FSS Survey Series: 2013/04

Celtic Sea Herring Acoustic Survey Cruise Report 2013

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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 vessels have actively targeted offshore summer feeding aggregations 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 spawning box C.

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 20th in the overall acoustic series or the seventh in the modified time series and conducted 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	Acoustics (SIC)	All
FEAS	Cormac Nolan	Acoustics	All
FEAS	Graham Johnston	Acoustics	All
FEAS	Turloch Smith	Acoustics	All
FEAS	Macdara O'Cuaig	Biologist	All
FEAS	Helen McCormick	Biologist	All
FEAS	Mairead Sullivan	Biologist	1
FEAS	Ross Fitzgerald	Biologist	1
FEAS	Imelda Heir	Biologist	2
FEAS	Dermot Fee	Biologist	2
GMIT	Mareike Volkenandt	SBO	All
Birdwatch IRL	Stephen McAvoy	SBO	All
GMIT	Gary Robinson	SBO	All
Birdwatch IRL	Niall Keogh	SBO	1
Birdwatch IRL	Caoimhe Muldoon	SBO	2
IWDG	David Williams	MMO	All
GMIT	Amy Lusher	Micro plastics	All
IS&W FPO	Frankie Griffin	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

- Collect water samples to determine marine microplastic occurrence

2.2.2 Area of operation

The autumn 2013 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 in the coastal waters.

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 10 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 9 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 3,351nmi; with approximately 3,049nmi 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 2 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 Dunmanus Bay on the 9th of October during hours of daylight. Good calibration results were obtained for all frequencies and settings were updated.

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 DVD. 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 midwater 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 14). 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

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^o to either side using a transect approach. Sightings in an area up to 90^o 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.

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 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) $= 0.6035 * L^{1.596}$ (L = length in cm)

Mackerel weight (grams) $= 0.0065 * L^{3.050}$ (L = length in cm)

Sprat weight (grams) = $0.0037 * L^{3.320}$ (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	1,259	107,285	98.3
Mixture	0	0	0.0
Probably	28	1,810	1.7
Total estimate	1,287	109,095	100
SSB Estimate			
Definitely	607	70,398	99.2
Mixture	0		0.0
Probably	5	550	0.8
SSB estimate	612	70,948	100

Total herring biomass shown above was determined from 16 survey strata of which 7 contained herring (Table 1). Survey biomass and abundance was derived from 220 echotraces identified as herring with the aid of 21 directed trawls (Figure 2, Table 3). Of the 220 herring echotraces over 98% were identified as 'definitely herring' and 2% as 'probably herring'. No 'mixed herring' echotraces were reported (Table 10).

Herring TSB (total stock biomass) and abundance (TSN) estimates were 109,095t (CV 27.6%) and 1,287 million individuals (CV 28.4%) respectively. The overall SSB (spawning stock biomass) observed during the survey was 70,948t (CV 25.8%), composed of a spawning abundance (SSN) of 612 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 21 trawl hauls were carried out during the survey (Figure 2), with 9 hauls containing herring and 3 contained >50% herring by weight of catch (Table 3).

In the southwest no herring were observed with the exception of a small number of low density echotraces (n=3) in the south Dingle spawning box (Figure 3, Table 10).

The offshore component which accounted for over 48% (c.2, 900nmi^2) of the total geographical area surveyed yielded few monospecific herring echotraces (n=11) and contributed 9% to the total biomass. One high density echotrace contributed almost all the biomass for the offshore strata combined (Figure 6b).

Herring were observed in mixed species catches in offshore (and experimental) strata. However, samples contained single or low digit numbers (n=<10) of herring. Due to the low numbers and proportion of the catch relative to other species these mixed species aggregations did not qualify as being allocated to 'herring mix' and were instead categorised as 'sprat mix'.

Two additional experimental strata were surveyed in the east area relating to an additional 800nmi² of coverage and 440nmi of transects (Table 1). Individual herring were observed in mixed catches with sprat and mackerel but in low numbers (n= <10).

Over 91% of observed herring biomass was located inshore along the south coast and in particular from Helvick Head east to Waterford Harbour (Figure 3) and is consistent with previous years. Within this area, clusters of high density and single high density echotraces dominated (Figure 6d, e).

From Helvick Head west to the Old Head of Kinsale clusters of medium and low density herring echotraces dominated within traditional fishing areas from Mine Head to Capel Island and from Cork Harbour to Kinsale (Figure 6f).

3.1.3 Herring stock composition

A total of 289 herring were aged from survey samples in addition to 1,725 length measurements and 500 length-weights recorded (Table 4). Herring age samples ranged from 0-9 winter-rings (Tables 5 & 6, Figure 5).

1 winter-ring herring dominated the 2013 estimate representing over 36% of TSB and 54% of TSN (Table 5 and 6). The 2 winter-ring age group were ranked second representing 27% of TSB and 22% of TSN. The third most dominate age group was 3 winter-ring group contributing over 22% to the TSB and 15% to TSN. Age ranking for 2012 estimate: 2, 3 and 4 winter rings respectively.

The proportion of older fish (5-8 winter rings) represented in the total biomass was 8.5% as compared to 14% in 2012. No 8 winter ring fish and one 9 winter ring fish was observed from the 289 aged fish sample. Aged samples in 2012 totalled 577.

Maturity analysis indicated 72% of the TSB as sexually mature (Tables 7 & 8, Figure 5). One spent fish was encountered from a trawl sample outside of Waterford Harbour. Mature herring (stages 3 to 8) sampled during the survey were in a pre-spawning state and comprised predominantly of stages 3-4.

3.2 Other pelagic species

3.2.1 Sprat

Sprat	Millions	Biomass (t)	% contribution
Total estimate			
Definitely	6,973	33,728	75.5
Mixture	3,775	10,957	24.5
Probably	0	0	0.0
Total estimate	10,748	44,685	100

Sprat were found in 8 of 18 survey strata (16 +2 experimental strata) during the survey and sampled in 13 of 21 hauls (Figure 4, Table 3). In total 1,017 individual length measurements and 1,108 length/weight measurements were recorded. Mean length was 8.9cm and mean weight was 6g. Individuals ranged from 5 to 14cm in length and 1 to 23g in weight.

In total 420 sprat echotraces were identified during the survey (Table 12). The highest concentration of biomass was observed offshore in the 'Smalls' strata and accounted for over 40% of the total biomass and over 41% of the total abundance (Table 12).

Dingle Bay contributed largely to the total estimate with over 27% of the TSB observed within the Bay. High density schools along the bottom were widespread in the outer Bay area (Figure 6a).

Experimental strata in the eastern survey area also contained significant amounts of sprat occurring as mixed species schools with mackerel and occurring over wide areas. The distribution of these schools extended further east towards the UK coast (Van Der Hooj *pers. comm.).* The 2013 sprat estimate includes the experimental strata.

The mean length of sprat observed from this year's survey is lower than in previous years and this can be attributed to the widespread occurrence of 0-group fish throughout the survey area both inshore and offshore. Coastal waters have historically been the areas where 0-group sprat are observed and often in numbers (O'Donnell 2012), whereas offshore schools are generally composed of large individuals.

3.3 Oceanography

A total of 60 CTD stations were carried. 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, shows the eastern region of the Celtic Sea was dominated by cooler water from the Irish Sea and the Irish Sea Front was located at approximately 6°30W. The influence of this water is evident down to c.40m where the thermocline was observed. This cooler water hugs the coast as far west as Cork Harbour where it meets the warmer southern waters. Waters to the west and south of the Irish Sea Front were more saline and no doubt influenced more by Atlantic water and less from coastal runoff from the UK and Ireland.

The western frontal boundary area saw the highest concentrations of offshore monospecific sprat echotraces (composed mainly of 0-group individuals). In the east of the front, in the cooler waters mixed species aggregations dominated and were composed of sprat and mackerel ranging from 50- 400g.

3.4 Marine mammal and seabird observations

3.4.1 Marine mammal sightings

One hundred and twenty hours of recorded effort were logged, beginning and ending at the Blasket Islands. Sea states in the first few days were often less than 4 with swells of a metre or less. The survey average was thought to be 4-5 on most days with periods of six and above. Bridge watches generally coincide with poor sea states and large swells, greatly reducing the probability of detecting smaller or more distant cetaceans.

There were 87 cetacean sightings of about 406 animals in total (Table 17). There were positive identifications of fin whales, minke whales, common dolphins and bottlenose dolphins. One unidentified whale near the Blaskets was highly likely to have been a humpback whale, but while the blows and breaching were consistent with this species, the distance was too great to see fins and shape. Highest abundance was mainly in the 5 – 8nmi west of Galley Head, and this would apply to both inshore and offshore blocks.

Unidentified whales were mostly thought to be fin whales – characteristic blows were seen but bodies were masked by swell and distance. The animal on 8/10/13 is the possible humpback mentioned earlier. It is possible that the sightings on 23/10/13 are re-sightings of the same animal about 3 – 4nmi apart on north and south transects, but it is difficult to be sure.

The feeding concentration of baleen whales under a large flock of diving gannets on 10/10/13 contained at least 3 fin whales but probably up to 5 or 6. This group was the only one where passing mode was suspended and a closer approach made.

Unidentified dolphins were mostly thought to be common dolphins seen either in silhouette or low in the water preventing positive identification. The single animal seen on 14/10/13 was thought to be a possible bottlenose dolphin as it was quite large and breached almost vertically, thought the head was not seen clearly enough to eliminate other possibilities. The 4 animals seen on 23/10/13 may also have been bottlenose, but their slow swim did not allow confirmation. A small group of bottlenose were clearly identified nearby shortly afterwards.

The single unidentified cetacean was seen as a large splash only. There were bottlenose dolphins nearby breaching and slapping their bodies down hard, but this splash was substantially bigger, suggesting the presence of a small whale.

Sightings from the bird observers are largely consistent with those of the marine mammal observer, though their longer shifts meant that they could sometimes add a group or two of common dolphins outside the hours recorded above. They also saw a single large blow some time after the unidentified cetacean breach but though it unlikely to be the same animal. They also saw another large blow on 15/10/13. The presence of large whales might therefore be underestimated in this data.

Observations from the bridge were often carried out in difficult conditions so only animals attracted to the boat or cued by feeding bird flocks at not too great a distance from the boat are likely to have been detected. Similarly, the field covered from the bridge would probably be little more than half that from the crow's nest, also suggesting that the number of observations arising from bridge watches are considerably less reliable.

3.4.2 Seabird sightings

Observation effort

In total 1,018nmi was surveyed over 15 days with 132hrs of logged observations (Figure 11). Due to bad weather conditions for four days it was not possible to make observations (16^{th}, 18^{th}, 20^{th} and 26^{th} October). No observations were carried out when the vessel was stationary (CTD stations, ship traffic and acoustic calibration) or during fishing activities, leading to a total of 104hrs of logged observation hours (from 132hr total). Survey conditions were mostly good with moderate sea state and wind force, however the conditions got worse towards the end of the survey with higher swells and stronger winds (Figure 12). The visibility was good throughout the survey with no rain and fog during days of surveying.

A total of 9,366 sea birds, of which 2,802 birds were in transect, were recorded during the survey (Table 1), representing 21 different sea bird species. The most abundant bird were gannets with 3,311 counts (622 in transect). Followed by Guillimots and small auks in general, with 1,421 and 1,258 counts respectively (1,227 and 543 in transect). Also the number of sooty shearwaters is high with 1524 counts, with 84% and 15% of the numbers seen in a single event as a big flock of birds on the 8th and 9th of October. Sightings of sooty shearwaters were low during all the other survey days.

Table 2 shows the daily counts per species. The species codes are explained in Table 1. Impressions can be seen in Annex Figure 4.

We recorded 17 birds of 5 coastal bird species and unidentified ducks and waders. All the terrestrial birds were associated with the boat for a few minutes up to a few days. We recorded 21 birds of 5 species of passerines, 1 merlin and 3 unidentified species (Table 3, Annex Figure 5).

The main source of marine litter came from plastics, followed by textiles, metal and wood (Table 4, Annex Figure 7). We counted 52 single objects of litter, with an average of one object every 36km surveyed (or one object every 19nm). Litter was sighted on all but one transect of the survey.

A shark was seen on the 14th and 24th of October, but both animals couldn't be identified further. A group of bluefin tuna was seen surface feeding on mackerel on the 14th of October (Annex Figure 8).

4 Discussion and Conclusions

4.1 Discussion

The aims and objectives of the survey were carried out as planned with no recorded downtime. Weather conditions were good overall but did deteriorate towards the end of the survey when covering core abundance areas. The low occurrence of fish (and thus fishing) in the first half of the survey meant extra time was available to extend the survey area in the east by approximately 800nmi² using two experimental strata. Additional CTDs sampling was also undertaken in these strata.

The 2013 survey estimate is much lower than observed in 2012 (over double the 2011 estimate) and is therefore more in line with the recent time series. This considered the 2013 estimate is lower than expected. Outside of year effects, this may be some way accounted for the by the poor weather encountered when surveying core inshore areas resulting in more scattered, broken and smaller echotraces. Also the low density herring observed from mixed species catches taken offshore that did not qualify for the 'mixed' herring categorisation. However, the 'mixed' contribution is thought to be minor.

The estimate was dominated by 1-group herring representing almost 40% of the total biomass. The age range and the dominate age cohorts in 2011-2012 are not visible in the 2013 estimate. Historically the proportion of immature fish in the estimate has been low with 1-group fish poorly represented even in years of good recruitment. Sampling intensity was lower with 5 valid herring hauls used during the analysis in 2013 compared to 12 the previous year (2013: 289 aged herring, 2012: 577). This was largely a consequence of highly clustered areas of abundance where the bulk of the stock was located. Outside these areas herring echotraces were typically of low density and well spread out making useful and valid trawl sampling difficult.

The distribution of the stock was almost entirely (91%) within coastal waters and this is comparable to previous years. Tramore and the CS inshore strata contributed 87% to the total biomass and continue to hold the bulk of the stock at this time of year.

The 2013 survey results should be treated with a degree of caution as it is thought to be an underestimate of the stock due to poor weather when surveying core areas and the unquantified biomass within mixed species aggregations observed offshore. The lower level of age sampling in 2013 compared to 2012 may introduce a degree of uncertainty in the age structure of the estimate. However, this will not be determined until compared with the commercial catch data.

4.2 Conclusions

- Herring TSB (total stock biomass) and abundance (TSN) estimates were 109,095t (CV 27.6%) and 1,287 million individuals (CV 28.4%) respectively. Spawning stock biomass (SSB) was 70,948t (CV 25.8%), relating to a spawning abundance (SSN) of 612 million individuals
- The 2013 survey estimate is much lower than observed in 2012 (over double the 2011 estimate) and is therefore more in line with the recent time series
- Herring distribution was comparable to previous years with the bulk of the stock located in coastal waters. Over 91% of TSB was located within inshore strata. Offshore strata contributed 9% to the total biomass
- The age profile as determined from survey samples was dominated by 1, 2 and 3 winter ring fish. Immature 1-group fish represented almost 40% of the total biomass. Older fish (5-9 winter-rings) were poorly represented. The survey derived age profile is not considered representative of the standing stock
- A small but unquantified amount of herring was observed from mixed species catches in offshore areas
- The 2013 survey results should be treated with a degree of caution as it is thought to be an underestimate of the stock

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References\Bibliography

Anon. (1994). Report of the planning group for herring surveys. *ICES C.M. 1994/H:3*

Anon (2002) Underwater noise of research vessels. Review and recommendations. 2002. ICES No. 209

Brophy, D., and B. S. Danilowicz. 2002. Tracing populations of Atlantic herring (*Clupea harengus* L.) in the Irish and Celtic seas using otolith microstructure. ICES Journal of Marine Science, 59:1305-1313.

Camphuysen, K. J., Fox, A. D., Leopold, M. F. and Petersen, I. K. 2004. Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K.: a comparison of ship and aerial sampling methods for marine birds, and their applicability to offshore wind farm assessments, NIOZ report to COWRIE (BAM – 02-2002), Texel, 37pp.

Camphuysen, C.J. & Webb, A. 1999. Multi-species feeding associations in North sea seabirds: jointly exploiting a patchy environment. Ardea 87(2): 177-198.

Cramp, S., Bourne, W.R.P. and Saunders, D. 1974. *The seabirds of Britain and Ireland*. Collins, London. 287 pp.

Cramp, S., *et al.* 1977-1994. *Handbook of the Birds of Europe the Middle East and North Africa - the Birds of the Western Palearctic*. Oxford University Press. [A 9 Vol multi-author work edited by Cramp and Cramp and Perrins.]

Dalen, J. and Nakken, O. (1983) "On the application of the echo integration method" ICES CM 1983/B:19

Foote, K.G. (1987). Fish target strengths for use in echo integrator surveys. *J. Acoust. Soc. Am.* 82: 981-987

Foote, K.G., Knudsen, H.P., Vestnes, G., MacLennan, D.N. and Simmonds, E.J. (1987). Calibration of acoustic instruments for fish density estimation: a practical guide. *Int. Coun. Explor. Sea. Coop. Res. Rep.* 144: 57 pp

Grainger, R. J. (1978). A study of herring stocks west of Ireland and their oceanograohic conditions. Oceanography. Galway, University College Galway: 262.

Hall, M.E., O'Connor, I., Breen, D., McGeehan, A., Hunt, J., Borawska, A., Meade, R., Groth, L., & Tierney, D. (in press) Distribution of seabirds at sea during the Cetacean on the Frontier scientific cruises August 2009 and February 2010. Irish Wildlife Manuals, National Parks and Wildlife Service, Department of Arts Heritage and the Gaeltacht, Dublin, Ireland.

Heinemann, D. 1981. A Range Finder for Pelagic Bird Censusing. Journal of Wildlife Management 45(2): 489-493.

ICES. 1994. Report of the Study Group on Herring Assessment and Biology in the Irish Sea and Adjacent Waters. ICES CM 1994/H :5. 67pp.

Komdeur, J., Bertelsen, J. & Cracknell, G. (ed.) 1992. *Manual for Aeroplane and Ship surveys of Waterfowl and Seabirds*. IWRB Special Publication No. 19, Ministry of the Environment, National Environmental Research Institute, Department of Wildlife Ecology, Kalø, Denmark.

Molloy, J., E. Barnwall, and J. Morrison. 1993. Herring Tagging Experiments around Ireland, 1991. Fishery Leaflet, 154: 7pp.

Molloy, J. (1968). "Herring investigations on the southwest coast of Ireland 1967." ICES CM 1968/H:14: 10 pp

Mackey, M., Ó Cadhla, O., Kelly, T.C., Aguilar de Soto, N. and Connolly, N. 2004. *Cetaceans and Seabirds of Ireland□s Atlantic Margin. Volume 1 – Seabird distribution, density and abundance*. Report on research carried out under the Irish Infrastructure Programme (PIP): Rockall Studies Group (RSG) projects 98/6 and 00/13, Porucpine Studies Group project P00/15 and Offshore Support Group (OSG) project 99/38. University College Cork.

Mitchell, P.I., Newton, S.F., Ratcliffe, N. & Dunn T.E. *Seabird Populations of Britain and Ireland. Results of the Seabird 2000 Census* 1998-2002. T. & A.D. Poyser.

O'Donnell, C., Griffin, K., Lynch D., Ullgren J., Goddijn L., Wall D. & Mackey M. (2004).Celtic Sea Herring Acoustic Survey Cruise Report, 2004.(http://catalog.marine.ie/geonetwork/srv/en/main.home)

O'Donnell, C., Nolan C., Sullivan, M., Lyons, K., McKeogh, E., McAvoy, S., Ingham, S., O'Sullivan, E. Celtic Sea Herring Acoustic Survey, 09 - 29 October, 2012. Marine Institute, 2012.(http://hdl.handle.net/10793/853)

Pollock, C.M., Reid, J.R., Webb, A., and Tasker, M.L. 1997. *The distribution of seabirds and cetaceans in the waters around Ireland*. JNCC Report No. 267

Stone C.J., Webb A., Barton C., Ratcliffe N., Reed T.C., Tasker M.L,. Camphuysen C.J & Pienkowski M.W. 1995. *An atlas of seabird distribution in north-west European waters*. Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough, PEI lJY United Kingdom.

Tasker, M.L., Jones, P.H., Dixon, T., & Blake, B.F. 1984. Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardised approach. Auk 101: 567-577.

Webb, A. and Durinck, J. 1992. Counting birds from ship. In J. Komdeur; J. Berelsen & G. Cracknell.

Wernham, C., Toms, M., Marchant, J., Clark, J., Siriwardena, G. & Baillie, S. 2002. *Migration Atlas: Movement of Birds in Britain and Ireland*. T. & A.D. Poyser.

5 Tables and Figures

Table 1. Survey Strata detail. Note: Strata 17&18 experimental strata were not included in the herring estimate but were included in the sprat estimate.

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	59.4	43
2	Dingle	Broad scale	Zigzag	9	na	65.2	88
3	Kenmare	Broad scale	Zigzag	6	na	41.4	91
4	Bantry	Broad scale	Zigzag	7	na	22.3	53
5	Dunmanus	Broad scale	Zigzag	5	na	36.2	17
6	Mizen	Broad scale	Parallel	14	4	344.9	1,162
7	Offshore CS	Broad scale	Parallel	32	2	1,161.6	1,948
8	Smalls	Broad scale	Parallel	9	2	200.1	944
9	CS Inshore	Broad scale	Parallel	34	2	518.7	1,265
10	Baginbun	Spawning grd	Parallel	10	1	61.1	39
11	Tramore	Spawning grd	Parallel	17	1	161.4	106
12	Waterford	Spawning grd	Zigzag	3	na	6.4	3
13	Ballycotton	Spawning grd	Parallel	15	1	125.1	113
14	Daunt	Spawning grd	Parallel	11	1	79.0	80
15	Dingle_S	Spawning grd	Parallel	6	1	22.7	14
16	Dingle_N	Spawning grd	Parallel	6	1	9.7	12
17	NE corner	Broad scale	Parallel	11	2	297.2	242
18	Smalls ext	Broad scale	Parallel	4	2	139.0	562
			Total	204		3,351.4	6,783

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

Echo Sounder System Calibration

Vessel :	R/V Celtic Explorer	Date :	9/10/2013
Echo sounder :	ERK0 PC	Locality :	Dunmanus Bay
Type of Sphere : CU-38,1	TS_{Sphere}: -33.53 dB (Corrected for soundvelocity or t,S)	Depth(Sea floor) :	39 m

Calibration Version 2.1.0.11

Comments:
Dunmanus Bay, Calm conditions

Reference Target:

TS	-33.53 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	25.87 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	6.99 deg	Along. Beam Angle	6.98 deg
Athw. Offset Angle	-0.04 deg	Along. Offset Angl	-0.04 deg
SaCorrection	-0.61 dB	Depth	8.8 m

Transceiver: GPT 38 kHz 009072033933 1 ES38B

Pulse Duration	1.024 ms	Sample Interval	0.191 m
Power	2000 W	Receiver Bandwidth	2.43 kHz

Sounder Type:
ER60 Version 2.2.1

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.	9.8 dB/km	Sound Velocity	1508.6 m/s

Beam Model results:

Transducer Gain =	25.86 dB	SaCorrection =	-0.68 dB
Athw. Beam Angle =	7.01 deg	Along. Beam Angle =	6.97 deg
Athw. Offset Angle =	-0.04 deg	Along. Offset Angle=	-0.06 deg

Data deviation from beam model:
RMS = 0.11 dB
Max = 0.29 dB No. = 290 Athw. = 3.7 deg Along = 2.4 deg
Min = -0.54 dB No. = 406 Athw. = -1.6 deg Along = 4.3 deg

Data deviation from polynomial model:
RMS = 0.07 dB
Max = -0.40 dB No. = 406 Athw. = -1.6 deg Along = 4.3 deg
Min = -0.40 dB No. = 406 Athw. = -1.6 deg Along = 4.3 deg

Comments :

Wind Force : 1 **Wind Direction** NW
Raw Data File: \\Expfileclstr\ER-60_Data\CSHAS_2013\RAW ER60 Files\Calibration\CSHAS_2013
Calibration File: \\Expfileclstr\ER-60_Data\ER-60\Calibrations_2013\CSHAS 2011\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	08.10.13	52.04	-10.42	10:10	58	0-12	36.0		86.9		1.0		12.1
2	08.10.13	51.97	-10.42	15:56	80	0-20	80.0		81.2		17.6		1.2
3	12.10.13	51.10	-7.97	11:53	98	0-4	1.4			0.5	99.0		0.5
4	12.10.13	51.42	-7.96	15:11	83	0-7	250.0		100.0				
5	13.10.13	51.03	-7.53	18:56	94	0-8	8.0			28.0			72.0
6	14.10.13	51.15	-7.38	11:49	98	0-6	1.0		70.0		20.0		10.0
7	15.10.13	51.56	-7.21	2:55	75	0-8	7.1	19.7	7.5				72.8
8	15.10.13	51.18	-7.16	8:30	90	20	3.9			0.3	91.5		8.2
9	16.10.13	51.13	-6.88	11:10	92	0-8	1.8			3.6	50.8		45.5
10	16.10.13	51.57	-6.88	16:08	71	0-15	15.0	3.8	39.2		54.5		2.5
11	17.10.13	51.61	-6.71	17:55	70	0-22	13.6		27.8	0.6	69.4		2.1
12	18.10.13	51.28	-6.44	14:41	124	0-7	1200.0	73.4					26.6
13	18.10.13	51.17	-6.16	11:36	101	20	50.2	0.6	76.6		2.5		20.3
14	20.10.13	51.71	-6.44	8:20	70	0-15	6.0		60.2	0.2	0.3		39.3
15	20.10.13	51.51	-6.44	11:46	82	13-35	4.2	6.4		1.4	89.9		2.3
16	21.10.13	52.17	-7.03	19:50	34	0-20	1000.0	32.5	67.5				
17	22.10.13	52.03	-7.22	12:14	46	0-8	500.0	57.7	42.2			0.2	
18	22.10.13	52.10	-7.34	20:12	34	0-30	500.0	36.3	63.7				
19	24.10.13	51.75	-7.98	10:30	60	0-15	250.0		19.3	76.7	0.9		3.1
20	25.10.13	51.64	-8.46	13:05	38	0-6	500.0	90.4	7.2		2.5		
21	26.10.13	52.02	-10.25	3:37	30	0-6	1200.0	0.1	97.3	2.5		0.1	

* Including demersal fish and invertebrates

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

Haul	12	16	17	18	20	
length (cm)						Total
9.5					1	
10					1	
10.5						
11					1	
11.5						
12					1	
12.5					1	1
13						
13.5						
14						
14.5						
15						
15.5						
16						
16.5						
17				1		1
17.5			1	4		5
18			3	9	5	17
18.5			8	12	14	34
19			9	10	27	46
19.5			17	10	19	46
20			8	7	16	31
20.5		1	3	4	5	13
21		1	1	4	4	10
21.5	1	3	4	3	2	13
22		1	4	3	1	9
22.5		5	6	5	1	17
23	2	8	4	4	1	19
23.5	2	14	6	6		28
24	5	11	5	4		25
24.5	11	19	6	4		40
25	14	13	3	2		32
25.5	14	10	7	3		34
26	16	7	2	2		27
26.5	16	3	1	2		22
27	11	3	1	1		16
27.5	5	1	1	1		8
28	3	1				4
28.5	1					1
Total	101	101	100	101	100	503

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	0.1	0.1	0	0	0	0	0	0	0	0.5
8	0	0	1	3.6	1.8	2	0.7	0.2	0	0	0	9.5
9	0	23.8	15.1	10.3	2.3	2	0.5	0.4	0	0	0	54.3
10	0	0	0.1	0.1	0	0	0	0	0	0	0	0.2
11	0	13.8	12.3	10	2.2	1.8	0.4	0.2	0	0	0	40.9
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	1.7	0.9	0.6	0.1	0.1	0	0	0	0	0	3.5
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0.1	0	0	0	0	0	0	0	0	0	0.1
16	0	0	0	0	0	0	0	0	0	0	0	0
Total	0.1	39.6	29.6	24.7	6.5	6	1.6	0.9	0	0	0	109.1
%	0.1	36.3	27.1	22.6	6	5.5	1.5	0.8	0	0	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	3.1	1.2	0.8	0.2	0.1	0	0	0	0	0	5.5
8	0	0.3	9.0	26.4	11.9	12.5	3.9	1.3	0	0.2	0	65.4
9	2.3	418.9	150.7	84.0	15.5	12.8	2.9	2.0	0	0	0	689.3
10	0	0.1	0.8	0.8	0.2	0.1	0	0	0	0	0	2.0
11	0.8	243.2	120.3	80.4	15.1	11.6	2.7	1.3	0	0	0	475.5
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0.4	30.2	9.2	4.9	0.9	0.8	0.2	0.1	0	0	0	46.7
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0.1	1.8	0.1	0	0	0	0	0	0	0	0	2.1
16	0	0	0	0	0	0	0	0	0	0	0	0
Total	3.8	697.6	291.4	197.4	43.7	37.9	9.8	4.7	0	0.2	0	1286.4
%	0.3	54.2	22.6	15.3	3.4	2.9	0.8	0.4	0	0	0	100.0
Cv (%)	30.1	32	27.8	24.8	27.8	29.9	32.9	31	0	70.2	0	-

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	0.3	0	0.5
8	0.1	9.4	0	9.5
9	22.9	31.4	0.1	54.3
10	0	0.2	0	0.2
11	13.3	27.5	0.1	40.9
12	0	0	0	0
13	1.7	1.9	0	3.5
14	0	0	0	0
15	0.1	0	0	0.1
16	0	0	0	0
Total	38.1	70.7	0.2	109.1
%	35	64.8	0.2	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	3.0	2.5	0	5.5
8	0.6	64.5	0.4	65.4
9	404.8	283.9	0.5	689.3
10	0	2	0	2
11	234.5	240.3	0.7	476
12	0	0	0	0
13	29.4	17.3	0	46.7
14	0	0	0	0
15	2	0	0	2
16	0	0	0	0
Total	674.1	610.7	2	1286.4
%	52.4	47.5	0	100

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

Length (cm)	Age (Rings) 0	1	2	3	4	5	6	7	8	9	10	Abund (mils)	Biomass (000's t)	Mn wt (g)
9.5	0.1											0.1		6.4
10	0.1											0.1		7.5
10.5												-	-	-
11	0.1											0.1	-	10.1
11.5	0.1											0.1	-	11.6
12	0.3											0.3	-	13.2
12.5	0.4											0.4	0.01	15.0
13												-	-	-
13.5	0.1											0.1	-	19.1
14	2.5											2.5	0.1	21.4
14.5												-	-	-
15												-	-	-
15.5												-	-	-
16												-	-	-
16.5												-	-	-
17		6.6										6.6	0.3	39.2
17.5		47.1										47.1	2.0	42.9
18		95.9										95.9	4.5	46.8
18.5		140.2										140.2	7.2	51.0
19		117.5										117.5	6.5	55.5
19.5		118.8										118.8	7.2	60.2
20		81.2										81.2	5.3	65.2
20.5		45.8										45.8	3.2	70.4
21		28.0	14.0									42.0	3.2	75.9
21.5		10.1	30.3									40.3	3.3	81.7
22		6.4	25.4	6.4								38.2	3.4	87.9
22.5			52.3	11.6								63.9	6.0	94.3
23			44.7	9.0								53.7	5.4	101.0
23.5			55.6	18.5								74.1	8.0	108.1
24			27.6	27.6								55.3	6.4	115.4
24.5			35.0	31.1								66.1	8.1	123.2
25			6.5	27.6	6.5							40.6	5.3	131.2
25.5				35.7	13.7	5.5						54.9	7.7	139.7
26				23.5	5.2	5.2						34.0	5.1	148.5
26.5				6.3	10.5	12.6	4.2					33.5	5.3	157.6
27					5.5	8.3	2.8					16.6	2.8	167.2
27.5					1.7	5.2	1.7	1.7				10.4	1.8	177.1
28					0.6	1.1	1.1					2.7	0.5	187.4
28.5								2.8				2.8	0.6	198.1
29												-	-	-
29.5								0.2				0.2	0.04	220.9
30										0.2		0.2	0.04	232.8
SSN (mil)	-	47.31	272	197	43.6	37.4	9.64	4.55	-	0.2	-	612.3		
SSB ('000s t)	-	3.2	28.1	24.7	6.5	6.0	1.6	0.9	-	0.04	-		70.9	
Mn Wt (g)	18.3	56.8	102	125	149	159	167	191	-	233	-			
Mn length (cm)	13.5	19.3	23.2	24.8	26.3	26.8	27.2	28.4	-	30.2	-			

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)
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	6	0	0	0	0	100	0	0	0	0	0	0.0
4	7	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	32	2	1	0	1	94	0.4	0	0	0.5	0.3	5.5
8	18	9	9	0	0	89	9.5	0	0	9.5	9.4	65.4
9	34	72	47	0	25	62	52.8	0	1.5	54.3	31.5	689.3
10	9	2	2	0	0	78	0.2	0	0	0.2	0.2	2.0
11	18	90	90	0	0	22	40.9	0	0	40.9	27.6	475.5
12	3	0	0	0	0	100	0	0	0	0	0	0.0
13	15	38	33	0	5	47	3.4	0	0.1	3.5	1.9	46.7
14	11	0	0	0	0	100	0	0	0	0	0	0.0
15	6	3	0	0	3	83	0	0	0.1	0.1	0	2.1
16	5	0	0	0	0	100	0	0	0	0	0	0.0
Total	197	216	182	0	34	79	107.3	0	1.8	109.1	70.9	1286.4
Cv (%)	-	-	-	-	-	-	-	-	-	27.6	25.8	28.4

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
0	202	3	-	0	-	25	40	0	24	-	2	0	1	2	239	5	0.1	31	3.8
1	25	164	-	30	-	102	28	42	13	-	65	21	106	63	381	346	342	270	697.6
2	157	795	-	186	-	112	187	185	62	-	137	211	70	295	112	549	479	856	291.4
3	38	262	-	133	-	13	213	151	60	-	28	48	220	111	210	156	299	615	197.4
4	34	53	-	165	-	2	42	30	17	-	54	14	31	162	57	193	47	330	43.7
5	5	43	-	87	-	1	47	7	5	-	22	11	9	27	125	65	71	49	37.9
6	3	1	-	25	-	0	33	7	1	-	5	1	13	6	12	91	24	121	9.8
7	1	15	-	24	-	0	24	3	0	-	1	0	4	5	4	7	33	25	4.7
8	2	0	-	4	-	0	15	0	0	-	0	0	1	0	6	3	4	23	0
9	2	2	-	2	-	0	52	0	0	-	0	0	0	0	1	0	2	3	0.2
Abundance	469	1338	-	656	-	256	681	423	183	-	312	305	454	671	1,147	1,414	1,300	2,322	1,286
SSB ("000 t)	36	151	-	100	-	20	95	41	20	-	33	36	46	93	91	122	122	246	71
CV	53	26	-	36	-	100	88	49	34	-	48	35	25	20	24	20	28	25	28

Table 12. Sprat biomass and abundance by survey strata. Note: Strata 17 & 18 are experimental strata in 2013.

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	0	0	0	0	100	0	0	0	0	0
2	9	42	38	4	0	0	11.7	0.4	0	12.0	2207.1
3	6	17	17	0	0	33	1.7	0	0	1.7	319.4
4	7	0	0	0	0	100	0	0	0	0	0
5	5	0	0	0	0	100	0	0	0	0	0
6	14	21	21	0	0	64	1.4	0	0	1.4	193.4
7	32	102	99	3	0	53	4.1	0.4	0	4.4	664.5
8	18	163	129	34	0	22	14.5	3.5	0	18.1	4419.8
9	34	0	0	0	0	100	0	0	0	0	0
10	9	1	1	0	0	89	0.1	0	0	0.1	10.1
11	18	0	0	0	0	100	0	0	0	0	0
12	3	0	0	0	0	100	0	0	0	0	0
13	15	0	0	0	0	100	0	0	0	0	0
14	11	0	0	0	0	100	0	0	0	0	0
15	6	0	0	0	0	100	0	0	0	0	0
16	5	0	0	0	0	100	0	0	0	0	0
17	4	60	0	60	0	50	0	5.5	0	5.5	2771.7
18	10	14	8	6	0	90	0.2	1.2	0	1.4	162.6
Total	211	420	313	107	0	76	33.7	11	0	44.7	10,749
Cv (%)	-	-	-	-	-	-	-	-	-	22.8	24.6

Table 13. Total number of sea bird species recorded. (on-transect observations only).

Family	Species	ID	Total	Total in transect
Petrels	Fulmar	F	243	30
	Sooty Shearwater	OT	1524	170
	Manx Shearwater	MX	192	46
	Balearic Shearwater	YQ	2	0
	Great Shearwater	GQ	1	0
	Storm Petrel	TM	17	3
Gannets	Gannet	GX	3311	622
Cormorants and Allies	Shag	SA	22	15
	Cormorant	CA	1	0
Skuas	Arctic Skua	AC	13	4
	Great Skua	NX	185	35
Gulls	Great Black-backed Gull	GB	243	27
	Black-headed Gull	BH	1	0
	Common Gull	CM	2	0
	Herring Gull	HG	46	0
	Kittiwake	KI	323	44
	Lesser Black-backed Gull	LB	110	4
	Mediterranean Gull	MG	2	0
	Yellow legged Gull	YG	1	0
	Unidentified Gull	UG	311	0
Auks	Puffin	PU	15	5
	Guillemot	GU	1421	1227
	Razorbill	RA	122	27
	Razorbill/Guillemot	RA/GU	1258	543
Total			9366	2802

Table 14. Daily count of sea birds in total (tot.) and in transect (tra.)

	08/10/2013		09/10/2013		10/10/2013		11/10/2013		12/10/2013		13/10/2013		14/10/2013		15/10/2013		17/10/2013		19/10/2013		21/10/2013		22/10/2013		23/10/2013		24/10/2013		25/10/2013	
Species	tot.	tra.	tot.	tra.	tot.	tra.	tot.	tra.	tot.	tra.	tot.	tra.	tot.	tra.	tot.	tra.	tot.	tra.	tot.	tra.	tot.	tra.	tot.	tra.	tot.	tra.	tot.	tra.	tot.	tra.
F	-	-	38	16	25	1	21	3	10	2	5	-	2	-	4	1	-	-	6	1	7	1	16	-	9	-	17	1	72	4
OT	1278	16	223	151	7	1	-	-	-	-	-	-	-	-	-	-	-	-	4	1	3	-	1	-	1	-	2	-	2	-
MX	3	1	4	-	163	43	2	1	-	-	-	-	1	1	-	-	-	-	-	-	1	-	-	-	-	-	4	-	14	-
YQ	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
TM	3	-	2	-	9	2	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-
GX	254	86	273	25	236	31	149	18	251	51	190	33	92	15	218	27	176	62	392	45	117	16	228	42	211	49	298	67	226	55
SA	5	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	13	8	1	1	2	2	-	-	-	-
CA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
AC	4	2	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	3	1	1	1
NX	11	5	68	47	7	1	22	8	31	3	21	5	17	2	29	5	1	-	17	3	4	1	15	1	-	-	2	-	6	-
GB	13	3	43	3	18	3	5	1	28	-	16	-	17	-	7	2	2	-	4	-	6	-	23	3	8	-	16	1	37	11
BH	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CM	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HG	2	-	2	-	2	-	1	-	11	-	-	-	2-	-	-	-	1	-	-	-	1	-	1	-	3	-	1	-	1	-
KI	23	9	6	1	7	-	12	-	26	6	35	4	37	2	4	-	1	-	17	-	5	-	1-	3	13	3	82	2	20	3
LB	-	-	1	-	1	-	13	2	34	-	6	-	44	2	-	-	-	-	3	-	-	-	-	-	1	-	2	-	1	-
YG	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MG	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
UG	-	-	-	-	-	-	6	-	201	-	43	-	-	-	-	-	-	-	-	-	-	-	-	-	54	-	-	-	7	-
PU	8	3	4	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-
GU	844	803	68	49	235	181	8	5	2	1	1	-	9	6	7	1	12	5	-	-	13	6	39	20	98	84	47	36	38	30
RA	44	26	14	-	12	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	17	-	23	1	9	-	1	-	-	-
RA/GU	105	43	68	47	311	72	18	2	1	-	1	-	5	1	2-	-	4	-	1	-	21	2	86	35	287	167	128	52	202	122

Table 15. Total count of coastal, inshore and terrestrial birds.

		Species	ID	Total
Coastal / inshore birds	Ducks	Unidentified		5
	Waders	Grey Phalarope	PL	1
		Turnstone	TT	1
		Dunlin	DN	1
		Purple Sandpiper		1
		Unidentified small wader		1
	Terns	Common Tern	CN	7
Terrestrial birds	Passerines	Meadow Pipit	MP	9
		Pied Wagtail	PW	4
		Chaffinch	CH	1
		Skylark	S.	1
		Redwing	RE	2
		Warbler		1
		Swallow	SL	1
		Unidentified		2
	Falcons	Merlin		1

Table 16. Overview of marine litter observations.

Litter	Object	Quantity	Description
plastic	unidentified	13	mostly little, flat pieces e.g. a packaging lids
	bottle	11	Fizzy drinks bottles mostly 0.5l and transparent
	bag	7	thin white or black plastic bags
	milk bottle	3	2l cartoons
	balloon	3	Semi inflated balloons
	bucket	2	white bucket
	box	2	e.g. ice cream containers
other	glove	2	orange working gloves
	brush	1	the head of a cleaning brush
	fishing rope	1	Orange polypropylene
	mat	1	blue "yoga" mat
	Styrofoam	1	white plate
	Wellington boot	1	
metal	oil can	1	e.g. for cooking oil
	marker pole	1	1m tall dahn marker -drifting
wood	wooden pallet	2	2x2m

Table 17. Summary of cetacean species sightings (number of sightings followed by best estimate of number of animals in parentheses) CN = Crow's Nest, BR = Bridge.

Date	Viewpoint	Time watched (hr:min)	Fin Whale	Minke Whale	UnID Whale	Common Dolphin	Bottlenose Dolphin	UnId Dolphin	UnID Cetacean
8/10/13	CN	9:30		3 (3)	1 (1)	9 (51)		2 (11)	
9/10/13	CN	5:30				1 (3)			
10/10/13	CN	9:15	1 (3+)	2 (2)	3 (4)	9 (37)	1 (10)	3 (22)	
11/10/13	CN	7:45			1 (1)				
12/10/13	CN	6:40							
13/10/13	CN	7:40				1 (6)			
14/10/13	CN	8:15				1 (10)		1 (1)	
15/10/13	CN	8:00			1 (1)	5 (24)		3 (6)	
16/10/13	BR	2:45				2 (19)			
17/10/13	CN	7:40				3 (24)			
18/10/13	None	0							
19/10/13	CN	8:00				1 (11)			
20/10/13	BR	7:00				5 (26)			
21/10/13	BR	6:55							
22/10/13	CN	6:00							
23/10/13	CN	8:15			2 (2)	9 (57)	1 (3)	1 (4)	
24/10/13	BR	7:30				8 (29)		2 (16)	
25/10/13	CN	6:50				2 (6)		1 (6)	1 (1)
26/10/13	BR	1:20				1(2)			
Totals		119:35	1 (3+)	5 (5)	8 (9)	57 (305)	2 (13)	13 (66)	1 (1)

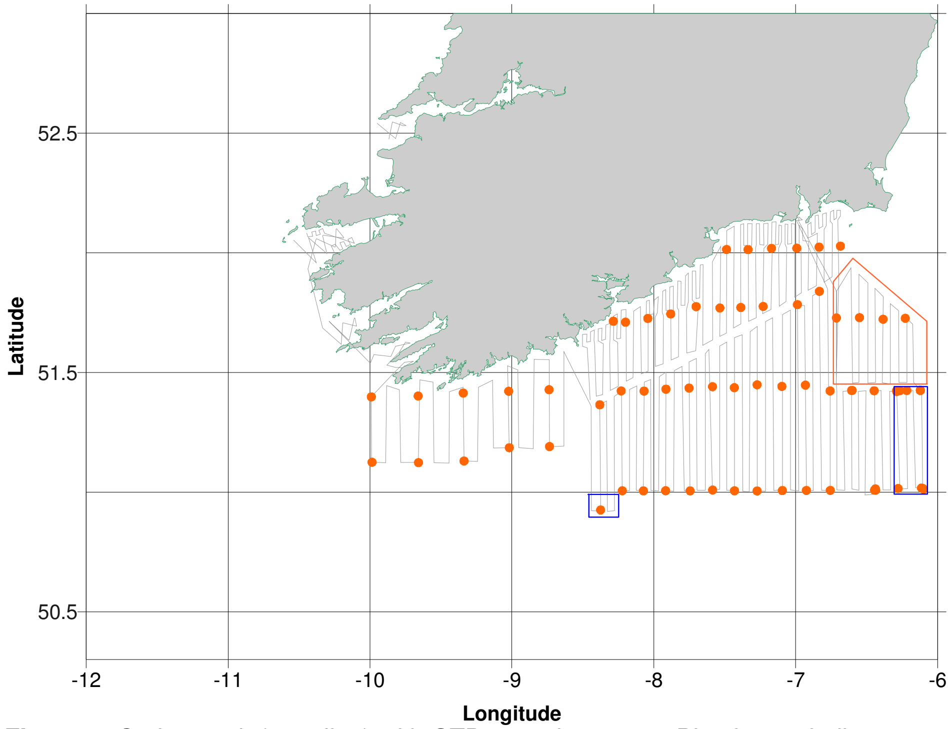


Figure 1. Cruise track (grey line) with CTD casts in orange. Blue boxes indicate extensions to existing strata; Orange box new experimental stratum.

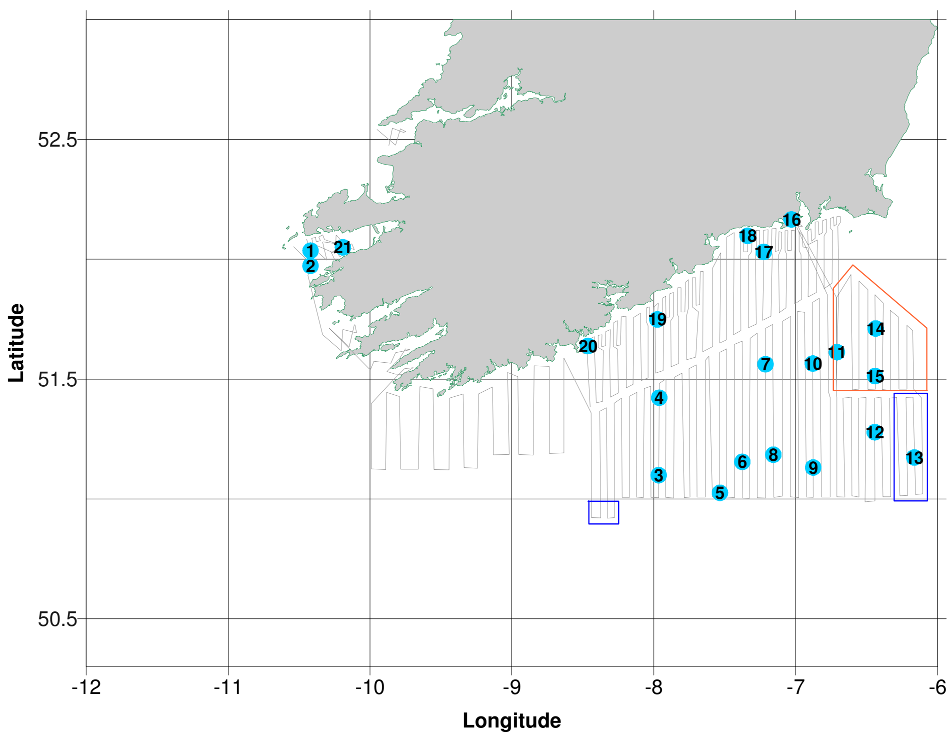


Figure 2. Directed midwater trawl positions.

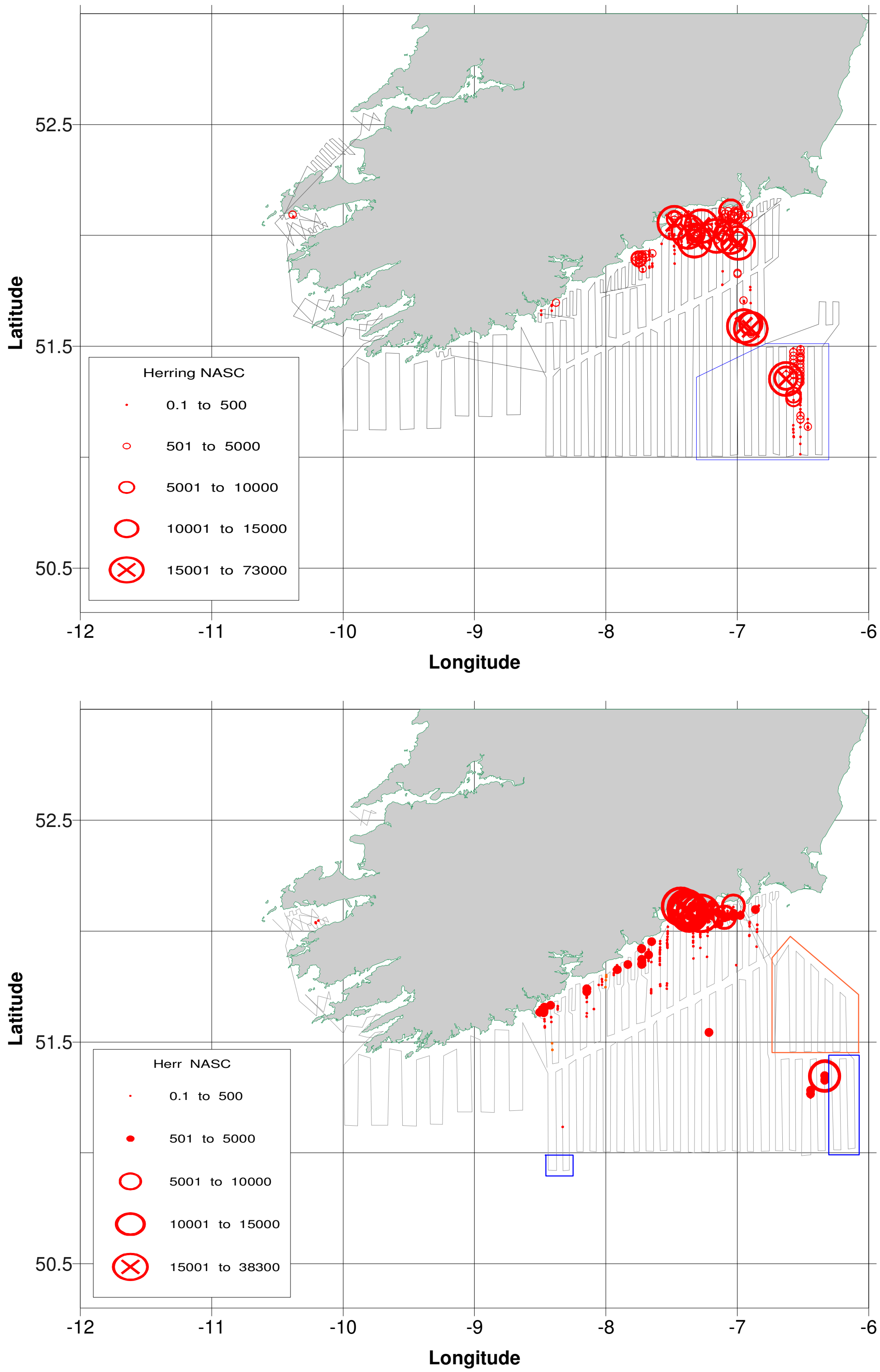


Figure 3. Weighted herring NASC (Nautical area scattering coefficient) plot showing the distribution of "definitely" and "probably" categories as red circles. Top Panel 2012, bottom panel 2013.

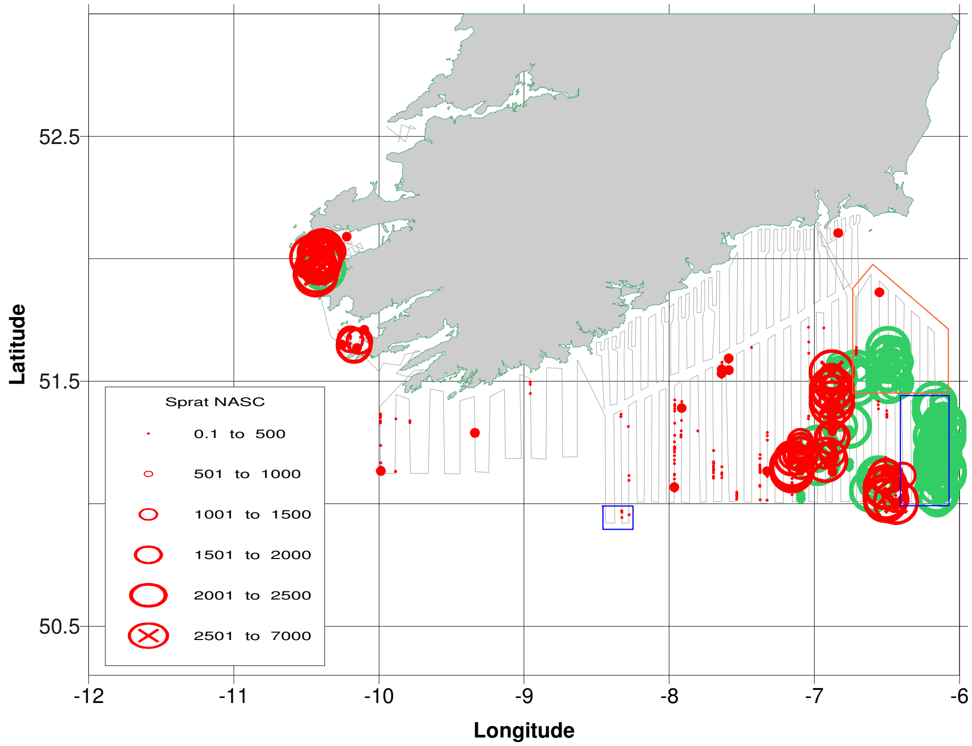
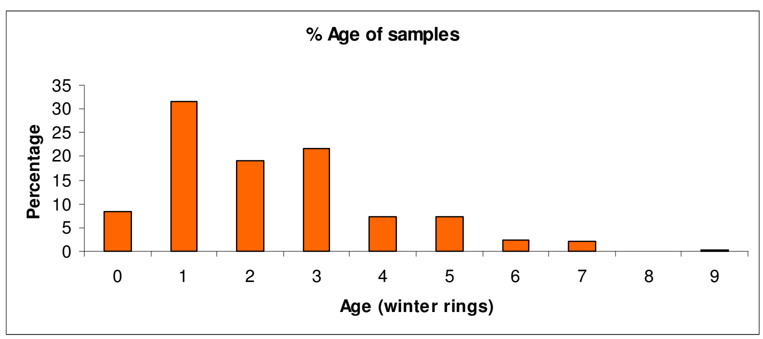


Figure 4. Weighted Sprat NASC (Nautical area scattering coefficient) distribution of "definitely" and "probably" categories (red) and "mixed" species schools (green).



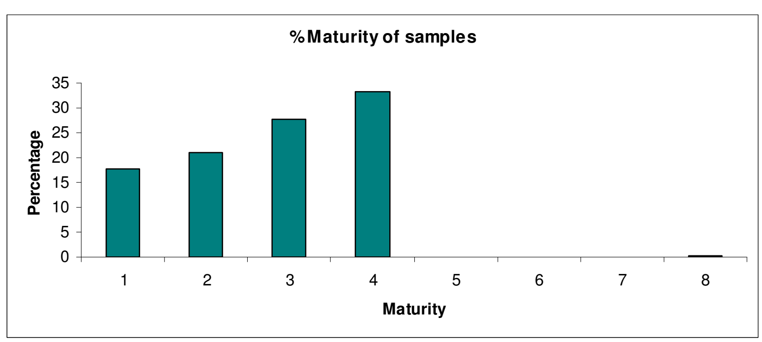
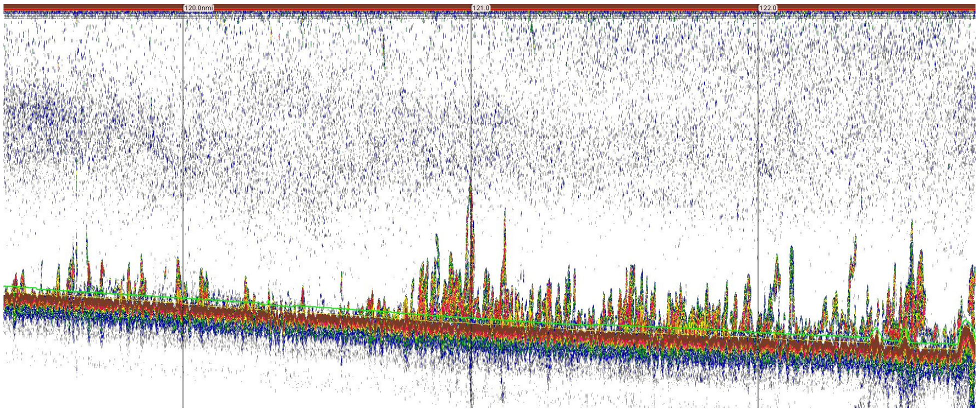
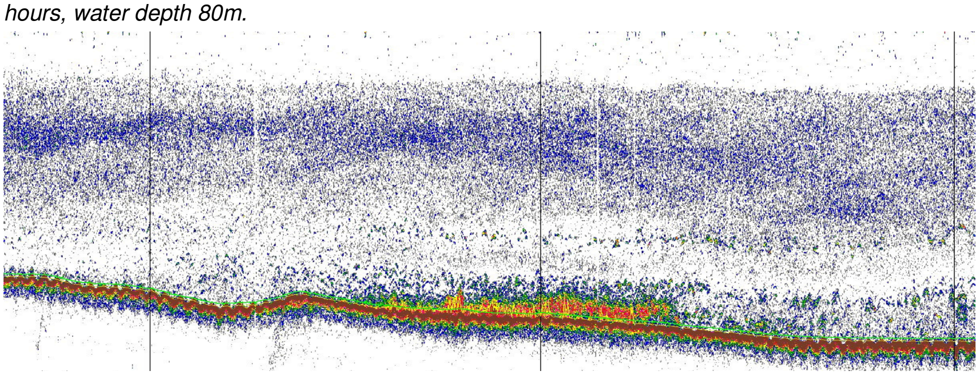


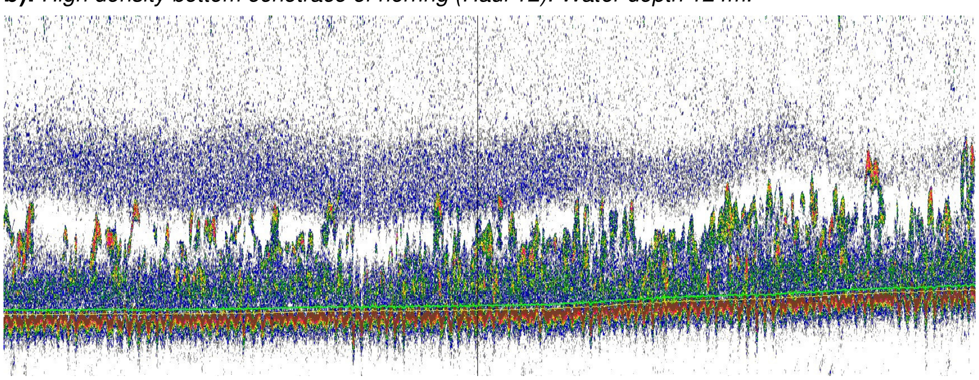
Figure 5. Percentage age and maturity of aged herring samples used in the analysis (n=289).



a). *High density sprat echotrace recorded in Dingle Bay (Haul 02) observed during daylight hours, water depth 80m.*

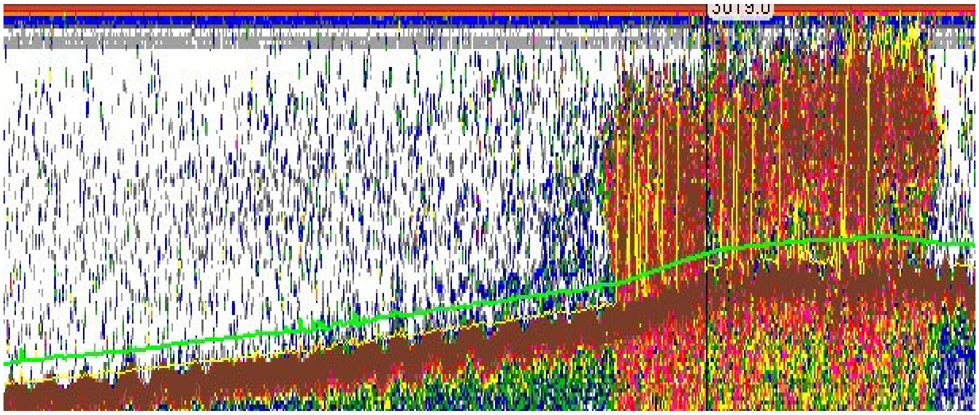


b). *High density bottom echotrace of herring (Haul 12). Water depth 124m.*

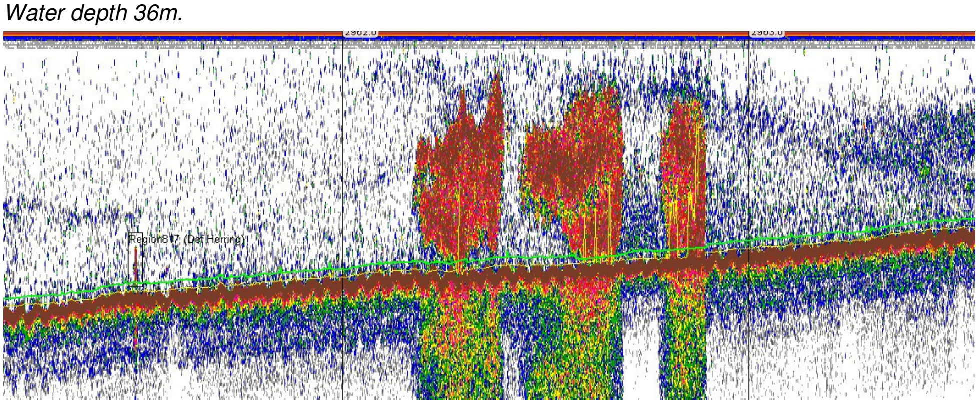


c). *High density midwater echotrace composed primarily of small (<6cm) sprat (Haul 15)re-corded during daytime and located offshore around the 'Smalls'. Water depth 82m.*

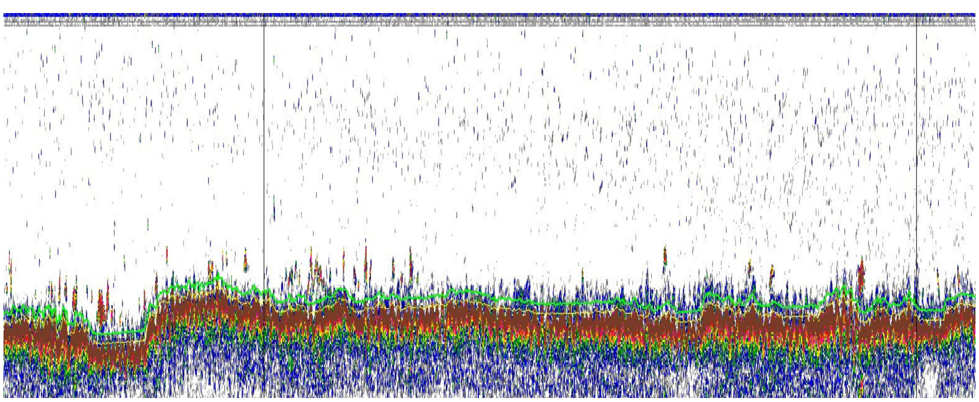
Figure 6a-f. Echograms recorded prior to trawling (EK60, 38 kHz). Celtic Sea herring acoustic survey, October 2012.



d). *Single highest density herring echotrace recorded during the survey in strata 11 (Tramore). Water depth 36m.*



e). *Second Highest density herring echotrace recorded in strata 11 (Tramore) Water depth 56m.*



f). *Medium density scattering layer of herring (Haul 20) recorded during daylight hours Strata 14 (Kinsale area). Bottom depth 38m.*

Figure 6a-f. Continued.

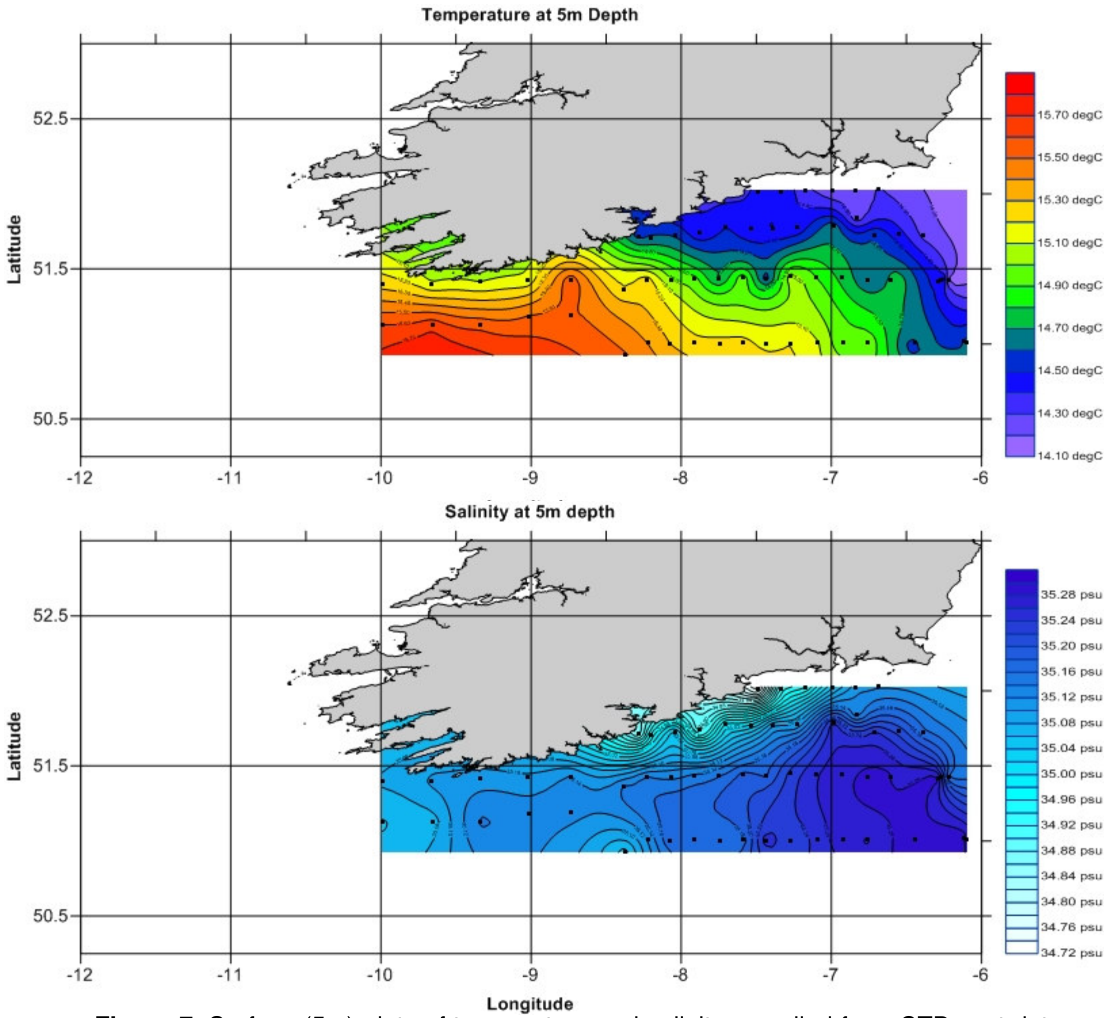


Figure 7. Surface (5m) plots of temperature and salinity compiled from CTD cast data (n=60). Station positions shown as block dots.

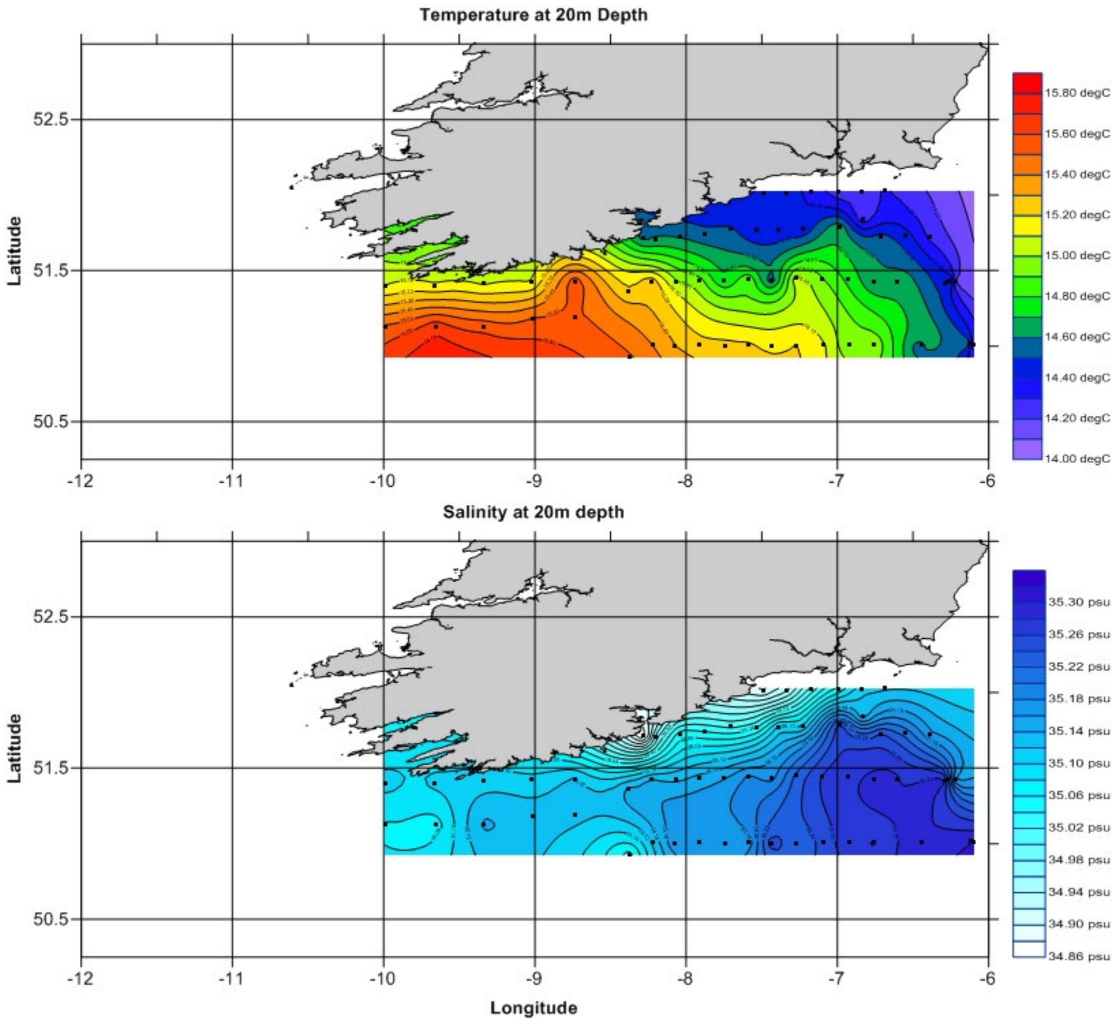


Figure 8. Temperature and salinity at 20m compiled from CTD cast data (n=60). Station positions shown as block dots.

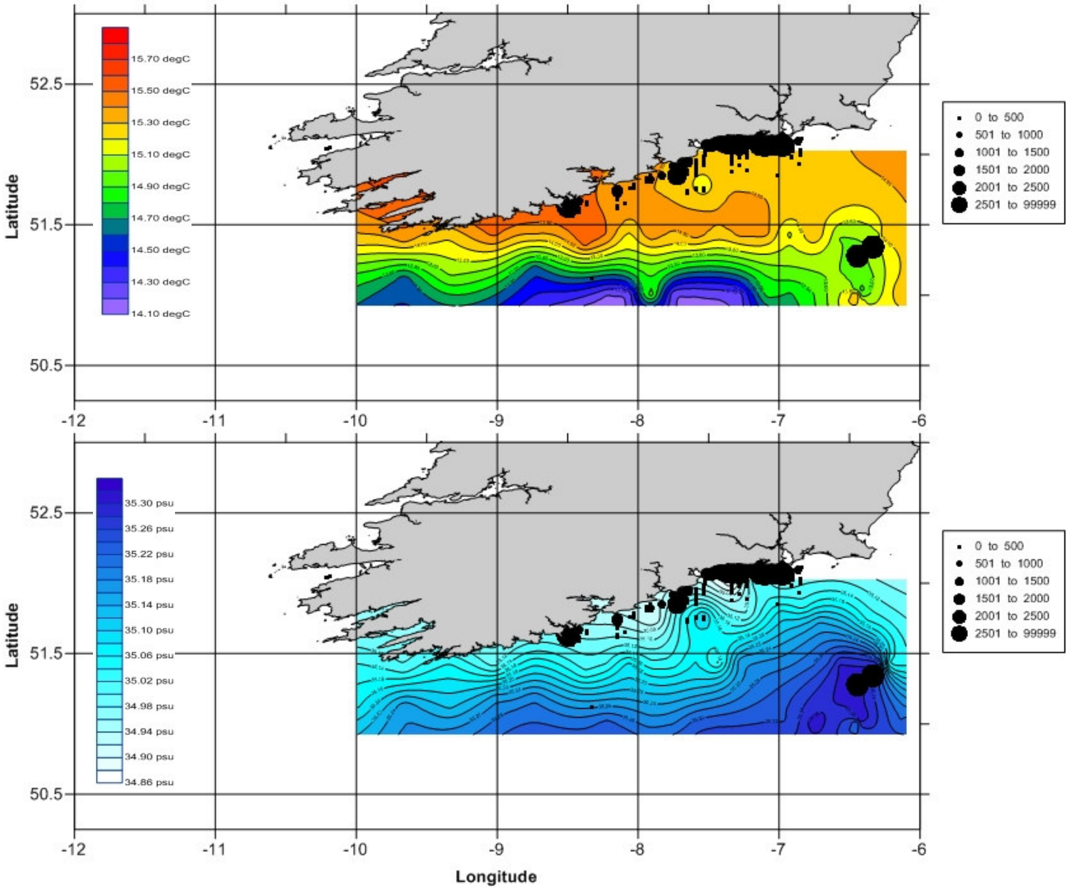


Figure 9. Habitat plots of temperature and salinity at 40m overlaid with herring NASC values (acoustic density) shown as weighted black circles.

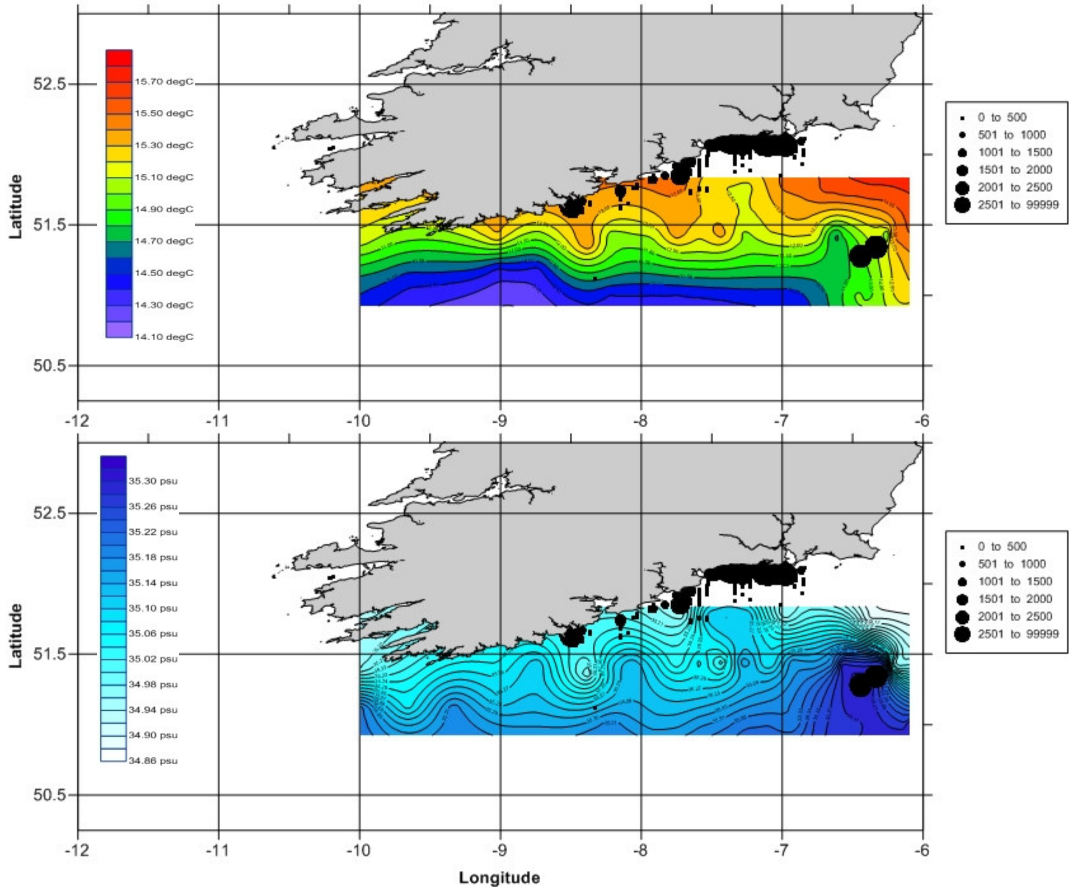


Figure 10. Habitat plots of temperature and salinity at 60m overlaid with herring NASC values (acoustic density) shown as black circles.

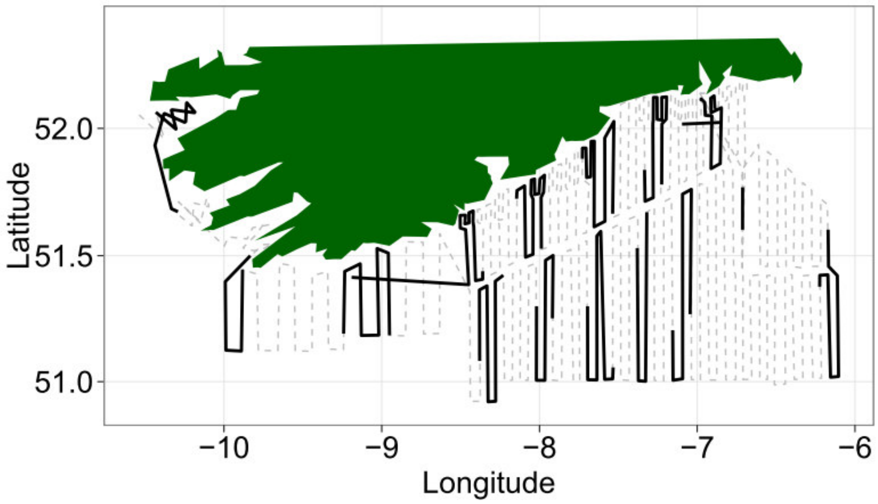


Figure 11. Bird survey effort. The dotted line shows the acoustic survey transect with the closed line showing transects with bird observations.

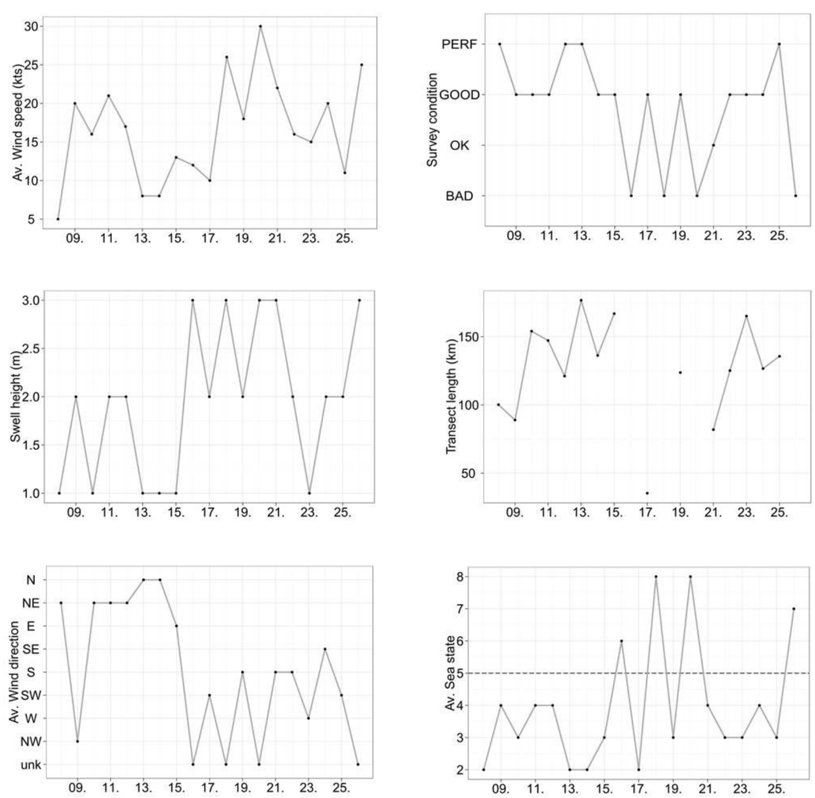


Figure 12. Environmental conditions during the full survey and obs effort. A. Average wind force over the day (ships anemometer). B. Average swell height in meters over the day (estimated). C. Average wind direction over the day (ships anemometer). D. Average survey conditions during the day, influenced by visibility, sun glare and weather conditions. E. Total transects length for the observation day(Km). F. Average sea state over the survey day (estimated). No obs when the sea state >5 (dotted l

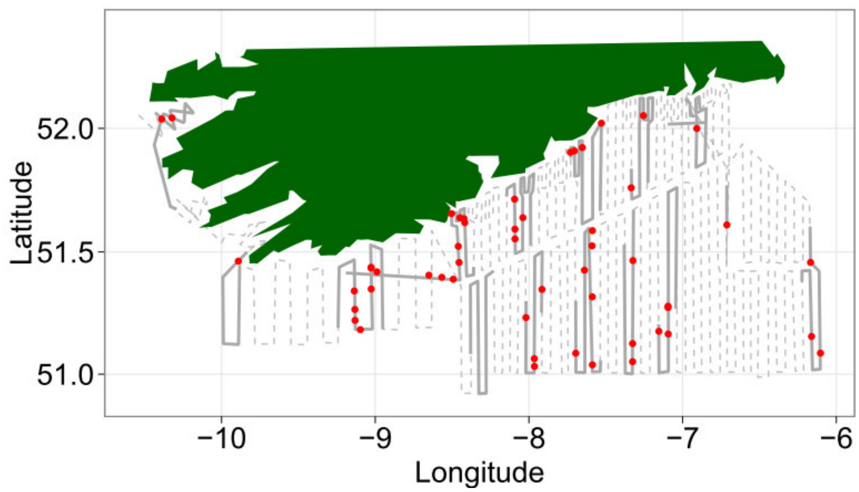


Figure 13. Surface litter distribution during the survey (red points). The dotted lines indicate the cruise transects. Grey line show the survey effort with bird/litter observations.

HERRING MIDWATER TRAWL

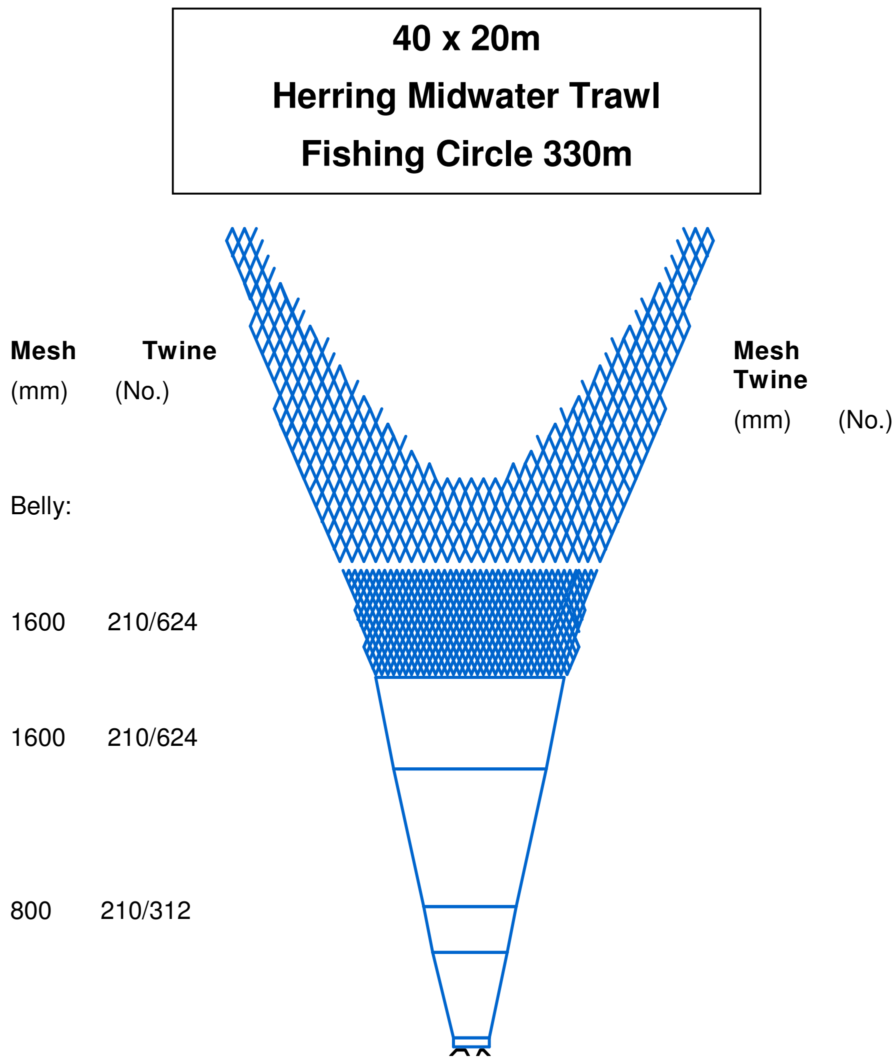


Figure 14. Single herring midwater trawl net plan and layout. Celtic Sea herring acoustic survey, October 2012.

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

6 Annex 1

Table 1. Scientific bird species name of species mentioned in this report

Family	Species	scientific name
Petrels	Fulmar	*Fulmarus glacialis glacialis*
	Sooty Shearwater	*Puffinus griseus*
	Manx Shearwater	*Puffinus puffinus*
	Balearic Shearwater	*Puffinus mauretanicus*
	Great Shearwater	*Puffinus gravis*
	Storm Petrel	*Hydrobates pelagicus*
Gannets	Gannet	*Morus bassanus*
Cormorants and Allies	Shag	*Phalacrocorax aristotelis aristotelis*
	Cormorant	*Phalacrocorax carbo carbo*
Skuas	Arctic Skua	*Stercorarius parasiticus*
	Great Skua	*Stercorarius skua*
Gulls	Great Black-backed Gull	*Larus marinus*
	Black-headed Gull	*Chroicocephalus ridibundus*
	Common Gull	*Larus canus canus*
	Herring Gull	*Larus argentatus argenteus*
	Kittiwake	*Rissa tridactyla*
	Lesser Black-backed Gull	*Larus fuscus graellsii*
	Mediterranean Gull	*Ichthyaetus melanocephalus*
	Yellow legged Gull	*Larus michahellis*
Auks	Puffin	*Fratercula arctica grabae*
	Guillemot	*Uria aalge albionis*
	Razorbill	*Alca torda islandica*
Waders	Grey Phalarope	*Phalaropus fulicarius*
	Turnstone	*Arenaria interpres*
	Dunlin	*Calidris alpina*
	Purple Sandpiper	*Calidris maritima*
Terns	Common Tern	*Sterna hirundo*
Passerines	Meadow Pipit	*Anthus pratensis*
	Pied Wagtail	*Motacilla alba*
	Chaffinch	*Fringilla coelebs*
	Skylark	*Alauda arvensis*
	Redwing	*Turdus iliacus*
Falcons	Merlin	*Falco columbarius*
Cetaceans	Common Dolphin	*Delphinus delphis*
	Minke Whale	*Balaenoptera acutorostrata acutorostrata*
	Fin Whale	*Balaenoptera physalus physalus*
	Humpback Whale	*Megaptera novaeangliae*
Pinnipeds	Grey Seal	*Halichoerus grypus grypus*
Moths	Death's Head Hawkmoth	*Acherontia atropos*

Figure 1. Sea bird species sample. A. Storm petrel. B. Great Skua with adult Gannets. C. Juvenile Gannet. D. Flock of Sooty Shearwaters. E. Arctic Skua. F. Lesser black-backed Gull. G. Shag. H. Juvenile Kittiwake. I. Guillemot. J. Fulmar. K. Mediterranean Gull. L. Mixed species feeding association during fishing.

Figure 2. Examples of terrestrial bird species. A. Dunlin. B. Pied Wagtail. C. Meadow Pipit. D. Chaffinch. E. Merlin.

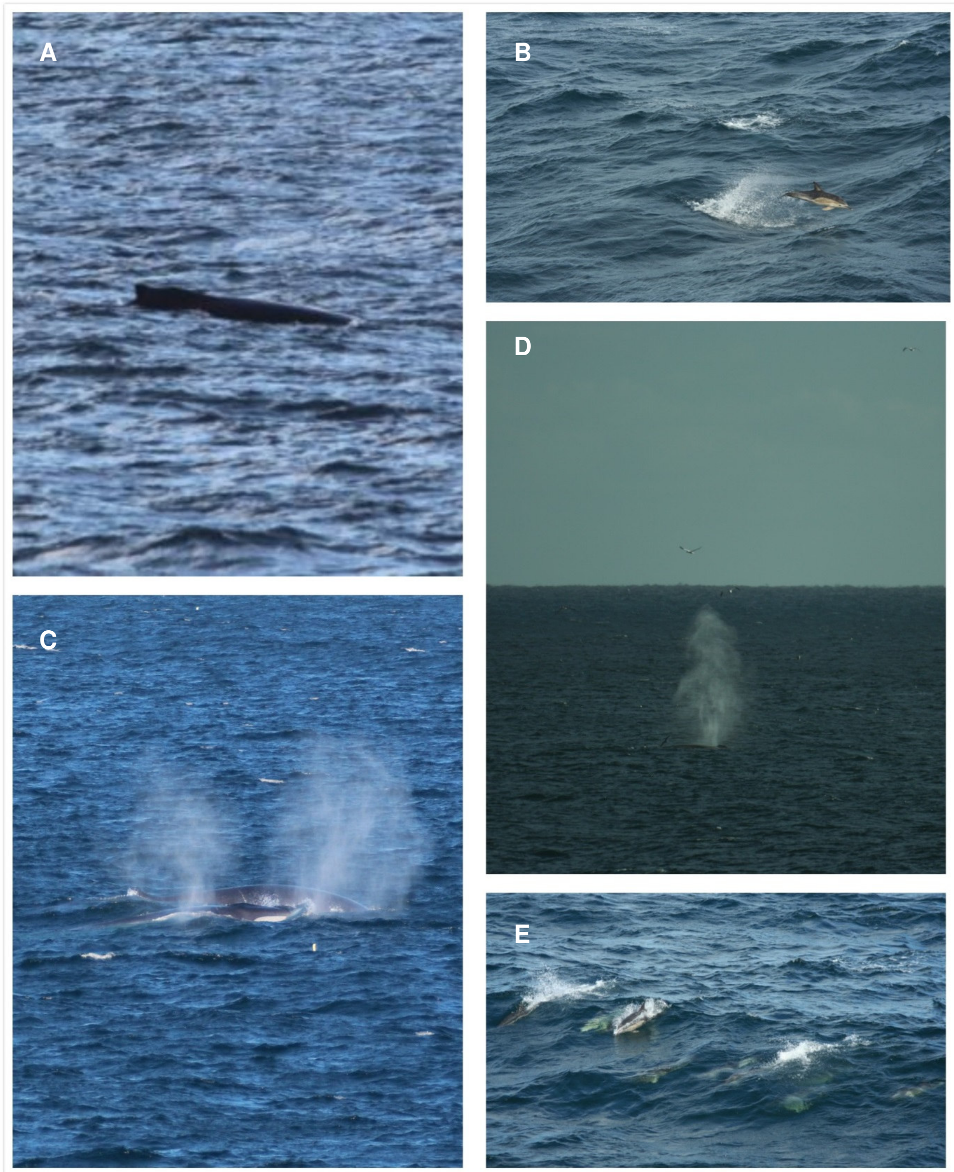


Figure 3. Examples of cetacean species. A. Humpback whale. B. Common dolphin. C. Two fin whales. D. Blow of a fin whale. E. Common dolphins.

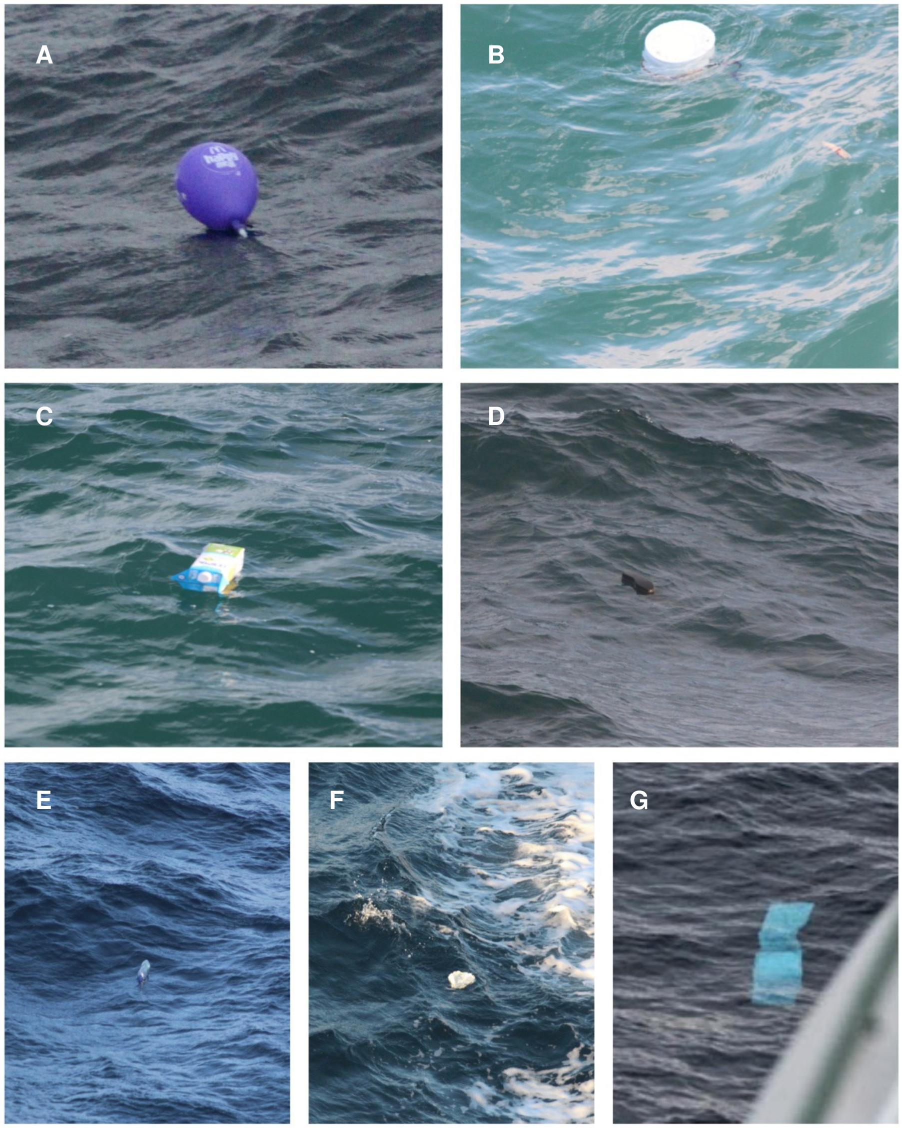


Figure 4. Examples of marine litter. A. Balloon. B. Plastic bucket. C. Milk carton. D. Boot. E. Plastic bottle. F. Unidentified plastic. G. “Yoga” mat.