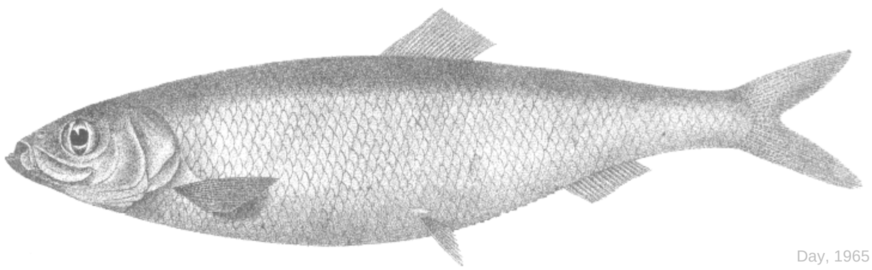
Annex 5c: CSAS

FSS Survey Series: 2015/04

Celtic Sea Herring Acoustic Survey Cruise Report 2015

02 - 22 October, 2015



Day, 1965

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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 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, and this survey is the 21st in the overall acoustic series or the tenth in the modified time series conducted exclusively in October.

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	Aco (SIC)	All
FEAS	Graham Johnston	Aco	All
FEAS	Robert Bunn	Aco	All
FEAS	Susan Beattie	Aco	2
FEAS	Dermot Fee	Bio	All
FEAS	Grainne Ni Choncuir	Bio	All
FEAS	Helen McCormick	Bio	1
FEAS	Turloch Smith	Bio	2
BWI	Niall Keogh	SBO	All
BWI	Deirdre Reidy	SBO	All
BWI	Andrew Pow er	SBO	All
BWI	Inge van der Knapp	Aco/SBO	1/2
IWDG	Mairead Donovan	MMO	All
IS&W FPO	Francis Griffin	Industry Rep	All
INFOMAR	Slava Sobolev	MBES	All
INFOMAR	Oisin McManus	MBES	All
INFOMAR	Mekayla Dale	MBES	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 pre-determined survey cruise track in core survey area

- Investigate high abundance herring aggregations using adaptive survey techniques Use the EM 2040 Bathy metric multibeam to map the extent of herring aggregations during adaptive surveys

- Determine an age stratified estimate of relative abundance of herring within the survey area (ICES Divisions VIIj, VIIg and VIIaS)

- Collect biological samples from directed trawling on insonified fish echotraces to determine age structure and maturity state of the herring stock

- Determine estimates of biomass and abundance for other small pelagic species within the survey area

- Collect physical oceanography data from vertical profiles from a deployed sensor array

- Survey by visual observations marine mammal and seabird abundance and distribution (ESAS-European Seabirds At Sea methodology) during the survey

2.2.2 Area of operation

The autumn 2015 survey covered the area from Loop Head in ICES Division VIIb (Figure 1) in Co. Clare and extended south along the western seaboard covering the main bays and inlets in Divisions VIIj , VIIg & VIIaS. The survey started in the southwest and worked in an easterly direction covering offshore strata and then working east to west along the coast. Bays in the southwest were survey last.

The survey was broken into 3 main components (Table 1). The first, a broad scale survey, was carried out to contain the stock within the survey confines and was based on the distribution of herring from previous years. A broad scale survey composed of 8 strata formed the boundary component of the survey. Broad scale outer lying areas are important transit areas for herring migrating to inshore spawning areas from offshore summer feeding grounds. The second component focused exclusively on known spawning areas and was made up of 1 stratum. The third component consisted of specific adaptive surveys focused on offshore aggregations.

2.2.3 Survey design

2.2.3.1 Core survey

A change in survey design was implemented in 2015 by consolidating inshore strata into a single stratum with uniform transect spacing (2 nmi) and increasing transect spacing in the offshore strata from 2 to 4 nmi spacing. Core geographical coverage was maintained as was sampling and analysis methodology.

A parallel transect design was used with transects running perpendicular to the coastline and lines of bathymetry where possible. Offshore extension reached up to 70 nmi (nautical miles). Transect resolution was set at between 2-8 nmi for the broad scale survey and increased to 2 nmi for the spawning ground inshore stratum. Bay areas were surveyed using a zigzag transect approach to maximise area coverage. Transect start points within each stratum are randomised each year within established baseline stratum bounds.

In total the core survey accounted for 2,336 nmi of transects covering an area of 6,580 nmi^2 (Table 1).

2.2.3.2 Adaptive survey

In 2015 time was allocated to adaptive sampling in high abundance areas identified during the core survey. Two candidate areas were identified as containing high herring abundance and were located outside of core survey coverage falling between transects.

Each candidate area was scouted using a Simrad SP70 long range low frequency omni sonar (range 20-30 kHz, *26 kHz applied) 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 300 m apart to ensure the full overlapping coverage of the EM2040 multibeam swath (300 kHz) in order that the full extent of the aggregation was contained. The EK60 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 100m.

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

Combined, the two adaptive surveys accounted for 210nmi of transects covering an area of 59 nmi² (Table 1).

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 2.

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 (Anon, 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 (60° 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 4 sec^{-1} while the EM2040 auto setting produced a ping rate of 3.5 sec^{-1}.

2.3.2 Calibration of acoustic equipment

A calibration of the EK60 was carried out in Dunmanus Bay on the 3rd of October at the start of the survey and again in the same location at the end of the survey (20th October). Both calibrations were carried out during hours of daylight and all frequencies were calibrated.

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 (Table 2). 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 5) 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 Echogram scrutinisation

Acoustic data was backed up every 24 hrs and scrutinised using Echoview® (V 5) post processing software. Partitioning of data into the categories shown below was largely subjective and was performed by a scientist experienced in scrutinising echograms.

The NASC (Nautical Area Scattering Coefficient) values from each herring region were allocated to one of 4 categories after inspection of the echograms. Categories identified on the basis of trace recognition were as follows:

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

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

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

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

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

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)

2.4.3 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 12). 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 "BEL Reeson" netsonde (50 kHz). 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 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.

2.4.4 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.

2.4.5 Marine mammal and seabird observations

2.4.5.1 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.

2.4.5.2 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

The analysis produced density values of abundance and biomass per nautical mile squared for each transect and mark category for each target species. These were then averaged over each stratum (weighted by transect length) and biomass and abundance estimated by applying the stratum area and summing the strata estimates. Note that interconnecting inshore and offshore inter-transects were not included in the analysis. Total estimates and age and maturity breakdowns were calculated. Coefficient of variation (cv, standard error divided by the estimate) was estimated in the usual way after assuming that transects were equally spatially distributed within a stratum and that they were statistically independent.

Biomass was calculated from numbers using length-weight relationships determined from the trawl samples taken during the survey for each of the analysis areas.

Herring weight (grams) $= 0.0265 * L^{3.3511}$ (L = length in cm)

Mackerel weight (grams) $= 0.0096 * L^{2.9073}$ (L = length in cm)

Sprat weight (grams) $= 0.0037 * L^{3.3063}$ (L = length in cm)

2.5.2 Abundance estimate

The recordings of area back scattering strength (NASC) per nautical mile were averaged over a one nautical mile EDSU (elementary distance sampling unit), and the allocation of NASC values to herring and other acoustic targets was based on the composition of the trawl catches and the appearance of the echotraces.

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

NASC values assigned according to scrutinisation methods (section 2.3.5) were used to estimate the target species numbers according to the method of Dalen and Nakken (1983).

To estimate the total abundance of fish, the unit area abundance for each stratum was multiplied by the number of square nautical miles within the strata and then summed for all strata to provide the total survey area. Biomass estimation was calculated by multiplying abundance in numbers by the average weight of the fish in each strata and then sum of all squares by strata and summed for the total area.

2.5.3 Adaptive survey data

In the standard fisheries acoustic surveys, the elementary distance sampling unit (EDSU) is the length of transect along which acoustic measurements are averaged in a single sample (Simmonds and MacLennan, 2005). The choice of how long to make the EDSU is a balance between capturing the spatial structure of a population and reducing the correlation between successive samples (Simmonds and MacLennan, 2005). For the core survey an EDSU of 1 nmi is used as standard. However, for adaptive surveys an EDSU of 0.05 nmi (100 m) was applied. This shorter EDSU was selected based on work carried out by Barbeaux, et al (2013) for surveying discreet aggregations of fish at high resolution.

The calculation of abundance used the same methodology applied for core surveys described above.

3 Results

3.1 Celtic Sea herring stock

3.1.1 Herring biomass and abundance

Herring	Millions	Biomass (t)	% contribution
Total estimate			
Definitely	184	24,710	100.0
Mixture	0	0	0.0
Probably	0	0	0.0
Possibly			
Total estimate	184	24,710	100

SSB Estimate			
Definitely	184	24,710	100.0
Mixture	0	0	0.0

For the core survey a total of three single herring echotraces were identified during routine 'on-track' observations. The echotraces occurred in a localised area within the Smalls offshore stratum and it was evident that they formed part of a much more substantial aggregation occurring off-track. The presence of aggregations occurring between survey transects initiated a fine spatial resolution survey approach in two key areas; the 'Trench' and 'Smalls' (Figure 2).

The Trench strata focused on a discreet area (5 nmi²) along a shallow gully containing herring. Two surveys were carried out on the same aggregation; one during daylight hours and again at night. The Smalls strata focused on a wider area (20 nmi²) straddling the 100m depth contour of the western edge of the Celtic Deep. This area was identified as containing a single high density herring aggregation extending over 1.5 nmi along the 100 m contour. Four replicate adaptive surveys were carried out on this aggregation; one complete survey of the aggregation and 3 further surveys with a seven day time interval. The three further surveys consisted of; one complete daylight survey; and a complete night/day survey (Table 1)

Total herring biomass was calculated from two high resolution adaptive strata; the daylight survey of the Trench area and the combined day/night survey of the Smalls strata and were chosen as the best candidate surveys. Within these strata 1,235 echotraces were identified as 'definitely herring' (EDSU = 100 m).

Herring TSB (total stock biomass) and abundance (TSN) estimates were 24,710 t and 184 million individuals (CV 18.4%) respectively. No immature fish were encountered during the adaptive surveys.

A breakdown of herring stock abundance and biomass by age, maturity, size and stratum is shown in Tables 4-10.

3.1.2 Herring distribution

A total of 27 trawl hauls were carried out during the survey (Figure 2), with 3 hauls containing >50% herring by weight of catch (Table 3).

Herring distribution was limited to offshore strata. During the core survey herring were identified in low numbers from mixed catches from the eastern survey area and in the smalls stratum (Figure 3 No estimate of biomass was calculated from these echotraces due to the low numbers encountered.

Stratum 10 (Trench) contained herring located close to the seabed (0-2 m) running linearly along the gully. The extent of the echotraces was mapped using the EM2040 bathymetric multibeam and extended up to 600 m length and 250 m wide (Figure 6a).

Stratum 14 & 15 (Smalls) this area was found to contain a large expansive aggregation of herring centred on the 100 m depth contour extending for between one and two nautical mile sin each plane (Figure 6b & c). This aggregation was surveyed using 4 separate surveys with a temporal gap of one week between the first and second events.

3.1.3 Herring stock composition

A total of 149 herring were aged from survey samples in addition to 1,250 length measurements and 300 length-weights recorded (Table 4). Herring age samples ranged from 2-8 winter-rings (Tables 5 & 6, Figure 5).

Three winter-ring herring dominated the 2015 adaptive survey estimate representing over 24% of TSB and 26% of TSN (Table 5 and 6). The 4 winter-ring age group were ranked second representing 23% of TSB and 22% of TSN. The third most dominate age group was 5 winter-ring group contributing 23% to the TSB and 21% to TSN.

Maturity analysis of samples taken from the 3 hauls undertaken during the adaptive surveys contained 100% mature fish (Tables 7 & 8, Figure 5). Mature herring (stages 3 to 8) sampled during the survey were in a pre-spawning state and comprised predominantly of stages 3-4 (93%). Less than 2% of fish (n=2) were spent observed during the survey and this is consistent with the dominant winter spawning stock component.

3.2 Other pelagic species

3.2.1 Sprat

Sprat	Millions	Biomass (t)	% contribution
Total estimate			
Definitely	19,418	77,157	92.1
Mixture	1,980	6,622	7.9
Probably	0	0	0.0
Total estimate	21,398	83,779	100

Sprat were found in 6 of 9 survey strata and sampled in 20 of 27 hauls (Figure 4, Table 3). In total 3,164 individual length measurements and 1,834 length/weight measurements were recorded. Mean length was 8.6 cm and mean weight was 5 g (8.2 cm and 4 g in 2014). Individuals ranged from 5.5 to 14. cm in length and 1 to 26 g in weight.

In total 829 individual sprat echotraces were identified during the core survey (Table 12). The highest concentration of biomass was observed offshore and accounted for 85% of total biomass and 95% of the total abundance (Table 12). Very high density echotraces of sprat were observed offshore (Figure 6e).

Inshore coastal waters accounted for the remaining 15.2% of stock biomass, where the Mizen and Dunmanus Bay strata were the main contributors (Figure 6f).

3.3 Oceanography

A total of 57 CTD stations were carried out. However, due to problems with the sensor suite during the survey, data from a number of stations (n=8) stations were deemed unusable. Surface plots of temperature and salinity are presented for the 5 and 20m depth profiles (Figures 7 & 8), while profiles for 40m and 60m profiles are overlaid with herring NASC data (Figures 9 & 10).

Sea surface temperature, as measured at 5 m, was relatively warm with temperatures above 14.5ºC for the larger area to a maximum of 15.4°C. Surface salinity follows a similar pattern and is relatively stable throughout the area with the exception of river plumes (Figure 7). Temperature and salinity profiles at 20 m depth (Figure 8) follow a similar stable pattern indicating the thermocline is located below 20 m, The influence of the cooler, less saline water along the south coast in the form of the Irish Sea Front is evident at 20 m.

Below 40 m depth warmer water dominates the eastern survey area where the bulk of herring and sprat biomass was observed (Figure 9 & 10). Herring were located primarily in waters above 15°C and close to a frontal boundary region. When located offshore herring are most frequently found in or around this thermohaline boundary region.

3.4 Marine mammal and seabird observations

3.4.1 Marine mammal sightings

Visual survey effort was recorded on 18 days between 3rd and 20th October inclusive amounting to a total of 108 hours and 50 minutes 'on effort'. All dedicated effort was recorded from the crow's nest and for 80% of the survey effort there was one dedicated observer. For the remaining 20% of the time there were two or more observers contributing to 'on effort' sightings. Effort was on average 6 hours and 3 minutes per day but ranged from a daily minimum of 2 hours and 19 minutes to a maximum of 9 hours and 12 minutes. 72% of survey effort was recorded whilst transecting the main survey lines at standard survey speed (c.10 knots) with the remaining 28% of effort occurring simultaneous to fishing effort or whilst completing shorter more condensed survey lines off the standard transect lines.

Sea state during observation hours ranged from Beaufort sea state 1 to 5. Out of the total time 'on effort' 1% was recorded as sea state 1; 13% as sea state 2; 22% was recorded as sea state 3; sea state 4 accounted for 46% of the time; sea state 5 was recorded 16% of survey time and the remaining 2% of observations were conducted in sea state 6.There was no swell (<1 m) for 38% of the total effort duration. "Light" swell (1 m) was recorded during 52% of effort and the swell was classified as "moderate" (1 to 2 m) for the remaining 10% of the time.

Visibility ranged from greater than 20 km to less than 1 km. For the most part (84% of the time) visibility was greater than 10 km whilst on survey effort. Visibility was between 6 and 10 km for 15% of the time surveyed and between 1 and 5 km for 1% of the time. Poor visibility (< 1 km) accounted for just 0.03% (1 hour and 50 minutes) of the total survey effort. Rain was recorded on five days during 7% of survey time but was always light and its effect on survey conditions would have been reflected in visibility records.

Visual encounters

A total of 93 sightings of identified cetacean species were made, comprising a minimum of 1,088 individuals (Table 13). There were a further 10 whale sightings of 11 individuals and two cetacean encounters of two individuals that were not identified to species level and similarly five unidentified dolphin sightings comprising an estimated

35 animals. The sightings counted include those recorded during dedicated survey effort as well as incidental sightings made by other scientific personnel and the ship's crew.

Summary

The presence of seven different cetacean species and the occurrence of multi-species feeding aggregations indicate the continued importance of the waters of the Celtic sea as a foraging ground for cetaceans. Previous research has identified the autumn as being within peak season for minke, humpback and fin whales in waters off the Irish south coast due to the foraging potential provided by high concentrations of pelagic schooling fish at that time of year (Wall *et al*., 2013). This year was the first time killer whales were recorded during the Celtic Sea herring survey, bringing the total number of species recorded during 12 Celtic Sea Herring Acoustic Surveys (2004 to 2015) to 11 (Table 14). Previous distribution records for killer whales have been dominated by inshore sightings of the species (Wall, *et al*., 2013), the sighting on this survey, 90 km south of Waterford, is likely to have been due to the high density of herring in the area at the time. The other species recorded this year had all been observed during one or more previous years. Common dolphins were again by far the most frequently observed species with a high number of sightings close to the average of previous years. Although it is imprudent to compare sightings locations and rates with previous years without accounting for the potential effects of environmental variables on detection rates it is worth mentioning that fin whale encounters were, like the 2014 survey, mainly in the eastern portion of the survey area off the Waterford coast. In contrast minke whale sightings were more widespread this year with some occurring further offshore to the south of Waterford, compared to last year's survey when all minke whale records were from coastal waters off Co. Cork. 2015 represents the fifth year with observations of humpback whale. The most intensive feeding activity was observed in areas where sprat were the dominant prey species. Areas with multi-species sightings were also recorded in coincidence with high herring concentrations.

A full summary by species is provided in Annex 1.

3.4.2 Seabird sightings and marine litter

A total of 53.52 hours (3,211 minutes) of seabird surveys was conducted across thirteen days between 3rd and 20th October 2015.

A cumulative total of 13,341 individual seabirds of 24 species was recorded, of which 6,275 were noted as 'off survey', outside of dedicated survey time or associating with the vessel 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 15. In addition, daily totals for 21 species of migrant terrestrial birds recorded on or around the vessel are also presented (Table 16).

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. No down-time was recorded and excellent weather conditions prevailed allowing for extended marine mammal and seabird survey effort.

Time was allocated to conduct adaptive surveys on off-track herring aggregations for quantitative and behavioural studies. As few on-track herring echotraces were encountered during the core survey the biomass estimate presented here was determined from the adaptive survey data. High abundance areas identified during the co-occurring fishery provided detailed real time information on the location and movements of aggregations. This year offshore fishing effort was almost exclusively restricted to a single discrete location and was surveyed as a focus area and closely resembled the situation in 2014. Adaptive surveys were carried out using established methods for data collection and analysis thus providing quantitative data for estimates of biomass. Using the EM2040 bathymetric multibeam (MBES) and the EK60 systems in harmony allowed the spatial extent of large offshore herring aggregations to be mapped for the first time.

The spatial mapping survey used a high intensity transect spacing of 300 m. Beam opening angles on the MB were manually set to standardise the volume of water sampled while ensuring the spatial integrity of successive EK60 transects as a means to reduce the effects of double counting. The swath coverage by ping of the MB systems was 400m compared to 11m for the single beam EK60. Large aggregations of herring observed at the Smalls stratum (#14&15) were found to be spatially stable over a period of seven days between successive surveys which was surprising given the stock is in a period of spawning migration. Changes in aggregation morphology over the 24 hr diel cycle were observed with herring in both adaptive and geographically distinct surveys exhibiting clear differences in day/night behaviour. Common to both areas was the preference of herring for deeper waters during daylight hours and a diffuse shoaling pattern with a large spatial footprint and in close contact with the seabed (thin and flat). During hours of darkness, herring in both areas were observed to form tightly packed shoals, increasing in vertical height while reducing the spatial footprint (tall and thin). During this transition phase shoals were seen to move by distances of up 1.5 nmi into shallower waters before returning to depth with the onset of daylight.

Although not an absolute measure of biomass the adaptive surveys provide a high degree of spatial resolution. Understanding the behaviour of offshore aggregations allows for the core survey design to be optimised so increasing the precision of annual estimates.

Sprat distribution over recent years has been characterised by the presence of high density aggregations 0-group fish in inshore water, namely around the southwest. Offshore areas are more commonly associated with mixed aggregations consisting of several age cohorts. In 2015 the 0-group sprat were found in large numbers in offshore waters. Conversely, inshore waters were dominated by older, likely the same age cohort, individuals occurring in large numbers. The presence of older fish close inshore is more related to conditions observed in November/December when SST is lower.

These schools of larger fish attracted multispecies feeding aggregations of marine mammals, tuna and seabirds.

4.2 Conclusions

- Very low herring abundance was observed during the core survey coverage. Observations of herring were limited to two discrete areas located offshore during off-track adaptive surveys.
- No herring schools were recorded on the inshore spawning grounds. A small quantity of herring was observed in mixed species aggregations in the eastern survey area but was not reported here.
- Herring TSB (total stock biomass) and abundance (TSN) estimates were 24,710 t and 184 million individuals (CV 18.4%) respectively from the adaptive survey data.
- Three winter-ring herring dominated the 2015 estimate (24% of TSB & 26% of TSN), followed by 4 winter-ring (23% of TSB & 22% of TSN) and the 5 winter-ring group (23% of TSB & 21% of TSN). No immature fish were observed from catches within the adaptive strata.
- The 2015 estimate of abundance was determined from adaptive surveys and so is not considered as comparable to the current time series or representative of the larger stock.
- The distribution of the stock observed during the survey was substantiated by the co-occurring fishery that was centered offshore. As a result it is not possible to say if the stock was contained within the survey area and may therefore not be a representative measure of abundance.

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5 Tables and Figures

Table 1. Survey Strata detail of core survey (strata 1-9) and adaptive surveys (strata 10-15).

Strata no.	Strata name	Survey type	Transect type	Active transects	Transect spacing (nmi)	Transect mileage (nmi)	Strata area (nmi²)
1	Mizen	Broad scale	Parallel	8	8	274.9	1381.6
2	Offshore	Broad scale	Parallel	4	24	802.0	2291.7
3	Smalls	Broad scale	Parallel	4	13	363.2	1307.2
4	Inshore	Spaw ning grd	Parallel	2	34	720.8	1335.9
5	Dunmanus	Broad scale	Zigzag	8	na	18.3	28.4
6	Bantry	Broad scale	Zigzag	6	na	25.8	37.4
7	Kenmre	Broad scale	Zigzag	5	na	21.3	56.9
8	Dingle	Broad scale	Zigzag	10	na	33.4	82.2
9	Kerry Head	Broad scale	Parallel	2	na	76.5	58.5
			Total	49		2,336.2	6,579.8
10	Trench (d)	Adaptive	Parallel	7	0.05	8.4	5.1
11	Trench (n)	Adaptive	Parallel	8	0.05	9.6	5.3
12	Smalls (d)	Adaptive	Parallel	14	0.05	49.0	12.9
13	Smalls 2 (d)	Adaptive	Parallel	19	0.05	50.5	13.4
14	Smalls 3 (d)	Adaptive	Parallel	11	0.05	42.3	6.8
15	Smalls 3 (n)	Adaptive	Parallel	20	0.05	49.7	15.3
			Total	79		209.5	58.8
			Grand total	128		2545.7	6638.6

d = daylight hrs, n = nightime

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Table 2. Calibration report: Simrad EK60 echosounder at 38 kHz.

Echo Sounder System Calibration

Vessel : R/V Celtic Explorer		Date : 03/10/2015	
Echo sounder : ER60 PC		Locality : Dunmanus Bay	
Type of Sphere : CU-38,1	TS_{Sphere}: -33.50 dB (Corrected for soundvelocity or t,S)	Depth(Sea floor) 33 m	

Calibration Version 2.1.0.11

Comments:
Dunmanus Bay, flat calm

Reference Target:

TS	-33.52 dB	Min. Distance	17.00 m
TS Deviation	5.0 dB	Max. Distance	22.00 m

Transducer: ES38B Serial No. 30227

Frequency	38000 Hz	Beamtype	Split
Gain	25.82 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	6.93 deg	Along. Beam Angle	6.91 deg
Athw. Offset Angle	-0.06 deg	Along. Offset Angl	-0.04 deg
SaCorrection	-0.67 dB	Depth	8.8 m

Transceiver: GPT 38 kHz 009072033933 1 ES38B

Pulse Duration	1.024 ms	Sample Interval	0.193 m
Power	2000 W	Receiver Bandwidth	2.43 kHz

Sounder Type:
ER60 Version 2.2.1

TS Detection:

Min. Value	-50.0 dB	Min. Spacing	100 %
Max. Beam Comp.	6.0 dB	Min. Echolength	80 %
Max. Phase Dev.	8.0	Max. Echolength	180 %

Environment:

Absorption Coeff.	9.0 dB/km	Sound Velocity	1505.2 m/s

Beam Model results:

Transducer Gain =	25.79 dB	SaCorrection =	-0.63 dB
Athw. Beam Angle =	7.06 deg	Along. Beam Angle =	7.04 deg
Athw. Offset Angle =	-0.04 deg	Along. Offset Angle=	-0.04 deg

Data deviation from beam model:
RMS = 0.08 dB
Max = 0.27 dB No. = 180 Athw. = 2.8 deg Along = 3.7 deg
Min = -0.35 dB No. = 365 Athw. = 4.6 deg Along = -1.5 deg

Data deviation from polynomial model:
RMS = 0.05 dB
Max = 0.17 dB No. = 180 Athw. = 2.8 deg Along = 3.7 deg
Min = -0.28 dB No. = 179 Athw. = 2.3 deg Along = 3.3 deg

Comments :

Wind Force : 1 **Wind Directio** SE
Raw Data File: \\Expfileclstr\ER-60_Data\CSHAS_2015\RAW ER60 Files\Calibration\CSHAS_2015
Calibration File: \\Expfileclstr\ER-60_Data\ER-60\Calibrations_2015\CSHAS 2015\38 KHZ

Calibration : Ciaran O'Donnell

Table 3. Catch table from directed trawl hauls.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target (m)	Bulk Catch (Kg)	Herring %	Mackerel %	Scad %	Sprat %	Pilchard %	Others* %
1	03.10.15	51.54	-10.04	19:12	71	60	176.0	0.1	2.3	0.0	96.3		1.3
2	05.10.15	51.19	-8.34	14:33	103	0	18.1		5.6	0.2			94.2
3	06.10.15	51.47	-7.91	09:39	87	0	220.0			0.7			99.3
4	07.10.15	51.25	-7.38	08:31	95	15	104.9	0.1	13.4	0.1	80.1		6.3
5	07.10.15	51.16	-7.27	13:28	95	35	91.2		0.0	0.3	91.5		8.2
6	07.10.15	51.12	-7.24	23:30	114	0	2500.0	100.0					
7	08.10.15	51.22	-7.06	10:49	92	35	77.0				96.5		3.5
8	08.10.15	51.75	-7.04	16:10	75	0	41.0			8.8	85.4		5.8
9	09.10.15	51.38	-6.74	08:47	86	35	113.5		0.0		98.6		1.4
10	09.10.15	51.41	-6.74	09:54	86	35	127.1		11.1		87.9		1.0
11	09.10.15	51.14	-6.63	15:02	106	45	117.0	0.5	2.8	0.6	88.9		7.2
12	10.10.15	51.31	-6.53	07:38	90	0-45	3500.0	98.1	2				0.4
13	11.10.15	51.79	-6.20	07:45	97	35-50	178.7	0.0	3.9	4.3	89.5		2.2
14	11.10.15	51.51	-6.01	15:04	107	75	150.0	13.3	0.6	2.1	37.0		47.0
15	12.10.15	51.23	-6.09	00:00	60	0-10	154.1	0.4	0.2	3.9	73.4		22.1
16	12.10.15	52.01	-6.68	17:51	60	10	220.0	0.1	99.4	0.0			0.5
17	13.10.15	52.02	-6.95	09:18	52	0-40	7.0	6.4	21.2	64.2		2.8	5.3
18	13.10.15	51.87	-7.01	12:38	68	0-8	0.0						
19	14.10.15	51.81	-7.33	13:54	76	0-5	200.0	0.1	65.8	0.2	32.8		1.1
20	15.10.15	52.04	-7.49	07:42	31	0-9	180.0	0.5	4.2		95.3		
21	15.10.15	51.73	-7.55	13:54	77	0-8	150.0		34.7	1.2	63.6		0.5
22	16.10.15	51.28	-6.63	09:00	89	25-65	32.0	19.9		0.2	73.7		6.2
23	16.10.15	51.23	-6.58	19:43	107	0-10	750.0	95.3			0.8		3.9
24	16.10.15	51.30	-6.53	21:28	100	0	350.0	1.5			5.4		93.2
25	17.10.15	51.85	-7.68	08:11	50	13-20	91.8	0.0	48.7	0.3	38.5	10.6	1.9
26	17.10.15	51.65	-7.77	13:53	81	0-15	87.3		0.8	2.1	85.9		11.2
27	19.10.15	51.54	-9.72	13:01	43	0-20	300.0		1.7		97.6		0.6

* Including pelagic, demersal fish and invertebrate

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Table 4. Length-frequency of herring hauls from adaptive strata used in the analysis. Haul 6 = Trench, Hauls 12 & 23 = Smalls.

Haul	**6**	**12**	**23**	
length (cm)				Total
11				
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	1			1
21.5	0		1	1
22	4		3	7
22.5	11	1	6	18
23	16	0	10	26
23.5	44	4	23	71
24	39	6	15	60
24.5	60	14	55	129
25	38	19	46	103
25.5	52	41	59	152
26	52	38	41	131
26.5	47	60	60	167
27	25	30	26	81
27.5	10	31	25	66
28	10	9	10	29
28.5	6	2	2	10
29	2	1	2	5
29.5	2			2
30				
30.5				
31				
31.5				
32				
32.5				
33				
Total	**419**	**256**	**384**	**1,059**

Table 5. Total biomass (000's tonnes) of herring at age (winter rings) by strata.

Strata	0	1	2	3	4	5	6	7	8	9	10	Total
10	0	0	0.2	0.3	0.2	0.2	0	0	0			0.9
14_15	0	0	4	5.9	5.6	5.6	1	0.9	0.8			23.8
Total	0	0	4.3	6.1	5.7	5.8	1.1	0.9	0.8			24.7
%	0	0	17.3	24.7	23.2	23.3	4.4	3.7	3.4			100

Table 6. Herring abundance (millions) at age (winter rings) by strata.

Strata	0	1	2	3	4	5	6	7	8	9	10	Total
10	0	0	2	2	1	1	0	0	0			7
14_15	0	0	38	46	40	37	7	5	4			177
Total	0	0.0	40.1	48.1	41.2	37.7	6.8	5.5	4.6			184.0
%	0	0.0	21.8	26.2	22.4	20.5	3.7	3.0	2.5			100
Cv (%)	0	0.0	21.1	19.0	17.7	16.8	16.9	16.6	17.2			18.4

Table 7. Herring biomass (000's tonnes) at maturity by strata.

Strata	Imm	Mature	Spent	Total
10	0.0	0.9	0.0	0.9
14_15	0.0	23.5	0.3	23.8
Total	0.0	24.4	0.3	24.7
%	0.0	0	0	0.0

Table 8. Herring abundance (millions) at maturity by strata.

Strata	Imm	Mature	Spent	Total
10	0.0	7.4	0.1	7.4
14_15	0.0	174.5	2.0	176.6
Total	0.0	181.9	2.1	184.0
%	0.0	0.0	0.0	0.0

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Table 9. Herring length at age (winter rings) as abundance (millions) and biomass (000's tonnes).

Length	Age (Rings)											Abund	Biomass	Mn wt
(cm)	0	1	2	3	4	5	6	7	8	9	10	(mils)	000's t	(g)
11														
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			0.0									0.0	0.0	61.3
21.5			0.4									0.4	0.0	74.7
22			1.2									1.2	0.1	80.7
22.5			2.6									2.6	0.2	86.8
23			4.2									4.2	0.4	93.4
23.5			10.2									10.2	1.0	100.2
24			2.2	5.0								7.2	0.8	107.4
24.5			16	8.0								24.0	2.8	115.0
25			1.2	12.1	7.3							20.6	2.5	122.9
25.5			1.3	12.1	12.1	2.7						28.2	3.7	131.3
26			0.8	6.2	7.7	4.6	0.8	0.8				20.9	2.9	140.0
26.5				4.7	8.2	14.1	3.5					30.5	4.6	149.1
27					3.7	10.1						13.7	2.2	158.7
27.5					2.2	5.5	1.1	3.3	1.1			13.2	2.2	168.6
28						0.7	1.4	1.4	1.4			5.0	0.9	178.9
28.5									1.1			1.1	0.2	189.0
29									0.9			0.9	0.2	201.0
29.5									0.0			0.04	0.01	188.5
30														
30.5														
31														
31.5														
32														
32.5														
33														
33.5														
TSN (mil)			40.1	48.1	41.2	37.7	6.83	5.5	4.6			184.0	-	-
TSB ('000s t)			4.3	6.1	5.7	5.8	1.1	0.9	0.8			-	24.7	-
Mn Wt (g)			107	127	139	153	158	167	183			-	-	-
Mn length (cm)			23.9	25.2	25.9	26.7	26.9	27.4	28.2			-	-	-

Table 10. Herring biomass and abundance by survey strata.

Category Stratum	No. transects	No. schools	Def schools	Mix schools	Prob schools	% zeros	Def Biomass	Mix Biomass	Prob Biomass	Biomass ('000t)	SSB ('000t)	Abundance millions
10	7	69	69	0	0	0	0.9	0	0	0.9	0.9	7.4
14_15	32	1166	1166	0	0	6	23.8	0	0	23.8	23.8	176.6
Total	39	1235	1235	0	0	5	24.7	0	0	24.7	24.7	184.0

Table 11. Survey time series. Abundance in millions, biomass in 000's tonnes). Age in winter rings. Estimate includes 'Smalls' strata from 2011 onwards.

Season Age (Rings)	1995 1996	1996 1997	1997 1998	1998 1999	1999 2000	2000 2001	2001 2002	2002 2003	2003 2004	2004 2005	2005 2006	2006 2007	2007 2008	2008 2009	2009 2010	2010 2011	2011 2012	2012 2013	2013 2014	2014 2015	2015* 2016
0	202	3	-	0	-	25	40	0	24	-	2	-	1	2	239	5	0.1	31	3.8	0	0
1	25	164	-	30	-	102	28	42	13	-	65	21	106	63	381	346	342	270	698	41	0
2	157	795	-	186	-	112	187	185	62	-	137	211	70	295	112	549	479	856	291	117	40
3	38	262	-	133	-	13	213	151	60	-	28	48	220	111	210	156	299	615	197	112	48
4	34	53	-	165	-	2	42	30	17	-	54	14	31	162	57	193	47	330	43.7	69	41
5	5	43	-	87	-	1	47	7	5	-	22	11	9	27	125	65	71	49	37.9	20	38
6	3	1	-	25	-	0	33	7	1	-	5	1	13	6	12	91	24	121	9.8	24	7
7	1	15	-	24	-	0	24	3	0	-	1	-	4	5	4	7	33	25	4.7	7	6
8	2	0	-	4	-	0	15	0	0	-	0	-	1	-	6	3	4	23	0	17	5
9	2	2	-	2	-	0	52	0	0	-	0	-	0	-	1	-	2	3	0.2	1	0
Abundance	469	1338	-	656	-	256	681	423	183	-	312	305	454	671	1,147	1,414	1,300	2,322	1,286	408	184
SSB	36	151	-	100	-	20	95	41	20	-	33	36	46	93	91	122	122	246	71	48	24.7
CV	53	26	-	36	-	100	88	49	34	-	48	35	25	20	24	20	28	25	28	59.1	18.4

*** Adaptive, not core survey**

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Table 12. Sprat biomass and abundance by survey strata.

Category Stratum	No. transects	No. schools	Def schools	Mix schools	Prob schools	% zeros	Def Biomass	Mix Biomass	Prob Biomass	Biomass ('000t)	Abundance millions
Mizen	8	43	43	0	0	50	1.8	0	0	1.8	167.3
Offshore	24	511	450	61	0	38	65.5	5.6	0	71.0	20287.7
Inshore	34	211	202	9	0	38	9.2	1	0	10.3	879.8
Dunmanus	7	31	31	0	0	14	0.4	0	0	0.4	31.1
Bantry	6	11	11	0	0	67	0	0	0	0.0	3.4
Kenmare	5	0	0	0	0	100	0	0	0	0.0	0.0
Dingle	10	22	22	0	0	70	0.2	0	0	0.2	28.2
Kerry Hd	10	0	0	0	0	100	0	0	0	0.0	0.0
Total	104	829	759	70	0	51	77.1	6.6	0	83.7	21,398
Cv (%)	-	-	-	-	-	-	-	-	-		

Table 13. Summary of cetacean species sightings

.

Species	No. of sightings	No. of individuals	Group size range
Humpback whale	3	3	1
Fin whale	7	17	1 - 5
Minke whale	9	16	1 - 4
Killer whale	1	3	3
Common bottlenose dolphin	1	3	3
Short-beaked common dolphin	71	≥1045	1 - 200
Harbour porpoise	1	1	1
Unidentified whale	10	11	1 - 2
Unidentified dolphin	5	35	4 - 10
Unidentified cetacean	2	2	1
Totals	110	≥1136	1 - 200

Table 14. Summary of cetacean species sightings.

Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Humpback whale	P	-	-	1 (1)	-	-	1 (2)	-	-	-	-	3 (3)
Fin whale	P	-	5 (5)	3 (5)	9 (28)	4 (7)	3 (6)	25 (49)	20 (7-12)	1 (3+)	13 (24)	7 (17)
Minke whale	P	-	7 (7)	13 (15)	7 (7)	13 (14)	4 (4)	6 (6)	6 (6)	5 (5)	4 (4)	9 (16)
Killer whale	-	-	-	-	-	-	-	-	-	-	-	1 (3)
Long-finned pilot whale	-	-	-	1 (16)	-	-	-	-	-	-	-	-
Risso's dolphin	-	-	-	2 (30)	-	2 (5)	1 (3)	-	-	-	1 (2)	-
Bottlenose dolphin	P	P	-	1 (4)	-	-	-	-	2 (6)	2 (13)	1 (1)	1 (3)
Common dolphin	P	P	P	65 (2126)	78 (1849)	40 (814)	73 (774)	83 (814)	52 (411)	57 (305)	76 (2171)	71 (1045)
White-beaked dolphin	P	-	-	-	-	-	-	-	-	-	-	-
White-sided dolphin	-	-	-	1 (70)	-	-	-	-	-	-	-	-
Harbour porpoise	P	-	-	3 (9)	3 (7)	-	2 (13)	-	5 (17)	-	3 (5)	1 (1)

Table 15. Total number of sea bird species recorded.

Vernacular Name	Scientific Name	On Survey	Off Survey	Total
Fulmar	*Fulmarus glacialis*	253	71	324
Sooty Shearwater	*Puffinus griseus*	35	80	115
Manx Shearwater	*Puffinus puffinus*	12	217	229
Balearic Shearwater	*Puffinus mauretanicus*	1		1
European Storm-petrel	*Hydrobates pelagicus*	151	321	472
Gannet	*Morus bassanus*	4867	3488	8355
Shag	*Phalacrocorax aristotelis*	17	4	21
Pomarine Skua	*Stercorarius pomarinus*		7	7
Arctic Skua	*Stercorarius parasiticus*	1	4	5
Long-tailed Skua	*Stercorarius longicaudus*		1	1
Great Skua	*Stercorarius skua*	53	158	211
Puffin	*Fratercula arctica*	10	7	17
Black Guillemot	*Cepphus grylle*		3	3
Razorbill	*Alca torda*	114	3	117
Guillemot	*Uria aalge*	830	2	832
Razorbill / Guillemot		36		36
Kittiwake	*Rissa tridactyla*	360	42	402
Black-headed Gull	*Chroicocephalus ridibundus*		24	24
Little Gull	*Hydrocoloeus minutus*	1		1
Mediterranean Gull	*Larus melanocephalus*	1	4	5
Common Gull	*Larus canus*	12	2	14
Lesser Black-backed Gull	*Larus fuscus*	112	1241	1353
Herring Gull	*Larus argentatus*	40	215	255
Yellow-legged Gull	*Larus michahellis*		1	1
Great Black-backed Gull	*Larus marinus*	140	140	280
Unidentified Large Gull sp.	*Larus sp.*	20	240	260
Total		7066	6275	13341

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Table 16. Totals of migrant terrestrial bird species recorded.

Vernacular Name	Scientific Name	Total
Teal	*Anas crecca*	1
Turnstone	*Arenaria interpres*	2
Dunlin	*Calidris alpina*	1
Snipe	*Gallinago gallinago*	4
Short-eared Owl	*Asio flammeus*	1
Merlin	*Falco columbarius*	2
Goldcrest	*Regulus regulus*	1
Skylark	*Alauda arvensis*	5
Swallow	*Hirundo rustica*	10
Chiffchaff	*Phylloscopus collybita*	2
Blackcap	*Sylvia atricapilla*	1
Starling	*Sturnus vulgaris*	2
Redwing	*Turdus iliacus*	11
Spotted Flycatcher	*Muscicapa striata*	1
Black Redstart	*Phoenicurus ochruros*	1
Grey Wagtail	*Motacilla cinerea*	1
‘alba' wagtail	*Motacilla alba/yarrellii*	1
Richard's Pipit	*Anthus richardi*	1
Meadow Pipit	*Anthus campestris*	41
Rock Pipit	*Anthus petrosus*	1
Linnet	*Linaria cannabina*	1
Goldfinch	*Carduelis carduelis*	2
	Total	93

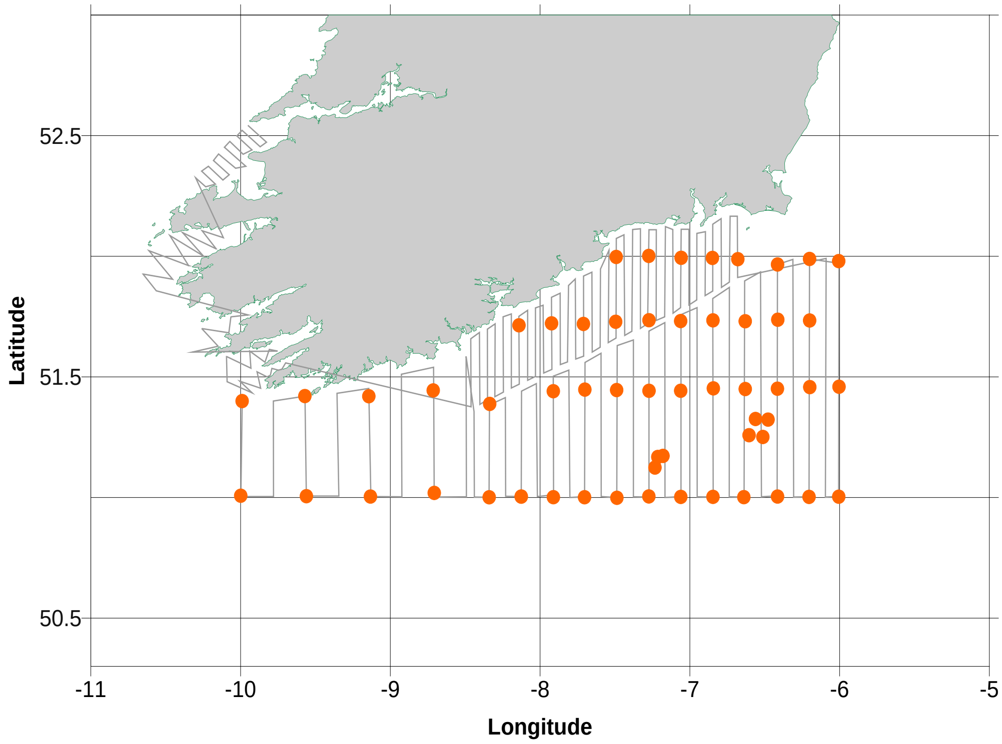

Figure 1. Cruise track (grey line) with hydrographic stations in orange.

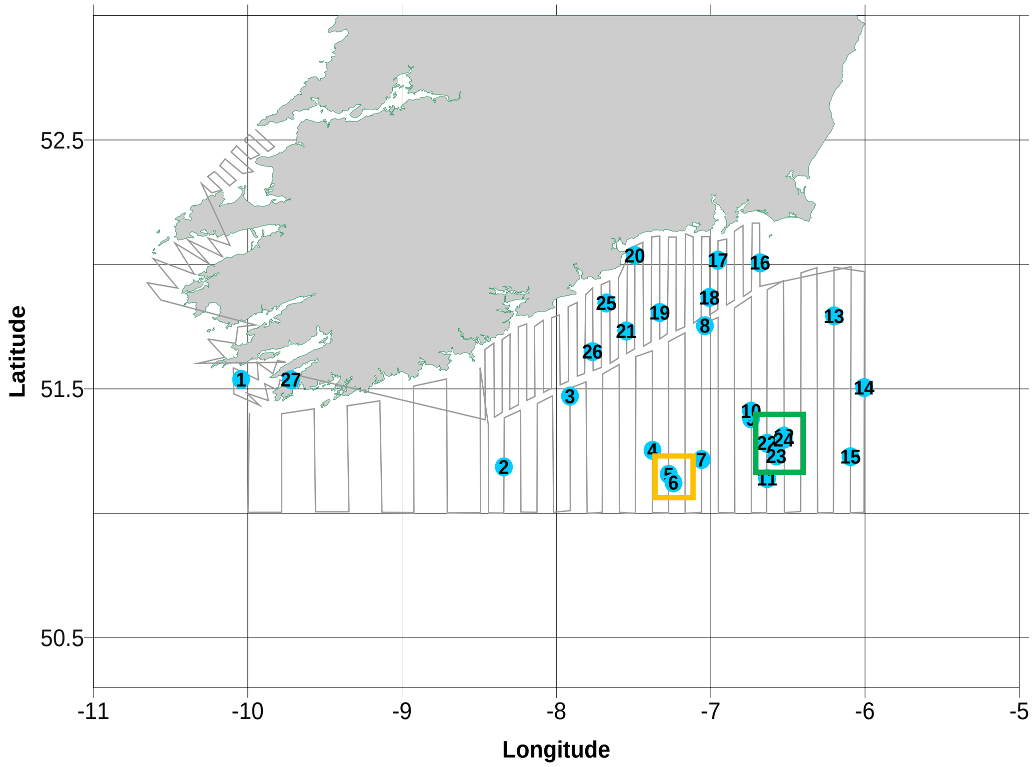

Figure 2. Directed midwater trawl positions. Detailed are the Trench (orange) and Smalls (green) adaptive survey areas.

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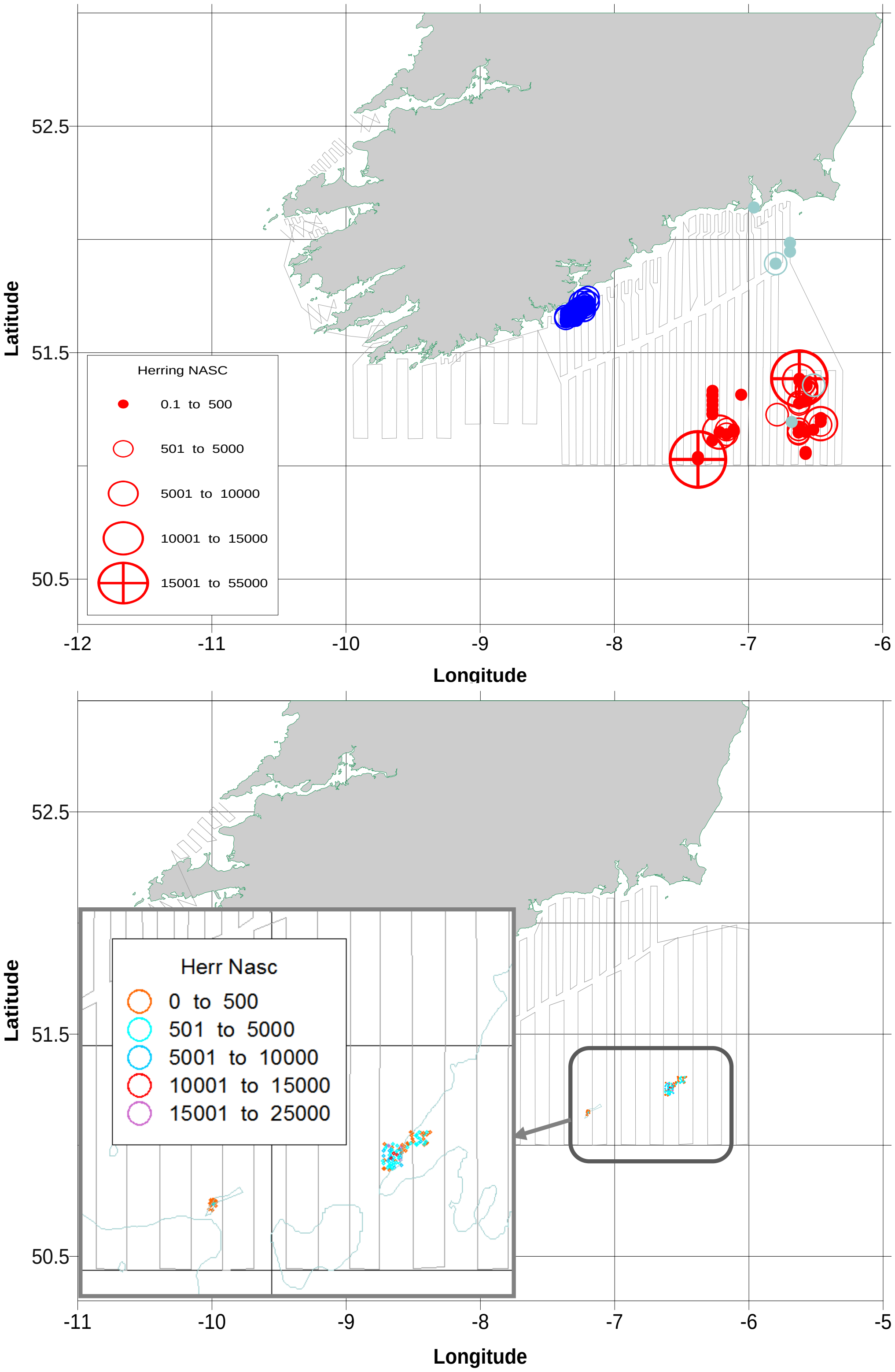

Figure 3. Weighted herring NASC (Nautical area scattering coefficient) plot of the distribution of "definitely" and "probably" categories (red circles), "mixed herring" (blue) and "possibly herring" (teal). Top Panel 2014, bottom panel 2015 for adaptive strata. Note: In 2015 the presence of herring echotraces in relation to core survey transects (vertical grey lines).

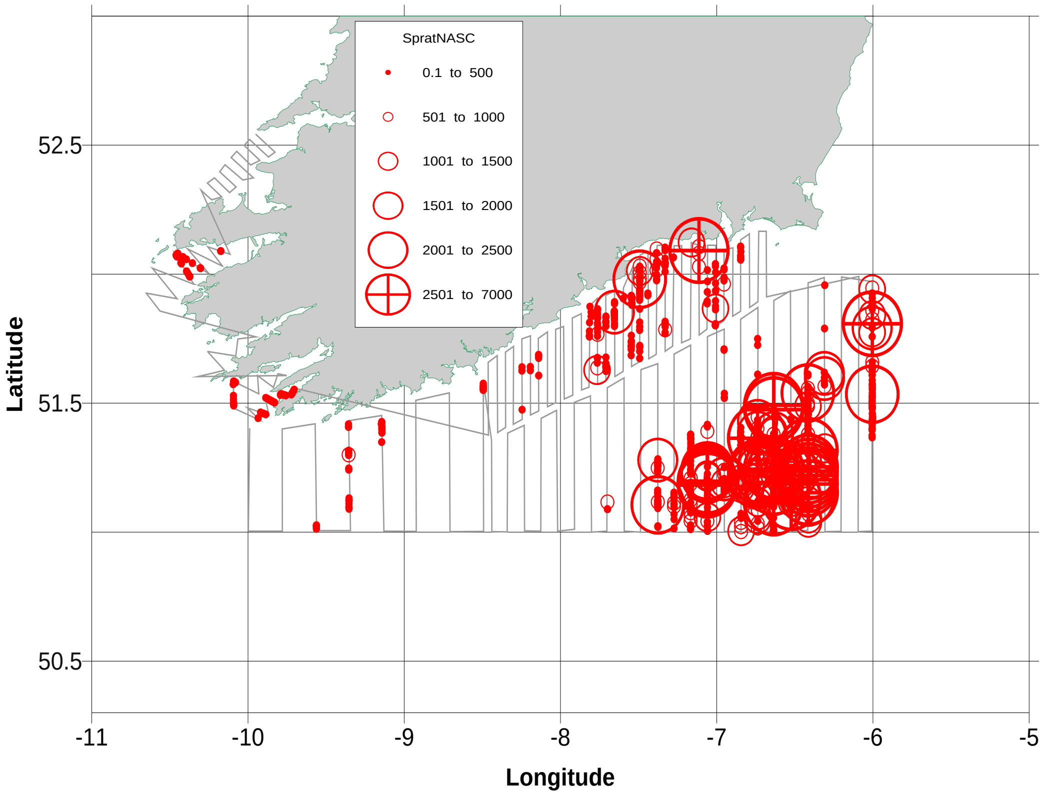

Figure 4. Weighted Sprat NASC (Nautical area scattering coefficient) distribution of "definitely" (red) sprat categories.

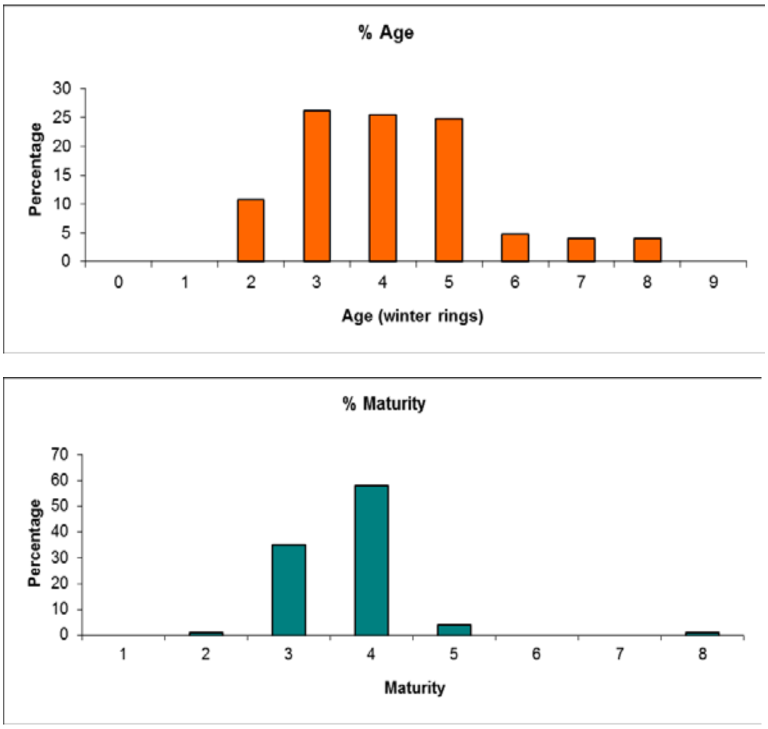

Figure 5. Percentage age and maturity of aged herring samples used in the analysis (n=149).

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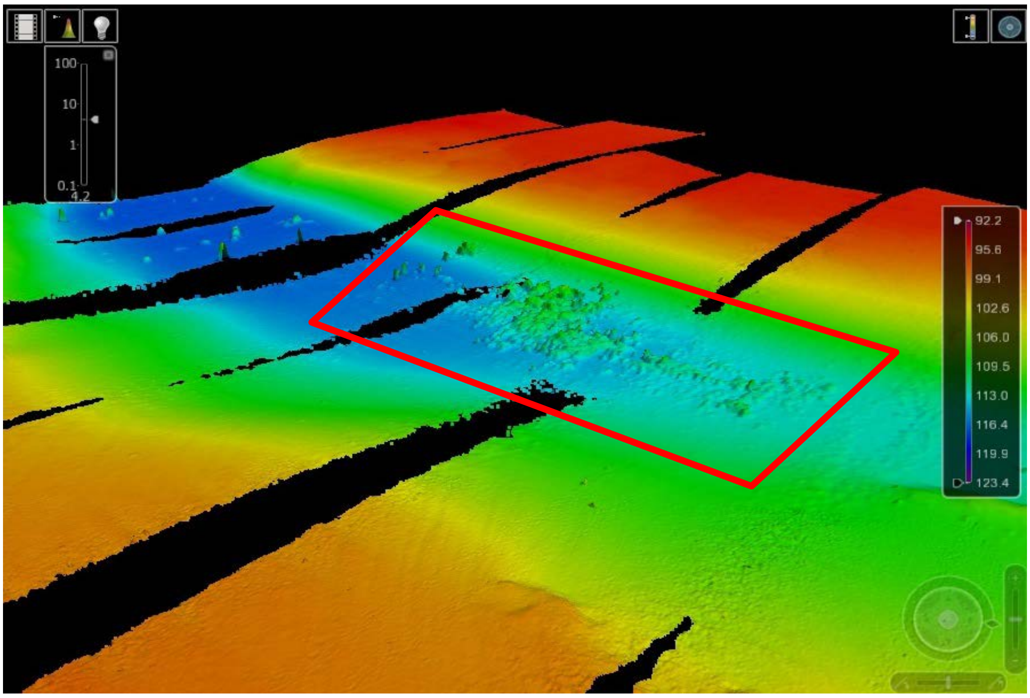
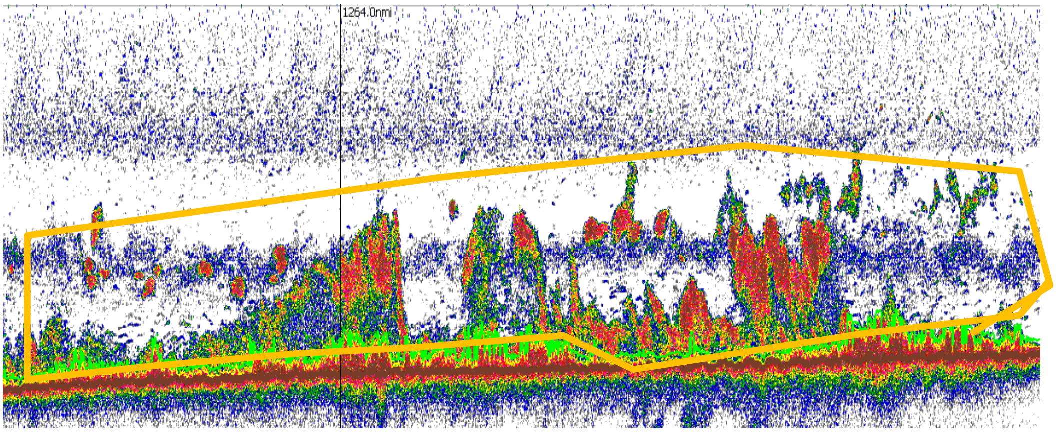
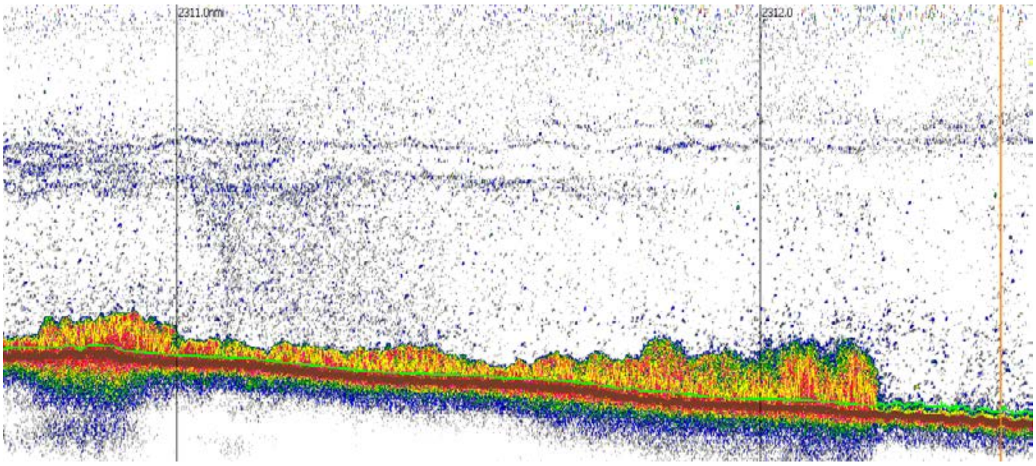


a). *Multibeam image (EM2040, 300 kHz) of herring (within red box) lying close to the bottom located within the Trench survey area during daylight hours. Aggregation extends for ~600 m along the trench and is ~250 m wide.*

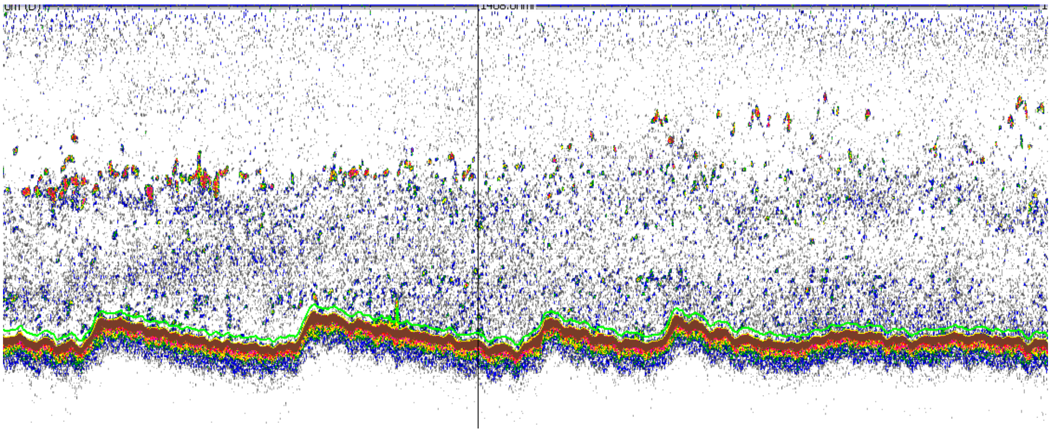


b). *High density echotrace containing herring (under green line) and sprat (orange box), recorded offshore in the Celtic Sea prior to Haul 12. Observed in daylight in the Smalls adaptive stratum, (#14) water depth 90 m.*

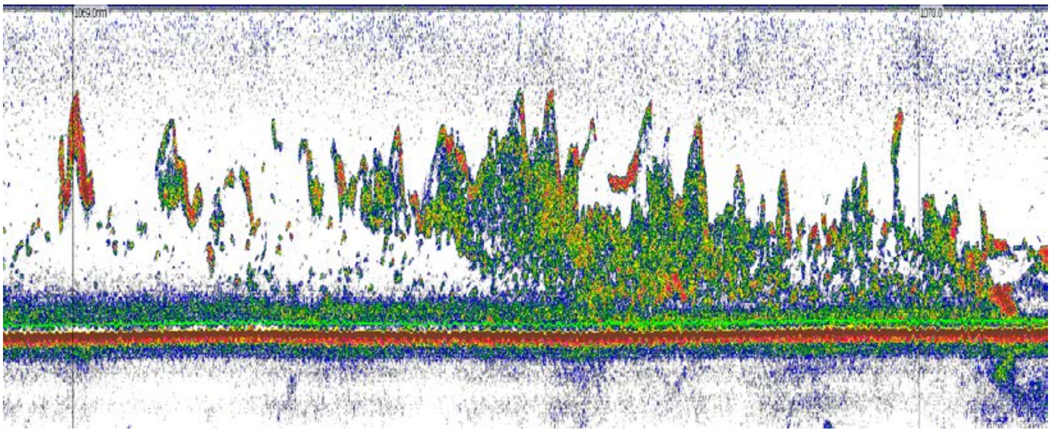
Figure 6. Images of herring recorded using a). the EM2040 multibeam (300 kHz) and b). EK60 (38 kHz)



c). *High density herring bottom echotrace observed at night recorded offshore in the 'Smalls' adaptive strata (#15). Water depth 93 m Vertical black bands represent 1 nmi.*

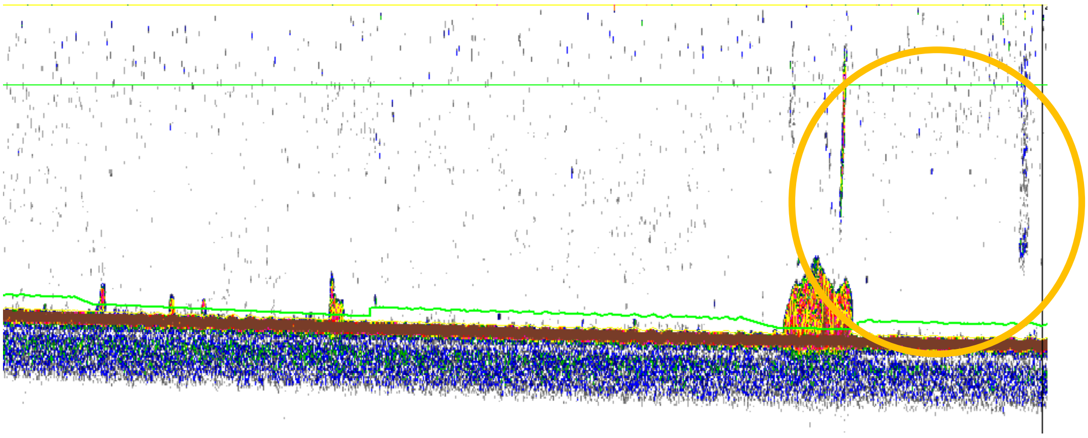


d). *Mixed species echotrace containing sprat (90%) recorded in the offshore strata prior to haul 13. Water depth 97 m.*



e). *Very high density sprat echotrace recorded offshore over c.1.5 nmi in length prior to Haul 09. Water depth 8 6m.*

Figure 6a-f. Continued.



f). *High density sprat echotraces recorded in Dunmanus Bay offshore prior to Haul 27. Water depth 43 m. Detailed (orange) are echotraces of common dolphins actively diving to feed on sprat.*

Figure 6a-f. Continued.

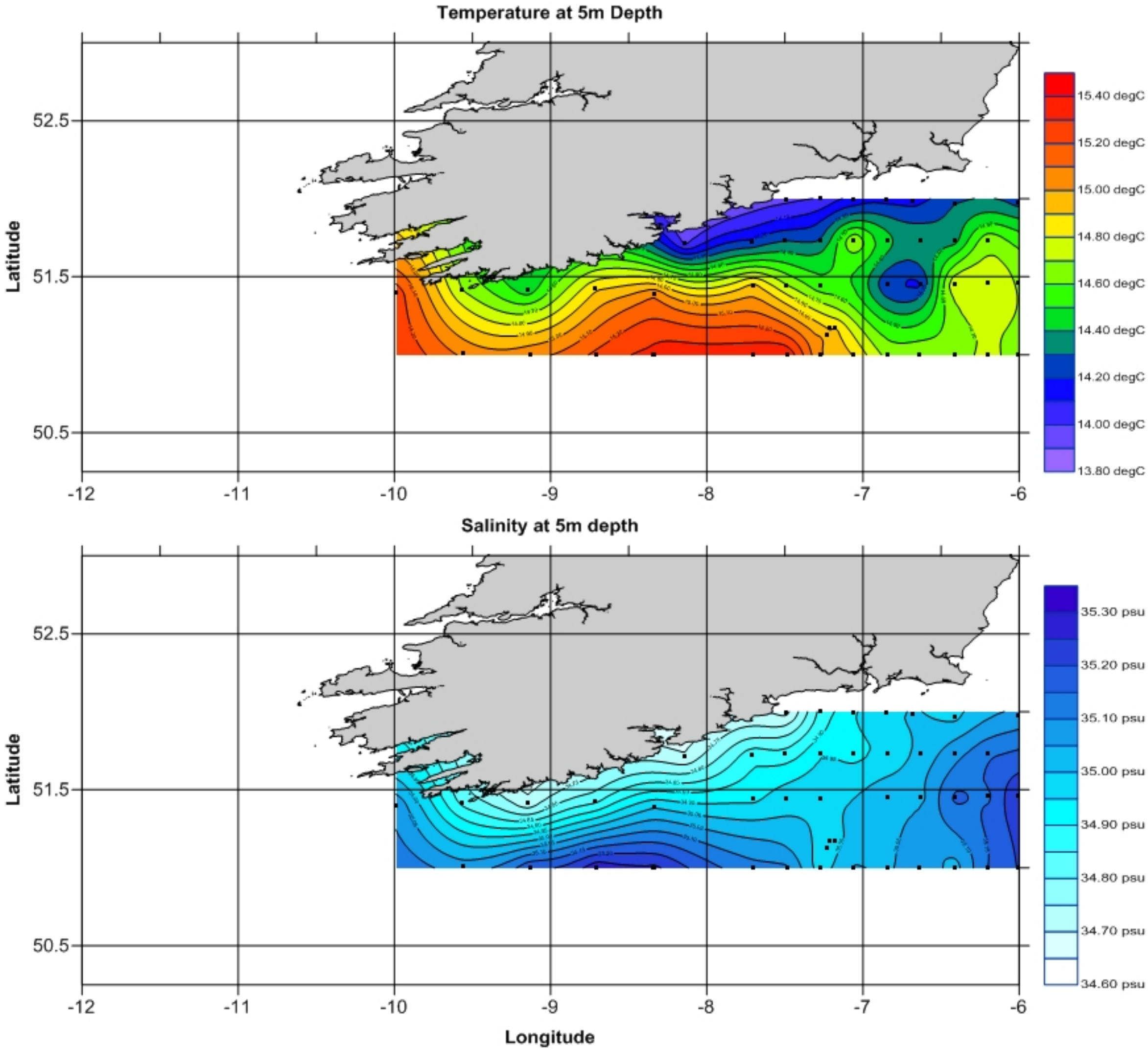


Figure 7. Surface (5m) plots of temperature and salinity compiled from CTD cast data. Station positions shown as block dots (n=49).

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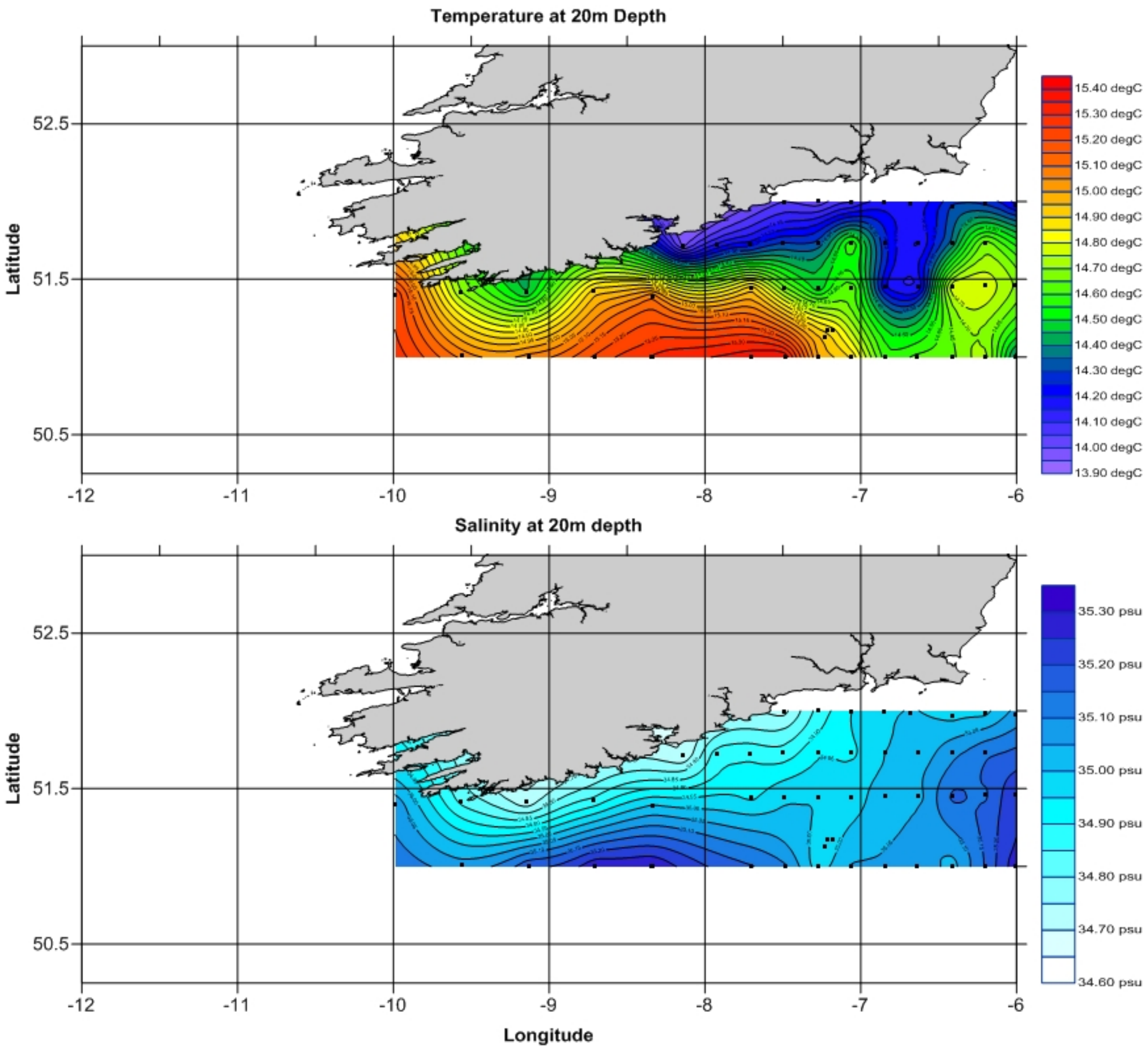

Figure 8. Surface (20m) plots of temperature and salinity compiled from CTD cast data. Station positions shown as block dots (n=49).

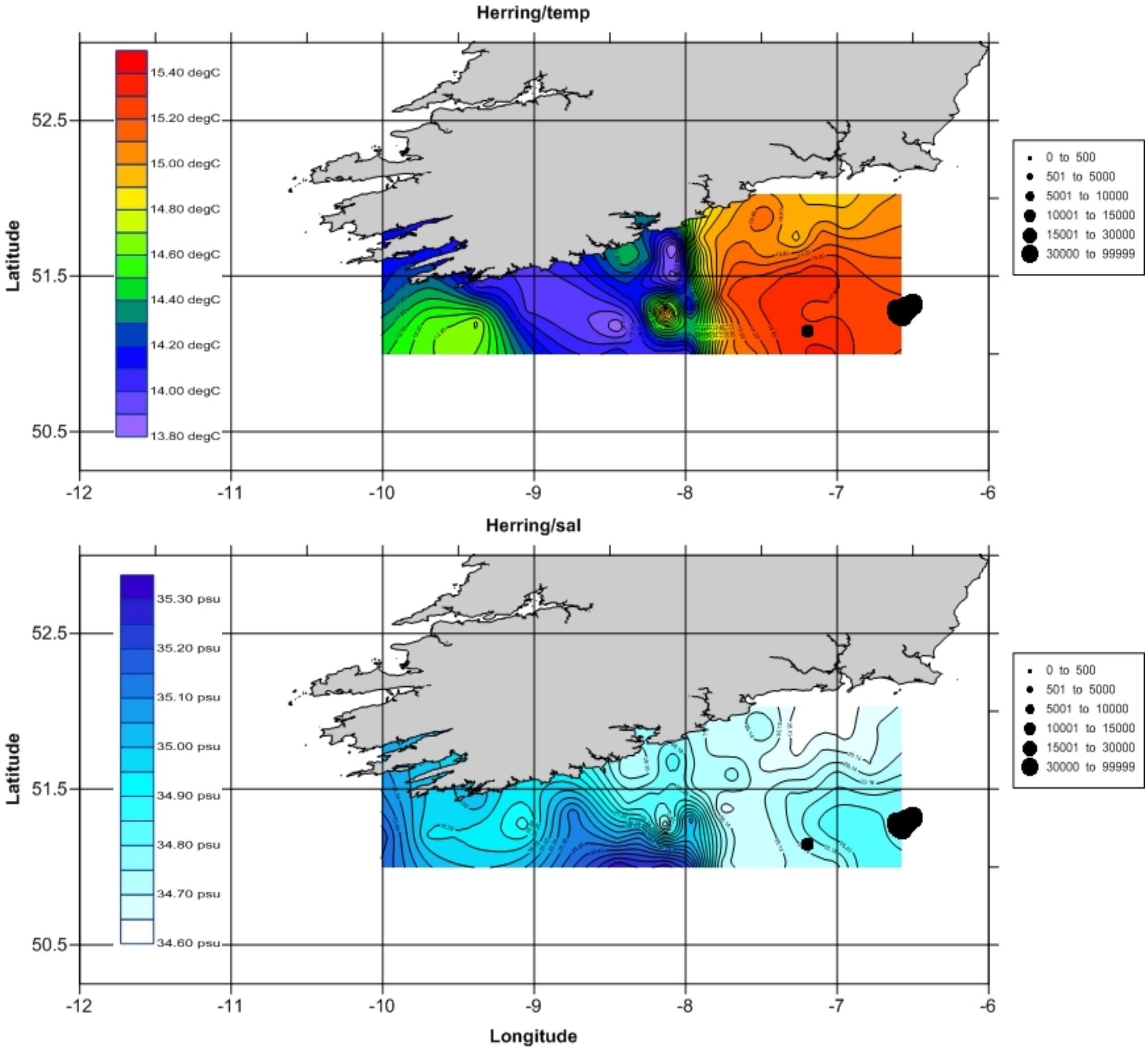

Figure 9. Habitat plots of temperature and salinity at 40m overlaid with herring NASC values (black circles).

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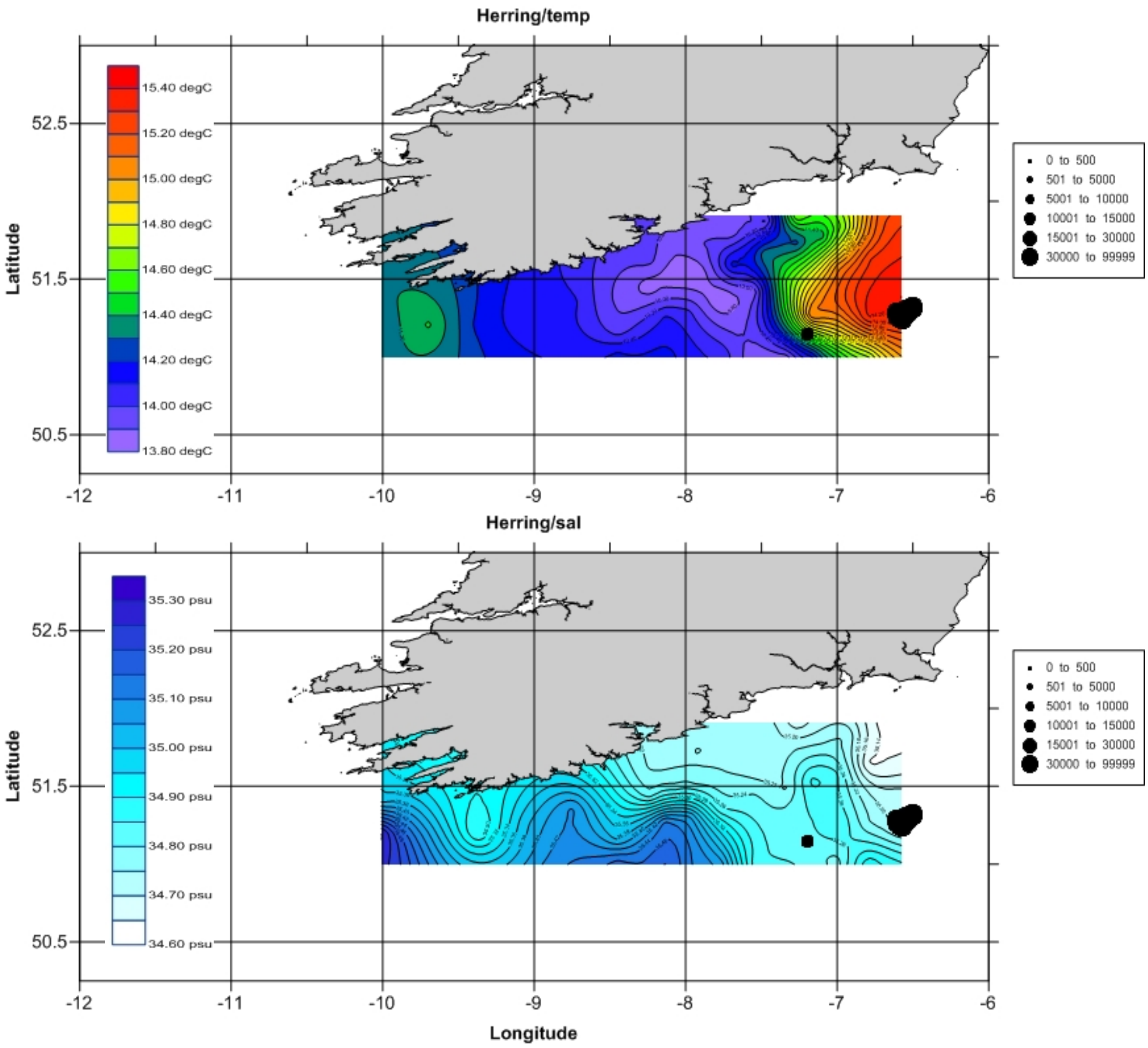

Figure 10. Habitat plots of temperature and salinity at 60m overlaid with herring NASC values (acoustic density) shown as black circles.

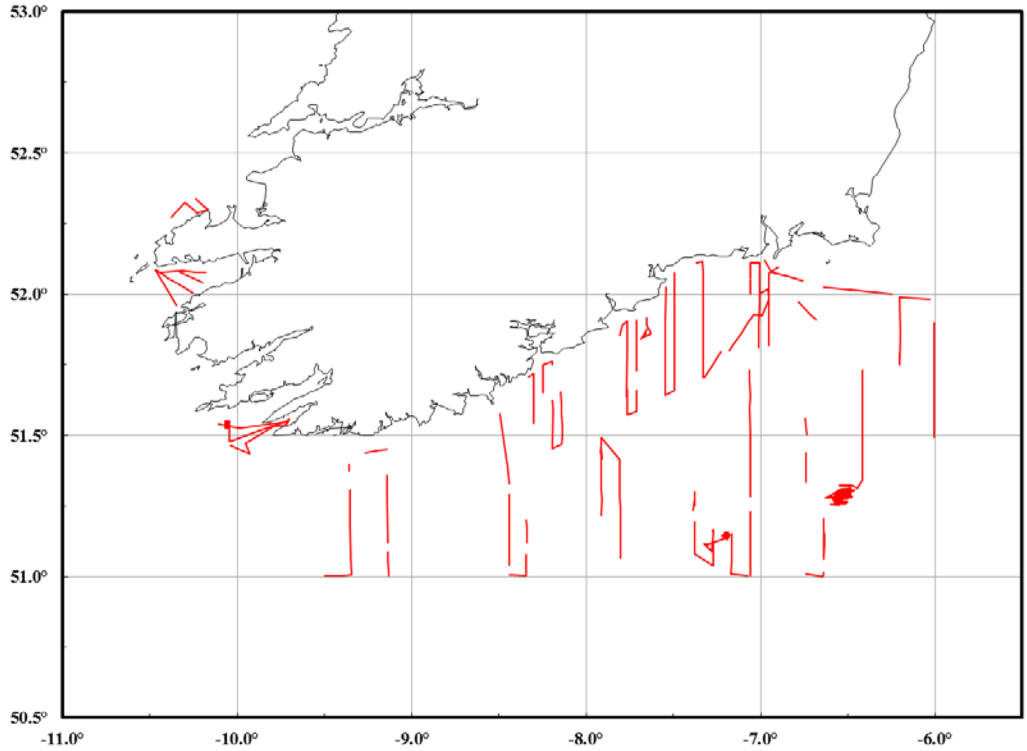

Figure 11. Marine mammal and seabird survey effort showing portion of the acoustic survey track where watch effort was attained.

HERRING MIDWATER TRAWL

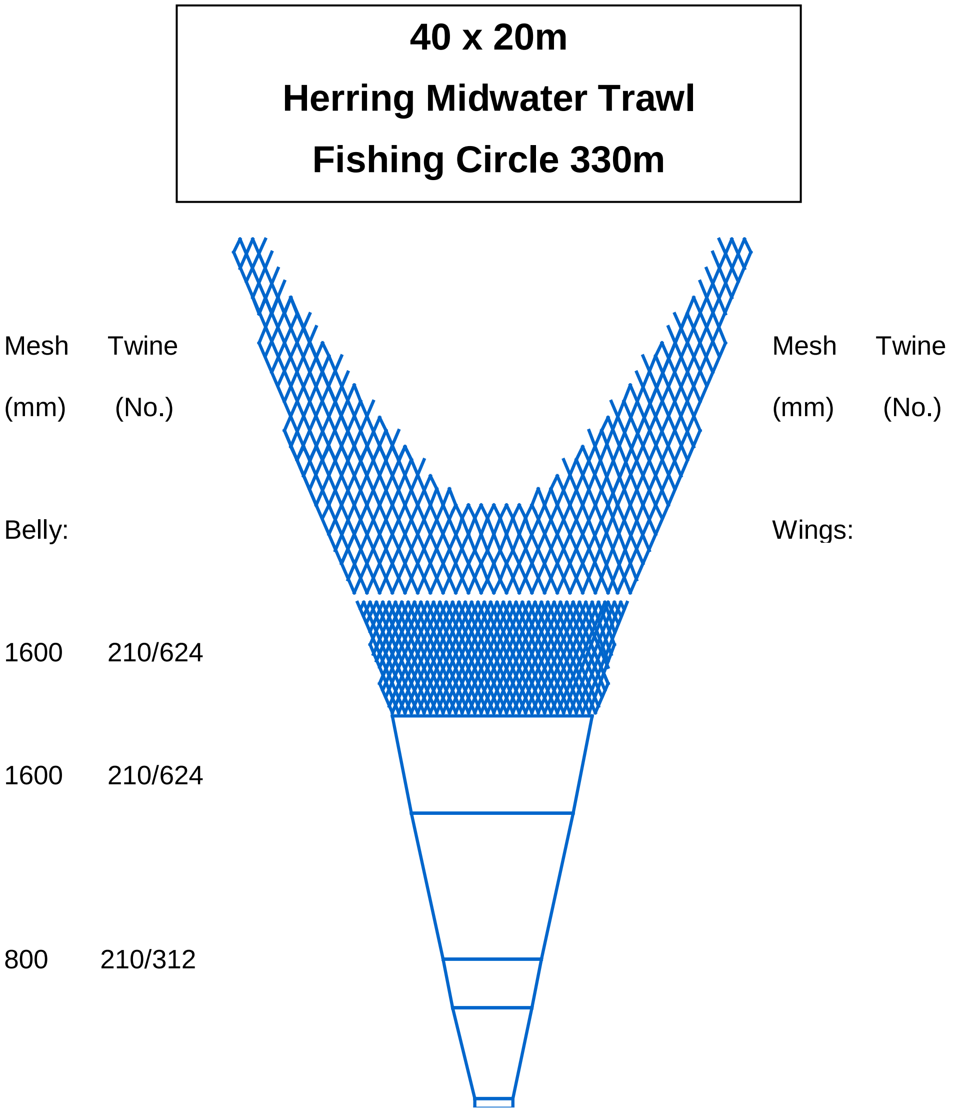

Figure 12. Single herring midwater trawl net plan and layout. Celtic Sea herring acoustic survey, October 2012.

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

6 Annex 1

Cetacean species account.

Humpback whale (*Megaptera novaeangliae*)

Humpback whales were encountered three times (two sightings were 'on effort' and one incidental) over the course of the survey involving a minimum of three individuals. The first two sightings were during the same day south of the Beara peninsula (refer to map in Figure 1 below) in an area with intensive feeding activity and as the sightings were greater than six hours apart it is indeterminable whether they were of the same individual or two different animals. Fish samples in this area confirmed the presence of sprat (*Sprattus sprattus*). The third sighting occurred further offshore, c. 90 km south of the Saltee islands, Co. Wexford, an area where hauls confirmed a high density of herring (*Clupea harengus*).

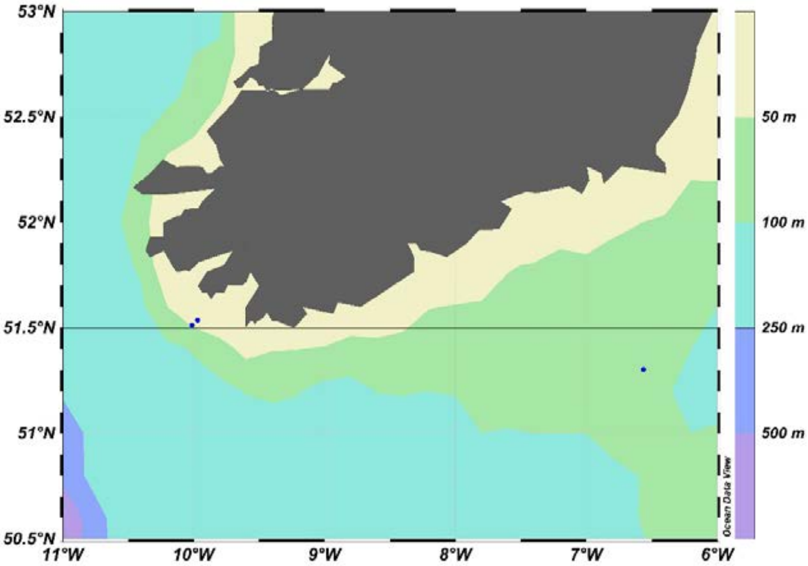

Figure 1. Map illustrating humpback whale sighting locations. Map prepared using Ocean Data View software (Schlitzer, 2015).

Image 1. Humpback whale south of Beara peninsula, Co. Cork on 03.10.2015 © Niall T. Keogh.

Fin whale (*Balaenoptera physalus*)

There were seven fin whale sightings involving a total of 17 individuals. Group sizes ranged between one and five animals. Five of the sightings were off the Waterford coast (refer to map in Figure 2 below). The other two were south of Beara amongst a mixed species group feeding on sprat and as there were two sightings in the same area within a seven hour period the later sighting may represent a resighting of the same animals. Likewise, animals observed east of Mine Head over two days may have been the same individuals. Although there was no intensive feeding observed in this area fish hauls confirmed the presence of relatively big sprat and there were common dolphins and minke whales observed in the same general area. There was one sighting of a single animal associated with the highest occurrence of herring in the fishing grounds south of Wexford. The quality of fin images captured was insufficient for reliable photo ID comparison with the existing IWDG catalogue.

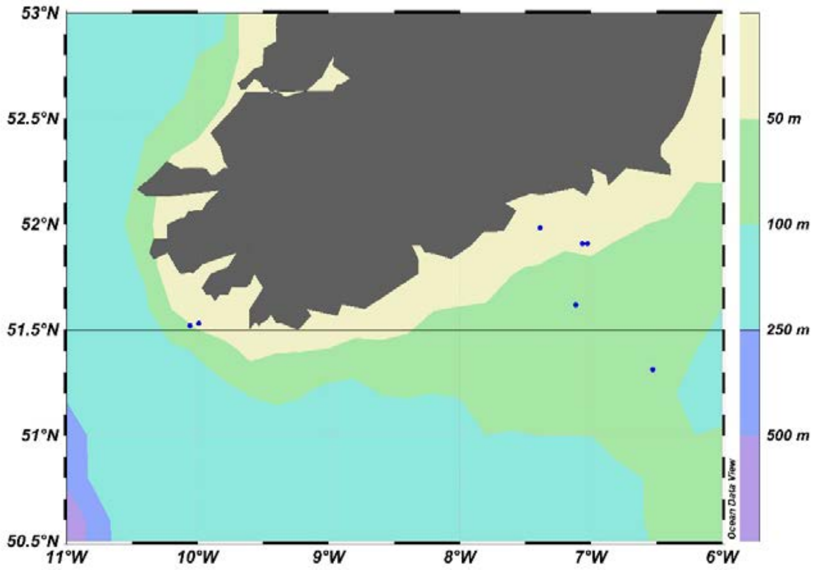

Figure 2. Map illustrating fin whale sighting locations. Map prepared using Ocean Data View software (Schlitzer, 2015).

Image 2. Fin whale east of Mine Head, Co. Waterford on 15.10.2015 © Mairéad O'Donovan

Minke whale (*Balaenoptera acutorostrata*)

There were nine minke whale sightings, five of which were of single animals and the others were groups of up to four animals. Six of the sightings were relatively close to shore (refer to map in Figure 3 below) and these all coincided with common dolphin sightings in the same area. On three of these occasions fish samples confirmed sprat to be main prey species present at the time. Two groups of three and four animals were both observed on the same day south of the Beara peninsula in an area of intensive mixed species feeding activity on sprat. As there were almost eight hours between the two records it's possible that the same animals were counted twice. The furthest offshore sightings were two of single animals south of the Nymphe bank, about 120 km southeast of Helvick head, Co. Waterford. These sightings were in an area featuring a relatively deep gully where fish hauls confirmed the presence of herring and sprat.

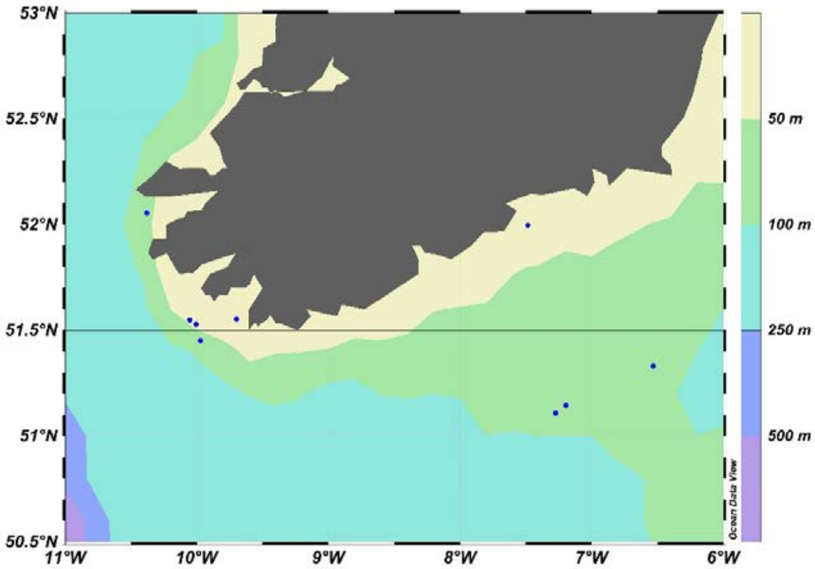

Figure 3. Map illustrating minke whale sighting locations. Map prepared using Ocean Data View software (Schlitzer, 2015).

Image 3. Minke whale in Dunmanus bay, Co. Cork on 19.10.2015 © Inge van der Knapp

Killer whale (*Orcinus orca*)

Killer whales were observed incidentally on one occasion by the chief scientist and a number of the ship's crew. Three individuals were reported within 500 m of the vessel whilst the fishing gear was being deployed. The location was within an expansive high density area of herring with a relatively high number of fishing vessels, approximately 90 km south of the Saltee islands, Co. Wexford (refer to the map in Figure 4 below). There were common dolphins recorded within seven minutes of the orca sighting.

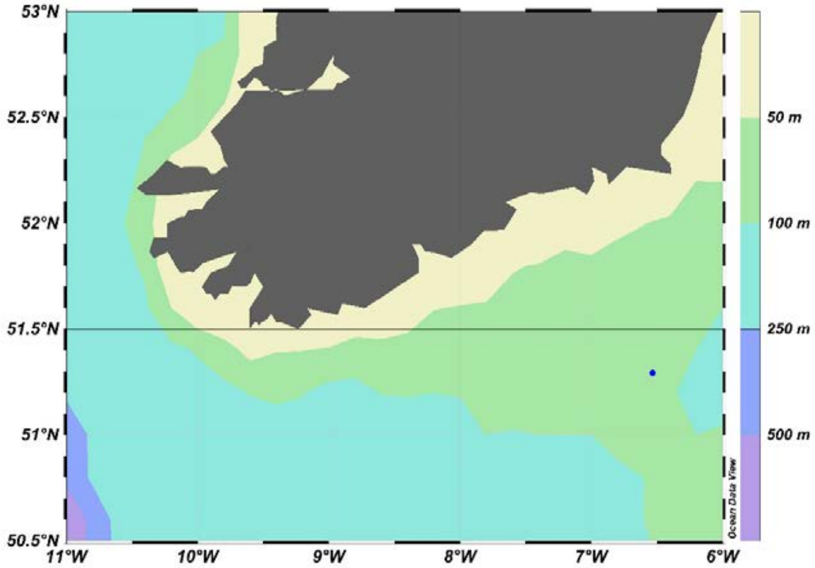

Figure 4. Map illustrating orca sighting location. Map prepared using Ocean Data View software (Schlitzer, 2015).

Common bottlenose dolphin (*Tursiops truncatus*)

There was one bottlenose dolphin encounter of three individuals, including one juvenile animal. The colouration of the animals suggested that they were of the species' in-shore ecotype. The sighting occurred 90 km southeast of the Cork coast (refer to the map in Figure 5 below).

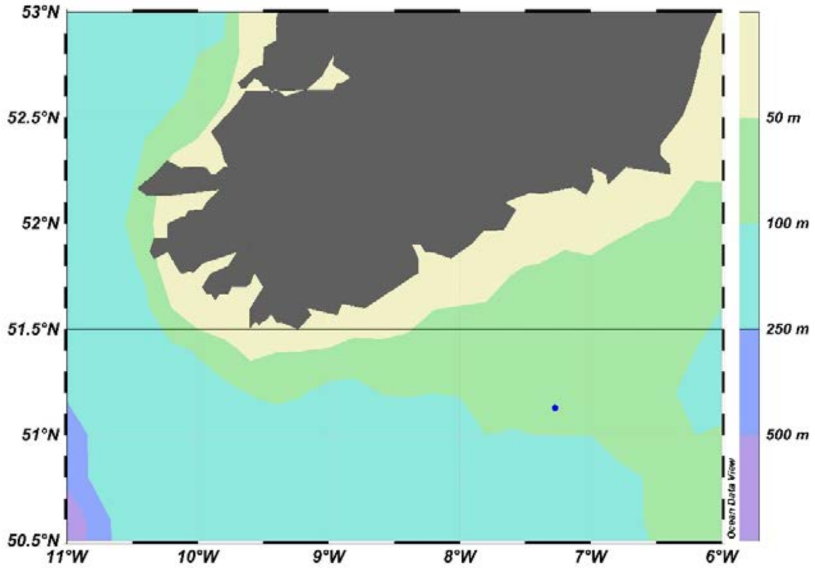

Figure 5. Map illustrating bottlenose dolphin sighting location. Map prepared using Ocean Data View software (Schlitzer, 2015).

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Short-beaked common dolphin (*Delphinus delphis*)

Common dolphins accounted for 71 of the total number of sightings and the largest group sizes (≥ 200 animals). Some groups associated with the vessel for more than one hour. There were juveniles and/or calves observed on seven occasions. Common dolphins were recorded amongst multi-species feeding groups off the Beara peninsula and individuals of the species were present on six out of nine occasions when minke whales were recorded. Although the map illustrating sightings distribution (refer to Figure 6) appears to indicate a higher density of sightings inshore this may be due to the survey line set-up (shorter lines closer together) rather than an actual higher relative abundance.

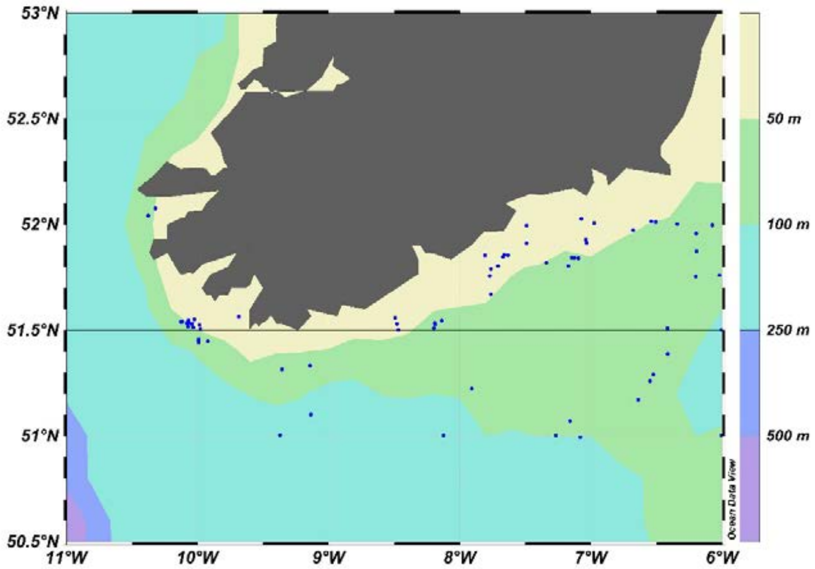

Figure 6. Map illustrating common dolphin sighting locations. Map prepared using Ocean Data View software (Schlitzer, 2015).

Image 4. Common dolphins south of Co. Waterford on 14.10.2015 © Mairéad O'Donovan

Harbour porpoise (*Phocoena phocoena*)

There was one incidental sighting of a single harbour porpoise made by a seabird observer south of the Beara peninsula close to an area with high feeding activity focussed on sprat. The inshore location of the sighting is typical of this coastal species (refer to the map in Figure 7 below).

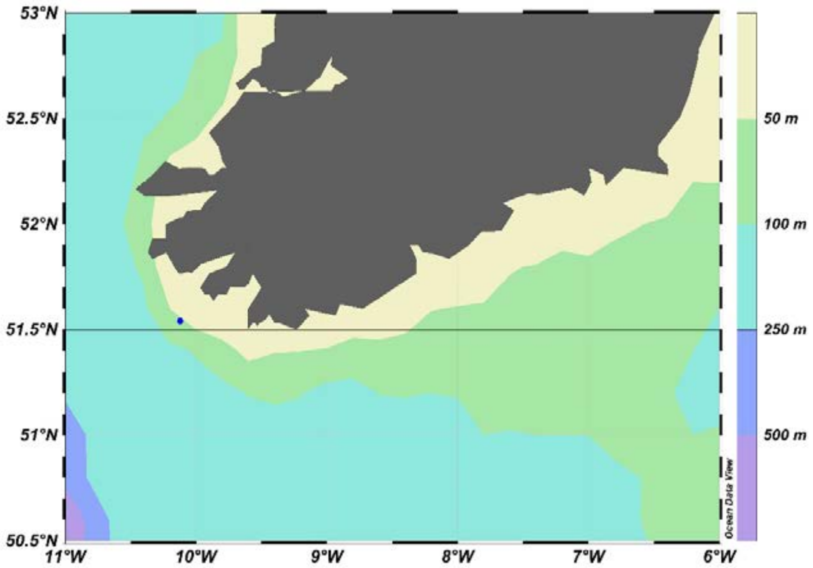

Figure 7. Map illustrating harbour porpoise sighting location. Map prepared using Ocean Data View software (Schlitzer, 2015).

Unidentified cetaceans

There were 17 sightings of unidentified animals. 10 of these were recorded as unidentified whale, five as unidentified dolphin and two as cetacean (refer to Figures 8 and 9 below). Unidentified dolphin group sizes ranged between four and ten animals. There was one record of two unidentified whales but otherwise the remainder of unidentified animal sightings were of single animals.

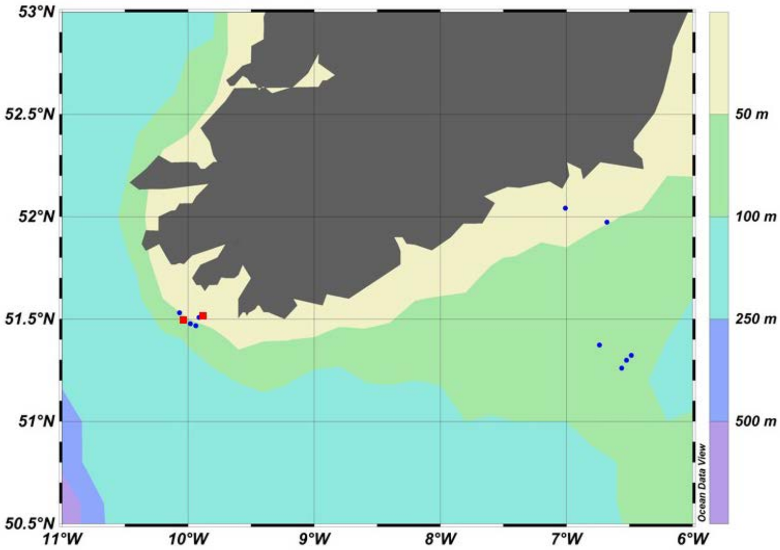

Figure 8. Map illustrating unidentified whale and cetacean sighting locations. Unidentified whale sightings are represented by blue circles, unidentified cetaceans by red squares. Map prepared using Ocean Data View software (Schlitzer, 2015).

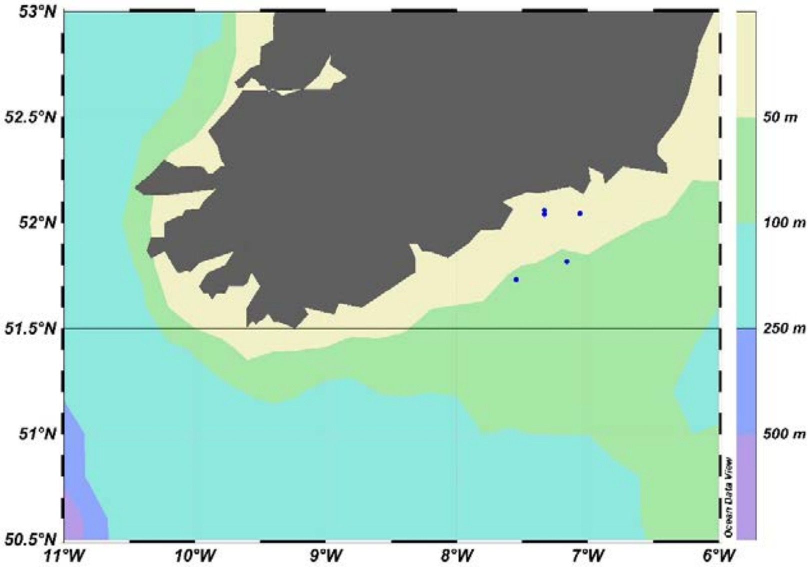

Figure 9. Map illustrating unidentified dolphin sighting locations. Map prepared using Ocean Data View software (Schlitzer, 2015).

Other species of marine megafauna

Bluefin tuna (*Thunnus thynnus*) were recorded on 9 occasions with a total of 42 individuals, all south of the Waterford and Wexford coasts (refer to map in Figure 10 below). The group sizes observed ranged between one and 12 animals and during several encounters animals appeared to be feeding and there was associated bird activity. There was one sighting of an unidentified turtle species made by one of the seabird observers approximately 110 km southeast of Carnsore point.

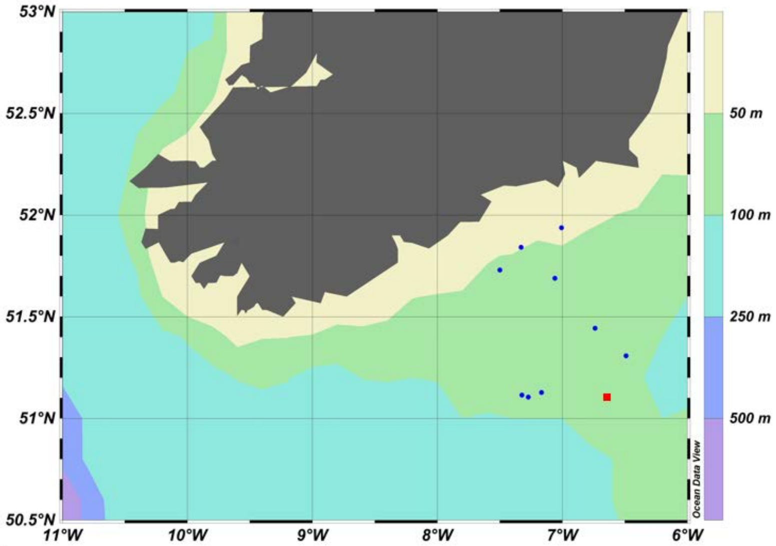

Figure 10. Map illustrating sighting locations of other marine megafauna. Tuna are represented by blue circles, turtles by red squares. Map prepared using Ocean Data View software (Schlitzer, 2015).

The only seal sightings were recorded on or near the Blasket islands off the coast of Co. Kerry whilst transiting through the Blasket sound. A minimum of 267 grey seals (*Halichoerus grypus*) including pups were photographed hauled out on the beach or within a few metres of the shore on Blascaod Mór. Shortly after an unidentified seal, presumably a grey seal, was observed by a seabird observer further north in the Blasket sound.

Image 5. Grey seals hauled out on An Blascaod Mór © Mairéad O'Donovan