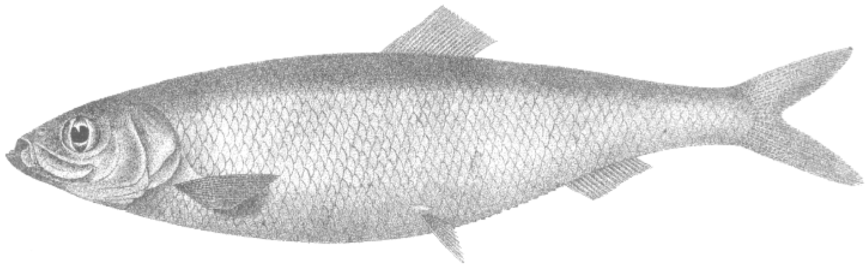
FSS Survey Series: 2017/04

Celtic Sea Herring Acoustic Survey Cruise Report 2017

15 - 04 November, 2017



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Cláir Chistí Eorpacha Struchtúrtha agus Infheistíochta na hÉireann 2014–2020
Cómhaoinithe ag Rialtas na hÉireann agus ag an Aontas Eorpach
Department of Agriculture, Food and the Marine
An Roinn Talmhaíochta, Bia agus Mara
EUROPEAN MARITIME AND FISHERIES FUND

Table of Contents

1 Introduction

In the southwest of Ireland and the Celtic Sea (ICES Divisions VIIaS, g & j), herring are an important commercial species to the pelagic and polyvalent fleet. The local fleet is composed of dry hold polyvalent vessels and a smaller number of large purpose built refrigerated seawater vessels (RSW). The stock is composed of both autumn and winter spawning components with the latter dominating. The fishery targets pre-spawning and spawning aggregations in Q3-4. The Irish commercial fishery has historically taken place within 1-20nmi (nautical miles) of the coast. Since the mid-2000s RSW fleet have actively targeted offshore aggregations migrating from summer feeding in the south Celtic Sea. In VIIj, the fishery is traditionally active from mid-November and is concentrated within several miles of the coast. The VIIaS fishery peaks towards the year end in December, but may be active from mid-October depending on location. In VIIg, along the south coast herring are targeted from October (offshore) to January at a number of known spawning sites and surrounding areas. Overall, the protracted spawning period of the two components extends from October through to January, with annual variation of up to 3 weeks. Spawning occurs in successive waves in a number of well known locations including large scale grounds and small discreet spawning beds. Since 2008 ICES division VIIaS (spawning box C) has been closed to fishing for vessels over 15m to protect first time spawners. For those vessels less than 15m a small allocation of the quota is given to this ‘sentinel’ fishery operating within the closed area.

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.

For a period in the 1970s and1980s, 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. In the Celtic Sea and VIIj, herring acoustic surveys have been carried out since 1989. Since 2004 the survey has been fixed in October and carried out onboard the RV *Celtic Explorer.*

The geographical confines of the annual 21 day survey have been modified in recent years to include areas to the south of the main winter spawning grounds in an effort to identify the whereabouts of winter spawning fish before the annual inshore spawning migration. Spatial resolution of acoustic transects has been increased over the entire south coast survey area. The acoustic component of the survey has been further complemented since 2004 by detailed hydrographic, marine mammal and seabird surveys.

2 Materials and Methods

2.1 Scientific Personnel

Organisation	Name	Capacity	Leg
FEAS	Ciaran O'Donnell	Acou (Chief Sci)	All
FEAS	Michael O'Malley	Acou	1
FEAS	Graham Johnston	Acou	All
FEAS	Eugene Mullins	Acou	1
Student	Sean McLoughlin	Acou	2
FEAS	Dave Tully	Acou	2
FEAS	Dee Lynch	Bio (Deck Sci)	1
FEAS	Grainne Ni Choncuir	Bio	All
FEAS	Sean O'Connor	Bio	All
FEAS	Dermot Fee	Bio	1
FEAS	Susan Beattie	Bio (Deck Sci)	2
MMO	Derek O'Driscoll	MMO	All
GMIT	Niall Keogh	SBO	All
Queens	Justin Judge	SBO	All
NPWS	Alyn Walsh	SBO	1
GMIT	Heidi Acampora	SBO	1
AMS	Slava Sobolev	Surveyor	All
Industry	John O'Regan	Ind Obs	All

*SBO- Seabird observer, MMO- marine mammal observer

2.2 Survey Plan

2.2.1 Survey objectives

The primary survey objectives are listed below:

- Carry out a two phase survey cruise track covering the core survey area
- Investigate high abundance herring aggregations using adaptive survey techniques. Use the EM 2040 Bathymetric multibeam to map the extent of herring aggregations during adaptive surveys
- Collect biological samples from directed trawling on insonified fish echotraces to determine age structure and maturity state of the herring stock
- Determine an age stratified estimate of relative abundance of herring within the survey area (ICES Divisions VIIj, VIIg and VIIaS)
- Determine estimates of biomass and abundance for sprat within the survey area
- Collect physical oceanography data from vertical profiles from a deployed sensor array
- Survey by visual observations marine mammal, surface litter and seabird abundance and distribution
- Recover temperature mooring buoys from the southwest Celtic Deep

2.2.2 Area of operation

The autumn 2017 survey covered the area from Mizen Head in ICES Division VIIb (Figure 1) in Co. Cork and extended along the south coast into the Celtic Sea (Divisions VIIj, VIIg & VIIaS). The survey began on the south coast and worked in an easterly direction covering the larger core survey area during the first pass before turning westwards to complete the second pass using interlaced transects.

The survey was broken into two components. The first used a double survey approach to contain the stock within the core survey area. The second adaptive component focused on high abundance areas of herring identified during the core surveys using higher intensity sampling effort (transect spacing).

2.2.3 Survey design

2.2.3.1 Core survey

A change in survey design was implemented in 2016 by consolidating all existing strata into a single core survey stratum with uniform transect spacing of 8 nmi (nautical miles). This broad scale survey composed of 8 nmi spaced transects and progressed from west to east (Pass 1). A second pass was then carried from east to west (Pass 2). Survey transects for each pass were set at 8 nmi and offset, resulting in a transect interlacing and an effective coverage of the grounds at a 4 nmi resolution.

A parallel transect design was used with transects running perpendicular to the coastline and lines of bathymetry where possible. Offshore extension reached up to 90 nmi. Transect start points within each stratum are randomised each year within established baseline stratum bounds.

In total the core surveys accounted for 1,989 nmi of transects covering an area of over 13,232 nmi^2.

2.2.3.2 Adaptive survey

Adaptive surveys were carried out in high abundance areas identified during the core survey. Candidate areas were identified from positional data from fishing activities during the co-occurring offshore fishery.

Each candidate area was scouted to determine geographical extent of target aggregations. A survey plan was then designed with transects running perpendicular to the lines of bathymetry. Parallel transects were spaced at either 0.5 or 1 nmi depending on area size. The EK60 single beam and EM2040 multibeam systems were run in parallel to provide quantitative and spatial data respectively. Survey design followed methods described in Simmonds and MacLennan (2005) for adaptive surveys. Individual transects were run in parallel crossing the extent of the herring aggregation with the end point determined when no further herring were observed for 0.5 nmi.

Directed fishing trawls and in-trawl optics were used to determine echotrace identification as applied during routine surveying operations.

Combined, the four adaptive surveys accounted for 740 nmi of transects covering an area of 1,728 nmi^2.

2.3 Equipment and system details and specifications

2.3.1 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). The acoustic settings for the EK60 38 kHz transducer are shown in Table 1.

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 8.8m 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 (ICES 2002). During fishing operations normal two-engine operations were employed to provide sufficient power to tow the net.

For the EM2040 bathymetric multibeam a manual fixed angular coverage was used (65° opening angle) to standardise the volume of water sampled. Pulse type and ping rate were set to auto to optimise data acquisition and the sampling frequency was set at 300 kHz to minimise interference on the EK60. The ping rate on the EK60 was maintained at 3 pings per second while the EM2040 auto setting produced a ping rate of approximately 3.5 pings per second.

2.3.2 Calibration of acoustic equipment

A calibration of the EK60 was carried out in Dunmanus Bay on the 15th of October at the start of the survey and in daylight hours following methods described by Demer *et al.* (2015). Calibration results and settings are provided in Table 1.

2.4 Survey protocols

2.4.1 Acoustic data acquisition

Acoustic data were observed and recorded onto the hard-drive of the processing unit using the equipment settings from previous surveys. The "RAW files" were logged via a continuous Ethernet connection to the vessels server and the ER60 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 7) 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.

2.4.2 Biological sampling

A single pelagic midwater trawl with the dimensions of 19 m in length (LOA) and 6 m at the wing ends and a fishing circle of 330 m was employed during the survey (Figure

15). Mesh size in the wings was 3.3 m through to 5 cm in the cod-end. The net was fished with a vertical mouth opening of approximately 9m, which was observed using a cable linked Simrad FS70 netsonde. The net was also fitted with a Scanmar depth sensor. 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, sprat and pilchard were taken to the nearest 0.5 cm below. Age, length, weight, sex and maturity data were recorded for individual herring within a random 50 fish sample from each trawl haul, where possible. All herring were aged onboard. The appropriate raising factors were calculated and applied to provide length frequency compositions for the bulk of each haul.

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

2.4.3 Oceanographic data collection

Oceanographic stations were carried out during the survey at predetermined locations along the track. Data on temperature, depth and salinity were collected using a calibrated Seabird 911 sampler at 1 m subsurface and 3 m above the seabed.

2.4.4 Marine mammal and seabird observations

2.4.4.1 Marine Mammal sighting survey

During the survey an observer kept a daylight watch on marine mammals from the crow's nest (18 m above sea level) when weather allowed or from the bridge (11 m).

During cetacean observations, watch effort was focused on an area dead ahead of the vessel and 45° to either side using a transect approach. Sightings in an area up to 90° either side of the vessel were recorded. The area was constantly scanned during these hours by eye and with binoculars. Ship's position, course and speed were recorded, environmental conditions were recorded every 15 minutes and included, sea state, visibility, cloud cover, swell height, precipitation, wind speed and wind direction. For each sighting the following data were recorded: time, location, species, distance, bearing and number of animals (adults, juveniles and calves) and behaviour. Relative abundance (RA) of cetaceans was calculated in terms of number of animals sighted per hour surveyed (aph). RA calculations for porpoise, dolphin species and minke whales were made using data collected in Beaufort sea state ≤ 3. RA calculations for large whale species were made using data collected in Beaufort sea state ≤ 5.

2.4.4.2 Seabird sighting survey

A standardized 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.

Two observers (a primary observer and a primary recorder, who also acted as a secondary observer), in rotation from a pool of three surveyors, were allocated to survey shifts of two hours, surveying from 08.00 (or first light) to 18.00 hours (dusk) each day. Environmental conditions, including wind force and direction, sea state, swell height, visibility and cloud cover, and the ship's speed and heading were recorded at 2-hourly intervals during surveys. In the intervening time, any changes to environmental conditions were also noted, so that a discreet set of environmental conditions was obtained for each 5-minute interval. No surveys were conducted in conditions greater than sea state 5, when high swell made working on deck unsafe or when visibility was reduced to less than 300 m.

The seabird observation platform was the wheelhouse deck, which is 10.5m 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 bow to beam) and ahead of the ship. This survey band was sub-divided (A = 0-50 m from the ship, B = 50-100 m, C = 100-200 m, D = 200-300 m, E > 300 m) to subsequently allow correction of differences in detection probability with distance from the observer. A fixed-interval range finder (Heinemann 1981) was used to periodically check distance estimates. The area was scanned by eye, with binoculars used only to confirm species identification.

All birds seen on the water within the survey area were counted, and those recorded within the 300 m band, were 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 at the moment the ship passed from one survey block (300 m x 300 m) to the next. Survey time intervals were set at 5 minutes. Additional bird species observed outside the survey area were also recorded and added to the species list for the research cruise, but these will not be included in maps of seabird abundance or density.

On acoustic survey transects the vessel had an average speed of 10 knots, while speed was reduced to 4 knots for trawling effort. Tows lasted around 45 minutes and were mostly separated by extended sessions of steaming at 10 knots, so that few birds were attracted to the ship. CTD stations were conducted on some transects, during which the vessel remained stationary for, on average, 18 minutes. Seabird surveying was interrupted while the ship was stationary at CTD stations and while towing since this can attract large numbers of birds. Where fish sampling operations were prolonged or at close intervals, seabird surveying was only recommenced after a period (45min – 1hr) of prolonged steaming at 10 knots, allowing the associating birds to disperse. Any bird recorded in the survey area that stayed with the ship for more than 2 minutes was regarded as being associated with the survey vessel (Camphuysen *et al.* 2004) and was coded as such (to be excluded from abundance and density calculations).

The daily total count data per day for each species is presented along with the daily survey effort. It is envisaged that this data will be analysed in the future and the seabird abundance (birds per km traveled), and seabird density (birds per km^2) will be mapped per 1⁄4 ICES rectangle (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. It is also hoped to combine this analysis with the results of the cetacean observation and acoustic survey. The binomial species names for the birds recorded are presented in the species accounts.

All visible marine litter was also recorded during bird observations. The litter was identified or described as accurately as possible; quantity, size and distance from the boat was noted. When possible, pictures of the objects were taken.

2.5 Analysis methods

2.5.1 Echogram partitioning

Acoustic data was backed up every 24 hrs and scrutinised using Echoview® (V 7) post processing software.

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

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

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 Celtic Sea Herring 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)

2.5.2 Abundance estimate

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).

3 Results

3.1 Celtic Sea herring stock

3.1.1 Herring biomass and abundance

Herring biomass and abundance was calculated from core and adaptive survey to stratum level.

Total herring biomass (TSB) and spawning stock biomass (SSB) by survey strata is provided in Table 3. The biomass presented below is a composite based on the largest area covered.

Herring	Abund ('000)	Biomass (t)
Total stock	26,593.0	3,688.7
Spawning stock	26,367.0	3,677

3.1.2 Herring distribution

A total of 14 trawl hauls were carried out during the survey (Figure 1), with 1 haul containing >50% herring by weight of catch (Table 2).

Core Surveys

Two core surveys were carried out; Pass 1 and Pass 2. No herring were observed during Pass 1. During Pass 2, herring were encountered inshore to the west of Cork Harbour and offshore in the Celtic Deep (Figure 2). A combined total of 5 echotraces were identified as herring during Pass 2. Offshore echotraces were encountered in the area where further adaptive work was carried out (see adaptive surveys below). Herring sampled during Haul 05 from inshore area contained smaller fish and immature individuals as compared to the offshore sample (Figure 4).

In terms of effort, acoustic sampling in core areas was comparable to 2016. The survey area was extended south to cover an area where herring medium density herring aggregations were encountered during the summer (O'Donnell *et. al*, 2017). As no herring were observed the stock was considered contained within the survey area.

Off track scouting was undertaken in the Trench area during the core surveys as aggregations were detected in this area in 2015. However, no herring were detected during two separate searches extending to approximately 35 nmi.

Adaptive Surveys

One localised area was identified from the fishery and two adaptive surveys were carried out (Figure 3). Adaptive survey 1 was conducted over a 12 hour period during dark and was made up of 10 transects (1 nmi spacing) accounting for 100 nmi of sampling effort within an area of 108 nmi^2. Tidal phase at the time was falling from a Spring high (2 days earlier). However, herring were caught in this area hours before the survey was undertaken and the survey was undertaken based on this real-time information.

The survey started in the south and worked northwards. Five herring echotraces were identified during this survey.

Adaptive survey 2 was conducted over a larger area encompassing adaptive area 1 at the southern boundary and extending northwards for a further 7 nmi. This survey took 20 hours to complete beginning in the late afternoon in the south and working northwards finishing the following morning. The survey was undertaken 5 days after the first and approaching Neap tidal phase. The survey used 18 transects spaced at 1 nmi (194 nmi of sampling effort) to cover the overall area of 201nmi². In total 19 herring echotraces were identified during this survey.

A third adaptive survey was carried over the area where herring were observed during the summer feeding phase in June (O'Donnell *et. al*, 2017). This large area was covered over a 40 hour period using 10 transects and accounted for 450 nmi of sampling effort. The total area covered was 1,420 nmi². No herring were observed in this area.

3.1.3 Herring stock composition

A total of 119 herring were aged from survey samples in addition to 291 length measurements and 26 length-weights. Herring age samples ranged from 0-8 winter-rings (Figures 4 & 5).

Core survey

Age composition of Pass 2 was dominated by 4 winter ring fish representing 28.2% of the total stock biomass (TSB) and 27.1% of total stock numbers (TSN), followed by 5 winter ring (20% TSB and 17.4% TSN) and 2 winter ring (16.9% TSB and 22.5% TSN) herring respectively. Combined these age cohorts accounted for 65.1% of TSB and 67.1% of TSB. Immature fish accounted over <1% (10.6 t) of the 3,426.1 t estimate.

Adaptive surveys

Adaptive surveys 1 and 2 focused on a specific area. However, the later covered a wider area and so directed comparison of estimates was not possible (Table 3). Survey 2 covered a larger area and was deemed the most representative. Age structure of survey 2 was composed of mature fish with 4, 5 and 2 winter ring fish dominating (Figure 5).

3.2 Other pelagic species

3.2.1 Sprat

Sprat were found widely distributed throughout the survey area and sampled in 11 of 14 hauls (Figure 6, Table 2). In total 2,084 individual length measurements and 599 length/weight measurements were recorded. Mean length was 7.7 cm and mean weight was 3.4 g (8.0 cm and 4 g in 2016). Individuals ranged from 1 to 14.5 cm in length and 1 to 22 g in weight.

In total 485 individual sprat echotraces were identified in total during core surveys (Pass 1: 372 and Pass 2: 113). Distribution was comparable between successive surveys and observations in 2016. Adaptive strata 3 contributed significantly to the overall biomass (20%).

Pass 2 and adaptive strata 2 contained the widest range of size classes from small to large as compared to adaptive strata 3 which was composed of a narrow length range. Overall the most dominant size class occurred at 7.5-8 cm (Figure 7).

3.3 Oceanography

A total of 34 CTD stations were carried out. Surface plots of temperature and salinity are presented using 5 m and 20 m depth profiles (Figures 9 & 10), while profiles for 60 m and near bottom profiles are overlaid with sprat and herring NASC data respectively (Figures 11 & 12).

Horizontal plots of temperature and salinity at 5, 20 and 60 m depths (Figure 9, 10 & 11) showed conditions were relatively uniform for the main body of the survey area and seasonal thermocline has broken down. At 60m the influence of fresh water from river outputs is evident extending outwards from the shore. Two large storm events passed over the area during the course of the survey (Ex hurricane Ophelia and storm Brian). Maximum wave height exceeded 17m in the eastern Celtic Sea (M5 weather buoy). Across all depth profiles the influence of the cooler Atlantic water is evident pushing eastward.

Four temperature moorings were deployed in June during the WESPAS survey in and around the area where herring aggregate prior to the northward spawning migration. Two of these moorings were lost during the storm events but two were recovered and service. These two moorings will finally be recovered in December this year and the data analysed. These data will be used to determine if temperature can be determined as a physical driver for migration onset.

3.4 Marine mammal and seabird observations

3.4.1 Marine mammal sightings

Survey effort

A total of 132 hours and 07 minutes of effort was recorded between October 15th and the 04th of November. Effort recorded for Leg 1 was 54 hours and 18 minutes, Leg 2 was 77 hours and 49 minutes. Due to adverse weather conditions during Leg 1 of the survey, two twenty-four hour periods (16^{th} and 21^{st} Oct) could not be surveyed as the vessel was in dock. A total of 10 hours and 43 minutes was surveyed from the bridge due to it being deemed unsafe to conduct the survey from the crow's nest by the duty bridge officer. The majority of the effort was conducted from the crow's nest during Leg 1 and for the entirety of Leg 2.

Environment

Fog was recorded for 3.1% of the total survey effort, rain was recorded for 7.4% and ranged in intensity from intermittent light (51.7%), continuous light (27.6%) and intermittent heavy (20.7%). The majority (89.5%) of the survey effort did not have any precipitation. Visibility ranged from <1km to 15km, with the most recorded visibility range being 6-10km (48%). Periods of low visibility (<1km) accounted for 8.2% of the survey effort, the low visibility was associated with fog and rain. The observed Beaufort Sea state during survey effort ranged from 1 to 6. A sea state of 1 was the most prevalent accounting for 27.1% of the survey effort, sea state 4 accounted for 20%, sea state 3 for 16.6%, sea state 2 for 15.1% and sea state 5 for 12%. A sea state of 6 was recorded 9.2% of the time, during which time observations were mostly conducted from the bridge.

Sightings report

A total of 136 cetacean sighting events occurred throughout the survey, comprising of a minimum of 706 individual animals (Figures 13 & 14). Positive identification of six cetacean species was recorded. There were six sightings of unidentified whales (six individuals) and four of unidentified dolphins (23 individuals). Common dolphins (Delphinus delphis) were the most frequently sighted species during the survey, making up 63.8% of total sightings. Fin whales (Balaenoptera physalus) were the second most frequently encountered species, with 27 individuals detected during 17 sightings. Eleven sightings of other cetacean species were recorded during the survey including humpback whale (Megaptera novaeangliae), minke whale (Balaenoptera acutorostrata), Risso's Dolphin (Grampus griseus), and harbour porpoise (Phocoena phocoena). Two species of pinniped, grey seal (Halichoerus grypus) and harbour seal (Phoca vitulina) were also recorded. An estimated 115 tuna (most probably blue fin - Thunnus thynnus) were observed during 10 sightings. Tuna were observed as they rushed the surface causing splashing, presumably during feeding. Feeding was also observed in 11 sightings of common dolphins and in two sightings of unidentified dolphin.

3.4.2 Seabird sightings and marine litter

A total of 66 hours and 14 minutes (3,974 minutes) of dedicated seabird surveys was conducted across sixteen days between 17th October and 2nd November 2017. Casual observations during transit to and from the survey area on 15th October and 3rd November amounted to 2 hours and 30 minutes of effort bringing the total effort for the survey period to 68 hours and 44 minutes (4,124 minutes). Inclement weather conditions meant that no surveys were conducted on 16th October (ex-Hurricane Ophelia) and 21st October (Storm Brian). A total of nine point counts were made during fishing tow operations during the survey.

A cumulative total of 10628 individual seabirds of 28 species was recorded, of which 3689 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 8. In addition, daily totals for twenty-four species of migrant terrestrial birds recorded on or around the vessel are also presented (Table 9).

The seabird team recorded presence of marine litter or debris observed in transect areas. Details of distance from the survey vessel, estimated size, material involved, colour and any branding were noted. Recording of marine litter using this format has been ongoing during CSHAS surveys since 2013, data of which is being compiled for future analysis.

4 Discussion and Conclusions

4.1 Discussion

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

Fishing was carried out on schools of interest as required. However, the lack of herring in the survey area meant that trawling opportunities were limited. Adaptive surveying and off track searching was carried out based on real time information from the fleet. Adaptive operations were highly reactive to the information received. In addition adaptive surveys were conducted with a sufficient temporal gap to allow for duplicate surveys across lunar tidal phase (Spring/Neap).

Geographical coverage extended southwards in 2017 as part of an adaptive stratum and based on observations of herring during the summer WESPAS survey. The eastern boundary of the Celtic Deep was surveyed by the RV *CEFAS Endeavour as* part of the annual PELTIC survey program and reported no herring in co-surveyed areas. Low herring abundance was observed within their survey area and is in line with previous years (Van Der Kooij pers. com. Oct, 2017). Overall the survey was considered to have contained the stock within the survey area as in 2014 to 2016.

The abundance of herring was significantly lower in 2017 for the increased amount of survey effort and area coverage. Timing of the survey was two weeks later than in previous years. Realistically this not thought to have been a significant factor in the low abundance observed. The co-occurring offshore fishery also saw low catches relative to searching effort offshore before the focus of the fishery moved inshore targeting aggregations of containing a higher proportion of small and juvenile fish.

The Celtic Deep region is no doubt an important pre-migration staging post for herring and during the summer feeding months. Anecdotal evidence from the demersal fishing fleet agrees with our observations (June) that herring were aggregating in this area from mid-summer. Post spawning, spent herring migrate southwards towards the feeding grounds as part of the overwintering migration. Stomach contents analysis of herring from the Celtic Deep area showed that some fish (46% of sample by weight) were actively feeding with stomachs full of krill.

The two large storm events were unusual in their strength and timing, occurring in quick succession. Storm Ophelia pushed northwards from the south and saw the seasonal breakdown of the thermocline coupled with the mixing of above average surface temperatures. The water column post the Ophelia storm event was fully mixed and saw temperatures in some offshore areas of 14℃ (O'Donnell, unpublished data).

Large predators including common dolphin, humpback and minke whales as well as blue fin tuna were present in around the Celtic Deep area. However, the presence of these large predators is not unusual and this alone cannot be responsible for the low abundance observed.

Sprat biomass and distribution follows a similar pattern to previous years with schools spread widely over the Celtic Sea. As sprat show strong diurnal migration into surface waters at night this makes acoustic measurement difficult. As the survey operates over 24 hrs estimates the annual abundance of sprat is limited in this regard.

4.2 Conclusions

- The stock was considered contained within the extended survey area in 2017 with no herring observed around the survey periphery or on the summer feeding grounds.
- Overall herring distribution was split into offshore and inshore aggregations. The offshore component was located in the same localised area as in recent years but in lower numbers. The inshore component contained a higher proportion if immature fish.
- The low biomass observed during the survey was supported by the lack of fishing opportunity relative to searching effort by the commercial fleet. The lack of herring samples from the survey prevented the calculation of CV for the survey estimate. During the survey period the focus of the herring fishery moved from offshore to inshore waters, albeit where catches were made up of a higher proportion if immature fish, due to lack of opportunity offshore.
- Tidal range and state are factors considered to influence fish behaviour in this area. Offshore adaptive surveys were carried out over with a temporal gap of over 5 days covering fall of peak spring tides and near neap tidal phases to counteract the tidal affect as much as possible.
- Herring observed offshore showed carpeting behaviour as in previous years in the same area and at the same time. However, abundance was significantly lower.
- Since 2013 survey observations indicate that the biomass of the offshore migratory component of the stock is decreasing and recruitment remains poor.
- The dominate age classes of the stock were not clearly evident from the lack of trawling opportunity. Samples taken offshore were composed of older, larger individuals. The presence of immature fish in coastal waters follows a similar pattern to previous years.

Acknowledgements

We would like to thank the captains Denis Rowan and Anthony Hobin and the crew of the Celtic Explorer for their help and professionalism during the survey. We also thank John O' Regan for his expert advice on fishing operations and for liaising with the commercial fishing fleet. Many thanks also to the seabird and marine mammal survey teams, who worked tirelessly during the survey in all weathers and with great enthusiasm.

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5 Tables and Figures

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

Echo Sounder System Calibration

Vessel : R/V Celtic Explorer		Date : 17/10/2016	
Echo sounder : EK60		Locality : Dunmanus Bay	
Type of Sphere : CU-38,1	**TS**$_{Sphere}$: -33.50 dB (Corrected for soundvelocity or t,S)	Depth(Sea floor) : 37 m	

Calibration Version 2.1.0.11

Comments:
Dunmanus Bay, post Ophelia

Reference Target:

TS	-33.51 dB	Min. Distance	18.00 m
TS Deviation	5.0 dB	Max. Distance	22.00 m

Transducer: ES38B Serial No. 30227

Frequency	38000 Hz	Beamtype	Split
Gain	25.47 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	6.96 deg	Along. Beam Angle	6.83deg
Athw. Offset Angle	-0.07 deg	Along. Offset Angl	-0.02 deg
SaCorrection	-0.66 dB	Depth	8.8 m

Transceiver: GPT 38 kHz 009072033933 1 ES38B

Pulse Duration	1.024 ms	Sample Interval	0.191 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.	8.0	Max. Echolength	180 %

Environment:

Absorption Coeff.	9.8 dB/km	Sound Velocity	1493.9 m/s

Beam Model results:

Transducer Gain =	25.73 dB	SaCorrection =	-0.68 dB
Athw. Beam Angle =	7.00 deg	Along. Beam Angle =	6.93 deg
Athw. Offset Angle =	-0.04 deg	Along. Offset Angle=	-0.04 deg

Data deviation from beam model:
RMS = 0.14 dB
Max = 0.32 dB No. = 243 Athw. = -3.4 deg Along = -3.3 deg
Min = -0.83 dB No. = 408 Athw. = -4.2 deg Along = 2.9 deg

Data deviation from polynomial model:
RMS = 0.08 dB
Max = 0.18 dB No. = 201 Athw. = 2.8 deg Along = -3.4 deg
Min = -0.65 dB No. = 123 Athw. = 0.5 deg Along = -2.9 deg

Comments :

Wind Force : 3 **Wind Direction** E
Raw Data File: \\Expfilelstr\ER-60_Data\CSHAS_2016\RAW ER60 Files\Calibration\CSHAS_2017
Calibration File: \\Expfilelstr\ER-60_Data\ER-60\Calibrations_2017\CSHAS 2017\38 KHZ

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)	Herring %	Mackerel %	Scad %	Sprat %	Pilchard %	Others* %
1	18.10.2017	51.41	-8.29	08:36	91	65	145.4		24.4	0.2	72.1		3.3
2	19.10.2017	50.81	-7.65	15:51	102	75	56.5		2.0	2.1	84.5		11.4
3	22.10.2017	51.42	-7.22	08:24	80	50	300.0			91.7			8.3
4	23.10.2017	51.19	-6.59	13:48	107	107	179.6	0.2	0.4	1.2	0.9		97.3
5	25.10.2017	51.61	-8.43	19:05	51	20	117.7	2.8	0.7	0.5	88.6	0.1	7.3
6	26.10.2017	51.55	-7.77	14:53	78	65	145.7		6.0	0.1	90.8		3.1
7	26.10.2017	51.83	-7.75	19:18	49	20	120.1		3.2	0.2	89.4	5.7	1.5
8	28.10.2017	52.06	-6.91	06:44	38	5	450.0	1.0			88.3		10.7
9	28.10.2017	51.40	-6.48	22:50	90	0	129.5	50.5	5.2	6.3	2.3		35.8
10	29.10.2017	51.57	-6.69	16:30	70	0	20.9		7.9		16.3	0.1	75.7
11	30.10.2017	51.51	-6.27	06:49	103	0	300.0		0.1	0.5			99.5
12	30.10.2017	51.86	-5.81	17:52	111	0	2000.0		1	95.4	0.14		3.1
13	31.10.2017	50.91	-6.75	13:09	95	5	160.3		26.2	3.2	68.3		2.3
14	01.11.2017	50.43	-7.48	17:33	100	0	3500.0			99.9			0.1

Table 3. Herring biomass and abundance by strata. Grey coloured strata excluded from the total biomass due to replicate coverage.

Strata	Name	Type	Area (nmi²)	Transects	TSN (Ind)	TSB (t)	SSN (Ind)	SSB (t)
1	Pass 1	Core	6,013.2	11	0	0.0	0	0.0
2	Pass 2	Core	7,210.5	18	24,718	3,426.1	24,517	3,415.5
3	Adp 1	Adpt	107.9	10	1,357	190	1,346	189
4	Adp 2	Adpt	201.1	18	1,875	262.6	1,852	261.0
5	Adp 3	Adpt	1,419.7	10	0	0.0	0	0.0
	Total		14,952.4	67	26,593	3,689	26,369	3,677

Table 4. Sprat biomass and abundance by strata. Grey coloured strata excluded from the total biomass due to replicate coverage.

Strata	**Name**	**Type**	**Area (nmi²)**	**Transects**	**TSN ('000)**	**TSB (t)**
1	Pass 1	Core	6,013.2	11	4,189	13,442.0
2	Pass 2	Core	7,210.5	18	13,285	52,472.5
3	Adp 1	Adpt	107.9	10	33	94.1
4	Adp 2	Adpt	201.1	18	261	754.8
5	Adp 3	Adpt	1,419.7	10	4,129	13,266.7
	Total		14952	67	17,676	66,494

Table 5. Marine mammal sightings, counts and group size ranges for cetaceans sighted during the survey.

Species	No. of sightings	No. of individuals	Group size range
Fin whale	17	27	1 - 3
Humpback whale	2	4	2
Minke whale	4	4	1
Common dolphin	97	628	2 - 50
Risso's dolphin	2	4	1 - 3
Harbour porpoise	4	10	1 - 5
Unidentified whale	6	6	1
Unidentified dolphin	4	23	5 - 8
Total	**136**	**706**	-

Table 6. Sightings summary of other marine fauna.

Species	No. of sightings	No. of individuals	Group size range
Grey Seal	7	7	1
Harbour Seal	1	1	1
Tuna species	10	115	5 - 20
Total	**18**	**123**	-

Table 7. Totals for all seabird species recorded between 15th October and 3rd November 2017.

Vernacular Name	Scientific Name	On Survey	Off Survey	Total
Common Scoter	*Melanitta nigra*	11	0	11
Red-throated Diver	*Gavia stellata*	2	0	2
Great Northern Diver	*Gavia immer*	3	0	3
European Storm-petrel	*Hydrobates pelagicus*	6	9	15
Leach's Storm-petrel	*Oceanodroma leucorhoa*	2	0	2
Fulmar	*Fulmarus glacialis*	162	414	576
Sooty shearwater	*Ardenna griseus*	103	9	112
Manx shearwater	*Puffinus puffinus*	67	4	71
Balearic Shearwater	*Puffinus mauretanicus*	1	0	1
Gannet	*Morus bassanus*	1788	1022	2810
Shag	*Phalacrocorax aristotelis*	1	0	1
Cormorant	*Phalacrocorax carbo*	1	1	2
Grey Phalarope	*Phalaropus fulicarius*	9	0	9
Kittiwake	*Rissa tridactyla*	999	643	1642
Sabine's Gull	*Xema sabini*	0	1	1
Black-headed Gull	*Chroicocephalus ridibundus*	42	2	44
Mediterranean Gull	*Ichthyaetus melanocephalus*	5	2	7
Common Gull	*Larus canus*	64	2	66
Great black-backed gull	*Larus marinus*	211	305	516
Herring gull	*Larus argentatus*	125	72	197
Lesser black-backed gull	*Larus fuscus graellsii*	115	1096	1211
Unidentified large gull sp.	*Larus sp.*	408	0	408
Arctic Tern	*Sterna paradisaea*	0	1	1
Great skua	*Stercorarius skua*	50	32	82
Pomarine Skua	*Stercorarius pomarinus*	0	4	4
Arctic Skua	*Stercorarius parasiticus*	7	5	12
Guillemot	*Uria aalge*	2235	14	2249
Razorbill	*Alca torda*	242	10	252
Unidentified guillemot/razorbill		253	40	293
Puffin	*Fratercula arctica*	27	1	28
Total		6939	3689	10628

Table 8. Totals of migrant terrestrial bird species recorded between 15th October and 3rd November 2017.

Vernacular Name	Scientific Name	Total
Greenland White-fronted Goose	*Anser albifrons flavirostris*	9
Wigeon	*Anas penelope*	1
Teal	*Anas crecca*	15
Tufted Duck	*Aythya fuligula*	1
Purple Sandpiper	*Calidris maritima*	1
Dunlin	*Calidris alpina*	1
Common Snipe	*Gallinago galinnago*	2
Skylark	*Alauda arvensis*	2
Swallow	*Hirundo rustica*	2
Willow Warbler	*Phylloscopus trochilus*	1
Chiffchaff	*Phylloscopus collybita*	7
Blackcap	*Sylvia atricapilla*	4
Starling	*Sturnus vulgaris*	85
Fieldfare	*Turdus pilaris*	1
Redwing	*Turdus iliacus*	1
Robin	*Erithacus rubecula*	1
Black Redstart	*Phoenicurus ochruros*	2
Wheatear	*Oenanthe oenanthe*	1
Pied Wagtail	*Motacilla alba yarrellii*	3
Meadow Pipit	*Anthus prateniss*	7
Rock Pipit	*Anthus petrosus*	1
Chaffinch	*Fringilla coelebs*	10
Brambling	*Fringilla montifringilla*	6
Goldfinch	*Carduelis carduelis*	30
Total		189

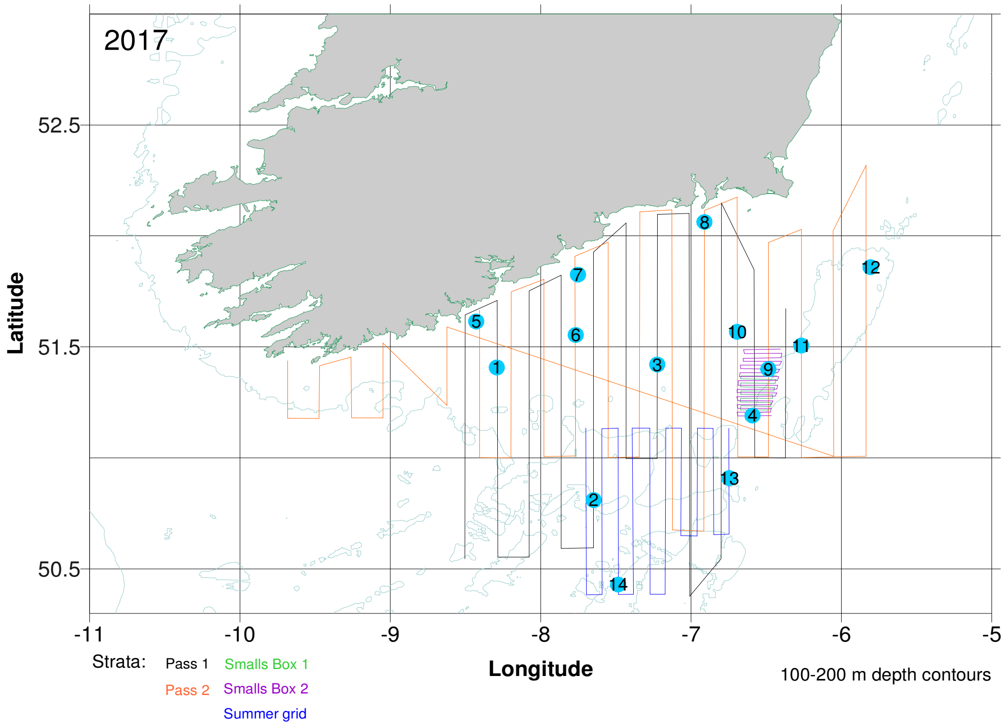


Figure 1. Survey cruise tracks coloured by strata. Pelagic trawl positions appear as numbered stations.

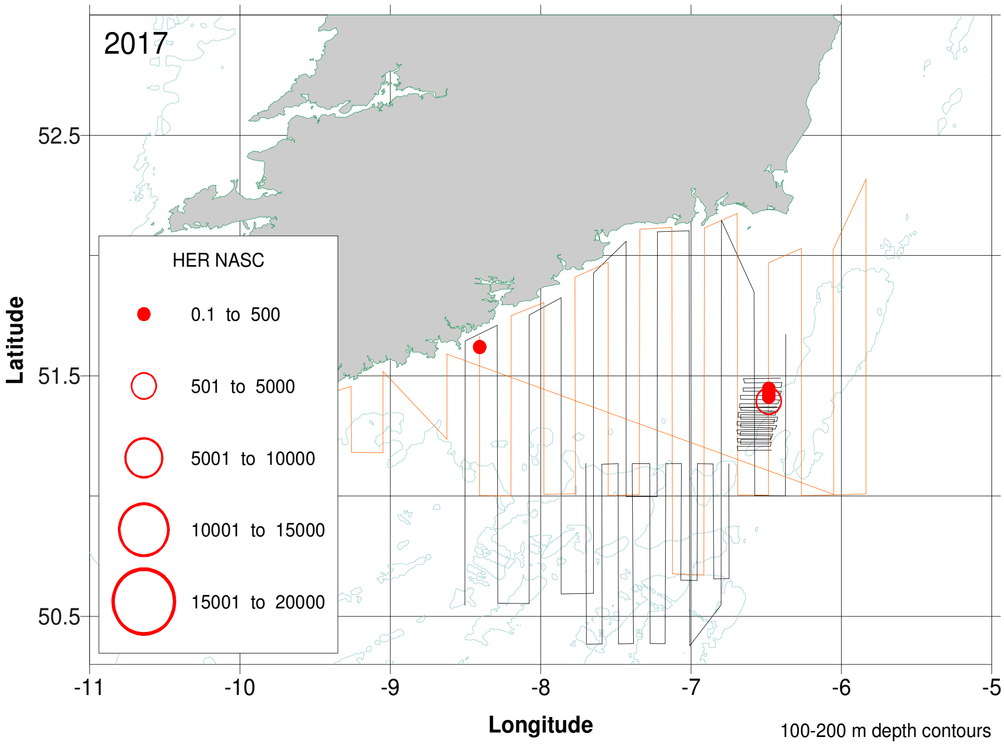


Figure 2. Herring NASC (Nautical area scattering coefficient) plot of herring distribution from replicate core survey effort. Pass 1; Black track, Pass 2; orange track. No herring observed during Pass 1)

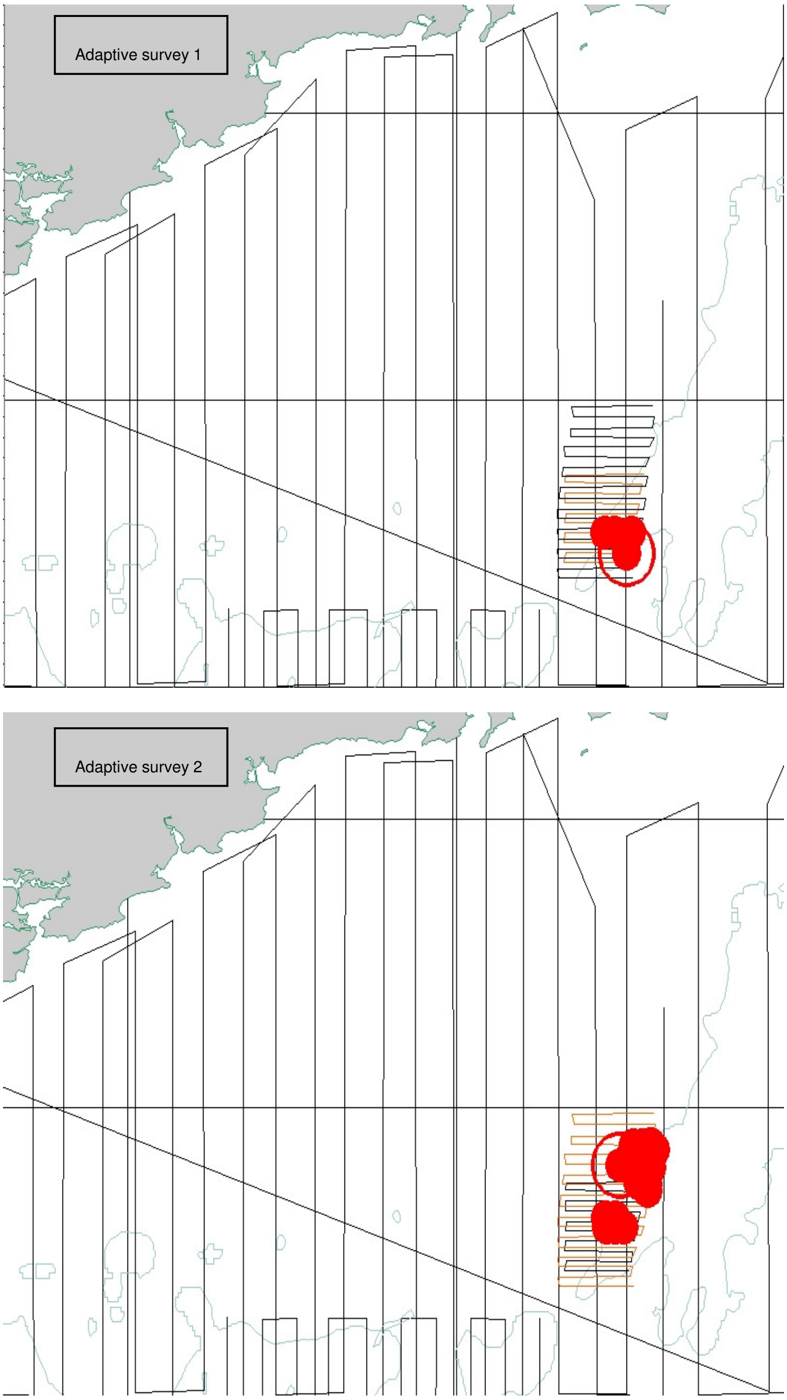
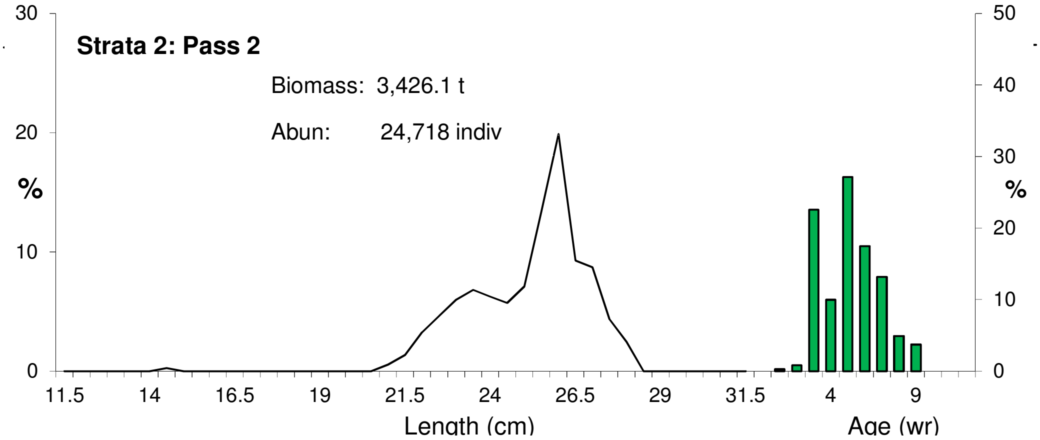


Figure 3. Herring NASC (Nautical area scattering coefficient) plot of the distribution from adaptive survey effort. Top Panel: adaptive Survey 1; bottom panel: adaptive Survey 2. Active transects shown in orange. Transects spacing is 1nmi



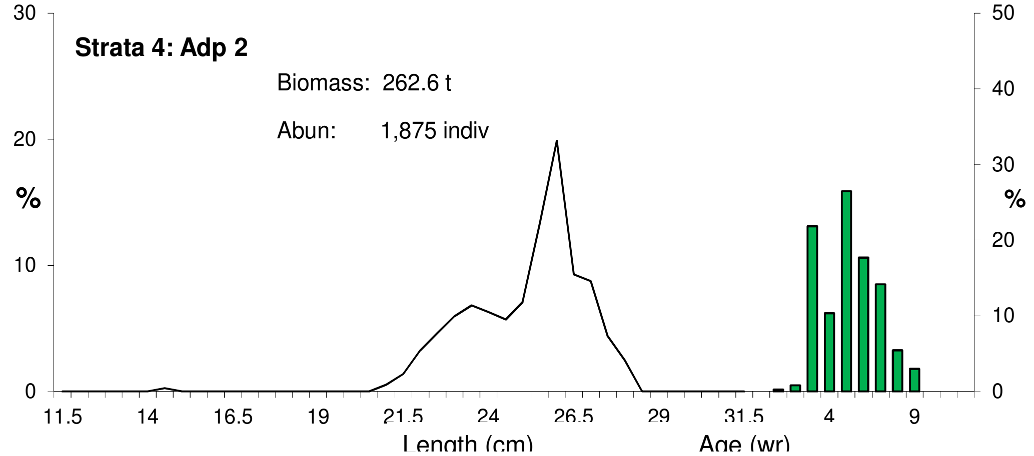


Figure 4. Age and length composition of herring from core survey (Pass 2) and adaptive survey 2.

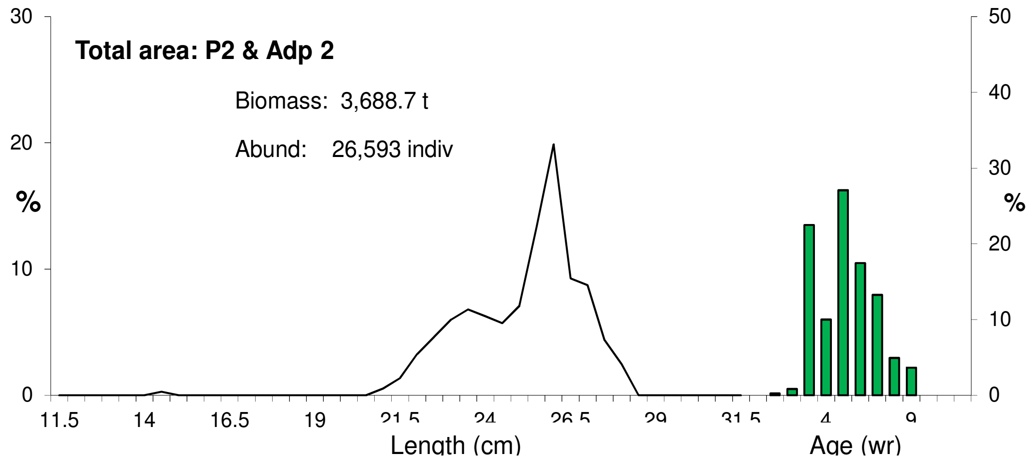


Figure 5. Age and length composition for combined survey effort.

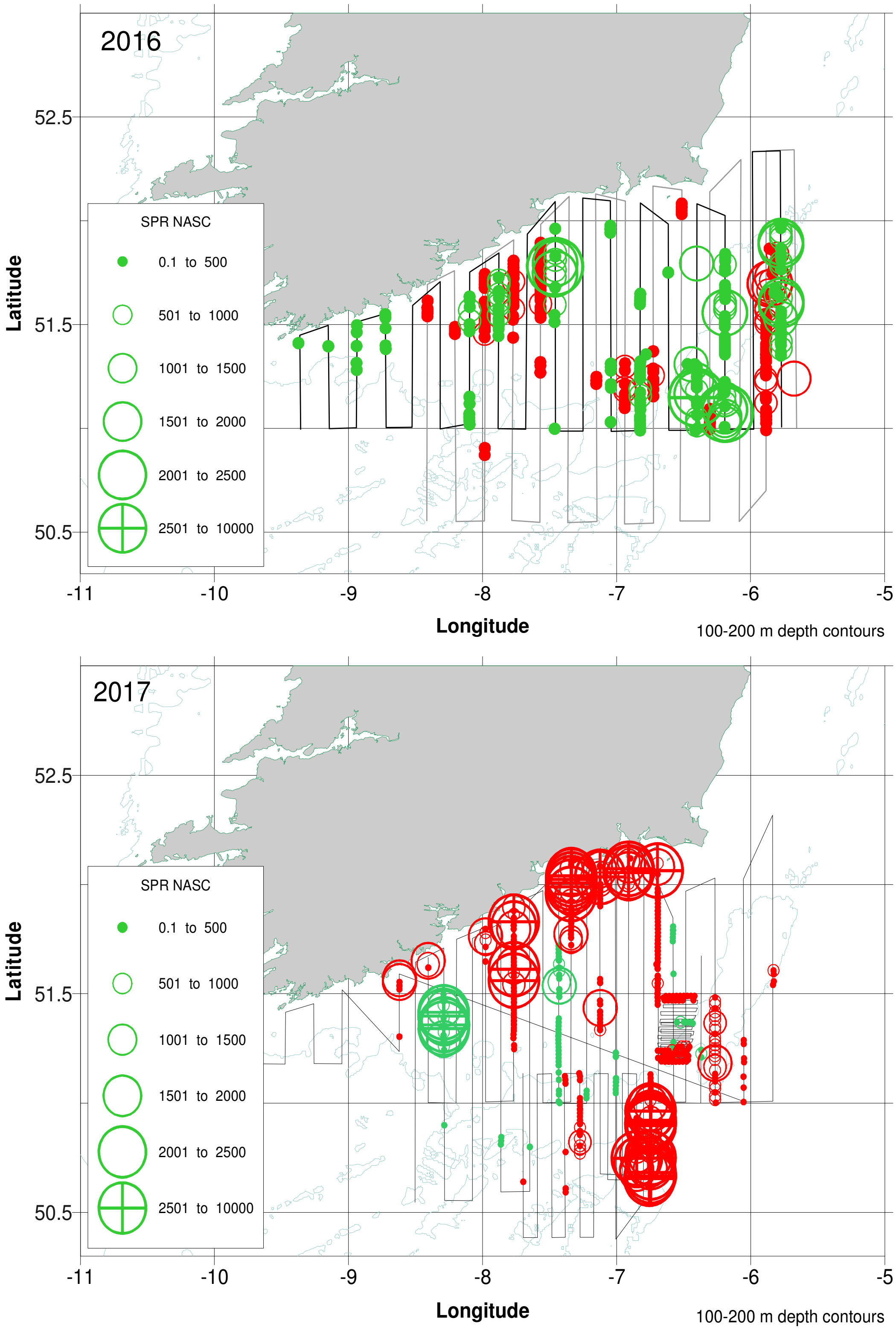


Figure 6. Sprat NASC (Nautical area scattering coefficient) plot of the distribution from replicate core survey effort. Green indicates Pass1 observations and red indicates Pass 2.

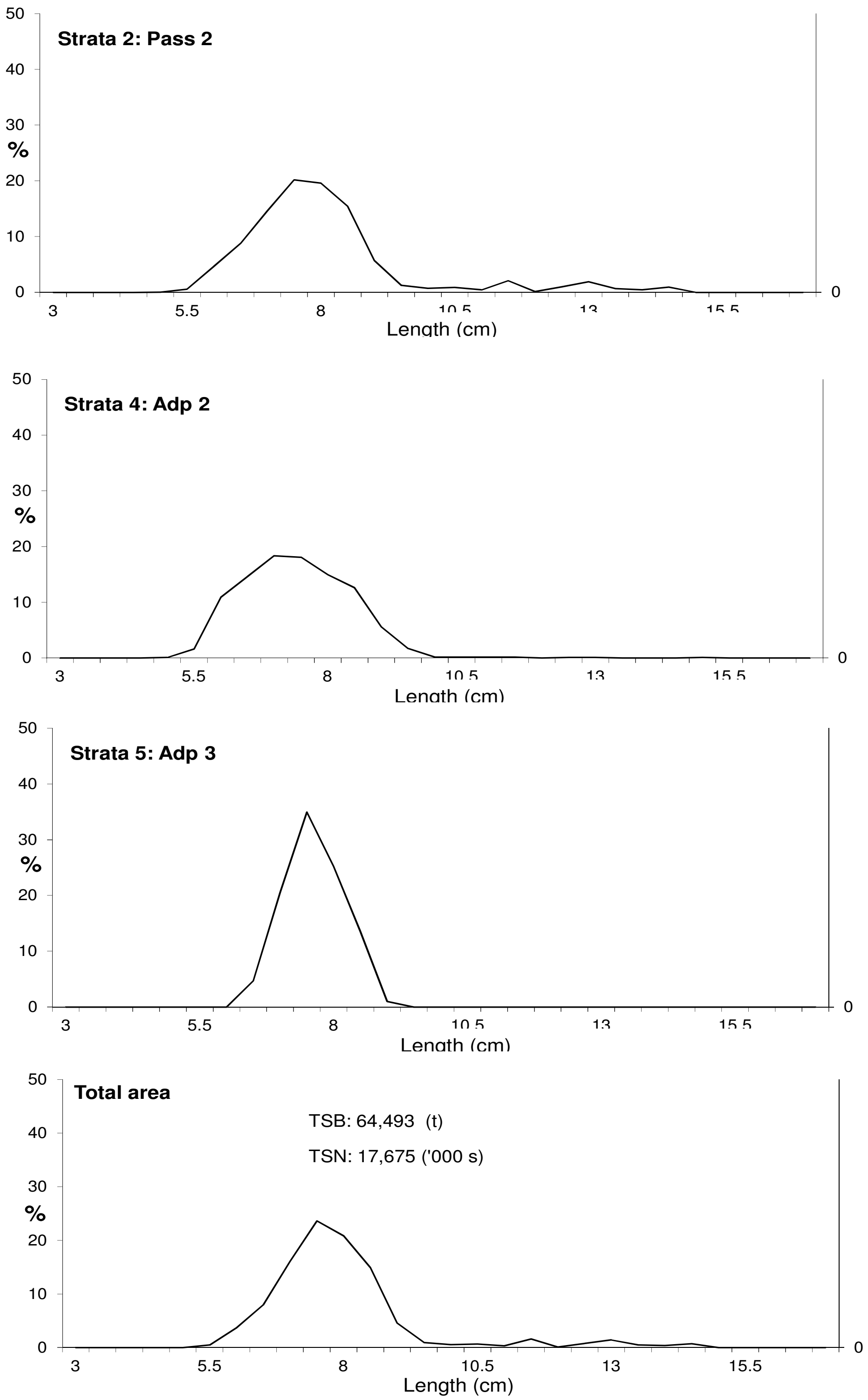
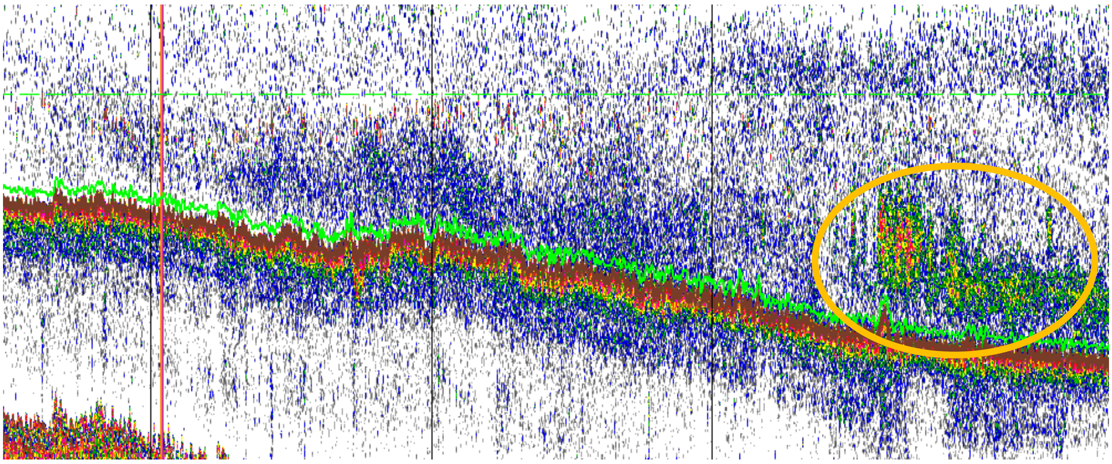
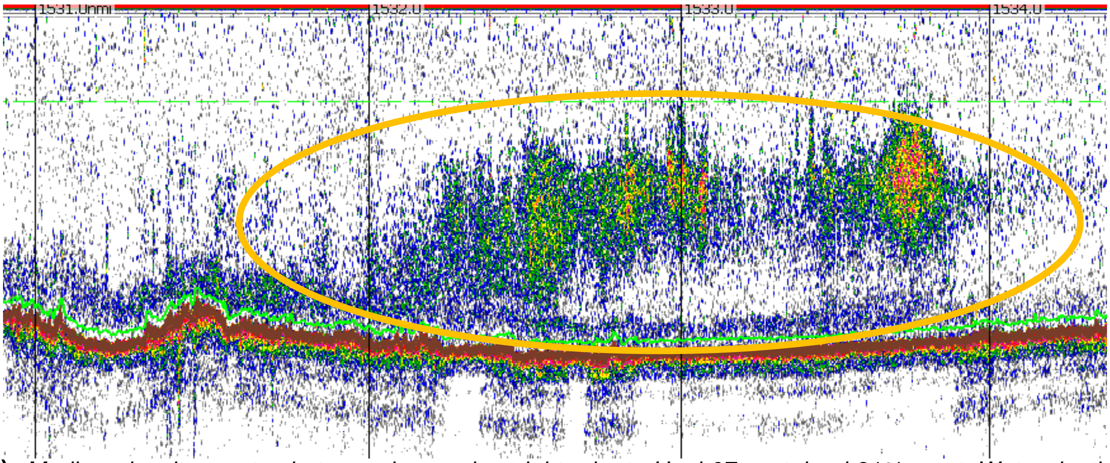


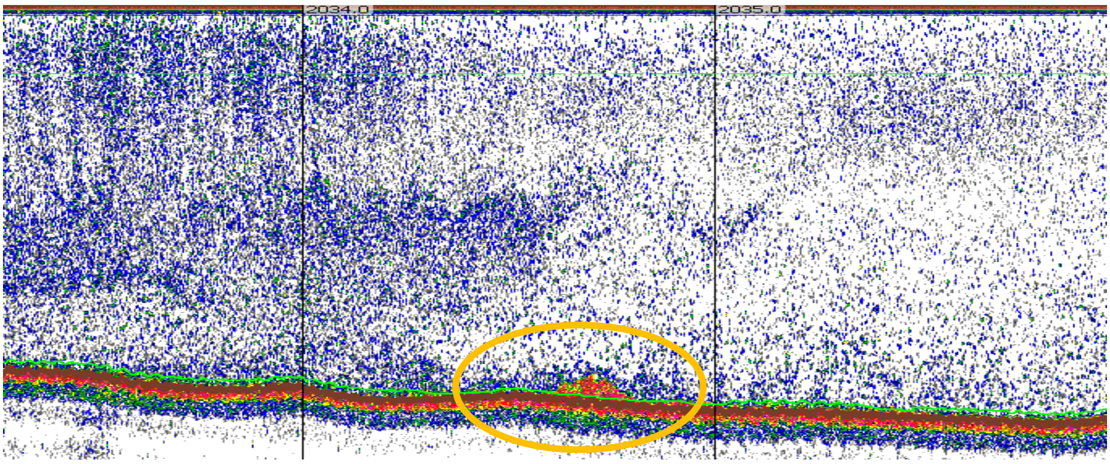
Figure 7. Length composition of sprat from by strata and combined survey effort.



a). *Low density echotrace containing 2% herring observed at night prior to Haul 05. Recorded inshore during Pass 1 core survey. Water depth 51 m school extending vertically to 5 m.*

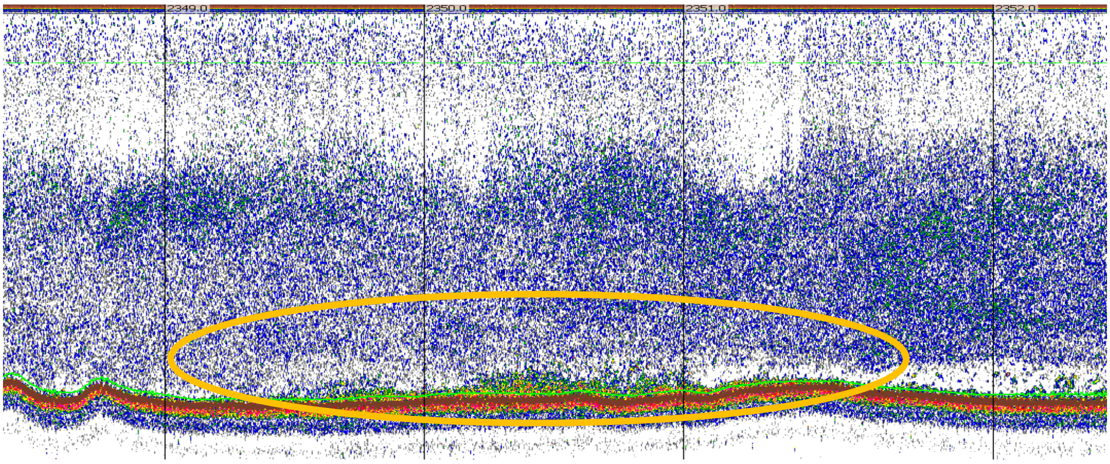


b). *Medium density sprat echotrace observed at night prior to Haul 07 contained 91% sprat. Water depth 49 m.*

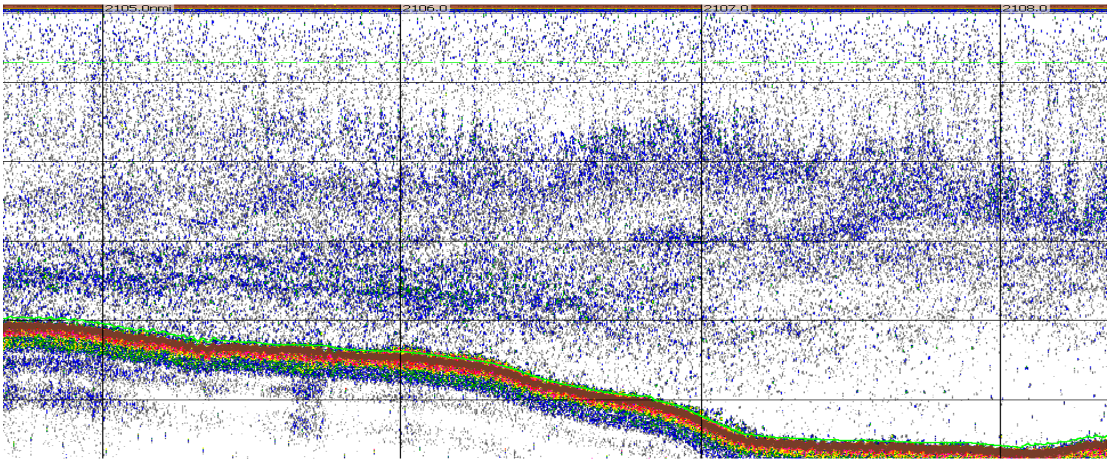


c). *High density herring echotrace showing hard bottom contact, observed during the night prior to Haul 09. Recorded offshore during Adaptive survey 2. Water depth 90 m.*

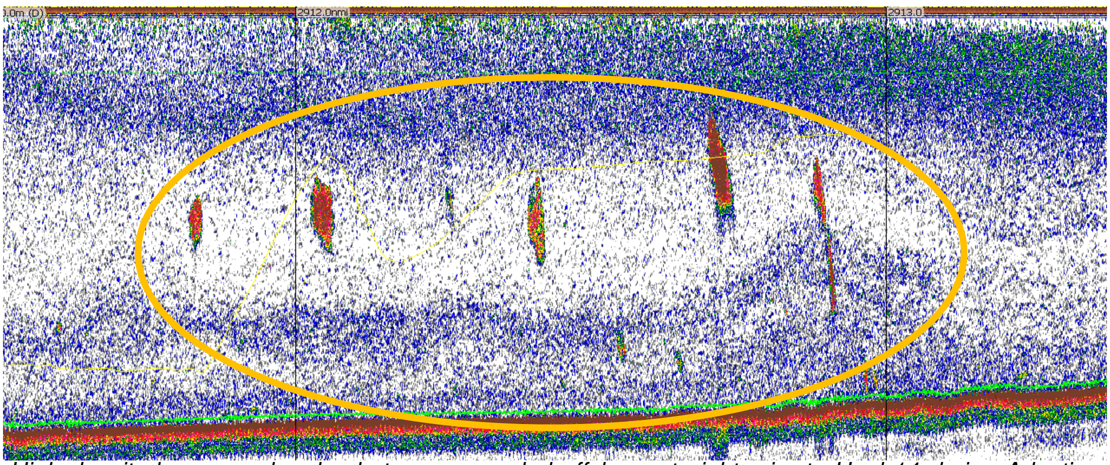
Figure 8. EK60 echograms (38 kHz) recorded prior to directed trawl stations.



d). *Medium density seabed echotrace containing whiting, observed at night prior to Haul 11. Recorded offshore during Pass 2. Water depth 100 m.*



e). *Herring echotrace tight on the seabed on a contour line straddling the Celtic Deep. Observed during Adaptive survey 2. Water depth 115 m.*



f). *High density horse mackerel echotraces recorded offshore at night prior to Haul 14 during Adaptive survey 3. Water depth is 100 m*

Figure 8a-f. Continued

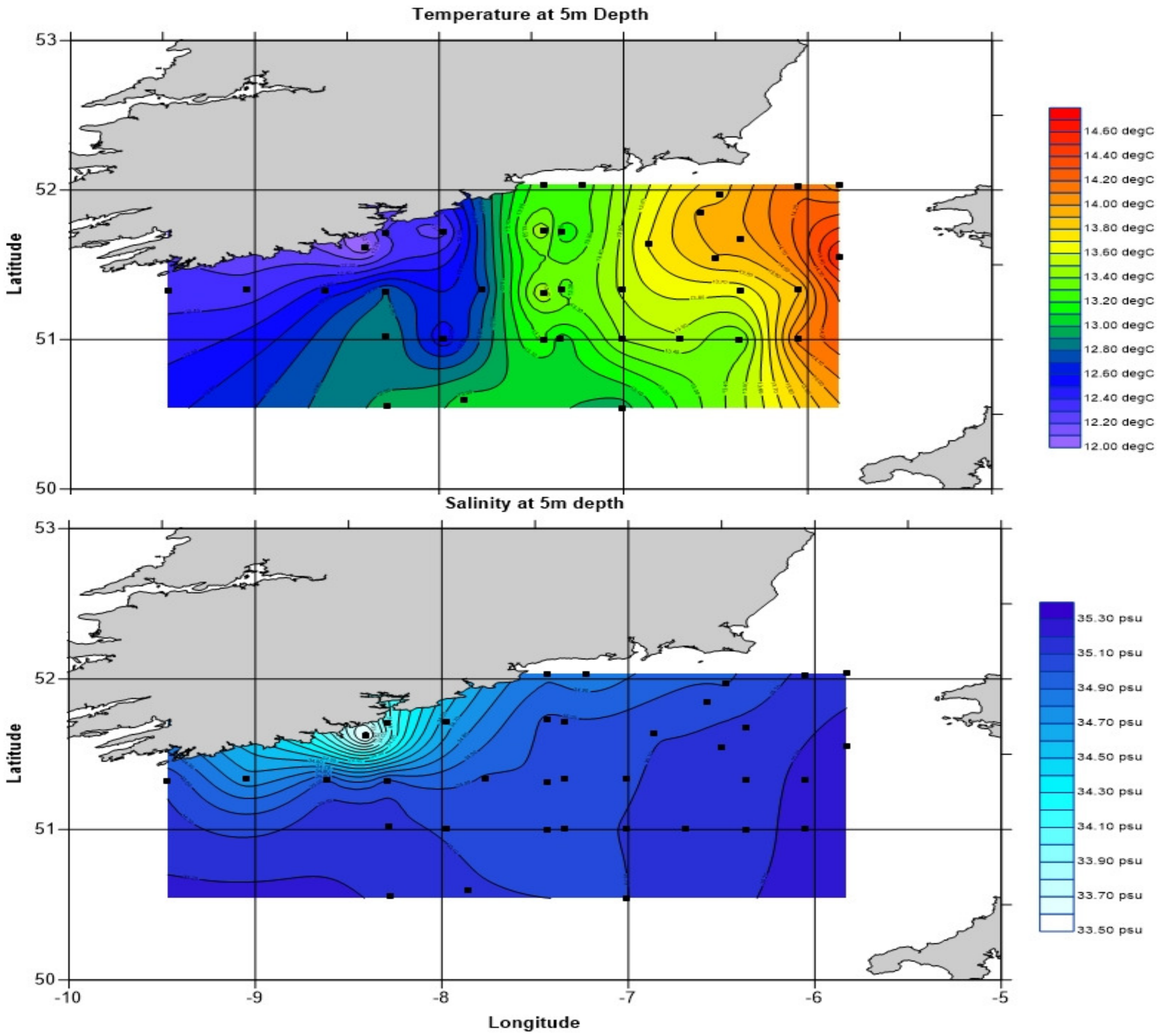


Figure 9. Surface (5 m) plots of temperature and salinity compiled from CTD cast data. Station positions shown as block dots (n=34).

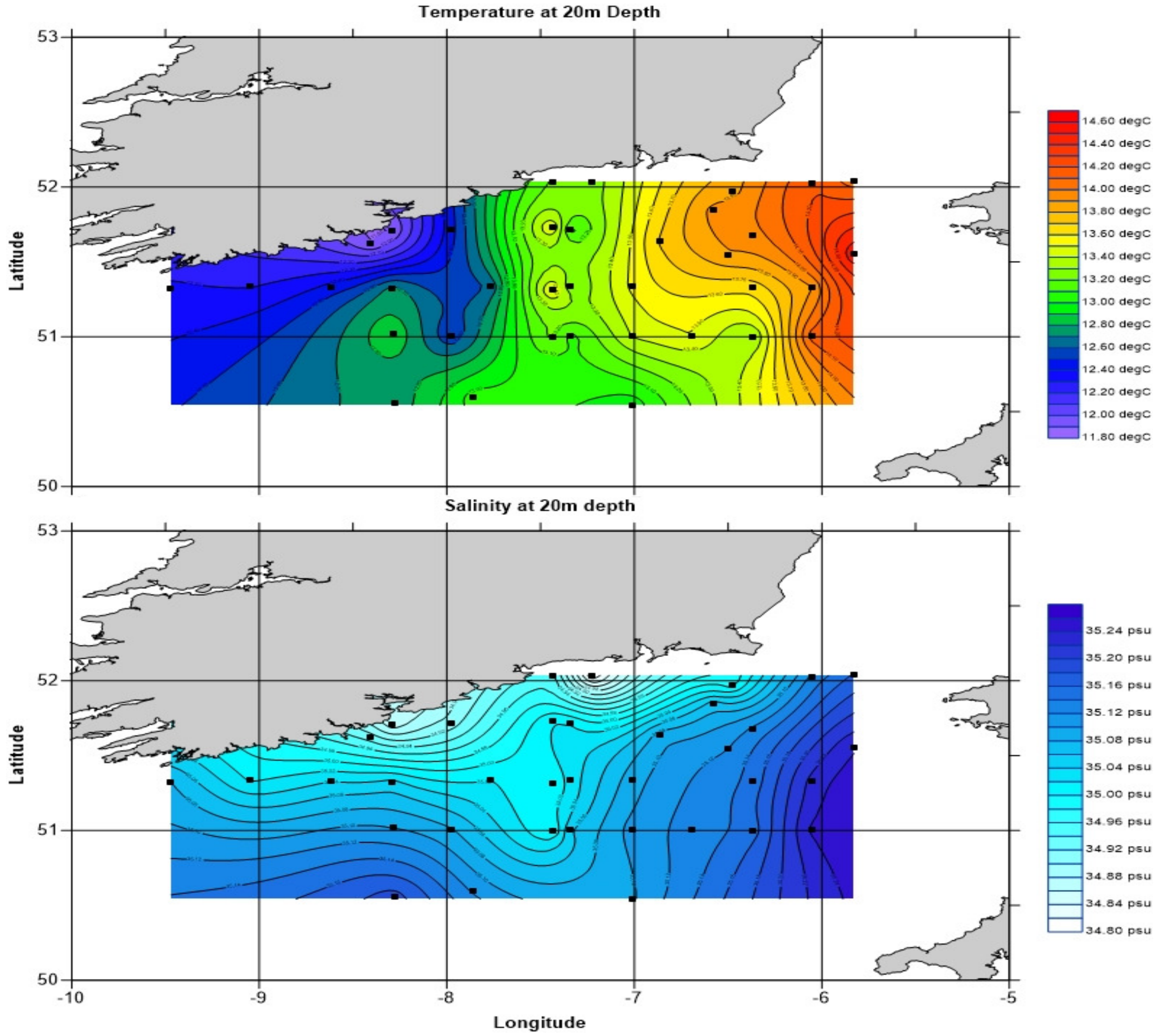


Figure 10. Surface (20 m) plots of temperature and salinity compiled from CTD cast data. Station positions shown as block dots (n=34).

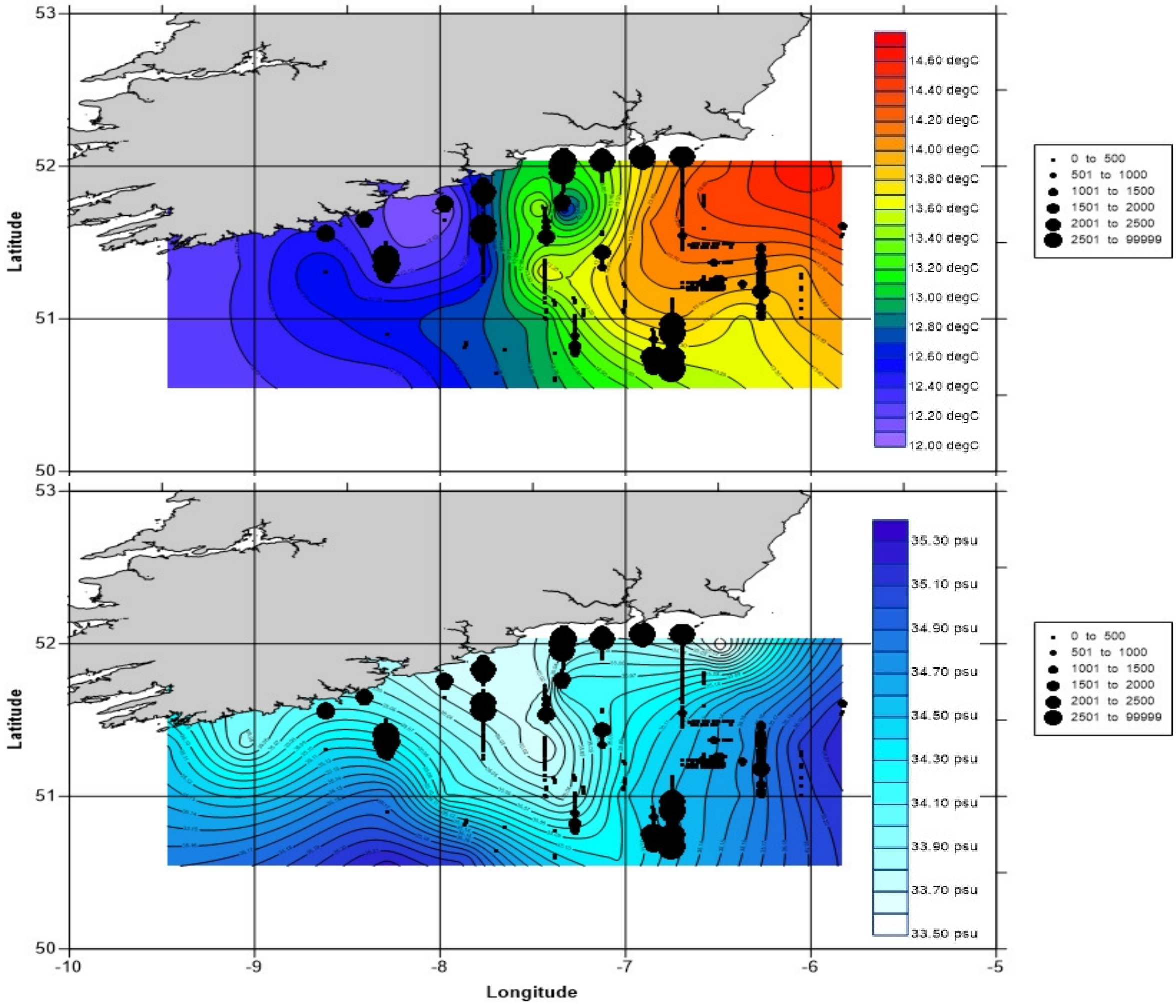


Figure 11. Habitat plots of temperature and salinity at 60 m overlaid with sprat NASC values (black circles).

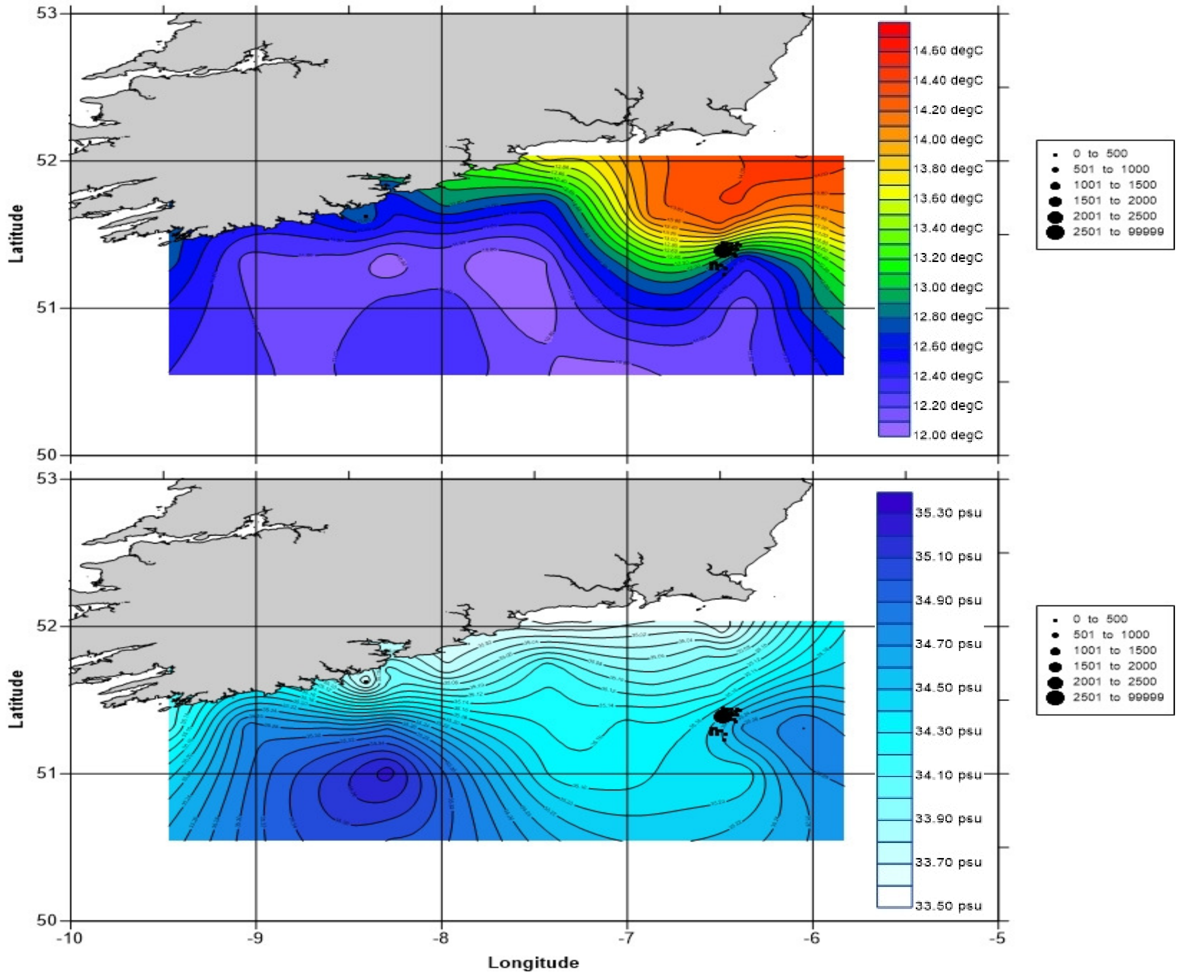


Figure 12. Habitat plots of temperature and salinity at the seabed overlaid with herring NASC values (acoustic density) shown as black circles.

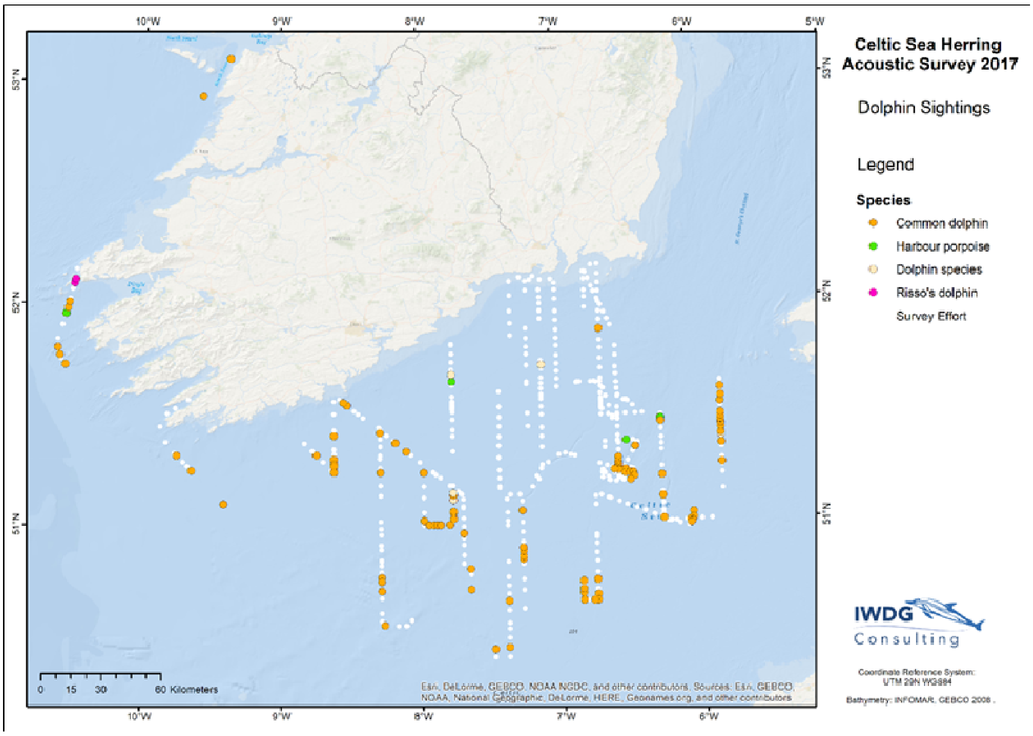


Figure 13. Sightings of dolphin species and survey effort.

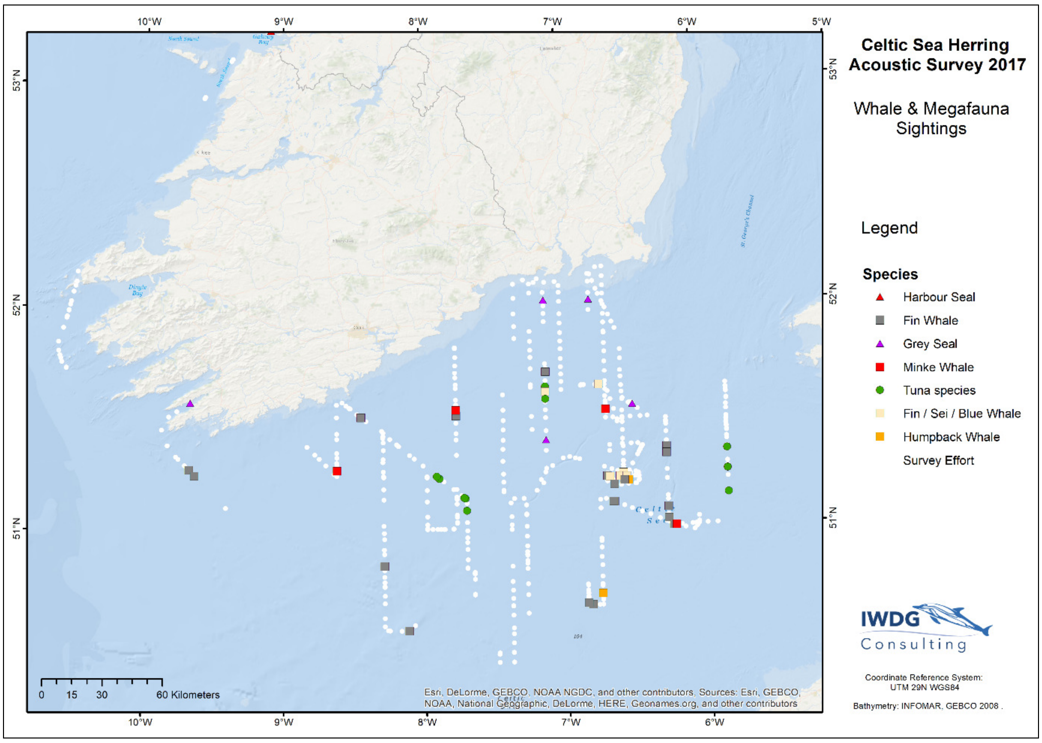


Figure 14. Sightings of whales and other megafauna and effort.

HERRING MIDWATER TRAWL

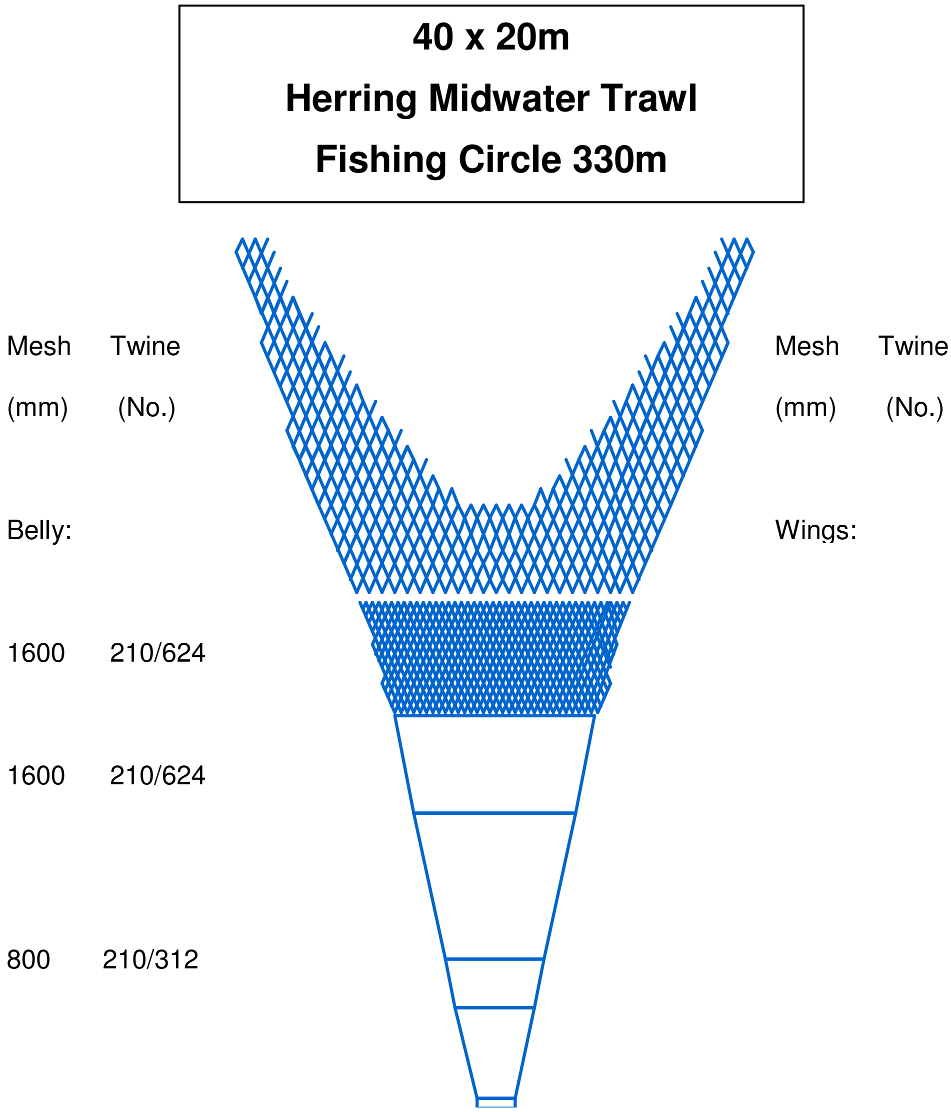


Figure 15. Single herring midwater trawl net plan and layout. Celtic Sea herring acoustic survey, October 2016.

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