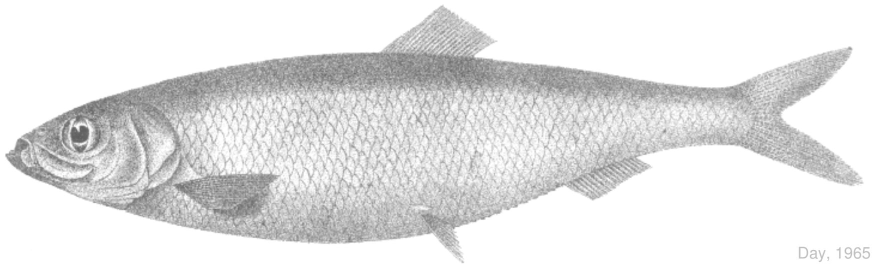
FSS Survey Series: 2014/04

Celtic Sea Herring Acoustic Survey Cruise Report 2014

06 - 26 October, 2014



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 traditionally begins in mid September 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 eighth 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	Cormac Nolan	Aco (SIC)	All
FEAS	Graham Johnston	Aco	All
FEAS	Andrew Campbell	Aco	1
FEAS	Meadhbh Moriarty	Aco	2
FEAS	Turloch Smith	Aco	All
FEAS	Macdara O'Cuaig	Bio	All
FEAS	Robert Bunn	Bio	All
FEAS	Mairead Sullivan	Bio	1
FEAS	Tobi Rapp	Bio	1
FEAS	John Enright	Bio	2
FEAS	Grainne Ni Choncuir	Bio	2
BWI	Niall Keogh	SBO	All
BWI	Stephen McAvoy	SBO	All
BWI	Katherine Keogan	SBO	1
NPWS	Ciaran Cronin	MMO	All
IWDG	William Hunt	MMO	All
IS&W FPO	John Regan	Industry Rep	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
- 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
- Sighting survey for marine surface litter

2.2.2 Area of operation

The autumn 2014 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. The survey started in the southwest and worked in an easterly direction covering offshore strata and then working east to west along the coast.

The survey was broken into 2 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 9 strata formed the boundary component of the survey. Broad scale outer lying areas are important transit areas for herring migrating to inshore spawning areas and from offshore summer feeding grounds. The second component focused exclusively on known spawning areas and was made up of 8 strata.

2.2.3 Survey design

A parallel transect design was used with transects running perpendicular to the coastline and lines of bathymetry where possible. Offshore extension reached up to 70nmi (nautical miles). Transect resolution was set at between 2-4nmi for the broad scale survey and increased to 1nmi for the spawning ground surveys. 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 combined survey accounted for 3,108nmi; with approximately 2, 623nmi of integrateable acoustic transect available (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.

2.3.2 Calibration of acoustic equipment

Calibration of the EK60 was carried out in Galway Bay on the 7th of October during hours of daylight. Only 2 frequencies (18 & 38 kHz) 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 viewed by a scientist experienced in viewing 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 (Anon, 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 19m in length (LOA) and 6m at the wing ends and a fishing circle of 330m was employed during the survey (Figure 12). Mesh size in the wings was 3.3m through to 5cm 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 0.5cm 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 1m subsurface and 3m 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 (18m above sea level) when weather allowed or from the bridge (11m).

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 and surface litter

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 300m.

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 = 0-50m from the ship, B = 50-100m, C = 100-200m, D = 200-300m, E > 300m) 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 300m 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 (300m x

300m) 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 a 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.

3 Results

3.1 Celtic Sea herring stock

3.1.1 Herring biomass and abundance

Herring	Millions	Biomass (t)	% contribution
Total estimate			
Definitely	402	49,310	98.7
Mixture	2	194	0.4
Probably	4	448	0.9
Possibly	27	3,318	
Total estimate	408	49,952	100
SSB Estimate			
Definitely	367	46,901	98.7
Mixture	2	184	0.4
Probably	3	411	0.9
SSB estimate	372	47,496	100

Total herring biomass shown above was determined from 18 survey strata of which 3 contained herring (Table 10). Survey biomass and abundance was derived from 167 echotraces identified as herring with the aid of 19 directed trawls (Figure 2, Table 3). Of the 167 herring echotraces over 98% were identified as 'definitely herring', less than 1% as 'probably herring' and less than 0.5% as 'mixed herring' echotraces (Table 10).

Herring TSB (total stock biomass) and abundance (TSN) estimates were 49,952t (CV 60.2%) and 408 million individuals (CV 59.1%) respectively. The overall SSB (spawning stock biomass) observed during the survey was 47,496t (CV 60.2%), composed of a spawning abundance (SSN) of 372 million individuals.

A breakdown of herring stock abundance and biomass by age, maturity, size and stratum is shown in Tables 5-10.

3.1.2 Herring distribution

A total of 19 trawl hauls were carried out during the survey (Figure 2), with 5 hauls containing herring and 3 contained >50% herring by weight of catch (Table 3).

Herring distribution was limited exclusively to 3 of 18 survey strata. Two offshore broadscale strata (#7 & 8) contained almost the entire observed herring biomass (99.6% of TSB) and was made up of 144 medium and high density herring echotraces (Figures 6a-d). A small amount of inshore herring were taken as a component of a mixed species echotraces within a localised area (spawning box strata #14) accounting for c.200t of the total stock estimate (Figure 3, Table 10). However, due to the local bathymetry it was not possible to trawl on each of the 115 low density echotraces attributed to the mixed species category in this strata and as a result the c.200t may in fact be an over estimate of the actual abundance.

3.1.3 Herring stock composition

A total of 206 herring were aged from survey samples in addition to 1,455 length measurements and 310 length-weights recorded (Table 4). Herring age samples ranged from 1-9 winter-rings (Tables 5 & 6, Figure 5).

3 winter-ring herring dominated the 2014 estimate representing over 28% of TSB and 27% of TSN (Table 5 and 6). The 2 winter-ring age group were ranked second representing 23% of TSB and 29% of TSN. The third most dominate age group was 4 winter-ring group contributing 21% to the TSB and 17% to TSN.

Maturity analysis indicated over 95% of the TSB as sexually mature (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. No spent fish were 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	7,329	43,259	78.9
Mixture	543	3,162	5.8
Probably	1,280	8,405	15.3
Total estimate	9,152	54,826	100

Sprat were found in 13 of 18 survey strata during the survey and sampled in 14 of 19 hauls (Figure 4, Table 3). In total 2,226 individual length measurements and 501 length/weight measurements were recorded. Mean length was 8.2cm and mean weight was 4g. Individuals ranged from 5 to 14.5cm in length and 1 to 29g in weight.

In total 956 individual sprat echotraces were identified during the survey (Table 12). The highest concentration of biomass was observed offshore in strata 7 and accounted for c.29% of total biomass and over 25% of the total abundance (Table 12). Very high density echotraces of sprat dominated (Figure 6e, f). The 'Smalls' strata (#8), contributed a further 12% to the TSB.

Inshore coastal waters accounted for the remaining 59% of stock biomass. The Mizen strata (#6), contributing c.17% to TSB has consistently contained a high portion of sprat biomass year-on-year. Dingle and Kenmare Bays contributed 7% and 11% to the TSB respectively.

The occurrence of high density aggregations of sprat extended further to the east approaching the Bristol Channel and western approaches to the English Channel (Van Der Hooj *pers. comm.).*

The mean length of sprat observed from this year's survey is comparable to previous years and this can be attributed to the widespread occurrence of 0-group fish throughout the survey area. Catches showed the presence of 2 distinct cohorts of 0-group and 1-groups.

3.3 Oceanography

A total of 51 CTD stations were carried out. Surface plots of temperature and salinity are presented for the 5, 20, 40 and the >60 m depth profiles in Figures 7-10.

Sea surface temperature, as measured at 5m, is relatively warm with temperatures above 14ºC for the larger area, the colder plumes of river water are evident around Cork Harbour. Surface salinity follows a similar pattern and is relatively stable throughout the area with the exception of river plumes, note also the plume south of Waterford Harbour (Figure 7). Temperature and salinity profiles at 20m depth (Figure 8) follow a similar stable pattern indicating both profiles are above the thermocline. The influence of the cooler, less saline water along the south coast in the form of the Irish Sea Front is not visible in surface waters as compared to previous years (O'Donnell *et al.,* 2013).

Profiles of 40m and 60m (Figures 9 & 10) are overlaid with herring acoustic density (NASC) data and it is evident that a depth of 40m is below the thermocline ceiling. It is evident from overlay plots that herring are distributed along the convergence region of warmer and cooler waters occurring in the northeastern survey area and is comparable to previous years.

3.4 Marine mammal and seabird observations

3.4.1 Marine mammal sightings

A total of 214 hours and 31 minutes of dedicated surveying was conducted between 06th- 24th October 2014, with 11 hrs of effort on most days covering daylight hours. Shorter survey days occurred on 6 days due to unsuitable weather and/or earlier nightfall (range 1.5 hr to 11 hrs). Some effort occurred on each of the 19 active survey days, although none occurred on the last day (25th) whilst the vessel waited in Galway Bay for her berth. A total of 197 hours and 10 minutes of observation were conducted from the Crow's Nest and a further 17 hours and 21 minutes conducted from the Bridge. Figure 11 gives a good approximation of actual transect area covered by observation effort. Gaps are a result of transect being conducted either during nightfall or when sea conditions were too poor to maintain effort.

A total of 152 specifically identified sighting events occurred, along with 17 sightings of unidentified animals. Seven different cetacean species were recorded, with sightings of three other marine species also logged i.e. Bluefin Tuna (*Thunnus thynnus*), Leatherback Turtle (*Dermochelys coriacaea*) and Grey Seal (*Halichoerus grypus*). By far the most frequent species sighted were Common Dolphins (*Delphinus delphis*) with 99 sighting events recorded. Fin Whales (*Balaenoptera physalus*) were the most frequently encountered of the large whales with 20 sighting events recorded, including one large aggregation of up to 16 animals off Ram Head in Co. Waterford on 22nd October. Table 13 summarises the sightings and estimates of number of individuals and groups size. Further species specific counts are presented in Annex 1.

3.4.2 Seabird sightings and marine litter

A total of 60.53 hours (3632 minutes) of seabird surveys was conducted across thirteen days between 8th and 24th October 2014.

A cumulative total of 9701 individual seabirds of 31 species were recorded, of which 2646 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 14. In addition, daily totals for 10 species of migrant terrestrial birds recorded on or around the vessel are also presented in Table 15.

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 despite two periods of bad weather that required the suspension of acoustic operations in the later third of the cruise. Weather conditions were generally favourable during the first half of the survey but deteriorated after the mid-cruise crew change. On the two occasions mentioned, data drops outs in the echogram caused by the large waves meant the vessel had to heave-to for 8 hours in the Smalls region (stratum 8) and a further 8 hours inshore (stratum 9). Two CTD stations had to be skipped due to rough seas and vessel speed was considerably reduce on southerly transects. This did not affect survey coverage as contingency is built into the survey design. It did however mean that time was not available to extend the survey area (*e.g.* to the east as in 2013). Due to the very strong southerly and south-westerly winds in the last week of the survey, many of the inshore transects in shallow water had to be cut short for safety reasons. Fortunately no herring schools were observed anywhere near the shortened ends of the transects and no reports of herring hauls closer to shore were received from smaller fishing vessels at the time.

The 2014 survey estimate of SSB (47 kt) is considerably lower (42%) than that observed in 2013 (71 kt) and a fraction of that seen in 2012 (246 kt). The large 2012 SSB is likely an over-estimate, being over double the value of the next highest in the time series, but no definite reason for this has been identified to date. Similarly the low 2014 estimate, the lowest in seven years, is most certainly an underestimate but, unlike 2012, there is an apparent reason. As the vast majority of the herring biomass was encountered in the south-eastern corner of the surveyed area it is apparent that the fish were still in transit to inshore spawning grounds. As a result it is likely that the whole spawning stock was not contained by the southern boundary of the survey grid and some portion of it remained unquantified and outside of the survey area. Unfortunately due to the weather delays it was not possible to extend the offshore transects to the south without jeopardising the coverage in the core inshore spawning areas (although it should be noted that only one herring school was recorded in proximity to the southern boundary and three full transects were void of herring before the eastern extent was reached). The view that the stock was still making its way north towards shore is supported by the fact that a very large school of herring was reported by a fishing vessel at roughly 8.25°W, 51.25°N, a number of days after the Celtic Explorer surveyed that area and recorded absolutely no herring echotraces.

Some extremely large, dense sprat schools were present this year and were comprehensively sampled using directed trawling providing a high degree of confidence in the sprat estimate. Indeed, 10 of the 19 hauls contained a large proportion of sprat and 80% of the estimated sprat biomass was attributed to 'definitely sprat' echotraces as a result.

Almost exclusively, herring were encountered in single species aggregations during the survey. The one exception to this can be seen south of Cork where a number of 'herring in a mix' NASC values are plotted in Figure 3. These marks are 'herring in a mix' due to one haul in that vicinity, which contained five herring. Ordinarily a five fish sample would not qualify for use during the analysis (n=50 threshold) however, due to the number and type of echotraces in this known herring area it was decided to include this mixed herring category. The 200 t of herring biomass that these NASC values equate to is probably therefore an overestimate but it does confirm that there were some herring in that area at that time. Unsafe fishing areas caused by varied bathymetry limited the amount of fishing that could be carried out to groundtruth these particular echotraces.

The low number of very high density herring echotraces (within just 2 survey strata) that make up the 2014 estimate has increased the coefficient of variation (CV) of the survey estimate more so than a more homogenous population distribution of smaller less dense echotraces. The CV on the biomass and abundance estimates in 2014 were 60.2% and 59.1% respectively, more than double the values in the recent time series.

The herring schools observed, although of few in number were of high density and this may have been as a result of no actively targeting fishing vessels to disturb them due to the late opening of the fishery. No pair trawlers were seen (via AIS) in the Smalls or surrounding area before the bulk of the stock was surveyed there. The one exception to this was a very large Dutch freezer trawler seen shooting and hauling a pelagic trawl and towing along the southern edge of the ‘Trench’ three or four times, undoubtedly - targeting herring. (After two days it left the area, trawled south west of Kerry, then steamed to VIa.) Early in the survey there were reports of a number of pair trawlers catching herring outside of the survey grid, to the north east. Fishing effort in this area was short lived and by the time the Explorer reached the furthest east planned transect fishing activity had ceased. Due to the adverse weather at the time the decision was made not to place additional survey effort outside of the planned grid.

Completely at odds to all recent Celtic Sea herring acoustic surveys, the distribution of the stock in 2014 was almost entirely outside the coastal strata (*e.g.* Tramore and CS Inshore accounted for 87% of biomass in 2013). The spawning stock had clearly not yet reached the inshore spawning grounds at the time of surveying and an unknown proportion of it may even have lain outside the strata bounds. The reason for the late migration could be higher ambient water temperature which has been ascribed to the later arrival of mackerel and horse mackerel in traditional northern fishing areas (C O’Donnell *pers. comms*). Either way, the fact remains that the reported biomass and abundance are more than likely underestimated and, coupled with the large CVs, may not be suitable for stock assessment purposes.

4.2 Conclusions

- Herring TSB (total stock biomass) and abundance (TSN) estimates were 49,952t (CV 60.2%) and 408 million individuals (CV 59.1%) respectively. Spawning stock biomass (SSB) was 47,496t (CV 60.2%), relating to a spawning abundance (SSN) of 372 million individuals.
- The 2014 survey SSB estimate is 42% lower than that observed in 2013.
- Herring distribution was completely different to previous years with the vast majority of the surveyed stock located in offshore waters in, and to the west of, the Smalls area.
- No herring schools were recorded on the inshore spawning grounds. A very small quantity of herring was observed in mixed species assemblages on inshore transects south of Cork.
- The age profile as determined from survey samples was dominated by 2, 3 and 4 winter ring fish (29%, 28% and 17% of total abundance respectively). This tallies well with the 2013 survey were 1, 2 and 3 ringers dominated and 1-group fish represented almost 40% of the total biomass. Older fish (5-9 winter-rings) were again poorly represented.
- The spawning stock had clearly not yet reached the inshore spawning grounds at the time of surveying and an unknown proportion of it may even have lain outside the strata bounds.
- Therefore the reported biomass and abundance are more than likely underestimated and, coupled with the large CVs, may not be suitable for stock assessment purposes.

Acknowledgements

We would like to thank Denis Rowan (Captain) and the crew of the Celtic Explorer for their help and professionalism during the survey. We also thank John Regan for his expert advice on fishing operations and for liaising with the commercial fishing fleet. Many thanks also to the bird survey team (Stephen McAvoy, Niall Keogh and Katherine Keoghan) who worked tirelessly during the survey in all weathers and with great enthusiasm.

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5 Tables and Figures

Table 1. Survey Strata detail.

Strata no.	Strata name	Survey type	Transect type	Active transects	Transect spacing	Transect mileage (nmi)	Strata area (nmi2)
1	Inside Shannon	Broad scale	Zigzag	5	na	23.7	43.8
2	Dingle	Broad scale	Zigzag	9	na	53.6	59.8
3	Kenmare	Broad scale	Zigzag	7	na	39.5	56.9
4	Bantry	Broad scale	Zigzag	6	na	22.5	25.5
5	Dunmanus	Broad scale	Zigzag	5	na	20.2	10.1
6	Mizen	Broad scale	Parallel	14	4	290.0	1196.3
7	Offshore CS	Broad scale	Parallel	31	2	879.0	1893.8
8	Smalls	Broad scale	Parallel	19	2	454.7	959.2
9 (a,b,c,d,e)	CS Inshore	Broad scale	Parallel	33	2	488.2	1057.2
10	Baginbun	Spawning grd	Parallel	9	1	27.3	33.6
11	Tramore	Spawning grd	Parallel	19	1	94.2	113.8
12	Waterford	Spawning grd	Zigzag	3	na	6.4	2.6
13	Ballycotton	Spawning grd	Parallel	16	1	92.2	91.6
14	Daunt	Spawning grd	Parallel	12	1	53.4	60.3
15	Stags	Spawning grd	Parallel	6	1	10.1	13.0
16	Dingle_S	Spawning grd	Parallel	6	1	10.5	11.7
17	Dingle_N	Spawning grd	Parallel	6	1	9.8	10.7
18	Kerry Head	Spawning grd	Parallel	12	1	49.6	58.5
			Total	218		2,624.9	5,699

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

Echo Sounder System Calibration

Vessel : R/V Celtic Explorer		Date : 06/10/2014	
Echo sounder : ER60 PC		Locality : Galway Bay	
Type of Sphere : CU-38,1	TS_{Sphere}: -33.50 dB (Corrected for soundvelocity o	Depth(Sea floor) 24 m	

Calibration Version 2.1.0.11

Comments:
Black Head

Reference Target:

TS	-33.52 dB	Min. Distance	15.00 m
TS Deviation	5.0 dB	Max. Distance	20.00 m

Transducer: ES38B Serial No. 30227

Frequency	38000 Hz	Beamtype	Split
Gain	25.92 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	6.98 deg	Along. Beam Angle	6.94 deg
Athw. Offset Angle	-0.05 deg	Along. Offset Angl	-0.05 deg
SaCorrection	-0.66 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.	8.7 dB/km	Sound Velocity	1509.1 m/s

Beam Model results:

Transducer Gain =	25.89 dB	SaCorrection =	-0.80 dB
Athw. Beam Angle =	6.98 deg	Along. Beam Angle =	6.95deg
Athw. Offset Angle =	-0.05 deg	Along. Offset Angle=	-0.06 deg

Data deviation from beam model:
RMS = 0.12 dB
Max = 0.26 dB No. = 240 Athw. = -3.7 deg Along = -3.4 deg
Min = -0.95 dB No. = 330 Athw. = -1.2 deg Along = 4.4 deg

Data deviation from polynomial model:
RMS = 0.07 dB
Max = 0.23 dB No. = 184 Athw. = 4.6 deg Along = 1.0 deg
Min = -0.81 dB No. = 330 Athw. = -1.2 deg Along = 4.4 deg

Comments :

Wind Force : 4 **Wind Directio** SW
Raw Data File: \\Expfileclstr\ER-60_Data\CSHAS_2014\RAW ER60 Files\Calibration\CSHAS_2014
Calibration File: \\Expfileclstr\ER-60_Data\ER-60\Calibrations_2014\CSHAS 2014\38 KHZ

Calibration : Cormac Nolan

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	08.10.14	52 01.22	10 19.81	06:25	52	0-10	34.3		86.2		13.1	0.0	0.7
2	08.10.14	51 42.32	10 07.68	15:19	70	15	8.5		4.1	11.9	83.8		0.2
3	09.10.14	51 06.71	09 44.13	10:02	115	5	47.6						100.0
4	10.10.14	51 15.25	08 54.11	10:30	98	1	4.7				0.1		99.9
5	10.10.14	51 29.16	08 40.89	16:05	80	20	1.1	1.1		19.3	69.3		10.3
6	12.10.14	51 19.84	07 48.24	12:33	86	20	3.5		22.9	2.4	72.4		2.4
7	12.10.14	51 19.57	07 45.02	17:57	86	25	14.4				76.5		23.5
8	13.10.14	51 19.09	07 35.34	07:50	88	0	11.6			0.3	98.7		1.0
9	14.10.14	51 02.33	07 22.71	00:26	95	5	1000.0	100.0					
10	14.10.14	51 35.71	07 16.05	14:08	73	15	150.0		0.2		99.8		
11	14.10.14	51 08.55	07 13.07	19:47	100	20	1000.0	100.0					
12	17.10.14	51 12.55	06 47.24	04:25	84	0	70.9	12.1		3.0			84.8
13	17.10.14	51 15.17	06 40.61	12:00	86	16	29.1		87.1	0.4	11.9		0.6
14	18.10.14	51 18.75	06 34.16	06:35	83	0	500.0	99.2					0.8
15	18.10.14	51 19.80	06 27.68	16:02	120	90	26.7			0.1	1.2		98.7
16	19.10.14	51 57.96	06 44.68	15:00	60	15	2.5			96.1	1.2		2.7
17	22.10.14	52 04.11	07 16.95	10:50	38	0	0.8		33.0	0.5	66.4		
18	22.10.14	51 53.66	07 39.09	06:58	35	5	250.0		0.9	0..96	99.0		0.1
19	23.10.14	51 43.04	08 10.92	10:11	36	5	34.6	1.4	65.9	1.2	22.3		9.2

* Including pelagic, demersal fish and invertebrates

Table 4. Length-frequency of herring hauls used in the analysis.

Haul	**9**	**11**	**12**	**14**	**19***	
length (cm)						Total
11						
11.5						
12						
12.5						0
13						0
13.5						0
14						0
14.5						0
15						0
15.5						0
16						0
16.5						0
17						0
17.5						0
18						0
18.5		3				3
19		12				12
19.5	2	20		4		26
20	3	25		13		41
20.5	5	23		17		45
21	3	32		12		47
21.5	7	27		20	3	57
22	6	60	2	16		84
22.5	16	45		32		93
23	24	58	5	28		115
23.5	29	54	4	39		126
24	31	38	3	26		98
24.5	24	27	6	42	1	100
25	44	25	10	51		130
25.5	47	19	7	60	1	134
26	60	21	6	34		121
26.5	38	9	10	35		92
27	30	6	9	24		69
27.5	19	3	7	8		37
28	9	2	2	3		16
28.5	3			2		5
29	4					4
29.5						0
30						0
30.5						0
31						0
31.5						0
32						0
32.5						0
33						0
Total	**404**	**509**	**71**	**466**	**5**	**1,455**

* Mixed species haul

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
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0.2	1.5	2.2	1.6	0.5	0.6	0.2	0.4	0	0	7.3
8	0	2.7	9.9	11.9	8.6	2.6	3.2	0.9	2.5	0.2	0	42.5
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0.1	0	0	0	0	0	0	0	0.2
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	3	11.4	14.2	10.2	3.1	3.8	1.1	2.9	0.2	0	50.0
%	0	6	22.9	28.4	20.5	6.2	7.6	2.3	5.8	0.5	0	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
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	3.4	14.7	17.5	11.0	3.2	3.5	1.2	2.3	0	0	57.1
8	0	37.5	102.1	94.0	58.2	16.6	20.0	5.5	14.2	1.1	0	349.1
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0.6	0.5	0.6	0	0	0	0	0	0	0	1.9
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	41.4	117.3	112.1	69.4	19.8	23.6	6.8	16.5	1.3	0	408.1
%	0	10.2	28.7	27.5	17.0	4.8	5.8	1.7	4.0	0	0	100
Cv (%)	NA	57.3	58.1	60.2	62.4	61.5	62.4	61.6	61.3	59.1	NA	NA

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

Strata	Imm	Mature	Spent	Total
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0.2	7.1	0	7.3
8	2.3	40.2	0	42.5
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0	0.2	0	0.2
15	0	0	0	0
16	0	0	0	0
17	0	0	0	0
18	0	0	0	0
Total	2.5	47.5	0	50
%	4.9	95.1	0	100

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

Strata	Imm	Mature	Spent	Total
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	2.8	54.3	0.0	57.11
8	33.0	316.1	0.0	349.1
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0.1	1.8	0	1.9
15	0	0	0	0
16	0	0	0	0
17	0	0	0	0
18	0	0	0	0
Total	35.9	372.2	0	408.1
%	8.8	91.2	0	100

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		0.2										0.2	0.0	49.0
19		1.1										1.1	0.1	53.5
19.5		4.29										4.3	0.3	58.3
20		10.5										10.5	0.7	63.4
20.5		4.2	8.42									12.6	0.9	68.8
21		7.12	3.55									10.7	0.8	74.5
21.5		8.17	6.53	1.63								16.3	1.3	80.5
22		3.93	13.1									17.0	1.5	86.9
22.5		1.88	22.7	1.88								26.5	2.5	93.6
23			25.1	2.09								27.2	2.7	100.7
23.5			21.5	12.3								33.7	3.7	108.2
24			11.6	11.6								23.2	2.7	116.0
24.5			4.87	29.3	2.46							36.7	4.6	124.2
25				27.7	13.8			1.96				43.5	5.8	132.8
25.5				19.6	23.9	2.15	2.15		2.15			50.0	7.1	141.8
26				6	10.5	9	4.5					30.0	4.5	151.3
26.5					11.4	7.14	11.4					30.0	4.8	161.1
27					6.01	1.49	3.01	3.01	7.51			21.0	3.6	171.5
27.5					1.25		2.5		3.75	1.25		8.8	1.6	182.2
28									3.09			3.1	0.6	193.5
28.5								1.82				1.8	0.4	205.2
29														
29.5														
30														
30.5														
31														
31.5														
32														
32.5														
33														
33.5														
SSN (mil)		16.3	107	112	69.4	19.8	23.6	6.78	16.5	1.3		372.2		
SSB ('000s t)		1.3	10.6	14.2	10.2	3.1	3.8	1.1	2.9	0.2			47.5	
Mn Wt (g)		72	97.4	127	147	155	161	169	174	182				
Mn length (cm)		21	23	24.9	26	26.5	26.7	27.1	27.4	27.8				

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
1	5	0	0	0	0	100	0	0	0	0	0	0.0
2	9	0	0	0	0	100	0	0	0	0	0	0.0
3	7	0	0	0	0	100	0	0	0	0	0	0.0
4	6	0	0	0	0	100	0	0	0	0	0	0.0
5	5	0	0	0	0	100	0	0	0	0	0	0.0
6	14	0	0	0	0	100	0	0	0	0	0	0.0
7	31	4	4	0	0	97	7.3	0	0	7.3	7.1	57.1
8	19	48	29	0	19	47	42	0	0.4	42.5	40.2	349.1
9	33	0	0	0	0	100	0	0	0	0	0	0.0
10	9	0	0	0	0	100	0	0	0	0	0	0.0
11	19	0	0	0	0	100	0	0	0	0	0	0.0
12	3	0	0	0	0	100	0	0	0	0	0	0.0
13	16	0	0	0	0	100	0	0	0	0	0	0.0
14	12	115	0	115	0	42	0	0.2	0	0.2	0.2	1.9
15	6	0	0	0	0	100	0	0	0	0	0	0.0
16	6	0	0	0	0	100	0	0	0	0	0	0.0
17	6	0	0	0	0	100	0	0	0	0	0	0.0
18	12	0	0	0	0	100	0	0	0	0	0	0.0
Total	218	167	33	115	19	92	49.3	0.2	0.4	50.0	47.5	408.1
Cv (%)	-	-	-	-	-	-	-	-	-	60.2	60.2	59.1

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

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
1	5	14	0	11	3	20	0	3.1	0.5	3.6	615.8
2	9	56	53	3	0	11	3.7	0	0	3.8	650.5
3	7	114	106	0	8	0	5.7	0	0.2	5.9	1338.8
4	6	0	0	0	0	100	0	0	0	0.0	0.0
5	5	0	0	0	0	100	0	0	0	0.0	0.0
6	14	119	21	0	98	43	4.4	0	4.7	9.1	1027.3
7	31	232	177	0	55	58	15.5	0	0.6	16.0	2272.6
8	19	214	185	0	29	63	6	0	0.6	6.6	2636.9
9	33	104	72	0	32	61	4	0	1	5.0	308.4
10	9	5	3	0	2	67	1	0	0.5	1.5	86.2
11	19	23	15	0	8	68	0.3	0	0.1	0.3	19.8
12	3	0	0	0	0	100	0	0	0	0.0	0.0
13	16	63	63	0	0	50	2.6	0	0	2.6	146.3
14	12	1	0	0	1	92	0	0	0.1	0.1	8.2
15	6	0	0	0	0	100	0	0	0	0.0	0.0
16	6	7	0	0	7	33	0	0	0.2	0.2	35.7
17	6	4	0	0	4	67	0	0	0	0.0	6.0
18	12	0	0	0	0	100	0	0	0	0.0	0.0
Total	218	956	695	14	247	61	43.3	3.2	8.4	54.8	9,152
Cv (%)	-	-	-	-	-	-	-	-	-	16.7	17

Table 13. Summary of cetacean species sightings (number of sightings followed by best estimate of number of animals in parentheses).

Species	No. of sightings	No. of individuals	Group size range
Fin Whale (Balaenoptera physalus)	20	32	1-4
Humpback Whale (Megaptera novaeangliae)	9	13	1-3
Minke Whale (Balaenoptera acutorostrata)	5	5	1
Risso's dolphin (Grampus griseus)	1	2	2
Bottlenose Dolphin (Tursiops truncatus)	1	1	1
Common Dolphin (Delphinus delphis)	99	2459	1-600
Harbour Porpoise (Phocoena phocoena)	3	5	1-2
Unidentified Large Whale	3	3	1
Unidentified Whale	7	7	1
Unidentified Dolphin	3	60	5-30
Unidentified Cetacean	3	3	1
Leatherback Turtle (Dermochelys coriacaea)	4	4	1
Bluefin Tuna (Thunnus thynnus)	9	222	2-100
Unidentified Tuna	1	1	1
Grey Seal (Halichoerus grypus)	1	1	1
Total	169	2804	n/a

Table 14. Total number of sea bird species recorded.

Vernacular Name	Scientific Name	On Survey	Off Survey	Total
Common Scoter	*Melanitta nigra*	1	2	3
Great Northern Diver	*Gavia immer*	3	1	4
Fulmar	*Fulmarus glacialis*	568	18	586
Fea's / Zino's Petrel	*Pterodroma feae / maderia*		1	1
Great Shearwater	*Puffinus gravis*	7		7
Sooty Shearwater	*Puffinus griseus*	289	516	805
Manx Shearwater	*Puffinus puffinus*	156	68	224
Balearic Shearwater	*Puffinus mauretanicus*	28	3	31
Macaronesian Shearwater	*Puffinus baroli*		1	1
Wilson's Storm-petrel	*Oceanites oceanicus*	1		1
European Storm-petrel	*Hydrobates pelagicus*	119	1096	1215
Leach's Storm-petrel	*Oceanodroma leucorhoa*		4	4
Gannet	*Morus bassanus*	3015	158	3173
Shag	*Phalacrocorax aristotelis*	5		5
Grey Phalarope	*Phalaropus fulicarius*		4	4
Pomarine Skua	*Stercorarius pomarinus*	5	22	27
Arctic Skua	*Stercorarius parasiticus*	5	9	14
Long-tailed Skua	*Stercorarius longicaudus*		1	1
Great Skua	*Stercorarius skua*	55	167	222
Puffin	*Fratercula arctica*	7	6	13
Razorbill	*Alca torda*	177		177
Guillemot	*Uria aalge*	1177		1177
Razorbill / Guillemot		191		191
Arctic Tern	*Sterna paradisaea*	1	5	6
Sabine's Gull	*Xema sabini*		1	1
Kittiwake	*Rissa tridactyla*	124	4	128
Black-headed Gull	*Chroicocephalus ridibundus*		1	1
Mediterranean Gull	*Larus melanocephalus*		1	1
Common Gull	*Larus canus*		2	2
Lesser Black-backed Gull	*Larus fuscus*	60	25	85
Herring Gull	*Larus argentatus*	6	34	40
Great Black-backed Gull	*Larus marinus*	423	40	463
Unidentified Large Gull sp.	*Larus sp.*	632	456	1088
Total		7055	2646	9701

Table 15. Totals of migrant terrestrial bird species recorded.

Vernacular Name	Scientific Name	Total
Grey Goose	*Anser sp.*	5
Common Snipe	*Gallinago gallinago*	4
Merlin	*Falco columbarius*	5
Goldcrest	*Regulus regulus*	1
Swallow	*Hirundo rustica*	4
Starling	*Sturnus vulgaris*	15
Redwing	*Turdus iliacus*	1
Black Redstart	*Phoenicurus ochruros*	1
Pied Wagtail	*Motacilla alba yarellii*	3
Meadow Pipit	*Anthus pratensis*	23
Total		62

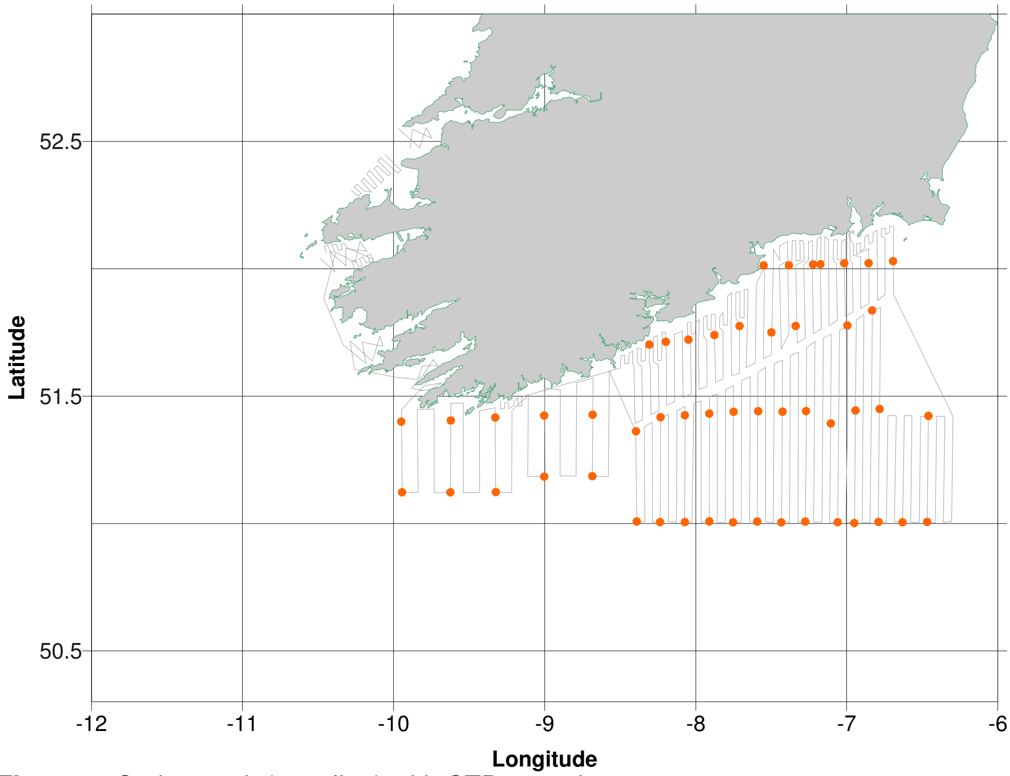


Figure 1. Cruise track (grey line) with CTD casts in orange.

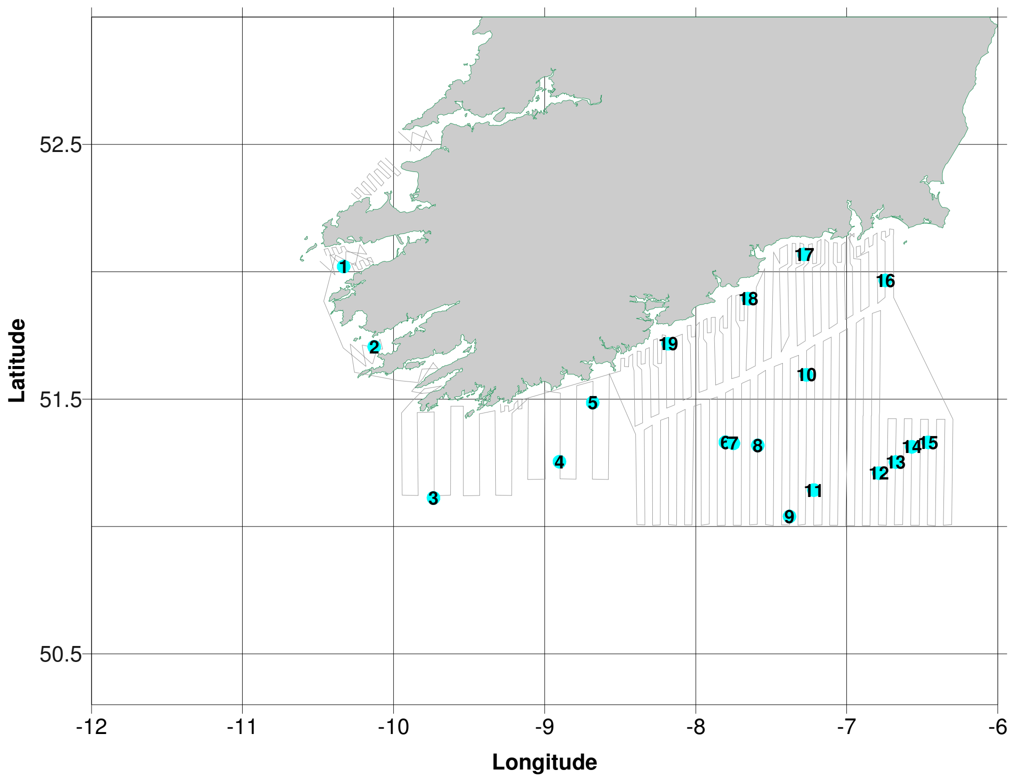


Figure 2. Directed midwater trawl positions.

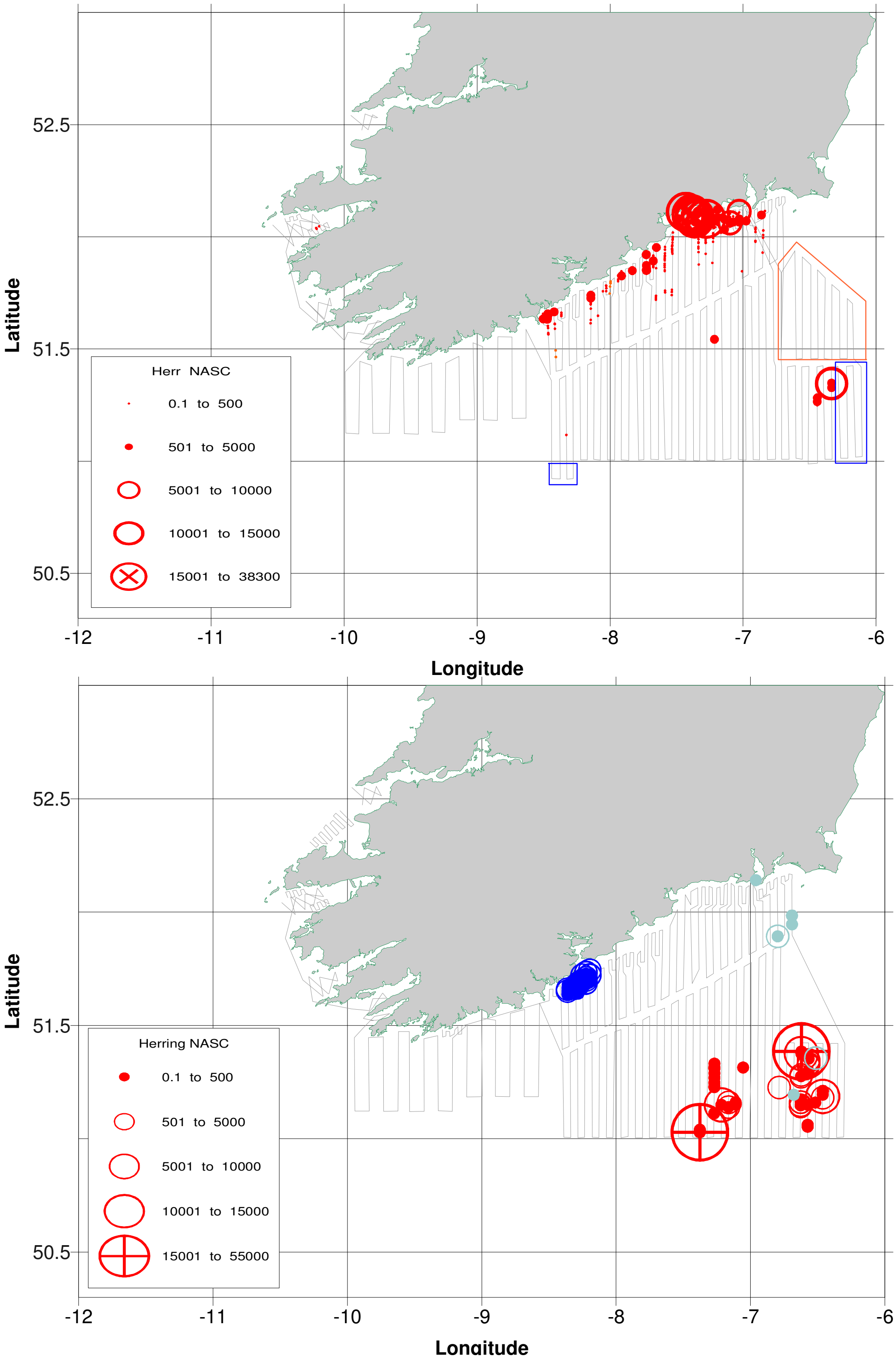


Figure 3. Weighted herring NASC (Nautical area scattering coefficient) plot of the distribution of "definitely" and "probably" categories (red circles), "mixed herring" (blue) and "possibly herring" (teal). Top Panel 2013, bottom panel 2014.

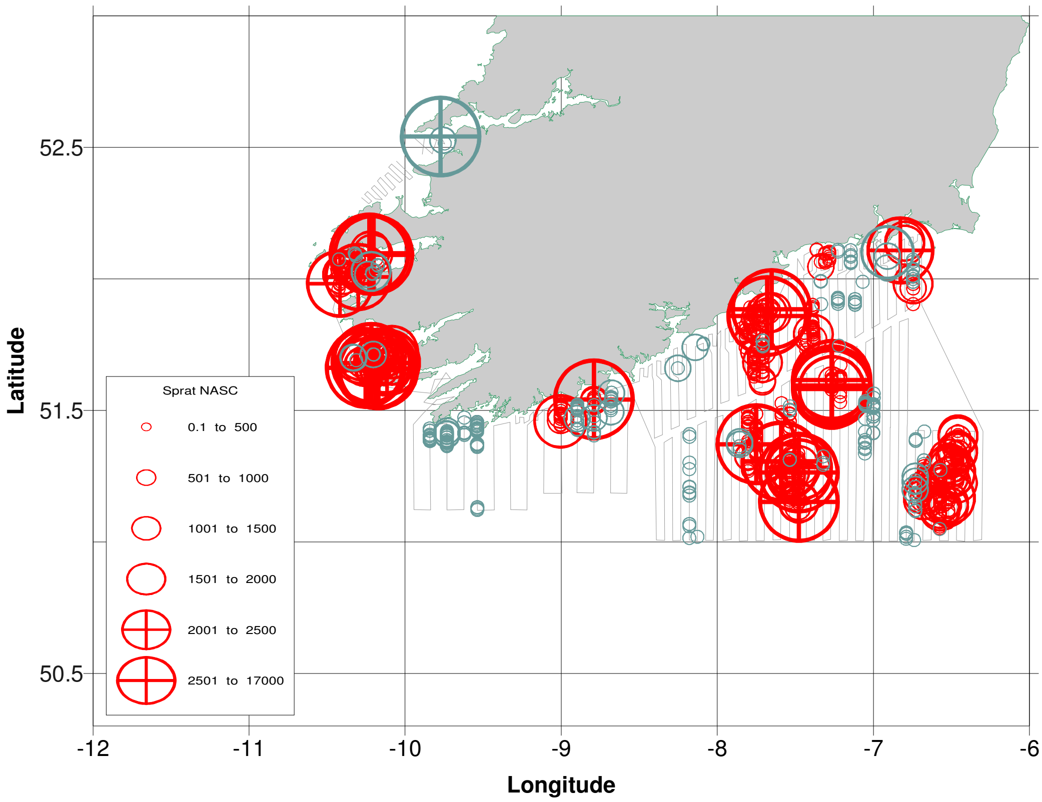


Figure 4. Weighted Sprat NASC (Nautical area scattering coefficient) distribution of "definitely" (red) and "probably" (green) categories.

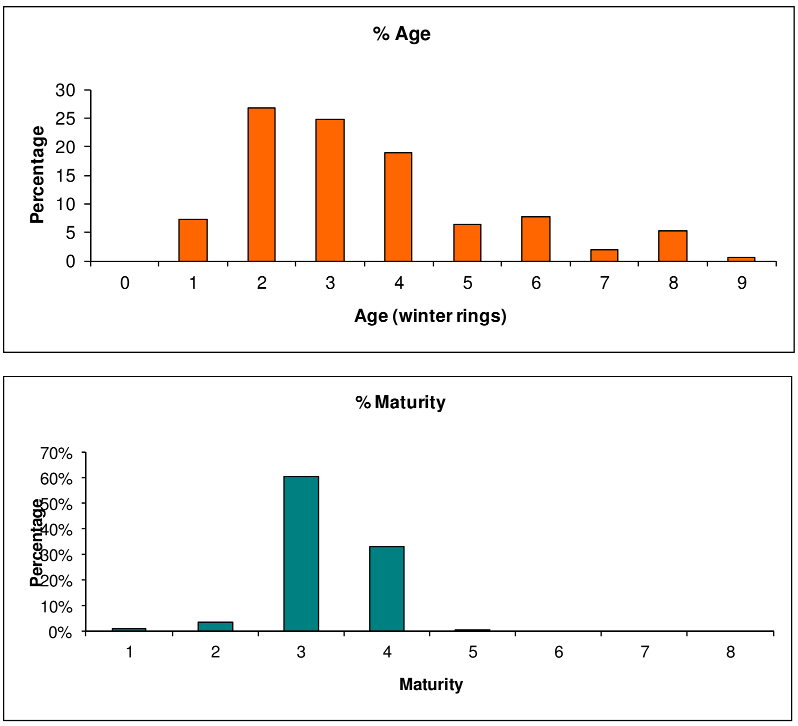
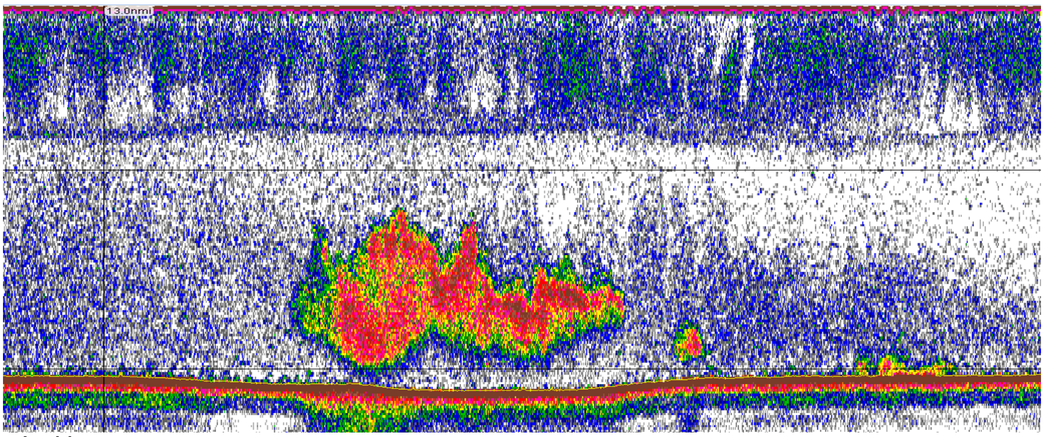
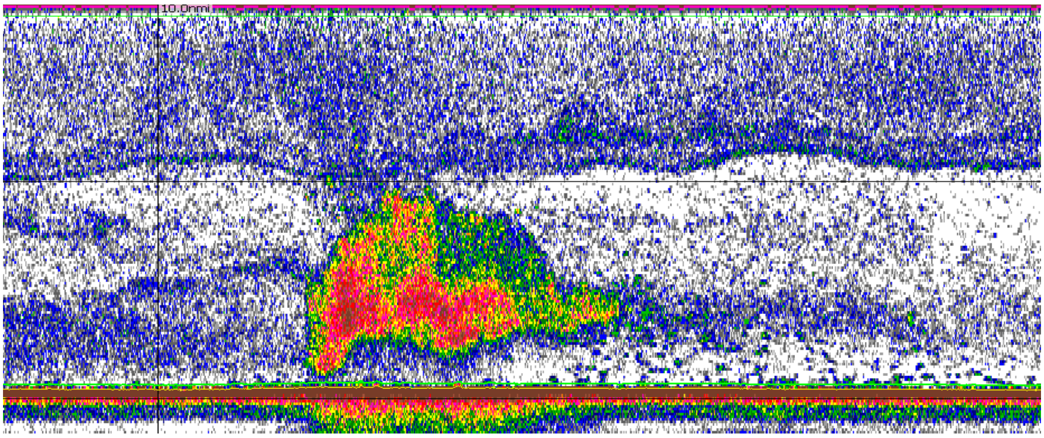


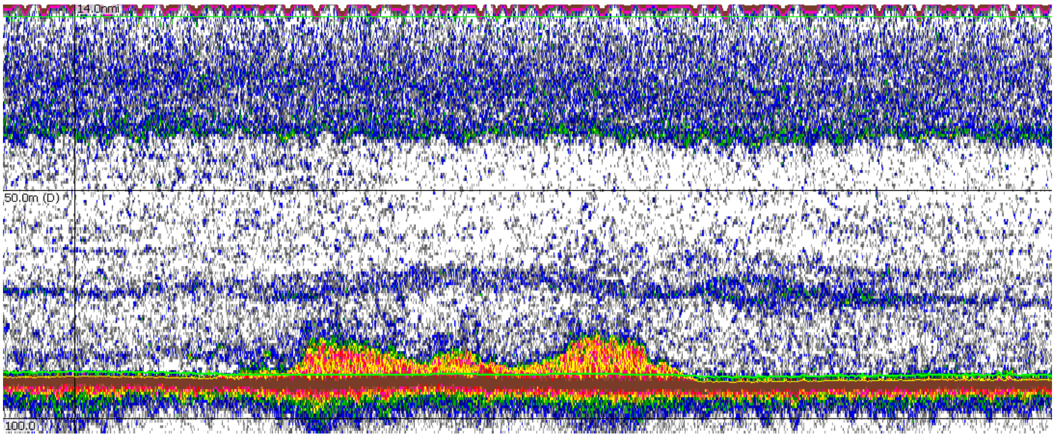
Figure 5. Percentage age and maturity of aged herring samples used in the analysis (n=206).



a). *High density herring echotrace, recorded offshore in the Celtic Sea prior to Haul 09. Observed at night in a water depth 95m.*

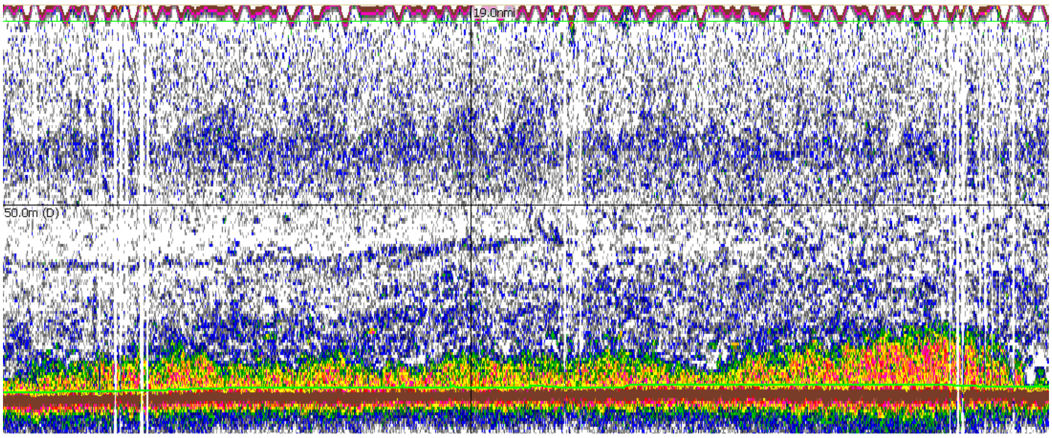


b). *High density echotrace of herring (Haul 11) recorded offshore in the Celtic Sea. Water depth 100m.*

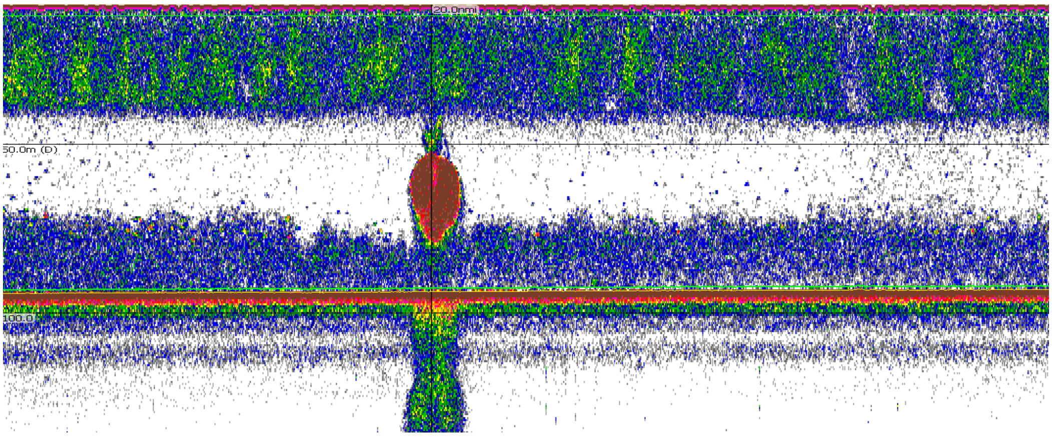


c). *High density herring bottom echotrace (Haul 12) recorded offshore in the 'Smalls' strata at night. Water depth 84m.*

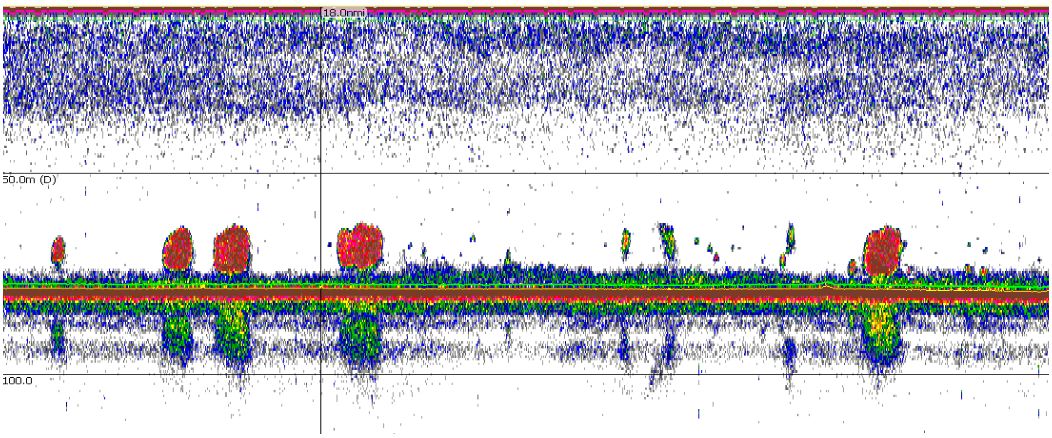
Figure 6a-f. Echograms of trawled biological samples, recorded prior to trawling (EK60, 38 kHz).



d). *High density herring bottom echotrace (Haul 14) recorded offshore in the 'Smalls' strata early morning, pre-dawn. Water depth 83m.*



e). *Very high density single echotrace of sprat recorded offshore in the Celtic Sea prior to Haul 08. Water depth 88m.*



f). *High density cluster of sprat echotraces recorded offshore in the Celtic Sea prior to Haul 10. Water depth 73m.*

Figure 6a-f. Continued.

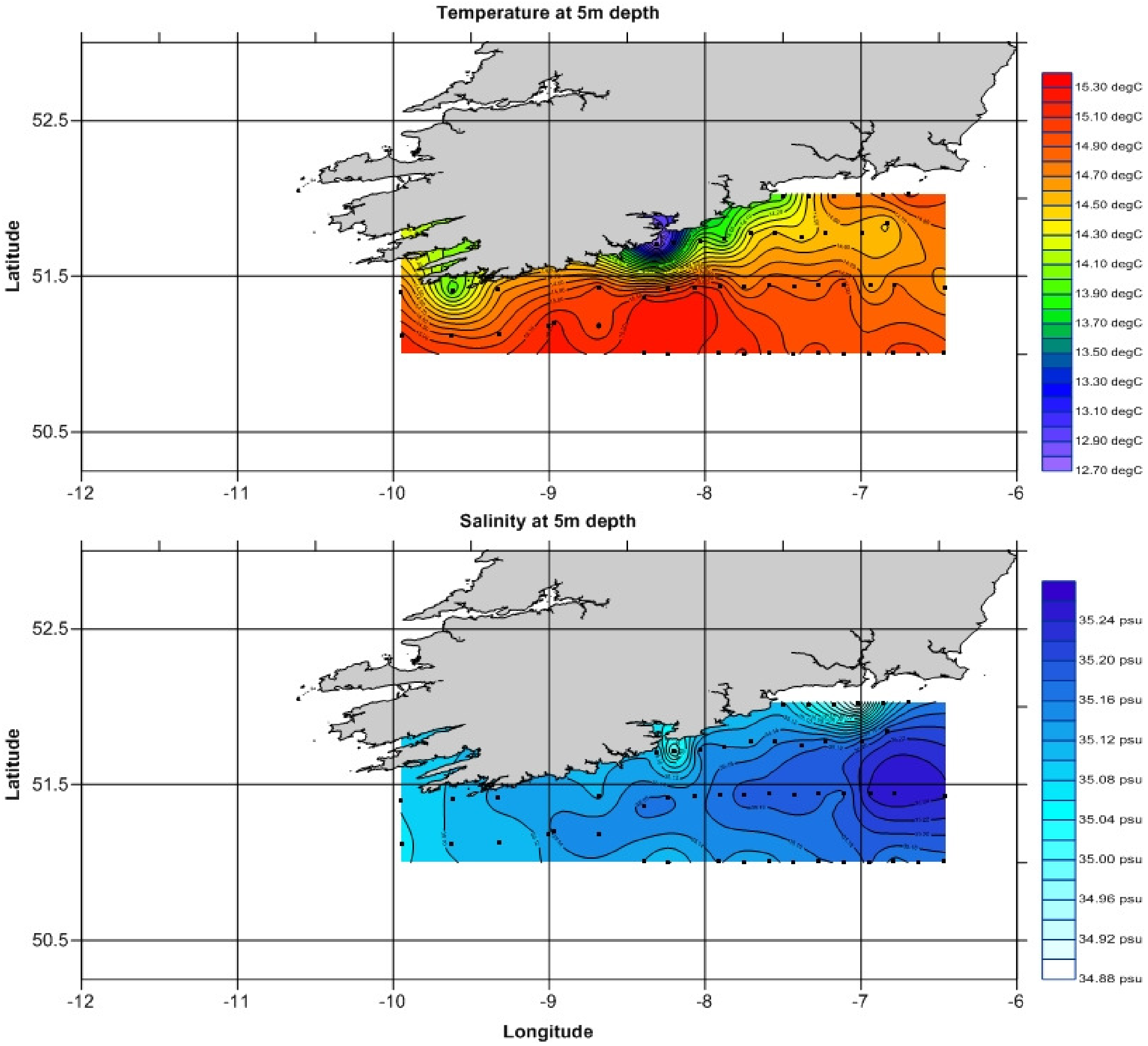


Figure 7. Surface (5m) plots of temperature and salinity compiled from CTD cast data. Station positions shown as block dots (n=51).

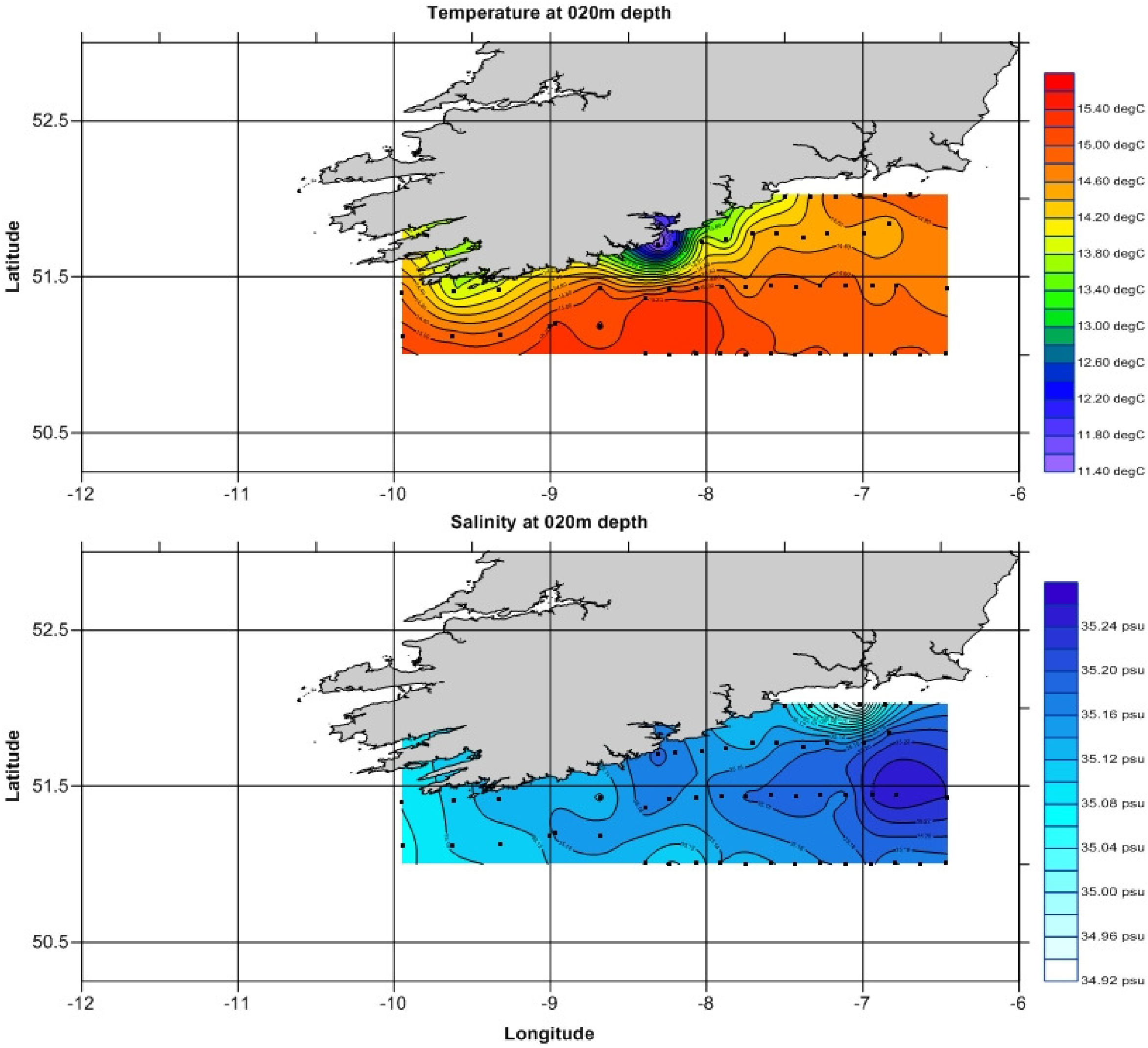


Figure 8. Temperature and salinity at 20m compiled from CTD cast data (n=51). Station positions shown as block dots.

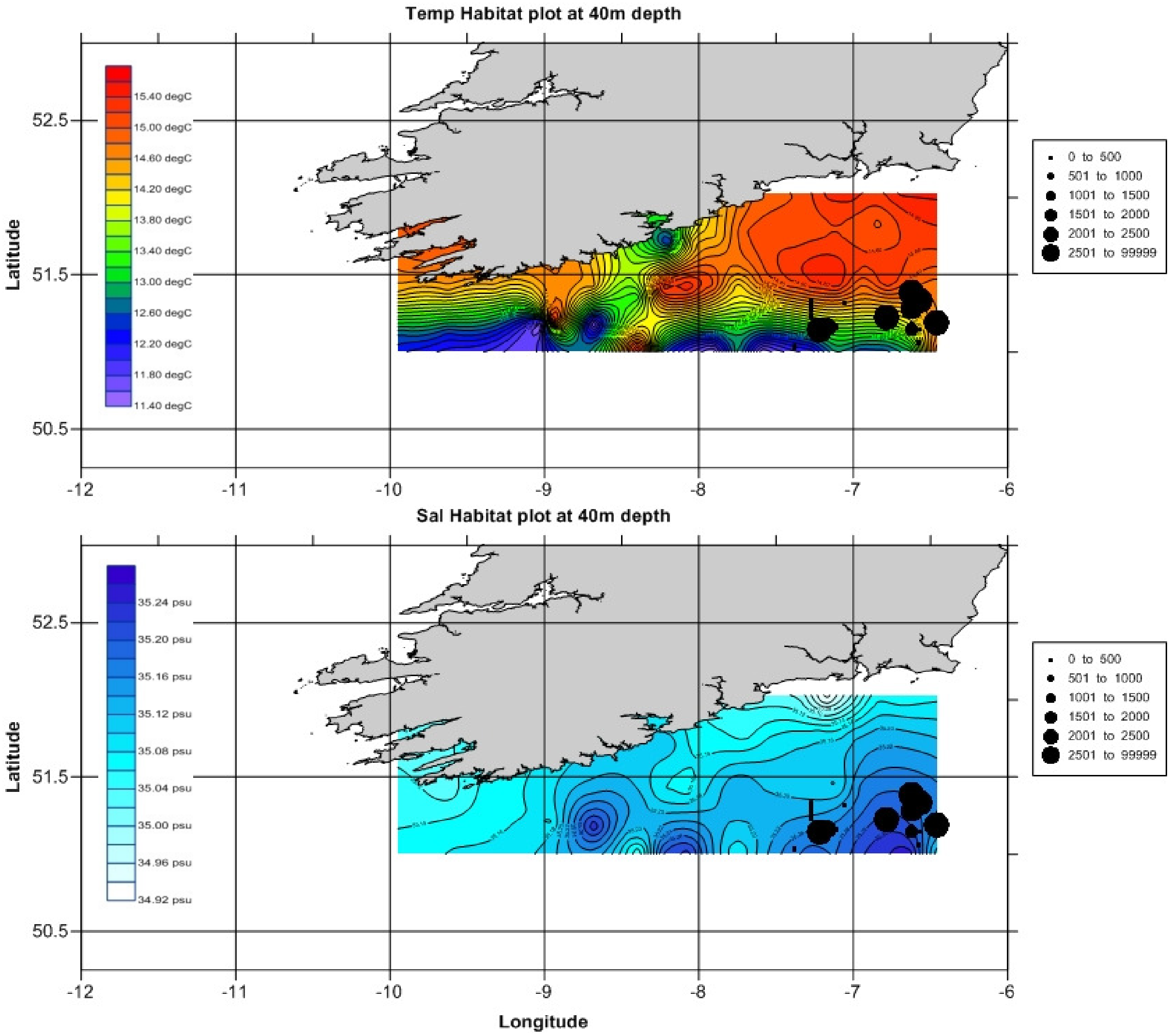


Figure 9. Habitat plots of temperature and salinity at 40m overlaid with herring NASC values (acoustic density) shown as weighted black circles.

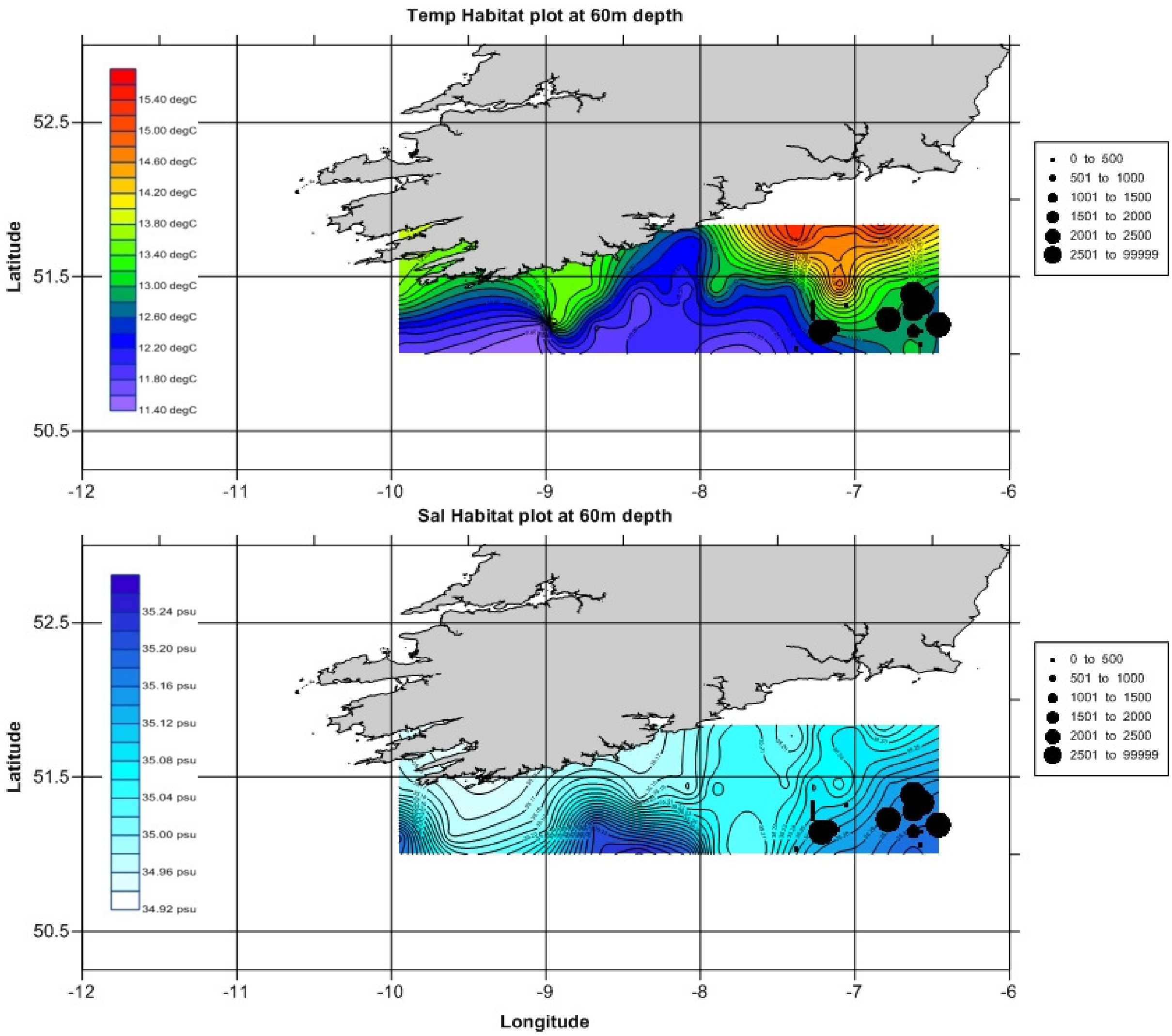


Figure 10. Habitat plots of temperature and salinity at 60m overlaid with herring NASC values (acoustic density) shown as black circles.

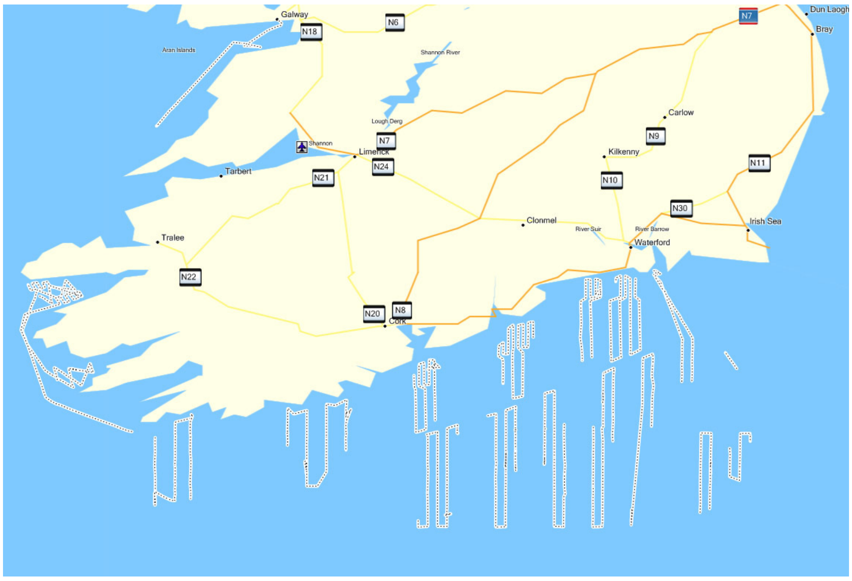


Figure 11. Marine mammal and seabird survey effort showing portion of the acoustic survey track where watch effort was attained.

HERRING MIDWATER TRAWL

40 x 20m

Herring Midwater Trawl

Fishing Circle 330m

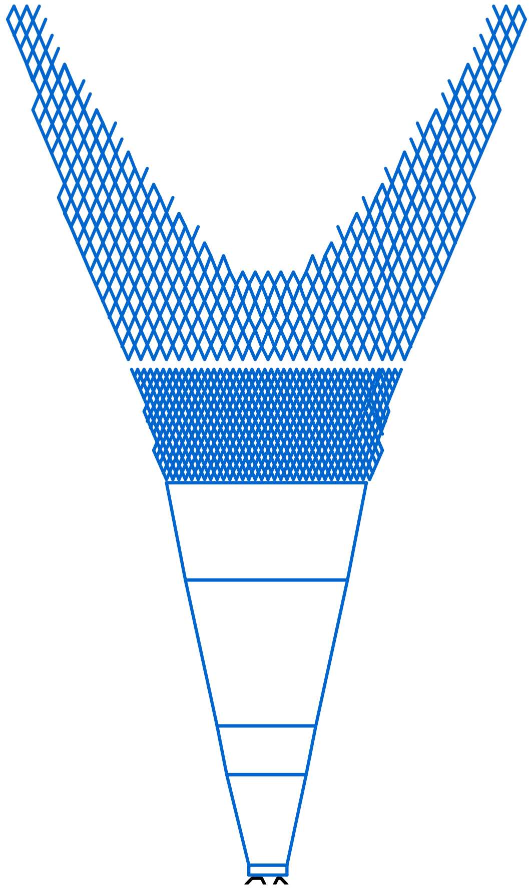


Figure 12. Single herring midwater trawl net plan and layout. Celtic Sea herring acoustic survey, October 2012.

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

6 Annex 1

Species Accounts: CETACEANS

Fin Whale (Balaenoptera physalus)

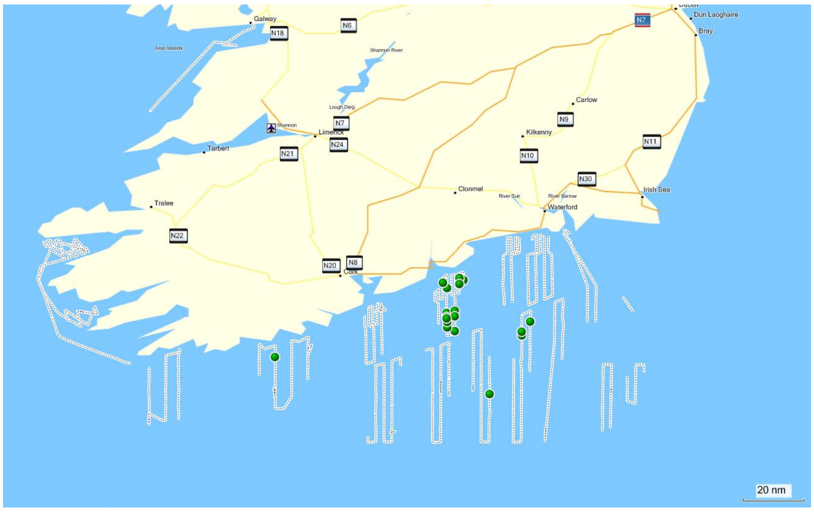


Figure 1. Fin Whale sighting events marked as green circles.

A total of 20 sighting events of Fin Whales occurred with 32 individual animals recorded. There were two significant aggregations noted, with 4 sightings (8 animals) on the 14th, and 10 sightings (16 animals) on the 22nd. The first group were approximately 27 miles SE of Ram Head, Co. Waterford, with the second group between 2 and 10 miles south of there. Photographs later indicated that at least one individually identifiable animal (likely FWIRL50 in IWDG catalogue) was seen in both groups, and as such it seems likely that at least some of the animals seen on the 14th were the same as those seen on the 22nd, approximately 20 miles apart. Feeding activity was noted in some individuals and many sightings seemed to correlate with the presence of Sprat (Sprattus sprattus) rather than Herring (Clupea harengus).

Humpback Whale (Megaptera novaeangliae)

Humpback Whales were encountered on 9 occasions in groups of 1-3, totalling an estimated 13 individuals. The easily identifiable individual HBIRL3 (aka 'Boomerang', see Fig. 5) was encountered twice on the 22nd October, south of Ram Head Co. Waterford. The first sighting of the species occurred on the 13th October when three separate groupings of 1, 2 & 3 animals were sighted at distance, identified by low, bushy blows with 8-10 blows in each sequence. Other sightings were mostly in association with Fin Whales with the last sighting on October 22nd. All sightings were in the seas south of Co. Waterford, and as with Fin Whales most sightings were correlated with the presence of Sprat in the area.

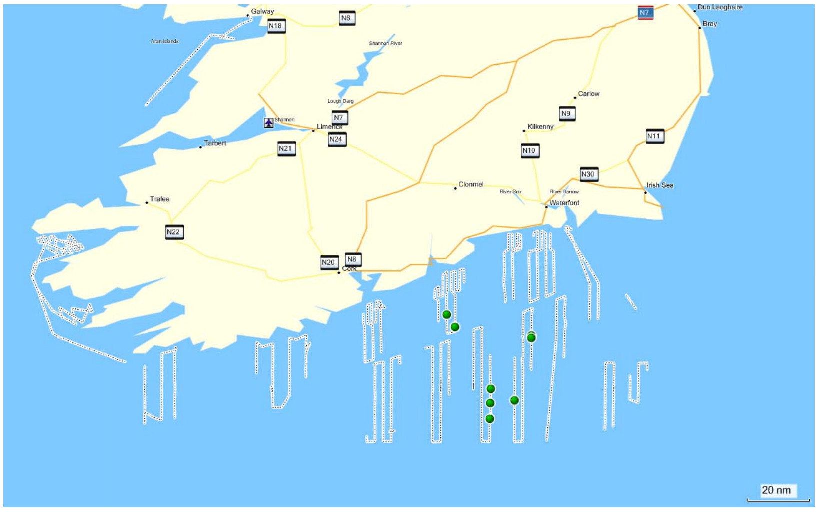


Figure 2. Humpback Whale sighting events marked as green circles.

Figure 3. Humpback Whale surfacing near Ram Head, Co. Waterford. (HBIRL3 aka 'Boomerang') © William Hunt

Minke Whale (Balaenoptera acutorostrata)

Figure 4. Minke Whale sighting events marked as green circles.

Minke Whales were encountered on 5 different occasions, each event comprising a single animal usually amidst feeding gannets and common dolphins. All occurred in the more inshore waters off the Cork and Kerry coasts, and it is somewhat surprising that none were seen south of Waterford where almost all the other baleen whales were noted amongst large concentrations of Sprat and Herring.

Figure 5. Minke Whale surfacing in Dingle Bay. © William Hunt

Risso's Dolphin (Grampus griseus)

Figure 6. Risso's Dolphin sighting events marked as green circles.

One sighting of Risso's Dolphins occurred, comprising 2 adults, with at least 1 heavily scarred male, 8 miles south of Roche's Point Co. Cork on 23rd October.

Figure 7. Risso's Dolphin ©NPWS.

Bottlenose Dolphin (Tursiops truncatus)

Figure 8. Bottlenose Dolphin sighting events marked as green circles.

A single animal briefly investigated the vessel whilst at anchor off Black Head, Co. Clare on the 7th October.

Common Dolphin (Delphinus delphis)

Numerous sightings of Common Dolphins occurred throughout the trip with sightings occurring on 15 of the 19 survey days. A total of 99 individual sightings were registered, with 2,459 animals recorded. Mean group size was 25 and ranged from individual animals to a group estimated to consist of 600 animals, sighted early on the 14th Oct approximately 50 miles south of Co. Waterford. A number of calf/adult pairs were sighted including one group of 3 adults with a calf each on the 20th October, south of Tramore, Co. Waterford. On the same day the melanistic animal captured in Fig. 12 below was also sighted.

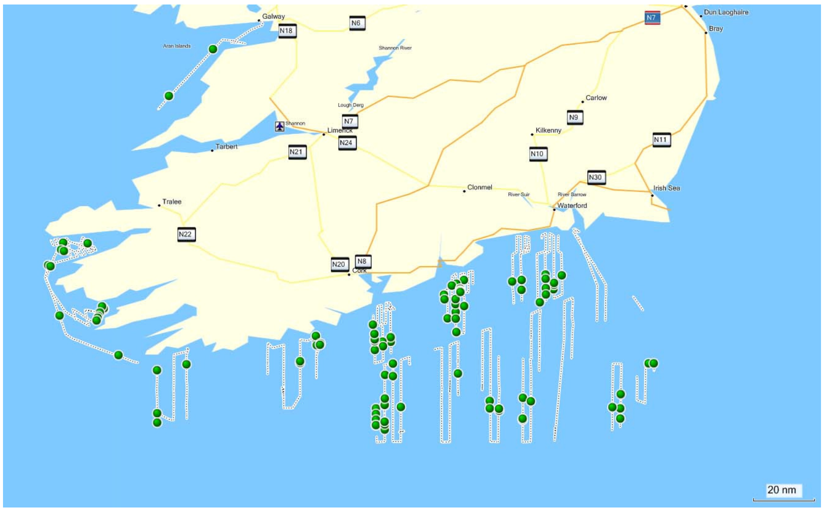


Figure 9. Common Dolphin sighting events marked as green circles.

Figure 10. Common Dolphins leaping. Melanistic individual present. © William Hunt

Harbour Porpoise (Phocoena phocoena)

Figure 11. Harbour Porpoise sighting events marked as green circles.

Three sightings of this species occurred in groups of 1-2 animals with a total of 5 individuals observed. Sightings occurred on the 6th, 10th & 13th October. Weather conditions for the first few days of the survey were very conducive to recording this species so it is somewhat surprising that no more were recorded off the Cork and Kerry coasts. Weather conditions for the rest of the survey were mostly too severe to reliably record this very unobtrusive species.

Unidentified Whale/Large Whale

Ten sightings of unidentifiable whales occurred during the survey. Each event involved a single animal, with the first sighting occurring on 13th Oct and the last on the 23rd October. Distance, poor lighting and brevity of encounters made positive ID of animals difficult. The large whales were noted to have conspicuous blows and were most likely to have been Fin or Humpback whales.

Unidentified Dolphin

Three dolphin sightings occurred, which could not be reliably identified to species level.

Unidentified Cetacean

There were 3 sightings of individual cetaceans which were extremely brief in nature or consisted of brief views of very inconspicuous blows, and it could not be determined with certainty if the sightings referred to whales or dolphins

Species Accounts: Other marine mega fauna

Grey Seal (Halichoerus grypus)

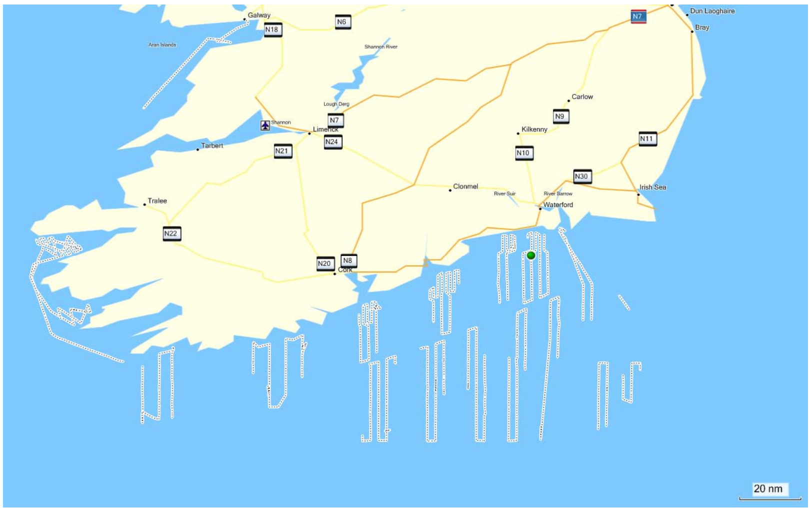


Figure 12. Grey Seal sighting event marked as green circle.

A single sighting of a Grey Seal occurred on the 20th October approximately 8 miles south of Tramore, Co. Waterford.

Bluefin Tuna (Thunnus thynnus)

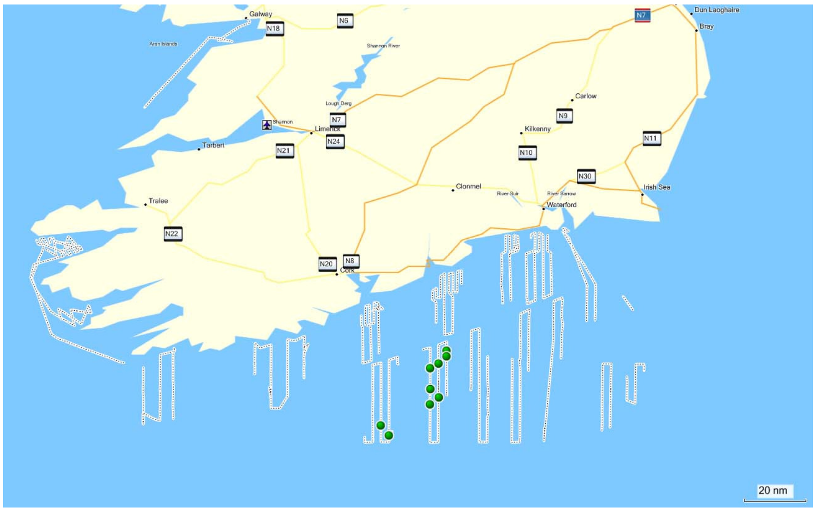


Figure 13. Bluefin Tuna sighting events marked as green circles.

Bluefin tuna were a regular sighting on the 11th & 12th October, with a large feeding frenzy estimated to be in excess of 100 individuals occurring on the 11th (Fig. 7). The sightings occurred generally in the region of 35 miles south of Ballycotton, Co. Cork. Tuna were identified by splashes at the surface, with spray directed almost horizontally in energetic bursts while feeding. A total of 9 sighting events were recorded, with an estimated 222 animals present. A single unidentified Tuna species was recorded on the 13th October. Although views were too poor to enable specific identification it was considered most likely to be another Bluefin Tuna.

Figure 14. Bluefin Tuna feeding, probably on sprat, near the surface approximately 45' S of Roche's Point. © William Hunt

Leatherback Turtle (Dermochelys coriacaea)

Four sightings of individual Leatherback turtles occurred. The first one was sighted off of Deenish Island, Co Kerry on the 8th October while a further 3 were sighted in the space of 30 minutes on the 11th October. These latter were seen over a distance of ~4 nautical miles.

Figure 15. Leatherback Turtle sighting events marked as green circles.

Figure 16. Leatherback turtle sighted near Deenish Island, Co. Kerry. © William Hunt