FSS Survey Series: 2017/03

Western European Shelf Pelagic Acoustic Survey (WESPAS)

06 June – 21 July, 2017

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Table of Contents

1 Introduction **4**

2 Materials and Methods **5**

2.1 Scientific Personnel 5
2.2 Survey Plan 5
2.2.1 Survey objectives 5
2.2.2 Survey design and area coverage 6
2.3 Fisheries acoustics 6
2.3.1 EK60 Calibration 6
2.3.2 Acoustic array 6
2.3.3 Acoustic data acquisition 7
2.3.4 Echogram scrutinisation 7
2.3.5 Calculation of acoustic abundance 8
2.4 Biological sampling 8
2.4.1 Herring stock identification 8
2.5 Physical Oceanography data collection 8
2.5.1 CTD casts and water sampling 9
2.5.2 CDOM filtration and measurement 9
2.5.3 Pico/nano plankton sampling 9
2.1 Zooplankton sampling 9
2.2 Marine mammal and seabird surveys 10
2.2.1 Marine mammal abundance and distribution 10
2.2.2 Seabird abundance and distribution 11

3 Results **13**

3.1 Malin Shelf herring (6aS, 7b, c and 6aN south of 58°30'N) 13
3.1.1 Biomass and abundance 13
3.1.2 Stock distribution 13
3.1.3 Stock composition 14
3.2 Boarfish 14
3.2.1 Biomass and abundance 14
4.2.2 Stock distribution 14
4.2.3 Stock composition 15
4.3 Horse mackerel 15
4.3.1 Biomass and abundance 15
4.3.2 Stock distribution 16
4.3.3 Stock composition 16
4.4 Celtic Sea herring (7g and j) 16
4.4.1 Biomass and abundance 16
4.4.2 Stock distribution 17
4.4.3 Stock composition 17
4.5 Oceanographic sampling 18
4.5.1 CTD sampling 18
4.5.2 CDOM 18
4.5.3 Pico/nano plankton sampling 18
4.1 Zooplankton biomass 19

4.2 Marine mammals and seabirds ... 19
4.2.1 Visual abundance survey ... 19
4.2.2 Seabird abundance and distribution ... 20

Discussion and Conclusions ... 21
4.3 Discussion ... 21
4.4 Conclusions ... 23
4.5 Recommendations ... 23

Acknowledgements ... 24

References ... 25

5 Tables and Figures ... 27

1 Introduction

The WESPAS survey program is the consolidation of two existing survey programs carried out by FEAS. The Malin Shelf herring acoustic survey has been carried out annually since 2008 and reports on the annual abundance of summer feeding aggregations of herring to the west of Scotland and to the north and west of Ireland from 54°N to 58°30'N. The boarfish survey was carried out from 2011 using a chartered fishing vessel and reports on the abundance of spawning aggregations of boarfish from 47°N to 57°N. In 2016 both surveys were combined and carried out onboard the RV *Celtic Explorer* over a 42 day period providing synoptic coverage of shelf waters from 47°N northwards to 58°30'N.

Age stratified relative stock abundance estimates of boarfish, herring and horse mackerel within the survey area were calculated using acoustic data and biological data from trawl sampling. Stock estimates of boarfish and horse mackerel were submitted to the ICES assessment Working Group for Widely Distributed Stocks (WGWIDE) meeting in August 2017. Herring estimates are submitted to the Herring Assessment Working Group (HAWG) meeting in March every year. Survey performance will be reviewed at the ICES Planning Group meeting for International Pelagic Surveys (WGIPS) meeting in January 2018.

2 Materials and Methods

2.1 Scientific Personnel

Leg	CE17009	CE17009	CE17011	CE17011
Dates	06-21 June	21-29 June	4-11 July	11-21 July
Days	15	8	7	10
Start	Galway	AST	Galway	AST
Off	AST	Galway	AST	Dublin
Acou (Chief Sci)	Ciaran O'Donnell	Ciaran O'Donnell	Mike O'Malley	Mike O'Malley
Acou	Turloch Smith	Mike O'Malley	Graham Johnston	Andy Campbell
Acou	John Power	Graham Johnston	John Enright	Brendan O'Hea
Acou	Frankie McDaid	Cormac Nolan	Artur Opanowski	Guillaume Bal
Bio (Deck Sci)	Grainne Ryan	Macin Blaszkowski	Macin Blaszkowski	Eugene Mullins
Bio	Ian Murphy	Dave Tully	Dave Tully	Deirdre Lynch
Bio	Sian Egerton	Sian Egerton	Frankie McDaid	John Power
Bio	Sinead O'Brien	John Enright	Shraveena Venkatesh	Shraveena Venkates
MMO	William Hunt	William Hunt	William Hunt	
MMO	Laurence Manning	Laurence Manning	Catherine O'Sullivan	Catherine O'Sullivar
SBO	Niall Keogh	Niall Keogh		
Zoo/Salps	Aidan Long	Aidan Long	Aidan Long	Aidan Long
Zoo/Salps	Alina Wieczorek	Alina Wieczorek	Grainne Cronin O'Reilly	Grainne Cronin O'R
CDOM +	Monica Mullins	Monica Mullins	Monica Mullins	Monica Mullins
CDOM +	Aedin McAleer	Aedin McAleer	Allan Grassie	Allan Grassie

AST: At-sea-transfer

2.2 Survey Plan

2.2.1 Survey objectives

The primary survey objectives are listed below:

- Collect split-beam acoustic data on boarfish, herring and horse mackerel feeding and spawning aggregations within a pre-determined survey area
- Determine an age stratified estimate of biomass and abundance for the above target species from survey data
- Collect biological samples from directed trawling on fish echotraces to determine age structure and maturity state of target stocks
- Take morphometric and genetic samples of individual herring in 6a/7b, c for stock identification analysis
- Use vertical CTD casts to determine hydrographic conditions and the extent of shelf frontal regions
- Collect plankton samples using dedicated vertical trawls to determine biomass of zooplankton and the spatial extent of areas of concentration

- Carry out visual surveys to determine the abundance and distribution of marine mammals and seabirds (ESAS) and surface litter.
- Use multibeam echosounders (EM2040) collect data on the aggregation morphology and behaviour of small pelagics
- Visual survey for to determine the abundance and distribution of jellyfish. Combined with analysis of trawl and plankton net caught individuals.
- Analysis of water samples to determine the composition and spatial distribution of pico and nano plankton populations, bacteria and CDOM

2.2.2 Survey design and area coverage

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

The survey area was stratified based on acoustic sampling effort strata and geographical stock boundaries. Transect start points were randomised within each stratum. Transect spacing was set at 15 (nautical miles) in open water areas and zig zag transects in the restricted Minch area. High intensity small scale surveys were carried out in specific areas of interest with a transect spacing of 10 nmi. Coverage extended from the 50 m contour to the shelf slope (250 m). An elementary distance sampling unit (EDSU) of 1 nmi was used during the analysis of acoustic data. In total the planned survey covered 5,140 nmi using 66 transects relating to a total area coverage of 73,859 nmi^2.

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

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

2.3 Fisheries acoustics

2.3.1 EK60 Calibration

All frequencies of the Simrad EK60 were calibrated in Dunmanus Bay on June 7 at the start of the survey. Calibration procedure followed methods laid out in Demer *et al.* (2015). The results of the calibration (38 kHz transducer) are provided in Table 1.

2.3.2 Acoustic array

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

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

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

2.3.3 Acoustic data acquisition

Acoustic data were recorded onto the hard-drive of the processing unit. The “RAW files” were logged via a continuous Ethernet connection to the vessels server and the EK60 hard drive as a backup in the event of data loss. In addition, as a further back up a hard copy was stored on an external hard drive. Myriax Echoview® Echolog (Version 8) live viewer was used to display the echogram during data collection to allow the scientists to scroll through echograms noting the locations and depths of fish shoals. A member of the scientific crew monitored the equipment continually. Time and location (GPS position) data was recorded for each transect within each strata. This log was used to monitor the time spent off track during fishing operations and hydrographic stations plus any other important observations.

2.3.4 Echogram scrutinisation

Acoustic data was backed up every 24 hrs and scrutinised using Echoview® (V 8) post processing software.

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

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

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

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

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

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

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

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

2.3.5 Calculation of acoustic abundance

Acoustic data were analysed using the StoX software package recently adopted for WGIPS coordinated surveys (ICES 2016). A description of StoX can be found here: http://www.imr.no/forskning/prosjekter/stox/nb-no. Estimation of abundance from acoustic surveys within StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990).

2.4 Biological sampling

A single pelagic midwater trawl with the dimensions of 85 m in length (LOA) and a fishing circle of 420 m was employed during the survey (Figure 23). Mesh size in the wings was 2.4 m through to 10 cm in the cod-end. The net was fished with a vertical mouth opening of approximately 25 m and was observed using a cable linked Simrad FS70 netsonde. Spread between the trawl doors was monitored using Scanmar distance sensors, all sensors being configured and viewed through a Scanmar Scanbas system.

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

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

2.4.1 Herring stock identification

When possible, a sample of 120 herring (>23cm) are taken for morphometric and genetic analysis. These fish are processed according to SGHERWAY procedures (ICES 2010).

2.5 Physical Oceanography data collection

Oceanographic stations were carried out during the survey at predetermined locations along the survey track using a calibrated SeaBird 911 rosette sampler. Data were collected from 1 m subsurface and 3-5 m above the seabed.

2.5.1 CTD casts and water sampling

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

2.5.2 CDOM filtration and measurement

Samples for the analysis of CDOM content and light absorption characteristics were collected via a filtration system. This method employed a WatsonMarlow 323 peristaltic pump to pull raw seawater samples through a 0.2 um micro pore filter in order to obtain a sample containing only dissolved compounds. These filtered samples were first sub sampled for optical analysis and the remainder was retained in a -200 °C freezer for further optical analysis at the lab. The optical experiment carried out on board determined the light absorption properties of CDOM in each sample. An absorption spectrum of the CDOM present in individual samples was obtained by using an Ocean Optics USB 4000 spectrophotometer coupled with a 1 m liquid wave guide capillary cell (LWCC), supplied by World Precision Instruments, and aa Ocean Optics DH-mini light source.

2.5.3 Pico/nano plankton sampling

An Accuri C6 flow cytometer was used to analyse raw and treated seawater samples to determine the presence and abundance of a number of species of micro planktonic organisms. This instrument employs a combination of the fluorescence and light scattering characteristics of the organisms present to identify and count the populations of the distinct species in each sample. A 2 ml vial of each sample is required for processing. Three duplicate samples of the raw seawater from each depth were processed by the flow cytometer. Firstly an untreated raw sample was processed. Secondly a sample that was treated with a Lysotracker and thirdly a sample that had been fixed with Gluteraldehyde and treated with a DNA staining substance called Sybergreen. Both the Lysotracker and Sybergreen have distinct fluorescence characteristics that help to discriminating between the different organisms in the samples.

2.1 Zooplankton sampling

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

Single tow stations samples were split in 50:50 for wet and dry processing. Sample splitting was carried out using a plankton sample splitter. The wet component was fixed for further analysis back at the lab. Fixing was carried using a 4% fix volume of buffered formalin. For replicate stations one sample was fixed in its entirety and the second was processed for dry weight.

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

2.2 Marine mammal and seabird surveys

2.2.1 Marine mammal abundance and distribution

Three marine mammal observers (MMOs) participated in the survey. Two MMOs were on-board from 06/06/17-29/06/17, two MMOs were on-board from 4/07/17-11/07/17 and one MMO was on-board from 11/07/17-21/07/17.

Cetacean watches were conducted using a standard single platform line transect survey design. Visual watches were undertaken from the vessel's crow's nest, located 17m above sea level (when conditions allowed), during daylight hours. In times of deteriorating weather, observations were carried out from the monkey island (15m above sea level) and the bridge (10m above sea level).

Between 06/06/17-29/06/17 continuous cetacean survey effort commenced every day at 06:00 local time and concluded at 18:00 local time, between 4/07/17-11/07/17 continuous effort commenced at 06:00 local time and concluded at 18:30 local time, and between 11/07/17-21/07/17 effort commenced at 08:00 local time and concluded at 20:00 local time. To prevent MMO fatigue and to optimise the validity of the data, survey effort was carried out in two-hour shifts.

Survey effort was concentrated in periods of sea state 6 or less and in moderate or good visibility. Survey effort conducted outside of these parameters was recorded as auxiliary effort. Survey effort for cetaceans was concentrated within an arc of 60o either side (i.e., to port and to starboard) of the vessel's track-line but all sightings to 90o both side of the track-line and further aft was also recorded. Searching for cetaceans was predominantly done with the naked eye, however, Nikon Prostaff 7s 8x42 binoculars and a Canon EOS100 DSLR camera with a 70-300mm zoom lens was used to confirm parameters such as species identification, group size and behaviour. Survey effort was also carried out during hauls and when at CTD stations. Survey effort was postponed during periods of poor weather.

The IFAW Logger 2000™ (IFAW, 2000) data collection software was used to record all positional, environmental and sightings (including position of sightings) data.

Using a portable GPS receiver with a USB connection, the Logger software automatically recorded the ships position directly into a Microsoft Access database every 10 seconds.

Input of environmental data was recorded at least every 30 minutes and sooner if there was a change in environmental conditions. The MMO inputted data regarding wind speed, wind direction, sea state, swell, visibility, cloud cover and precipitation. All data entry was time stamped by Logger and saved in the Access database.

The distance of each sighting from the ship was estimated using a fixed interval range finder, while the bearing from the ship was estimated with an angle board. This data, along with data such as species identification, group size, composition, heading, sighting cues, surfacing interval, behaviour and any associations with birds or other cetaceans was also recorded on the time stamped Logger sighting record page.

Where species identification could not be confirmed, sightings were recorded at an appropriate taxonomic/confidence level (i.e. probable, possible, unidentified whale, unidentified dolphin etc.). Recordings of sightings were aided with the use of a handheld audio voice recorder.

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

2.2.2 Seabird abundance and distribution

Surveys of seabirds at sea were conducted from the R.V. *Celtic Explorer* across seventeen days between 9th and 28th June 2017. While on transect, the ship travelled at an average speed of 10 knots, except when increased swell prohibited this. A standardised line transect method with sub-bands to allow correction for species detection bias and 'snapshots' to account for flying birds was used (following recommendations of Tasker et al. 1984; Komdeur et al. 1992; Camphuysen et al. 2004), as outlined below.

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

The seabird observation platform was the monkey island, which is 12m above the waterline and provided a good view of the survey area. The survey area was defined as a 300m wide band operated on one side (in a 90˚ arc from the bow) and 300m ahead of the ship. This survey band was sub-divided (A = 0-50m from the ship, B = 50-100m, C = 100-200m, D = 200-300m, E = >300m) to subsequently allow correction of species differences in detection probability with distance from the observer. A fixed-interval range finder (Heinemann 1981) was used to check distance estimates for birds sitting on the water or those flying birds which were recorded during 'snapshot' counts. The area was scanned by eye, with binoculars used only to confirm species identification or count the number of birds present in a flock. All birds seen within the survey area were counted, and those recorded sitting on the water in survey bands A to D noted as 'in transect'. All flying birds within the survey area were also noted, but only those recorded during a 'snapshot' were regarded as 'in transect'. This method avoids overestimating bird numbers in flight (Tasker et al. 1984). The frequency of the snapshot scan was ship-speed dependent, such that they were timed to occur when the ship passed from one survey area to the next (every 300m). Any bird recorded within the survey area that was regarded as being associated with the survey vessel was noted as such (to be excluded from abundance and density calculations). Survey time intervals were set at one minute. Additional bird species observed outside the survey area or ad hoc counts of birds not occurring in the survey area were also recorded and added to the database for the research cruise, but are not included in abundance or density analysis.

During the 2017 survey, a series of point counts were made of seabirds associating with the vessel during fishing operations. These began as soon as the towed net began to appear near the surface of the water and finished once the fishing operation was complete, with the net back on board and any surplus fish cleared from the deck. Details such as date, time, location and details of the haul (gross tonnage, species present etc.) were noted for each of these point counts.

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

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

3 Results

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

3.1.1 Biomass and abundance

MS Herring	Abund ('000)	Biomass (t)
TSB estimate	601,804	107,900
SSB estimate	597,076	107,277

The Malin Shelf Herring total stock biomass (TSB) was 107,900 t and total stock numbers (TSN) was 601,804,000. The CV for the survey was 0.45.

The Malin Shelf survey area was divided into 6 strata representing a total area coverage of 23,202 nmi^2 (Figure 2 & Table 5). A breakdown of herring stock abundance and biomass by age, maturity and stratum is detailed in Table 3 and Figures 3 & 4. The Malin Shelf survey time series is provided in Table 4.

3.1.2 Stock distribution

A total of 42 trawl hauls were carried out during the survey (Figure 1), with 3 hauls containing >50% herring by weight of catch within the Malin Shelf survey area (Table 2). A total of 161 echotraces were assigned to herring as compared to 82 in 2016.

Herring were distributed in four out of the six strata (Figure 3). There were no herring allocated to echotraces in both The Minch and West Coast Strata, however very small numbers of herring (<3 individuals) were found in mixed catches in these areas on 3 occasions. It was difficult to allocate any herring to echotraces in these areas due to the extremely low numbers of herring as a percentage of the catch. It is likely that the herring in these areas were not forming schools, but were individuals or in mixed aggregations difficult to separate acoustically. A total of only 72 EDSUs (1 nmi. In length) contained herring in the Malin Shelf survey area. This included a small number of high NASC value EDSUs and was largely responsible for the high CV in the survey. Herring were distributed in areas similar to 2016, with areas of high density occurring to the west of the Hebrides (West of the Flannan Isles) and the western Stanton Banks area (Figure 3). The area covered by the RV Celtic Explorer was similar to the 2016 survey. The area of 6aN to the north of 58°30'N was again covered by RV Scotia in 2017; the overall estimate of the survey for the stock assessment of herring in 6a will therefore be complete when both surveys are combined during WGIPS 2018. Herring were found slightly further south than in 2016. Herring schools were predominantly located in close proximity to the seabed (Figure 11i). Overall the bulk of the stock was located north of 55˚N, similar to the survey last year (2016), as a consequence, the stock was clustered into a relatively small area of 6a (Figure 3). The seasonal distribution of herring during the survey period is most commonly observed in 3 particular regions; north of 57°N (west of the Hebrides), between 56-57°N (south and west of Barra Head) and south of 56°N (north and west of Donegal). No herring were observed south of the 55°N line of latitude in 2017 and is unusual for herring at this time of year based on observations up to and including 2015.

3.1.3 Stock composition

A total of 200 herring were aged from survey samples in addition to 1,262 length measurements and 605 length-weights recorded. Herring age samples ranged from 2-9 year olds (Table 3 & Figure 4). A further 360 herring were processed for morphometric and genetic analysis under SGHERWAY protocols (ICES 2010) in 2017; from hauls 36, 37 and 39.

Three year old herring dominated the 2017 survey estimate representing over 43% of TSB and 45% of TSN (Table 3). Four year old herring were ranked second representing 18% of TSB and 18% of TSN. The third most dominate age group was six year olds contributing 17% to the TSB and 16% to TSN. Combined these three age classes represented 78% of TSB and 80% of TSN

Maturity analysis of herring samples indicated overall 99% of fish were mature. Maturity analysis by age class showed that 95% of 2 year old fish, 99% of 3 year old fish, and 99% of 4 year olds were mature, rising to 100% of fish of five years and older (Table 3).

3.2 Boarfish

3.2.1 Biomass and abundance

Boarfish	Abund ('000)	Biomass (t)
TSB estimate	4,387,487	223,860
SSB estimate	4,085,881	218,810

Boarfish TSB (total stock biomass) and abundance (TSN) estimates were 223,860.1 t and 4,387,487,000 individuals (CV 21.9 %) respectively.

The boarfish survey area was divided into 5 strata representing a total area coverage of 55,036 nmi^2 (Figure 2). A breakdown of boarfish stock abundance and biomass by age, maturity and stratum is detailed in Table 6 & 7 and Figures 5 & 6. The boarfish survey time series is provided in Table 8.

4.2.2 Stock distribution

A total of 42 trawl hauls were carried out during the survey (Figure 1), with 14 hauls containing >50% boarfish (Table 2).

A total of 1,116 echotraces were assigned to boarfish as compared to 394 in 2016. Boarfish were observed in all survey strata (Table 7). The highest occurrence was in the Celtic Sea (stratum 3) where over 63% of the total survey biomass was observed. Within stratum 3 the highest density of fish was observed in the southern survey area, south of 50°N (Figure 9b). This pattern of distribution is similar to previous years but the number of schools was larger and the mean acoustic density greater than in 2016 (Figure 5). The west coast stratum contained the second largest biomass of 24.8% and again followed the previously observed pattern of abundance. The shelf area between 53-54°N increasingly appears to be a favoured area over recent years to match that in the southwest (between 51-52°N). Distribution on the Porcupine Bank (strata 4) was wider than in previous years and for the first time in the time series (2011-2017) boarfish were observed in number on the eastern slopes of the Bank (Figure 9d). The distribution of boarfish to the northwest and north of Ireland were predominantly restricted to the shelf edge (<180m). The northern extension of the stock as observed during the survey would indicate that containment is achieved in this regard. Shelf areas to the south of 56°N remain and important and consistent contributor to the overall biomass. This is especially true due to the dominance of the older, larger fish in these strata that appear to favour these northern latitudes (Figure 6). However, the overall contribution in terms of biomass was somewhat reduced in 2017 due to the large increase in biomass in the Celtic Sea. Juvenile boarfish were observed in low numbers overall and mostly in the mid Celtic Sea area (Figure 9a)

4.2.3 Stock composition

A total of 859 boarfish were aged from survey samples in addition to 4,495 length measurements and 2,543 length-weights recorded. Boarfish age samples ranged from 1-15+ years (Table 6 & Figure 6). Age structure of the stock was determined using an established age length key.

The 15+ year age class group continues to dominate the boarfish time series contributing over 32.6% of TSB and 21.2% of TSN of the 2017 estimate (Table 6). Seven and eight year fish were ranked second and third respectively representing over 10% of TSB and 11% of TSN each to the overall biomass. The fourth ranked group was the nine year olds 9.3% to the TSB and 9.1% to TSN. Combined, the 7, 8 and 9 year age classes represent 29.6% of TSB and 31% of TSN

Maturity analysis of boarfish samples indicated 97.7% of observed biomass was composed of mature individuals (93.1 % for abundance). Maturity analysis by age class showed that 79% of 3 year old fish were mature, rising to 100% for fish eight years and older (Table 6).

4.3 Horse mackerel

4.3.1 Biomass and abundance

Horse mackerel	Abund ('000)	Biomass (t)
TSB estimate	969,655.0	228,115.8
SSB estimate	953,516.0	227,395.6

Horse mackerel TSB (total stock biomass) and abundance (TSN) estimates were 228,116 t and 969,655,000 individuals (CV 25.5%) respectively.

The horse mackerel survey area was divided into 7 strata using a similar geographical footprint as the boarfish survey area of 57,826 nmi^2 including an extension of coverage to include a spawning aggregation in the Minch (strata 1 – HERAS survey) as shown in Figure 2. A breakdown of horse mackerel stock abundance and biomass by age, maturity and stratum is detailed in Tables 9 & 10 and Figures 7 & 8.

4.3.2 Stock distribution

A total of 42 trawl hauls were carried out during the survey (Figure 1), with 4 hauls containing >50% horse mackerel out of 20 containing horse mackerel overall (Table 2).

A total of 480 echotraces were assigned to horse mackerel. Horse mackerel were widely distributed throughout the survey area in all but two of seven strata. The northern most strata yielded no horse mackerel and this is somewhat consistent with 2016 (Figure 7). The exceptions in 2017 were observations in north of 55°N and most notably an active spawning aggregation in the southern Minch (Figure 9f), the latter contributing over 56,000 t (24.7%) to the TSB (Table 10).

Observations of horse mackerel along the west coast were comparable to 2016 in terms of distribution but the number and overall acoustic density of assigned schools was higher. The west coast stratum produced 72,300 t in 2017, contributing 31.7% to the TSB. Schools of horse mackerel were frequently observed on the seabed and most often over a rocky substrate and along the west coast were often observed in areas containing boarfish.

Small amounts of horse mackerel were observed on the Porcupine Bank and this distribution of abundance is similar to 2016. In the Celtic Sea distribution was more widely dispersed with a low number of schools spread over a large area (Figure 9c).

4.3.3 Stock composition

A total of 618 horse mackerel were aged from survey samples in addition to 1,807 length measurements and 392 length-weights recorded. Horse mackerel age samples ranged from 1-16 years (Table 9 & Figure 8). Age structure of the stock was determined using a combination of aged otoliths and an age length key from commercial landings data.

The 14 year age class dominated the 2017 horse mackerel survey estimate representing over 25.7% of TSB and 16.6% of TSN (Table 9). This can largely be attributed to the large contribution of the Minch active spawning aggregation. The 7 year age class ranked second representing over 13.7% of TSB and 11.6% of TSN (Table 9). Eight year old fish were ranked third contributing 8.1% to TSB and 7.0% to TSN. Combined these three age classes represented 47.5% of TSB and 35.2% of TSN.

Maturity analysis of horse mackerel samples indicated 99.7% of the TSB was mature. Maturity analysis by age class showed that 98% of 2 year old fish were mature, rising to 100% for fish three years and older (Table 9).

4.4 Celtic Sea herring (7g and j)

4.4.1 Biomass and abundance

CS Herring	Abund ('000)	Biomass (t)
Total stock	758,146.0	107,338.4
Spawning stock	683,537.0	99,505

The estimate of Celtic Sea herring TSB (total stock biomass) and abundance (TSN) estimates were 107,338.4 t and 785,146,000 individuals (CV 28%) respectively. However, this estimate is not considered accurate and should not be used for stock assessment purposes. The high estimate, as compared to the Q4 survey, is related more to the calculation method than the true stock abundance. This was the first time this stock was assessed in detail during the summer and methods will be further refined to increase the precision of future estimates.

The CS herring survey area was divided into 3 strata, one broadscale (S1: Celtic Sea) and two high intensity (S2: NW bank and S3: Celtic Deep). The former represented an area of over 27,600 nmi², whereas the high intensity strata focused on areas in the region 1,000-2,000 nmi². Combined effort accounted for 30,500 nmi² (Figure 2). A breakdown of CS herring stock abundance and biomass by age, maturity and stratum is detailed in Tables 12 & 13 and Figures 9 & 10.

4.4.2 Stock distribution

CS herring were observed in two regions during the survey; the first was in the western Celtic Sea and is thought to be a component of the stock which spawns along the southwest coast. The presence of this fish is important in that during the period of the survey times series (2011-present) no herring have previously been observed. The second area of herring was determined using focused survey effort once herring were detected. A high intensity survey pattern was initiated to survey the scope of the aggregations. This cluster was considered a component of the stock which spawns along the south coast in the mid and eastern region. This component has been the focus of survey effort in Q4 due to recent changes in distribution and behaviour (O'Donnell *et al*, 2016) and tracking the location of summer feeding grounds is an important part of this process.

A small amount of herring was observed in the southern survey, occurring as a bycatch. However, there were insufficient amounts, both acoustically and biologically to produce a reliable estimate of abundance. It is also likely that these specific fish were part of the either UK or French origin spawners due to their southern location (Haul 06, 49°N, Figure 1, Table 2) and not part of the focal Celtic Sea stock.

4.4.3 Stock composition

A total of 52 CS herring were aged from survey samples in addition to 391 length measurements and 250 length-weights recorded. CS Herring age samples ranged from 1-8 years (Table 12 & 13 and Figure 10). Age structure of the stock was determined from aged otoliths.

The three and six year age classes dominated the estimate (Table 12). However, this estimate of abundance is not considered reliable and should be treated with a high degree of caution due to the previously explained reasons. A single trawl sample was used to determine the age structure of the overall estimate and would further decrease the reliability of the estimate.

Maturity analysis indicated 92% of the TSB was mature.

4.5 Oceanographic sampling

4.5.1 CTD sampling

In total 86 CTD casts were carried out (Figure 12). Horizontal temperature and salinity maps for the survey area are provided for depths 5 m, 20, 40 and 60 m in Figures 13-16 respectively.

Hydrographic conditions encountered during the survey showed the influence of warmer waters at the surface further south and cooler waters further north as would be expected during the summer months. Surface waters in the Celtic Sea were dominated by warm surface pool and this was likely influenced by good weather encountered when sampling occurred. Coastal margins saw reduced salinity due to the influence of riverine inputs. Using salinity as a boundary indicator, the Irish Shelf front was evident through all depth channels at around 11°W (Figures 13-16).

Below the thermocline (35-55m) and at the seabed (Figures 17 & 18) the dominant feature is the cooler water in the Celtic Sea, west coast and Porcupine Bank area. Herring were most frequently encountered below the thermocline and when positional data is overlaid with herring data (Figure 17) it is evident that herring have a preference for the cooler regions.

For boarfish thermal preference appears as important as salinity (Figure 18). The greatest density of boarfish is aligned with full strength seawater and off the west coast this occurs on the oceanic side of the Irish Shelf Front. The pattern of distribution changes relative to temperature and depth along the west coast and Porcupine Bank where boarfish take a midwater position below the thermocline.

Horse mackerel (Figure 19) distribution is not as easily determined relative to temperature and salinity data. That said, a large and active spawning aggregation was sampled in the southern Minch in relatively warm and low saline area. Further south, distribution of the bulk of the stock appeared to be more related to depth than ambient conditions. As horse mackerel migrated to the surface at night to feed feeding opportunity is also an important consideration.

4.5.2 CDOM

CDOM sampling was undertaken at all of the 86 oceanographic stations during the survey. Analysis of samples is currently underway.

4.5.3 Pico/nano plankton sampling

Sampling of pico and nano plankton communities was carried out at all of the 86 oceanographic stations during the survey. The software that controls the Accuri C6 flow cytometer is able to graphically display the optical and physical characteristics of the organisms present in any sample. The forward scattering of incident light gives an indication on the size of an organism whereas the side scatter of the light relates to the shape of that particular organism. The three fluorescence sensors are set to respond to different colours of fluorescence, orange, green and red, and help to differentiate between the photosynthetic pigments that are unique to the individual species of plankton that are being studied. Further analysis is currently on-going.

4.1 Zooplankton biomass

Plankton samples were collected at 83 stations during the survey. Species composition analysis is currently underway using chemically fixed samples. Dry weight biomass for zooplankton on a per station basis is shown in Figure 18.

Zooplankton biomass (dry weight) by station was higher overall than compared to the same time in 2016 (Figure 18). Zooplankton distribution, as determined from dry weight analysis, showed a relatively uniform distribution throughout the survey with little sign of the spatial patchiness observed in 2016. This defined difference between years is difficult to explain over such a short sampling time frame (2 successive years) but given the sampling effort and intensity this has the potential to provide important information on plankton distribution that was previous lacking.

4.2 Marine mammals and seabirds

4.2.1 Visual abundance survey

In total, 343 hours and 38 minutes of survey effort was conducted over the entire survey. Environmental data was collected a total of 1,096 times during the survey.

In total, 155 marine mammal sightings, consisting of 1307 individuals, were recorded throughout the survey. This accounts for sightings both on and off effort. The sightings included; three whale species, four dolphin species, one porpoise species, two seal species, unidentified large baleen whale sightings, unidentified whale sightings, unidentified cetacean sightings, unidentified dolphin sightings and unidentified seal sightings. A list of the species encountered can be seen in Table 14, and the distribution of the sightings can be seen in Figures 21 and 22.

Common dolphins (Delphinus delphis) were the most frequently encountered and abundant species observed making up 43% of all sightings, and 75% of all individuals counted. Altogether, there were 66 sightings of common dolphins which consisted of 979 individuals. Large numbers of common dolphins were recorded on two occasions; one of which consisted of approximately 200 dolphins and the other of approximately 100 dolphins.

Minke whales (Balaenoptera acutorostrata) were the second most frequently observed species, accounting for 14% of all sightings, with 22 sightings consisting of 25 individuals. Unidentified dolphin species were the second most abundant encounter, accounting for 11% of all individuals counted (142 individuals).Three orcas (Orcinus orca) were observed off the west of Ireland. The pod included a mother, juvenile and a calf. The orcas were observed leaping and breaching. Humpback whales (Megaptera novaeangliae) were seen twice off the west coast of Ireland. On one of these occasions two whales were observed feeding along with numerous diving gannets and common dolphins. On one occasion, a harbour porpoise was observed breaching four times swimming away from the vessel. In the Outer Hebrides a dead, fresh looking, harbour porpoise was seen floating at the water surface.

In addition to the above, 16 auxiliary sightings were reported by crew members to the MMOs including; one whale species, three dolphin species, one porpoise species, an unidentified dolphin species and an unidentified seal species. Unfortunately the MMOs did not get the opportunity to observe these sightings; therefore they have not been included in the analysis. The distribution of these sightings can be seen in Figure 21.

Five species of other marine mega fauna were recorded during the survey which included; one turtle species and four fish species (3 of which were shark species). One sighting of an unidentified fish species and four sightings of unidentified shark species were also logged. In total, 35 individuals were observed. A list of the species encountered can be seen in Table 2.

On one occasion, off the north-eastern coast of Northern Ireland, a thresher shark was observed breaching three times at a height of between 1-2m.

Further to the above, two auxiliary sightings were reported by crew members to the MMOs (which the MMOs did not detect) including one sighting of an ocean sunfish and one of an unidentified shark.

The distribution of all of the marine mega fauna sightings can be seen in Figure 22.

4.2.2 Seabird abundance and distribution

A total of 95 hours and 51 minutes (5751 minutes) of dedicated seabird surveys was conducted across seventeen days between 9th and 28th June 2017. Inclement weather conditions meant that casual observations only were conducted on 23rd and 27th June while no surveys were conducted on 7th, 8th or 26th June. A total of fourteen point counts were made during fishing tow operations during the survey.

A cumulative total of 11,311 individual seabirds of 23 species was recorded, of which 2762 were noted as ‘off survey’ (outside of dedicated survey time or associating with the vessel, including during fishing operations point counts) and as such will be excluded from future analysis of abundance and density.

A synopsis of daily totals for all seabird species recorded is presented in Table 13. In addition, daily totals for six species of migrant terrestrial birds recorded on or around the vessel are also presented (Table 14).

Discussion and Conclusions

4.3 Discussion

The objectives of the survey were carried out successfully and as planned. The survey area was similar to 2016. The area of 6aN to the north of 58°30'N was covered by the RV Scotia in 2017 and the results for this survey will be combined with results from the RV Celtic Explorer to determine a complete estimate for herring in 6a. Good weather conditions dominated for the majority of the survey allowing for extended marine mammal and seabird survey effort. Good weather also afforded time for the deployment of static moorings as part of a herring spawning migration study. Overall, weather induced downtime amounted to just 12 hours over the 42 day survey period.

Malin Shelf herring distribution was concentrated in an area to the west of the Hebrides in 6aN and in the western Stanton Bank area (Figure 3). There were no herring observed south of 55°N in 6aS or 7b, c. This was similar to 2016, but this was not the case in years previous to that. The age profile of survey samples in 2017 is interesting; 3 year old herring dominated the stock (43% in terms of biomass, and 45% in terms of abundance). In 2016, there was a much more even distribution of year classes. The CV estimate for the survey is high in 2017 (45%); this is expected because of the few echotraces observed (161) and the patchy distribution of herring in general within the survey area.

The distribution of boarfish was comparable to 2016 and earlier years in the recent time series. Acoustic density and number of echotraces assigned to boarfish was much higher than observed in 2016 and more in line with 2015, making last year's estimate standout as an outlier rather than qualifying a trend. Trawling and acoustic sampling effort were comparable to 2016. The exception was that the survey rotation and therefore timing was earlier. In 2017 the survey started in the south and worked north, in opposition to previous years. In reality this meant a temporal mismatch of 6 weeks. Boarfish were found to the east of the Porcupine Bank for the first time since 2011. The dominate cohorts within the stock were visible in the estimate and a high degree of trawl sampling was undertaken to ensure representative sampling of the population in all strata was achieved. A CV of 21.9% on the abundance estimate provides a high degree of confidence in the estimate.

Horse mackerel were distributed in comparable regions along the Irish west coast and Porcupine Bank. Significantly a large aggregation of active spawning fish was observed in the southern Minch and this contributed significantly to the overall biomass and the age profile of the stock. The abundance of horse mackerel in the Celtic Sea was much higher than observed in 2016. It is difficult to say if the increase in biomass observed between years was a consequence the change in survey timing or annual variation between acoustically derived estimates. More years are required in the time series to determine any trend. This survey will continue to provide a relative abundance estimate for horse and paired with survey in the Bay of Biscay has the potential to provide a measure of the stock over a large geographical area.

A summer Celtic Sea herring survey was carried out for the first time in 2017. Coverage during previous years (2011-2016) had not encountered any feeding aggregations to the west of 7°W. However, this year a small amount of herring from the southwest spawning component was observed. Additional survey time was re-allocated to allow for a more detailed survey of feeding grounds in the eastern Celtic Sea. This additional survey coverage yielded herring. However, the estimates are not considered realistic due to the low number of trawl samples (n=1) and constraints of the calculation methods. However, this will be addressed in coming surveys in a bid to provide an additional estimate of abundance for a key component of this stock.

Hydrographic conditions in surface waters were as to be expected during the summer months with warmer waters dominating more southern latitudes and well stratified water masses with a strong thermocline. Thermocline depth ranged from 35-55m depending on location. The conditions encountered during the survey are comparable with those observed in 2016. The only notable difference was the northerly limit of warmer Atlantic water. In 2016, temperature plots taken at 50 m (below the thermocline) showed a northerly limit equal to the southern Porcupine Bank (53°N) and Porcupine Sea Bight. In 2017, warmer waters (>12°C) extended to 59°N and covering shelf waters.

4.4 Conclusions

- Malin Shelf herring biomass was higher in 2017 compared to 2016 (SSB_{2017} = 107,277 t). However, the CV on the survey is high (45%) due to the localised distribution of herring in only a few areas.
- Malin Shelf herring TSB (total stock biomass) and abundance (TSN) estimates were 107,900 t and 601,804,000 individuals respectively.
- Herring were distributed a little further south in 2017 compared to 2016, however, no herring were observed south of 55°N. This was similar to 2016 where no herring were observed south of 56°N.
- The dominant age class in the 2017 survey was 3 year olds (43% TSB, and 45% TSN).
- The three most dominant year classes were 3, 4 and 6 year old fish and together represented over 78% of the TSB in 2017.
- Boarfish distribution showed a similar pattern to previous years. The number of schools and acoustic density was higher than in 2016 and more comparable to 2015 and the recent time series.
- Boarfish TSB (total stock biomass) and abundance (TSN) estimates were 230,062 t and 4,387,487,000 individuals (CV 21.9%) respectively.
- The order of survey direction was switched in 2017 compared to previous years in the time series. This led to a temporal difference of around 6 weeks compared to the previous years. It is not possible to quantify the impact if any this has had on the abundance estimates. This considered 2017 estimate of boarfish is considered as robust and this is reflected by the low CV (21.9%).
- Horse mackerel estimate is considered as reliable accounting for the large increase from first observation in 2016. The presence of increased amounts of fish in the Celtic Sea and the occurrence of an active spawning aggregation in the southern Minch reflect the importance of this survey as an alternative measure of the stock.
- Horse mackerel TSB (total stock biomass) and abundance (TSN) estimates were 228,116 t and 969,655,000 individuals (CV 25.5%) respectively.
- The estimate of Celtic Sea herring abundance is not considered reliable and should not be used for stock assessment purposes. However, it is intended that this will be further developed in 2018 to provide an additional measure of this stock.

4.5 Recommendations

- In 2018 continue to work from south to north as this provides opportunity to align with surveys in the south (PELGAS- France) and north (HERAS- Scotland) and provide synoptic estimates of abundance for a multiple species.
- In 2018 that zooplankton sampling be continued and developed after a successful pilot in 2016.

- Research the possibility of egg counts from plankton samples (WP2) as a means to track spawning, and peak spawning events by geographic region for boarfish and horse mackerel.
- Survey continues to report on horse mackerel acoustic abundance for the development of a wider area index. Linking with the PELGAS survey through WGACEGG provides an opportunity for both boarfish and horse mackerel in this regard.
- To further develop this survey more ship-time is required. As the survey is observing not only target species for the focal component but also the distribution of other species that are also surveyed during the year, specifically Celtic Sea herring.

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5 Tables and Figures

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

Echo Sounder System Calibration Report

Vessel :	RV Celtic Explorer		Date :	07.06.17	
Echo sounder :	Drop Keel		Locality :	Dunmanus Bay	
Type of Sphere :	CU 64	TS_{Sphere}:	-33.50 dB	Depth(Sea floor) :	33 m

Calibration Version 2.1.0.12

Comments:
Weather conditions good

Reference Target:

TS	-33.52 dB	Min. Distance	18.0m
TS Deviation	5 dB	Max. Distance	22.0m

Transducer: ES38B Serial No.

Frequency	38000 Hz	Beamtype	Split
Gain	26.50 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	7.10 deg	Along. Beam Angle	7.10 deg
Athw. Offset Angle	0.00 deg	Along. Offset Angl	0.00 deg
SaCorrection	0.00 dB	Depth	8.80 m

Transceiver: GPT 38 kHz 009072033933 1 ES38B

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

Sounder Type:
ER60 Version 2.4.3

TS Detection:

Min. Value	-50.0 dB	Min. Spacing	100%
Max. Beam Comp.	6.0 dB	Min. Echolength	80%
Max. Phase Dev.	8	Max. Echolength	180%

Environment:

Absorption Coeff.	9.0 dB/km	Sound Velocity	1493.9 m/s

Beam Model results:

Transducer Gain =	25.47 dB	SaCorrection =	-0.66 dB
Athw. Beam Angle =	6.96 deg	Along. Beam Angle	6.83 deg
Athw. Offset Angle =	-0.07 deg	Along. Offset Angl	-0.02 deg

Data deviation from beam model:

RMS = 0.18 dB
Max = 0.39 dB No. = 141 Athw. = 1.8 deg Along = 3.8 deg
Min = -0.81 dB No. = 345 Athw. = 2.4 deg Along = -4.5 deg

Data deviation from polynomial model:

RMS = 0.12 dB
Max = 0.42 dB No. = 349 Athw. = 3.5 deg Along = -3.4 deg
Min = -0.52 dB No. = 332 Athw. = -0.6 deg Along = -4.7 deg

Comments :
SE wind F3, strong tide

Wind Force : F3 **Wind Direction :** SE

Raw Data File: C:\Program files\Simrad\Scientific\EK60\Data\Calibration\WESPAS 2017\Drop Keel

Calibration File: C:\Program files\Simrad\Scientific\EK60\Data\Calibration\WESPAS 2017\Drop Keel

Calibration : Ciaran O'Donnell

Table 2. Catch table from directed trawl hauls.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target btm (m)	Bulk Catch (Kg)	Boarfish %	Mackerel %	Herring %	H Mack %	Others^ %
1	09.06.17	47.66	-7.17	08:00	158	0-45	1,200	98.6	0.3		0.9	0.2
2	10.06.17	48.17	-7.88	11:55	183	20-45	124	98.0		0.5	1.4	0.1
3	10.06.17	48.18	-7.17	16:28	164	124	1,000	45.3	4.3		50.1	0.3
4	11.06.17	48.42	-8.50	14:30	163	0-50	3,500	98.6	0.4		0.9	0.1
5	11.06.17	48.42	-9.19	19:25	161	0-35	1,200	0.1	0.1		99.6	0.1
6	12.06.17	48.94	-7.57	16:45	120	0-15	2,000	99.4		0.2	0.4	0.1
7	13.06.17	48.94	-9.82	08:58	161	0-25	92	91.2	8.0			0.8
8	13.06.17	49.20	10.85	18:20	164	0-75	1,000	90.9	0.8		0.6	7.8
9	14.06.17	49.44	-10.59	09:20	144	0-20	600	21.6	2.8		75.7	
10	15.06.17	49.69	-9.99	19:30	123	0-15	119		44.8		48.7	6.5
11	16.07.17	49.94	-9.71	20:38	130	50-80	23		68.7		25.9	5.3
12	17.06.17	50.20	-10.79	09:40	174	0-35	160		1.7		97.2	1.1
13	18.06.17	50.45	-7.54	05:02	102	55-75	1,500		0.8	99.2		
14	19.06.17	50.70	-10.69	11:07	163	0-35	17		75.9	16.5		7.7
15	20.06.17	50.86	-6.42	09:55	92	0-15	24					100.0
16	22.06.17	50.97	-9.68	11:53	122	65	0					
17	22.06.17	50.97	-11.13	19:41	191	80	500	97.0			3.0	
18	23.06.17	51.44	-10.67	13:25	160	150	118	14.3	54.3		20.1	11.3
19	24.06.17	51.94	-10.99	08:00	146	0-20	6,000		1.0			99.0
20	24.06.17	52.39	-10.43	20:21	91	65	32					100.0
21	26.06.17	52.94	-13.55	12:12	210	160	800	100.0				
22	27.06.17	53.45	-13.29	08:34	185	0-30	0					
23	27.06.17	53.45	-13.93	13:01	222	160	92	98.0			2.0	
24	28.06.17	52.69	-10.79	11:15	121	0-45	187		16.9		7.5	75.7
25	05.07.17	53.19	-10.82	15:11	129	0-24	59		1.7			98.3
26	05.07.17	53.44	-11.19	23:10	139	0-40	400	63.7	1.3	0.3	34.3	0.6
27	06.07.17	53.69	-10.84	16:31	152	0-30	21		87.7			12.3
28	07.07.17	53.93	-11.09	06:26	205	100-155	500	69.2	1.8		29.0	
29	08.07.17	54.68	-9.77	06:49	100	0-40	36					100.0
30	08.07.17	54.93	-10.11	15:43	120	0-40	150	100.0				
31	10.07.17	55.68	-7.80	08:17	90	0-30	500		99.6	0.1		0.4
32	10.07.17	55.68	-8.90	14:58	110	40-60	150	93.3	0.3		6.3	0.2
33	12.07.17	56.20	-8.31	10:03	145	0-10	19	0.5	6.0	62.2		31.9
34	13.07.17	56.70	-7.60	07:43	200	170-200	10					100.0
35	13.07.17	56.70	-8.96	16:10	128	0-20	12	88.1		1.6		10.3
36	13.07.17	56.96	-8.59	22:07	135	0-30	64			90.9	2.1	7.0
37	15.07.17	57.71	-8.77	12:52	157	0-30	259		23.5	27.1		49.4
38	15.07.17	57.71	-9.31	17:48	145	0-40	0					
39	17.07.17	58.21	-8.07	06:37	123	0-25	5,000		3.0	97.0		
40	18.07.17	58.55	-5.58	07:58	125	75-125	56					100.0
41	18.07.17	58.34	-5.81	12:50	105	0-50	1,000		0.4	0.2		99.3
42	19.07.17	56.92	-7.16	12:43	147	0-30	1,500		67.4	0.1	30.6	2.0

Table 3. Malin Shelf herring stock estimate 2017 (6aS, 7bc and 6aN (south of 58°30'N).

Length (cm)	Age (years) 1	2	3	4	5	6	7	8	9	10	11	12+	Numbers (*10³)	Biomass ('000 t)	Mean Wt. (g)	Mat (%)
14																
14.5																
15																
15.5																
16																
16.5																
17																
17.5																
18																
18.5																
19																
19.5																
20																
20.5																
21																
21.5																
22																
22.5																
23																
23.5		1855											1855	198.5	107	100
24																
24.5		915	6714										7629	918.4	120.38	88
25		2463	13280										15743	2069.2	131.44	100
25.5		2249	12422	3182									17853	2460.6	137.82	79
26			22434	1296									23730	3520.9	148.37	100
26.5		3492	36772	15649									55913	8794.9	157.3	100
27			59592	16471	1122								77185	12807.9	165.94	100
27.5			70817	5434	3401	394							80046	14126.6	176.48	100
28			27477	36117	19011	3160	445						86211	15656.3	181.6	100
28.5			21225	17243	15886	20032	1432		420				76238	14718.4	193.06	100
29			2676	8252	13369	31290	9533						65118	12908.4	198.23	100
29.5				7321	10478	23609	1958	3771					47137	9535.9	202.3	100
30					8330	5132	11798	4146					29406	6303.3	214.36	100
30.5						9833	2809						12641	2718.9	215.08	100
31						920		1963					2884	620.6	215.22	100
31.5									2215				2215	540.7	244.11	100
TSN (*10³)		10974	273408	110966	71595	94370	27975	9881	2635				601804			
TSB (t)		1427.4	45926.9	19735.6	13761.7	18602	5729.9	2097	619.1					107900		
Mean L (cm)		24.78	26.49	27.27	28.21	28.71	29.07	29.51	30.52							
Mean Wt. (g)		130.08	167.98	177.85	192.22	197.12	204.82	212.22	234.96						178.82	
% Mature		95	99	99	100	100	100	100	100							
SSB (t)		1323	45409	19736	13762	18602	5730	2097	619				597076	107277		

Table 4. Malin Shelf herring survey time series 2008-2017. Survey coverage: - ^ 6aS & 7bc; * 6aS, 6aN & 7b; ** 6a & 7bc; ***6aS, 7bc & 6aN (south of 58°30'N).

Age	2008^	2009^	2010*	2011*	2012*	2013*	2014*	2015**	2016***	2017***
0	-	-	-	-	-	-	-	-	-	-
1	6.1	416.4	524.8	82.1	608.3	-	1115.4	4.93	-	-
2	75.9	81.3	504.3	202.5	451.5	96.2	214.7	162.05	9.73	10.97
3	64.7	11.4	133.3	752	444.6	254.3	166.3	291.68	102.285	273.41
4	38.4	15.1	107.4	381	516.1	265.8	380	580.67	91.445	110.97
5	22.3	7.7	103	110.8	180.3	78.7	352.1	487.25	91.423	71.60
6	26.2	7.1	83.7	124	115.4	26.9	125	513.42	58.193	94.37
7	9.1	7.5	57.6	118.4	116.9	18.5	18.9	143.85	46.488	27.98
8	5	0.4	35.3	70.7	83.8	10.8	9.7	33.37	2.681	9.88
9	3.7	0.9	17.5	41.6	56.3	4.1	4.7	-	0.521	2.64
10+	-	-	-	25.6	42	1.2	-	8.32	-	-
TSN (mil)	251.4	547.7	1,566.9	1,908.7	2,615.0	756.6	2,386.8	2,225.5	402.77	601.804
TSB (t)	44,611	46,460	192,979	313,305	397,797	118,946	294,200	449,343	70,745	107,900
SSB (t)	43,006	20,906	170,154	284,632	325,835	92,700	200,200	425,392	69,270	107,277
CV	34.2	32.2	24.7	22.4	22.8	21.5	28.6	28.6	31.3	45.5

Table 5. Malin Shelf herring spawning stock biomass and abundance by strata 2017

Strata	Name	Area (nmi²)	Transects	Abun ('000)	Bio (t)
1	Minches	2910	8	0	0
2	W Hebrides	2156	2	11,851	2,119
3	SW Hebrides	7027	7	409,496	76,341
4	NW Coast	4680	4	151,700	24,834
5	W Coast	5324	6	0	0
6	N Malin	2951	2	24,029	3,983
	Total	23,202.0	29	597,076	107,277.0

Table 6. Total boarfish stock estimate.

Length	Age (years)															Numbers	Biomass	Mn Wt	Mature
(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	(000's)	(t)	(g)	(%)
6																			
6.5	153.8															24291	153.8	6	0
7	405.1															45987	405.1	9	50
7.5	391.5	547.3														100244	938.8	9	7.69
8		681.6														63338	681.6	11	40
8.5																5453	0	0	0
9		60.7	214													16268	274.7	17	67
9.5			1414.1													70367	1414.1	20	50
10			4059.3													179548	4059.3	23	93
10.5			2071.6	2313.1	43.1											170067	4427.8	26	72.7
11			80.7	7144.5	1661.5											302062	8886.8	29	93
11.5				1031.3	2228.5	4289										233388	7548.9	32	100
12					332.1	1173.6	6193.9	177.5								208171	7877.1	38	93
12.5					141.8	116.8	3479.4	1540.1	323.5	423.1						147428	6024.7	41	100
13					270.1	67.5	388	8268.2	5525.6	320.2						324659	14839.6	46	100
13.5					696.8	1345.3	9685.7	6633.5	4464.8	996.5					158.8	469483	23981.4	51	100
14							1231.5	6090.3	10303.3	9410.6	2756.8				739.2	535801	30531.7	57	100
14.5						1113.9	393.2		186.5	4042.5	2053.6	5233.9	3526	5381.1	8964.6	482189	30895.3	64	100
15							1211.3	240.5		376.3	2616.4	106.1	1384.9	6111.6	19142.5	433504	31189.6	72	100
15.5										1496.9				4159.7	18473.8	299299	24130.3	81	100
16															15865.7	180266	15865.7	88	100
16.5															6103.6	65117	6103.6	94	100
17															3204.6	31889	3204.6	100	100
17.5															306.4	2797	306.4	110	100
18															119.3	1326	119.3	90	100
18.5																			
TSN (1000)	110918	126696	344601	367249	155963	209007	493047	468255	397218	285818	120851	82051	74389	220423	931001	4387487			
TSB (t)	950.4	1289.5	7839.7	10488.9	5374	8106.2	22583.2	22950.2	20803.7	17066	7426.7	5340	4910.9	15652.3	73078.4		223860.1		
Mean length (cm)	7.07	7.79	9.98	10.93	11.59	12.08	12.9	13.34	13.57	14.11	14.45	14.51	14.63	14.93	15.41				
Mean weight (g)	8.57	10.18	22.75	28.56	34.46	38.78	45.8	49.01	52.37	59.71	61.45	65.08	66.02	71.01	78.49			50.27	
% mature*	24	28	79	89	97	99	98	100	100	100	100	100	100	100	100				
SSB	232.7	355.2	6218.5	9378.7	5227.9	8025.1	22155.6	22937.9	20803.7	17066.1	7426.8	5340.0	4910.9	15652.4	73078.5	218810.0			

Table 7. Boarfish biomass and abundance by strata.

Strata	Name	Area (nmi²)	Transects	Abun ('000)	Bio (t)
1	W Hebrides	2,443.3	5	22,394	1,152
2	S Hebrides	1,897.4	4	72,335	5,133
3	W Coast	14,378.5	20	931,853	55,663
4	Porcupine Bk	5,122.1	6	288,657	20,478
5	Celtic Sea	28,905.7	15	3,072,251	141,435
	Total	52,747.1	50	4,387,490	223,860.0

Table 8. Boarfish survey time series. Note: 2016 CV estimate calculated using StoX.

Age (Yrs)	2011	2012	2013	2014	2015	2016	2017
0	-	-	-	-	-	-	-
1	5.0	21.5	-	-	198.5	4.6	110.9
2	11.6	10.8	78.0	-	319.2	35.7	126.7
3	57.8	174.1	1,842.9	15.0	16.6	45.5	344.6
4	187.4	64.8	696.4	98.2	34.3	43.6	367.3
5	436.7	95.0	381.6	102.3	80.0	6.0	156.0
6	1,165.9	736.1	253.8	104.9	112.0	10.0	209.0
7	1,184.2	973.8	1,056.6	414.6	437.4	169.0	493.1
8	703.6	758.9	879.4	343.8	362.9	112.6	468.3
9	1,094.5	848.6	800.9	341.9	353.5	117.6	397.2
10	1,031.5	955.9	703.8	332.3	360.0	96.6	285.8
11	332.9	650.9	263.7	129.9	131.7	17.0	120.9
12	653.3	1,099.7	202.9	104.9	113.0	32.0	82.1
13	336.0	857.2	296.6	166.4	174.0	48.7	74.4
14	385.0	655.8	169.8	88.5	108.0	18.3	220.4
15+	3,519.0	6,353.7	1,464.3	855.1	1,195.0	400.1	931.0
TSN (10-6)	11,104	14,257	9,091	3,098	3,996	1,157	4,387
TSB (t)	670,176	863,446	439,890	187,779	232,634	69,690	230,062
SSB (t)	669,392	861,544	423,158	187,654	226,659	69,103	218,810
CV	21.2	10.6	17.5	15.1	17.0	16.4	21.9

Table 9. Horse mackerel stock estimate.

Length	Age (years)																					Numbers	Biomass	Mn Wt	Mature
(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	(000's)	(t)	(g)	(%)
13																						0	0		0
14																						0	0		0
15	315.7																					11692	315.7	27	0
16																						0	0	0	0
17																						151			0
18		72.1																				1427	72.1	50.53	0
19		411																				5700	411	72	100
20		3022.2																				38600	3022.2	78	89
21		4675.9																				53012	4675.9	88	100
22		8336	355.9																			86437	8691.9	101	100
23		20	7940.9																			69582	7960.9	114	100
24			3080.7	3164.8	372.5																	48885	6618	135	100
25			3479.6	651.1		118.1																28518	4248.8	149	100
26			3904.7	201.5	1393.5	120.7																34131	5620.5	165	100
27			891.7	1478.5	199.9	361.2	493.5	249.7														20201	3674.5	182	100
28				1620.6	372.6	435	458.1	201.2														15398	3087.6	201	100
29					58	1226.9	1487.9	806.7														15366	3579.6	233	100
30						1099.5	2674	6631.1	285.1	71.1												43075	10760.8	250	100
31					206.4	2328.3	7578.7	2839.9	314.8													49795	13268.1	266	100
32						1854.7	8271.9	1690.9	1180.4	769.4	38.9	831.1	1740.3	4388.2								72695	20765.8	286	100
33					225.8	1545.4	7085.5	1828.8	3693.3	6033.7	4027	1873	398.2	4777.8								102489	31488.5	307.24	100
34						2015.3	3070.6	2186.2	2193.9	3543.6	996.3	5420.3	5489.2	8357.4	846.5							102458	34119.2	333.01	100
35						1673.8		1193.8			5777.4	3757.8	3567.5	5773.9	219.6							62413	21963.8	351.91	100
36								986.8				1000.1	606.3	13313		1330.8						45445	17237.4	379.3	100
37														15863								39857	15863.2	398.01	100
38													1088	2641.8								8325	3729.8	448.02	100
39														2869.6	1362.5							9420	4232.1	449.27	100
40															102.2							207	102.2	493	100
41															778.9							1436	778.9	542.37	100
42														691.5		1135.8						2939	1827.3	621.67	100
TSN (1000)	11,692	181,766	146,974	45,388	16,175	46,016	112,954	67,748	25,354	33,210	32,568	37,702	37,582	160,762	8,559	5,207						969655			
TSB (t)	316	16,537	19,654	7,117	2,829	12,779	31,120	18,615	7,667	10,418	10,840	12,882	12,890	58,677	3,310	2,467							228115.8		
Mean length (cm)	15	21.16	24.05	25.41	26.51	31.3	31.56	31.35	32.86	33.21	34.1	34.12	34.25	35.38	36.71	38.08									
Mean weight (g)	27.0	91.0	133.7	156.8	174.9	277.7	275.5	274.8	302.4	313.7	332.8	341.7	343.0	365.0	359.0	473.8								235.29	
% mature*	0	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100									
SSB	0	16,133	19,654	7,117	2,829	12,779	31,120	18,615	7,668	10,418	10,840	12,882	12,890	58,677	3,310	2,467						227395.4			

Table 10. Horse mackerel biomass and abundance by strata.

Strata	Name	Area (nmi²)	Transects	Abun ('000)	Bio (t)
1	W Hebrides	2,443.3	5	0	0
2	S Hebrides	1,897.4	4	0	0
3	W Coast	15,778.6	20	340,082	72,308
4	Porcupine Bk	5,122.1	6	8,235	1,189
5	Celtic Sea	28,905.7	17	450,103	98,135
7	N Stanton	2,121.5	3	1,195	117
8	Minch	1,557.6	9	170,040	56,367
	Total	57,826.2	64	969,655	228,116

Table 11. Horse mackerel survey time series.

Age (Yrs)	2016	2017
0	-	-
1	1.1	11.7
2	100.2	181.8
3	4.9	147
4	43.5	45.4
5	19.0	16.2
6	7.6	46
7	40.6	113
8	66.6	67.7
9	8.5	25.4
10	1.8	33.2
11	9.5	32.6
12	10.6	37.7
13	4.7	37.6
14	21.1	160.8
15	6.5	8.6
16	1.6	5.2
17	5.3	-
18	-	-
19	-	-
20	-	-
21	1.1	-
TSN (10^{-6})	354.5	969,655
TSB (t)	69,267	228,116
SSB (t)	65,194	227,395.6
CV	42.0	25.5

Table 12. Celtic Sea herring stock estimate.

	Age (years)												Numbers	Biomass	Mn Wt
Length	1	2	3	4	5	6	7	8	9	10	11	Unknown	(*10-6)	('000 t)	(g)
11.5															
12															
12.5															
13															
13.5															
14															
14.5															
15															
15.5															
16															
16.5															
17															
17.5															
18															
18.5															
19															
19.5															
20															
20.5															
21	276.5												2194	276.5	126
21.5													2194		
22													1097		
22.5												510.2	5486	510.2	93
23												2523.5	25235	2523.5	100
23.5												3746.2	34012	3746.2	110
24			6541	2086.7									76802	8627.8	112
24.5			1866.1	4234									50470	6100.1	121
25		1824	9915.2	2529.1									109717	14268.2	130
25.5			5164.8	5092.4									76802	10257.3	134
26				1705.9	7787.5	6724.8	1949.5						118495	18167.8	153
26.5					5415.1	5512.4							73510	10927.6	149
27					6997	10890							105328	17886.4	170
27.5						6493.1							37304	6493.1	174
28					2167.3			3238.2					28526	5405.5	189
28.5												776.8	4389	776.8	177
29								1371.5					6583	1371.5	208
29.5															
30															
30.5															
31															
31.5															
TSN (1000)	2194	14074	188321	123293	142180	180557	11633	23480				69122	758146.0		
TSB (t)	276.5	1824	23487	15648	22367	29620	1949.5	4609.7				7556.7		107338.4	
Mean length (cm)	21	25	24.76	24.95	26.59	26.76	26	28.28							
Mean weight (g)	126	129.6	124.72	126.92	157.31	164.05	167.59	196.32							142.2

Table 13. Celtic Sea herring biomass and abundance by strata.

Strata	Name	Area (nmi²)	Transects	Abun ('000)	Bio (t)
1	Celtic Sea	27,650.5	15	34,589	4,902
2	NW Bank	1,063.7	4	303,704	43,086
3	Celtic Deep	1,784.8	4	419,853	59,350.8
	Total	30,498.9	23	758,146	107,338.4

Table 14. Marine mammal sightings, counts and group size ranges for cetaceans sighted during the survey (includes on and off effort).

Species	Latin Name	No. of Sightings	No. Of Individuals	Range of Group Size
Bottlenose dolphin	*Tursiops truncatus*	7	63	1-15
Common dolphin	*Delphinus delphis*	66	979	1-200
Common seal	*Phoca vitulina*	2	3	1-2
Fin whale	*Balaenoptera physalus*	4	5	1-2
Grey seal	*Halichoerus grypus*	7	7	1
Harbour porpoise	*Phocoena phocoena*	5	9	1-3
Humpback whale	*Megaptera novaeangliae*	2	3	1-2
Killer whale	Orcinus orca	1	3	3
Minke whale	*Balaenoptera acutorostrata*	22	25	1-3
Risso's dolphin	*Grampus griseus*	7	56	3-20
UnID cetacean		3	3	1
UnID dolphin		20	142	1-50
UnID large baleen whale		3	3	1
UnID seal		3	3	1
UnID whale		3	3	1
	Total	155	1307	

Table 15. Summary of marine megafauna sightings during the survey (includes on and off effort)

Species	Latin Name	No. of Sightings	No. Of Individuals	Range of Group Size
Basking shark	*Cetorhinus maximus*	2	2	1
Blue shark	*Prionace glauca*	8	8	1
Leatherback turtle	*Dermochelys coriacea*	1	1	1
Ocean sunfish	*Mola mola*	12	18	1-4
Thresher shark	*Alopias vulpinus*	1	1	1
Unidentified fish		1	1	1
Unidentified shark		4	4	1
	Total	29	35	

Table 16. Totals for all seabird species recorded between 5th and 29th July 2016.

Vernacular Name	Scientific Name	On Survey	Off Survey	Total
Wilson's storm-petrel	*Oceanites oceanicus*	3	0	3
European storm-petrel	*Hydrobates pelagicus*	1097	645	1742
Leach's storm-petrel	*Oceanodroma leucorhoa*	2	0	2
Fulmar	*Fulmarus glacialis*	705	495	1200
Cory's shearwater	*Calonectris borealis*	11	2	13
Sooty shearwater	*Ardenna griseus*	22	8	30
Great shearwater	*Ardenna gravis*	3	1	4
Manx shearwater	*Puffinus puffinus*	2855	206	3061
Balearic shearwater	*Puffinus mauretanicus*	1	0	1
Gannet	*Morus bassanus*	3157	1151	4308
Kittiwake	*Rissa tridactyla*	11	22	33
Sabine's gull	*Xema sabini*	1	3	4
Black-headed gull	*Chroicocephalus philadelphia*	0	1	1
Great black-backed gull	*Larus marinus*	1	36	37
Herring gull	*Larus argentatus*	1	15	16
Lesser black-backed gull	*Larus fuscus graellsii*	458	164	622
Unidentified large gull sp.	*Larus sp.*	150	0	150
Common tern	*Sterna hirundo*	5	0	5
Arctic tern	*Sterna paradisaea*	3	1	4
Great skua	*Stercorarius skua*	11	6	17
Pomarine skua	*Stercorarius pomarinus*	0	1	1
Guillemot	*Uria aalge*	11	1	12
Razorbill	*Alca torda*	5	1	6
Puffin	*Fratercula arctica*	36	3	39
Total		8549	2762	11311

Table 17. Totals of migrant terrestrial bird species recorded between 5th and 29th July 2016.

Vernacular Name	Scientific Name	Total
Oystercatcher	*Haematopus ostralegus*	2
Golden Plover	*Pluvialis apricaria*	1
Whimbrel	*Numenius phaeopus*	1
Racing pigeon	*Columba livia* domest.	18
Swift	*Apus apus*	5
Greenish warbler	*Phylloscopus trochiloides*	1
Total		28

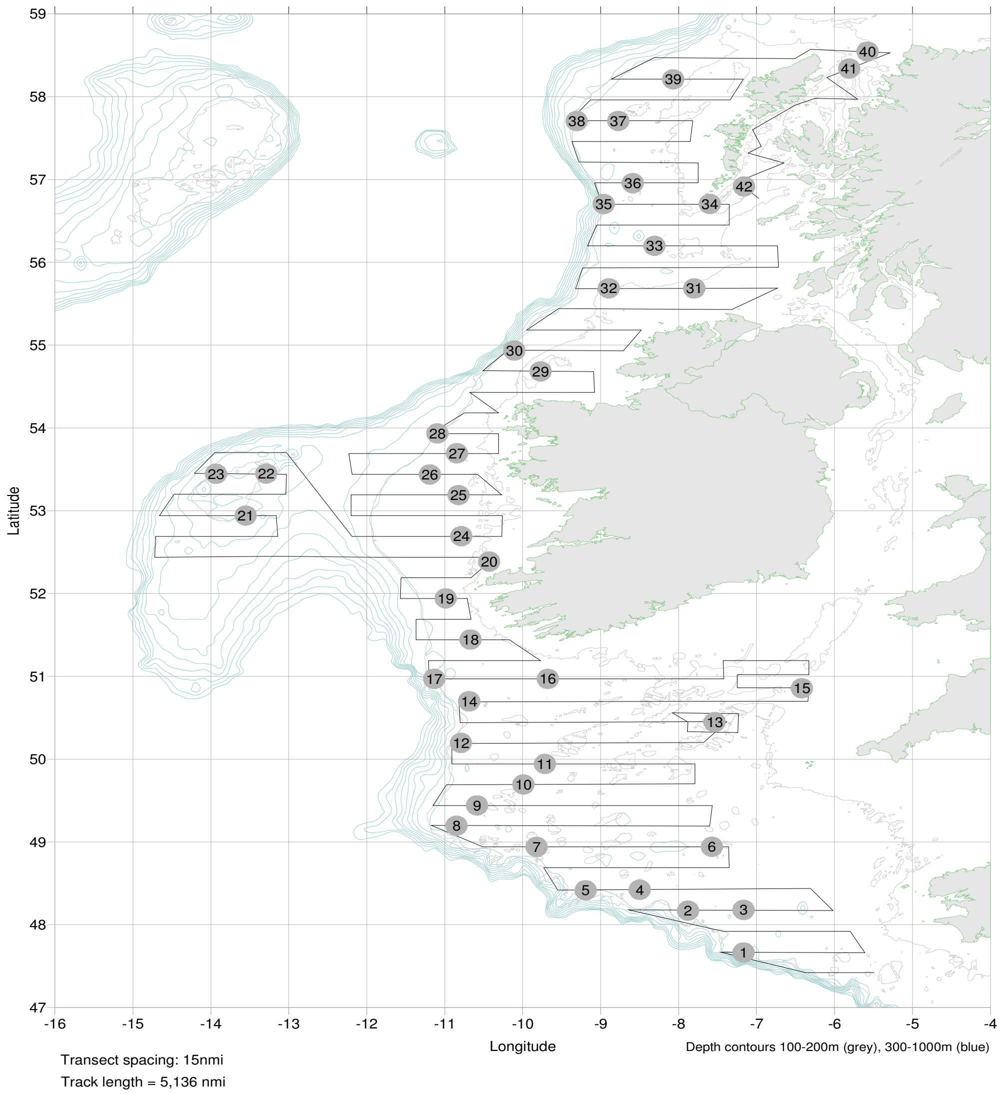


Figure 1. Survey cruise track (grey line) and numbered directed pelagic trawl stations. Corresponding catch details are provided in Table 2.

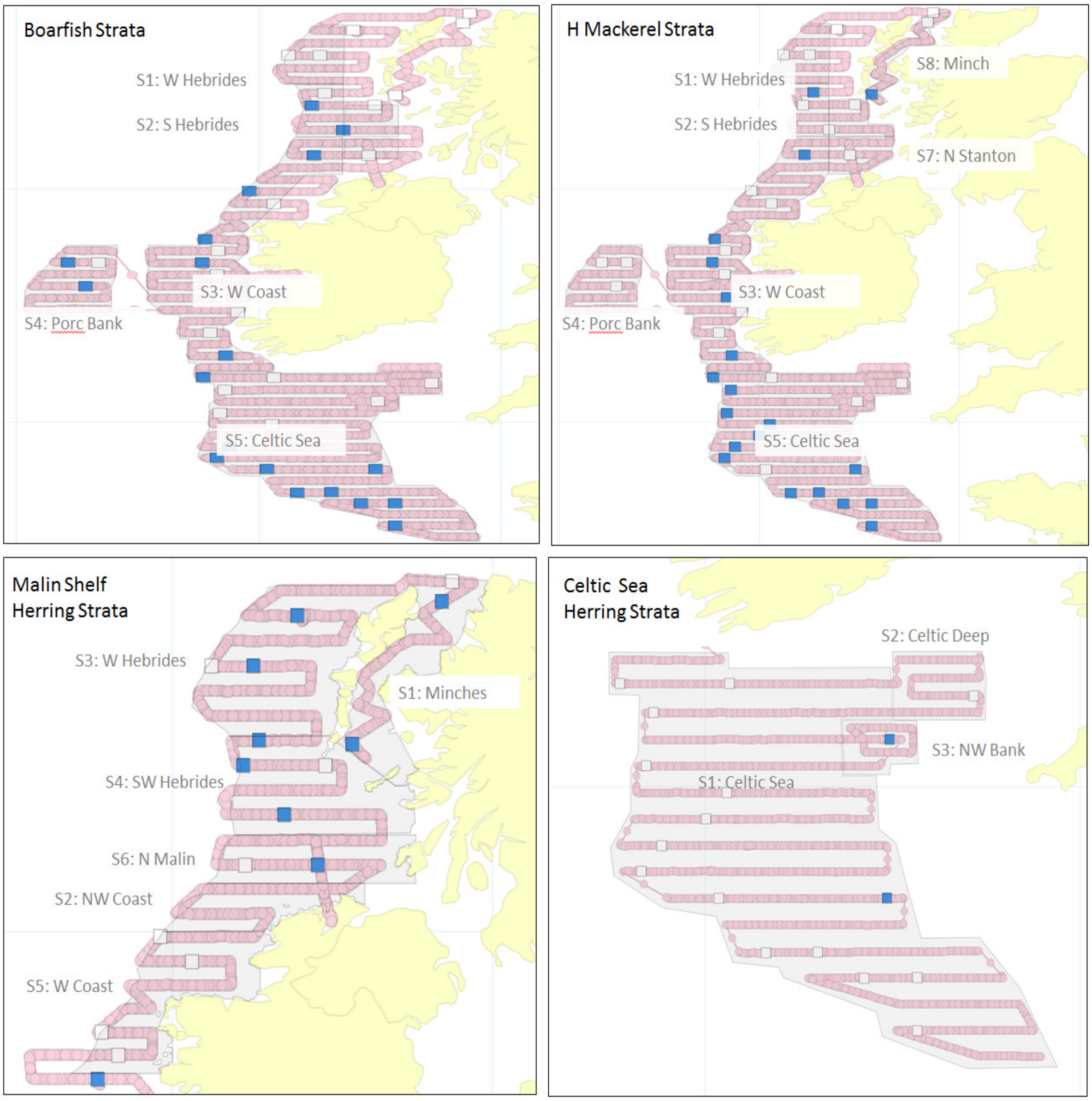


Figure 2. Acoustic sampling area stratification as applied during the calculation of species specific acoustic abundance.

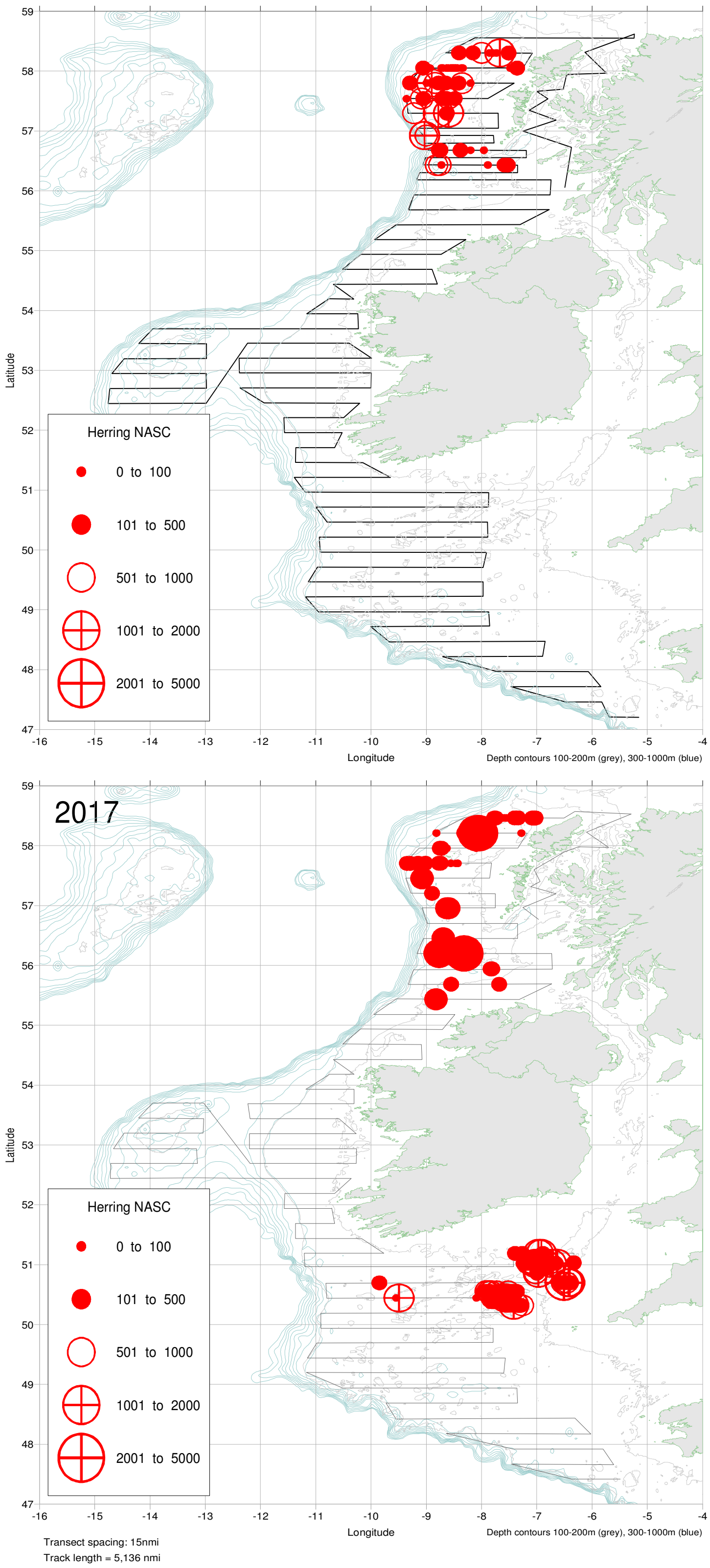


Figure 3. Malin Shelf herring distribution by NASC (Nautical area scattering coefficient). Top panel 2016, bottom panel 2017. Celtic Sea herring distribution also plotted in 2017.

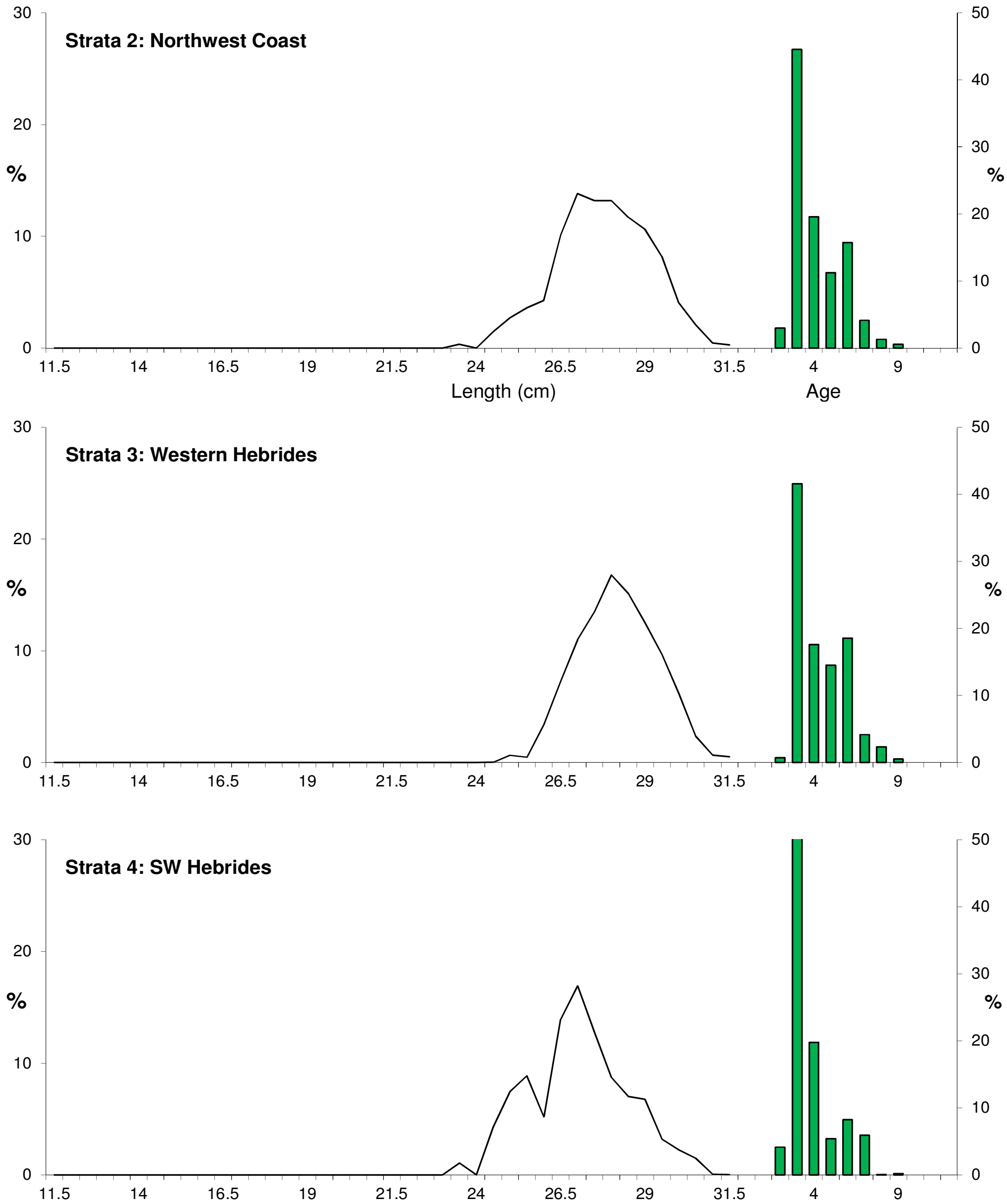
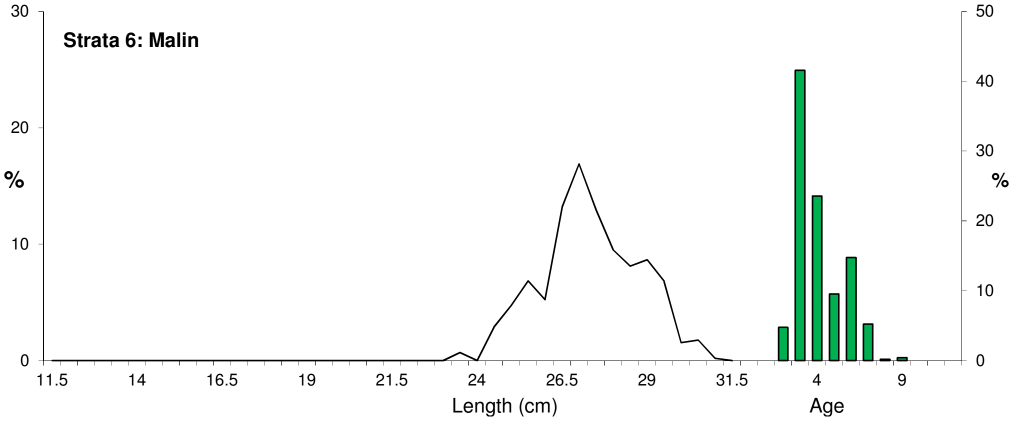


Figure 4. Length and age distribution of Malin Shelf herring by stratum and total survey area.



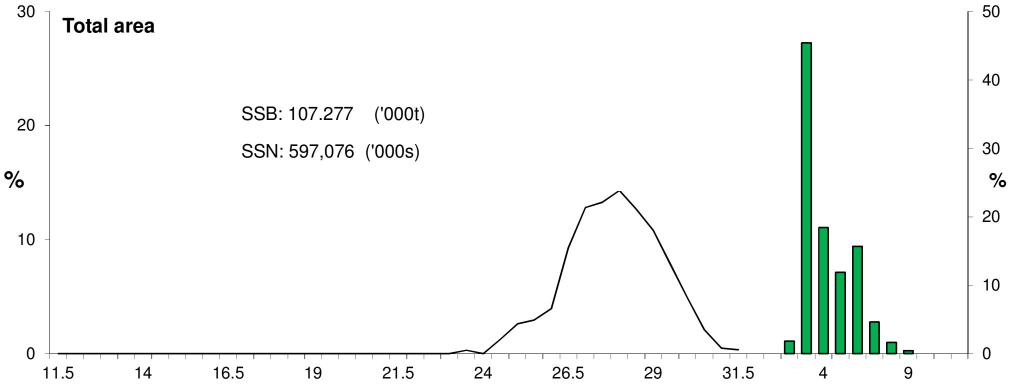


Figure 4. Cont.

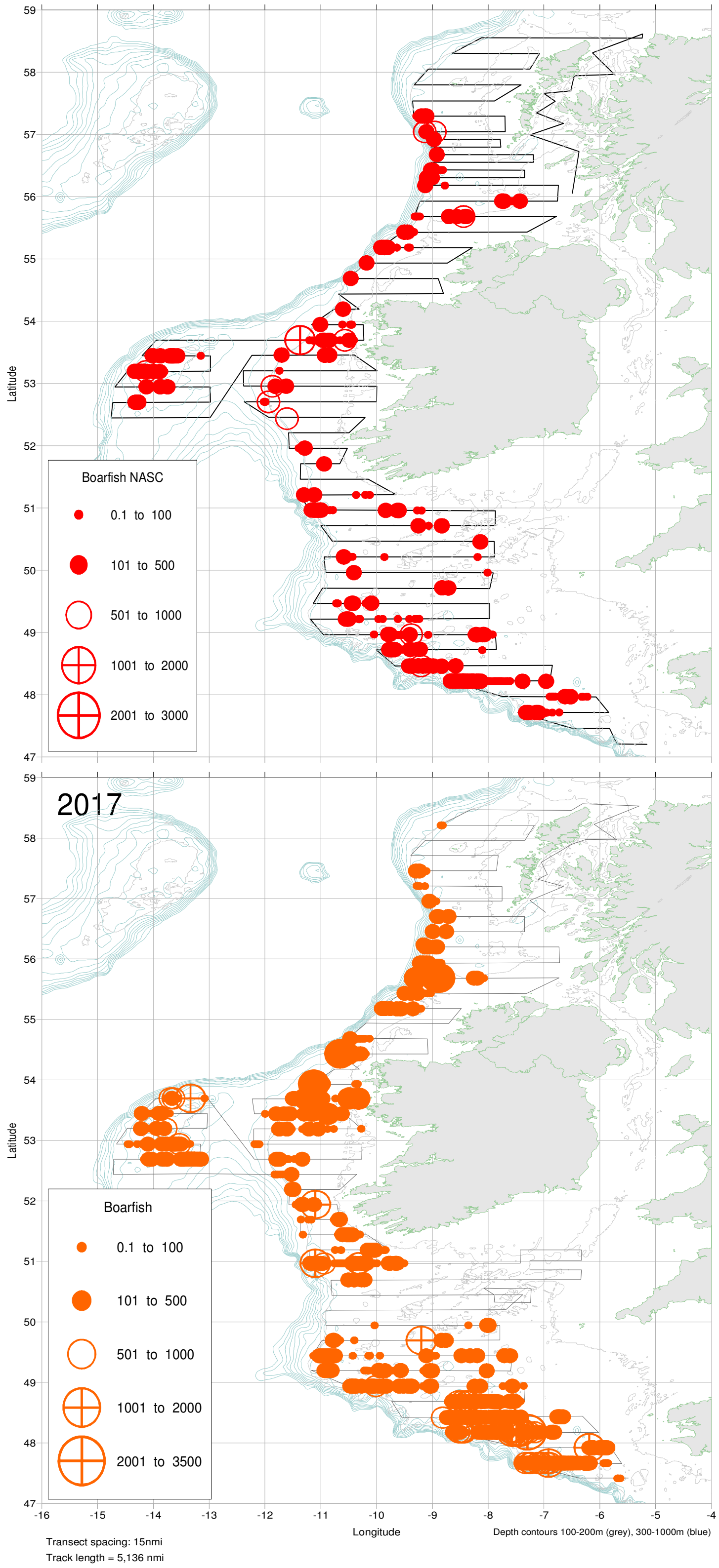


Figure 5. Boarfish distribution by NASC (Nautical area scattering coefficient). Top panel 2016, bottom panel 2017.

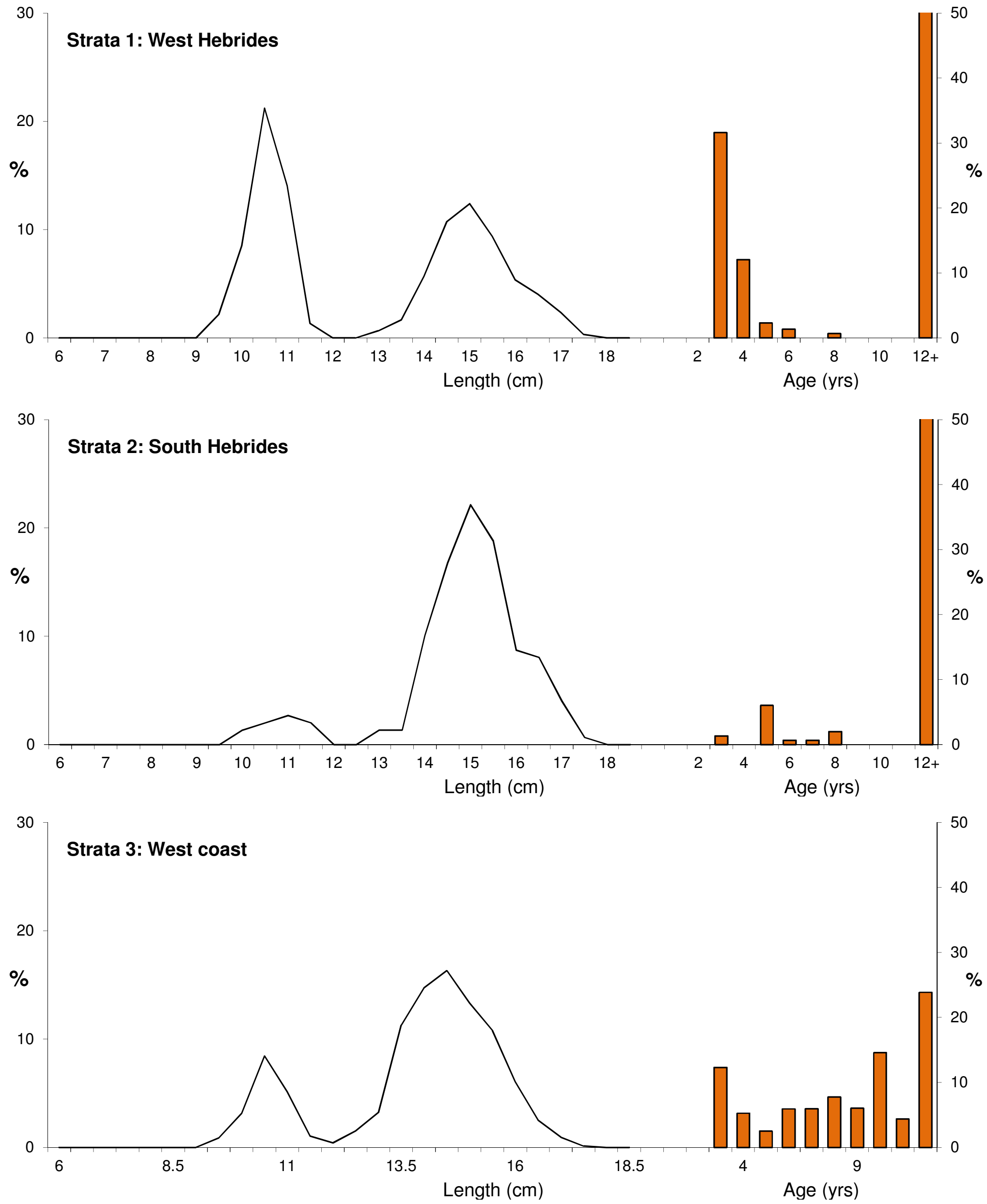


Figure 6. Length and age distribution of boarfish by stratum and total survey area.

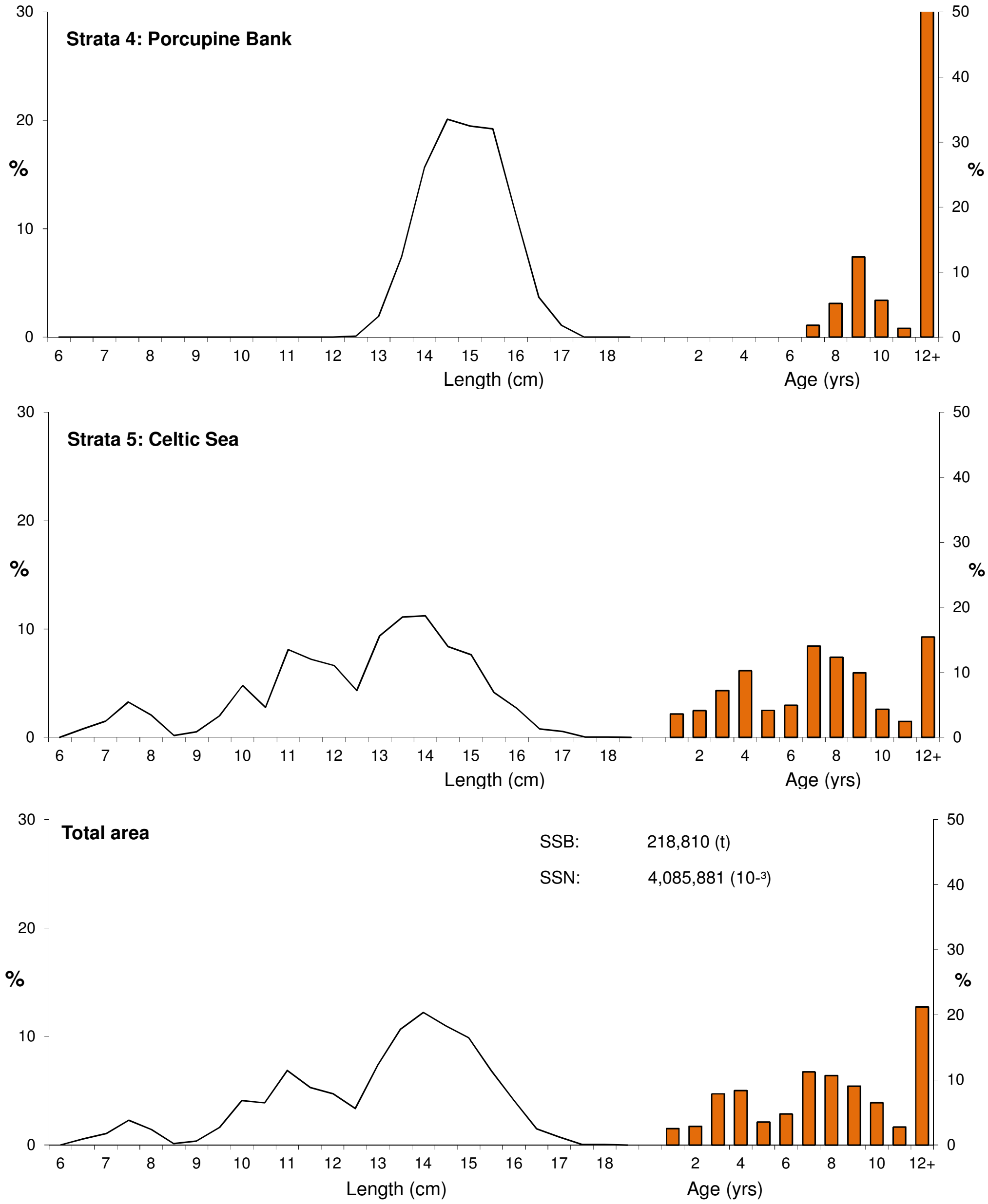
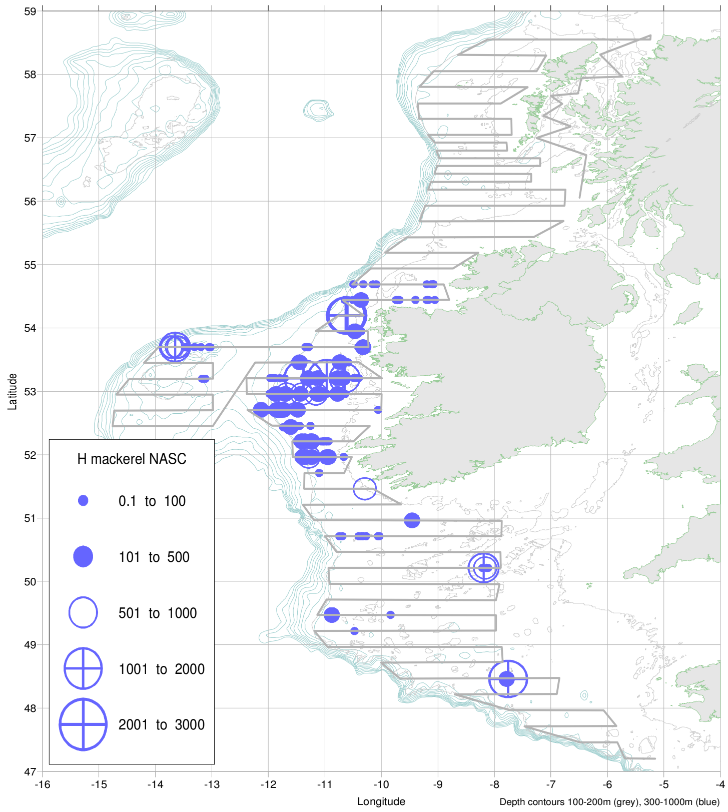


Figure 6. cont.



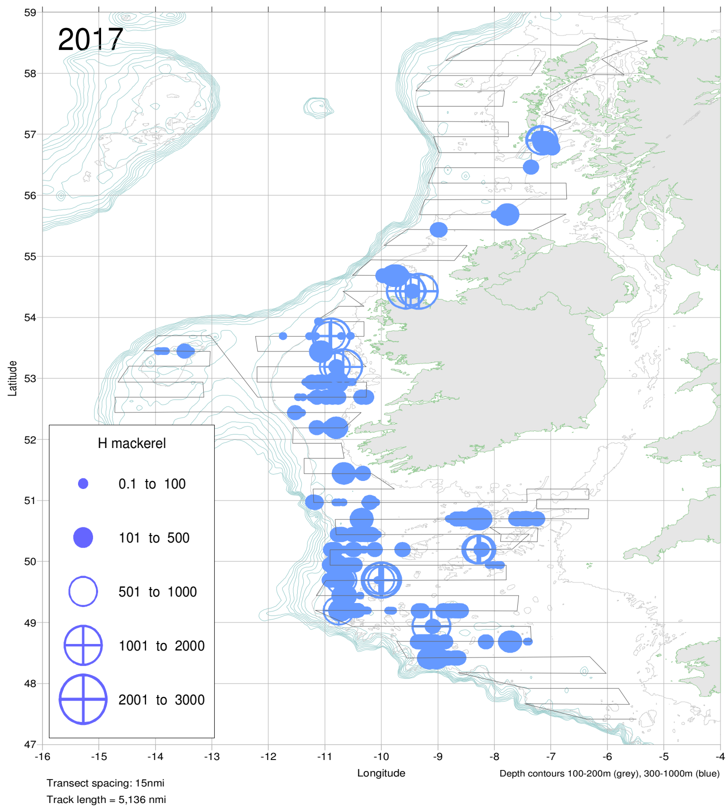


Figure 7. Horse mackerel distribution by NASC (Nautical area scattering coefficient). Top panel 2016, bottom panel 2017.

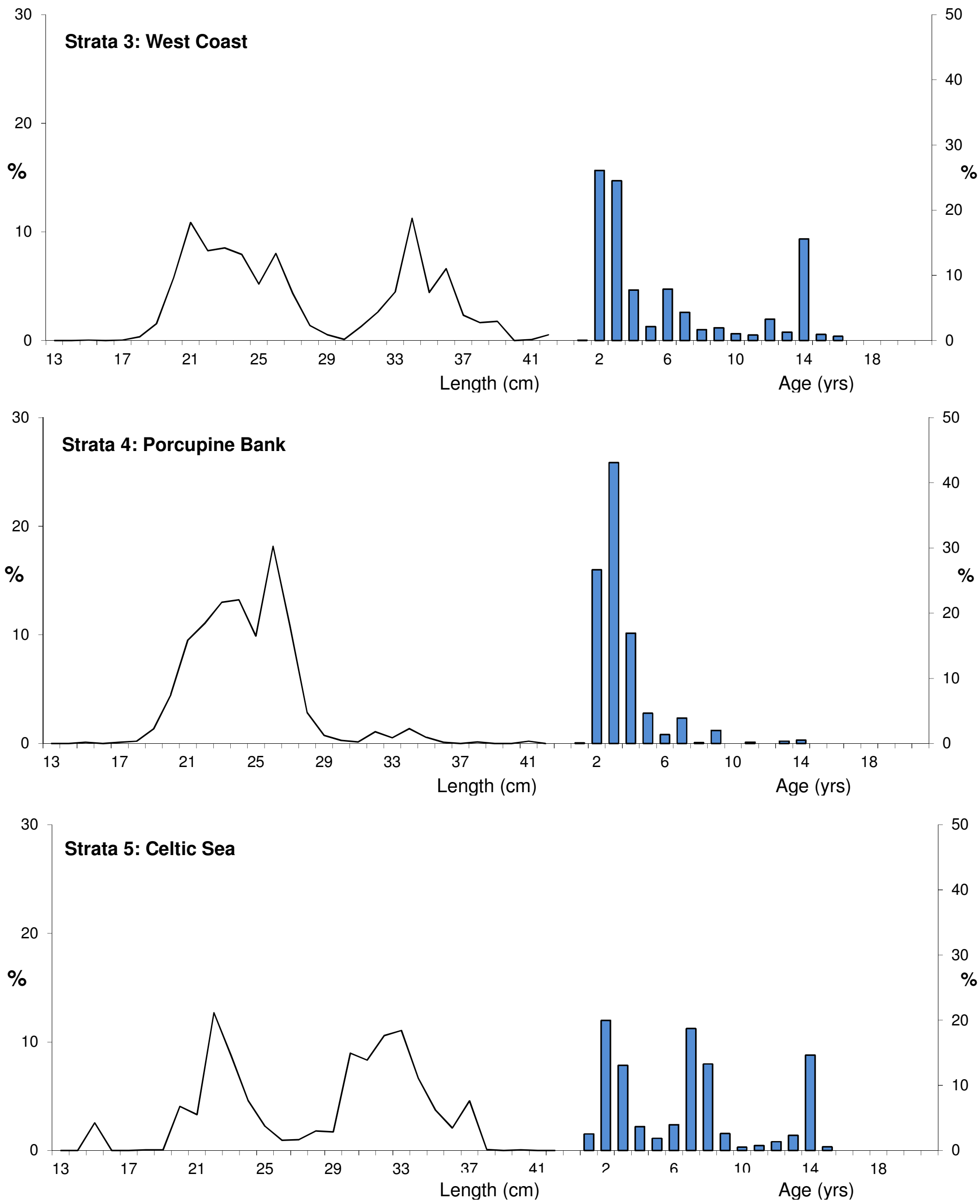


Figure 8. Length and age distribution of horse mackerel by stratum and total survey area.

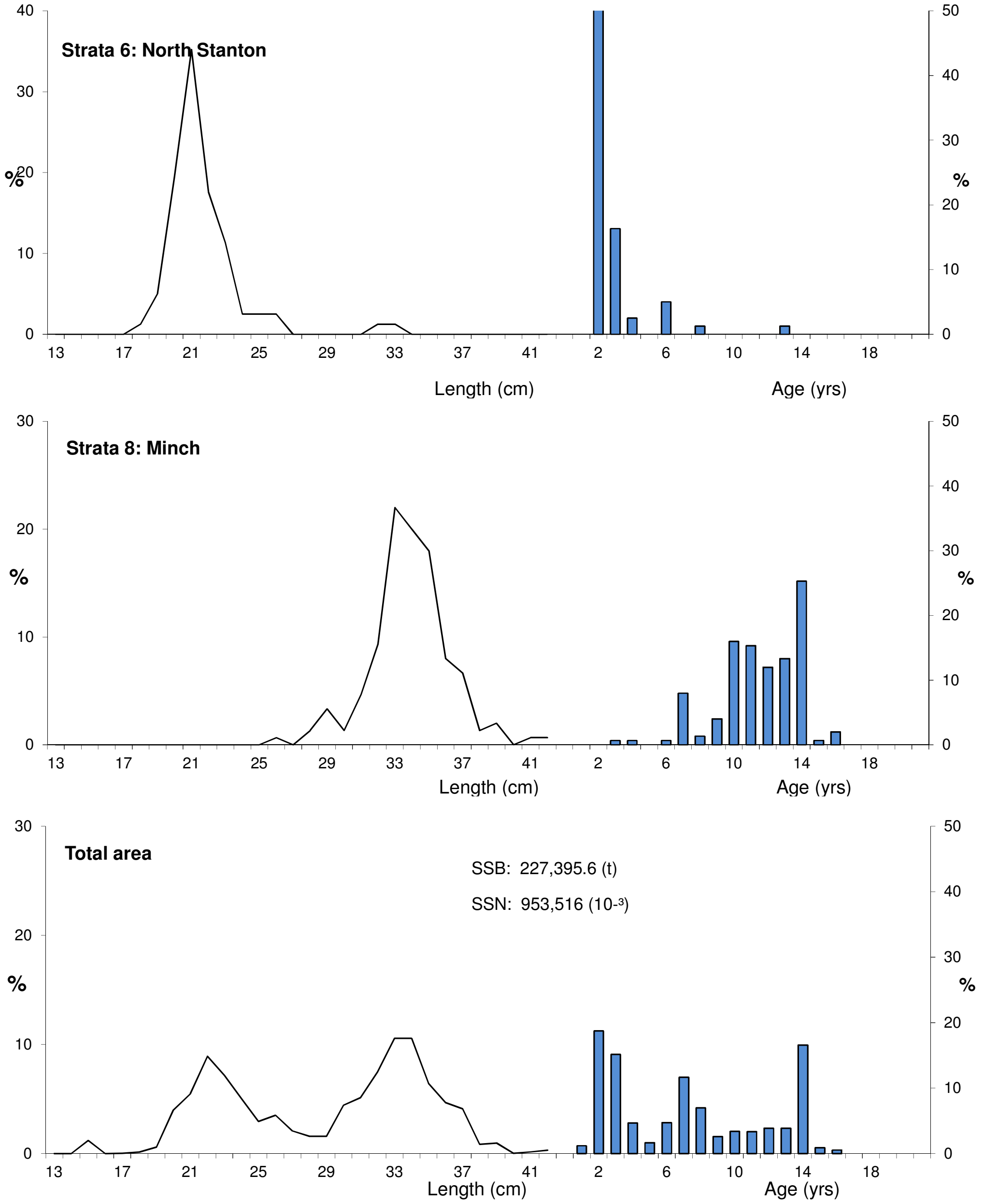


Figure 8. continued

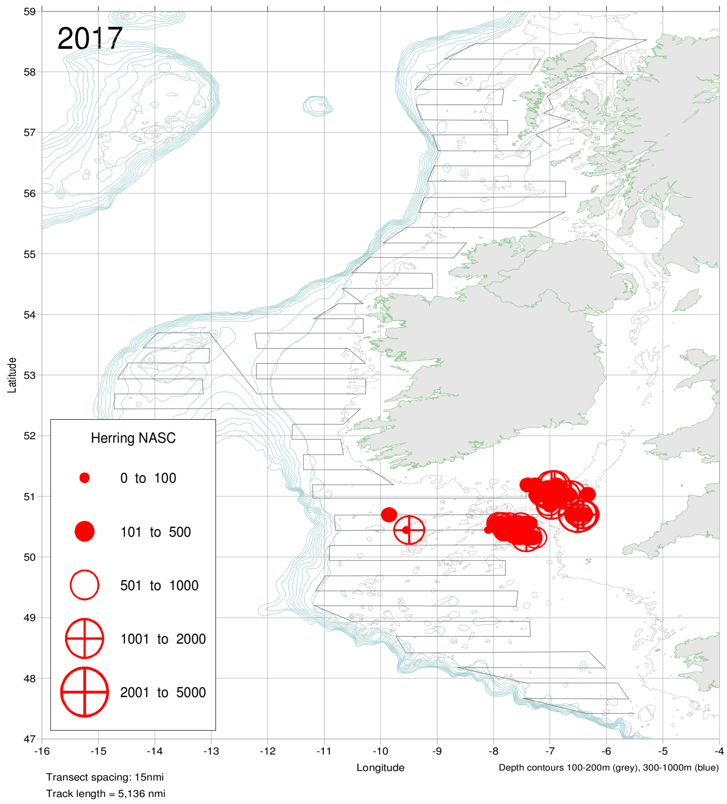


Figure 9. Celtic Sea herring distribution by NASC (Nautical area scattering coefficient).

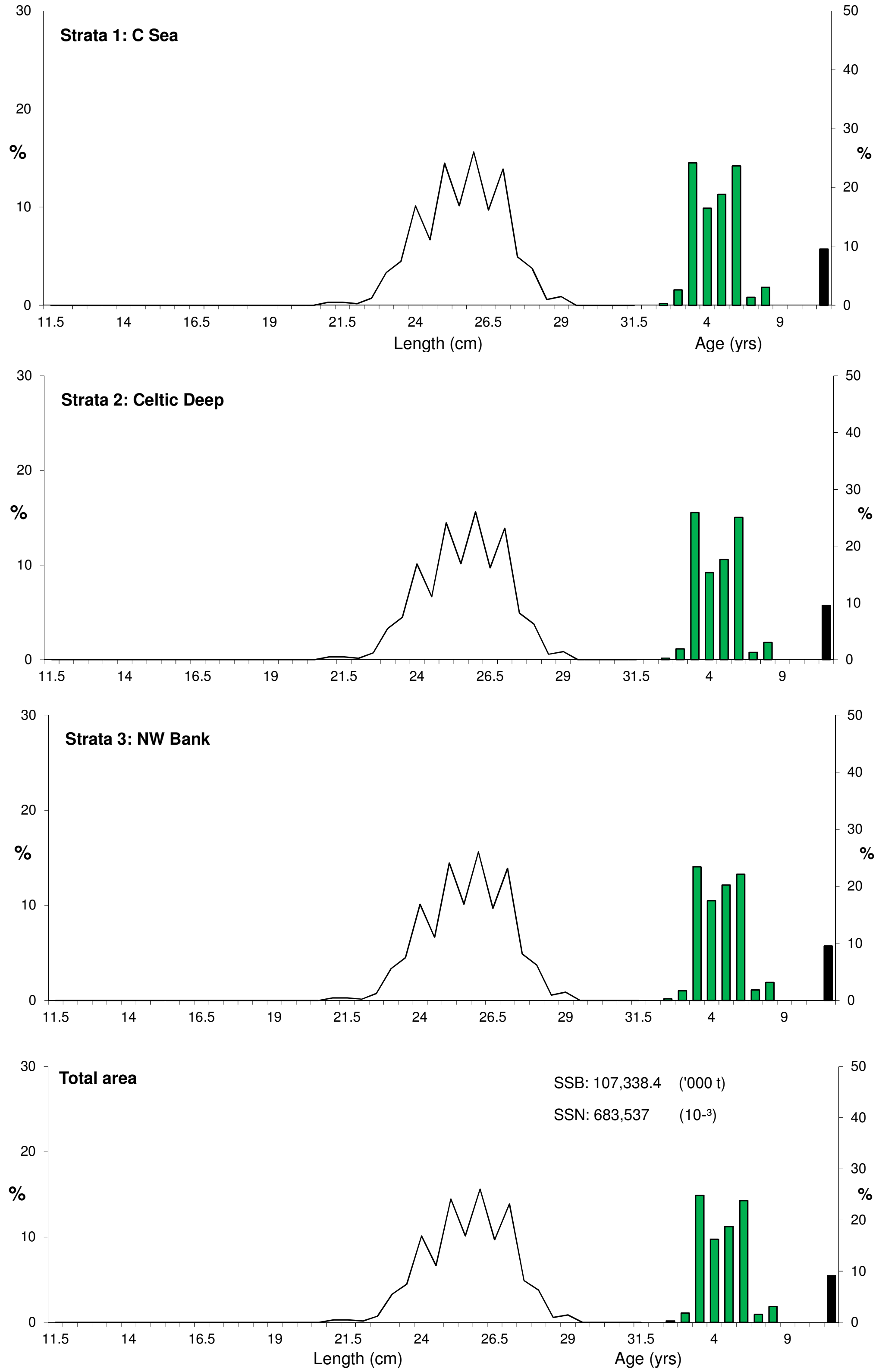
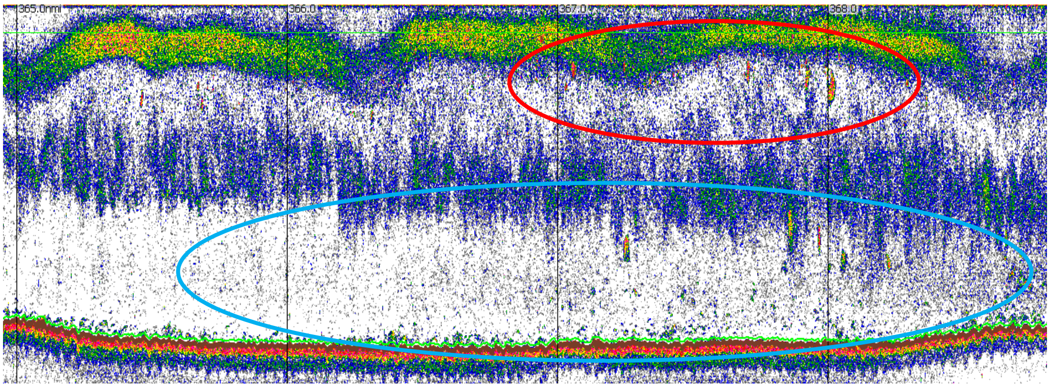
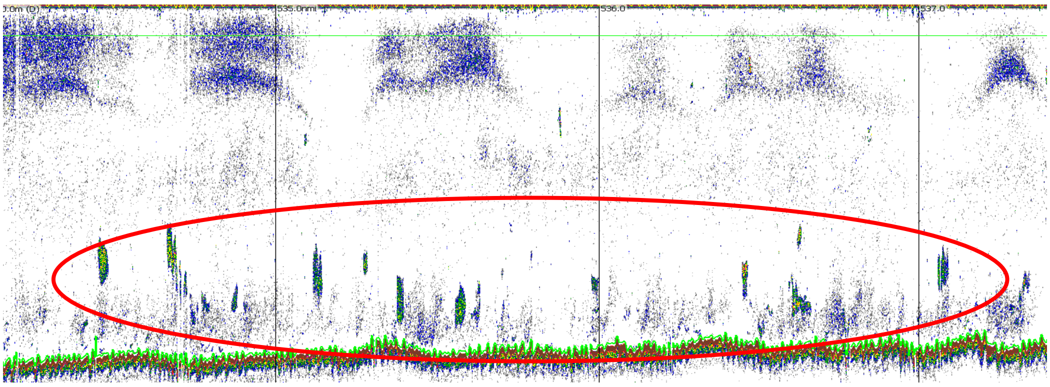


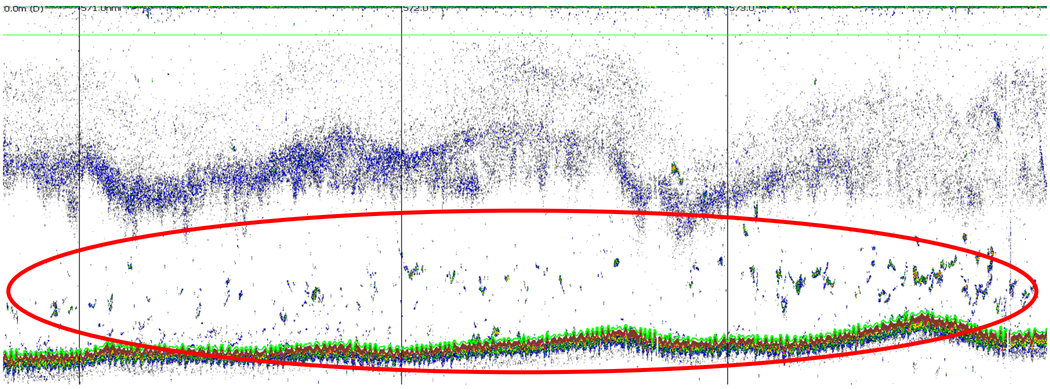
Figure 10. Length and age distribution of Celtic Sea herring by stratum and total survey area. Note: black bar indicates a gap in age/length key.



a). *Haul 03, Southern Celtic Sea. Surface schools of juvenile boarfish (circled red) and mature boarfish and horse mackerel in lower depth channel (circled blue). Water depth 164m.*

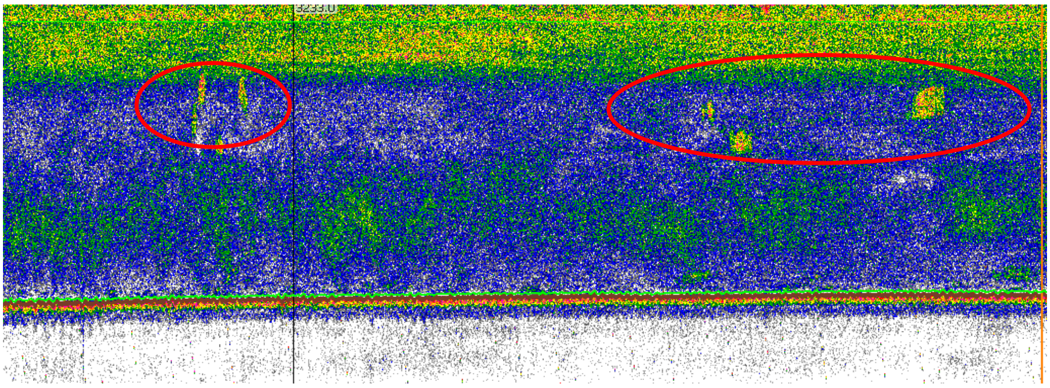


b). *Haul 04, Southern Celtic Sea. Medium density boarfish schools along the shelf slope, water depth 163 m.*

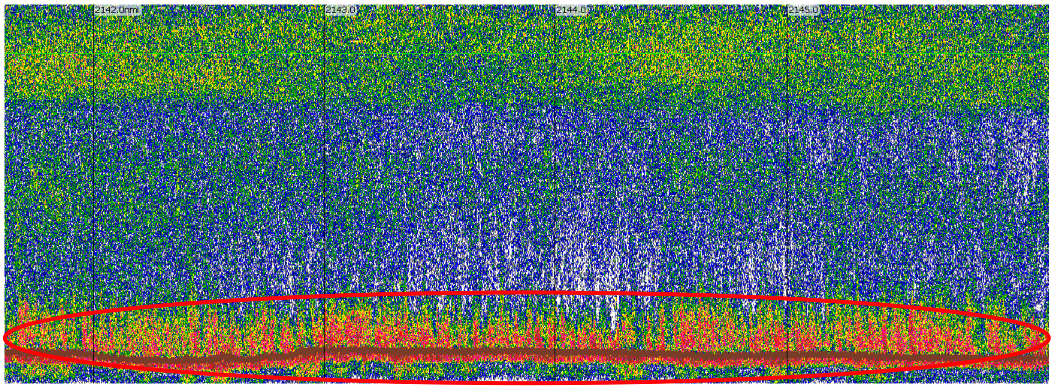


c). *Haul 05. Southern Celtic Sea. Medium density horse mackerel feeding layer, water depth 161 m.*

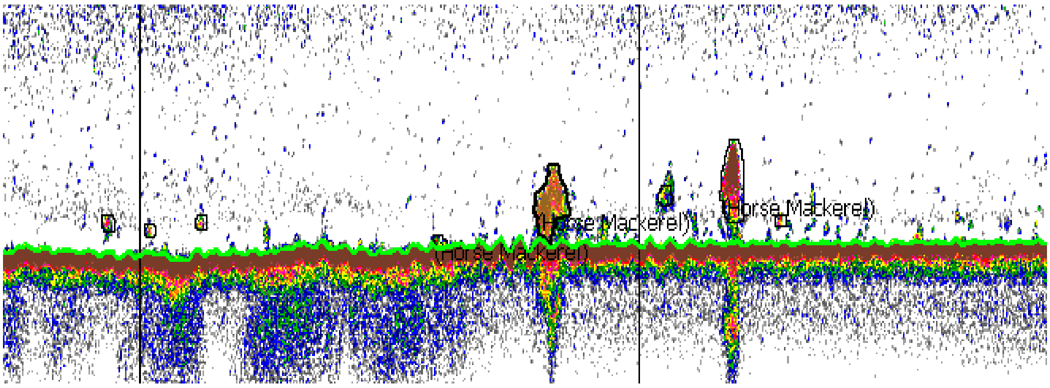
Figures 11a-j. Echotraces recorded on an EK60 echosounder (38 kHz) with images captured from Echoview. Note: Vertical bands on echogram represent 1nmi (nautical mile) intervals.



d). *Haul 21. Typical below the thermocline boarfish schools on the Porcupine Bank, water depth 210 m.*

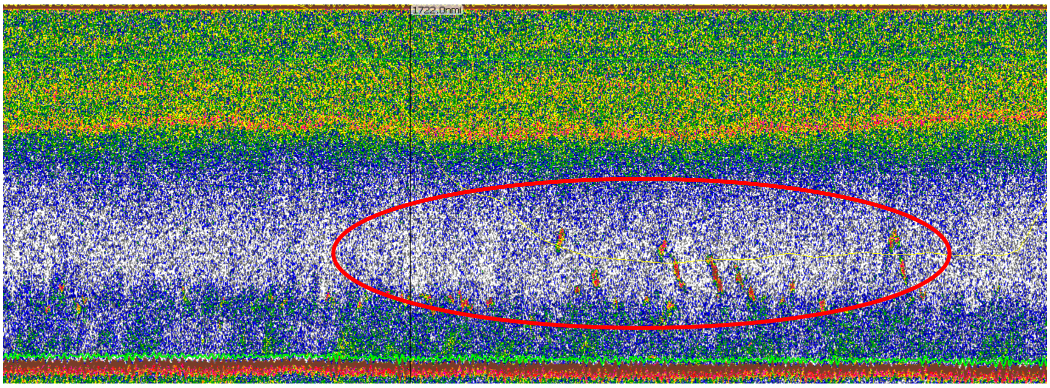


e). *Haul 15. Celtic Deep. High density layer containing sprat, juvenile sandeel and jellyfish, water depth 92 m.*

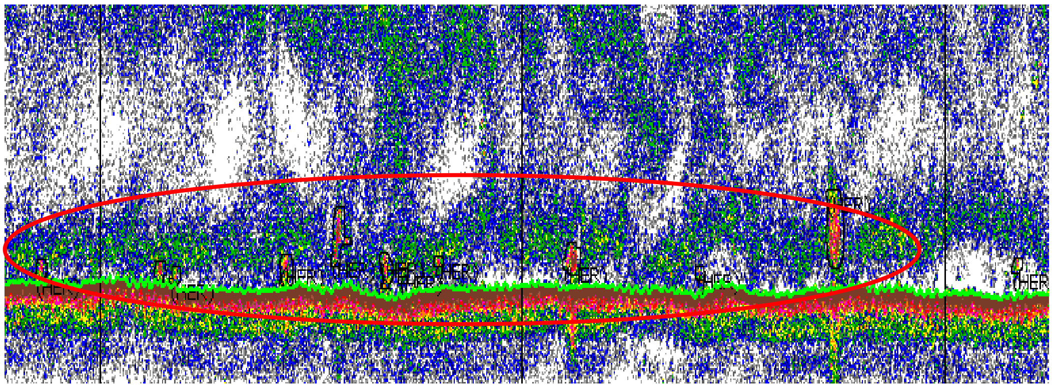


f). *Donegal Bay, high density horse mackerel schools, water depth 146 m.*

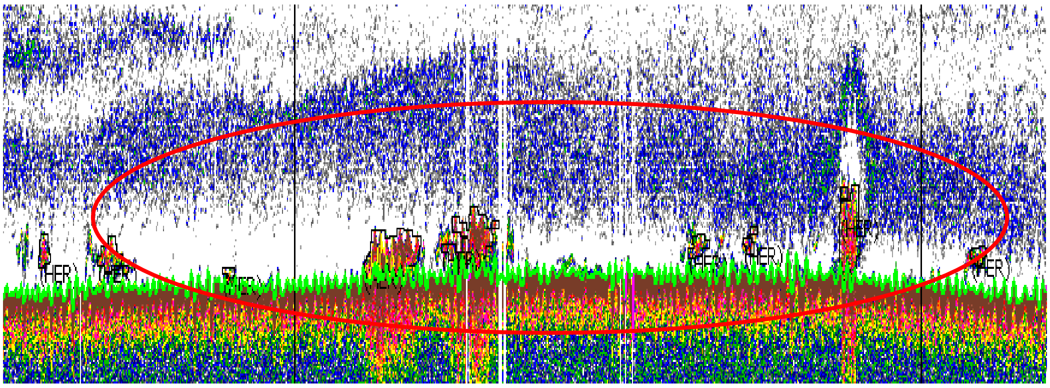
Figures 11a-i. continued



g). *Haul 13. Celtic Sea herring, east Celtic Sea coast boarfish bottom schools, water depth 102 m.*



h). *Haul 33. Western Stanton Bank, series of herring marks, water depth 145 m.*



i). *Haul 39. West of the Hebrides. High density marks of herring close to the bottom. Water depth 123 m.*

Figures11-i. continued.

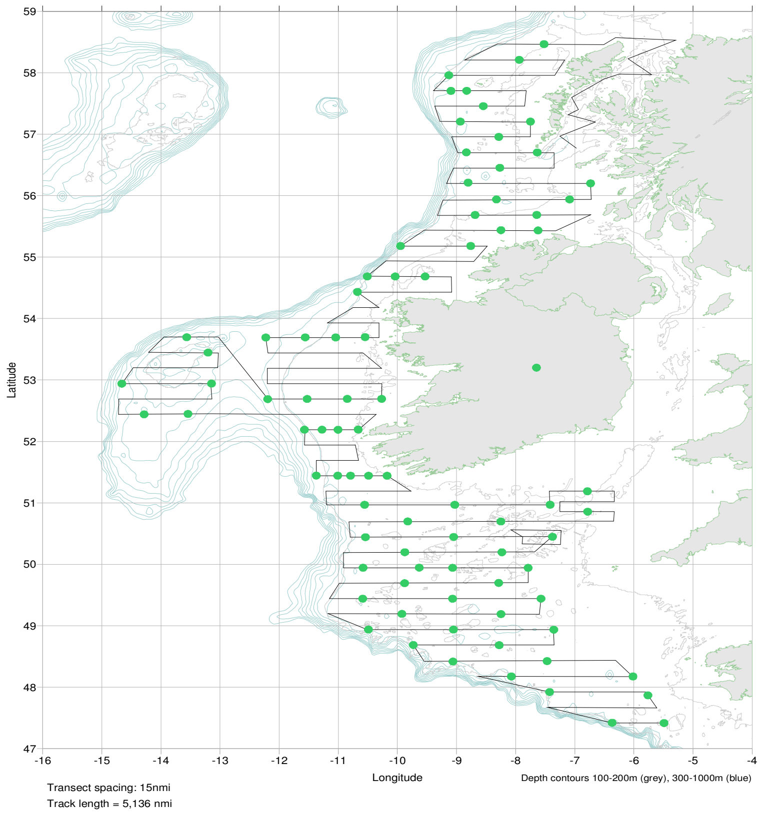


Figure 12. Position of hydrographic and co-occurring zooplankton sampling stations (n=86).

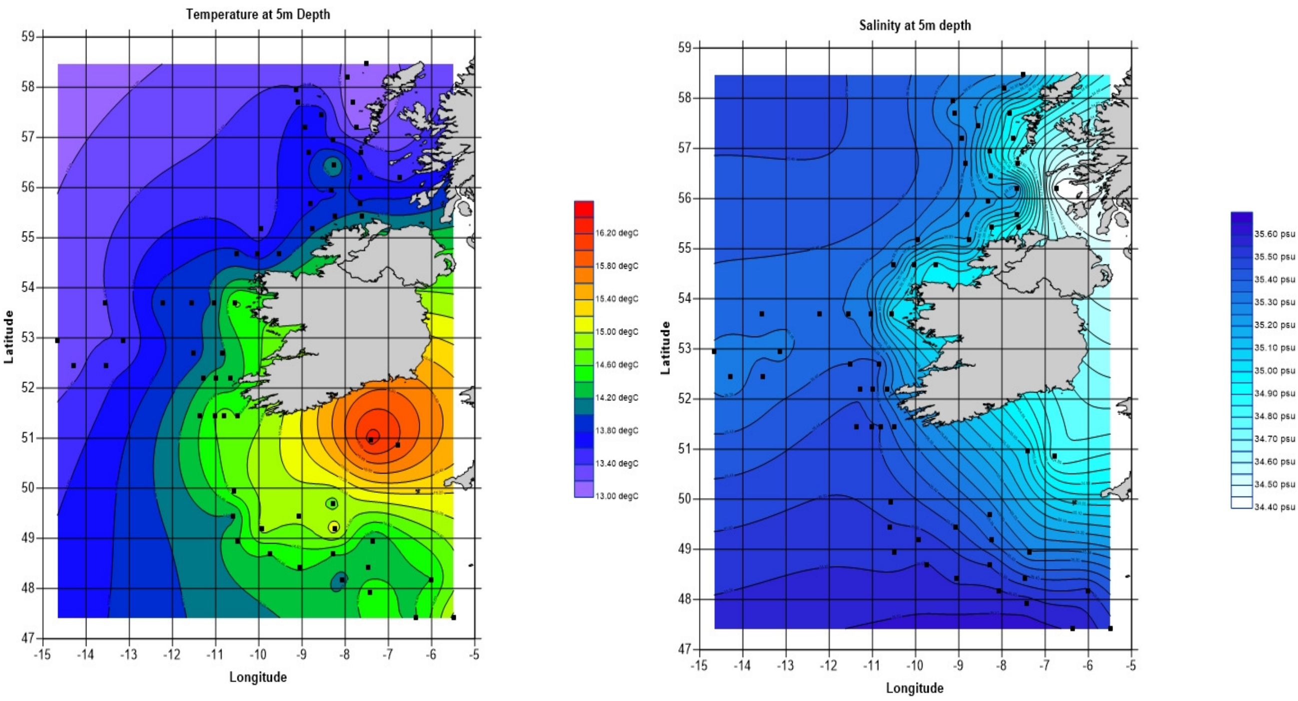


Figure 13. Surface (5m) plots of temperature and salinity compiled from CTD cast data. Station positions with valid data shown as block dots (n=86).

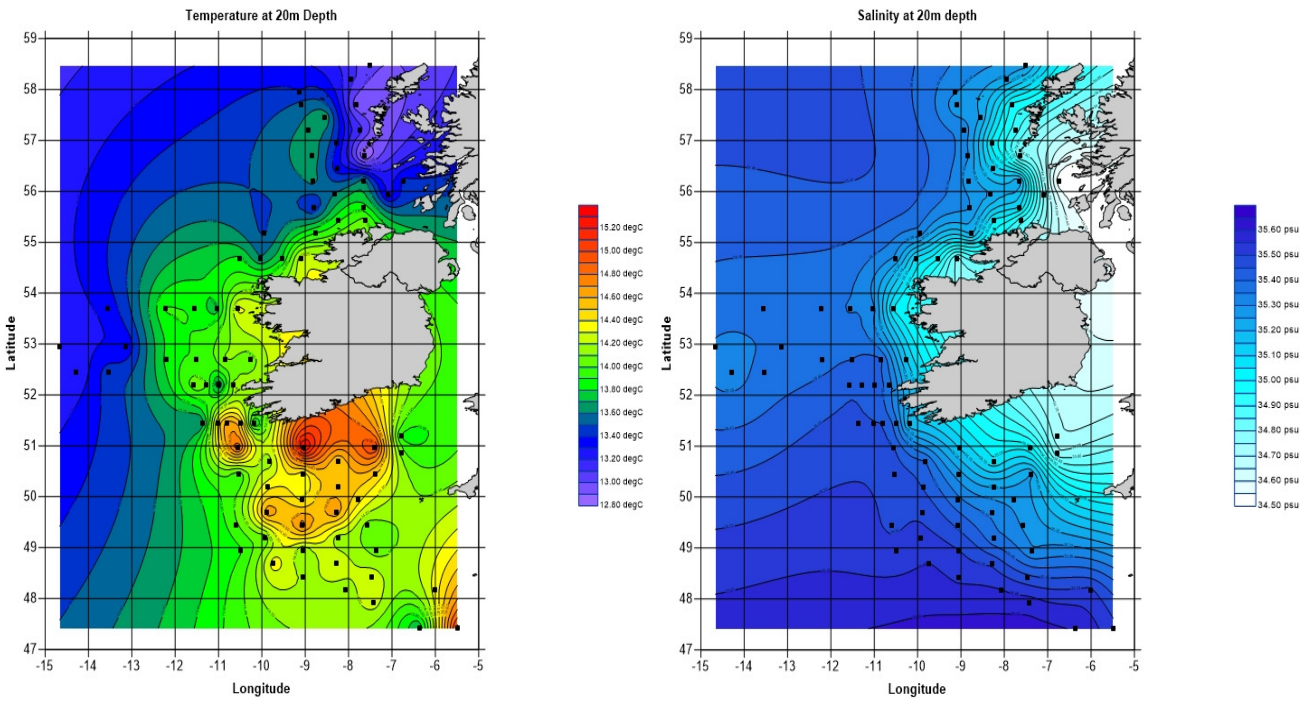


Figure 14. Plots of temperature and salinity compiled from CTD cast data at 20m depth. Station positions with valid data shown as block dots (n=86).

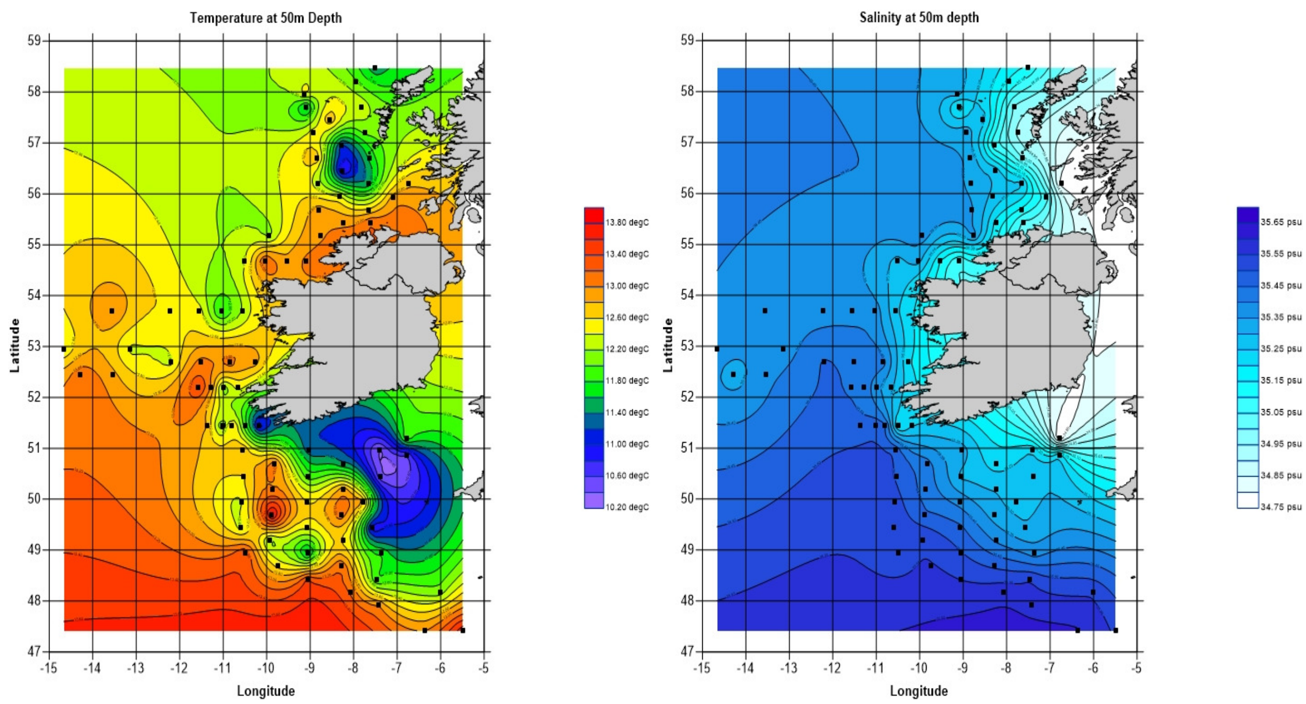


Figure 15. Plots of temperature and salinity compiled from CTD cast data at 50m depth. Station positions with valid data shown as block dots (n=86).

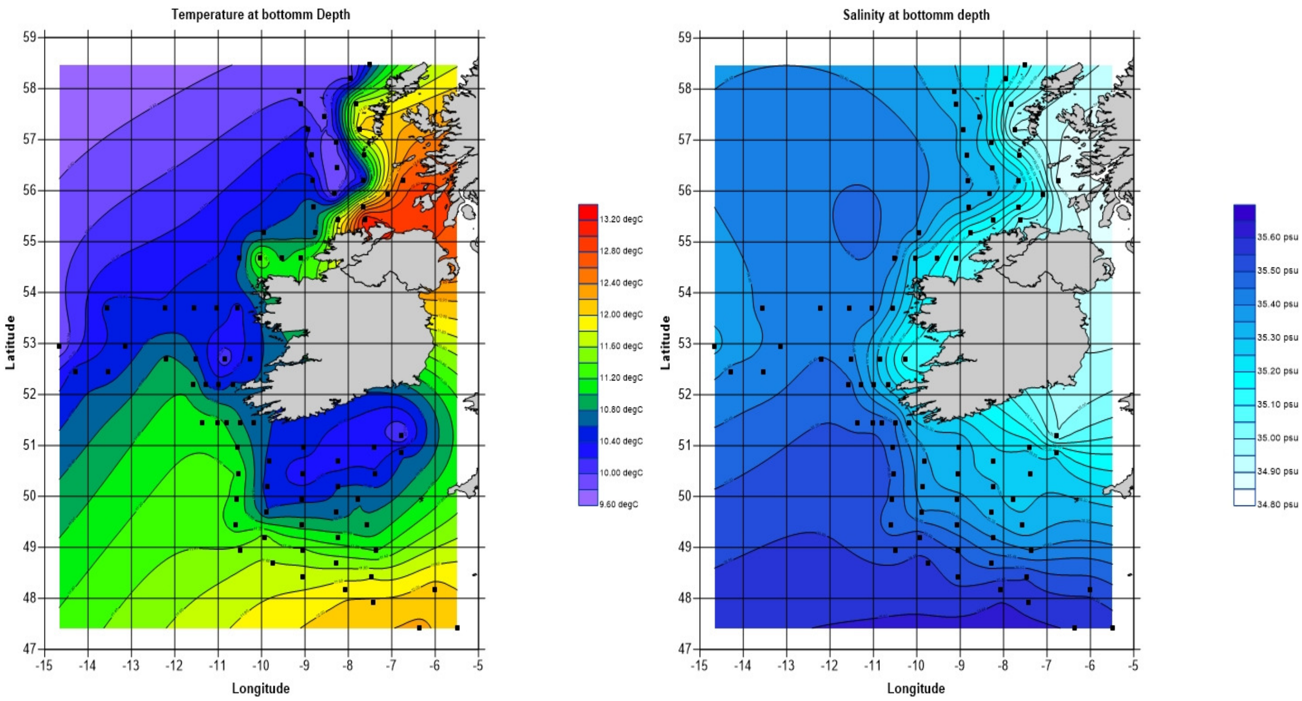


Figure 16. Plots of temperature and salinity compiled from CTD cast data at the seabed (+3-5m). Station positions with valid data shown as block dots (n=86).

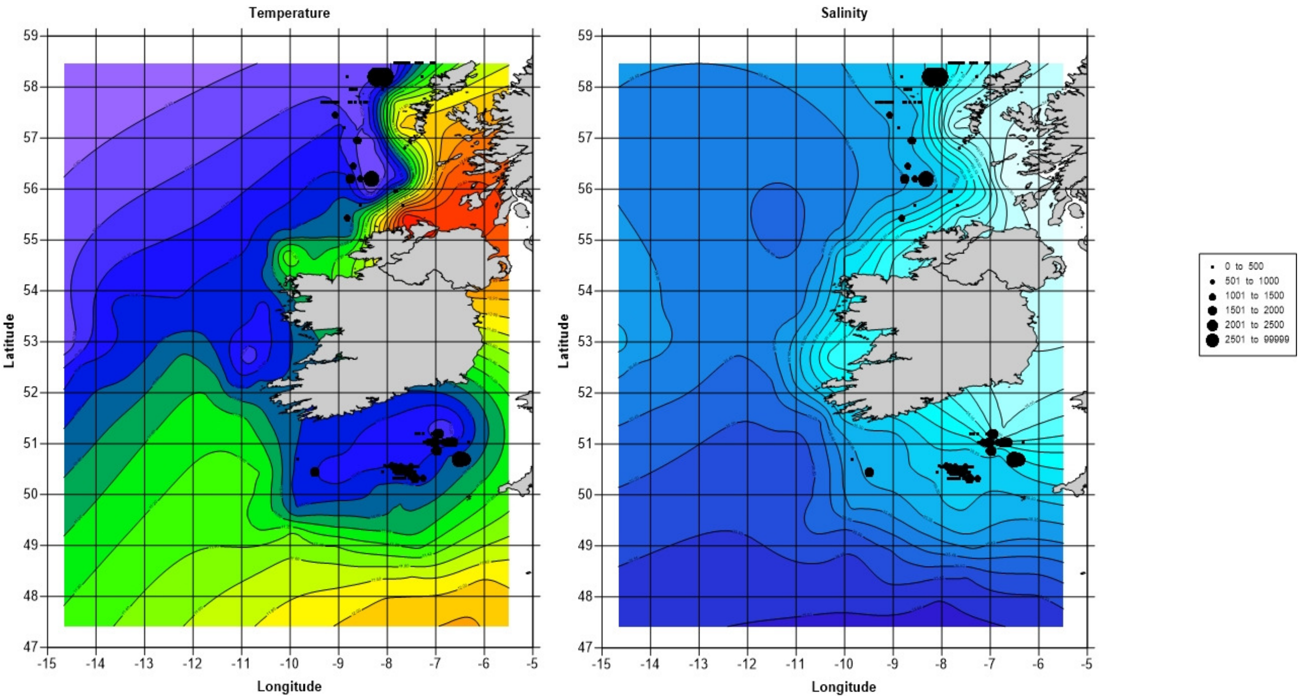


Figure 17. Habitat plots of temperature and salinity with herring distribution. Sea floor values overlaid with herring NASC values (black circles).

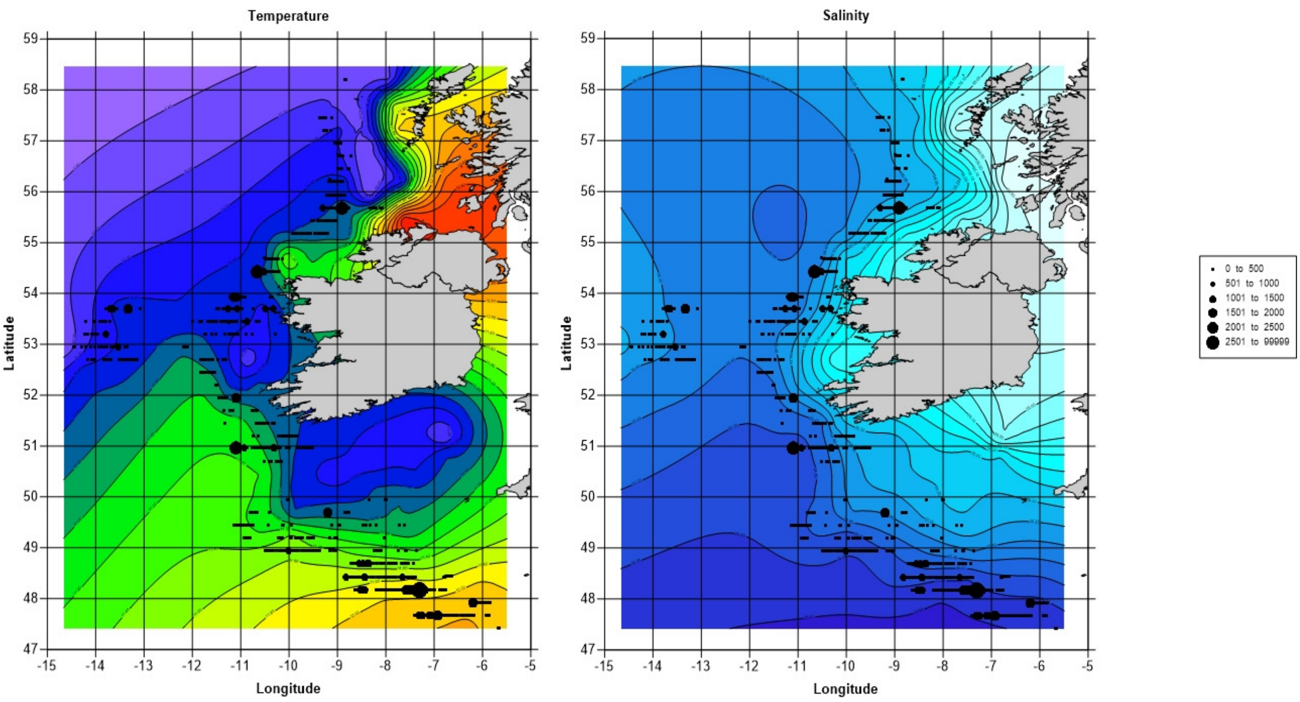


Figure 18. Habitat plots of temperature and salinity with boarfish distribution. Sea floor values overlaid with boarfish NASC values (black circles).

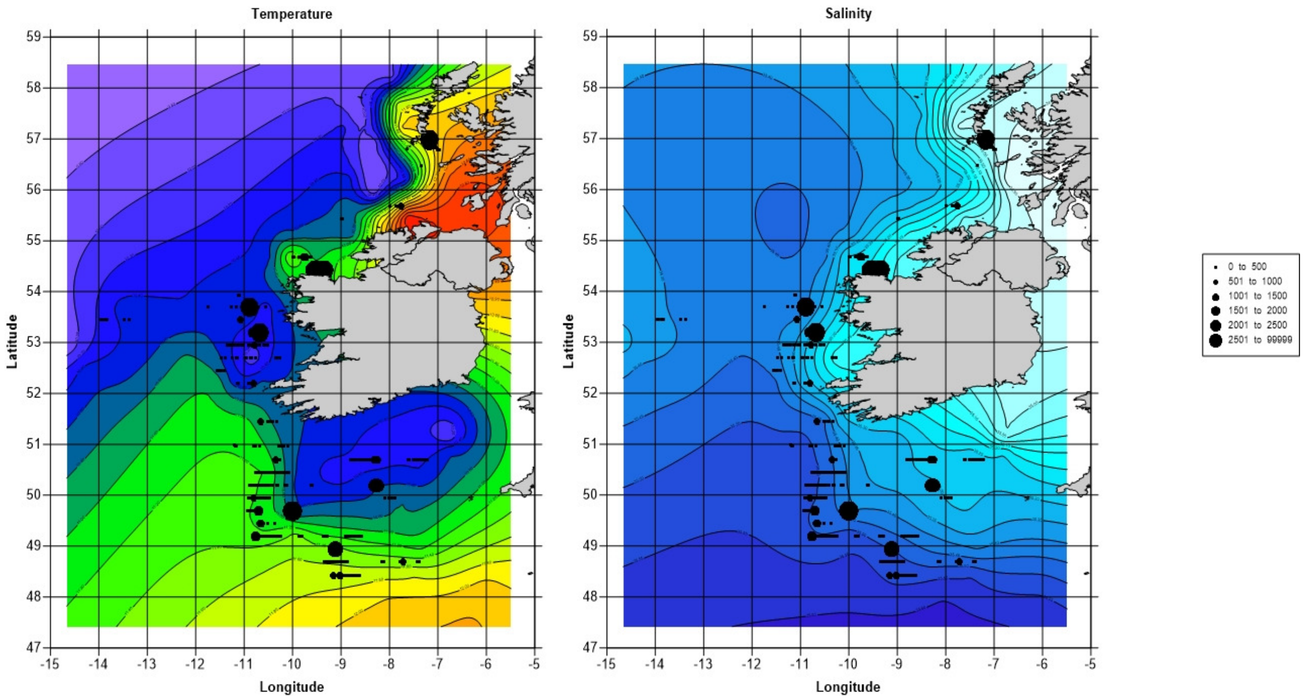


Figure 19. Habitat plots of temperature and salinity with horse mackerel distribution. Sea floor values overlaid with horse mackerel NASC values (black circles).

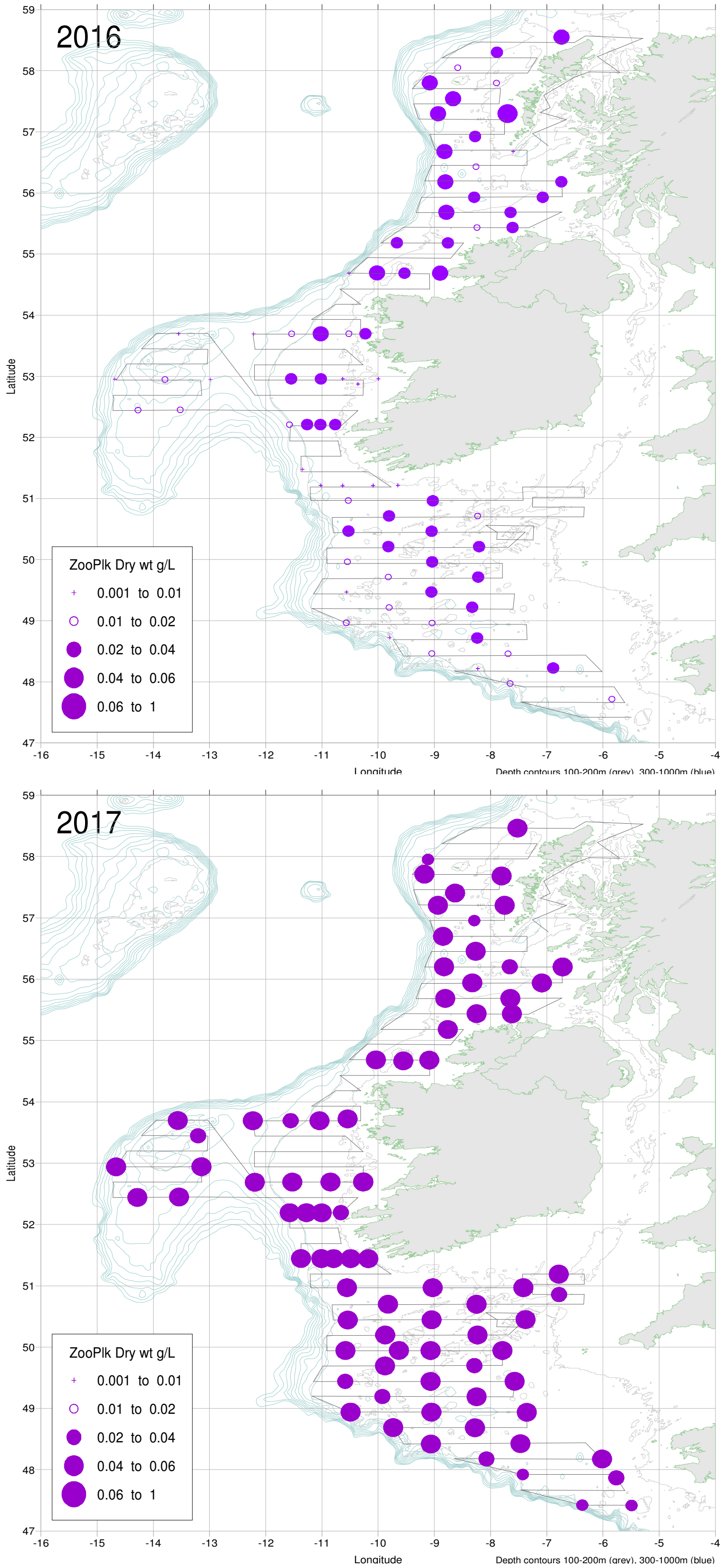


Figure 20. Zooplankton biomass by station (g dry wt m^3) top panel 2016 bottom panel 2017.

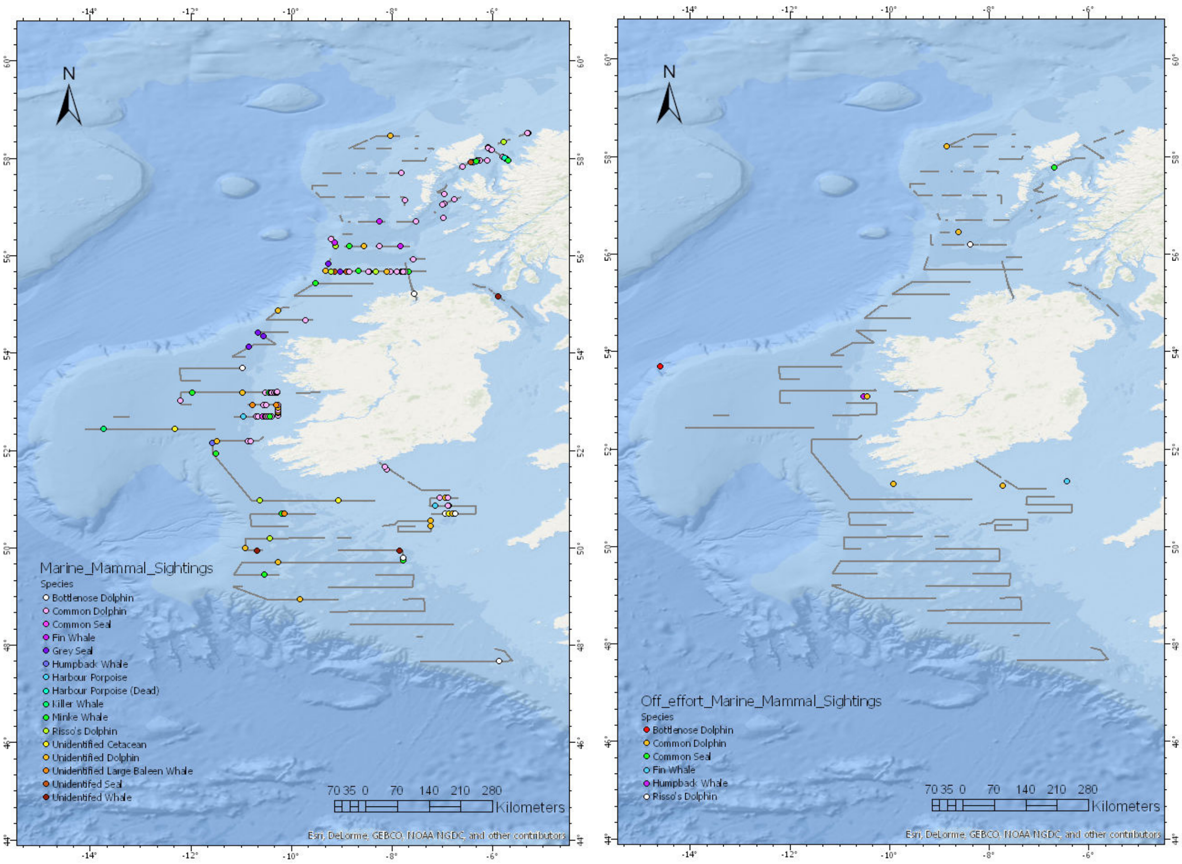


Figure 21. Distribution of marine mammal sightings while on-effort (left pane) and off-effort (right pane) profiled with observer effort.

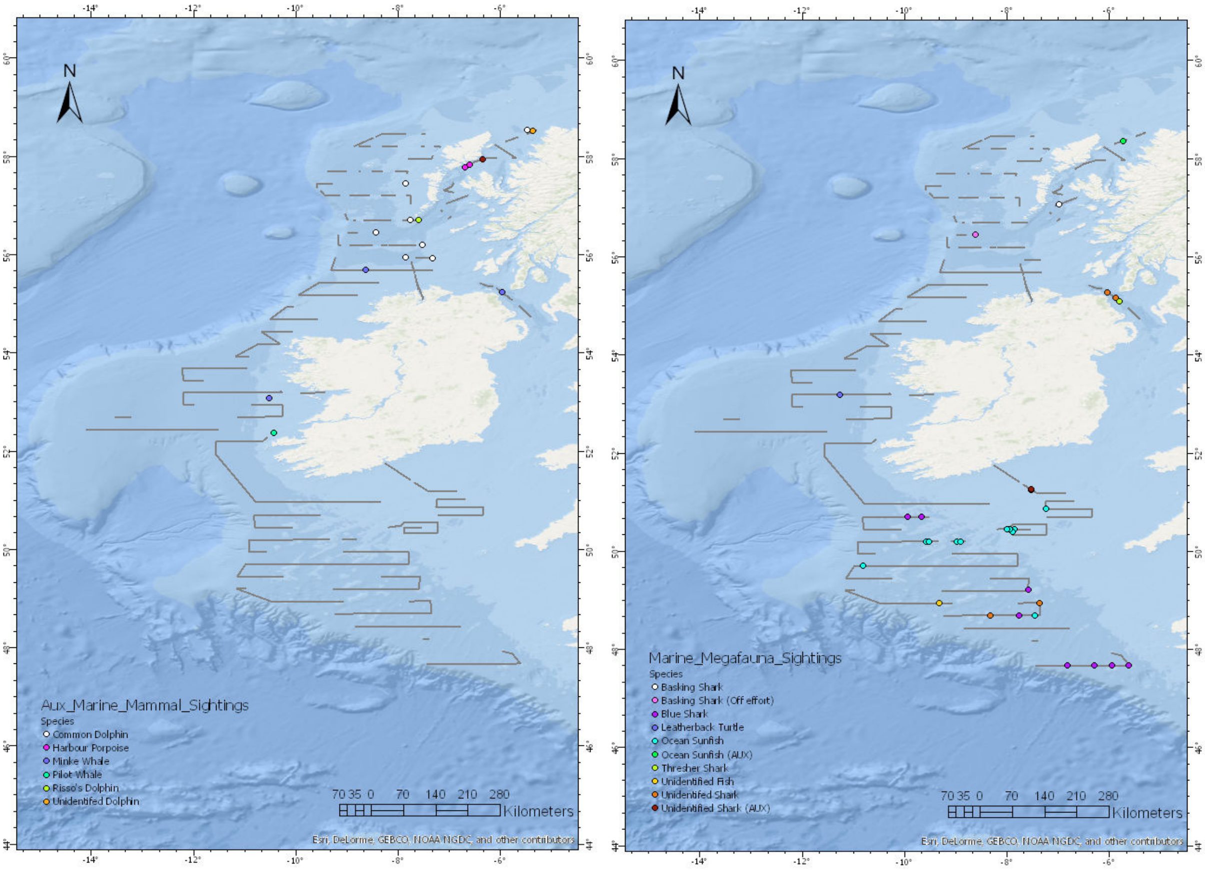


Figure 22. Distribution of marine megafauna sightings, including auxiliary sightings, while on and off effort during the survey profiled with observer effort.

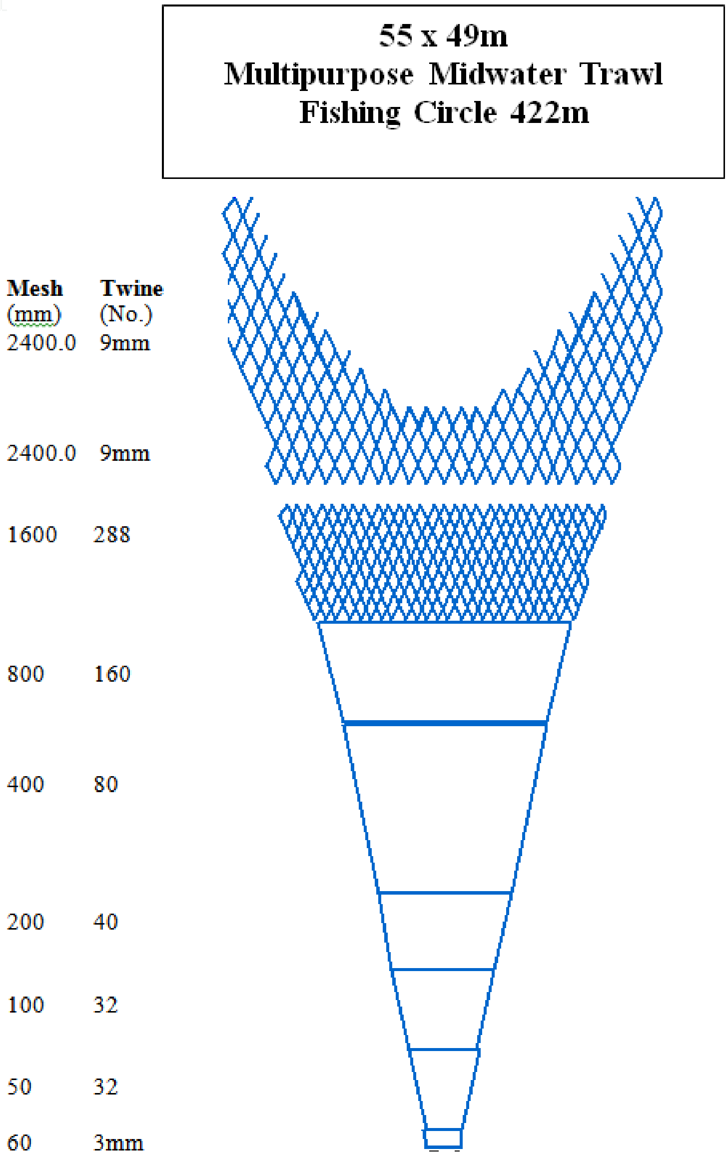


Figure 23. Single multipurpose midwater trawl net plan and layout.

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