SERIES OF ICES SURVEY PROTOCOLS

SISP 9 – IPS

Manual for International Pelagic Surveys (IPS)

Version 1.00

Working Group of International Pelagic Surveys

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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Recommended format for purposes of citation:

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

http://doi.org/10.17895/ices.pub/7582

ISBN 978-87-7482-163-2

ISSN 2304-6252

Contents

1 Introduction

This manual was developed through the ICES Working Group of International Pelagic Surveys (WGIPS) as a guide to the methodologies adhered to during the planning, execution and analysis phases of WGIPS coordinated surveys.

The group coordinates 29 individual surveys undertaken in the Northeast Atlantic by nine countries (Ireland, Germany, Scotland, UK (England, Scotland, Northern Ireland), Russian Federation, Norway, Netherlands, Faroe Islands, Denmark and Iceland), accounting for 519 at-sea survey days per annum.

Combined, the group reports on the distribution and age disaggregated abundance of stocks of herring, blue whiting, mackerel, boarfish, sprat, sardine and anchovy to ICES for assessment purposes from 52°N to 74°N and from 30°E to 18°W. In addition to biological data from target species, the group also routinely collects data over a range of environmental parameters both biotic and abiotic.

Details on survey specific methods are reported annually in the cruise reports that appear in the WGIPS report:

WGIPS: http://www.ices.dk/community/groups/Pages/WGIPS.aspx

Details of the ICES assessment working groups to which WGIPS report can be found at:

WGWIDE: http://www.ices.dk/community/groups/Pages/WGWIDE.aspx

HAWG: http://www.ices.dk/community/groups/Pages/HAWG.aspxSurveys

2 Coordinated surveys

2.1 International blue whiting spawning stock survey (IBWSS)

2.1.1 Background

The IBWSS survey was established in 2004 and is carried out annually in March/April by vessels from Russia, Norway, Ireland, Faroes and the Netherlands. Before 2004, the spawning areas of blue whiting west of the British Isles have most actively been surveyed by Norway and Russia. Some coordination of these survey activities took place over a number of years, until the Russian spawning stock survey was discontinued in 1996. Russia resumed the blue whiting spawning stock survey in 2001. In 2003, ACFM concluded that: “Several surveys on blue whiting are currently going on. ICES recommends that a coordinated survey be organized covering the main spawning grounds of blue whiting”.

2.1.1.1 Survey objectives

The survey aims to determine the distribution and abundance at age and length of the Northeast Atlantic blue whiting stock during the spawning season to the west of Britain and Ireland (Figure 2.1.1.1). This estimate is used as a tuning index by ICES to determine the size of the population and the results are submitted annually to WGWIDE. Survey data are submitted to the WGNAPES online database. Coordination and planning of blue whiting surveys is undertaken during an annual post-cruise meeting and reported to WGIPS.

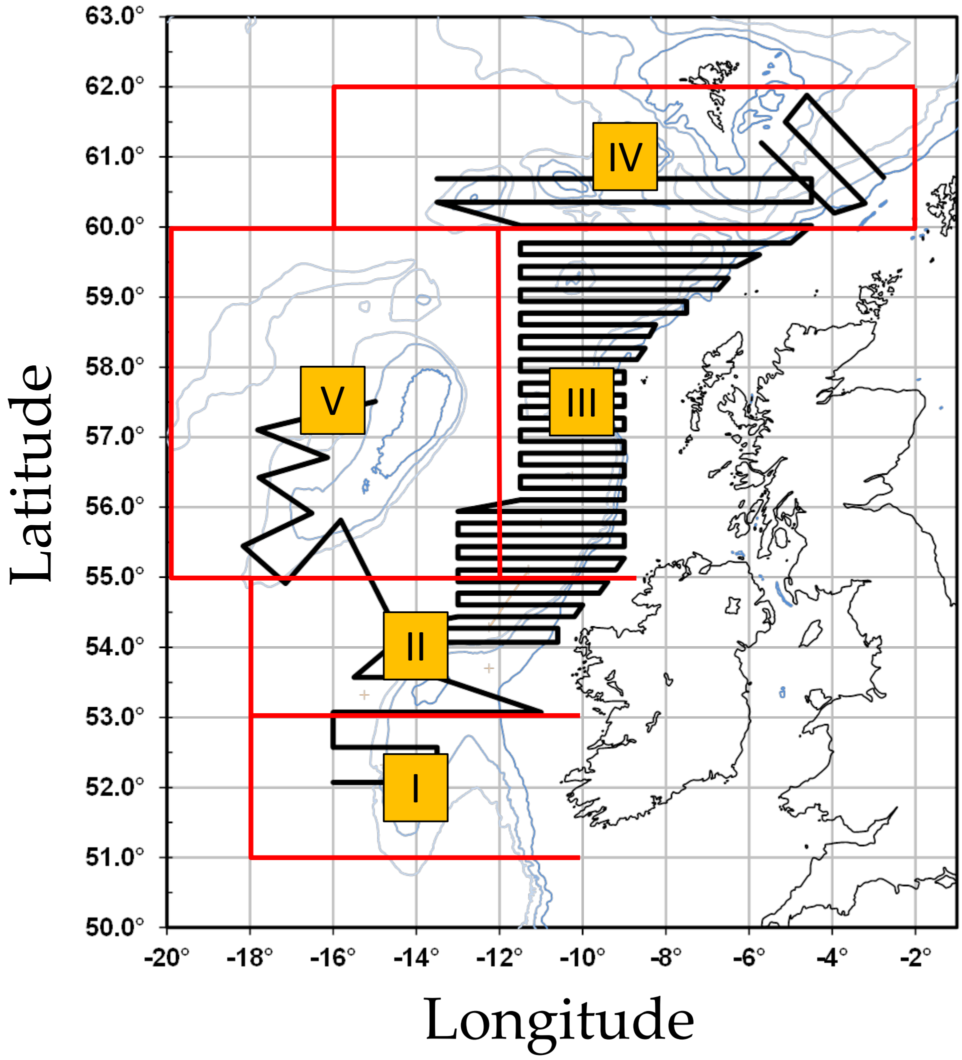


Figure 2.1.1.1. Geographical extent of the IBWSS survey area (red lines) with planned vessel cruise tracks (black lines) of the 2013 survey indicated as an example. Numbers indicate survey subareas used for reporting purposes (I: southern Porcupine Bank; II: northern Porcupine Bank; III: Hebrides; IV: Faroes/Shetland; V: Rockall).

2.1.1.2 Survey design and area coverage

The design of the International Blue Whiting Spawning stock Survey (IBWSS) has traditionally been aimed at reducing the effects of double counting of the northward migrating spawning aggregation. Survey timing should remain consistent across years with as little variation as possible. Consideration is given to the start and end times of the survey window to assure a synoptic coverage while taking into account vessel availability in the different countries and temporal occurrence of spawning aggregations. Survey coordinators are tasked with the communication and organization of participants to ensure the temporal alignment of survey effort. The spatial confines of the survey, although not fixed, are defined based on core spawning areas and secondary target areas. The overall design uses stratified transects with a random start (random latitude) to ensure transect coverage is not replicated but randomized between years. Survey stratification is based on statistical rectangles with a range of 1 degree in latitude and 2 degrees in longitude. The survey design follows a variable transect spacing, ranging from 30 nm in areas historically containing less dense aggregations, to 7.5 nm in the core survey area. To avoid exact replication of coverage, transects are allocated systematically with a random start location. The recommended maximum duration to cover the transects in the survey area is 3 weeks.

A main problem affecting the outcome of the survey relates to adverse weather conditions encountered in the Northeast Atlantic at the time of the survey. This may result in reduced area coverage because bad weather forces vessels to seek shelter or slowing them down on transect.

The applied survey design aims to allocate maximum effort in the area that historically contained the bulk of blue whiting spawning aggregations (subarea III: Hebrides) in order to have a high probability to guarantee adequate coverage there. However, when the size of the stock is high, blue whiting aggregations are found to be distributed more evenly over the whole survey area. In such situations, survey effort needs to be adjusted accordingly. The advantage of the variable transect spacing approach is that it will allow for relatively easy adaptation of the survey design without great loss of coverage in cases of unforeseen circumstances. For instance, this may mean skipping some of the horizontal transects to keep pace with other participating vessels and therefore guarantee consistent temporal progression between vessels.

2.1.1.3 Data collection

Acoustic

Acoustic data are collected using a Simrad EK60 scientific echosounder. Split-beam transducers are mounted on the various vessels in different configurations (Table 2.1.1.3.1). Several operating frequencies are used during the surveys (e.g. 18, 38, 120 and 200 kHz) for echotrace recognition purposes, however most of these could only be used in shelf sea areas due to range limitations. The 38 kHz data can cover the depths where blue whiting usually occurs (300–650 m) and is consequently used to generate the abundance estimate. All frequencies are to be calibrated directly prior, after or during the survey.

EK 60 set up during the survey follows a standard protocol as outlined in the EK 60 user manual. The current (2013) operating version of the software is V2.4.3 and it is advised that latest software release should be installed when available. Settings during the survey are as outlined in the table below.

At the start of the survey, the vessel log (GPS distance) should be reset to ‘zero’ to ensure consistency in log output files. All off-track incidents and transect start/endpoints are recorded on paper (Time, position, latitude, longitude, log number).

Table 2.1.1.3.1. Echosounder settings used during the most current IBWSS.

	Vilnyus	Celtic Explorer	Magnus Heinason	Tridens
Echo sounder	Simrad EK60	Simrad EK 60	Simrad EK60	Simrad EK 60
Frequency (kHz)	**38**	**38**, 18, 120, 200	**38**	**38**, 120
Primary transducer	ES38B	ES 38B	ES38B	ES 38B
Transducer installation	Hull	Drop keel	Hull	Towed body
Transducer depth (m)	4.5	8.7	3	7
Upper integration limit (m)	10	15	7	15
Absorption coeff. (dB/km)	10	9.8	9.7	10.2
Pulse length (ms)	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.425	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)	-30.6	-20.6	-20.9	-20.6
Sv Transducer gain (dB)				
Ts Transducer gain (dB)	25.92	25.46	25.69	26.32
s_A correction (dB)	-0.66	-0.76	-0.69	-0.6
3 dB beam width (dg)				
alongship:	7.2	6.93	6.95	7.04
athw. ship:	7.17	6.99	6.96	7.12
Maximum range (m)	750	750	750	750
Post processing software	FAMAS	Myriax Echoview	Myriax Echoview	LSSS

Biological

All vessels use a midwater trawl for biological sampling, the properties of which are provided in Table 2.1.1.3.2. All components of the catch from the trawl hauls are sorted and weighed; fish and other taxa were identified to species level. Trawl metrics are monitored using a net sonde. Fish samples are to be divided into species composition by weight. Length frequency and length weight data should be collected for each component of the catch. Length measurements of 100 blue whiting are to be taken to the nearest 0.5 cm below for every trawl, of which 50 length-representative samples have to be measured for weight, sex, age and maturity.

Biological sampling is used to verify the composition of echotraces during echo integration. Decisions to fish on particular echotraces are largely subjective and an attempt should be made to also target echotraces of low-density scattering layers not just high-density shoals. No bottom-trawl gear is used during this survey.

Table 2.1.1.3.2. Details of biological and hydrographic sampling gear used during the IBWSS.

	Vilnyus	Celtic Explorer	Magnus Heinason	Tridens
Trawl dimensions				
Circumference (m)	716	768	640	1120
Vertical opening (m)	50	50	40	30-70
Mesh size in codend (mm)	16	20	40	±20
Typical towing speed (kn)	3.0-3.7	3.5-4.0	3.0-4.0	3.5-4.0
Plankton sampling	0	0	21	0
Sampling net	-	-	WP2 plankton net	-
Standard sampling depth (m)	-	-	200	-
Hydrographic sampling				
CTD Unit	SBE19plus	SBE911	SBE911	SBE911
Standard sampling depth (m)	1000	1000	1000	1000

Hydrographic

Environment details (temperature and salinity) are measured by CTD casts taken at evenly spread out stations up to a maximum depth of 1,100m in open water along survey tracks, maximally 30 nm apart.

2.1.1.4 Analysis

Scrutinisation protocol

Acoustic scrutiny is based on trawl information and subjective categorization. Post-processing software and procedures differ among participants:

- On 'Blennholm', the acoustic recordings were scrutinized using the Large Scale Survey System (LSSS) once or twice per day. Blue whiting were separated from other recordings using catch information and characteristics of the recordings.
- On 'Fridtjof Nansen', the FAMAS software was used as the primary post-processing tool for acoustic data. Data were partitioned into the following categories: blue whiting, plankton, mesopelagic species and other species. The acoustic recordings were scrutinized once per day.
- On 'Celtic Explorer', acoustic data were backed up every 24 hrs and scrutinised using Myriax's EchoView (V 4.8) post-processing software for the previous day's work. Data were 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 Myriax's EchoView (V 5.x) post-processing software. Data were partitioned into the following categories: plankton (<200 m depth layer), mesopelagic species, blue whiting and krill. Partitioning of data into the above categories was based on trawl samples.
- On 'Tridens', acoustic data were backed up continuously and scrutinized every 24 hrs using the Large Scale Survey System LSSS (V 1.7) post-processing software. Blue whiting were identified and separated from other recordings based on trawl catch information and characteristics of the recordings.

Abundance estimation

The acoustic trawl data are analysed with a SAS based routine called "BEAM" (Totland and Godø, 2001) and used to calculate age and length stratified estimates of total biomass and abundance (numbers of individuals) within the survey area as a whole and within subareas (i.e. the main areas in the terminology of BEAM). Strata of 1° latitude by 2° longitude were used. The area of a stratum was adjusted, when necessary, to correspond with the area that was representatively covered by the survey track. This was particularly important in the shelf break zone where high densities of blue whiting dropped quickly to zero at depths less than 200 m.

To obtain an estimate of length distribution within each stratum, all length samples within that stratum were used. If the focal stratum was not sampled representatively, additional samples from the adjacent strata were used. In such cases, only samples representing a similar kind of registration that dominated the focal stratum were included. Because this includes a degree of subjectivity, the sensitivity of the estimate with respect to the selected samples was crudely assessed by studying the influence of these samples on the length distribution in the stratum. No weighting of individual trawl samples was used because of differences in trawls and numbers of fish sampled and measurements. The number of fish in the stratum is then calculated from the total acoustic density and the length composition of fish.

The methodology is in general terms described by Toresen *et al.* (1998). More information on this survey is given by, e.g. Monstad, (1986). 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:

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

For conversion from acoustic density (sA, m2/n.m.2) to fish density (ρ) the following relationship was used:

$$\rho = sA / \langle\sigma\rangle,$$

where $\langle\sigma\rangle = 3.795 \cdot 10–6\ L2.00$ is the average acoustic backscattering cross section (m^2). The total estimated abundance by stratum is redistributed into length classes using the length distribution estimated from trawl samples. Biomass estimates and age-specific estimates are calculated for main areas using age–length and length-weight keys that are obtained by using estimated numbers in each length class within strata as the weighting variable of individual data.

BEAM does not distinguish between mature and immature individuals, and calculations dealing with only mature fish were therefore carried out separately after the final BEAM run for each subarea. Proportions of mature individuals at length and age were estimated with logistic regression by weighting individual observations with estimated numbers within length class and stratum (variable 'popw' in the standard output dataset 'vgear' of BEAM). The estimates of spawning-stock biomass and numbers of mature individuals by age and length were obtained by multiplying the numbers of individuals in each age and length class by estimated proportions of mature individuals. Spawning-stock biomass is then obtained by multiplication of numbers at length by mean weight at length; this is valid assuming that immature and mature individuals have the same length-weight relationship.

2.1.1.5 Reporting

The survey report should follow the existing cruise report format as provided: http://oar.marine.ie/handle/10793/868

2.1.1.6 Caveats/limitations

For acoustic data collection the vessels involved will carry spare GPT's and transducer (38 kHz) as well as the associated cabling where towed bodies are involved to allow for at-sea repairs/replacement. On some vessels, transducers are positioned on a drop keel, allowing at-sea access. In the cases where a drop keel is available, weather disruption of data collection are rare.

The main problem affecting the outcome of the survey relates to adverse weather conditions encountered in the Northeast Atlantic at the time of the survey. If the situation is too bad, large areas within the core spawning area could not be covered, as bad weather caused one of the vessels to seek shelter while another one was delayed due to unscheduled activities. As the survey is fixed in time and ship time is booked well in advance an annual snapshot of abundance can therefore be adversely affected by poor weather conditions. In periods of prolonged poor weather the precision of the survey is thus reduced. If some vessels are found to lack behind others, the tight transect spacing in the core area may 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.

In instances where biological samples are deemed insufficient additional samples may be obtained from the commercial fishery working in the area within the same time frame.

2.1.2 International ecosystem survey in the Nordic Seas (IESNS)

2.1.2.1 Background

The IESNS is undertaken annually in May to determine the distribution, abundance and age structure of the Norwegian Spring-spawning Herring stock. The survey is carried out over 40 days starting around 1 May.

The aim of the survey is 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 collecting data on plankton abundance and hydrographical conditions in the area. In addition, acoustics and directed trawl sampling of blue whiting is performed.

The survey area is split into three Subareas: Area I, Barents Sea area, Area II, Northern and central Norwegian Sea Area, and Area III, the Southwestern Area (Figure 2.1.2.1.1).

The survey was first established in 1995 by the Faroese, Iceland, Norway and Russia. Since 1997, the EU has participated (except 2002 and 2003) and from 2004 onwards, it was more developed into an ecosystem survey.

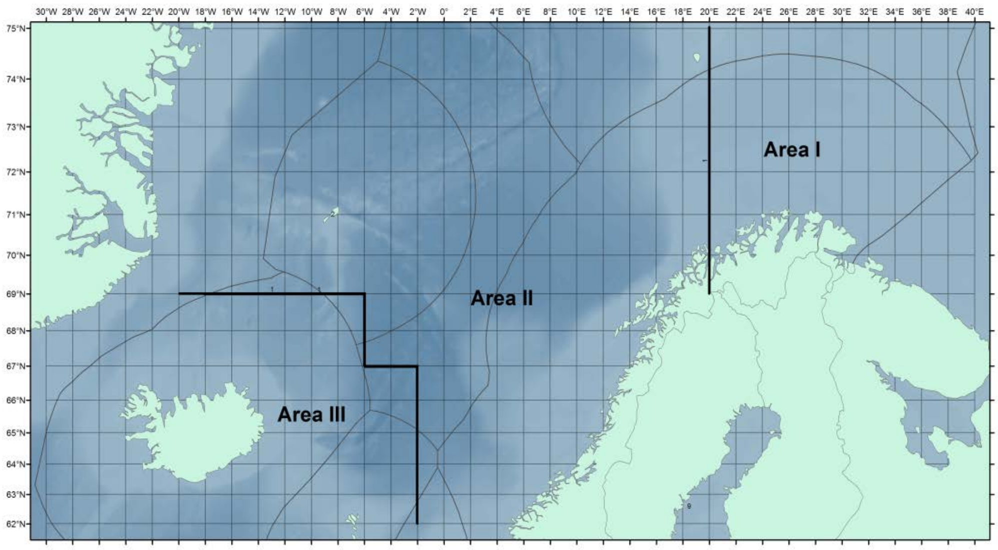


Figure 2.1.2.1.1. Areas defined for acoustic estimation of Norwegian spring-spawning herring in the Nordic Seas.

2.1.2.2 Survey time-series

The results from the surveys have been compiled into annual survey reports and estimates from the PGSPFN (until 1997), PGNAPES (until 2009), WGNAPES (until 2011) and now WGIPS.

The datasets have been stored in the online PGNAPES database since 2007. The future ambition is to get the data back to 1995 uploaded to the database.

2.1.2.3 Survey objectives

The survey objectives are listed below:

- Carry out a predetermined survey cruise track
- Determine an age stratified estimate of relative abundance of herring within the survey area
- Determine an age stratified estimate of relative abundance of blue whiting within the survey area
- Collect biological samples from directed trawling on insonified fish echotraces to determine age structure and maturity state of the herring stock
- Collect physical oceanography data from vertical profiles (CTD).
- Plankton sampling (WP2 and Dyedi)

2.1.2.4 Survey design and area coverage

One survey per year is carried out. A predetermined cruise track is used based on previous area coverage and supplemented with adaptive surveying where and when time allows. The survey abundance index is determined from predetermined survey coverage alone and should not include additional adaptive strata. The survey should begin in the South (62°N) and work in a northerly then easterly direction into the Barents Sea.

The survey traditionally is designed so to cover the 2 degrees by 1 degree squares in the whole area. However, with new technologies emerging, a transition towards “Stratified systematic transect design” is in process. (Figure 2.1.2.4.1). This means that these two methods will be used in the coming years, to ensure the quality of the estimate is satisfactory in future.

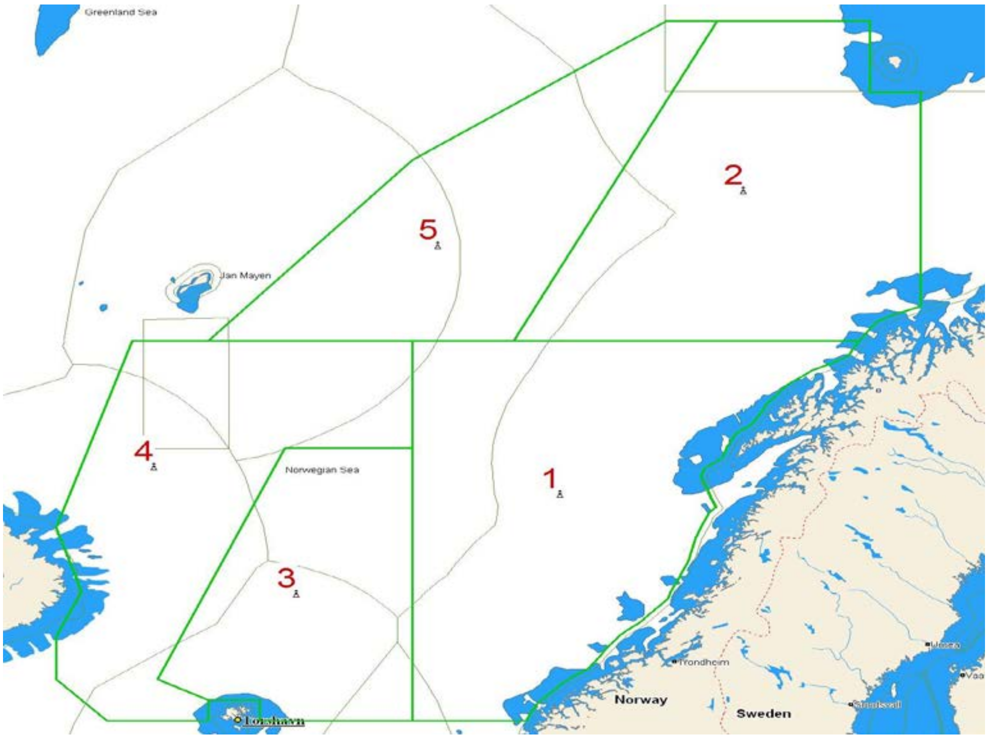


Figure 2.1.2.4.1. Areas defined for acoustic estimation of Norwegian spring-spawning herring in the Nordic Seas.

Acoustic data are to be collected using an EDSU (elementary sampling distance unit) of 1 nautical mile.

2.1.2.5 Data collection

Acoustic

Acoustic data are collected using a Simrad EK60 scientific echosounder. Split-beam transducers are mounted on the various vessels in different configurations. Several operating frequencies are used during the surveys (e.g. 18, 38, 120 and 200 kHz) for trace recognition purposes, but with 38 kHz data used to generate the abundance estimate (Table 2.1.2.5.1) All frequencies are to be calibrated prior to the survey.

EK 60 set up during the survey follows a standard protocol as outlined in the EK 60 user manual. The current (2013) operating version of the software is V2.4.3 and it is advised that latest software release should be installed when available. Settings during the survey are as outlined in the table below.

Environment details (temperature and salinity) are taken from a CTD cast taken in open water or exposed bays in the survey area and not from enclosed bodies such as sheltered bays.

At the survey start, the vessel log (GPS distance) should be reset to 'zero' to ensure consistency in log output files. If the systems crashes a reset of the vessel log should be calculated to closely match that of the last valid output file. All off track incidents and transect start/endpoints are recorded as text annotations in the sounder screen using the annotation feature as well in paper form (Time, position, latitude, longitude, log number).

Table 2.1.2.5.1. Echosounder settings employed during the IESNS.

Echosounder	Simrad EK 60			
Frequency (kHz)	18	38	120	200
Primary Transducer	ES 18–11	ES 38B	ES 120–7	ES 200–7
Pulse length (ms)	1024	1024	1024	1024
Power (W)	2000	2000	1000	Vessel dependant
Ping rate	Max	Max	Max	Max

Biological sampling

Biological sampling is carried out using a single vessel pelagic midwater trawls (country dependent); with a vertical opening of 25–55 m (Table 2.1.2.5.2) Trawl metrics are monitored using a net sonde. All components of the catch from the trawl hauls should be sorted and weighed; fish and other taxa are identified to species level. Fish samples are to be divided into species composition by weight. Length frequency and length weight data should be collected for each component of the catch. Length measurements of herring, and blue whiting to be taken to the nearest 0.5cm below. (Or finer resolution)

Biological sampling is used to verify the composition of echotraces during echo integration. Decisions to fish on particular echotraces are largely subjective and an attempt should be made to target echotraces low-density scattering layers not just high-density shoals. No bottom-trawl gear is used during this survey.

Table 2.1.2.5.2. Different trawls used in the IESNS surveys.

	Dana	J. Hjort	Arni Friðriksson	Magnus Heinason	Vilnyus
Circumference (m)		832	640	640	716
Vertical opening (m)	25–35	45–50	45–50	45–55	50
Mesh size in codend (mm)		35	40	40	16
Towing speed	3.0–40	4.0–4.5	3.0–4.0	3.0–4.0	3.2–4.1

Catches from trawl hauls are sorted and weighed; fish are identified to species level, when possible, and other taxa to higher taxonomic levels. Normally a subsample of 30–100 herring and blue whiting are sexed, aged, and measured for length and weight, and their maturity status is estimated using established methods. An additional sample of 70–300 fish is measured for length.

Hydrographic and plankton stations

All vessels collect hydrographical data using a SBE 911 CTD. Maximum sampling depth is 1000 m. Zooplankton is sampled by a WPII on all vessels except the Russian vessel which uses a Dyedi net, according to the standard procedure for the surveys. Mesh sizes are 180 or 200 µm. The net is hauled vertically from 200 m or the bottom to the surface. All samples are split in two and one-half is preserved in formalin while the other half is dried and weighed. On the Danish, the Icelandic and the Norwegian vessels the samples for dry weight are size fractionated before drying. Data are presented as g dry weight per m^2.

2.1.3 Data analysis

2.1.3.1 Scrutinisation protocol

Acoustic data should be backed up every 24 hrs and scrutinised using adequate post-processing software. Partitioning of data into the categories is largely a subjective process back up with trawl data and so it is vital that an experienced scientist who has experience of this survey and area undertake the scrutinisation of echograms.

The RAW EK 60 data files are imported into adequate post-processing software for post-processing. The echograms are analysed at a threshold of -70 dB and where necessary plankton can be filtered out by thresholding to –65 dB.

2.1.3.2 Abundance estimation

Acoustic estimates of herring and blue whiting abundance are obtained during the surveys. This is carried out by visual scrutiny of the echo recordings using post-processing systems. The allocation of sA-values to herring, blue whiting and other acoustic targets are based on the composition of the trawl catches and the appearance of echo recordings. To estimate the abundance, the allocated sA-values are averaged for ICES-squares (0.5° latitude by 1° longitude). For each statistical square, the unit area density of fish (sA) in number per square nautical mile ($N*nm^{-2}$) is calculated using standard equations (Foote *et al.*, 1987; Toresen *et al.*, 1998). The following target strength (TS) function is 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

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

To estimate the total abundance of fish, the unit area abundance for each statistical square is multiplied by the number of square nautical miles in each statistical square then summed for all the statistical squares within defined subareas and over the total area. Biomass estimation is calculated by multiplying abundance in numbers by the average weight of the fish in each statistical square then summing all squares within defined subareas and over the total area. The Norwegian BEAM software (Totland and Godø, 2001) has been used (from 2001–2013) to make estimates of total biomass and numbers of individuals by age and length in the whole survey area and within different subareas. A transition to the new StoX application will be performed over next few years. Parallel estimates with BEAM software will be performed in the transition period.

2.1.3.3 Reporting

The survey report should follow the existing cruise report format.

2.1.4 Coordinated Nordic Seas ecosystem survey (IESSNS)

2.1.4.1 Background

The Northeast Atlantic mackerel (*Scomber scombrus*, Linnaeus 1758) is one of the most important commercial fish species in the Atlantic Ocean due to its large stock size, high value and as it is a very healthy fish product (Iversen, 2002; 2004). The bulk (> 90%) of all mackerel harvested is now used directly for human consumption worldwide. Taking into account the commercial and ecological importance of mackerel, the abundance estimation and spatial distribution of the stock during the wintering, feeding and spawning period is surprisingly poorly studied. Scientific information and data sources available from the feeding period on NEA mackerel after 2006, is mostly published as grey literature by the ICES Working Group for Widely Distributed Species (WGWIDE; see Nøttestad and Jacobsen, 2009; Nøttestad *et al.*, 2007; 2010; 2011; 2012; 2013). No reliable acoustic methodology is at present available and accepted in ICES for abundance estimation and spatial distribution of mackerel in the Northeast Atlantic. During the WKPELA benchmark meeting on NEA mackerel in Copenhagen 17–21 February 2014, acoustic methods were recommended to be used in future quantitative surveys for complementary purposes. However, no acoustic abundance estimates of NEA mackerel solely based on multifrequency echosounderestimates and/or multibeam sonar recordings were evaluated and accepted during the benchmark meeting.

2.1.4.2 Time-series

The IESSNS survey in the Norwegian Sea was initiated by Norway at the beginning of the 1990s. Faroe Islands and Iceland have been participating on the joint mackerel-ecosystem survey since 2009, but the Icelandic survey results for 2009 were not included in a joint cruise report that year. ICES WGWIDE recommends that a coordinated IESSNS survey be organized covering the main feeding grounds of NEA mackerel. The time-series for abundance estimation using swept-area from pelagic trawling goes back to 2007. Research vessels and chartered commercial fishing vessels from Norway, Faroe Islands and Iceland were used for mackerel monitoring surveys in the Norwegian Sea and adjacent waters in July August 2007–2013. In the first year in 2007, the surveys were conducted by two Norwegian vessels only, a Faroese vessel joined the survey in 2008, and one Icelandic research vessel and one Faroese chartered commercial vessel have taken part with one or two Norwegian vessels each year since 2009. The spatial survey coverage differed somewhat from year-to-year depending on effort, but always covered major parts of the Norwegian Sea, the exception being 2008 when the coverage was more northerly due to other monitoring priorities such as Atlantic salmon and marine mammals. The temporal coverage was every year from 2007 to 2013, with the exception of 2009, limited within a 5–6 weeks period between all vessels involved in order to avoid any double or zero counting of NEA mackerel during the internationally coordinated survey. The survey was designed with predominantly parallel east-west survey lines, and fixed sampling stations at predetermined geographical positions. There has not been any abundance estimation from the IESSNS survey based on acoustic estimates from multifrequency echosounder. The acoustic data has rather been used as complementary and supplementary sources of information along the cruise tracks during the surveys.

2.1.4.3 Survey objectives

Major aims of the survey were to quantify abundance, spatio-temporal distribution, aggregation and feeding ecology of Northeast Atlantic mackerel in relation to distribution of other pelagic fish species such as Norwegian spring-spawning herring and blue whiting, oceanographic conditions and prey communities. The survey aims to determine the distribution and abundance at age and length of Northeast Atlantic (NEA) mackerel and Norwegian spring-spawning herring during the feeding season in the Nordic Seas and surrounding coastal and offshore areas. This abundance estimate on NEA mackerel is now considered used as a tuning index by ICES to determine the size of the population and the results are submitted annually to WGWIDE. Survey data from the IESSNS survey are submitted to the WGNAPES online database. Coordination and planning of the ecosystem-mackerel surveys is undertaken during an annual post-cruise meeting and reported to WGIPS and WGWIDE.

2.1.4.4 Survey design and area coverage

Transects are spaced at a maximum distance of 60 nautical miles and minimum 40 nautical miles. An example of survey coverage and additional complementary sampling is provided in Figure 2.1.4.4.1. Two aspects should be considered in choosing the direction of transects. Transects should preferably run perpendicular to the greatest gradients in fish density, which are often related to gradients in bottom topography and hydrography. This means that transects will normally run perpendicular to the coast. The second aspect considers the direction in which the fish are migrating. If there is evidence of rapid displacement of the fish throughout the area, it is advisable to run the transects parallel with the direction of the migration. In the case of NEA mackerel the major migration distance during July August is south towards north with the Atlantic current. This survey design will minimize the bias caused by migration. Ship's speed during the survey is typically 10–12 knots. At higher speeds, problems are encountered with engine noise or propeller cavitations. These problems, however, depend on the vessel. In rough weather, the ship's speed may be reduced in order to avoid problems with air bubbles under the ship, although this problem is alleviated by the use of a drop keel.

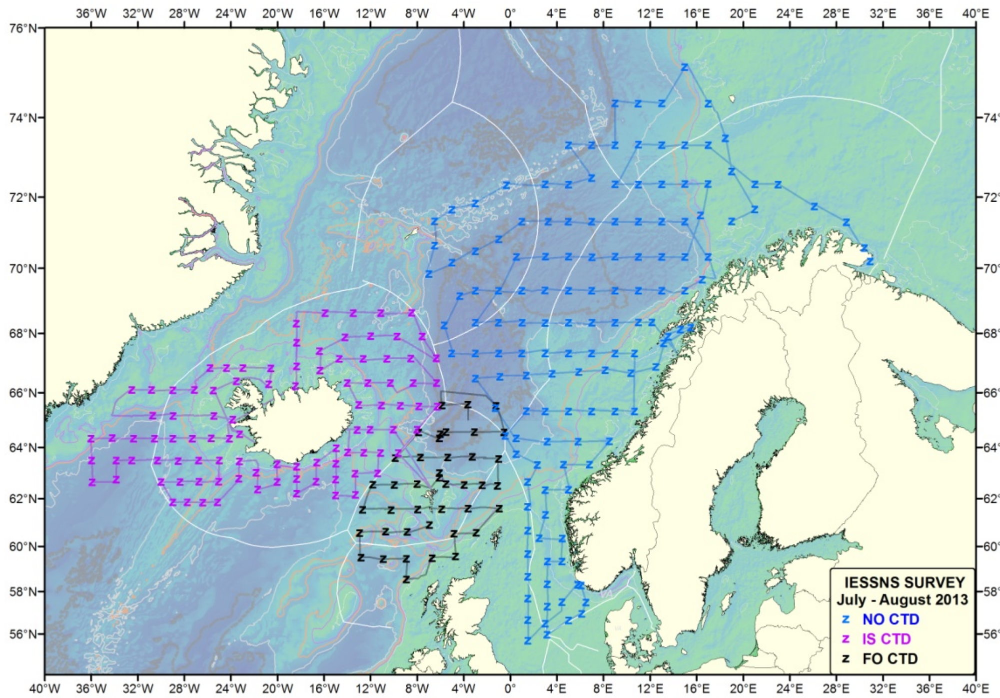


Figure 2.1.4.4.1. CTD stations (0–500 m) using SEABIRD SBE 37 (Arni Fridriksson) SEABIRD SB 25+ (Finnur Friði) and SAIV SD200 (Libas and Eros) CTD sensors and WP2 plankton net samples (0–200 m depth). These samples were taken systematically on every pelagic trawl station on all four vessels.

2.1.4.5 Data collection

2.1.4.5.1 Acoustic

A time-series from IESSNS is now included in the stock assessment model for NEA-mackerel. This time-series is based on trawl catches and are not including acoustic data of any kind. However, it is important to monitor the vertical distribution of mackerel to estimate the proportion of mackerel located below trawling depth.

Calibration

All frequencies are to be calibrated directly prior, after or during the survey. EK 60 set up during the survey follows a standard protocol as outlined in the EK 60 user manual. The current (2013) operating version of the software is V2.4.3 and it is advised that latest software release should be installed when available. At the survey start, the vessel log (GPS distance) should be reset to 'zero' to ensure consistency in log output files. All off-track incidents and transect start/endpoints are recorded on paper (Time, position, lat, long, log number).

Frequencies to scrutinize and store data

Scrutinizing is based on scientific echosounders using 38 kHz for herring and 200 kHz for mackerel as the main frequencies for abundance estimate. Species are identified and partitioned using catch information, characteristic of the recordings and frequency response. The echosounder data will only be scrutinized down to 200 m depth, due to the need to apply the highest possible ping rate.

Mackerel and herring are the target species for the survey and echosounder settings should be optimized for this purpose. It is recommended that frequencies 18, 38, 70, 120 and 200 kHz are used and minimum 38 and 200 kHz, in order to help separate mackerel from other fish targets in the ensonified volume. The echosounders should be calibrated prior to the survey according to standard procedures, and with power maximum settings according to Korneliussen *et al.* (2008, Table 2.1.4.5.1.1) at 1.024 ms pulse duration. A common pulse duration is ensuring the best pixel overlap in the subsequent analysis, and if 18 kHz is used, this is the lowest recommended pulse duration, even if it can also transmit 0.512 ms.

Table 2.1.4.5.1.1. Parameters and recommended maximum input power for common sizes of Simrad transducer.

Parameter	Maximum input power per frequency (kHz)							
	18	38	70	70	120	200	333	400
Approximate transducer area (10^{-3} m^2)	200	100	30	12	10	4.4	1.6[a]	1.1
Approximate 3-dB beam width (°)	11	7	7	11	7	7	7	7
Recommended maximum input power for 60% electro-acoustic efficiency (W)	5000	2500	750	300	250	110	40	28

[a]Transducer area estimated by authors.

System setup and ping rate

First, the echosounder must be run as master whenever other acoustic instruments, like ADCP and sonar are used. Other instruments transmitting must always be run as slaves on the master pinging alternatively. If their transmit pulse is interfering on any of the echosounder frequencies, it should be electronically delayed to appear in the lower part of the echogram where no target registrations are expected. In order to keep the ping repetition frequency (PRF) as high as possible, without any delay, all external ER60 displays (on the bridge or in the fish lab, etc.) should be turned off, or set to maximum range − 200 m depth. Bridge navigational sounder should be turned off to prevent interference. All range settings of the EK60, like displays, storage range, Ethernet output, etc., should be set to the maximum range, 200 m. A PRF of 2/s, or interval = 0.5 with constant ping rate should be checked, and rechecked if not reached. In most of the survey area, the bottom is not reached with these settings, and the bottom detector should be set to 200 m both in the start and stop for all frequencies.

Normally, when trying to measure fish close to the sea surface it is recommended to start about 2 m below the transducer to leave a free zone to avoid nearfield effects. Starting the multifrequency analysis from this range would usually be fair, but tight packing of the transducers is needed for beam overlap at ranges less than 20 m. Some vessels, however, have various problems with back radiation on the transducers at low frequencies, and this must be evaluated for each vessel. The blind zone, which is the transducer draft + the nearfield zone may therefore be larger on some vessels than others.

False bottom

In survey areas where the bottom or bottom slope may create a false bottom echo, it is necessary that the operator constantly observe the echosounder display, and adjust the ping interval for removing the problem. When having passed the problematic area, ping interval should be changed back to the normal, fixed value of 0.5.

2.1.4.6 Scrutinisation

During IESSNS, the echoes are usually allocated to the following categories:

- herring
- mackerel
- plankton (including krill)
- others

The scrutinizing is based on combination of visual clues in the echograms, information from single echoes, disappearance of echoes when changing lower integration threshold, trawl catches, and possibly comparing echoes from different frequencies. This is an expert process prone to errors and subject to a large degree of subjectivity. Often it is useful to look observations over some tens of miles at time, as some continuity that facilitates scrutinizing can usually be expected.

Acoustic scrutiny is based on trawl information and subjective categorization. Post-processing software and procedures differ among participants:

Acoustic recordings were scrutinized on most vessels by using the Large Scale Survey System (LSSS) once or twice per day. Acoustic recordings were also scrutinized using Echoview post-processing system.

Norwegian spring-spawning herring

Herring should be scrutinized on 38 kHz. The procedure on how to scrutinize for herring is presented in ICES (2009). In the Norwegian Sea and eastern Atlantic covered by the survey, most of the herring occur in well-defined schools, often of a characteristic shape as pillar-shaped large dense schools or as layers of very small and dense school close to the surface.

The allocation of echotraces to species is governed by the results of trawl hauls. In many cases, these are considered together with observations from the netsonde/fisheye and the echogram during the haul. In some cases, it is not possible to assign schools (echotraces) to species directly e.g. where the haul contains a mixture of species and no clear differentiation can be made between the observed schools. In such situations, the integral is assigned to a species mixture category according to the trawl results. This is defined as percentage by number or weight taking into account the correct conversion to scattering length; post-processing software is then used to apply weights and lengths.

However, different species are known to have different catchability, so the exact proportions in the trawl are unlikely to be an exact sample of the true mixture. The following procedure is kept to on board the Norwegian and European vessels:

The main principle has been to use as little threshold as possible at any time, but experience show that for herring down to approx. 50 meters about -60 dB is suitable. However, this applies only at normal plankton concentrations. At extremely high levels, like experienced near the coast in the southern parts of this survey, we went all the way down to -54 dB in order to remove the plankton. Testing the effect of such thresholding by using school boxes and assessing the effect of the increased threshold show that we lose only small amounts of herring in these cases given the school is close to the surface, i.e. within the upper 50 meters. Use -54 dB when in doubt about which threshold to apply.

Herring layer, approximate. upper 50 meters

When starting a new 5-mile, first a layer is entered which defines the lower depth of the vertical herring distribution. This depth is found by looking for herring schools as discrete jumps in the integrator line and include the lowest school. We then set the threshold at a level where all the plankton is removed. This is done by varying the threshold and looking for changes in the colouring of the upper level. Herring schools will often appear as very tiny red dots, size only a few pixels, hardly visible. Note that this threshold applies only for the upper channel, down to approx. 50 meters. A note is made of the NASC when the correct threshold is found. This value is noted and is given to herring after the threshold has been reduced again to -82 dB. The threshold is lowered again to -82 dB, herring is given the noted value and the rest, up to 100% is given to plankton.

Lower layers

In the western part of the survey area, herring may be encountered in deeper layers. Schools can be isolated in boxes.

Mackerel

Mackerel should be scrutinized on 200 kHz. Mackerel targets will give about 6 dB stronger backscattering at this frequency compared to the 38 kHz, and is therefore important if extra target trawling is planned for later data scrutiny.

Mackerel has no swimbladder and is, therefore, a weak sound scatter compared to fish with swimbladder, especially so at the most commonly used frequency of 38 kHz (Foote, 1980). A known feature is that mackerel scatter sound stronger at higher frequencies (i.e. >100 kHz) compared to lower ones. This property has been investigated by scientists during the SIMFAMI project (Fernandes *et al.*, 2006) to develop an identification algorithm for mackerel schools based on the relative frequency response, r(f). Essentially, r(f) is defined as the backscattered energy at frequency f compared with the backscattered energy at the reference frequency of 38 kHz. Modelling has shown that the typical r(f = 200 kHz) of mackerel is caused by the bone (Gorska *et al.*, 2005; 2007) and the transition frequency (where backscatter of the bone becomes stronger than the flesh) depends on the bone radius (Nesse *et al.*, 2009). Korneliussen (2010) described the method of identifying mackerel schools from acoustic data based on the expected values of the relative frequency response, r(f). Relationships for r(f) were based on data collected during dedicated acoustic mackerel surveys between 1999–2004, as well as pen experiments:

$$r(18) : r(38) : r(70) : r(120) : r(200) : r(364) = 1.1 : 1.0 : 1.0 : 1.3 : 4.0 : 3.6$$

Apart from the r(f) properties, the algorithm consists of two more components to select mackerel echoes, based on the backscattering strength range (to avoid too strong and too weak values) and the geographical position (to exclude places where mackerel are knowingly not found).

Mackerel are often observed as small schools or dispersed in layers. When scrutinizing to mackerel it is essential to visually detect areas of the echogram with increased backscattering, and these areas or often only a few pixels. The best way to identify such areas is to look for jumps in the integration line. It can be necessary to increase the threshold to -70 dB to be able to identify these jumps in the integrator line (remember to set the threshold back to -82 dB before saving scrutinized data). Identified areas should then be boxed out and the r(f) should be checked. Only areas with r(f) similar to the relationship given above should be scrutinized to mackerel, but minor deviations can be accepted as the r(f) varies slightly with mackerel condition, tilt angle etc.

2.1.4.7 Biological sampling

Zooplankton sampling

The standard equipment for zooplankton sampling is the WP2 net, with 180 or 200 µm mesh size and 56 cm aperture. The net is hauled vertically from 200 m or the bottom to the surface at a speed of 0.5 m s-1. It is important not to stop the haul or lower the speed until the net is above the sea surface.

Samples are divided in two, and one-half is dried for 24 hours at 70° C before weighing. The weighing must be done in a laboratory on land, and samples can be dried on board and frozen for storage and transportation. In that case, samples must be dried again for at least 6 hours before weighing. The other half is fixed in 4% formaldehyde and seawater with proper buffering for later analyses (species determination). If samples are very large further subsampling may be necessary.

Oceanographic conditions

At the Norwegian Sea survey, a CTD profile should be taken for every 60 nm in connection with the plankton station. Temperature and salinity should be monitored from the surface layer and from the near-bottom or deepest layer regularly for calibration of the CTD sonde. It is importance to select relatively homogenous layers to take the samples in to obtain good calibration accuracy. Water samples for calibration the CTD shall be taken regularly. All vessels should also if possible collected and recorded data from the surface either applying a thermosalinograph (temperature and salinity) placed at approximately 6 m depth underneath the surface or a thermograph logging temperatures continuously near the surface throughout the survey.

Trawl sampling

To obtain information about quantity and composition of NEA mackerel in the survey area, pelagic trawls hauls are undertaken at the surface at predefined geographical positions approximately 50–60 nautical miles distance between stations. Different pelagic trawls were applied prior to 2012 (see Table 2.1.4.7.1). Nevertheless towing speed and duration were comparable were standardized between vessels and nations from 2007 to 2013. All vessels applied the Multpelt 832 pelagic trawl (ICES, 2013; Valdemarsen *et al.*, 2014) in 2012 and 2013 while prior to that different pelagic trawls, all aimed at surface based mackerel sampling, were used. The trawls were towed in the surface waters with help of floats attached to the wings and the headline (see ICES 2013 and Valdemarsen *et al.*, 2014 for detailed design and operation). Tow duration is 30 minutes and towing speed should be 5 knots, but could be lower in unfavourable current, wind and wave conditions (ICES, 2013; Valdemarsen *et al.*, 2014). The towing distance is recorded for each haul. The catch of the different species is weighed (±0.1.kg) onboard and a total of 100 mackerel individuals are sampled from the catch randomly and total length (±1 cm) and whole body weight (±0.1 g) recorded from each trawl haul. The otoliths from the first 25 individuals are retrieved for age reading.

Table 2.1.4.7.1. Trawl settings and operation details during the international mackerel survey in the Nordic Seas in July August 2012. The column for influence indicates observed differences between vessels likely to influence performance. Influence is categorized as 0 (no influence) and + (some influence).

Properties	Libas	Arni Fridriksson	Eros	Finnur Fridi	Influence
Trawl producer	Egersund Trawl AS	Tornet/Hampiðjan (50:50)	Egersund Trawl AS	Vónin	0
Warp in front of doors	Dyneema – 36 mm	Dynex-34 mm	Dyneema -32 mm	Dynex – 34mm	+
Warp length during towing	350 m	350 m	350 m	350 m	0
Difference in warp length port/starboard	0-4 m	3-12 m	0-4 m	5-12 m	0
Weight at the lower wing ends	400 kg	400 kg	300 kg	400 kg	0
Setback in metres	6 m	6 m	6 m	6 m	+
Type of trawl door	Seaflex adjustable hatches	Jupiter	Seaflex adjustable hatches	Injector F-15	0
Weight of traw door	2000 kg	2200 kg	1700 kg	2000 kg	+
Area trawl door	9 m^2 75% hatches (effective 6.5m^2)	7 m^2	7.5 m^2 25% hatches (effective 6.5m^2)	6 m^2	+
Towing speed (GPS) in knots	4.6 (4.3-5.2)	5.0 (4.5-5.5)	4.5 (4.3-4.7)	4.9 (4.1-5.1)	+
Setting time	5-6 min	3.5-6 min	5-6 min	5-6 min	+
Trawl height	26-34	27-30	29-31	~ 35	+
Door distance	115-125 m	113-117 m	120-125 m	110	+
Trawl width*	-	64-68 m	-	~ 60 m	+
Turn radius	2-8 degrees turn	5-10 degrees turn	5-6 degrees turn	5-10 degrees turn	+
Hauling time warp	5-6 min	3.5-6 min	5-6 min	5 min	+
A flapper in front end of cod-end	Yes	No	Yes	No	+
Trawl door depth (port and starboard)	5-12, 5-12 m	8-13, 10-15 m	10-15 m	5-15 m	+
Headline depth	0-1 m	0-1 m	0-1 m	0-1 m	+
Float arrangements on the headline	Kite +2 buoys on each wing	Kite + 2 buoys on wings	Kite with 1 elongated buoy + 2 buoys on each wingtip	Dynex float rope, whole headline (382 kg buoyancy) + 2 buoys on wings and 1 in middle	+
Weighing of catch	All weighted	All weighted	All weighted	All weighted	+

2.1.4.8 Analysis

The swept-area estimation approach is the same as used and presented in ICES WGWIDE reports and survey reports (e.g. Nøttestad 2010; 2012; 2014). The swept-area biomass indices were estimated from catch weight (C), towing distance (D) and nominal horizontal opening (h) for the different survey trawls as:

$$\text{Swept-area biomass index [kg km}^{-2}\text{]} = \text{C [kg]} \times \text{D}^{-1} \text{ (km)} \times \text{h}^{-1} \text{ (km)}.$$

The total biomass index (B) within rectangles of 1° latitude and 2° longitude was then determined by multiplying the estimate of swept-area biomass with rectangle area.

$$\text{B (Total biomass [kg])} = \text{Swept-area biomass} \times \text{A (km}^2\text{)}$$

where A is the area of the rectangle.

Swept-area biomass was not estimated for the years 2008 and 2009 due to poor horizontal coverage in 2008, suboptimal pelagic trawling targeting Atlantic salmon in 2008 and 2009, and too varying and less coordinated survey for the different vessels in 2009.

Sea area proportion of rectangles overlapping land was calculated with polygon clipping in R using a suite of packages available on http://cran.r-project.org and http://r-forge.r-project.org (R Development Core Team 2013).

An interpolation was undertaken for un-trawled rectangles within the mackerel distribution area. Interpolation for rectangles not covered by trawling within the mackerel distribution or on the edges of the area covered was only done for those that had adjacent rectangles with one or more tows on three or four sides. The interpolation was done by taking the average values of the adjacent rectangles.

N-Atlantic EEZs shown as overlays on Figures 1–3 and used in the allocation of biomass to EEZs were taken from shapefiles on http://www.marineregions.org.

A naive bootstrap approach was applied to estimate the uncertainty around the obtained swept-area biomass indices from 2007 to 2013. The bootstrap units were the 1° latitude by 2° longitude rectangle biomass estimates themselves, across the whole area. The total biomass for each bootstrap replicate was summed and stored in a vector of bootstrap total biomass estimates, yielding bootstrap quasi CV and 90% CI. Number of replicates was 10 000. Only the occupied rectangle values were bootstrapped, as including the interpolated values in the bootstrap would lead to a reduction in the quasi-CVs. The distribution area of mackerel was calculated for the same years as the swept-area biomass indices and represents the total area occupied by mackerel during the survey period at the feeding grounds. This was done by summarizing the area for all rectangles inhabited by mackerel, which included both trawled and interpolated values.

The horizontal Centre of Gravity (COG) was calculated by the following procedure. First, the positions of all rectangles were converted from degrees to Cartesian coordinates via radians (http://www.geomidpoint.com/calculation.html). Then the coordinates for all rectangles were weighted according to fish abundance (kg) and the COG was found by averaging the weighted coordinates.

Age-disaggregated abundance indices

In the estimation of the age-disaggregated abundance indices of age groups 0–14, the total survey area was split up into four regions; southeast of 65˚N 0˚W, northeast of 65˚N 0˚W, between 0 and 19˚W and west of 19˚W. The estimations were done for one area at the time and the results then merged. The separation between areas was done to reduce the effect of spatial differences in length distribution, as for instance fish from a given year class far to the west is generally bigger than the fish from the same year class in the southeast (Nøttestad *et al.*, 1999). Age readings were missing for part of the survey area in 2010, for that area (west of 19˚W), matrix_1 from the same area in 2011 was used for calculating the age of the fish in the area.

Age determination based on length-measured fish only was done according to the procedure described in (Fridriksson, 1934). The relative proportion of different year classes for each station was calculated by the following equation:

$$P_a = \frac{TW_a}{\sum_{a=1}^{n} TW_a}$$

where a is a given age group, Pa the proportion of the age class for a given station and TW the total weight of mackerel for the age group in the sample.

The mean weight (W) within an age group (a) for each station was calculated as:

$$W_a = \frac{TW_a}{N_a}$$

where Na is the number of mackerel in the sample. The allocation of Wa and Pa for all stations to rectangles were done with the same procedure as described for the catches under data analyses.

The number-at-age (Nage) was then calculated as:

$$N_{age} = \sum_{i=1}^{n} \frac{B_i * P_i}{W_i}$$

where i is the rectangle number and B the biomass of mackerel (kg).

Internal consistency

Continuation ratio logits (CRLs) is a type of model for ordered categorical responses (such as age groups) described by Agresti, (1990). It has been used for modelling age length keys (Kvist *et al.*, 2000 and Rindorf and Lewy, 2001). This model is used to test for internal consistency in the number-at-age data. A strong correlation coefficient between age groups indicates that there is a strong consistency between the numbers of fish of a year class between consecutive years.

Fish samples are to be divided into species composition by weight. Length frequency and length weight data should be collected for each component of the catch. Length measurements of 100 blue whiting are to be taken to the nearest 0.5cm below for every trawl, of which 50 length-representative samples have to be measured for weight, sex, age and maturity.

Biological sampling is used to verify the composition of echotraces during echo integration. Decisions to fish on particular echotraces are largely subjective and an attempt should be made to also target echotraces of low-density scattering layers not just high density shoals. No bottom-trawl gear is used during this survey.

2.1.4.9 Abundance

LSSS

The analyses of abundance estimation of NEA mackerel from LSSS are based on multifrequency echosounder methodologies (Korneliussen and Ona, 2003) from Korneliussen (2010) and Korneliussen *et al*. (2006; 2008). See also IMR (1999) and Peña *et al*. (2014) for suggested scientific approaches to estimate abundances of NEA mackerel during summer and autumn.

Echoview

From the acoustic data, backscatter potentially coming from mackerel schools were extracted per 1 nm EDSU (equivalent distant sampling unit) along-transects in covered areas using Echoview post-processing software (V5.4). To convert the acoustically derived densities to abundance, standard methods were used (e.g. Simmonds and MacLennan, 2005). Nautical area scattering coefficient (sA) allocated to mackerel based on the algorithm were taken from the 200 kHz data rather than the more conventional 38 kHz (van der Kooij *et al.*, 2014). The first reason for this was the possible inclusion of e.g. clupeid pixels within selected mackerel schools, which would lead to overestimation of mackerel within the school. Although this would result in inflated mackerel backscatter when using either 38 or 200 kHz, the effects at 200 kHz are much smaller, because mackerel Target Strength (TS) relative to fish with swimbladders could be as much as 8 dB higher at 200 kHz (Korneliussen, 2010). The second reason for using the mackerel backscatter at 200 kHz was the likely higher stability of the mackerel backscatter at 200 kHz than at 38 kHz, due to potential effects of temperature and fat content on scattering properties of the flesh, which is dominant at 38 kHz (Gorska *et al.*, 2007; Korneliussen, 2010). These physical properties could have been the cause for observations where mackerel schools were not visible at 38 kHz, whereas clearly visible at 200 kHz. The only mackerel TS values published to date are those at the conventional 38 kHz frequency. A similar method previously applied to herring (Saunders *et al.*, 2012) was consequently applied to derive a mackerel TS at 200 kHz by using the frequency response equation (Korneliussen and Ona, 2003): $r(f) = sv(f)/sv(38)$. Here f = 200 kHz and r(200) = 3.4, according to the most current data (Korneliussen, pers. comm.). This represents 5.31 dB on the logarithmic scale, which was combined with the existing TS length relationship for mackerel at 38 kHz according to:

$TS_{38kHz} = 20Log_{10}(L) - 86.4$ dB (Misund and Beltestad, 1996) becomes:

$TS_{200kHz} = 20Log_{10}(L) - 86.4$ dB + 5.31 dB which is:

$TS_{200kHz} = 20Log_{10}(L) - 81.09$ dB

The above method simplifies some of the complex acoustic properties of mackerel (Nesse *et al.*, 2009), and should be considered an interim solution until current ongoing theoretical and field experiments have yielded a validated TS value at 200 kHz. To convert the acoustic density of mackerel to numbers, a mean length was required.

2.1.4.10 Reporting

Reports are submitted annually through WGIPS.

2.1.4.11 Caveats/limitations

Limitations related to the acoustic measurements of NEA mackerel during the IESSNS survey are:

1) The acoustic dead zone at the surface (0–15 m depth)
2) Limited in situ TS values for NEA mackerel depending on depth distribution and tilt angle.
3) Dense plankton concentrations masking loose concentrations of mackerel close to the surface.
4) Vessel avoidance creating uncertainty and possibly bias related to acoustic measurements with multifrequency echosounder data.
5) Limited spatial coverage underneath the transducer depth when mackerel is distributed in the upper 30–40 m of the water column.

2.1.5 International acoustic survey in the North Sea, West of Scotland and Malin Shelf (HERAS)

2.1.5.1 Background

The HERAS and MSHAS 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 (MSHAS). 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. The survey is carried out by vessels from Denmark, Germany, Netherlands, Ireland, Norway and Scotland. Coordination and planning of the surveys are undertaken during the annual WGIPS meeting.

2.1.5.2 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 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. The actual time-series can be found in the latest version of the WGIPS report (http://www.ices.dk/community/groups/Pages/WGIPS.aspx)

2.1.5.3 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 and IIIa), 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 (western Baltic).

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.

2.1.5.4 Survey design and area coverage

The HERAS and MSHAS surveys are carried out annually in June/July. The surveys cover the continental shelf north of 52°N in the North Sea and west of Scotland and Ireland to a northern limit of 62°N (Figure 2.1.5.4.1). The survey area is bound to the east by the Norwegian, Danish, Swedish and German coastline and to the west by the shelf edge between 200 and 400 m depth. By carrying out the coordinated survey at the same time from the Kattegat to Donegal, all herring in these areas are covered simultaneously, reducing uncertainty due to area boundaries.

A stratified, systematic, parallel 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. Each ICES rectangle should be covered with a minimum of one transect and with higher intensity where historically a high abundance or variability of abundance has been detected. Transect spacings of 7.5 and 15 nautical miles are used in the areas covered by Ireland and Scotland. In the Norwegian area a spacing of 15 nm is used, Danish area is covered with 10–15 nm spaced transects and the southern areas covered by the Netherlands and Germany typically uses a spacing of 15–30 nm.

Transects should preferably run perpendicular to the greatest gradients in fish density which are generally related to gradients in bottom topography and hydrography. This means that transects will normally be run perpendicular to the coast. Ships' speed during the survey should be kept at 10–12 knots.

If species identification depends on recognition of schools on the echogram, the survey will have to be interrupted during periods in the 24-hour cycle when the schools disperse. This occurs during the hours of darkness, depending on the area. When schools disperse during darkness, some of the herring may rise to the surface and get above the transducer. This is consideration is valid in most of the survey area covered in this survey with the exception of the Kattegat/Skagerrak covered by Denmark where herring is found in dispersed layers mixed with other fish at all times.

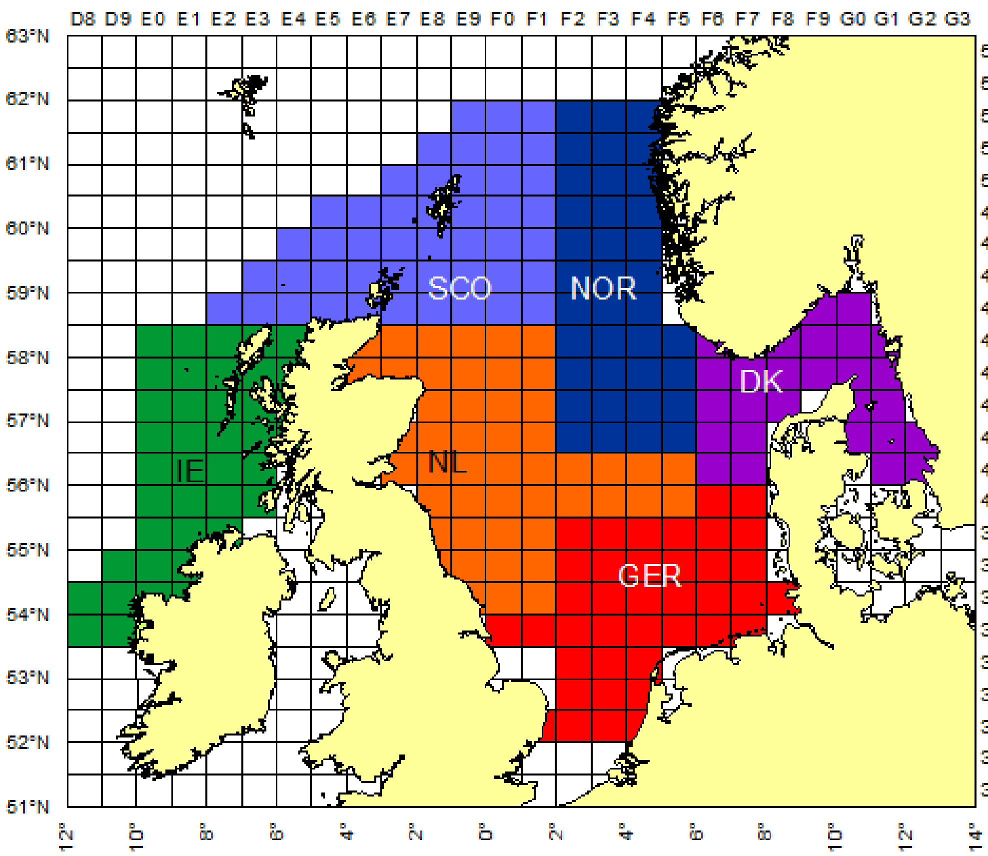


Figure 2.1.5.4.1. Area coverage by the surveys within HERAS. IE: Ireland, SCO: Scotland; NL: Netherlands; NOR: Norway; GER: Germany and DK: Denmark.

2.1.5.5 Data collection

2.1.5.5.1 Acoustic

The acoustic data are collected using a Simrad EK60 scientific echosounder with 38 kHz transducers mounted on the hull, drop keel or towed bodies depending on vessel.

Prior to 2006, Simrad EK500 and EY500 were also used. Most participating vessels carry additional transducers at various operating frequencies (e.g. 18, 120, 200) and collect data concurrently from these during the survey for the purpose of echotrace classification. The 38 kHz data only is used to generate the abundance estimate.

EK60 setup during the survey follows a standard protocol as outlined in the EK 60 user manual. The current (2013) operating version of the software is V2.4.3 and it is advised that latest software release should be installed when available. All frequencies are to be calibrated directly prior, after or during the survey.

At the survey start, the vessel log (GPS distance) should be reset to 'zero' to ensure consistency in log output files. A record should be kept of all transect start/endpoints as well as other disruptions to the survey track including trawling operations start and end times.

2.1.5.5.2 Biological

Species allocation of the acoustic records is impossible if no trawl information is available. The general rule is to make as many trawl hauls as time permits, especially if echotraces are visible on the echosounder after a blank period. The principal objective is to obtain a sample from the school or the layer that appears as an echotrace on the sounder. The trawling gear used is of little importance as long as it is suitable for catching a sample of the target-school or layer. During trawling it is important to take note of the traces on the echosounder and the netsonde in order to judge if the target-school entered the net or if some other traces "spoil" the sample. It is recommended that notes be made on the appearance and behaviour of fish in the net during every haul.

The fish sample obtained from the trawl catch is divided into species by weight and by number. 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 either representative or length stratified samples are taken for maturity, age (otolith extraction) and weight.

In several areas the biological sampling includes measures to allow discrimination among different stocks of herring. In the Norwegian and Danish part of the survey the total herring estimate is divided into North Sea Autumn Spawners and Western Baltic Spring Spawners. The mean weights and mean lengths used are the same for the two stocks as they are not divided on an individual basis. The split is based on vertebral counts in the Norwegian part and on otolith shape analysis in the Danish survey area.

In the Malin Shelf area (West of 4°W) a combination of body morphology and otolith shape is used to discriminate between herring from the VIaS and VIaN spawning components.

2.1.5.5.3 Analysis

Echo integration and further data analyses are carried out in national laboratories for the area they cover using either MAREC LSSS (Large Scale Survey System), Myriax Echoview or EchoAnn software as well as other nationally developed analysis programmes.

2.1.5.5.4 Scrutinisation protocol

Acoustic data should be backed up every 24 hrs and scrutinised using adequate post-processing software. Partitioning of data into the categories is to some extent a subjective process backed up with trawl data and so it is vital that an experienced scientist who has experience of this survey and area undertake the scrutinisation of echograms. Different methods of species allocation are being used in the various areas. The method used depends largely upon the schooling behaviour of the herring and sprat, and the mixing with other species. In the North Sea and Division VIa the species allocation is based mainly on the identification of individual schools on the echogram. In the Skagerrak-Kattegat, the identification is based on composition of trawl catches. Species allocation is generally aided by the use of multi frequency data through templates implemented in the preferred post-processing programme.

Joint sessions of scientists from participating countries comparing echograms and scrutinisation procedures are encouraged to ensure a standardized approach to the interpretation of echograms. The next joint scrutinisation workshop for participants in this survey is planned to take place in 2015 and it is expected that a detailed description of the specific current routines used by individual laboratories as well as recommendations for best practice in this survey will result and be integrated in the next version of this manual.

2.1.5.5.5 Abundance estimation

At the present time abundance estimation is carried out entirely within each participating laboratory for the area they cover following the universal principles detailed in Section 6.4 in this manual and using the agreed target strength to fish length relationships given in Section 6.1.

The aggregated national data are reported through a standardized data exchange format and uploaded into the FishFrame database (see Section 7.2). 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 Div. IIIa.

In 2015, a workshop is planned to provide detailed descriptions of the current workflows followed by national institutes and to agree a combined abundance estimation procedure based on disaggregated acoustic and biological data from all areas.

2.1.5.5.6 Reporting

A combined survey report is produced annually through WGIPS.

2.1.5.5.7 Caveats/limitations

The survey is carried out with large survey vessels. This allows safe and timely completion of the large area the surveys cover, but also leads to a few limitations. Coastal areas are often too shallow to allow full survey operations (especially trawling) and might produce estimates of high uncertainty due to physical restrictions in sampling of acoustic data.

Juvenile herring (0 winter rings) and sprat are typically found further inshore than older herring which is the main target of the survey. An expansion of the survey area to also include all coastal areas to account for coverage of potentially important sprat (and herring) nursery areas would require additional ship time as well as smaller vessels, especially on the West coast of Scotland with its highly complex coastline and multitude of sea lochs. This is not feasible within the framework of the present survey to both survey these areas and complete the entire survey area within a three – four week period.

The survey does therefore not fully account for very young herring (particularly to the West of Scotland), and does not necessarily give an absolute picture of sprat abundance and distribution either.

Issues in differentiating between herring and sprat in acoustic surveys are currently also not likely to be solved. Due to sprat and herring occasionally occurring in mixed schools and due to the high plasticity in school shapes of both herring and sprat, together with the currently assumed identical backscattering characteristics of these species, it is not possible to distinguish between sprat and herring based on echo recordings alone. An allocation of echo recordings to individual species can only be based on catch composition and length frequencies obtained from directed trawl hauls. It is therefore important to stress that an adequate level of trawl sampling must be maintained in areas of known overlap between these two species to allow confident separation of the echo integrals.

2.2 Individual surveys

In addition to the coordinated international multi-vessel surveys listed above a number of other national acoustic survey programs also report through and are coordinated by WGIPS. Individual surveys also provide annual tuning data to the assessment working group for stock specific surveys.

2.2.1 The Irish Sea acoustic survey

2.2.1.1 Background

The ISAS is undertaken annually to determine the distribution, abundance and age structure of the herring stock within ICES Divisions VIIaN The survey is carried out during late August to mid-September on board the RV 'Corystes' since 2005 and before that on the RV 'Lough Foyle'. A complete time-series for VIIaN, from acoustic surveys as applied outlined below dates back to 1994. Acoustic surveys were also conducted in 1991 and 1992, but were conducted in focused areas of VIIaN.

The survey is timed to coincide with the main annual spawning migration, with the main fishery also mainly targeting these aggregations. There are a number of spawning grounds around the Irish Sea, but the most important spawning area in the Irish Sea are found in coastal waters to the east of the Isle of Man (Douglas Bank) and on the Irish Coast at around 54°N (between Annalong and Dundalk Bay). There are two recognized stock components in the Irish Sea, corresponding to these main spawning areas. The Manx stock spawning primarily on the Douglas Bank and the smaller Mourne stock located off the east coast of Northern Ireland. Since 1984, the Herring Assessment Working Group (HAWG) combined the data from the two stock components and assessments treats the data as coming from a single-stock. Irish Sea herring are autumn-spawning fish, but a few occurrences of winter spawning have been documented and reported by the industry.

A herring larval survey is also conducted in November to provide an estimate of spawning-stock biomass, but the age structured acoustic survey index is the main tuning fleet in the assessment for the stock.

2.2.1.2 Survey time-series

The survey time-series are reported annually to ICES and included the WGIPS and HAWG reports.

2.2.1.3 Survey objectives

The survey is aims to provide an annual estimate the distribution, abundance and population structure of herring and sprat in the Irish Sea VIIaN by echo-integration and targeted midwater trawling. Biological data collection, length frequency distribution and age, is carried from targeted pelagic trawling. The derived estimates and age structure of herring are used as a tuning index submitted annually to the HAWG. Hydrographic data, surface temperature and salinity, are recorded using the through-flow thermosalinograph.

The survey design is stratified by eleven biologically and geophysical defined stratum. Systematic transects cover approximately 1200 nm, in 12 ICES rectangles. The position of transects, spaced 8–10 nm, around the periphery of the Irish Sea is randomized within +/- 4 nm of a baseline start 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 in spawning aggregations. Survey coverage is outlined in Figure 2.2.1.3.1. Survey timing is aimed to coincide with the period during which migrating mature herring are moving from staging areas in the north of the region to the main spawning grounds to the southeast of the Isle of Man. When possible, given tidal current and ground conditions, directed midwater trawling is carried on identified acoustic targets.

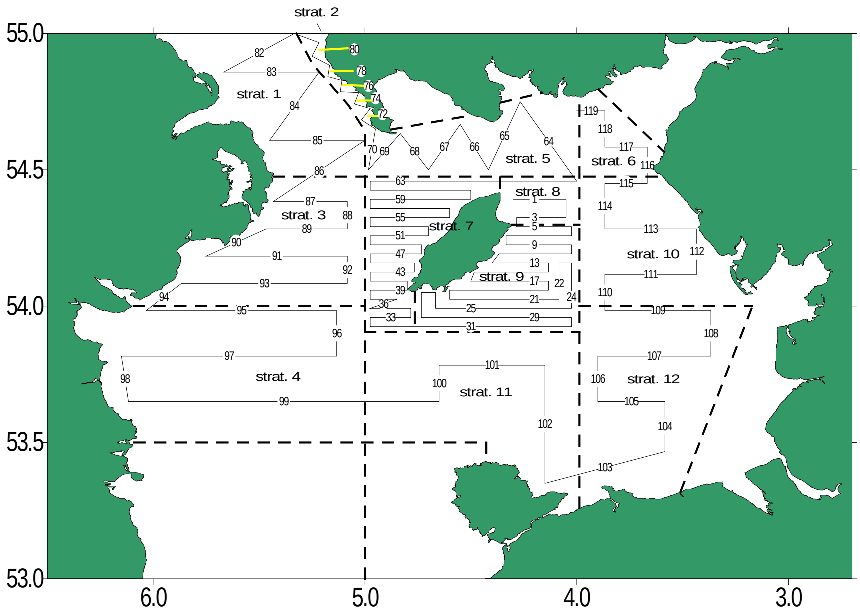


Figure 2.2.1.3.1. Survey strata and transect coverage of the Irish Sea acoustic survey.

2.2.1.4 Data collection

2.2.1.4.1 Acoustic

Acoustic data at 38 kHz and 120 kHz are collected in 15-minute Elementary Distance Sampling Units (EDSUs) 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 parameter settings used during the survey are given in Table 2.2.1.4.1. The acoustic system is calibrated at the commencement of the cruise using methods as defined by the hardware manufacturer. Transducer calibrations are carried out at the start of the survey and are only conducted following established methods (Foote *et al.*, 1987). Calibration results are only deemed acceptable within the guidelines issued by the hardware manufacturer (Section 3.3). It is a requirement that calibration results for the 38 kHz transducer are provided in the cruise report. The nautical surface-area backscattering (NASC) estimates are calculated for schools, school groups and scattering layers using a threshold of -60 dB. Acoustic data are backed up every 24 hrs and scrutinised using Echoview® (V 5) post-processing software.

Table 2.2.1.4.1.1. Echosounder settings employed during the ISHS.

ECHOSOUNDER	SIMRAD EK 60	
Installation	Hull mounted	
Frequency (kHz)	38	120
Primary Transducer	ES 18-11	ES 380-7
Pulse length (ms)	1024	512
Power (W)	2000	1000
Ping rate	0.7s	0.7s

2.2.1.4.2 Biological

Biological sampling is carried out using a single pelagic midwater trawl with a vertical opening of c. 15 m. The standardized pelagic trawl operated during this survey is based on a single vessel single pelagic midwater trawl design historically used in the herring fishery and fitted with a 20 mm codend liner to ensure the retention of small and juvenile fish. Trawl metrics are monitored using SCANMAR net monitoring suite of sensors. Net performance is determined by inspecting the measurements of the net during deployment. During trawling acoustic data are recorded along with measurements of the net position, depth, net opening, longitude and latitude to allow allocation of acoustic NASC to be validated with sampling information. No fixed trawl duration is employed during the survey with the emphasis on taking a representative sample of the targeted echotrace.

The trawl catches are sorted to species and length measurements are carried out on each species to the nearest 0.5 cm below. Further biological samples, including otoliths, are taken from 1–2 individuals of each size class from target species, to make up 50 individual, and measured to a 0.1 mm accuracy. Because of the large size of some catches a subsample of the catch is sufficient to obtain an accurate assessment of the length frequency distribution of the species caught.

2.2.1.4.3 Hydrographic data

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

2.2.1.5 Data analysis

Scrutinisation protocol

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 more robust estimate of population length composition. The single-species or mixed-species mean target strength (TS) is calculated from trawl data for each interval as 10 log {(Σs,l Ns,l.100.1.TSs,l) / Σs,l Ns,l } where Ns,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). Acoustic data should be backed up every 24 hrs and scrutinised using Echoview® (V 5) post-processing software Partitioning of data into the categories shown below is largely a subjective process back up with trawl data and so it is vital that an experienced scientist who has experience of this survey and area undertake the scrutinisation of echograms.

The NASC values from each region are allocated to one of five categories after inspection of the echograms. Categories identified on the basis of trace recognition were as follows:

1) Definitely herring: echotraces or traces were identified on the basis of captures of herring from the fishing trawls which had sampled the echotraces directly, and on large marks which had the characteristics of “definite” herring traces (i.e. very high intensity (red), narrow inverted tear-shaped marks either directly on the bottom or in midwater and in the case of spawning shoals very dense aggregations in close proximity to the seabed).

2) Probably herring: attributed to smaller echotraces that had not been fished but which had the characteristic of “definite” herring traces.

3) Possibly herring: were attributed to small echotraces outside areas where fishing was carried out, but which had the characteristics of definite herring traces or similarities to historic observations.

4) Definite Clupeoid mixture: echotraces or traces were identified on the basis of capture of herring as part of a clupeoid mixture (mostly juvenile herring and sprat) from the fishing trawls which had sampled the echotraces directly, and on marks which had the characteristics of “definite Clupeoid mix” traces (i.e. scattered midwater targets inshore or normally round in shape and occurring in defined depth strata in offshore areas).

5) Probably Clupeoid mixture: attributed to smaller echotraces that had not been fished but which had the characteristic of “definite” Clupeoid mix traces.

The RAW EK 60 data files are imported into Echoview for post-processing. The echograms are divided into transects using annotations and timestamps corresponding to the 15 minute survey intervals. Echotraces belonging one of the five categories above are identified visually and echo integration performed on the enclosed regions. The echograms are analysed at a threshold of -60 dB.

2.2.1.6 Abundance estimation

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. Age–length data from the commercial fishery are normally not used, in order to avoid spurious correlations between survey data and catch data in ICES assessment. Mean weights at age, calculated from length-weight parameters for the survey, and the ICES WG maturity ogives for VIIa herring, are used to calculate spawning biomass of herring from the estimated numbers-at-age. The weighted mean fish density is estimated for each survey stratum 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.

2.2.1.7 Reporting

The results of the survey are reported annually to ICES and the age disaggregated numbers-at-age time-series is reported in the WGIPS and HAWG reports.

2.2.1.8 Caveats/limitations

Survey effort is focused 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. However, very few trawl catches of adult herring have been made off the Irish and English coasts over the period of the surveys, and a more intensive survey of these regions, at the expense of time spent around the Isle of Man (where 85% of the spawning-stock biomass originate), remains unwarranted at present. The stock distribution and the appropriateness of this adaptive survey design has also been confirmed in recent years with an extended survey programme where successive surveys have been conducted at fortnightly intervals.

2.2.2 Celtic Sea herring acoustic survey (CSHAS)

2.2.2.1 Background

The CSHAS is undertaken annually to determine the distribution, abundance and age structure of autumn and winter spawning components of the herring stock within ICES Divisions VIIj-g and VIIaS (Figure 2.2.2.1.1.). The survey is carried out over 21 days starting in early October on board the RV 'Celtic Explorer'.

For a period in the 1970s and 1980s, larval surveys were conducted for herring in this area. However, since 1989, acoustic surveys have been carried out, and currently are the only tuning indices available for this stock. Since 2004 the survey has been carried out on board the RV 'Celtic Explorer', prior to this a commercial charter vessel was used. Survey estimates and age structure of herring are used as a tuning index submitted annually to the HAWG.

The stock structure and discrimination of herring in this area has been investigated recently. Hatfield *et al.* (2007) has shown the Celtic Sea stock to be fairly discrete. However, it is known that fish in the eastern Celtic Sea recruit from nursery areas in the Irish Sea, returning to the Celtic Sea as young adults (Brophy *et al.*, 2002; Molloy *et al.*, 1993). The stock identity of VIIj herring is less clear, though there is evidence that they have linkages with VIIb and VIaS (ICES, 1994; Grainger, 1978). Molloy (1968) identified possible linkages between young fish in VIIj and those of the Celtic Sea herring. For the purpose of stock assessment and management divisions VIIaS, VIIg and VIIj have been combined since 1982. A protracted spawning period exists for the two stock components extending from October through to mid-January. The age profile of the stock extends to a maximum of 9 winter rings and is dominated by younger fish of the 1–3 winter ring cohorts.

The survey reports the biomass and abundance of other small pelagics including sprat and pilchard where sufficient observations allow. Detailed hydrographic sampling is undertaken and all data are submitted to ICES annually. Additionally coordinated marine mammal, marine litter and seabird distribution surveys are also undertaken by NGO's working on board the ship and contributing to the survey output. The survey cruise report for 2013 is available at: http://oar.marine.ie/handle/10793/920

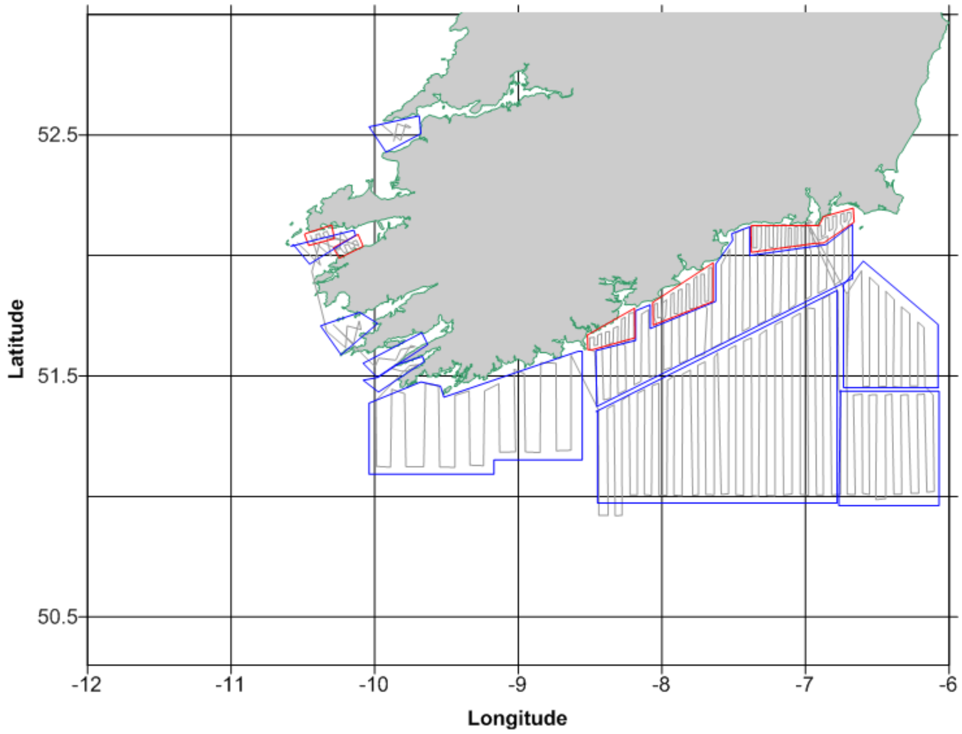


Figure 2.2.2.1.1. Standardized survey strata (broadscale: blue and spawning box: red) and transect coverage (grey lines) during the CSHAS survey 2013.

2.2.2.2 Survey time-series

Prior to 2004, the survey was carried out using a commercial charter vessel with a calibrated 38 kHz transducer deployed in a tow body. Timing varied by up to 4 weeks in certain years and this coincided with a period of low stock abundance and poor recruitment. With the arrival of the RV 'Celtic Explorer' in 2004 the survey became established temporally. Geographical coverage has evolved with changes in dynamics of the stock during the summer feeding phase (2009 onwards) and also with changes in the abundance of the autumn component of the spawning stock (2006 onwards). Historically the autumn stock component dominated southwestern areas but is now at a historic low level. The winter spawning component has grown to become the focus of the stock and the survey and the survey effort is now more focused on the Celtic Sea. The survey time-series is presented in Table 2.2.3.1.1.

Adaptive surveying is carried out when time allows and decisions on if or how to incorporate these data are carefully considered at assessment level by the HAWG. In 2010 the 38 kHz dataset was compromised by an intermittent cabling fault. Survey data for this year was analysed using the 18 kHz dataset (Saunders *et. al.*, 2012).

Table 2.2.3.1.1. CSHAS survey time-series. Abundance in millions, biomass in 000's tonnes. Age in winter rings.

Season Age (Rings)	1995 1996	1996 1997	1997 1998	1998 1999	1999 2000	2000 2001	2001 2002	2002 2003	2003 2004	2004 2005	2005 2006	2006 2007	2007 2008	2008 2009	2009 2010	2010 2011	2011 2012	2012 2013	2013 2014
0	202	3	-	0	-	25	40	0	24	-	2	0	1	2	239	5	0.1	31	3.8
1	25	164	-	30	-	102	28	42	13	-	65	21	106	63	381	346	342	270	697.6
2	157	795	-	186	-	112	187	185	62	-	137	211	70	295	112	549	479	856	291.4
3	38	262	-	133	-	13	213	151	60	-	28	48	220	111	210	156	299	615	197.4
4	34	53	-	165	-	2	42	30	17	-	54	14	31	162	57	193	47	330	43.7
5	5	43	-	87	-	1	47	7	5	-	22	11	9	27	125	65	71	49	37.9
6	3	1	-	25	-	0	33	7	1	-	5	1	13	6	12	91	24	121	9.8
7	1	15	-	24	-	0	24	3	0	-	1	0	4	5	4	7	33	25	4.7
8	2	0	-	4	-	0	15	0	0	-	0	0	1	0	6	3	4	23	0
9	2	2	-	2	-	0	52	0	0	-	0	0	0	0	1	0	2	3	0.2
Abundance	469	1338	-	656	-	256	681	423	183	-	312	305	454	671	1,147	1,414	1,300	2,322	1,286
SSB (''000 t)	36	151	-	100	-	20	95	41	20	-	33	36	46	93	91	122	122	246	71
CV	53	26	-	36	-	100	88	49	34	-	48	35	25	20	24	20	28	25	28

2.2.2.3 Survey objectives

The survey objectives are listed below:

- Carry out a predetermined survey cruise track.
- Determine an age-stratified estimate of relative abundance of herring within the survey area (ICES Divisions VIIj, VIIg and VIIaS).
- Collect biological samples from directed trawling on insonified fish echotraces to determine age structure and maturity state of the herring stock.
- Determine aggregated estimate of biomass and abundance for sprat.
- Collect additional acoustic data through adaptive surveying where time allows.
- Collect physical oceanography data from vertical profiles from a deployed sensor array.
- Survey by visual observations marine mammal and seabird abundance and distribution (ESAS-European Seabirds At Sea methodology).
- Sighting survey for marine surface litter.
- Collect water samples to determine marine microplastic occurrence.

2.2.2.4 Survey design and area coverage

One survey per year is carried out. A predetermined cruise track is to be used during the CSHAS based on previous area coverage and supplemented with adaptive surveying where and when time allows. The survey abundance index is determined from predetermined survey coverage alone. A systematic parallel transect design should be used with transects running perpendicular to the coastline and lines of bathymetry where possible. The survey should begin in the North and work in a southerly then easterly direction covering offshore strata first in the Celtic Sea before moving inshore.

The survey is broken into two main components and stratified accordingly. The first broad scale survey is carried out to contain the stock within the survey confines and is based on the distribution of herring from previous surveys and historic commercial catch data. The broad scale survey is an important component as herring transit these offshore strata when moving from summer feeding grounds to inshore coastal spawning areas. The second component focused exclusively on known spawning areas within c.15 nautical miles of the coast. The start point within each stratum is randomized annually from established boundary points. Survey strata are not based on ICES statistical rectangles and are based on historic catch data. The survey design needs to adhere to principles outline in Simmonds and MacLennan, (2005) while maintaining established stratification.

The order in which each stratum is surveyed is to remain constant across years to ensure consistency of timing. Transect resolution is set at between 2–4 nmi for the broad scale survey and increased to 1 nmi for the spawning ground surveys and should be maintained. Bay areas are surveyed using a zigzag transect approach to maximize area coverage.

Acoustic data are to be collected using an EDSU (elementary sampling distance unit) of 1 nmi. An estimate of CV is required to accompany estimates of biomass and abundance.

Normal geographical coverage extends to c. 6 000 nmi^2 (nautical miles) annually using approximately 3 100 nmi of transects to cover the allotted strata. The survey is to be conducted over 24 hours.

2.2.2.5 Data collection

Acoustic

Acoustic data are collected using a Simrad EK60 scientific echosounder. Split-beam transducers are mounted within the vessel's drop keel and lowered to the working depth of 3.3 m below the vessel's hull or 8.8 m sub surface. Four operating frequencies are used during the survey (18, 38, 120 and 200 kHz) for trace recognition purposes, with 38 kHz data used to generate the abundance estimate (Table 2.2.2.5.1.1). All frequencies are to be calibrated prior to the survey.

While on survey track the vessel is to be operated in 'silent mode' (propelled using DC twin electric motor propulsion system (ICES, 1995)). During fishing operations normal 2 engine operations can be used to provide sufficient power to tow the net in poor weather.

EK 60 set up during the survey follows a standard protocol as outlined in the EK 60 user manual. The current (2013) operating version of the software is V2.4.3 and it is advised that latest software release should be installed when available. Settings during the survey are as outlined in the table below.

Environment details (temperature and salinity) are taken from a CTD cast taken in open water or exposed bays in the survey area and not from enclosed bodies such as sheltered bays.

At the survey start, the vessel log (GPS distance) should be reset to 'zero' to ensure consistency in log output files. If the systems crashes a reset of the vessel log should be calculated to closely match that of the last valid output file. All off track incidents and transect start/endpoints are recorded as text annotations in the sounder screen using the annotation feature as well in paper form (Time, position, lat, long, log number).

Table 2.2.2.5.1.1. Echosounder settings employed during the CSHAS.

ECHOSOUNDER	SIMRAD EK 60			
Installation	Drop keel			
Frequency (kHz)	18	38	120	200
Primary Transducer	ES 18-11	ES 38B	ES 120-7	ES 200-7
Pulse length (ms)	1024	1024	1024	1024
Power (W)	2000	2000	1000	500
Ping rate	Max	Max	Max	Max

Biological sampling

Biological sampling is carried out using a single pelagic midwater trawl with a vertical opening of c. 9 m. Trawl metrics are monitored using a net sonde and SCANMAR net monitoring suite of sensors. All components of the catch from the trawl hauls should be sorted and weighed; fish and other taxa are identified to species level. Fish samples are to be divided into species composition by weight. Species other than the herring were weighed as a component of the catch. Length frequency and length weight data should be collected for each component of the catch. Length measurements of herring, sprat and pilchard are to be taken to the nearest 0.5 cm below.

Biological sampling is used to verify the composition of echotraces during echo integration. Decisions to fish on particular echotraces are largely subjective and an attempt should be made to target echotraces low density scattering layers not just high density shoals. No bottom-trawl gear is used during this survey. However, the small size of the midwater gear used and its manoeuvrability in relation to the vessel power allows samples at or below 1m from the bottom to be taken over clean ground.

The standardized pelagic trawl operated during this survey is based on a single vessel single pelagic midwater trawl design historically used in the herring fishery (Figure 2.2.2.5.1.1).

The trawl has been modified to work on a larger vessel such as the RV 'Celtic Explorer' and fitted with a 20 mm codend liner to ensure the retention of small and juvenile fish. Trawl monitoring, trawl door type and dimensions and rigging are provided in Table 2.2.2.5.1.2. No fixed trawl duration is employed during the survey. The emphasis is on taking a representative sample of the targeted echotrace. In practice, trawl duration of 30 minutes (active fishing) is sufficient to do this. The chief scientist has then to determine whether the sample is composed of the targeted echotrace.

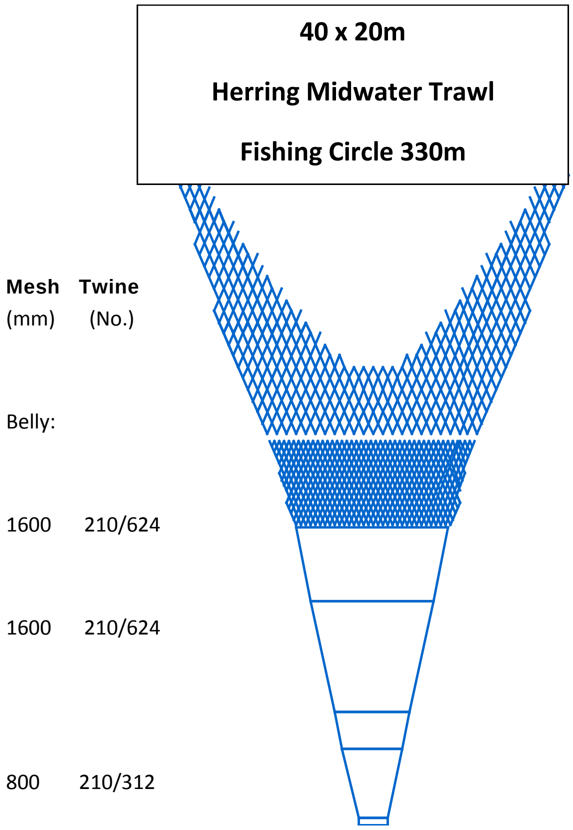


Figure 2.2.2.5.1.1. Single herring midwater trawl plan as used on the CSHAS. Note: All mesh sizes given in half meshes; schematic does not include 32m codend.

Table 2.2.2.5.1.2. Single herring midwater trawl metrics as routinely used during the CSHAS.

Towing speed	c. 3.5 Kts
Headline opening	7–11 m (Mean of 8m)
Door spread	64–78 m
Warp: depth ratio	c.3:1
Trawl doors	Thyborron Type 10 Pelagic V doors
Size	3.5m²
Weight	700 Kg
Clump weights	500 Kg per side
Bridles	80 m (40mm Dynex®)
Net monitoring system	SCANMAR Distance sensors (Trawl doors)
	SCANMAR Catch sensor
	50 kHz Bel reson Headline transducer (cable link)
	SCANMAR Trawleye widebeam, (acoustic link)

All components of the catch from the trawl hauls are to be sorted and weighed; fish and other taxa are identified to species level. Fish samples are divided into species composition by weight. Species other than the herring are weighed as a component of the catch. Length frequency and length weight data are collected for each component of the catch. Length measurements of herring, sprat and pilchard are taken to the nearest 0.5cm below. Age, length, weight, sex and maturity data are to be recorded for individual herring within a random 50 fish sample from each trawl haul, where possible. All herring are to be aged on board if possible. The appropriate raising factors should be calculated and applied to provide length frequency compositions for the bulk of each haul. Sampling protocol is outlined in Figure 2.2.2.5.1.2.

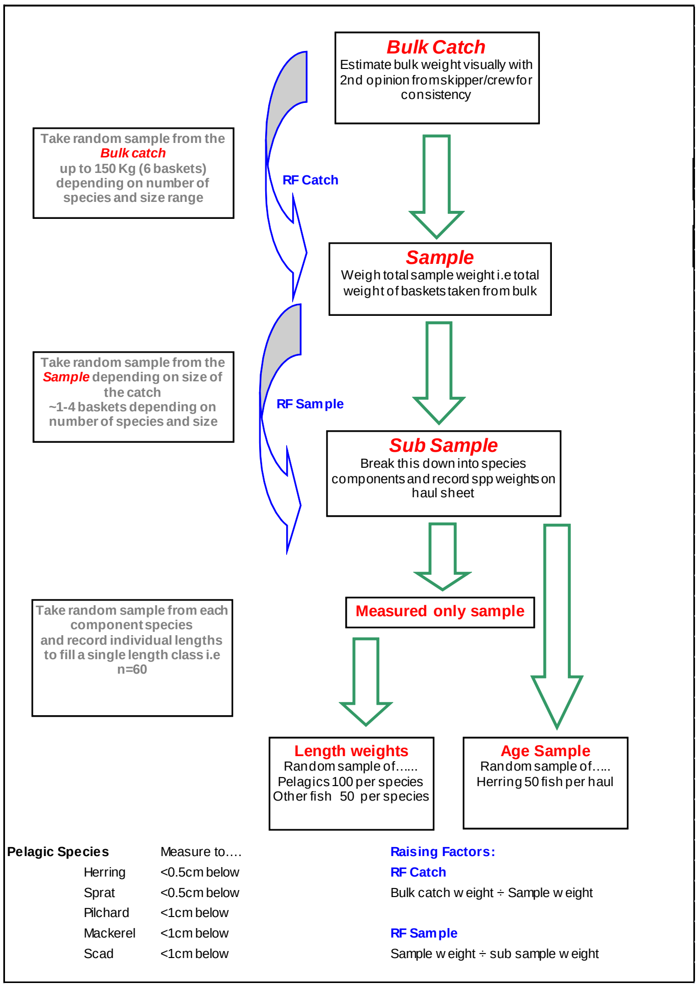


Figure 2.2.2.5.1.2. Sampling protocol employed during the CSHAS Hydrographic.

Hydrographic sampling should be carried following predetermined stations following established layout for this survey area (Sea-bird 911 sampler equipped with a full sensor suite). Sensors are calibrated annually by the manufacturer and this information is available through the ship. Water samples are not routinely taken during the survey.

Fall-back options

In instances where biological samples are deemed insufficient then a system is in place to collect additional samples from the commercial fishery from vessels working in the area within the same time frame.

For acoustic data collection the RV 'Celtic Explorer' carries spare GPT's and transducer (38 kHz) as well as the associated cabling to allow for at-sea repairs/replacement. As the transducers are positioned on a drop keel at-sea access is available. Due to the vessels size (~65m) and the depth of the transducers (drop keel at c. 9 m) instances where weather disrupts data collection are rare in the Celtic Sea.

2.2.2.6 Data analysis

2.2.2.6.1 Scrutinisation protocol

Acoustic data should be backed up every 24 hours and scrutinised using Echoview® (V 5) post-processing software or later versions. A standardized Echoview template has been established with the allocation categories included and is available on board. Partitioning of data into the categories shown below is largely a subjective process back up with trawl data and so it is vital that an experienced scientist who has experience of this survey and area undertake the scrutinisation of echograms.

The NASC (Nautical Area Scattering Coefficient) values from each herring/sprat/pilchard region are allocated to one of four categories after inspection of the echograms. Categories identified on the basis of trace recognition were as follows:

1) "Definitely herring" echotraces or traces were identified on the basis of captures of herring from the fishing trawls which had sampled the echotraces directly, and on large marks which had the characteristics of "definite" herring traces (i.e. very high intensity (red), narrow inverted tear-shaped marks either directly on the bottom or in midwater and in the case of spawning shoals very dense aggregations in close proximity to the seabed).

2) "Probably herring" were attributed to smaller echotraces that had not been fished but which had the characteristic of "definite" herring traces.

3) "Herring in a mixture" were attributed to NASC values arising from all fish traces in which herring were thought to be contained, owing to the presence of a proportion of herring within the nearest trawl haul or within a haul that had been carried out on similar echotraces in similar water depths.

4) "Possibly herring" were attributed to small echotraces outside areas where fishing was carried out, but which had the characteristics of definite herring traces.

The RAW EK 60 data files are imported into Echoview for post-processing. The echograms were divided into transects using annotations as recorded during logging. Echotraces belonging to one of the four categories above were identified visually and echo integration was performed on the enclosed regions. The echograms were analysed at a threshold of -70 dB and where necessary plankton can be filtered out by thresholding to –65 dB.

2.2.2.6.2 Abundance estimation

The recordings of area backscattering strength (NASC) per nautical mile are averaged over a one nautical mile EDSU (elementary distance sampling unit), and the allocation of NASC values to mark category for each target species is based on the composition of the trawl catches and the appearance of the echotraces. NASC values are assigned according to scrutinisation methods (Section 2.2.3.4) and are used to estimate the target species numbers according to the method of Dalen and Nakken, (1983). Note that interconnecting inshore and offshore inter-transects are not included in the analysis. Total estimates and age and maturity breakdowns are calculated.

Coefficient of variation is estimated assuming that transects are equally spatially distributed within a stratum and that they are statistically independent. Biomass is calculated from numbers using length-weight relationships determined from the trawl samples taken during the survey for each of the analysis areas.

To estimate the abundance, the allocated NASC values are averaged by survey strata. For each stratum, the unit area density of fish (SA) in number per square nautical mile ($N*nmi^{-2}$) is calculated using standard equations (Foote *et al.*, 1987; Toresen *et al.*, 1998).

The calculation of biomass and abundance from survey data has been scripted in R as an in-house developed package to standardize the processing of survey data. The R script is open source and available on request.

2.2.2.7 Reporting

The survey report should follow the existing cruise report format as provided: http://oar.marine.ie/handle/10793/920

2.2.2.8 Caveats

Known limitations specific to this survey are centred on poor weather and the effect of poor weather on fish behaviour. In poor weather herring shoals tend to break up and disperse often carpeting the bottom. This leads to a twofold problem, the first being the ability to acoustically see the targets within the ADZ (acoustic dead zone) and the second relates to being able to affectively sample echotraces using a trawl when the fish are dispersed by poor weather. As the survey is fixed in time and ship time is booked well in advance an annual snapshot of abundance can be adversely affected by poor weather conditions. In periods of prolonged poor weather, the precision of the survey is thus reduced. Also as the fishery is underway at the same time as the survey herring shoals are often broken up and disturbed due to the amount of fishing activity going on in areas of high abundance.

For sprat, the timing of the survey is considered a limitation on the precision. Sprat are still feeding when the survey is undertaken and are therefore generally dispersed in mixed species feeding layers and not as ideally suited to acoustic sampling as aggregated schools. Post survey and after the autumnal plankton bloom is when the mature sprat aggregate and move into deeper waters to overwinter. A dedicated sprat survey at this time would be able to provide a more representative estimate of sprat abundance. As a result, estimates of sprat abundance as determined from the CSHAS should be treated with a degree of caution.

For pilchard and anchovy, occasional high-density echotraces are observed but again timing is an issue and generally, schools are dispersed in mixed species feeding layers. As a result, annual reporting of abundance for these species would not be representative of the stocks present within the Celtic Sea.

2.2.3 Boarfish acoustic survey (BFAS)

2.2.3.1 Background

The BFAS was first carried out as a pilot survey in 2011 and has continued annually using a commercial charter vessel. The survey is used to determine the distribution of abundance of spawning aggregations of boarfish within the core spawning areas to the west of Ireland and the Celtic Sea (Figure 2.2.3.1.1). Survey results are submitted annually to WGWIDE as age disaggregated data and used as a tuning index for the stock. The survey is carried out over 21 days in early July and is timed to coincide with the Malin shelf (RV 'Celtic Explorer') herring survey (see Section 2.1.4). Data from both surveys are complied to produce the estimate of abundance.

From the early 1970s, the abundance of boarfish (*Capros aper*) was seen to increase exponentially and distribution spread increasingly northwards along the western seaboard and Bay of Biscay (Blanchard and Vandermeirsch, 2005). At the same time, boarfish were caught in increasing quantities in both pelagic and demersal fisheries. This in turn resulted in damage to more commercially valuable target species. Exploratory fishing for boarfish by Irish vessels began in the later 1980s when commercial quantities were encountered during the spring horse mackerel (*Trachurus trachurus*) and mackerel (*Scrombrus scomber*) fishery in northern Biscay. During the early 2000s the Irish landings were relatively small (<700 t per year) and it was not until 2006 that a directed fishery developed prompted by increasing abundance of boarfish. Fishing was undertaken primarily by vessels from the Castletownbere and Killybegs based RSW fleets (refrigerated seawater vessels), which targeted boarfish from northern Biscay to the southern Celtic Sea. In 2007–2008, vessels from Scotland and Denmark also began targeting boarfish in quantity. Irish landings are primarily landed into fishmeal plants in Denmark and the Faroe Islands with increasing amounts being landed in Killybegs in recent years.

A precautionary interim management plan was adopted in November 2010 covering ICES Divisions VI, VII and VIII. Landings in 2010 reached over 137 000 t prior to the introduction of TAC control. In addition to the TAC, seasonal closures were implemented; from 1 September – 31 October (Division VIIg) to protect herring feeding and prespawning aggregations and from 15 March – 31 August where mackerel are frequently encountered as a large bycatch. A catch rule ceiling of 5% bycatch was also implemented within the fishery where boarfish are taken with other TAC controlled species. In 2013, the EU TAC was set at 82 000 t with an Irish allocation of 56 666 t, a roll over from 2012.

The survey cruise report for 2013 is available at: http://oar.marine.ie/handle/10793/822

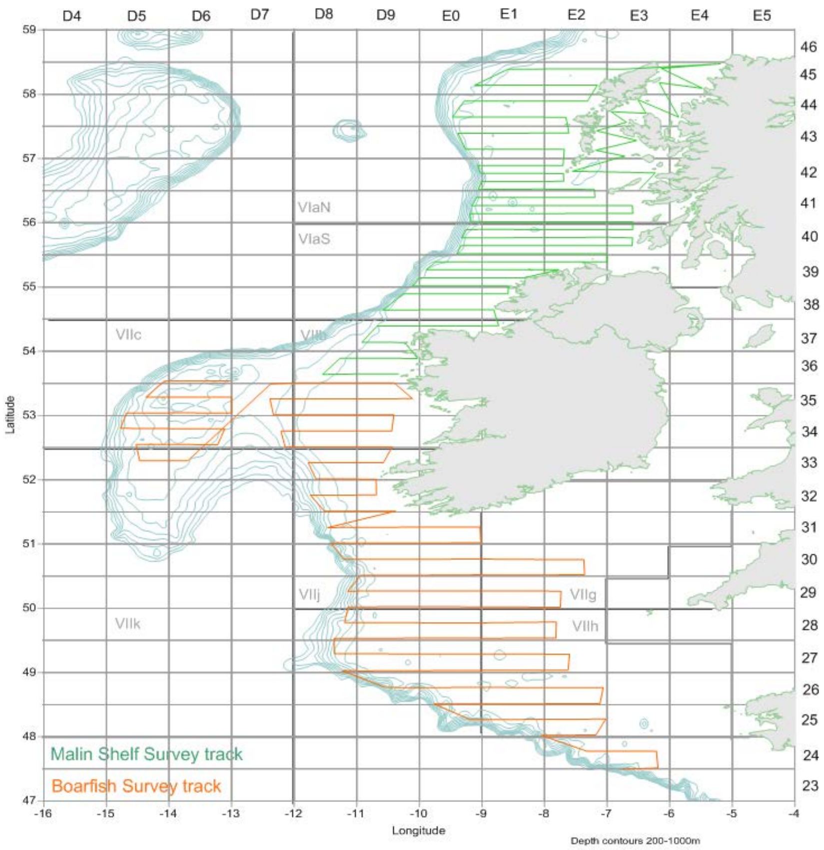


Figure 2.2.3.1.1. Composite of area coverage during the BFAS survey.

2.2.3.2 Survey time-series

The first survey was carried out in 2011 as a pilot survey and was conducted over 24 hours. For the second and subsequent surveys, a daylight operating protocol was adopted to account for diel changes in behaviour and thus availability to the acoustic equipment. As a result, surveys conducted in 2012–2013 are used in the assessment.

Due to the absence of a species-specific TS-Length relationship for boarfish a modelled TS was applied to the time-series in 2013 (Fässler *et al.*, 2012).

The current survey time-series is presented in Table 2.2.3.2.1.

Table 2.2.3.2.1. BFAS survey time-series. Abundance in millions, biomass in 000's tonnes. Age in years.

Age (Yrs)	2011	2012	2013
0	-	-	-
1	4.9	21.5	-
2	11.3	10.8	78.0
3	54.2	174.1	1,842.9
4	176.0	64.8	696.4
5	404.7	95.0	381.6
6	1,068.0	736.1	253.8
7	1,052.0	973.8	1,056.6
8	632.5	758.9	879.4
9	946.1	848.6	800.9
10	831.8	955.9	703.8
11	259.7	650.9	263.7
12	457.2	1,099.7	202.9
13	281.7	857.2	296.6
14	257.2	655.8	169.8
15+	1,746.0	6,353.7	1,464.3
TSN (mil)	8,183	14,257	9,091
TSB ('000t)	456,115	863,446	439,890
SSB ('000t)	455,375	861,544	423,158
CV	17.5	10.6	17.5

2.2.3.3 Survey objectives

The primary survey objectives of the survey are listed below:

- Collect integrated and calibrated acoustic data on boarfish (*Capros aper*) aggregations within the predetermined survey area
- Determine the biomass and abundance of boarfish within the survey area
- Collect biological samples from directed trawling on insonified echotraces to determine age structure and maturity state of survey stock as well as to identify echotrace to species.
- Determine the extent and behaviour of boarfish aggregations within the survey area to aid the design of future surveys
- Dovetail with the RV 'Celtic Explorer' in the northern area to ensure close spatio-temporal alignment and synoptic coverage

2.2.3.4 Survey design and area coverage

One survey per year is carried out. The survey should begin in the Porcupine Bank with enough time allowed so that close temporal alignment is achieved with the RV Celtic Explorer arriving from the north. Therefore, consultation during the planning phase for both surveys is required. A time allowance for vessels to conduct an acoustic and fishing inter-calibration exercise should also be included at the planning stage. The survey should be carried out from north to south to ensure consistency with previous surveys.

Transect spacing is set at 15 nmi for the main body of the survey and 7.5 or 15 nmi for the peripheral areas covered by the Malin shelf survey. The survey is to be carried out from 04:00–00:00 each day (both surveys) to coincide with the hours of daylight when boarfish are most often observed in homogenous schools. During the hours of darkness boarfish schools tend to disperse into mixed species scattering layers.

The survey covers in the order of 57 000 nmi^2 annually using a total of c.4 000 nmi of track. Coverage should cover coastal waters from the c.50m contour to the shelf slope (350 m). An elementary distance sampling unit (EDSU) of 1nmi is used. The PSU (primary sampling unit) is represented by ICES statistical rectangle. For the area covered by the RV Celtic Explorer only strata (rectangles) bordering the shelf edge are considered during the analysis as boarfish are only found at the shelf edge in northern waters.

2.2.3.5 Data collection

2.2.3.5.1 Acoustic

If available then the ships in-situ transducers should be calibrated using standardized methods described. If not available then the tow body system should be deployed and calibrated. The tow body contains a Simrad ES-38B (38 KHz) split-beam transducer and is operated using a portable EK 60 scientific echosounder topside unit. Once deployed on the towing boom using the existing set rigging configuration short sea trials will determine the length of the towing strop. The towing strop needs to be adjusted so that a working depth of 3–3.5 m for the transducer is achieved.

Cruising speed will largely be determined by the weather and the effect on the quality of acoustic data. Where possible cruising speed should be maintained at 10 kts.

EK 60 set up during the survey follows a standard protocol as outlined in the EK 60 user manual. The current (2013) operating version of the software is V2.4.3 and it is advised that latest software release should be installed when available. Settings during the survey are as outlined in the table below.

Environment details (temperature and salinity) are taken from a CTD cast taken in open water or exposed bays in the survey area and not from enclosed bodies such as sheltered bays. A portable CTD unit should be used to determine hydrographic conditions when using a commercial vessel.

At the survey start the vessel log (GPS distance) should be reset to ‘zero’ to ensure consistency in log output files. If the systems crashes a reset of the vessel log should be calculated to closely match that of the last valid output file. All off track incidents and transect start/endpoints are recorded as text annotations in the sounder screen using the annotation feature as well in paper form (Time, position, lat, long, log number). Acoustic settings employed during the survey are listed in Table 2.2.3.5.1.1

Table 2.2.3.5.1.1. Echosounder settings employed during the BFAS.

ECHOSOUNDER	SIMRAD EK 60
Installation	Tow body
Frequency (kHz)	38
Primary Transducer	ES 38B
Pulse length (ms)	1024
Power (W)	2000
Ping rate	Max

2.2.3.5.2 Biological sampling

The pelagic trawl operated during the survey is provided by the charter vessel and is rigged and fished as would be during commercial operations. It is therefore important to get a copy of the trawl plan and rigging detail. However, it is advised before publishing the net plan in the survey report that the scientist in charge check with the skipper that they have permission to do so.

Regardless of the trawl dimension, a 20 mm codend liner will be fitted prior to the survey to ensure the retention of small and juvenile fish. Trawl monitoring, trawl door type and dimensions should be confirmed with the skipper. No fixed trawl duration is employed during the survey. The emphasis is on taking a representative sample of the targeted echotrace. In practice, trawl duration of 30 minutes (active fishing) is sufficient to do this. The chief scientist has to then determine whether the sample is composed of the targeted echotrace.

Biological sampling is used to verify the composition of echotraces during echo integration. Decisions to fish on particular echotraces are largely subjective and an attempt should be made to target echotraces low density scattering layers not just high density shoals. No bottom-trawl gear is used during this survey. However, the dexterity of the skipper in using the gear will allow for samples to be taken close to the bottom to be taken over clean ground. However, on a commercial charter the decision to fish at or near the bottom is at the skippers' discretion.

All components of the catch from the trawl hauls are to be sorted and weighed; fish and other taxa are identified to species level. Fish samples are divided into species composition by weight. Species other than the boarfish are weighed as a component of the catch. Length frequency and length weight data are collected for each component of the catch. Length measurements of boarfish, herring, sprat and pilchard are taken to the nearest 0.5cm below. Age, length, weight, sex and maturity data are to be recorded for individual boarfish within a random 50 fish sample from each trawl haul, where possible. The appropriate raising factors should be calculated and applied to provide length frequency compositions for the bulk of each haul. Sampling protocol is outlined in Figure 2.2.3.5.2.1.

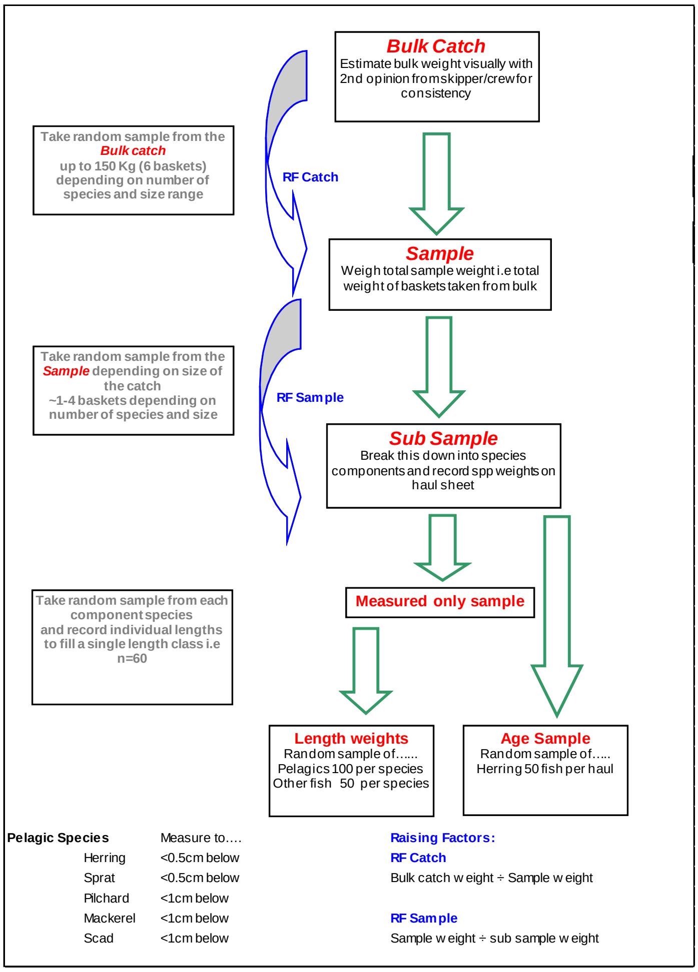


Figure 2.2.3.5.2.1. Sampling protocol employed during the BFAS.

Trawl haul validation (net performance) is to be determined by the chief scientist by inspecting the measurements of the net during deployment from the net monitoring equipment. In cases where the net was not deemed to be operating or fishing correctly then the biological sample should be rejected.

In case where the target echotrace was not caught or missed then this should also be rejected from the analysis.

A minimum sample size of 50 fish for boarfish is deemed a valid sample for inclusion into the analysis. In instances where biological samples are deemed insufficient then a system is in place to collect additional samples from the commercial fishery that is underway in the same locale during the same time period as the survey.

2.2.3.5.3 Fall-back options

In instances where biological samples are deemed insufficient then samples from the fishery can be used to fill in gaps. It should be noted that as the survey takes place during a period in which the fishery is closed and so the use of commercial L/Wt/A/M data from the fishery from the same geographical are must be carefully considered and communicated in the cruise report.

For acoustic data collection as the tow body is particularly susceptible to data degradation due to poor all attempts should be made, where possible, to calibrate and use the *in-situ* ships transducer (ES-38B) for the collection of survey data.

2.2.3.6 Data analysis

2.2.3.6.1 Scrutinisation protocol

Acoustic data should be backed up every 24 hrs and scrutinised using Echoview® (V 5) post-processing software or later versions. A standardized Echoview template has been established with the allocation categories included and is available on board. Partitioning of data into the categories shown below is largely a subjective process back up with trawl data and so it is vital that an experienced scientist who has experience of this survey and area undertake the scrutinisation of echograms.

The NASC (Nautical Area Scattering Coefficient) values from each boarfish/horse mackerel/herring/blue whiting/pilchard region are allocated to one of four categories after inspection of the echograms. Categories identified based on trace recognition were as follows:

1) "Definitely boarfish" echotraces were identified on the basis of captures of boarfish from the fishing trawls which were sampled directly. Based on the directly sampled schools we also characterized echotrace as definitely boarfish which appeared very similar on the echogram i.e. large marks which showed as very high intensity (red), located high in the water column (day) and as strong circular schools.
2) "Probably boarfish" were attributed to smaller echotraces that had not been fished but which had similar characteristics to "definite" boarfish traces.
3) "Boarfish in a mixture" were attributed to NASC values arising from all fish traces in which boarfish were contained, based on the presence of a proportion of boarfish in the catch or within the nearest trawl haul. Boarfish were often taken during trawling in mixed species layers during the hours of darkness.
4) "Possibly boarfish" were attributed to small echotraces outside areas where fishing was carried out, but which had the characteristics of definite boarfish traces.

This set of categories allowed us to present the biomass estimates in terms of the best estimate (Cats 1–3), the minimum estimate (Cat 1 + 3), and the maximum estimate (Cats 1–4).

Echograms were divided into transects and off track events, including trawl hauls and hydrographic stations were excluded. Echo integration was performed on regions that were defined by enclosing selected parts of the echogram that corresponded to one of the four categories above. The echograms were generally analysed and echo integrals calculated, at a threshold of -70 dB, where necessary heavy backscatter from plankton was filtered out by thresholding at –65 dB.

2.2.3.6.2 Abundance estimation

The recordings of area backscattering strength (NASC) per nautical mile are averaged over a one nautical mile EDSU (elementary distance sampling unit), and the allocation of NASC values to mark category for each target species is based on the composition of the trawl catches and the appearance of the echotraces. NASC values are assigned according to scrutinisation methods (Section 2.2.3.4) and are used to estimate the target species numbers according to the method of Dalen and Nakken, (1983). Note that interconnecting inshore and offshore inter-transects are not included in the analysis. Total estimates and age and maturity breakdowns are calculated.

Coefficient of variation is estimated assuming that transects are equally spatially distributed within a stratum and that they are statistically independent. Biomass is calculated from numbers using length-weight relationships determined from the trawl samples taken during the survey for each of the analysis areas.

To estimate the abundance, the allocated NASC values are averaged by survey strata. For each stratum, the unit area density of fish (SA) in number per square nautical mile (N^*nmi^{-2}) is calculated using standard equations (Foote *et al.*, 1987, Toresen *et al.*, 1998).

The calculation of biomass and abundance from survey data has been scripted in R as an in-house developed package to standardize the processing of survey data. The R script is open source and available on request.

2.2.3.7 Reporting

The survey report should follow the existing cruise report format as provided: http://oar.marine.ie/handle/10793/822

2.2.3.8 Caveats

Boarfish, traditionally a warmer water species that has in recent years moved northwards spawns when water temperatures reach 12ºC and higher. Typically, peak spawning occurs around Ireland in July and the survey was originally timed to coincide with this. When conditions and temperature allow spawning will continue throughout the summer and is interspersed with feeding. The survey is timed to coincide with peak spawning and thus when boarfish are aggregated for spawning. If conditions are not optimum for spawning then boarfish revert back to feeding behaviour. When feeding, boarfish are generally dispersed and well spread out, as is often observed at night. Schooling during feeding periods does occur but the timing and/or diel drivers are not known. This therefore introduces an element of uncertainty into the survey.

2.2.4 Pelagic ecosystem survey in the Western Channel and eastern Celtic Sea (PELTIC)

2.2.4.1 Background

The PELTIC survey is an annual survey which focuses on the distribution, abundance and age structure of small pelagic fish species in ICES Divisions VIIe-f (Figure 2.2.4.1.1), predominantly sprat, sardine, mackerel and anchovy. Of equal importance is the aim to improve the understanding of the role of these mid-trophic species in the pelagic ecosystem by simultaneously sampling the multiple trophic levels and the physical oceanography. The survey is carried out over ~18 days in October on board the RV 'Cefas Endeavour'. Starting in 2012 five autumn surveys are scheduled to take place.

Several small pelagic fish species are found off Southwest England: sprat, sardine, anchovy, horse mackerel and herring. Particularly sprat, sardine and horse mackerel are targeted by locally important fisheries which are thought to operate sustainably. However, most of these stocks are data limited (ICES, 2013). Recently these fisheries have started to catch anchovy opportunistically which have appeared in relatively large numbers in some years. Evidence has emerged that this northern anchovy is likely to be a separate population from those in the Bay of Biscay (Petitgas *et al.*, 2012; Zarraonaindia *et al.*, 2009, 2012). This area is also an important nursery for mackerel and, in consequence, it has been closed to mackerel directed trawling activities since the 1990s to avoid bycatch of juvenile mackerel. Large-scale changes in mackerel behaviour and distribution elsewhere have emphasized the lack of knowledge and it is not known what current role the area plays in the mackerel life cycle.

Contributing to its relatively rich pelagic diversity is the fact that the area includes the boundary between the warmer Lusitanian waters in the south and cooler boreal waters in the north. It can be considered a transition zone where large-scale environmental or climatic variability may influence the latitudinal position of the boundary and therefore also the species composition. There is for example evidence that the boreal herring dominates this transition region during colder periods, and sardine during warmer periods (Southward *et al.*, 1988). Since the mid-nineties both anchovy and sardine have apparently increased in the north, a feature that has been linked to climate variability (Beare *et al.*, 2004; Petitgas *et al.*, 2012; Alheit *et al.*, 2012). This increase in these mid-trophic species has been linked to associated effects in higher trophic levels, leading to for example range expansion of the critically endangered Balearic shearwater (Wynn *et al.*, 2007, Luczak *et al.*, 2011).

However, a lack of fisheries independent data means that there is very little information on the productivity of this region of the UK's seas, its contribution to the ecosystem and more widely distributed stocks.

The PELTIC survey is funded by the UK government and currently not part of the European data collection framework. However, the biomass and distribution of the small pelagic fish community, particularly sprat, pilchard, anchovy and mackerel are reported to different ICES working groups. Equally important are the concurrently collected data on zoo-and ichtyoplankton, hydrography and marine mammals and seabirds. Combined they provide an opportunity to study the ecological mechanisms which operate in this ecosystem. At the time of writing only two autumn survey have been conducted and many of the methods are still being fine-tuned. Here the current best practise methods are presented.

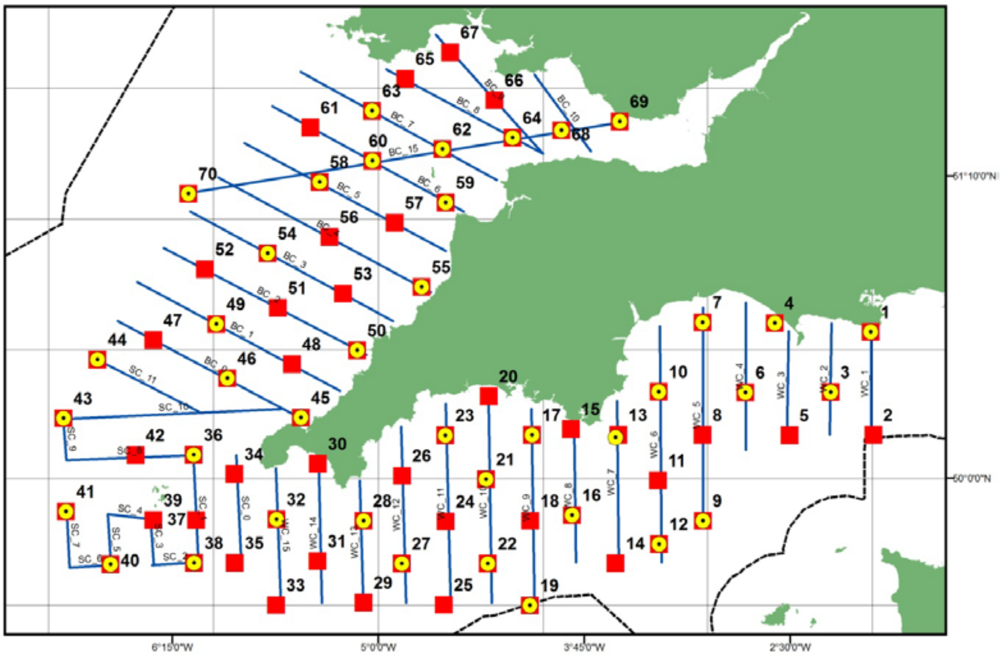


Figure 2.2.4.1.1. Survey design including transects (blue), zooplankton (red squares) and hydrographic stations (yellow circles).

2.2.4.2 Survey time-series

The PELTIC survey series started in its current form in October 2012 and in total five annual surveys have been scheduled as part of a UK government funded project Poseidon (DEFRA, MF1112). An additional one-off summer survey was conducted in May-June 2011 using similar methods although it covered the whole Celtic Sea shelf area and followed larger inter-transect distances. The timing of autumn survey series has varied by about two weeks so far, due to variations within the research vessel survey schedule. However, preliminary results are suggesting that the timing relative to the autumn bloom has a more significant effect on the ecosystem and therefore the survey results. Survey results have to therefore be studied in light of the timing of this event, as was found also previously in relation to spring bloom events (Greenstreet *et al.*, 2006).

2.2.4.3 Survey objectives

The survey objectives are listed below:

- Carry out a predetermined survey track
- Determine distribution and relative abundance of the key small pelagic fish species in the survey area (ICES Divisions VIIe, VIIf and parts of VIIg). Species of particular interest are sprat, sardine, anchovy, mackerel and horse mackerel.
- Collect biological samples from directed trawling on insonified fish echotraces to validate species and size composition of acoustic marks, and to collect biological samples for age determination, maturity state and diets (stomachs) of the small pelagic fish
- Sample zoo-and ichtyoplankton communities (vertical casts) using two ringnets (80 and 270 μm) to establish the species and length composition of zooplankton, as well as the spawning area and intensity of sardine respectively.
- Collect physical oceanographic data from vertical profiles using a deployed sensor array.
- Survey by visual observations marine mammal and seabird abundance and distribution (ESAS-European Seabirds At Sea methodology)
- Collect continuous surface oceanography data using ferrybox sampler.
- Collect water samples for nutrient and TA/DIC analysis in support of a programme on ocean acidification
- Sighting survey for marine surface litter.

2.2.4.4 Survey design and area coverage

One survey per year is carried out. The timing of the survey coincides with the start of the sprat fishery (when the population is thought to be aggregated in the western Channel), the autumn spawning peak of sardine (pilchard) and the arrival of anchovy in the western Channel. A predetermined cruise track is used during the PELTIC based on regularly spaced transects and which provide the survey abundance index. The survey follows a systematic parallel transect design with transects running perpendicular to the coastline or bathymetry.

Three main areas are identified in the survey: The first is the western English Channel, which is carried out with highest priority as most of the small pelagic fish biomass, and diversity is found here. It is also most important for local inshore fisheries. The second component comprises an area around the Isles of Scilly, the surveying of which, due to its exposed nature is sometimes compromised. The third component is he “Bristol Channel” and covers the area east of the southwestern point of Cornwall. These separate components are considered based on geographic position and some prior knowledge of the small pelagic fish communities, as obtained during preceding bottom-trawl surveys and (historic) landing data. As the time-series continues to collect data, strata will be adapted to reflect communities and or meso scale ecoregions. Within the three components ICES statistical rectangles are used as summary strata until more ecologically meaningful areas are identified. The survey design needs to adhere to principles outline in Simmonds and MacLennan, (2005). Acoustic data are collected using an EDSU (elementary distance sampling unit) of 1 nmi.

After removing the off-transect data a total of 1 500 nmi of acoustic sampling units are collected for species abundance analysis. During the first two years, 2012 and 2013, a 24-hour surveying regime was maintained: independent of daylight, transects were run at fixed speed until one of the primary (i.e. zooplankton or hydrographic) or opportunistic (trawl) stations were reached. High densities of static gear in some inshore areas require coverage in daylight, which means that at times, inshore parts of adjacent transects are covered first after which the offshore parts are completed. However, care has to be taken that both inshore and offshore parts of the transects are covered evenly in day-or nighttime. The reason is that some of the target species may display diurnal behaviour, which affects the acoustic energy recorded. Consistently sampling the inshore parts during daylight would bias the results when it comes to the spatial distribution of the various populations.

2.2.4.5 Data collection

Acoustic

Acoustic data are collected using a Simrad EK60 scientific echosounder. Split-beam transducers are mounted on the vessel’s drop keel and lowered to the working depth of 3.2 m below the vessel’s hull or 8.2 m sub surface. Three operating frequencies are used during the survey (38, 120 and 200 kHz) for trace recognition purposes, with 38 kHz data used to generate the abundance estimate for clupeids (and other fish with swimbladder) and 200kHz for mackerel (Table 2.2.4.5.1). All frequencies are calibrated at the start of the survey.

EK 60 set up during the survey follows a standard protocol as outlined in the EK 60 user manual. The most recent available software release is installed at the start of the survey. Settings during the survey are as outlined in the table below. During the first day of surveying, and subsequently when conditions change significantly, environmental variables, temperature and salinity, are taken from available CTD casts and uploaded in the EK60 software.

At all times the EK60 display and a live data stream in the processing software (Myriax Echoview) are monitored. Other than, the start and end times and locations of transect and stations, observations on biological echotraces, as well as non-biological marks caused by for example ship wash, are recorded.

Although bad weather or large oceanic swells at times cause the occasional empty pings or surface aeration, generally little time is lost in acoustic data acquisition due to the depth of the dropkeel mounted transducer.

Table 2.2.4.5.1. Echosounder settings employed during the CSHAS.

ECHOSOUNDER	SIMRAD EK 60		
Installation	Drop keel		
Frequency (kHz)	38	120	200
Primary Transducer	ES 38B	ES 120-7C	ES 200-7C
Pulse length (ms)	512	512	512
Power (W)	2000	250	110
Ping rate	0.6	0.6	0.6

Biological sampling

Biological sampling is used to verify the species- and length-composition of echotraces during echo integration. Decisions to fish on particular echotraces are largely subjective and it is generally attempted to target a variety of echotraces ranging from low-density scattering layers to high-density shoals. When targeting smaller schools, the trawl is only deployed when a series of smaller schools are present for about 2 nmi, to increase the chances of catching the marks. No bottom-trawl gear is used during this survey due to the large numbers of demersal species present in the study area. However, the relatively small size of the midwater gear used and its manoeuvrability in relation to the vessel power allows samples at about 1–2m from the bottom to be taken over clean ground.

Biological sampling is carried out using a single pelagic midwater trawl with a vertical opening of c. 12m. Trawl metrics are monitored using a Marport 50kHz cable-less net sonde and SCANMAR net monitoring sensors.

Since 2013, the standardized pelagic trawl operated during this survey is based on a single vessel single pelagic midwater trawl as also used by the Marine Institute during the Celtic Sea herring survey (Figure 2.2.4.5.1.1).

The trawl has been modified to work on a larger vessel such as the RV Cefas Endeavour and fitted with a 20mm codend liner to ensure the retention of small and juvenile fish. Trawl monitoring, trawl door type and dimensions and rigging are provided in Table 2.2.4.5.2. No fixed trawl duration is employed during the survey, as the primary aim is to take a representative sample of the targeted echotrace. Although previously several attempts were made when a trace was missed at the first attempt, this rarely proved successful and in future surveys, a single attempt will be made only. In practice, trawl duration of 30 minutes (active fishing) is sufficient to do this.

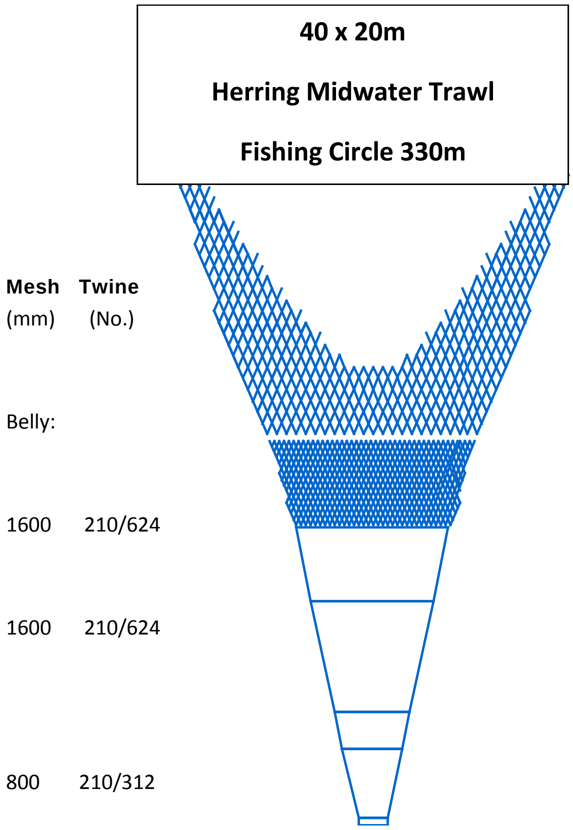


Figure 2.2.4.5.1.1. Single herring midwater trawl plan as used on the PELTIC. Note: All mesh sizes given in half meshes; schematic does not include 32 m brailer.

Table 2.2.4.5.2 Single herring midwater trawl metrics as routinely used during the PELTIC survey.

Towing speed	c. 3.5 Kts
Headline opening	~11m
Door spread	75 m
Warp: depth ratio	c.3:1
Trawl doors	Morgere SPFTH 20.5 Pelagic V doors
Size	6.3m²
Weight	1200 Kg
Clump weights	500 Kg per side
Bridles	65 m (20mm wire rope)
Net monitoring system	SCANMAR Distance sensors (Trawl doors)
	SCANMAR Catch sensor
	50 kHz Marport Headline transducer (cable-less link)
	SCANMAR Trawleye widebeam, (acoustic link)

All components of the catch from the trawl hauls are sorted and weighed; fish and other taxa are identified to species level. Fish samples are divided into species composition by weight. Length frequency and length weight data are collected for all species of the catch. Length measurements of sprat, pilchard, anchovy and herring are to be taken to the nearest 0.5 cm below, mackerel and horse mackerel are measured to the whole cm below total length. Where possible the total catch component of the haul per species is measured, however when this is impossible, a suitable sub sample will be taken that offers a true (length) representation of the species.

Any sub samples are clearly labelled. Trawl haul validation (net performance) is to be determined by the chief scientist by inspecting the measurements of the net during deployment from the net monitoring equipment (Table 2.2.4.5.1). In cases where the net was not deemed to be operating or fishing correctly, then the biological sample should be rejected for inclusion in the target identification.

In case where the target echotrace was not caught or missed then this should also be rejected from the analysis.

For the six key species; pilchard, anchovy, sprat, herring, mackerel and horse mackerel 10 specimens per length class per station are sampled. This is increased to 20 per length sample for Anchovy. These six species will have otolith, sex and maturity and stomach samples collected from them. This number may be reduced when sufficient samples have been collected from a similar area. Other fish species are sorted weighed and measured but will not have any further biological sampling carried out upon them. All pilchard, anchovy, sprat, herring, mackerel and horse mackerel are to be aged on board if possible.

Zooplankton

The various planktonic size components are sampled at ~70 fixed plankton stations along-transects using two ringnets of different mesh: 270 µm (ichtyoplankton and macro-zooplankton) and 80 µm (zooplankton), which are fixed to a frame to enable simultaneous deployment. Both nets contain flowmeters (General Oceanics mechanical flowmeters with standard rotor, model 2030R) mounted in the centre of the aperture of the net and a mini-CTD (SAIV) is attached to the bridle. At each zooplankton station, a water sample is taken at the surface and fixed on lugol for phytoplankton analysis back in the lab and at a subset of stations; another water sample was collected for future microzooplankton analysis.

Ichtyoplankton samples are processed on board to provide in situ information on spawning locations of particularly sardine. Zooplankton samples are processed back in the lab using a zooscan to determine size distribution, and a subset is analysed taxonomically.

Hydrographic

Hydrographic sampling is carried out by in situ measurements using CTDs and a ferrybox, and via remote sensing.

Vertical casts with an ESM2 logger at 46 regularly spaced stations along the acoustic transects provide data on the properties of the water column including temperature, salinity, fluorescence, optical backscatter, dissolved oxygen and Photo-synthetically Available Radiation, PAR. The Rosette water sampler (equipped with a FSI CTD) is used for collection of water samples at discrete depths at a sub section of sampling stations based on a combination of local conditions encountered during the deployment of the instruments and available satellite derived temperature and chlorophyll maps. Additional temperature profiles are obtained from a SAIV mini CTD attached to the plankton ringnets (see above). PAR profiles are analysed to calculate the vertical light attenuation coefficient (Kd) and the depth of the photic zone. Information on the light penetration through the water column is also derived from Secchi disk depth measurements. Samples for calibration of instruments and additional parameters were analysed back at the lab.

A Ferrybox provides continuous measurements of different environmental variables at the surface (4 m depth) including temperature, salinity, fluorescence, dissolved oxygen.

Daily satellite derived maps of chlorophyll concentration, sea surface temperature and frontal systems are monitored. Maps of frontal systems are downloaded from Neodaas (www.neodaas.ac.uk) while composite sea surface temperature and chlorophyll maps were prepared by land-based staff using ArcGIS and data available from My Ocean (www.myocean.eu.org).

2.2.4.6 Scrutinisation protocol

Raw acoustic data are backed up every 24 hours and copied to a processing computer. Myriax Echoview® (most recent version) software is used to create relevant post-processing files. A batch of transects is loaded in an existing Echoview template, and (seabed and surface) exclusion lines are drawn and checked for errors. The Echoview processing template uses typical multifrequency response properties to separate four different echo-types: fish with a swimbladder, jellyfish and juvenile fish, fish without swimbladder and fluid-like zooplankton (sensu Ballon *et al.*, 2011). For each Echoview processing file a duplicate processing file is created which contains a different algorithm specifically designed to extract mackerel. Details on the detection algorithm are described elsewhere (van der Kooij *et al.*, 2014 sensu Korneliussen, 2010).

The swimbladder-fish component is then further scrutinized and partitioned into species and where possible size categories. This is largely a subjective process backed up with trawl data and so it is vital that an experienced scientist who has experience of this survey and area undertake the scrutinisation of echograms.

Within every on-transect 1 nmi EDSU (elementary distance sampling unit), the NASC (Nautical Area Scattering Coefficient) values for the swimbladder-fish echogram are allocated to one of the below categories after inspection of the echograms. Categories can be adapted according to echotraces encountered:

1) Echoes in the bottom 5–10 m of the water column consisting of loosely aggregated gadoids and clupeids in mixture.
2) Dense schools in midwater consisting of single species as confirmed by trawl: sprat, anchovy, sardine or horse mackerel.
3) Diffuse Unidentified Scattering Targets (DUST) in mid water, often containing fish. This is particularly apparent at night but also during day in particularly the offshore areas of the western Channel. Trawl haul is used to partition the backscatter.
4) Probable sardine schools: ground-truth trawl not available, but acoustic features match those of sardine from adjacent areas and sardine eggs were recorded in nearby plankton stations.
5) Probable horse mackerel or boarfish schools – apparent in deeper waters and occur near the seabed, in midwater or high up in the watercolumn, no trawl data of specific school available.
6) Residual remove: remnant scatterings that were not entirely removed using the echotrace algorithm and particularly involved very dense layers of the

jellyfish and juvenile fish category. High densities may be due to resonance of air bubbles in these layers and plankton samples at these sites contained ctenophores or siphonophores.

A final category was derived from the separate mackerel processing files based on 200 kHz echogram:

7) Mackerel

2.2.4.7 Abundance estimation

The recordings of area backscattering strength (NASC) per nautical mile are averaged over a one nautical mile EDSU, and the allocation of NASC values to mark category for each target species is based on the composition of the trawl catches and the appearance of the echotraces. NASC values are assigned according to scrutinisation methods (6.2) and are used to estimate the target species numbers according to the method of Dalen and Nakken (1983). Note that interconnecting inshore and offshore inter-transects are not included in the analysis. Total estimates and age and maturity breakdowns are calculated.

Coefficient of variation is estimated using a bootstrap methods and assumes that transects are equally spatially distributed within a stratum and that they are statistically independent. Biomass is calculated from numbers using length-weight relationships determined from the trawl samples taken during the survey for each of the analysis areas.

To estimate the abundance, the allocated NASC values are averaged by stratum within the survey area. For each stratum, the unit area density of fish (SA) in number per square nautical mile (N*nmi-2) is calculated using standard equations (Foote *et al.*, 1987, Toresen *et al.*, 1998).

The calculation of biomass and abundance from survey data are currently being scripted in R to standardize the processing of survey data and quality control the data during the survey.

2.2.4.8 Caveats

At the time of writing two autumn PELTIC surveys have been conducted, as well as a one-off summer PELTIC survey (2011) and two previous small-scale acoustic surveys conducted on chartered commercial fishing boats (van der Kooij *et al.*, 2011, 2012). Other than those surveys, very limited spatially resolved information on the pelagic fish community and other components of the ecosystem are available. Every new survey has presented new challenges which require fine-tuning of methods and interpretations.

Possible limitations known from nearby areas that may also effect PELTIC are poor weather and its effects on fish behaviour. Details are provided under Section 2.2.3.8 the Celtic Sea herring survey. Other possible issues are the effects of the fishery, which in the case of sprat is underway at the same time as the survey and may cause schools to be broken up and disturbed. Changes indiurnal behaviour are not known for all of target species and future studies will have to focus on this. In the PELTIC 2014 survey, the English Channel component will be surveyed acoustically during daylight only.

The timing of the survey was chosen to coincide with sprat aggregating in the western Channel, the spawning peak of sardine, which has become of increasing importance in recent years compared to the late spring-spawning (Coombs *et al.*, 2010), and the arrival of anchovy in the open waters of the English Channel. Previously, a local bottom-trawl survey demonstrated that large numbers of juvenile mackerel were also found at this time of year and may even contribute to a recruitment index. Due to the limited information about these species in the area, it is not certain that the timing is optimal for all species however and further work should reveal this.

One of the key unknowns at the moment is the limited information on stock identity. The survey attempts to assess the biomass of the various species but this requires covering the whole stock. For sprat in the Northeast Atlantic, four stocks are recognized although there is not necessarily the scientific evidence to back this up. It is unlikely that the survey covers the entire sardine population, but hopefully by combining data with adjacent surveys, e.g. in the Bay of Biscay and the Celtic Sea, these obstacles can be overcome.

2.3 Survey design

Survey stratification is based on ICES statistical rectangles with a range of 0.5 degrees in latitude and 1 degree in longitude, large squares 2° lat by 1° long or other geographical bounds. Details of stratification are detailed by survey in Section 2.

Transect orientation and designs for coordinated and individual surveys are determined following methodologies outlined in McLennan and Simmonds, (2005). Transect spacing for coordinated and individual surveys are decided by participants to provide best coverage and containment of the stock within the survey area.

Survey timing should remain consistent across years with as little variation as possible. Survey coordinators are tasked with the communication and organization of participants to ensure the temporal alignment of survey effort.

2.4 Survey planning and coordination

The main forum for the coordinated surveys to discuss, review and compile survey data are the post cruise meeting. Meetings are undertaken as close as possible to the end of the at-sea survey period.

Participants are asked to attend the meeting with the necessary information, quality checked, at national level for calculation of 'global' estimates from compiled data. Survey coordinators will define the deadlines for uploading of survey data to central databases and data reporting. The report provides detailed information of age disaggregated abundance, distribution and maturity of target species.

The whole assessment process from data retrieval from the database to the final accepted assessment should be transparent to all participants in the survey. The usual method where one participant runs an assessment programme on top of the survey data and reports it back to the group must be fully documented so it is possible to re-run the assessment (also by other participants). If the assessment process generates a new set of data (i.e. disaggregated data such as average sA or biomass estimates per square or strata, as is currently done for HERAS in FishFrameAcoustic, see Section 7), such data should be part of the assessment documentation.

Survey planning should be carried out for the following year during the post cruise meeting for coordinated surveys. Preliminary plans should then be finalized during the WGIPS meeting for inclusion into the final report.

For planning purposes participants should provide details on the resources that they can offer for a survey to allow effective planning of the next survey. Details should include:

- Vessel(s)
- Vessel time (effective survey days)
- Possible/impossible dates and areas of operation
- Possibilities for sharing expertise through exchange of personnel

Other individual surveys should include planning details in the survey report for inclusion into the WGIPS report.

3 Acoustic measurements

3.1 Equipment

The standard equipment used for surveying is the Simrad EK60 operating a split-beam transducer at 38 kHz.

3.1.1 Acoustic equipment requirements for wider ecosystem surveys

Advanced dynamic models of ecosystem interactions, required by an ecosystem-based fishery management (EBFM), must be based on the analysis of the spatial and temporal distributions of key species from all trophic levels in relation to topographic and oceanographic features. Such an approach inevitably increases the monitoring data needs, posing considerable challenges to oceanographers and fishery survey scientists. Acoustic methods, if necessary and adequate equipment is used, can meet these increased data needs for the pelagic ecosystem (Koslow, 2009). The acoustic frequencies best suited for detection of organisms in the size range from euphausids and large copepods to micronekton and nekton – approximately 12–333 kHz – are also able to sample effectively from 100 to 500 m through the water, depending on the frequency used.

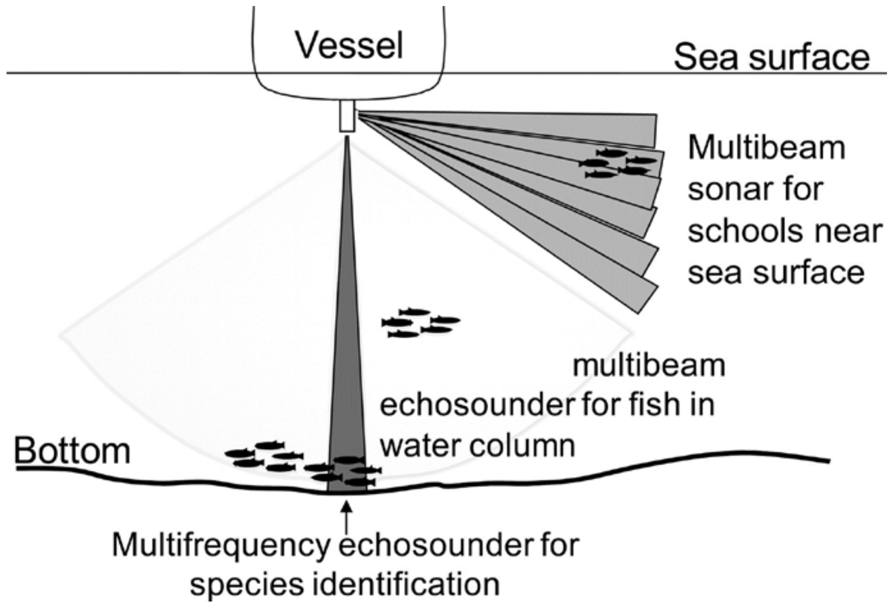
To fulfil the data needs for single species stock assessment models (abundance and biomass of target species at length and age), acoustic survey equipment requirements can be reduced to the bare minimum: a single-beam 38 kHz echosounder.

However, in order to monitor the wider pelagic ecosystem, acoustic techniques employed during surveys will inevitably have to be extended to the full potential. This essentially covers two fundamental aspects that will become more important:

(A) increase of data quantity in space and time;

(B) improved methods to remotely identify (additional) organisms;

Point (A) can be achieved by use of multibeam systems that can scan a far bigger water volume than the currently used single-beam systems. Point (B) can be achieved by multifrequency (or broadband) acoustic approaches to identify species. This means simultaneous use of more transducers operating at different frequencies (ideally 4 or more) spanning a wide as possible frequency range (e.g. from 18 kHz to 333 kHz). An illustration of an integrated approach combining several acoustic monitoring techniques is shown below (From Korneliussen *et al.*, 2009):



Multibeam

Multibeam sonars have been developed to observe near surface schooling fish that might otherwise avoid the vessel and acoustic detection. Viewing the schools in three dimensions, rather than two, enhances the study of school structure, behaviour and species interactions. However, the sampling volume and the related data are increased by an order of magnitude compared with those of conventional vertically profiling sounders. These systems are generally deployed in conjunction with downwards-looking echosounders.

Multifrequency

Multifrequency acoustic systems are used to separate organisms with markedly different sound-scattering characteristics, based on their different reflectance at low and high frequencies. Examples of the types of organism successfully discriminated in this way include fish with swimbladders (e.g. herring), distinguished from euphausids, layers of copepods, small fish and large fish without swimbladders. Another technology providing "true multifrequency" data are broadband acoustics, allowing acoustic instruments to probe the environment over a continuous frequency band simultaneously.

3.2 Instrument settings

Some instrument settings do have a significant influence on acoustic measurements and have to be adjusted at the start of each survey (or compensated for in the post-processing of the data). Minimal requirements currently used for surveys reporting through WGIPS can be found in Tables 3.2.1–3.2.2. It has to be noted that these are the absolute minimum requirements for the surveys as they are run at the time of writing. Most of the surveys use only the 38 kHz as main frequency, which is very likely to change within the transition towards an ecosystem approach; further, a dropped keel is at the moment only a recommended setup which is likely to become a requirement in the coming years. While some of the vessels already comply with these potential future standards others only fulfil the minimum requirements listed below.

Table 3.2.1. Survey dependent Settings for coordinated surveys:

IBWSS		IESNS	
ECHOSOUNDER	SIMRAD EK60	ECHOSOUNDER	SIMRAD EK60
Frequency	38 kHz	Frequency	38 kHz
Primary transducer	38B	Primary transducer	38B
Pulse length	1.024	Pulse length	1.024
Power	2000	Power	2000
Beam angle	7°	Beam angle	7°
Transducer installation	Drop keel (highly recommended)	Transducer installation	Drop keel (highly recommended)
Transducer depth	Vessel dependent	Transducer depth	Vessel dependent
Upper integration limit	Vessel dependent	Upper integration limit	Vessel dependent
Maximum range	750 m	Maximum range	500 - 750 m
Post-processing software	FAMAS / Myriax Echoview / MAREC LSSS	Post-processing software	FAMAS / Myriax Echoview / MAREC LSSS / EchoN
IESSNS		**HERAS**	
ECHOSOUNDER	SIMRAD EK60	ECHOSOUNDER	SIMRAD EK60
Frequency	38 120 200 kHz	Frequency	38 kHz
Primary transducer	38B	Primary transducer	38B
Pulse length (primary transducer)	1.024	Pulse length (primary transducer)	1.024
Power	2000	Power	2000
Beam angle	7°	Beam angle	7°
Transducer installation	Drop keel (highly recommended)	Transducer installation	Drop keel (highly recommended)
Transducer depth	Vessel dependent	Transducer depth	Vessel dependent
Upper integration limit	Vessel dependent	Upper integration limit	Vessel dependent
Maximum range	500 - 750 m	Maximum range	150 - 500 m
Post-processing software	Myriax Echoview / MAREC LSSS	Post-processing software	Myriax Echoview / MAREC LSSS / EchoN

Table 3.2.2. Survey dependent Settings for individual surveys:

	SOLEA	CELTIC EXPLORER	CELTIC EXPLORER	CORYSTES	CEFAS ENDEAVOUR
Survey	Western Baltic	CSHS	BFAS	Irish Sea	PELTIC
Echosounder	EK 60	EK 60	EK 60	EK 60	EK 60
Frequency (kHz)	38, 120	38, 18, 120, 200	38, 18, 120, 200	38, 120	38, 120, 200
Primary transducer	ES 38B	ES 38B	ES 38B	ES 38B	ES 38B
Transducer installation	Hull mounted	Drop keel	Drop keel	Hull	Drop keel
Transducer depth (m)	4	8.7	8.7	4.5	8.7
Maximum range (m)	150	250	500	300	150
Post-processing software	Myriax Echoview	Myriax Echoview	Myriax Echoview	Myriax Echoview	Myriax Echoview

It is vital that settings for the acoustic recording of survey data are the same as those used during the calibration. Consequently, information about transducer gain and SA correction settings have to be determined through calibration (see Section 3.3).

It is recommended that regular recordings of these settings be undertaken, to create a log of the main functionality of the acoustic measuring system.

It is also recommended that each year the same settings (Min Sv = -60 dB) are used for the printer in order to facilitate comparison of echogram.

The Elementary Distance Sampling Unit (EDSU) is the length of cruise track, where acoustic measurements are averaged to give one sample. The majority of surveys reporting through WGIPS use an EDSU of 1nmi (nautical mile).

The ping rate should be set according to the local circumstances. Due to the nature of the measuring unit (i.e. the nautical area scattering coefficient; see Section 6.2), changing the ping rate does not affect the accuracy of the measured fish densities. However, to obtain a consistent number of pings per distance sampling unit, a fixed ping rate should be chosen. Setting the ping rate to "maximum" would result in varying different numbers of pings per EDSU, depending on the water depths. Thus, an optimal fixed ping rate will keep data quantity within acceptable limits and avoid secondary seabed echoes contaminating the recordings in deep water. Usually, values of 1s-1 or higher are chosen for surveys in shelf seas shallower than 200m, while lower ping rates should be used in deeper waters.

3.3 Calibration

The calibration of transducers must be conducted at least once during the survey using the same settings as during data collection. If possible, the transducer should be calibrated both at the beginning and the end of the survey. All available frequencies should be calibrated during each exercise. Transducer calibrations should be carried out following established methods. Calibration procedures are described in "Simrad ER60 Scientific echosounder reference manual" and provide a guide to an acceptable quality threshold for results. (http://ntuio.oc.ntu.edu.tw/ocean2012/wp-content/uploads/2013/06/164692ad_ek60_reference_manual_english_lores.pdf)

A table of calibration results should be included in all national survey reports and made available if requested for inclusion into coordinated survey report.

3.4 Intercalibration

Coordinated surveys using multiple vessels are encouraged to undertake acoustic and trawl intercalibration exercises following methods detailed in Simmonds and MacLennan (2005).

4 Trawl sampling

4.1 Trawl gear

Proper species allocation of the acoustic records cannot be guaranteed if no corresponding biological information from trawling is available. The principal objective is to obtain a sample from the school or the layer that appears as an echotrace on the sounder by means of directed trawling. During trawling, it is important to take note of the traces on the echosounder and the netsonde in order to judge if the target-school entered the net or if some other traces contaminate the sample. If a target is missed during a haul, the catch composition should not be used for species allocation.

Directed trawling on insonified echotraces using a single pelagic midwater trawl is the main method of collecting biological data during WGIPS surveys. This type of trawl allows sample collection of midwater echotraces as well as those occurring close to the bottom.

As no standardized single pelagic midwater trawl exists for the majority of WGIPS surveys, a range of trawls of different dimensions are employed. The type of midwater trawl must be deemed suitable to catch a qualitatively representative sample of the target-school or layer.

As the IESSNS survey reports abundance by means of swept-area methods (non-directed trawling at predetermined locations) a standardized single pelagic midwater trawl is used.

The details of trawls used in coordinated and national survey programs are reported in the Annex’s of the WGIPS annual report:

http://prep.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/SSGESST/2012/WGIPS12b.pd

4.2 Biological sampling

4.2.1 Species composition

The first step of trawl catch analysis is to determine species composition. This can be carried out by separating the catch into species components by weight and number either by exhaustive sampling, subsampling (raising to the total catch) or by a combination of both. If the catch contains specimens which differ significantly from the main catch, e.g. by size or low abundance, these may be set aside from the total catch, before handling the remaining catch.

Second step is to record biological parameters of the target species within the catch (length, age, sex, sexual maturity and individual weight measurements). Biological variables routinely collected for each survey are listed in Table 4.2.1.1.

Table 4.2.1.1. Sampling levels for target species by survey. O=otoliths, S=scales, L=length, M=maturity, G=gender.

	IBWSS	IESNS	HERAS	IESSNS	BIAS	Irish Sea	PELTIC	CSHAS	BFAS
Herring	-	SOLMG	OLMG	OLMG	OLMG	OLMG	OLMG	OLMG	OLMG
Sprat	-	-	OLMG	-	OLMG	OLMG	OLMG	LMG	LMG
Blue whiting	OLMG	OLMG	-	OLMG	-	-	-	LMG	LMG
Boarfish	-	-	-	-	-	-	-	LMG	OLMG
Mackerel	-	OL	-	OLMG	-	-	OLMG	LMG	LMG
Horse mackerel	-	-	-	-	-	-	OLMG	LMG	LMG
Sardine	-	-	-	-	-	-	OLMG	OLMG	OLMG
Anchovy	-	-	-	-	-	-	OLMG	OLMG	OLMG

4.2.2 Length measurements

The length measured should be the total length of the fish as shown in Figure 4.2.2.1 below, rounding down towards the nearest length interval. Clupeid and boarfish measurements are typically recorded to the nearest 0.5 cm below and other species to the whole cm below although some participants will measure other species at the higher resolution.

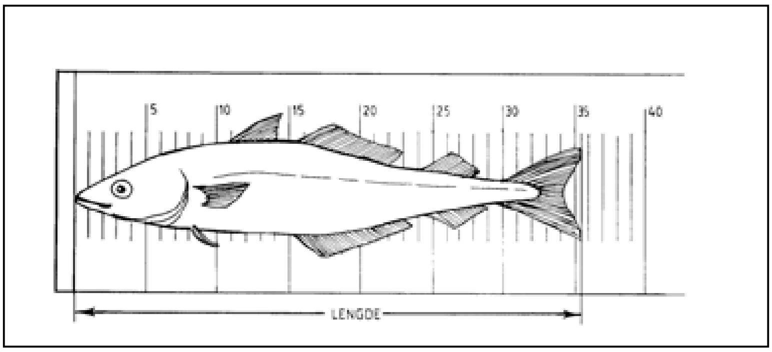


Figure 4.2.2.1. Total length measurement of fish.

Mackerel is measured with the tip of the caudal fin stretched backwards as shown in Figure 4.2.2.2.

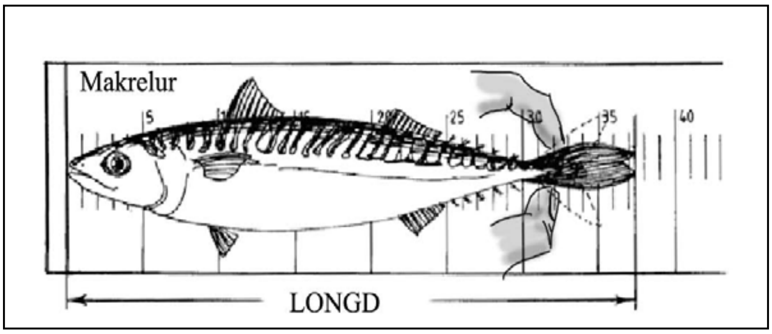


Figure 4.2.2.2. Total length measurement of mackerel.

4.2.3 Maturity analysis

Maturity should be determined by experienced personnel to internationally accepted standards and where possible following recommendations from ICES species-specific maturity workshops. Within each coordinated survey, it is recommended that the participating institutes agree on the maturity scales used for each species. If different scales are used, there should be agreement on how to convert between them.

4.2.4 Age sampling

Age determination is done by reading winter growth rings on the sagittal otoliths or in the case of Norwegian Spring-spawning herring, scales. Aging may be done onboard using standard procedure for otolith or scale reading or they may be examined at a later stage in the institute laboratories. Age reading protocols used should again be agreed among institutes participating in each survey and should follow recommendations from the latest advice from the most recent exchange for each species:

http://www.ices.dk/reports/acfm/pgccdbs/PGCCDBSdocrepository.asp

5 Hydrographic sampling

5.1 Hydrographic data

Temperature, salinity and oxygen content in the water column should be measured with a CTD probe either at predetermined positions or at least in connection with each haul.

For the IBWSS, IESNS and IESSNS surveys the positions for CTD stations are predetermined by the survey coordinator and CTD stations are taken down to a maximum depth of 1000 m.

Participants are encouraged to ensure if no water samples are collected for validation purposes that the sensor suite is calibrated annually.

5.2 Plankton sampling

Plankton samples are taken within the IBWSS, IESNS and IESSNS surveys. The standard gear is a WP2 net, equipped with mesh sizes of 180 or 200 µm and an aperture of 56 cm. In the Barents Sea, Russia uses a Dyedi net for plankton sampling (IESNS survey only). This net has a mesh size of 180 µm and an aperture of 37 cm. WP2 and Dyedi are hauled vertically from 200 m water depth (or bottom layer) to the sea surface at a speed of 0.5 m s^{-1}. Plankton stations are spaced relatively evenly of the survey area and are approximately 30 nautical miles apart. Sampling positions may change among years depending on the acoustic transects.

There are indications that the Dyedi net has a lower catching efficiency compared to the WP2. 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.

All plankton samples are working up in that way that 50% of one sample are preserved in Formalin, while the other half is used for zooplankton dry weight estimation.

5.3 Ichthyoplankton sampling

With regard to clupeid larvae in the North Sea and adjacent waters, an internationally coordinated larvae sampling program exists under the auspices of ICES since 1972. The survey covers the main spawning grounds of autumn and winter spawning herring in the North Sea. For the International Herring Larvae Surveys (IHLS) a dedicated manual exists. This manual is updated whenever needed; last time in 2010. The manual is available from the WGIPS report 2010 (ICES, 2010). The IHLS time-series is part of the eggs and larvae database at the ICES Data Centre (http://www.ices.dk/marine-data/data-portals/Pages/Eggs-and-larvae.aspx).

5.4 Other

If possible, continuous underway measurements of surface temperature and salinity as well as metrological parameters such as wind direction and windspeed should be collected and stored.

6 Data analysis

6.1 Target strengths

The target strength to length relationships applied during the analysis of survey data are listed in Table 6.1.1.

Participants are encouraged to collect in-situ TS measurements of target species where it is possible during surveys.

Table 6.1.1. Species-specific target strength to length relationships.

Species	Target Strength	Reference
Blue whiting	TS = 20 log10 (L) - 65.2	Pedersen *et al.*, 2011
Herring	TS = 20 log10 (L) - 71.2	ICES, 1982
Herring (ASH)	TS = 20 log10 (L) - 71.9	Foote, *et al.*, 1987
Sprat	TS = 20 log10 (L) - 71.2	ICES, 1982
H. mackerel	TS = 20 log10 (L) - 67.5	Foote, 1987
Anchovy	TS = 20 log10 (L) - 71.2	ICES, 1982
Pilchard	TS = 20 log10 (L) - 71.2	ICES, 1982
Mackerel	TS = 20 log10 (L) - 84.9	Edwards *et al.*, 1984
Boarfish	TS = 20 log10 (L) - 66.24	Fässler *et al.*, 2012
Physoclist	TS = 20 log10 (L) - 67.5	Foote, *et al.*, 1987

6.2 Scrutinisation

The process of echogram scrutinisation, i.e. the allocation of nautical area scattering coefficient (acronym: NASC; symbol: sA) values to species, is primarily a subjective process that should be carried out by an experienced expert. This person will have to be familiar with the scrutinisation process, the survey area and the target species. Species may vary greatly in the way in which they aggregate and temporal and geographical features specific to the situation need to be taken into account (Figures 6.2.1. and 6.2.2.).

Given the potential sources of error associated with the scrutinisation process, it is preferable to have additional information available. This information may be obtained from targeted trawling, multifrequency acoustic data or known behavioural characteristics of the target species. The use of trawling information should be treated with caution, as gear catchability may differ between species. One has to judge whether the catch-composition is a true reflection of the real species composition of the logged school/layer data and whether the allocated percentage species composition can be justified.

In light of the increased data need as a consequence of surveying the wider ecosystem, an effort will have to be made to scrutinize as many species as possible. Methods of determining species allocation are often highly specific to the survey being undertaken. The method used depends largely upon the schooling behaviour of the target species, and the mixing with other species. For example, in the North Sea and Division VIa the species allocation is based mainly on the identification of individual schools on the echogram. In the Skagerrak-Kattegat area and southern North Sea, the identification is based on the composition of trawl catches. A few typical target species echograms are shown below.

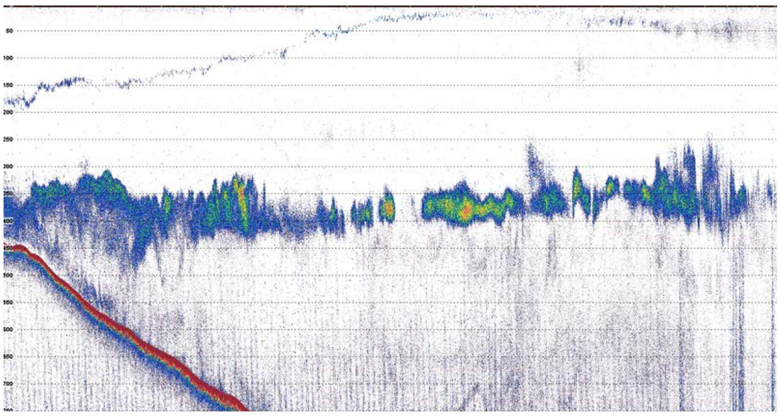


Figure 6.2.1. An example of a typical blue whiting echotrace from the IBWSS. Frequency: 38 kHz; threshold: -70 dB.

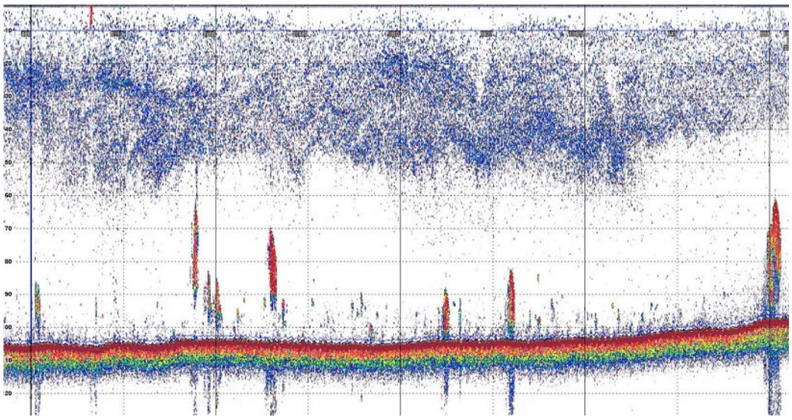


Figure 6.2.2. Example of a typical herring echotrace from HERAS. Frequency: 38 kHz; threshold: -70 dB.

Primarily, decisions made during the scrutinising process will be based on subjective criteria. However, joint sessions of scientists scrutinising each other's data has shown that their estimated quantities of herring were within a range of 10%, if the acoustic data has adequate trawl information to go with it (Reid *et al.,* 1998).

Some of the factors that may facilitate the decision-making process include visual clues in the echograms, consulting historical echograms of the same species/area, removal of unwanted echoes by lowering the threshold, composition of trawl catches, and comparing echoes from different frequencies if available. It is often useful to look at observations over an extended period of time/distance, as patterns may emerge that help in making a decision on the allocation of species.

At the end of the scrutinisation process, it is also important to exclude invalid acoustic data that cannot and/or must not be used for further analysis. This includes data recorded during shooting/hauling of the net, trawling or CTD operations or while steaming between transect lines. If this is not done, resulting biomass estimates may be overestimated. Equally, areas containing 'bad data' such as lost pings or noise caused by air bubbles in bad weather, which can contaminate potential fish traces, may need to be filtered out.

6.3 Software

Of the several commercially available post-processing software packages, Echoview (http://www.echoview.com/) and the Large Scale Survey System, known as LSSS (http://www.marec.no/) are the most commonly used within the group.

User manuals containing full details are available through the links provided.

6.4 Abundance estimation

This section describes the calculation of numbers and biomass by species from the echo integrator data and trawl data. From Simmonds *et al.* (1992).

The symbols used in this section are defined in the text but for completeness they have been collated and are given below:

F_i	estimated area density of species i
K	equipment physical calibration factor
$<\sigma_i>$	mean acoustic cross-section of species i
E_i	partitioned echo-integral for species i
E_m	echo-integral of a species mixture
c_i	echo-integrator conversion factor for species i
TS	target strength
TS_n	target strength of one fish
TS_w	target strength of unit weight of fish
a_i, b_i	constants in the target strength to fish length formula
a_n, b_n	constants in formula relating TS_n to fish length
a_w, b_w	constants in formula relating TS_w to fish length
a_f, b_f	constants in the fish weight-length formula
L	fish length
W	weight
L_j	fish length at midpoint of size class j
f_{ij}	relative length frequency for size class j of species i
w_i	proportion of species i in trawl catches
A_k	area of the elementary statistical sampling rectangle k
Q	total biomass
Q_i	total biomass for species i

The objective is to estimate the density of targets from the observed echo integrals. This may be done using the following equation from Foote *et al.* (1987):

$$F_i = \left(\frac{K}{<\sigma_i>}\right)E_i \qquad \textbf{(1)}$$

The subscript i refers to one species or category or target. K is a calibration factor, $<\sigma i>$ is the mean acoustic cross section of species i, Ei is the mean echo integral after partitioning and Fi is the estimated area density of species i. The quantity is the number or weight of species i, depending on whether σi is the mean cross section per fish or unit weight. ci= (K/<σi>) is the integrator conversion factor, which may be different for each species. Furthermore, ci depends upon the size-distribution of the insonified target, and if this differs over the whole surveyed area, the calculated conversion factors must take the regional variation into account.

K is determined from the physical calibration of the equipment, which is described in Section 1 above. K does not depend upon the species or biological parameters. Several calibrations may be performed during a survey. The measured values of K or the settings of the EK60 may be different but they should be within 10% of each other. If two successive measurements are very different the cause should be investigated since the equipment may be malfunctioning. Otherwise, K should be taken as the average of two measurements before and after the relevant part of the survey.

Where the results of the calibration are applied to the sounder, at the start of the survey, the calibration factor K equals 1, and the formula can be altered to not include the factor. Modern acoustic analysis software, that allows the results from the calibration to be applied to non-corrected sounder data at the time of the analysis, providing an output equivalent to that from a calibrated sounder.

Where K=1 the formula can be written as:

$$Fi = \frac{Ei}{<a>}$$

Conversion factors for a single species

The mean cross section <σi> should be derived from a function which describes the length-dependence of the target-strength, normally expressed in the form:

$$TS = a_i + b_i Log_{10}(L) \tag{2}$$

Where ai and bi are constants for the i'th species, which by agreement with the other participants in the survey are given in Table 6.1.1

The equivalent formula for the cross section is:

$$\sigma_i = 4\pi 10^{\left(\left(a_i + b_i Log(L)\right)/10\right)} \tag{3}$$

The mean cross section is calculated as the σ average over the size distribution of the insonified fish. Thus, Lj is the midpoint of the j'th size class and fij is the corresponding frequency as deduced from the fishing samples by the method described earlier. The echo integrator conversion factor is ci= K/<σi>. The calculation may be repeated for any species with a target strength function.

$$< \sigma_i >= 4\pi \sum_j f_{ij} 10^{\left(\left(a_i + b_i Log(L_j)\right)/10\right)} \tag{4}$$

Note that it is the cross section that is averaged, not the target-strength. The arithmetic average of the target-strengths gives a geometric mean, which is incorrect. The term "mean target-strength" may be encountered in the literature, but this is normally the target-strength equivalent to $<\sigma_i>$, calculated as $10\log_{10}(<\sigma_i>/4\pi)$. Some authors refer to TS as 10 log(σ_{bs}) the definition of σ is different from σ_{bs} and should not be confused.

Conversion factors for mixed species layers or categories

Sometimes several species are found in mixed concentrations such that the marks on the echogram due to each species cannot be distinguished. From inspection of the echogram, the echo integrals can be partitioned to provide data for the mixture as one category, but not for the individual species. However, further partitioning to species level is possible by reference to the composition of the trawl catches (Nakken and Dommasnes, 1975).

Suppose Em is the echo integral of the mixture, and wi is the proportion of the i'th species, calculated from fishing data. It is necessary to know the target-strength or the acoustic cross section, which may be determined in the same manner as for single species above. The fish density contributed by each species is proportional to wi. Thus the partitioned fish densities are:

$$F_i = \frac{w_i K}{(\sum_i w_i < \sigma_i >)} E_m \quad \textbf{(5)}$$

The wi may be expressed as the proportional number or weight of each species, according to the units used for <σi> and ci. Consistent units must be used throughout the analysis, but the principles are the same whether it is the number of individuals or the total weight that is to be estimated.

Using weight-length relationships

The abundance is expressed either as the total weight or as the number of fish in the stock. When considering the structure of the stock, it is convenient to work with the numbers at each age. However, an assessment of the commercial fishing opportunities would normally be expressed as the weight of stock yield. Consistent units must be used throughout the analysis. Thus if the abundance is required as a weight while the target-strength function is given for individual fish, the latter must be converted to compatible units. This may be done by reference to the weight-length relationship for the species in question.

For a fish of length L, the weight W is variable but the mean relationship is given by an equation of the form:

$$W = a_f L^{b_f} \quad \textbf{(6)}$$

Where af and bf are taken as constants for one species. However, af and bf could be considered as variables varying differently with stock and time of year as well as species. Suppose the target-strength of one fish is given as:

$$TS_n = a_n + b_n \log_{10}(L) \quad \textbf{(7)}$$

The corresponding function TSw, the target-strength of unit weight of fish has the same form with different constants:

$$TS_w = a_w + b_w \log_{10}(L) \quad \textbf{(8)}$$

The number of individuals in a unit weight of fish is (1/W), so the constant coefficients are related to the formulae:

$$b_w = b_n - 10 b_f \quad \textbf{(9)}$$

$$a_w = a_n - 10 \log_{10}(a_f) \quad \textbf{(10)}$$

Estimating abundance

So far, the analysis has produced an estimate of the mean density of the insonified fish, for each part of the area surveyed, and for each species considered. The next step is to determine the total abundance in the surveyed area. The abundance is calculated independently for each species or category of target for which data have been obtained by partitioning the echo integrals. The calculations are the same for each category:

$$Q_i = \sum_{k=1}^{n} A_k F_i \quad (11)$$

The total biomass for all species is:

$$Q = \sum_{i} Q_i \quad (12)$$

The Fi are the mean densities and Ak are the elements of the area that have been selected for spatial averaging. The may be calculated from the shape of an area or measured, depending upon the complexity of the area. The presence of land should be taken into account, possibly by measuring the proportions of land and sea.

7 Data exchange and database

Currently, two types of database are used by WGIPS coordinated surveys as a repository for acoustic, biological and hydrographic data. Both databases are accessible online and the data stored within are analysed to provide the estimates of abundance for the target species involved.

7.1 WGNAPES database

Overview and exchange format

At the PGSPFN meeting in Bergen 2001 the group agreed to set up a common database for the data collected in the Norwegian Sea since 1996 by the different nations. This was due to the fact, that the data handling was becoming more and more difficult, as the amount of data collected is huge. Already then, a draft database design was made. In 2007, a database web server (Oracle 10g express edition) was set up at "Faroe Marine Research Institute" The coordinated surveys of the IBWSS and IESSNS groups have committed to submit all relevant cruise data to this central database, to achieve easy access to the complete time-series.

The database was developed on a Microsoft Access platform, and the Access-version is very useful during a survey, facilitating the collection and organization of data and ensuring the quality and integrity of the dataset. Another great benefit is that the table exports fit right into the central database on the Internet.

Data files can be interchanged between the vessels using the *.csv format (comma-separated-values) with tables arranged as described by the WGNAPES database format.

Complete national cruise databases in Access format (*.mdb) are submitted to the Faroe Marine Research institute when all data are produced.

Internet access to the data:

Data are stored in an Oracle 10g Express edition database (freeware). The database server is based at the "Faroe Marine Research Institute" (FAMRI), Tórshavn, Faroe Islands.

By executing SQL queries through the Application Express web-interface, the user can extract data in any form.

URL: http://oracle.frs.fo/apex

Usernames and passwords are given to every nation participating in the surveys. User access is limited to select data from the database.

Insert, update and delete operations can only be performed by the schema owner (Database_owner).

7.2 FishFrame database

Since 2007, WGIPS has been using FishFrameAcoustic as the groups' standard database for basic, disaggregated fisheries and acoustics data (stage 1 data) and aggregated national data (stage 3 data) from the HERAS survey.

FishFrameAcoustic is at the moment hosted by DTU-Aqua and accessed through the web page:

http://dmz-web08.dfu.min.dk/NorthSea/FishFrame/ and the user's manual is given on web page:

http://dmz-web08.dfu.min.dk/NorthSea/FishFrame/Info/Documentation/FishFrame%20user%20manual.pdf

WGIPS use FishFrameAcoustic as a tool to derive global estimates from national, aggregated data (stage 3 data).

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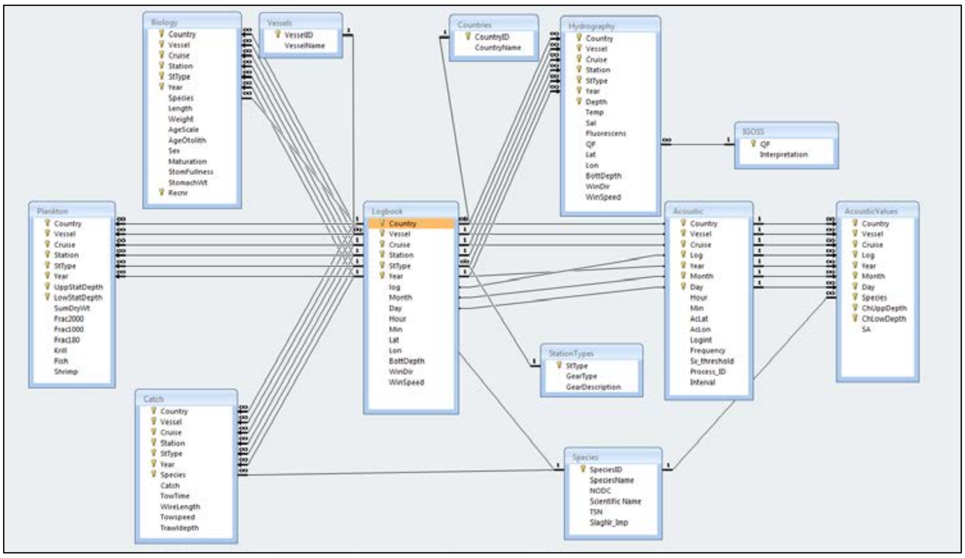
Annex 1: WGNAPES database

Table 8.2.1.1. WGNAPES access database constraints.



Parameters in bold indicate primary key variables, and used together they form a unique key from the logbook to the other sheets, except to the acoustic table. The acoustic table can be linked to the logbook by the cruise identifier together with country, vessel, Cruise, log, year and month.

Logbook:

Country	Post code, 2 chars according to Countries table
Vessel	Call sign, 2 or 6 digits acc. to Vessels table
Cruise	Cruise identifier
Station	National station number
StType	Geartype/activity: one line per activity at the same station: National definition of station type
Year	YYYY (4 digits)
Log	Value from the acoustic log (Nm)
Month	MM
Day	DD
Hour	HH, time GMT 0–24
Min	MM
Lat	Decimal degrees, negative latitude south 0° ”0.0000”
Lon	Decimal degrees, negative longitude west of 0° “0.0000”
BottDepth	Bottom depth (m)
WinDir	Compass degrees
WinSpeed	m/s

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

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)

Hydrography:

Country	Post code, 2 chars according to countries table
Vessel	Call sign, 2 or 6 digits acc. to Vessels table
Cruise	Cruise identifier
Station	National station numbers
StType	Geartype/activity: National definition of station type
Year	YYYY (4 digits)
Depth	Depth of measurement (m)
Temp	°C (at least 2 decimals)
Sal	Salinity (psu, at least 3 decimals)
QF	Quality of salinity data: 0–5 (IGOSS quality flags)

Fluorescens	mg/m^3

Plankton:

Country	Post code, 2 chars according to countries table
Vessel	Call sign, 2 or 6 digits acc. to Vessels table
Cruise	Cruise identifier
Station	National station numbers
StType	Geartype/activity: National definition of station type
Year	YYYY (4 digits)
UppStatDepth	Upper station depth (m)
LowStatDepth	Lower station depth (m), if only one depth then same as upper
SumDryWt	Plankton mg dry weight/m^2 in each interval
Frac2000	Size graded values, 2000 my sieve
Frac1000	1000 my sieve
Frac180	180 my sieve
Krill	From 2000 my sieve
Fish	-"-
Shrimp	-"-

Catch:

Country	Post code, 2 chars according to countries table
Vessel	Call sign, 2 or 6 digits acc. to Vessels table
Cruise	Cruise identifier
Station	National station numbers
StType	Geartype/activity: National definition of station type
Year	YYYY (4 digits)
Species	Species code: HER, BLU,…
Catch	Kg
Towtime	Minutes
Wirelength	(m)
TowSpeed	Knots
Trawldepth	(m)

Biology:

Country	Post code, 2 chars according to countries table
Vessel	Call sign, 2 or 6 digits acc. to Vessels table
Cruise	Cruise identifier
Station	National station numbers
StType	Geartype/activity: National definition of station type
Year	YYYY (4 digits)
Species	Species code: HER, BLU,…
Length	Cm with one decimal (dot as decimal sign)

Weight	G
AgeScale	Year from scale readings
AgeOtholit	Year from otolith
Sex	Empty means not sexed, 1= Female, 2= Male, 0= not possible to determine sex
Maturation	Maturation scale: Herring 1–8, Blue whiting 1–7
StomFullness	Stomach fullness, visual scale 1–5 (ICES)
StomachWt	Weight of stomach with content (g)
Recnr	Serial number identifying the fish

Supporting tables:

Countries:

CountryID	Postal code:FO,DE,NL,NO,IS,RU,SE,IE,DK
Countryname	Countryname

Values in Countries table:

CountryID	Countryname
FO	Faroe Islands
DE	Germany
NL	Netherlands
NO	Norway
IS	Iceland
RU	Russia
SE	Sweden
IE	Ireland
DK	Denmark

Vessels:

VesselID	Callsign
Vesselname	Vesselname

Values in Vessel table:

VESSELID	VESSELNAME
LJBD	Nybo
LIWG	Brennholm
DBFR	Walter Herwig III
EIGB	Celtic Explorer
LDGJ	Johan Hjort
LHUW	Michael Sars
LLZG	G.O. Sars (old)

VESSELID	VESSELNAME
LMEL	G.O. Sars (new)
OW2252	Magnus Heinason
OXBH	Dana
PBVO	Tridens
SEPI	Argos
TFEA	Bjarni Sæmundsson
TFJA	Arni Fridriksson (old)
TFNA	Arni Fridriksson
UANA	Fritjof Nansen
UFJJ	Smolensk
UHOB	Atlantniro
UALU	Atlantida
XPXP	Finnur Fríði
OW2140	Christian í Grótinum
TFLF	Hoffell
LIVA	EROS
LMOG	Gardar
LMQI	Libas

IGOSS:

QF	QUALITY FLAG
Interpretation	Interpretation

Species:

SPECIESID	3 CHARACTER CODE
SpeciesName	Species name in English
NODC	NODC-code
Scientific name	Scientific name latin
Name_NO	Norwegian Name

Gear:

STTYPE	GEARTYPE/ACTIVITY: NATIONAL DEFINITION OF STATION TYPE
GearType	PLANKTON,CTD, or TRAWL (mandatory)
Geardescription	Informative description of gear

Example of data export from Access

To make exports from the base will ensure that data exported are ready to import into the other participants databases.

Exporting plankton, hydrography, biology, or catch data always implies the export of the logbook table as it is the parent table of these underlying tables.

Exporting acoustic values always implies the export of the Acoustic tables as the acoustic table is a parent table of the acousticvalues table.

Is important to have the structure of the database in mind when exporting and supplying other participants with exported data.

Exporting data from access:

Mark the table you want to export (Figure A)

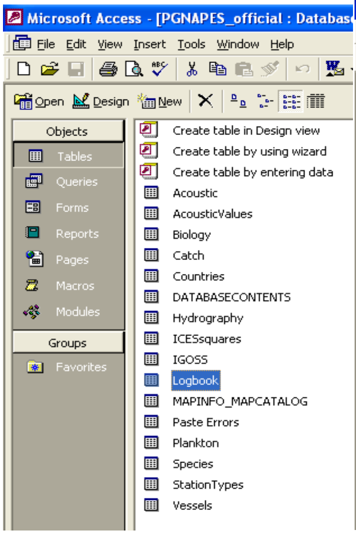
Go to File/export (Figure B)

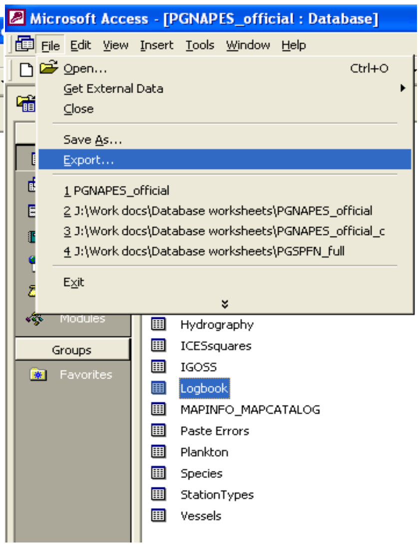
Save as "TEXT" format, supply file name

Save as delimited

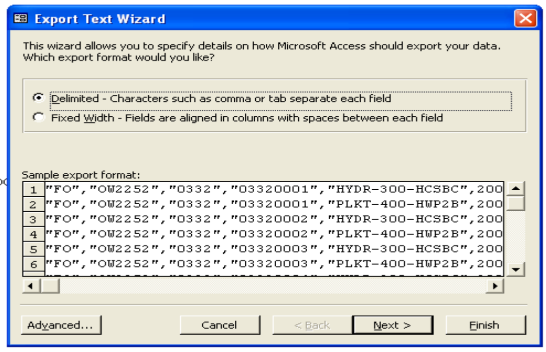
Make sure it is comma delimited (Figure C), and include Fields Names on first row is tagged (Figure D)

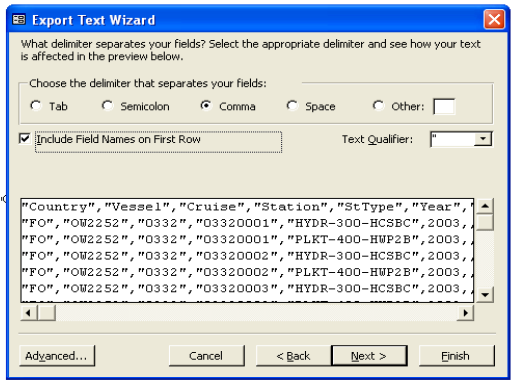
Press finish





A B





C D

The file format is ordinary ASCII-format. The data values within the files are arranged as Comma-Separated-Values (*.csv) as shown in the example below.

"Country","Vessel","Cruise","Station","StType","Year","log","Month","Day","Hour","Min","Lat","Lon","BottDepth","WinDir","WinSpeed"

"FO","OW2252","0332","03320001","HYDR-300-HCSBC",2003,,5,3,1,11,61.83,-7.00,77,45,15

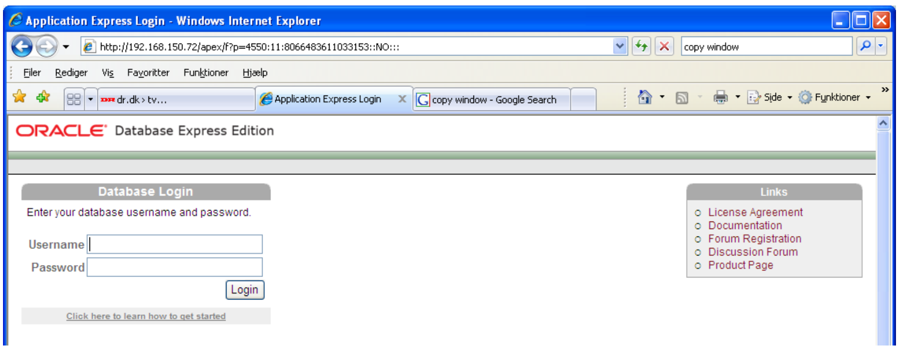
"FO","OW2252","0332","03320001","PLKT-400-HWP2B",2003,,5,3,1,45,61.83,-7.00,77,45,15

"FO","OW2252","0332","03320002","HYDR-300-HCSBC",2003,,5,3,3,20,61.66,-7.30,130,45,15

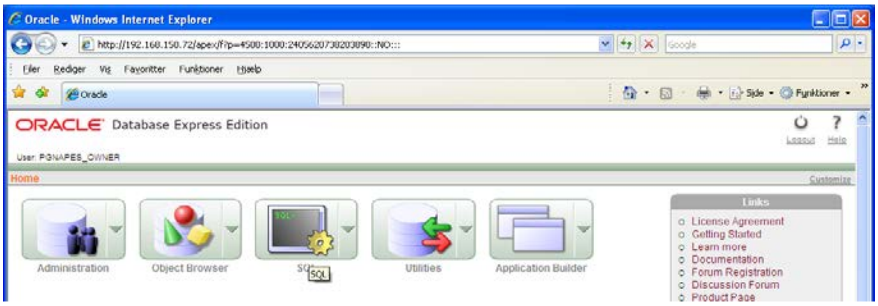
Internet access to the data:

URL: *http://oracle.frs.fo/apex*

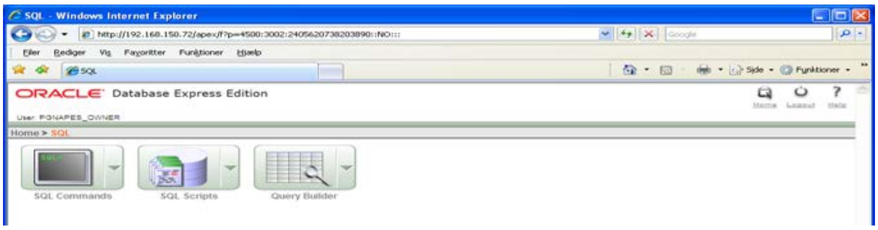
Log in on first page:



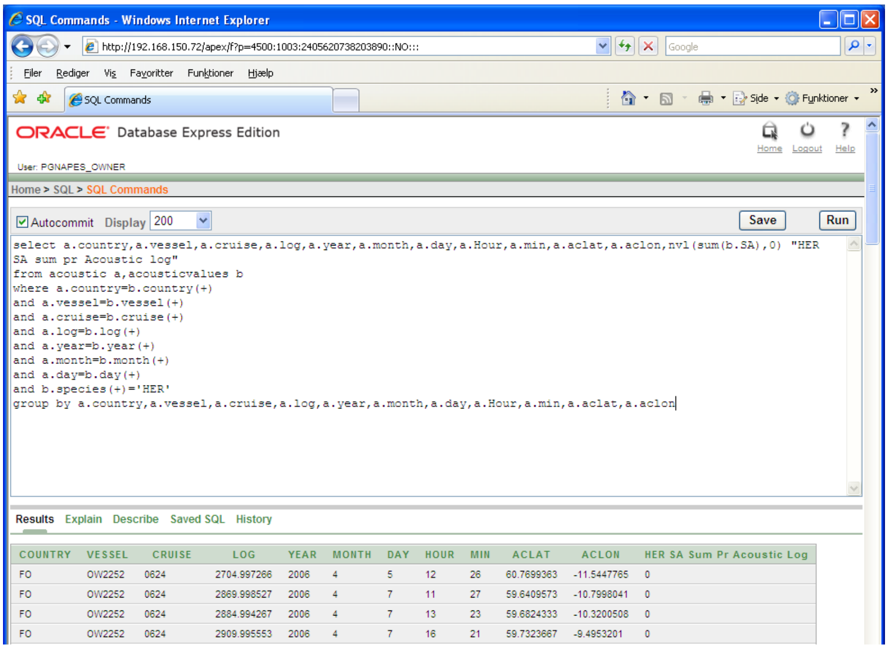
Select the SQL button


Oracle - Windows Internet Explorer
Filer Rediger Vis Favoritter Funktioner Hjælp
ORACLE Database Express Edition
User: PGNAPES_OWNER
Home
Customize
Logout
Help
Administration
Object Browser
SQL
Utilities
Application Builder
Links
License Agreement
Getting Started
Learn more
Documentation
Forum Registration
Discussion Forum
Product Page

Select the SQL Commands button



Write or paste your SQL statement into the SQLtext box and press the RUN button. Number of rows displayed are default 10, but can be changed in the Display drop down field.



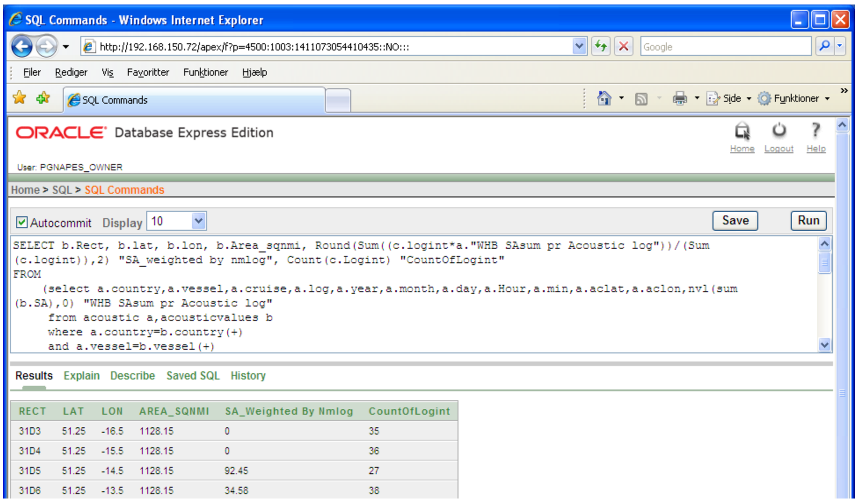
Saving SQL-statements:

It is possible to save your SQL statements, by pressing the "SAVE" button. Retrieve your saved SQL's by pressing the "Saved SQL" button.

It is recommended to copy and paste the SQL statements on page 7 and onwards, to get a feel of the system.

Exporting from database:

It is possible to download data from the database. After the SQL is executed, the link csv export pops up below the results pane. By clicking the CSV export link data will be downloaded to your computer. The user will be prompted, to choose to look at the data or to store the data locally.



Observe that the format of the browser output and CSV file (decimal sign, thousands separator, text qualifier, etc.) depends on the language settings of your browser (Internet Explorer 'Internet options/language).

Standard Query Language

Writing SQL statements is relatively easy. Basically, a select statement is divided into 3 parts.

Select clause: What do you want to see.

From clause: From which table(s) are you selecting data.

Where clause: Conditions on data selected.

Tutorials are easily found on the web:

http://www.w3schools.com/sql/default.asp

http://www.sqlcourse.com/

http://www.1keydata.com/sql/sql.html

http://www.geocities.com/SiliconValley/Vista/2207/sql1.html

Preliminary sample selects (more will evolve over time)

Copy and paste these selects into the SQL-query web interface.

PLANKTONSTATIONS	TRAWLSTATIONS	CTDSTATIONS
select l.*	select l.*	select l.*
from logbook l,stationtypes s	from logbook l,stationtypes s	from logbook l,stationtypes s
where l.sttype=s.sttype	where l.sttype=s.sttype	where l.sttype=s.sttype
and s.geartype='PLANKTON'	and s.geartype='TRAWL'	and s.geartype='CTD'

Herring : SA sum pr acoustic log	Herring: Average SA per statistical square
Select a.country,a.vessel,a.cruise,a.log,a.year,a.month,a.day,a.Hour,a.min,a.aclat,a.aclon,nvl(sum(b.SA),0) "HER SA sum pr Acoustic log" from acoustic a,acousticvalues b where a.country=b.country(+) and a.vessel=b.vessel(+) and a.cruise=b.cruise(+) and a.log=b.log(+) and a.year=b.year(+) and a.month=b.month(+) and a.day=b.day(+) and b.species(+)='HER' and a.cruise in('list of cruises','cruise1','cruise2','cruise3') group by a.country,a.vessel,a.cruise,a.log,a.year,a.month,a.day,a.Hour,a.min,a.aclat,a.aclon	SELECT b.Rect, b.lat, b.lon, b.Area_sqnmi, Sum((c.logint*a."WHB SAsum pr Acoustic log"))/(Sum(c.logint)) "SA_weighted by nmlog", Count(c.Logint) "CountOfLogint" FROM (select a.country,a.vessel,a.cruise,a.log,a.year,a.month,a.day,a.Hour,a.min,a.aclat,a.aclon,nvl(sum(b.SA),0) "WHB SAsum pr Acoustic log" from acoustic a,acousticvalues b where a.country=b.country(+) and a.vessel=b.vessel(+) and a.cruise=b.cruise(+) and a.log=b.log(+) and a.year=b.year(+) and a.month=b.month(+) and a.day=b.day(+) and b.species(+)='HER' and a.cruise in('list of cruises','cruise1','cruise2','cruise3') group by a.country,a.vessel,a.cruise,a.log,a.year,a.month,a.day,a.Hour,a.min,a.aclat,a.aclon) a, ICESsquares b, Acoustic c WHERE a.country=c.country(+) and a.vessel=c.vessel(+) and a.cruise=c.cruise(+) and a.log=c.log(+) and a.year=c.year(+) and a.month=c.month(+) and a.day=c.day(+) and ((c.AcLat Between b.lat_min And b.lat_max) AND (c.AcLon Between b.lon_min And b.lon_max)) GROUP BY b.Rect, b.lat, b.lon, b.Area_sqnmi order by b.rect

Blue whiting : SA sum pr acoustic log	Blue whiting: Avg SA pr statistical square
select a.country,a.vessel,a.cruise,a.log,a.year,a.month,a.day,a.Hour,a.min,a.aclat,a.aclon,nvl(sum(b.SA),0) "WHB SAsum pr Acoustic log" from acoustic a,acousticvalues b where a.country=b.country(+) and a.vessel=b.vessel(+) and a.cruise=b.cruise(+) and a.log=b.log(+) and a.year=b.year(+) and a.month=b.month(+) and a.day=b.day(+) and b.species(+)='WHB' and a.cruise in(‘list of cruises’,’cruise1’,’cruise2’,’cruise3’) group by a.country,a.vessel,a.cruise,a.log,a.year,a.month,a.day,a.Hour,a.min,a.aclat,a.aclon	SELECT b.Rect, b.lat, b.lon, b.Area_sqnmi, Round(Sum((c.logint*a."WHB SAsum pr Acoustic log"))/(Sum(c.logint)),2) "SA_weighted by nmlog", Count(c.Logint) "CountOfLogint" FROM (select a.country,a.vessel,a.cruise,a.log,a.year,a.month,a.day,a.Hour,a.min,a.aclat,a.aclon,nvl(sum(b.SA),0) "WHB SAsum pr Acoustic log" from acoustic a,acousticvalues b where a.country=b.country(+) and a.vessel=b.vessel(+) and a.cruise=b.cruise(+) and a.log=b.log(+) and a.year=b.year(+) and a.month=b.month(+) and a.day=b.day(+) and b.species(+)='WHB' and a.cruise in(‘list of cruises’,’cruise1’,’cruise2’,’cruise3’) group by a.country,a.vessel,a.cruise,a.log,a.year,a.month,a.day,a.Hour,a.min,a.aclat,a.aclon) a, ICESsquares b, Acoustic c WHERE a.country=c.country(+) and a.vessel=c.vessel(+) and a.cruise=c.cruise(+) and a.log=c.log(+) and a.year=c.year(+) and a.month=c.month(+) and a.day=c.day(+) and ((c.AcLat Between b.lat_min And b.lat_max) AND (c.AcLon Between b.lon_min And b.lon_max)) GROUP BY b.Rect, b.lat, b.lon, b.Area_sqnmi order by b.rect

Select all data from a table	Records in database, overview
Select * from <tablename>	Select a.country,a.year,a.vessel,a.cruise,a.log,b.catch,c.bio,d.hydr,e.acoustic,f.acousticval,g.pl from (select country,year,vessel,cruise,count(station)LOG from logbook group by country,year,vessel,cruise order by country,year,vessel,cruise) a, (select country,year,cruise,count(station)catch from catch group by country,year,cruise order by country,year,cruise) b, (select country,year,cruise,count(station)bio from biology group by country,year,cruise)c, (select country,year,cruise,count(station)hydr from hydrography group by country,year,cruise)d, (select country,year,cruise,count(log) acoustic from acoustic group by country,year,cruise) e, (select country,year,cruise,count(log) acousticval from acousticvalues group by country,year,cruise) f, (select country,year,cruise,count(station) pl from plankton group by country,year,cruise) g where a.country=b.country (+)and a.year=b.year(+) and a.cruise=b.cruise(+) and a.country=c.country(+) and a.year=c.year(+) and a.cruise=c.cruise(+) and a.country=d.country(+) and a.year=d.year(+) and a.cruise=d.cruise(+) and a.country=e.country(+) and a.year=e.year(+) and a.cruise=e.cruise(+) and a.country=f.country(+) and a.year=f.year(+) and a.cruise=f.cruise(+) and a.country=g.country(+) and a.year=g.year(+) and a.cruise=g.cruise(+) order by a.country,a.year,a.vessel,a.cruise

New sub headings

1) Survey objectives
2) Survey design and area coverage
3) Data collection
    - Acoustic
    - Biological
    - Hydrographic
    - Etc. etc.
4) Analysis
5) Shortfalls
6) Reporting