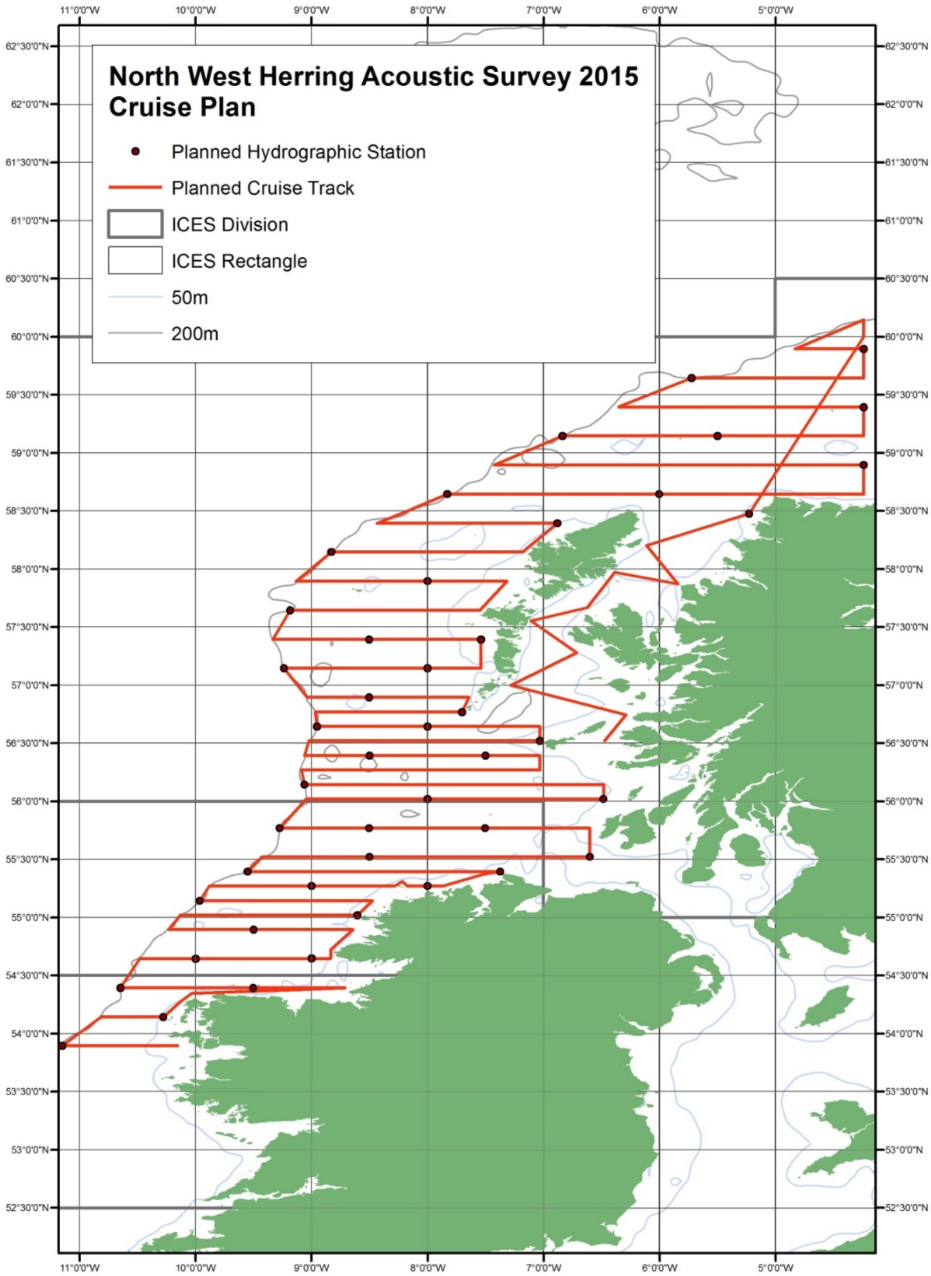
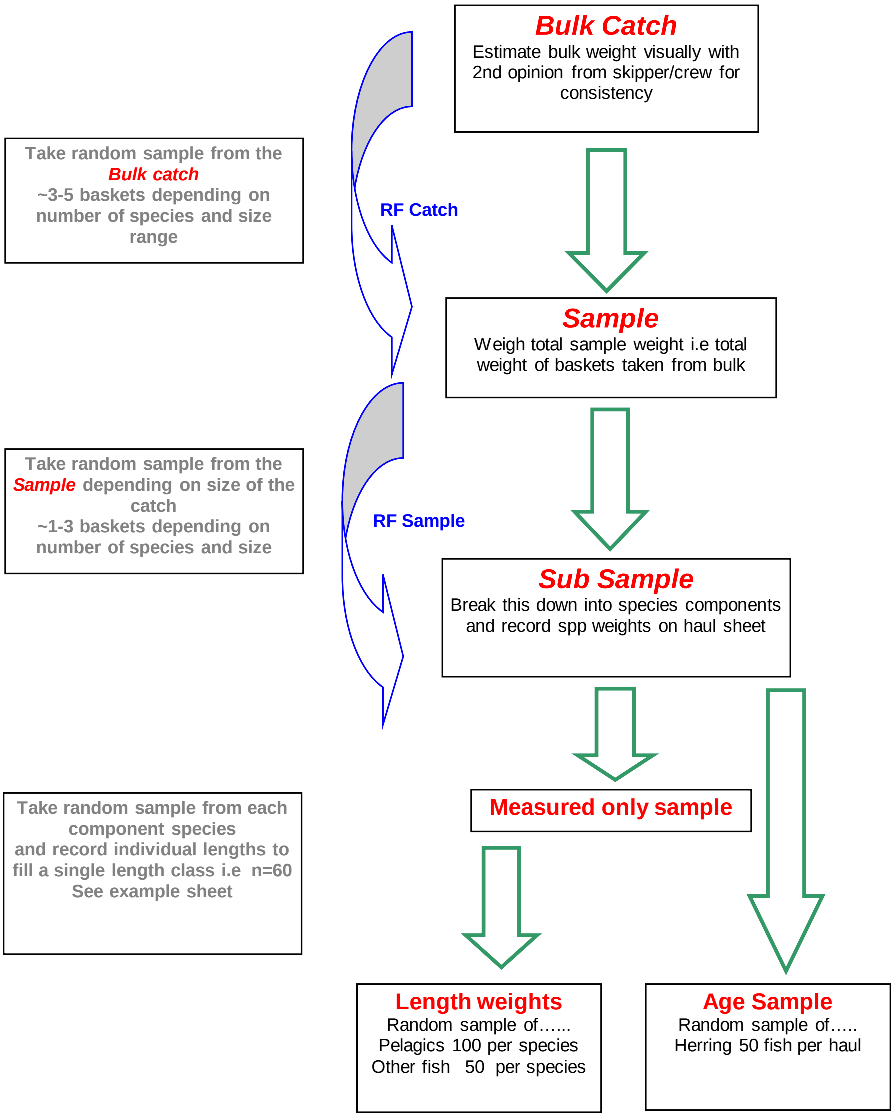


Figure 2. Example of typical survey design (2015 cruise plan).

BIOLOGICAL SAMPLING PROTOCOL FOR HERRING SURVEYS



Pelagic Species	Measure to….
Herring	<0.5cm below
Sprat	<0.5cm below
Pilchard	<1cm below
Mackerel	<1cm below
Scad	<1cm below

Raising Factors:

RF Catch

Bulk catch weight ÷ Sample weight

RF Sample

Sample weight ÷ sub sample weight

Figure 3. Flow diagram of biological sampling protocol for representative samples.

Annex 1 Abundance estimates

Total abundance, NT, is given by $\sum_{m}^{Mark-types} N_{T,m}$, the sum over the total abundance by mark-types.

$$N_{T,m} = \sum_{s}^{strata} N_{m,s}$$

Suppressing the mark-type index, m, the stratum abundance is

$$N_s = area_s \sum_{l}^{transects} \bar{n}_{s,t} l_{s,t} \Big/ \sum_{j} l_{s,j}$$

,where l is the transect length and $\bar{n}$ is the transect mean abundance n.mi-2 which is given by

$$\sum_{j}^{track\cdot fragments} n_{s,t,j} d_{s,t,j} \Big/ l_{s,t}$$

, where d is the distance of the track fragment and ns,t,j is the mean abundance n.mi-2 for the jth track fragment.

Because hauls are assigned with their own stratification that will not necessarily coincide with the acoustic strata, the conversion of NASC into mean density is done at the track fragment level, usually a 1 n.mi segment, but these could be just for the schools themselves. The haul assigned, $h_{m,s,t,j}$, depends strongly on the mark-type (m) and since more than one school can be in a track fragment it needs to be specified. Since age and maturity length-keys are to be applied, the basic estimation is mean density by length bins. The ns,t,j is found by summing over the ns,t,j.

$$n_{t,j,i} = \frac{NASC_{t,j}}{\bar{\sigma}_{h_{m,t,j}}} p_{i,h_{m,t,j}}$$

, where i indices length bins, pi is the proportion of herring in the ith length bin, and is given by $\sum_{spe}^{species} \sum_{i} p_{spe,i} 10^{(a+b\log 10(L_{spe,i}))/10}$

, where pspe,i applies over all species considered in the haul, Lspe,i is the length to use for the ith length bin and the data comes from the haul (of combination of hauls) assigned, $h_{m,t,j}$. For non-mix mark-types, the later simplifies to

$$\sum_{i} p_{herring,i} 10^{(073+20\log 10(L_{herring,i}))/10}$$

.

For biomass, a mean weight is also applied to the nt,j,i using the estimated regression relationship, a Lib.

For abundance by age and maturity, the abundance by length bin, nt,j,i, is averaged over track fragments and then transects to give a strata (and mark-type) mean. The age and maturity keys are applied to the results.

$V_s = area_s^2 s_s^2 W_s$, where $W_s = \sum_l^{transects} l^2{}_{s,t} \Big/ (\sum_j l_{s,j})^2$ and s2 is the sample variance.

The variance for the total is the sum of strata variances.

The total biomass can be obtained directly from the track fragment mean biomass by

$B_T = \sum_k^{track \cdot fragment} \overline{n}_k w_k$, where wk is a factor that takes into account the factors for transect and strata averaging, i.e. $w_k = \frac{1n.mi}{l_{t_k}} \frac{l_{t_k}}{\sum_t^{stratum.s_k} l_{s_k,t}} area_{s_k} = \frac{1}{\sum_t^{stratum.s_k} l_{s_k,t}} area_{s_k}$,

where the 1 n.mi is the length of the track fragment. This ignores the mark-type since that is already accounted for in the $\overline{n}_k$. The $\overline{n}_k w_k$ is the biomass from a track fragment and they can then be used to map the biomass at a fine spatial scale.

Estimates were made for SSB, total abundance and biomass, abundance by age (ring counts), and abundance by age x length bins. A cv (based on strata standard error divided by the strata mean) is estimated for SSB, total abundance and biomass, and abundance by age.

Annex 5: Data analysis methods used by the Netherlands

Total and spawning stock abundance and biomass estimates are calculated by ICES statistical rectangle, age (winter rings), length, and maturity using an R package (acousaR) and associated scripts. The package, scripts, and example survey data are available at: https://code.google.com/p/acousa/. The latest version of the package can be downloaded from: https://github.com/saschafassler/acousaR/releases.

The following input data tables are required:

Acoustic

Country	Post code, 2 chars according to countries table
Vessel	Call sign, 2 or 6 digits acc. to Vessels table
Cruise	Cruise identifier
Log	Min 4 digits (Nm)
Year	YYYY (4 digits)
Month	MM
Day	DD
Hour	HH, time GMT 0–24
Min	MM
AcLat	Decimal degrees, negative latitude south 0° "0.0000" The position refers to the beginning of the interval.
AcLon	Decimal degrees, negative longitude west of 0° "0.0000" The position refers to the beginning of the interval.
Logint	Nm, Log_end-Log start
Frequency	KHz
Sv_threshold	DB
Process_ID	Process ID
Interval	Interval

AcousticValues

Country	Post code, 2 chars according to countries table
Vessel	Call sign, 2 or 6 digits acc. to Vessels table
Cruise	Cruise identifier
Log	Min 4 digits (Nm)
Year	YYYY (4 digits)
Month	MM
Day	DD
Species	Species code: HER, BLU,…
ChUppDepth	Upper channel depth (m) Rel. to surface
ChLowDepth	Lower channel depth (m) Rel. to surface
SA	Acoustic readings (m^2/nm^2)

Trawl

HAUL	HAUL NUMBERS
day	DD
month	MM
year	YYYY (4 digits)
hour	HH, time GMT 0–24
minute	MM
haul_duration	Haul duration (minutes)
lat	Decimal degrees, negative latitude south 0° "0.0000" The position refers to the beginning of the interval.
lon	Decimal degrees, negative longitude west of 0° "0.0000" The position refers to the beginning of the interval.
depth	Trawl depth, (meters)
wind direction	Wind direction (in degrees)
wind force	Beaufort scale
gear	Gear used

Samples

HAUL	STATION NUMBERS
fishno	Serial number identifying the fish
weight	g
length	cm with one decimal (dot as decimal sign)
sex	Empty means not sexed, 1= Female, 2= Male, 0= not possible to determine sex
mat	Maturation scale: Herring 1–8, Blue whiting 1–7
age	Year from otolith

CatchLF

Spreadsheet per species with the first column labelled 'haul' and entries equal to 0.5cm length class values (e.g. 14.5,15,15.5,16,...). Further column headers are equal to haul numbers. Cell entries contain numbers per length class in every haul.

ICEScoastFact

Spreadsheet per species with cells representing individual ICES rectangles with the first column containing ICES statistical rectangle numbers (starting at '54' in the second row, '53' in the third row,...). Further columns are labelled with ICES statistical rectangle codes in the first rows (starting with 'D0' in the second column, 'D1' in the third column,...). The different cells contain the proportion of surface area covered by sea within the different ICES statistical rectangles.

ICESstrata

Spreadsheet with cells representing individual ICES rectangles with the first column containing ICES statistical rectangle numbers (starting at '54' in the second row, '53' in the third row,...). Further columns are labelled with ICES statistical rectangle codes in the first rows (starting with 'D0' in the second column, 'D1' in the third column,...). The different cells contain a letter referring to the biological strata that the different ICES statistical rectangles belong to.

Use of acousaR functions

readACOUraw() to combine the acoustic input datasets

SPPselect() to select data belonging to the species to be analysed

addStrata() to allocate strata to the species data

strata are allocated subjectively to covered ICES statistical rectangles based on similarities in observed cumulative length–frequency distributions of the different species.

nascBYrect() calculate the mean sA of the species per ICES statistical rectangle

nBYstrata() calculate species numbers per ICES statistical rectangle and survey strata

wBYstrata() calculate species biomass per ICES statistical rectangle and survey strata

acousa2FishFrame() convert survey estimates to FishFrame XML input files

Annex 6: Data analysis methods used by Denmark

Kagerrak and Kattegat part of HERAS with RV Dana, background and calculation method.

Karl-Johan Stæhr

DTU-Aqua, 2015

Geographical area:

DTU-Aqua have since the 80's participated in the international coordinated acoustic survey HERAS covering Skagerrak and Kattegat including ICES rectangles 41F6-F7, 41G1-G2, 42F6-F7, 42G0-G2, 43F6-G1, 44F6-G1, 45F8-G1 and 46F9-G0.

The conditions in the area is very un-homogenous when comes to depth and hydrography.

Depth

The total depth various in the area between very shallow and depths up to 670 m. See Figure 1. 32% of the area is deeper than 150 m.

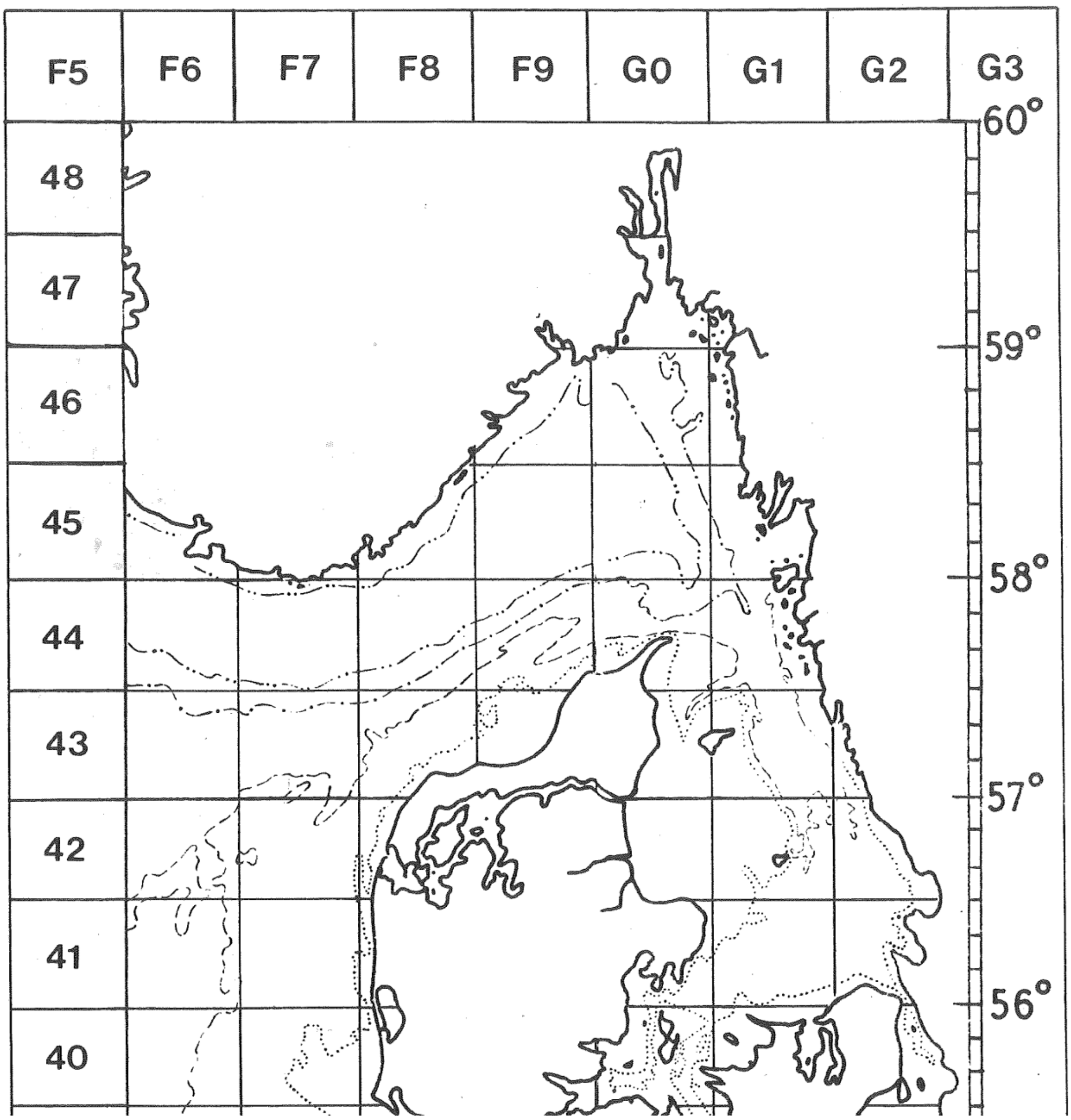


Figure 1. Depth contours in the survey are of Dana. (… 20m, ---- 40m, -.-.- 100m, -..-.. 200m).

Hydrography

The mean salinity and temperature in Kattegat is normally 29.5 to 30.5 0/00 and 13–14° C with a strong salinity and temperature spring layer around 10 m depth.

In Skagerrak and the most western part of the area the mean salinity and temperature is around 34 to 35 0/00 and 7–8◦C. Most year a warmer less saline water mass is seen in the surface layer along the Norwegian coast giving a strong spring layer in 20 to 25 m depth with a drop in salinity at 8 to 10 0/00 and temperature drop of 10◦C. This phenomenon is due to the out streaming of water from the Baltic and can some years cover the entire Skagerrak.

The distribution of herring and mackerel will often be connected to this spring layer as scattered layer.

Fish stocks in the area.

The pelagic fish stocks in the survey area is dominated by herring where to stocks, North Sea autumn spawners and Western Baltic spring spawners, are present during the survey period. The herring are in the survey are mostly distributed in pelagic scattered layers, offend connected to the spring layer. Only in the shallow areas along the Jutland west coast and in Kattegat shoaling behaviour is seen. The two stocks are mixing throughout the survey area due to condition of the fish.

Mackerel is found throughout the survey area also in scattered layers connected to the spring layer.

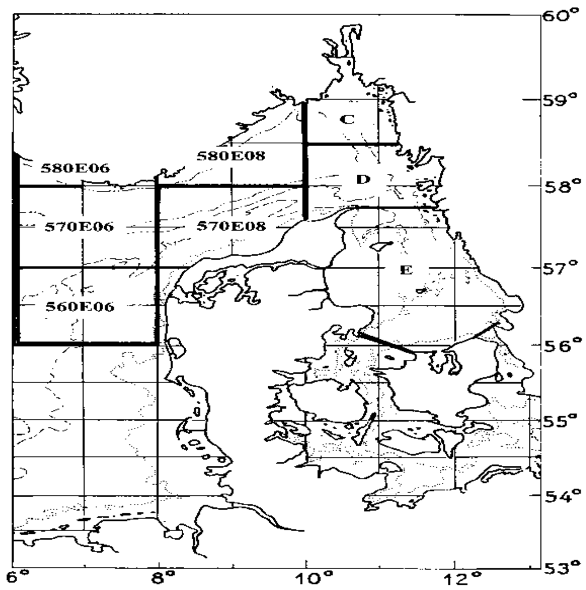
Sprat is found in the four most southern rectangles in the North Sea part of the survey area and in Kattegat. In Kattegat sprat are both seen as shoals and scattered layers.

Survey strategy

Stratification

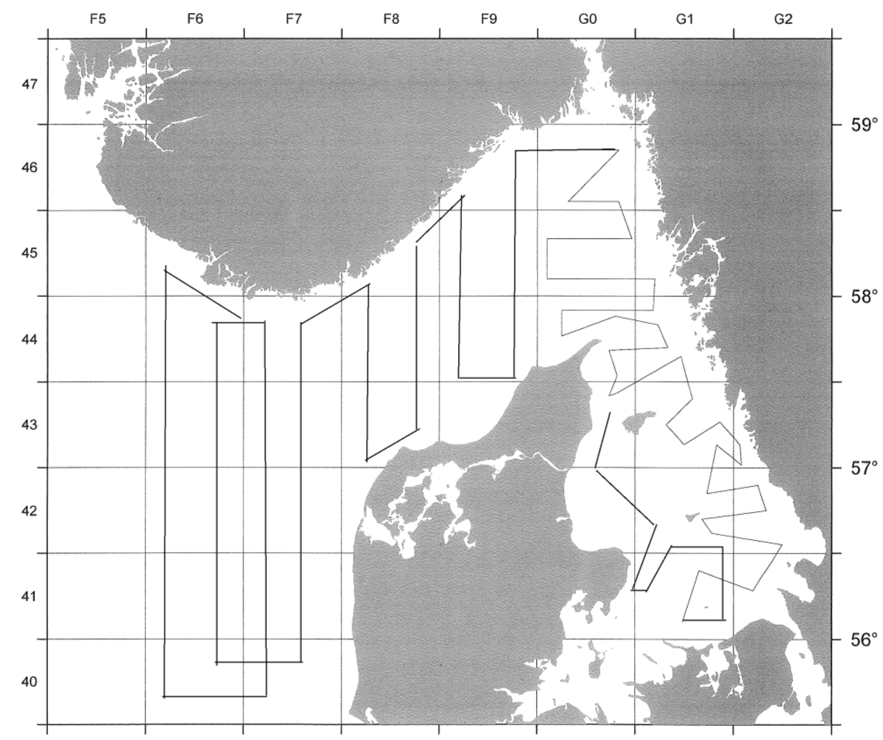
Historically the surveys are have been divided in 8 larger strata dividing the survey are due to areas due to bottom depth, and based on this believed behavior of the target species.

In the later years, focus has been moved from these larger strata to ICES rectangles when it comes to the stock calculation process.



Acoustic transects

In the western part of the area until 010 E are the acoustic transects are planned as north–south transects with 16 NM spacing. Along the Swedish coast I Skagerrak the transects are planned east-west transects with 12 NM spacing. For Kattegat the surveys transect are more zigzag due to shallow water and heavy ships traffic.



Fishery

The timing for fishery stations for species identification is controlled by the working hour regulations on the vessel. Therefore, fishery can be made in two time windows, 10.00 to 16.00 UTC and 20.30 to 02.00 UTC. This gives spaces for two trawl hauls in daytime and two trawl hauls during night-time.

The distribution of trawl hauls have in view that all ICES rectangles and bottom depth areas shall be covered with trawl hauls with in the larger strata.

Normally the day hauls are taken as bottom hauls on shallow waters and the night hauls are taken as surface hauls.

Data sampling

Acoustic data

Acoustic data are collected using mainly the Simrad EK60 38 kHz echosounder with the transducer (Type ES 38 7x7 degrees main lobe) in a towed body. The towed body runs at approx. 3 m depth in good weather and down to about 6–7 m, as needed, depending on the weather conditions, this year mostly at 4–5 m. The speed of the vessel during acoustic sampling is 9–11 knots. In addition, EK60 18 kHz and 120 kHz data were collected. They are not directly used for the survey estimate, but as an aid during judging when distinguishing between fish and plankton. The acoustic data are recorded as raw data on hard disk 24 hours a day also during fishing operations. During trawl hauls, the towed body is taken aboard and the EK60 38 kHz echosounder run on the hull transducer, but data taken during fishing periods are not used for the biomass estimate. The sampling unit (ESDU) is one nautical mile (nm). Data are stored down to 500 m. The data are stored as Simrad EK 60 Raw files.

Biological data

Pelagic hauls are carried out using a FOTÖ trawl (16 mm in the codend), while demersal hauls are carried out using an EXPO trawl (16 mm in the codend). Trawling are carried out in the time intervals 1000 to 1600 and 2030 to 0300 UTC , usually two day hauls (pelagic on larger depth and demersal in shallow waters) and two night hauls (mostly surface or midwater). The strategy are to cover most depth zones within each geographical stratum with trawl hauls. One-hour hauls were used as a standard during the survey.

The total weight of each catch is estimated and the catch sorted into species. Total weight per species and length measurements are made.

The clupeid fish were measured to the nearest 0.5 cm total length below, other fish to 1 cm, and the weight to the nearest 0.1g wet weight. From each trawl haul 6 herring (if available) per 0.5 cm length class are collected and frozen for individual determination in land-laboratory of length, weight, age, race (North Sea autumn spawners or Baltic Sea spring spawners) and maturity.

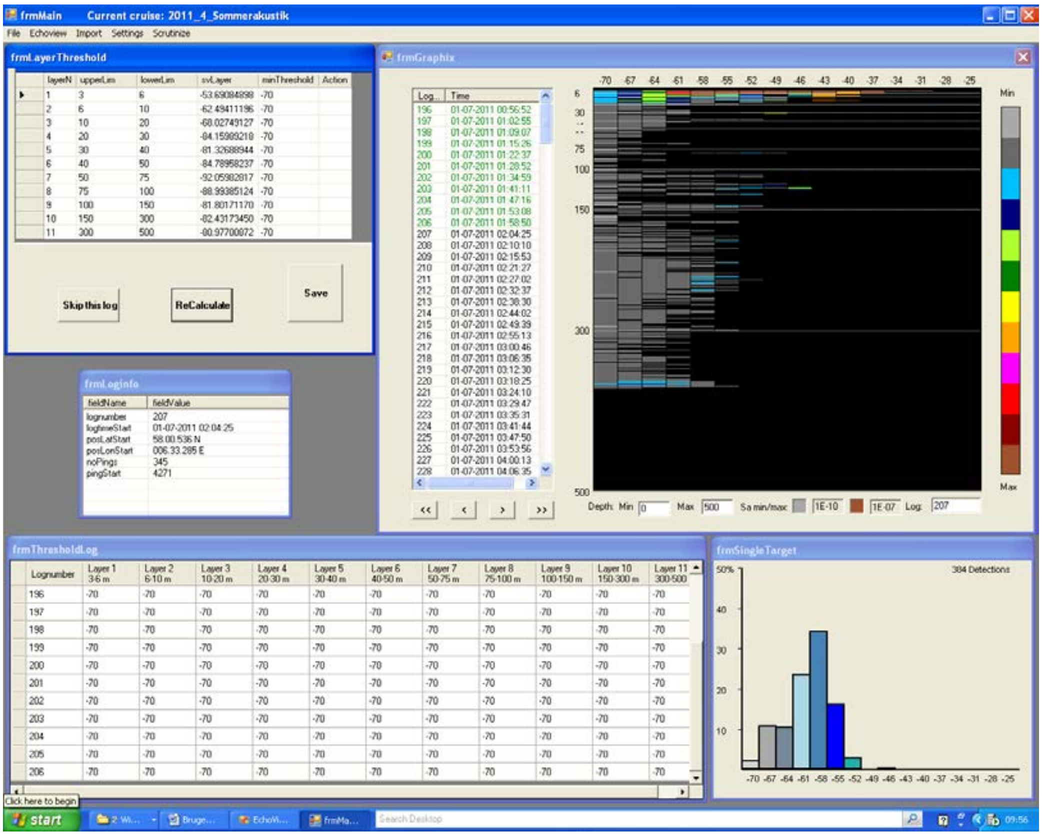
For sprat 10 specimens for each 0.5 cm length class are collected and frozen for individual determination in land-laboratory of length, weight, age, and maturity

Data processing

Judging

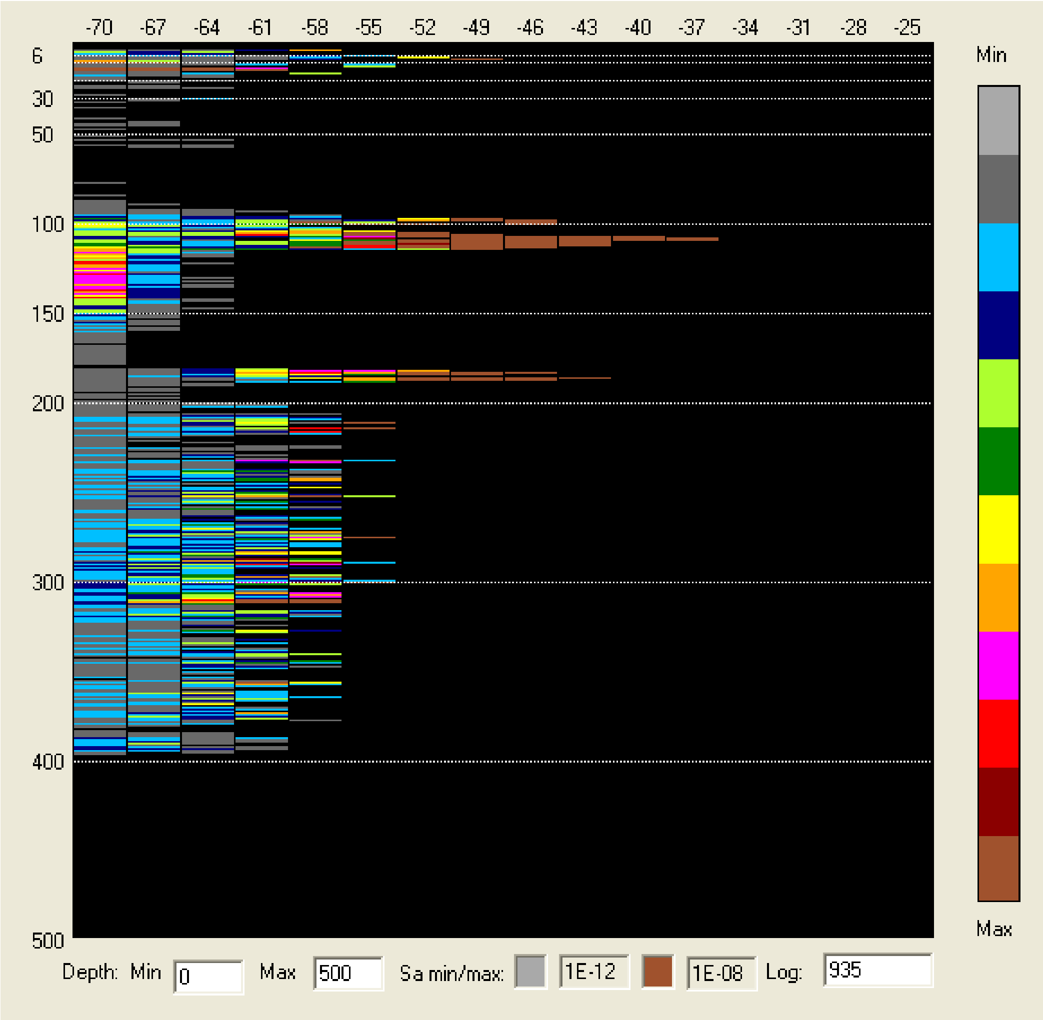
Judging to remove noise and energy not believed to come from fish. The judging is made with DTU-Aqua judging program, Ev2Akubio.

In the judging process all echoes per 1 NM is sorted to the 1 m depth channel it originates from. For each 1 m depth per 1 NM channel the echoes is sorted due to energy in 3 dB intervals from -70 dB and up. By use of a manual variable threshold echoes expected not belonging to fish are removed.



As a result of this process the energy per 1 nm originated from fish is stored in a database as Sv for fish in depth layer defined by the operator.

Herring have never been fished at depth larger than 150 m and all reflected energy for layers deeper than 150 m are left out of the calculation.



Allocation of trawl hauls

All trawl hauls in a stratum are allocated to the strata. If there are trawl hauls near to the boarder of a stratum and if there are in the same depth area they are allocated to. All trawl hauls allocated to a stratum are weighted by the total catch.

Biological data

Biological data on single fish collected and frozen during the survey are made at the institute after the survey.

For sprat length, weight, maturity, sex and age are determined for all specimens per half cm length group in each haul.

For herring length, weight, maturity, sex and age are determined for all specimens per half cm length group in each haul. All otoliths are photographed for a Fourier shape analyses for estimation of the race of the herring (North Sea autumn spawners or Baltic spring spawners). A number of the otolith is processed for a microstructure analyses of the daily rings formed in the otoliths during the larval period for determination of the herring race. These data are used to calibrate the Fourier shape analyses. For herring a 8 stage maturity scale is used.

Calculation procedure

Step 1:

Based on the Sv for fish per depth layer per NM coming from the judging procedure the total Sv per NM is calculated. The mean over all NM in the user-defined strata (ICES square or other geographical area) is calculated. Output of the process is Sv per NM2.

Step 2:

Based on the trawl hauls allocated for a given strata the mean TS for a fish in the strata is calculated from the species distribution and the length distribution per species.

TS is calculated per species and length by the formula TS = a* log L – b where L is the length of the fish. The species included in the calculation of mean TS and the parameters a) and b) per species is given in the text table below.

Based on the mean Sv per stratum and the mean TS per stratum the number of "mean fish" per stratum are estimated.

TS parameters used in the calculation

Comon name	latin name	icesCode	a	b
Anchovy	Engraulis encrasicolus	ANE	20	71,2
Blue whiting	Micromesistius poutassou	WHB	20	67,5
Cod	Gadus morhua	COD	20	67,5
Garfish	Belone belone	GAR	21,7	81,5
Greater sandeel	Hyperoplus lanceolatus	GSE	21,7	81,5
Grey gurnard	Eutrigla gurnardus	GUG	20	67,5
Haddock	Melanogrammus aeglefinus	HAD	20	67,5
Hake	Merluccius merluccius	HKE	20	67,5
Herring	Clupea harengus	HER	20	71,2
Horsemackerel	Trachurus trachurus	HOM	20	67,5
Lesser silver smelt	Argentina sphyraena	ANE	20	71,2
Lumpfish	Cyclopterus lumpus	LUM	21,7	81,5
Mackerel	Scomber scombrus	MAC	20	84,9
Norway pout	Trisopterus esmarkii	NOP	20	67,5
Pearlside	Maurolicus muelleri	PLS	20	71,2
Picked dogfish	Squalus acanthias	DGS	21,7	81,5
Pilchard	Sardina pilchardus	PIL	20	71,2
Pollack	Pollachius pollachius	POL	20	67,5
Saithe	Pollachius virens	POK	20	67,5
Sandeel	Ammodytes marinus	MSE	21,7	81,5
Sandeel	Ammodytes tobianus	TSE	21,7	81,5
Sprat	Sprattus sprattus	SPR	20	71,2
Whiting	Merlangius merlangus	WHG	20	67,5

Step 3:

Based on the species distribution and the length distribution per species in the trawl hauls allocated to the stratum the number of "mean fish" is distributed as fish per species and length group in the stratum.

Step 4:

Sprat:

Using the single fish data on sprat in the trawl hauls allocated for the stratum a length-maturity key, a maturity-length-age key and a maturity-length-age-mean weight key is estimated.

Based on these three keys the number by age and maturity, mean length by age and maturity and mean weight by age and maturity is estimated.

Sprat with maturity stage ≥3 and/or age ≥3 is regarded as mature.

Herring:

Using the single fish data on herring in the trawl hauls allocated for the stratum a length-race key, a race-length-maturity key, a race-maturity-length-age key and a race-maturity-length-age-mean weight key is estimated.

Based on these four keys the number by race, age and maturity, mean length by race, age and maturity and mean weight by race, age and maturity is estimated.

For North Sea autumn spawners specimens with maturity stage ≥3 and/or age ≥5 are regarded as mature and for Baltic spring spawners specimens with maturity stage ≥2 and/or age ≥5 are regarded as mature.