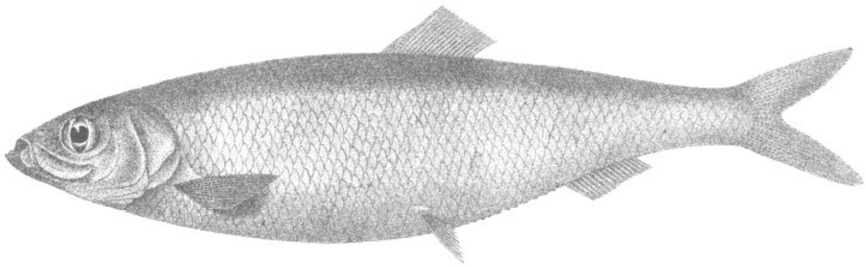
FSS Survey Series: 2019/04

Celtic Sea Herring Acoustic Survey Cruise Report 2019

09 - 29 October, 2019



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1 Introduction

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

The stock structure and discrimination of herring in this area has been investigated recently. Hatfield et al. (2007) has shown the Celtic Sea stock to be fairly discrete. However, it is known that fish in the eastern Celtic Sea recruit from nursery areas in the Irish Sea, returning to the Celtic Sea as young adults (Brophy et al. 2002; Molloy et al., 1993). The stock identity of VIIj herring is less clear, though there is evidence that they have linkages with VIIb and VIaS (ICES, 1994; Grainger, 1978). Molloy (1968) identified possible linkages between young fish in VIIj and those of the Celtic Sea herring. For the purpose of stock assessment and management divisions VIIaS, VIIg and VIIj have been combined since 1982.

For a period in the 1970s and1980s, larval surveys were conducted for herring in this area. However, since 1989, acoustic surveys have been carried out, and currently are the only tuning indices available for this stock. In the Celtic Sea and VIIj, herring acoustic surveys have been carried out since 1989. Since 2004 the survey has been fixed in October and carried out onboard the RV *Celtic Explorer.*

Survey design and geographical coverage have been modified over the time series to adapt to changes in stock size and behaviour. Since 2016, the wider core distribution area has been surveyed by means of two independent surveys and supplemented with small high resolution adaptive surveys focusing on areas of high abundance.

2 Materials and Methods

2.1 Scientific Personnel

Leg	Leg 1	Date	Leg 2	Date
Start	Cork	09.10.19	Cork	19.10.19
End	Cork	19.10.19	Galway	29.10.19

Organisation	Name	Name	Capacity
FEAS	Ciaran O'Donnell	Ciaran O'Donnell	Acou (Chief Sci)
FEAS	Graham Johnston	Graham Johnston	Acou
FEAS	Sinead O'Brien	Sinead O'Brien	Acou
FEAS	Deirdre Lynch	Eugene Mullins	Acou
FEAS	David Tully	David Tully	Bio (Deck Sci)
FEAS	Ian Murphy	Tobi Rapp	Bio
Con	Karl Bentley	Gary Robinson	Bio
UCD	Danielle Crowley	Danielle Crowley	Bio
NPWS	John Power	John Power	MMO
NPWS	Paul Connaughton	Paul Connaughton	SBO
Queens	Ashley Johnston	Ashley Johnston	SBO
IS&WFPO	John O'Regan	John O'Regan	Industry Obs

SBO- Seabird observer, MMO- marine mammal observer

2.2 Survey Plan

2.2.1 Survey objectives

The primary survey objectives are listed below:

- Carry out a two phase survey cruise track covering the core survey area
- Cary out additional adaptive surveys as required on areas of interest
- Collect biological samples from directed trawling on insonified fish echotraces to determine age structure and maturity state of the herring stock
- Determine an age stratified estimate of relative abundance of herring within the survey area (ICES Divisions VIIj, VIIg and VIIaS)
- Determine estimates of biomass and abundance for sprat within the survey area
- Collect physical oceanography data from vertical profiles from a deployed sensor array
- Survey by visual observations marine mammal and seabird abundance and distribution

2.2.2 Area of operation

The autumn 2019 survey covered the area from Mizen Head and extended along the south coast into the Celtic Sea (Divisions VIIj, VIIg & VIIaS), see Figure 1. The survey worked in an easterly direction covering the larger core survey area during the first pass before turning westwards to complete the second pass using interlaced transects.

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

2.2.3 Survey design

2.2.3.1 Core survey

In 2016, a change in survey design was implemented by consolidating all existing strata into a single core survey stratum. This broad scale survey composed of 8 nmi (nautical miles) spaced transects. A second pass was then carried out interlacing transects from the previous pass. Interlaced transects providing an effective coverage of 4 nmi resolution. Each pass acts as an independent estimate.

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

In total the core surveys accounted for 3,011 nmi of transects covering an area of over 16,360 nmi^2.

2.2.3.2 Adaptive survey

Adaptive surveys were carried out on areas of interest identified during the core survey.

Each candidate area was scouted to determine geographical extent of target aggregations where possible. A survey plan was then designed using parallel transects running perpendicular to the lines of bathymetry. Transect spacing is determined on a survey basis and uses a balance of time available and area coverage to achieve the high resolution of sampling effort. The EK60 single beam data is supplemented with either EM2040 bathymetric multibeam data or Omni sonar data (Simrad SU90) to provide increased spatial resolution on the extent of aggregations. Survey design followed methods described in Simmonds and MacLennan (2005) for adaptive surveys. Individual transects were run in parallel crossing the extent of the herring aggregation with the end point determined when no further herring were observed for 0.5 nmi.

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

Five adaptive surveys were carried out and accounted for 700 nmi of transects and an area coverage of 1,508 nmi^2.

2.3 Equipment and system details and specifications

2.3.1 Acoustic array

Equipment settings for the acoustic equipment were determined before the start of the survey program and were based on established settings employed by FEAS on previous surveys (O'Donnell *et al.,* 2004). The acoustic settings for the EK60 38 kHz transducer are shown in Table 1.

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

While on survey track the vessel is normally propelled using DC twin electric motor propulsion system with power supplied from 1 main diesel engine, so in effect providing "silent cruising" as compared to normal operations (ICES 2002). During fishing operations normal two-engine operations were employed to provide sufficient power to tow the net.

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

2.3.2 Calibration of acoustic equipment

A calibration of the EK60 was carried out at the end of the WESPAS survey in July and the results applied for use in this survey. The procedure followed methods described by Demer *et al.* (2015). Calibration results and settings are provided in Table 1.

2.4 Survey protocols

2.4.1 Acoustic data acquisition

The "RAW files" were logged via a continuous Ethernet connection to the vessels server and the ER60 hard drive as a backup in the event of data loss. In addition, as a further back up a hard copy was stored on an external hard drive. Myriax Echoview® Echolog (Version 7) live viewer was used to display the echogram during data collection to allow the scientists to scroll through echograms noting the locations and depths of fish shoals. A member of the scientific crew monitored the equipment continually. Time and location (GPS position) data was recorded for each transect within each strata. This log was used to monitor the time spent off track during fishing operations and hydrographic stations plus any other important observations.

2.4.2 Biological sampling

A single pelagic midwater trawl with the dimensions of 19 m in length (LOA) and 6 m at the wing ends and a fishing circle of 330 m was employed during the survey (Figure 14). Mesh size in the wings was 3.3 m through to 5 cm in the cod-end. The net was fished with a vertical mouth opening of approximately 9m, which was observed using a cable linked Simrad FS70 netsonde. The net was also fitted with a Scanmar depth sensor. Spread between the trawl doors was monitored using Scanmar distance sensors, all sensors being configured and viewed through a Scanmar Scanbas system.

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

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

2.4.3 Oceanographic data collection

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

2.4.4 Marine mammal and seabird observations

2.4.4.1 Marine Mammal sighting survey

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

During cetacean observations, watch effort was focused on an area dead ahead of the vessel and 45^{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.

2.4.4.2 Seabird sighting survey

A standardized line transect method with sub-bands to allow correction for species detection bias and ‘snapshots’ to account for flying birds was used (following recommendations of Tasker *et al.* 1984; Komdeur *et al.*1992; Camphuysen *et al*. 2004), as outlined below.

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

The seabird observation platform was the wheelhouse deck, which is 10.5m above the waterline and provided a good view of the survey area. The survey area was defined as a 300m wide band operated on one side (in a 90° arc from bow to beam) and ahead of the ship. This survey band was sub-divided (A = 0-50 m from the ship, B = 50-100 m, C = 100-200 m, D = 200-300 m, E > 300 m) to subsequently allow correction of differences in detection probability with distance from the observer. A fixed-interval range finder (Heinemann 1981) was used to periodically check distance estimates. The area was scanned by eye, with binoculars used only to confirm species identification.

All birds seen on the water within the survey area were counted, and those recorded within the 300 m band, were noted as 'in transect'. All flying birds within the survey area were also noted, but only those recorded during a 'snapshot' were regarded as 'in transect'. This method avoids overestimating bird numbers in flight (Tasker *et al*. 1984). The frequency of the snapshot scan was ship-speed dependent, such that they were timed to occur at the moment the ship passed from one survey block (300 m x 300 m) to the next. Survey time intervals were set at 5 minutes. Additional bird species observed outside the survey area were also recorded and added to the species list for the research cruise, but these will not be included in maps of seabird abundance or density.

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

The daily total count data per day for each species is presented along with the daily survey effort. It is envisaged that this data will be analyzed in the future and the seabird abundance (birds per km traveled), and seabird density (birds per km^2) will be mapped per 1⁄4 ICES rectangle (15' latitude x 30' longitude), allowing comparison to the results of previous seabird surveys in Irish waters (e.g. Hall *et al*. in press, Mackey *et al*. 2004, Pollock *et al*. 1997). Through further analysis, species-specific correction factors will be applied to birds observed on the water. It is also hoped to combine this analysis with the results of the cetacean observation and acoustic survey. The binomial species names for the birds recorded are presented in the species accounts.

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

2.5 Analysis methods

2.5.1 Echogram partitioning

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

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

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

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

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

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

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

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

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

2.5.2 Abundance estimate

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

3 Results

3.1 Celtic Sea herring stock

3.1.1 Herring biomass and abundance

Total herring biomass (TSB) and spawning stock biomass (SSB) by survey strata are provided in Table 3. The biomass presented below was determined using Pass 1 (core survey) data representing the largest geographical area surveyed.

Herring	Abund ('000)	Biomass (t)
Total stock	106,900.0	2,244.5
Spawning stock	112.0	9.2

3.1.2 Herring distribution

A total of 21 trawl hauls were carried out during the survey (Figure 1). Of the 21, 9 contained herring of varying proportions (Table 2).

Core Surveys

Two core surveys were carried out; Pass 1 and Pass 2. A total of 27 echotraces were identified as herring during both passes (Pass 1: 12, Pass 2: 15). In general, the wider survey area was dominated by low level observations of immature, 0-wr (winter ring) herring made up of individuals of 15cm or less (Figure 4). These Immature 0-wr fish were most frequently encountered as mixed fish scattering layers also containing sprat. (Figure 8b) The distribution of herring occurred as two patches, firstly in coastal waters from Cork Harbour eastwards to Helvick. Secondly in offshore waters around the 'Smalls' area and further east (Figure 2). Offshore aggregations were mainly composed 0-wr and to a lesser extent 1-wr fish (17-19 cm).

One aggregation, observed during Pass 2 in the southwest was composed of 2-wr fish ranging from 19-22 cm (Figure 8a). However, the size of the aggregation was small and contributed little to the overall SSB. This was the only aggregation observed during the core surveys to contain mature herring.

In terms of effort, acoustic sampling in core areas was comparable to 2016-2018.

Adaptive Surveys

Five adaptive surveys were conducted; two offshore and three inshore (Figure 1). Of which, two were found to contain herring. Three temporally spaced (19th, 21st, 22-23rd October) individual inshore surveys were carried out covering inshore waters out to 8 nmi from Helvick Head to the Old Head of Kinsale. Survey effort was inter-laced both with the Core surveys and also with successive adaptive effort to ensure comprehensive coverage of the ground. Only one of the three surveys yielded a low abundance of herring (Figure 4).

Two offshore adaptive surveys were carried out on the ‘Smalls’ grounds. From this effort, one survey yielded the largest herring observed during the survey, albeit in low number and are thought to be a component of the mature migratory component of the stock (Figure 4 & 8c, Smalls 2).

3.1.3 Herring stock composition

A total of 263 herring were aged from survey samples, in addition to 338 length measurements and 356 length-weights. Herring age samples ranged from 0-5 winter-rings (Figures 4 & 5, Tables 3 & 4). Length at age and maturity by strata are presented in Figure 1-3 in the Appendix.

Core survey

The Pass 1 survey represents the 2019 estimate based on the largest stratum area surveyed and follows the procedure adopted in 2017. Pass 1 represents a total biomass of 2,244.5 t and a total abundance of 106,900,000 individuals. Age composition of Pass 1 was dominated by immature 0-wr and 1-wr fish, when combined accounted for 99.5% of the TSB and TSN respectively. The breakdown of cohort structure is dominated by 0-wr fish made up 65.4% of TSB and 81.4% of TSB compared with 34.1% of TSB and 18.3% of TSN for 1-wr fish.

Mature fish observed during Pass 1 were composed of 1-wr fish (a total of 0.3% of which were determined as mature) and 2-wr fish (67% mature) which combined totalled 9.2 t of biomass and 112,000 individuals (Appendix, Figure 1).

Immature fish accounted over 99.6% (2,235.3 t) of the 2,244.5 t TSB estimate.

Adaptive surveys

Of the five adaptive surveys carried out, two were found to contain herring; one inshore and one offshore. In total, three inshore surveys were carried out with one yielding herring. This survey was carried out from Helvick Head in the east to the old Head of Kinsale in the west. The TSB survey was considered negligible (26 t).

Two offshore replicate surveys were carried out in the Smalls region, one of which yielded 825 t of herring of mixed age structure (0-5 wr). The age composition of herring was dominated by 2-wr fish representing 49% of biomass and 35% of total abundance. Ranked second were 0-wr fish (20% biomass, 50% abundance) and third were the 1-wr fish (15% and 9.6% respectively). Older cohorts containing fish of 3, 4 and 5-wr combined contributed 13% of total biomass and 4.2% of total abundance for this strata (Smalls #1).

3.2 Other pelagic species

3.2.1 Sprat

Sprat	Abund ('000)	Biomass (t)
Total stock	10,344.0	60,608.1

Sprat were found widely distributed throughout the survey area and sampled in all hauls (Figure 6, Table 2). In total, 4,896 individual length measurements and 2,100 length/weight measurements were recorded. Mean length was 9.2 cm and mean weight was 5.9 g (9.3 cm and 7.0 g in 2018). Individuals ranged from 5.5 to 14.0 cm in length and 1 to 19 g in weight. Biomass and abundance by survey strata is presented in Table 5 and the survey time series in Table 6.

Sprat estimate for 2019 (Pass 1) is 60, 608 t and 10,344,000 individuals.

A total of 612 (505 in 2018) individual sprat echotraces were identified in total. During core surveys this related to Pass 1: 226 and Pass 2: 220. Distribution was comparable with recent years with an increased abundance in the eastern survey area that was consistent across both passes. This more eastern distribution was sprat in also noted during the UK Peltic survey (J. Vanderkooij, pers. comm.).

Offshore areas, particularly around the Smalls were found to contain some very high density sprat aggregations (Figure 8d). Sprat distribution was found to be associated with areas where the seasonal thermocline had already been eroded. Offshore areas where the thermocline was still evident (south of 51°30N and east of 09ºW) saw fewer sprat schools with the except of the Celtic Deep region where tidal forcing prevents the existence of stratified waters (Figure 6 & 11).

3.3 Oceanography

A total of 35 CTD stations were carried out across the survey area. Surface plots of temperature and salinity are presented using 5 m and 20 m depth profiles (Figures 9 & 10), while profiles for 60 m and near bottom profiles are overlaid with sprat and herring NASC data respectively (Figures 11 & 12).

Horizontal plots of temperature and salinity at 5 and 20 m depths showed conditions were relatively uniform for surface waters above the thermocline (Figures 9 &10). Waters to the north of 51ºN and east of 7ºW appear fully mixed with no evidence of the seasonal thermocline, as compared to elsewhere where the thermocline was still evident down to c.45m (Figures 11 & 12).

From surface waters down to 20m, a frontal temperature boundary exists around 9ºW, with cooler waters to the west and notably warmer water to the east with a range difference of 2.4ºC (range 12.7 to 15.1ºC). In deeper waters (60m to bottom), the warmer profile extends to the bottom (3-5m from sea floor) in the north-eastern region of the survey area in the southern Irish sea. Forced tidal mixing of the water column in the

Celtic Deep area ensures all but a temporary thermocline between monthly tidal phases (O'Donnell, *unpublished data*).

The distribution of sprat within the eastern survey area appears to be associated with areas where the thermocline has been eroded and waters are fully mixed and could be linked to increased feeding opportunity at boundary fronts (Figure 11). In the western area (west of 8ºW), sprat distribution occurs in inshore waters with reduced salinity from riverine input and are dominated by the cooler Atlantic water. Herring distribution relative to hydrographic conditions is more difficult to determine given the low occurrence of schools. For the eastern are around the Celtic Deep (Figure 12), the presence of herring was most notable on thermal boundary fronts.

3.4 Marine mammal and seabird observations

3.4.1 Marine mammal abundance and distribution survey

Survey effort

The cetacean survey was conducted from the 10/10/19 to the 28/10/19 using a single cetacean observer located in the Crow's nest, 17 m above sea level. To prevent observer fatigue and optimise the validity of the data, regular breaks were taken throughout each survey day. In total, 107 hours and 27 minutes of survey effort was conducted over the course of CSHAS 2019. In total, 103 hours and 50 minutes of survey effort were conducted using a line transect methodology, while 1 hours and 23 minutes of effort were conducted using the point sampling methodology. A further 2 hours and 13 minutes of effort were conducted as a casual watch.

Environment

The Cybertracker (http://www.cybertracker.org/) data collection software package (Version 3.501) was used to collect all positional, environmental and sightings data, and save it to a Microsoft Access database. Positional data was collected using a portable GPS receiver with a USB connection and recorded every 5 seconds.

Environmental data was timestamped and recorded with GPS data at the beginning and end of each line transect. Environmental data was recorded at least every 15-30 minutes, or sooner if there was a change in environmental conditions. Environmental data recorded included; wind speed, wind direction, sea state, swell, visibility, cloud cover and precipitation. All data entry was time stamped by Cybertracker and saved in the Access database.

Sightings report

A total of 204 sightings, were recorded throughout the survey. This includes 145 primary sightings, 38 sightings recorded as auxiliary sightings, 20 sightings recorded as incidental sightings, and 1 re-sighting of previously encountered individuals. From the total 204 sightings, marine mammals accounted for 163 sightings. The marine mammal sightings included; 1 whale species, 1 dolphin species, 1 porpoise species, 1 seal species and a number of sightings which could not be identified to species level. The remaining 41 sightings consisted of other marine megafauna.

Of the 204 sightings, 191 were recorded while conducting line transects, 1 sighting was recorded while conducting point sampling, while the remaining 12 sightings were recorded off survey effort. A list of the species encountered can be seen in Tables 7 & 8, and the distribution of the sightings can be seen in Figure 13.

Common dolphins (Delphinus delphis) were the most frequently encountered and most abundant species accounting for 141 sightings (69.1% of all sightings) and comprising of 1672 individuals in total (52.2% of all encountered individuals.)

Bluefin tuna (Thunnus thynnus) were the most frequently encountered species of marine megafauna excluding marine mammals, and the second most frequently observed species overall. Bluefin tuna were encountered on 36 occasions, accounting for 17.6% of all sightings. These sightings consisted of a total of 1,422 individuals (44.4% of all encountered individuals).

Large baleen whales were encountered on a number of occasions. Fin whales (Balaenoptera physalus) were recorded on 3 occasions (1.5% of all sightings) and totalled 3 individuals (0.1% of individuals). Other encounters with large baleen whale could not be reliably identified to species, these included 2 sightings identified as Balaenoptera sp. (1.0% of all sightings) and 5 sightings identified as Mysticeti sp. (2.5% of all sightings).

The grey seal (Halichoerus grypus) were sighted on 3 occasions (1.5% of all sightings) with each sighting comprising a single individual.

An additional 6 sightings of Portuguese man o' war (Physalia physalis) were also recorded during survey effort, their distribution can be seen in Figure 13.

3.4.2 Seabird abundance and distribution survey

In total, 117 hours and 33 minutes of survey effort was conducted over the course of CSHAS 2019. In total, 96 hours and 9 minutes of survey effort were conducted using a line transect methodology, while 15 hours and 42 minutes of effort were conducted using the point sampling methodology. A further 15 hours and 41 minutes of effort were conducted as a casual watch.

A total of 4,219 seabird sightings were recorded throughout the survey, totalling 28,110 individuals. In total, 12,476 seabirds were recorded as “in transect”, while 15,634 were recorded “off transect”. The species encountered included 32 species from 9 families (Table 9). A further 25 sightings of terrestrial birds were also recorded, comprising of 85 individuals (Table 10).

Guillemot (Uria aalge) were the most frequently sighted and the most abundant species accounting for 1331 sightings (31.5% of all sightings) and comprising of 7027 individuals in total (25% of all encountered individuals.) Of these, 6,095 individuals were recorded as ‘in transect’.

Kittiwake (Rissa tridactyla) were the third most frequently observed species accounting for 623 sightings (14.8% of all sightings), however, they were the second most abundant species comprising of 7,001 individuals in total (24.9% of all encountered individuals.) Of these, 2555 individuals were recorded as ‘in transect’.

Gannets (Morus bassanus) were the second most frequently sighted and the third most abundant species accounting for 861 sightings (20.4% of all sightings) and comprising of 6,903 individuals in total (24.6% of all encountered individuals.) Of these, 1,723 individuals were recorded as ‘in transect’.

Fulmar (Fulmarus glacialis) were the fourth most frequently sighted and the fourth most abundant species accounting for 403 sightings (9.6% of all sightings) and comprising of 2,605 individuals in total (9.3% of all encountered individuals.) Of these, 496 individuals were recorded as ‘in transect’.

A number of terrestrial species were also recorded during the survey including 2 sightings (totalling 31 individuals) of redwing (Turdus iliacus) a ring ousel (Turdus torquatus), and a pair of tufted duck (Aythya fuligula).

4 Discussion and Conclusions

4.1 Discussion

The objectives of the survey were carried out successfully and as planned. No weather induced downtime was recorded. Planned area coverage was achieved and exceeded, with additional replicate strata added, comprehensive trawl sampling and off-transect scouting around the Trench area.

Geographical coverage was comparable to 2018 (-3%), with acoustic sampling effort (miles covered) increased by 25%. Offshore hotspots were covered comprehensively, including the western Celtic Deep and Trench area. As the offshore fishery had closed by the time the survey was active no real time effort data was available. However, earlier searching effort carried out by the commercial herring fleet substantiated survey observations regarding the lack of aggregations overall.

Immature 0-group herring were observed across the survey area, albeit in low numbers and as observed in 2018. Overall, the contribution of 0-group herring accounts for over 65% of the total stock abundance for the Pass 1 estimate (and 81% of abundance). Combined, the proportion of immature fish in the Pass 1 estimate is 99.6% of total biomass and 99.9% of total abundance (abundance CV 55%).

The presence of mature fish was low overall, both from the official estimate (9.2 t, Pass 1) and adaptive effort (Smalls #1 adaptive survey: 353 t). Early indications of the potential of a new emerging year class first identified during this survey in 2018 as 0-wr were somewhat short lived. The presence of this year class, appearing now 1-wr fish, during the WESPAS survey in June 2019 was encouraging (O'Donnell *et.al.* 2019). This 1-wr year class was well represented in catches during the early part of the fourth quarter fishery before it was closed.

The absence of the offshore migratory component of the stock within the wider survey area cannot be attributed to containment as good area coverage was attained in the Celtic Sea. Mature fish did appear on the inshore grounds during and after the survey albeit in low numbers. However, immature fish (0 and 1-wr fish) still made up a significant proportion of these landings and warranted the main fishery remained closed. During the survey, as the directed fishery was closed, several catch samples came from by-catches of herring taken during the inshore sprat fishery along the south coast. Post the survey, catch samples came from the directed herring sentinel fishery.

Known sources of error within acoustic survey derived estimates are described as random and systematic and are associated with survey design, fish behaviour and abundance estimation process. Acoustic surveys by design perform optimally when stocks are high and widely distributed within the survey area. The ability of the survey to perform reduces with decreasing standing stock biomass. Given the current low standing stock biomass the ability of the survey to provide quality estimates is therefore limited.

Sprat abundance remains relatively constant in the medium term time series and this year saw an increase in abundance primarily driven by increased occurrence of fish around the Small area.

4.2 Conclusions

- The stock was considered contained within the Celtic Sea survey area. No offshore herring or aggregations around the survey periphery or during extensive adaptive and off-track searching.
- Survey effort was increase by 25% in terms of transit miles covered within a comparable survey area.
- The 2019 TSB estimate (Pass 1) is 2,244.5 t and 106,900,000 individuals (CV 55%) and lower than the 2018 estimate (9,788.2 t and a total abundance of 213,491,000 individuals) given increased survey effort.
- The contribution of 0 and 1-winter ring fish from around the around Cork Harbour remains relatively constant, albeit in low background numbers.
- Immature fish from the official Pass 1 estimate represented over 99.6% of total biomass and 99.9% of total abundance (abundance CV 55%).
- The potential of a positive signal in recruitment first identified in October 2018 (CSHAS) and tracked in part in the summer of 2019 (WESPAS) were not observed in number during the 2019 CSHAS but did appear as a significant cohort in the early directed fishery and as by-catch within the inshore sprat fishery.
- Low numbers of mature herring were identified from two trawl hauls (one inshore and one offshore) and as so provide a limited view of the age structure of the mature stock and is again reflective of the low standing stock biomass.
- Observations during the survey are in agreement with the early commercial fishing effort regarding distribution of the stock. After a period of offshore searching the focus of the herring fishery moved to inshore waters.
- Given the current low standing stock biomass the ability of the survey to provide quality estimates is limited.
- Sprat biomass remains relatively consistent in the medium term estimates and was higher this year due to the increased density observed offshore.

5 Acknowledgements

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7 Tables and Figures

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

Echo Sounder System Calibration

Vessel : R/V Celtic Explorer		Date : 26.10.2018	
Echo sounder : ER60 PC		Locality : Ireland	
Type of Sphere : WC-38,1	TS Sphere: -42.40 dB (Corrected for soundvelocity	Depth(Sea flo 39 m	

Calibration Version 2.1.0.12

Comments:
CSHAS. Dunmanus Bay 26.10.18

Reference Target:

TS	-42.40 dB	Min. Distance	16.00 m
TS Deviation	5.0 dB	Max. Distance	19.50 m

Transducer: ES38B Serial No. 30227

Frequency	38000 Hz	Beamtype	Split
Gain	25.65 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	7.03 deg	Along. Beam Angle	6.86 deg
Athw. Offset Angle	-0.01 deg	Along. Offset Angl	0.00 deg
SaCorrection	-0.63 dB	Depth	8.80 m

Transceiver: GPT 38 kHz 009072033933 2-1 ES38B

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

Sounder Type:
EK60 Version 2.4.3

TS Detection:

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

Environment:

Absorption Coeff.	8.9 dB/km	Sound Velocity	1509.2 m/s

Beam Model results:

Transducer Gain =	25.65 dB	SaCorrection =	-0.66 dB
Athw. Beam Angle =	6.98 deg	Along. Beam Angle =	6.92 deg
Athw. Offset Angle =	-0.04 deg	Along. Offset Angle=	-0.05 deg

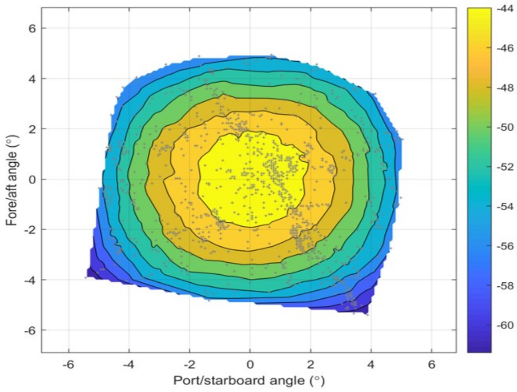
Data deviation from beam model:
RMS = 0.11 dB
Max = 0.33 dB No. = 82 Athw. = -2.9 deg Along = -2.2 deg
Min = -0.33 dB No. = 370 Athw. = 2.3 deg Along = -4.4 deg

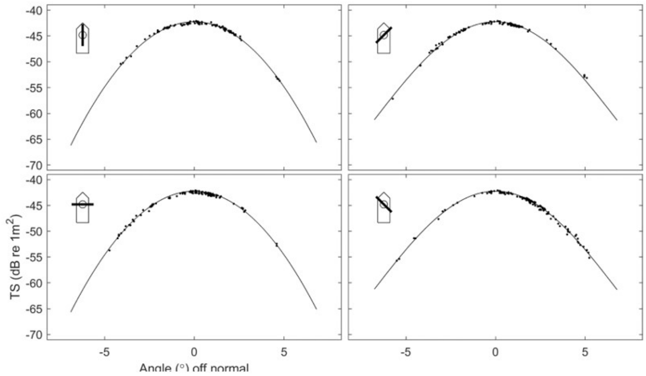
Data deviation from polynomial model:
RMS = 0.09 dB
Max = 0.25 dB No. = 82 Athw. = -2.9 deg Along = -2.2 deg
Min = -0.27 dB No. = 370 Athw. = 2.3 deg Along = -4.4 deg

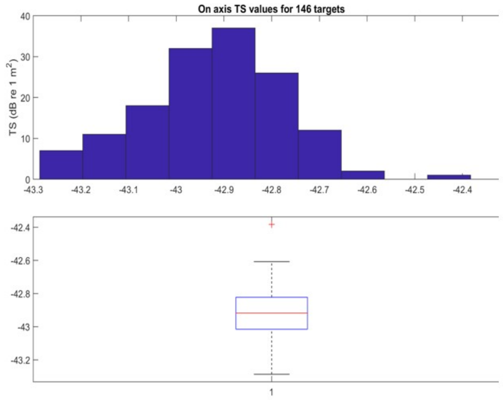
Comments :
Dunmanus Bay
Wind Force : 2 kn. **Wind Direction :** N degrees
Raw Data File: E:\CE18016_CSHAS 2018\Calibration\38 kHz Cal\CSHAS 2018-D20181026-T090459.raw
Calibration File: E:\CE18016_CSHAS 2018\Calibration\38 kHz Cal\Cal 38 kHz.txt

Calibration: Ciaran O'Donnell

Table 1. Calibration report cont.







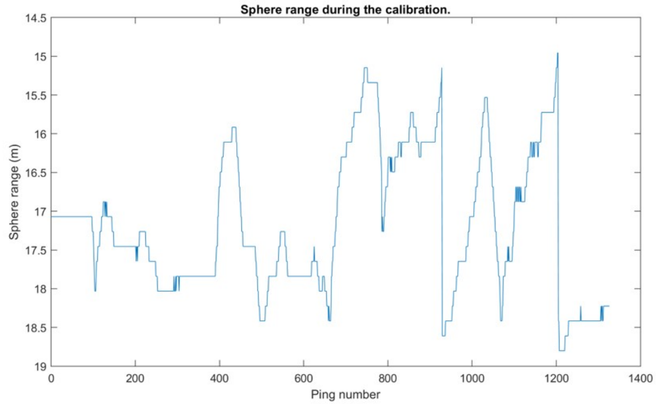


Table 2. Catch table from directed trawl hauls.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target btm (m)	Bulk Catch (Kg)	Herring %	Mackerel %	Scad %	Sprat %	Pilchard %	Others* %
1	10.10.19	51.66	-8.18	16:13	74	15	161.5	0.6	62.7	0.1	36.3		0.2
2	11.10.19	51.50	-7.97	09:37	85	20	77.7	2.5	1.7		94.6		1.2
3	11.10.19	51.76	-7.76	15:55	78	15	144.4	0.1	52.6		47.0	0.2	0.1
4	12.10.19	51.47	-7.54	09:29	78	20	137.8		5.4		93.9		0.7
5	12.10.19	51.94	-7.33	16:02	57	20	210.0		4.1		95.0	0.6	0.3
6	13.10.19	51.52	-7.11	08:38	73	20	270.0		38.1		61.0	0.8	0.1
7	13.10.19	51.71	-7.12	12:00	69	0-30	240.0		66.0		33.9		0.1
8	13.10.19	51.53	-6.90	20:31	77	0-35	600.0		0.4		96.7		2.9
9	15.10.19	51.59	-6.54	08:25	80	30	300.0	0.1	32.2	2.1	65.5		0.1
10	15.10.19	51.26	-6.56	13:37	79	0-25	32.6	60.3	0.3		9.8		29.6
11	15.10.19	51.49	-6.74	20:23	79	0	360.0				74.6		25.4
12	16.10.19	51.73	-6.26	15:20	85	30	54.0		5	1.2	71.41		22.2
13	17.10.19	51.44	-5.82	13:33	85	0	3.7		28.5	2.2	38.7	27.5	3.1
14	19.10.19	51.71	-8.00	03:32	50	0	120.0	0.3	0.2		89.1		10.4
15	19.10.19	52.04	-7.47	20:40	33	0-20	800.0	0.2	3.3		94.0		2.5
16	20.10.19	51.51	-6.66	17:02	80	0-25	195.0		29.8		69.5		0.8
17	21.10.19	52.12	-7.25	21:00	23	0-20	600.0	0.1	3.4		93.0		3.6
18	22.10.19	51.21	-7.25	16:07	90	0	240.0				96.8		3.2
19	23.10.19	51.63	-7.44	08:24	74	0	150.0		0.8		98.1		1.1
20	24.10.19	51.67	-8.31	17:30	47	10	540.0		14.8		52.0	11.2	22.0
21	27,10,19	51.29	-9.79	12:30	94	10	122.6	6.7	43.1		46.4		3.7

Table 3. Herring biomass and abundance by strata. Highlighted strata (Pass 1) presented as total stock biomass based on largest stratum area surveyed.

Strata	Name	Type	Area (nmi²)	Transects	TSN ('000)	TSB (t)	SSN ('000)	SSB (t)	CV (Abun)
1	Pass 1	Core	8643.9	13	106,900	2,244.5	112	9.2	55
2	Pass 2	Core	7715.3	24	64,482	1,765.9	4,361	312.5	56
3	Smalls 1	Adaptive	308.7	6	22,427	825.7	4,429	353.4	46
4	Smalls 2	Adaptive	280.9	4	-	-	-	-	-
5	Inshore_Helvick to Ballycotton	Adaptive	292.5	8	1,477	26	0	0	61
6	Inshore_Baginbun to Helvick	Adaptive	250.5	15	-	-	-	-	-
7	Inshore_Helvick to Old Head	Adaptive	375.0	20	-	-	-	-	-
	Total		17,866.8	90					

Table 4. Celtic Sea herring survey time series.

Season Age (wr)	2002 2003	2003 2004	2004 2005	2005 2006	2006 2007	2007 2008	2008 2009	2009 2010	2010 2011	2011 2012	2012 2013	2013 2014	2014 2015	2015 2016	2016 2017	2017 2018	2018 2019	2019 2020
0	0	24	-	2	-	1	2	239	5	0.1	31	3.8	0	0	0	0	109	87
1	42	13	-	65	21	106	63	381	346	342	270	697.6	41	0	125	0	56	19.5
2	185	62	-	137	211	70	295	112	549	479	856	291.4	117	40	21	6	16	0.1
3	151	60	-	28	48	220	111	210	156	299	615	197.4	112	48	43	3	27	-
4	30	17	-	54	14	31	162	57	193	47	330	43.7	69	41	40	7	6	-
5	7	5	-	22	11	9	27	125	65	71	49	37.9	20	38	36	5	0	-
6	7	1	-	5	1	13	6	12	91	24	121	9.8	24	7	25	4	0	-
7	3	0	-	1	-	4	5	4	7	33	25	4.7	7	6	5	1	-	-
8	0	0	-	0	-	1	-	6	3	4	23	0	17	5	6	1	-	-
9	0	0	-	0	-	0	-	1	-	2	3	0.2	1	0	0	0	-	-
Abundance	423	183	-	312	305	454	671	1,147	1,414	1,300	2,322	1,286	408	184	301	27	213	106.9
SSB ('000t)	41	20	-	33	36	46	93	91	122	122	246	71	48	25	30	4	8	0.009
CV	49	34	-	48	35	25	20	24	20	28	25	28	59.1	18.4	33	NA	49.6	55.0
Design	AR	AR	-	ARS	ARS	ARS	ARS	ARS	ARS	ARS	ARS	ARS	ARM	ARM	CRM	CRM	CRM	CRM

Table 5. Sprat biomass and abundance by strata.

Strata	Name	Type	Area (nmi²)	Transects	TSN ('000)	TSB (t)
1	Pass 1	Core	8643.9	13	10,343,946	60,608.1
2	Pass 2	Core	7715.3	24	7,428,264	42,787.7
3	Smalls 1	Adaptive	308.7	6	234,230	1,093.2
4	Smalls 2	Adaptive	280.9	4	1,417,976	6,617.8
5	Inshore_Helvick to Ballycotton	Adaptive	292.5	8	251,071	1,251.8
6	Inshore_Baginbun to Helvick	Adaptive	250.5	15	118,813	1,134.9
7	Inshore_Helvick to Old Head	Adaptive	375.0	20	295,838	1,883.7
	Total		17,867	90		

Table 6. Celtic Sea sprat survey time series. Based on 24hr survey effort.

Year	Abundance ('000s)	Biomass (t)
2004	5,646	50,810
2005	2,571	29,017
2006	-	-
2007	132	1,918
2008	540	5,493
2009	1,418	16,229
2010	-	-
2011	5,832	31,593
2012	4,589	35,114
2013	10,748	44,685
2014	9,152	54,826
2015	21,398	83,779
2016	8,171	42,694
2017	40,276	70,745
2018	6,934	47,806
2019	10,344	60,608

Table 7. Marine mammal sightings, counts and group size ranges for cetaceans sighted.

Common Name	Species name	No. of Sightings	No. of individuals	Group Size
Common dolphin	*Delphinus delphis*	141	1672	1-250
Harbour porpoise	*Phocoena phocoena*	3	6	1-3
Fin/ Blue/ Sei whale	*Balaenoptera physalus/ borealis/ musculus*	2	2	1
Fin whale	*Balaenoptera physalus*	3	3	1
Unidentified baleen whale	*Mysticeti sp.*	5	7	1-3
Unidentified Small Whale		1	1	1
Unidentified dolphin	*Delphinidae sp.*	5	66	1-50
Total		**160**	**1757**	

Table 8. Sightings summary of other marine fauna.

Common Name	Species name	No. of Sightings	No. of individuals	Group Size
Grey seal	*Halichoerus grypus*	3	3	1
Total		**3**	**3**	
Bluefin tuna	*Thunnus thynnus*	36	1422	3-250
Tuna sp.	*Thunnus sp.*	5	23	1-10
Total		**41**	**1445**	

Table 9. Totals for all seabird species recorded.

Common Name	Species name	No. of Sightings	No. of Individuals	In Transect	Off Transect
Arctic Skua	*Stercoratius parasiticus*	28	32	8	24
Arctic Tern	*Sterna paradisaea*	2	2	1	1
Balearic Shearwater	*Puffinus mauretanicus*	4	4	0	4
Black-headed Gull	*Larus ridibundus*	7	10	0	10
Common Gull	*Larus canus*	63	282	39	243
Common Tern	*Sterna hirundo*	2	3	1	2
Cormorant	*Phalacrocorax carbo*	3	3	0	3
Fulmar	*Fulmarus glacialis*	403	2605	496	2109
Gannet	*Morus bassanus*	861	6903	1723	5180
Great Black-backed Gull	*Larus marinus*	90	366	95	271
Great Northern Diver	*Gavia immer*	3	11	1	10
Great Shearwater	*Puffinus graves*	2	2	1	1
Great Skua	*Stercoratius skua*	139	205	42	163
Guillemot	*Uria aalge*	1331	7027	6095	932
Gull sp.	*Laridae sp.*	7	319	75	244
Herring Gull	*Larus argentatus*	35	103	15	88
Kittiwake	*Rissa tridactyla*	623	7001	2555	4446
Lesser Black-backed Gull	*Larus fuscus*	115	1320	142	1178
Little Auk	*Alle alle*	1	1	0	1
Long-tailed Skua	*Stercoratius longicaudus*	2	3	3	0
Manx Shearwater	*Puffinus puffinus*	42	77	32	45
Mediterranean Gull	*Larus melanocephalus*	6	7	3	4
Petrel sp.	*Hydrobatidae sp.*	1	1	0	1
Pomarine Skua	*Stercoratius pomarinus*	18	24	7	17
Puffin	*Fratercula arctica*	21	39	12	27
Razorbill	*Alea torda*	321	1027	507	520
Razorbill / Guillemot	*Alea torda / Uria aalge*	20	616	586	30
Red-throated Diver	*Gavia stellata*	1	1	0	1
Sabine's Gull	*Larus sabini*	2	2	1	1

Table 10. Totals of migrant terrestrial bird species recorded.

Common Name	Species name	No. of Sightings	No. of Individuals
Blackcap	*Sylvia atricapilia*	1	1
Brambling	*Fringilla montifringilla*	1	1
Buzzard	*Buteo buteo*	1	1
Common Scoter	*Melanitta nigra*	1	9
Fieldfare	*Turdus pilaris*	1	1
Grey Phalarope	*Phalaropus fulicarius*	2	2
Meadow Pipit	*Anthus pratensis*	6	11
Red-breasted flycatcher	*Ficedula parva*	1	1
Redwing	*Turdus iliacus*	2	31
Ring Ousel	*Turdus torquatus*	1	1
Shelduck	*Tadorna tadorna*	1	1
Snipe	*Gallinago gallinago*	1	1
Starling	*Sturnus vulgaris*	3	18
Tufted Duck	*Aythya fuligula*	1	2
Wheatear	*Oenanthe oenanthe*	1	1
Whimbrel	*Numenius phaeopus*	1	3
	Total	**25**	**85**

Longitude

100-200 m depth c

Total survey track = 3,742 nmi

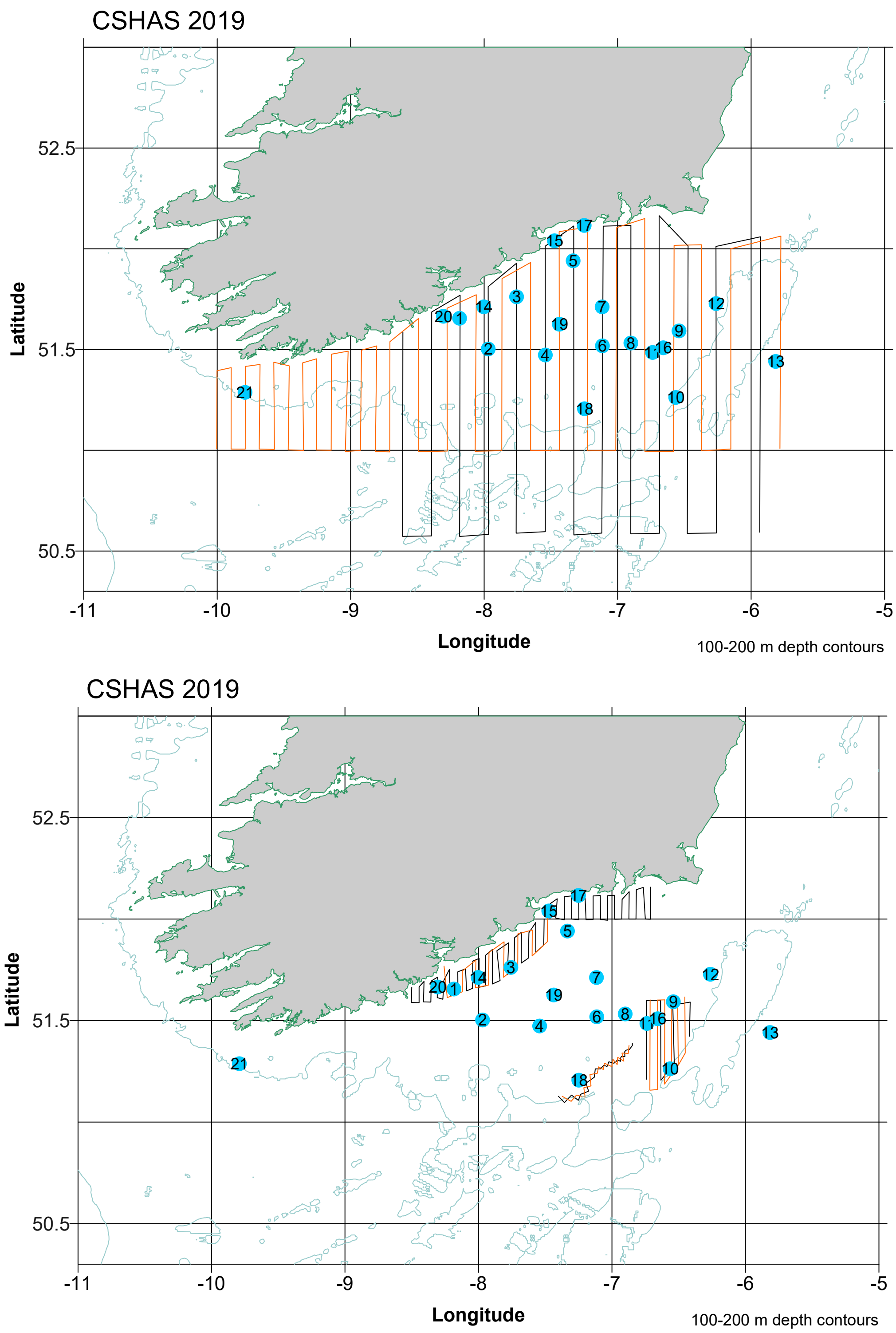


Figure 1. Top panel: Core replicate survey effort cruise tracks and numbered haul stations. (Pass 1: black track, Pass 2: orange track). Bottom panel: Adaptive survey effort mini surveys 1-6. Replicate coverage shown as orange track.

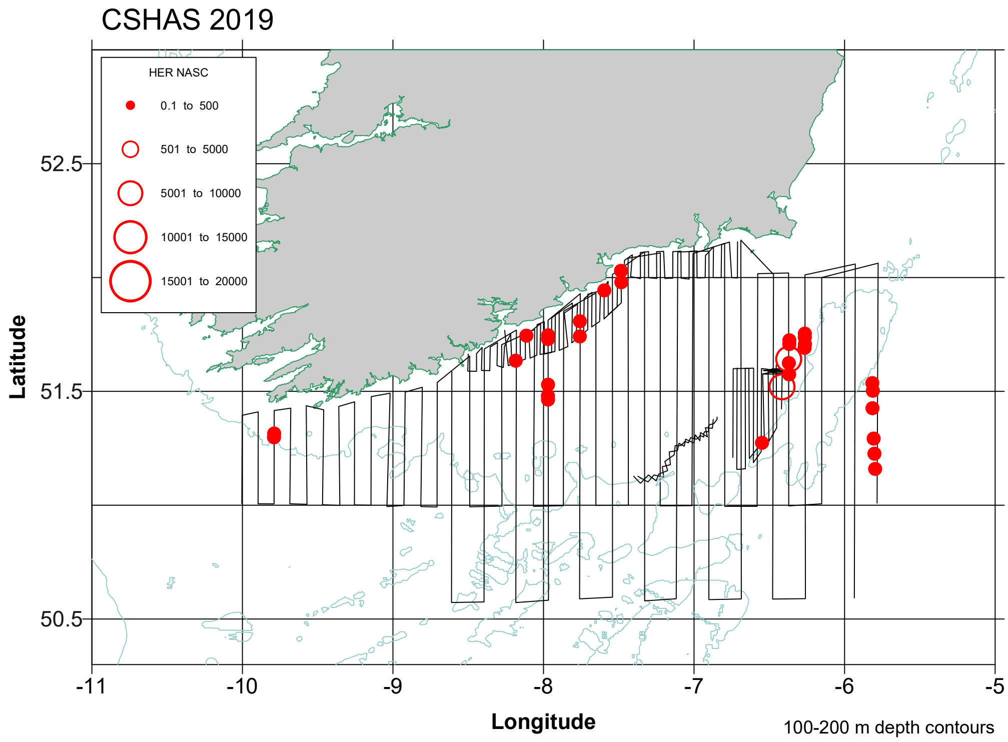


Figure 2. Herring NASC (Nautical area scattering coefficient) plot of herring distribution from combined survey effort.

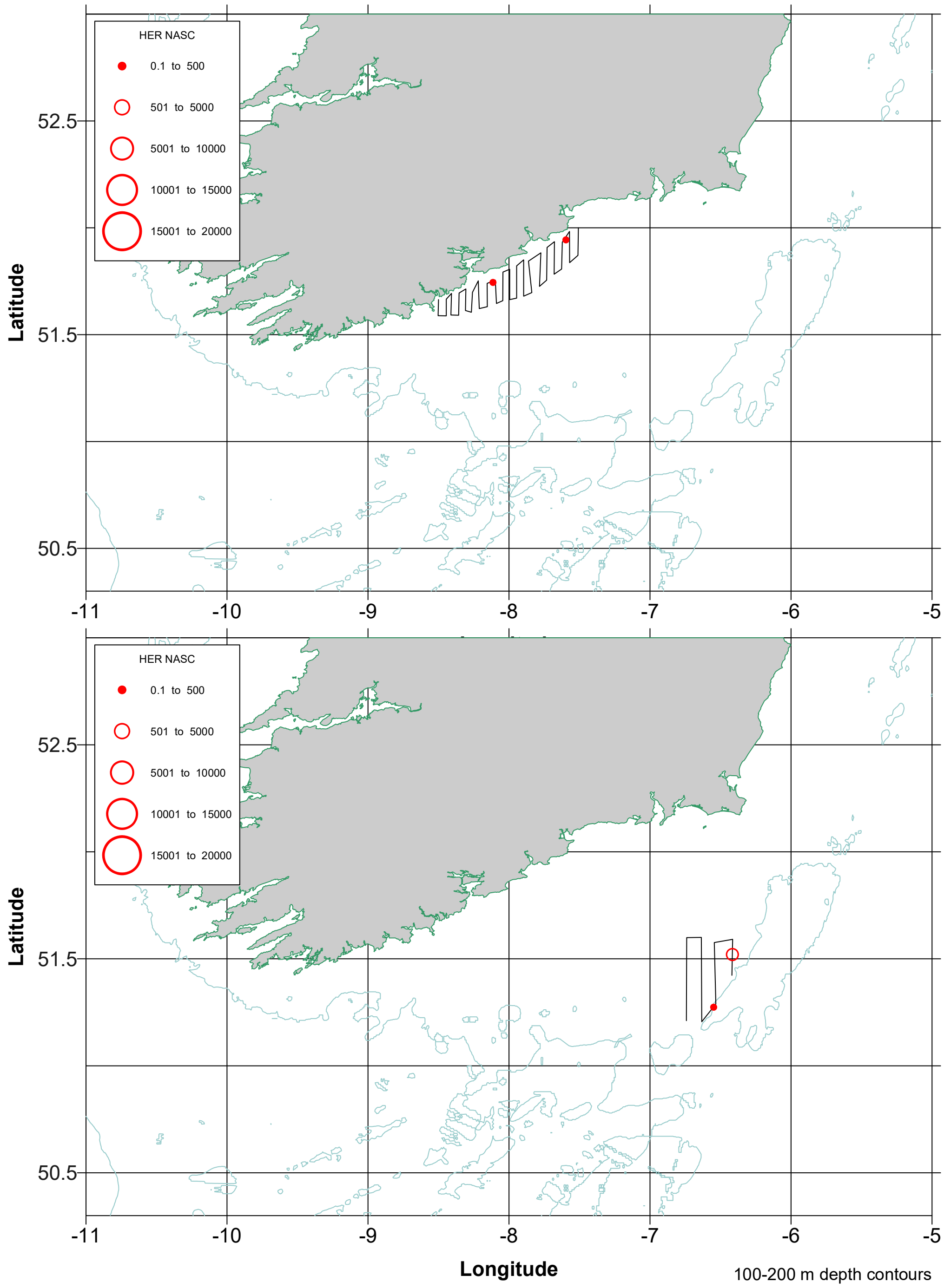


Figure 3. Herring NASC (Nautical area scattering coefficient) plot of the distribution from adaptive survey effort. Top Panel: coastal area; bottom panel: offshore area.

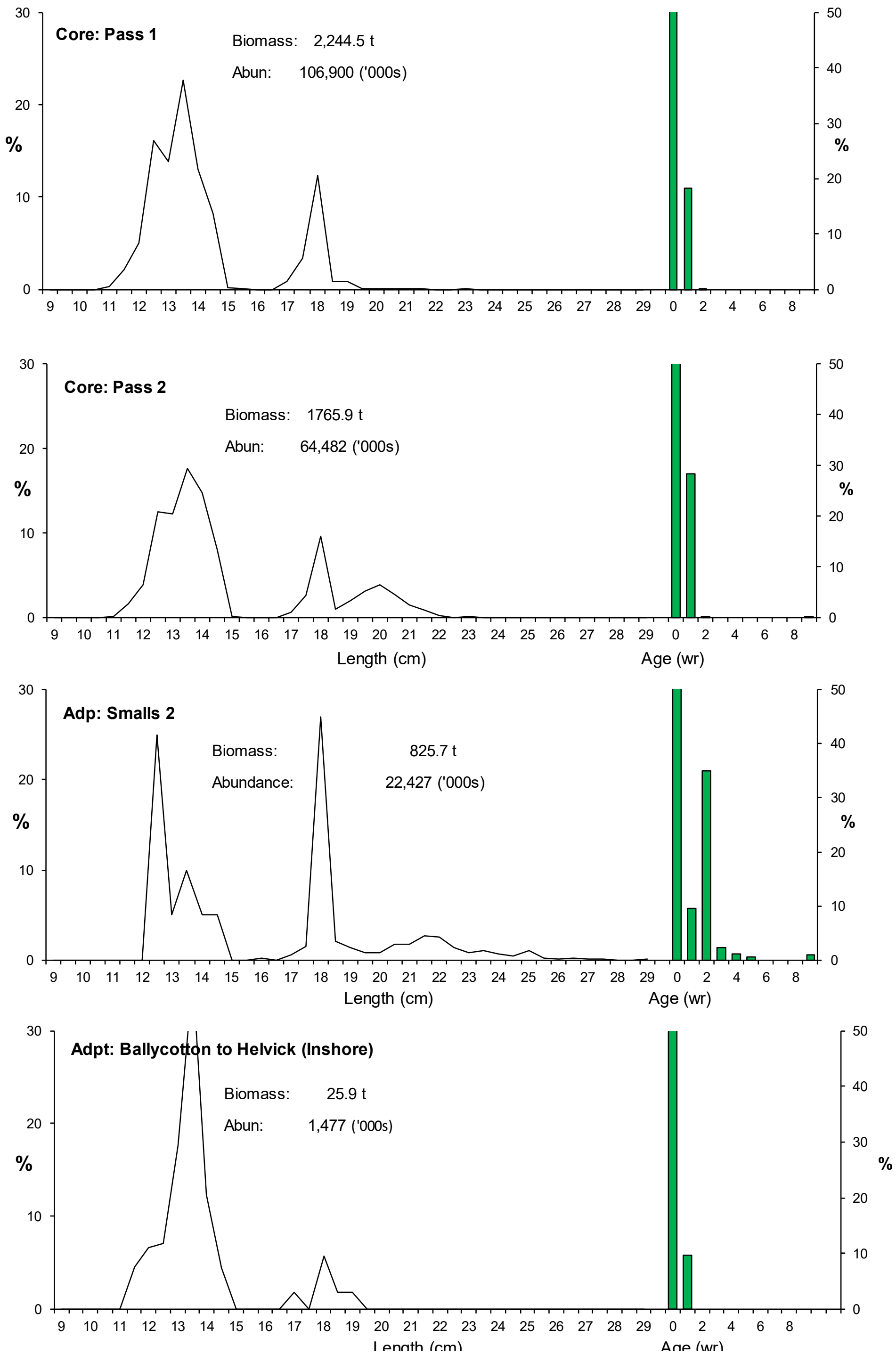


Figure 4. Age and length composition of herring from core and adaptive survey strata.

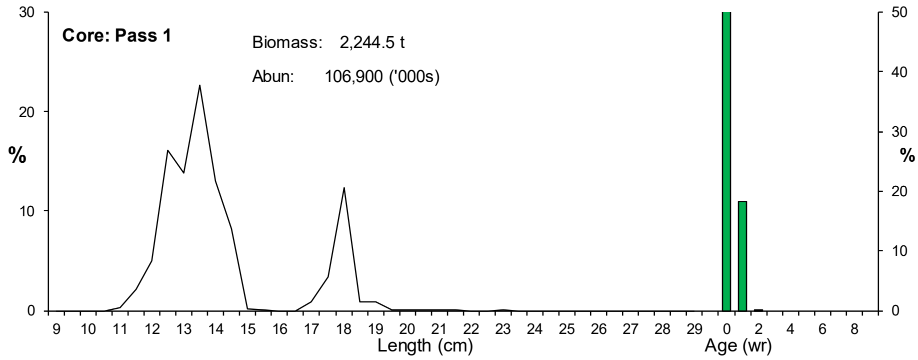


Figure 5. Age and length composition of 2019 stock estimate based on largest stratum area surveyed; Core survey Pass 1.

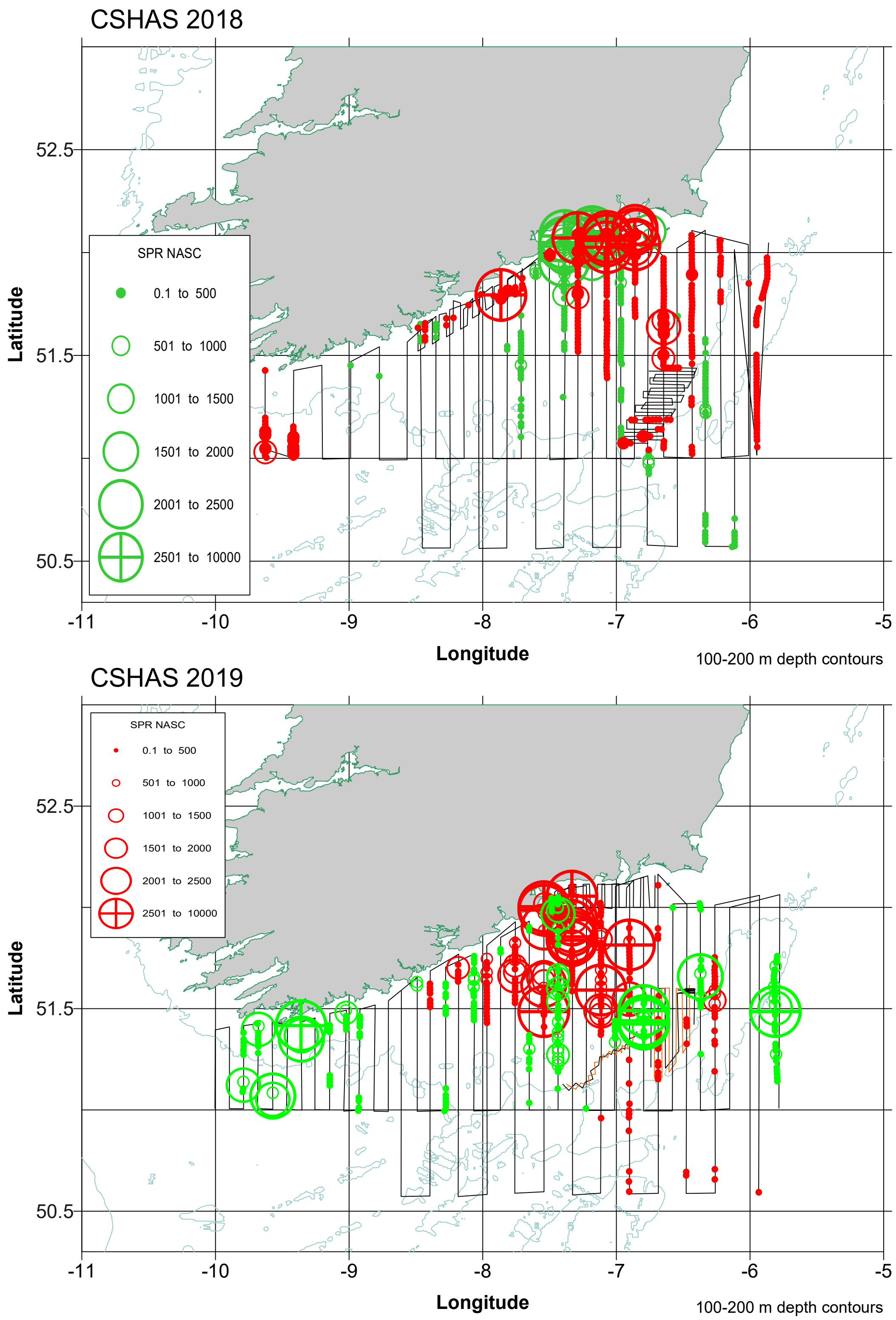


Figure 6. Sprat NASC (Nautical area scattering coefficient) plot of the distribution from replicate core survey effort. Green indicates Pass1 observations and red indicates Pass 2.

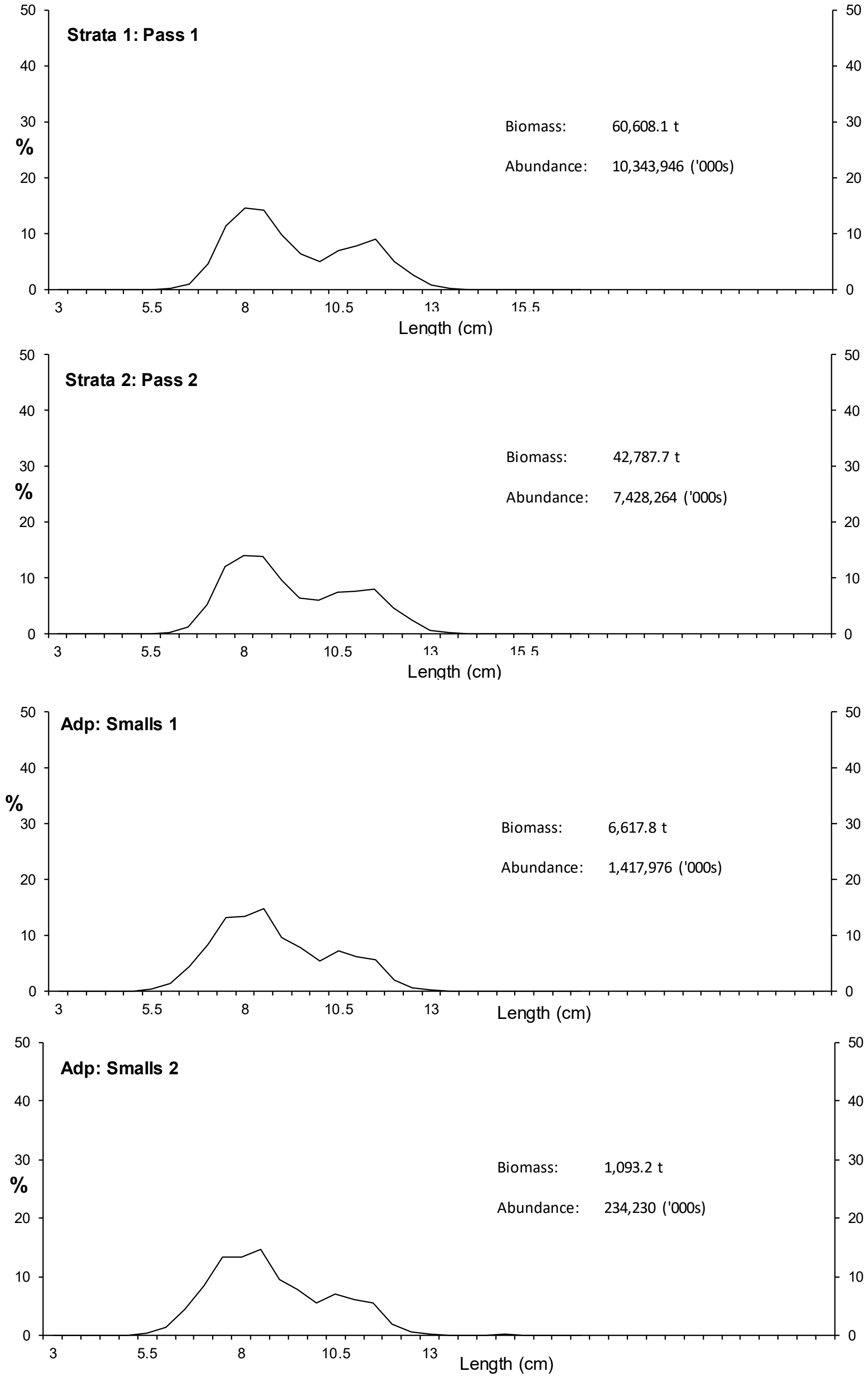


Figure 7. Length composition of sprat by strata and combined survey effort.

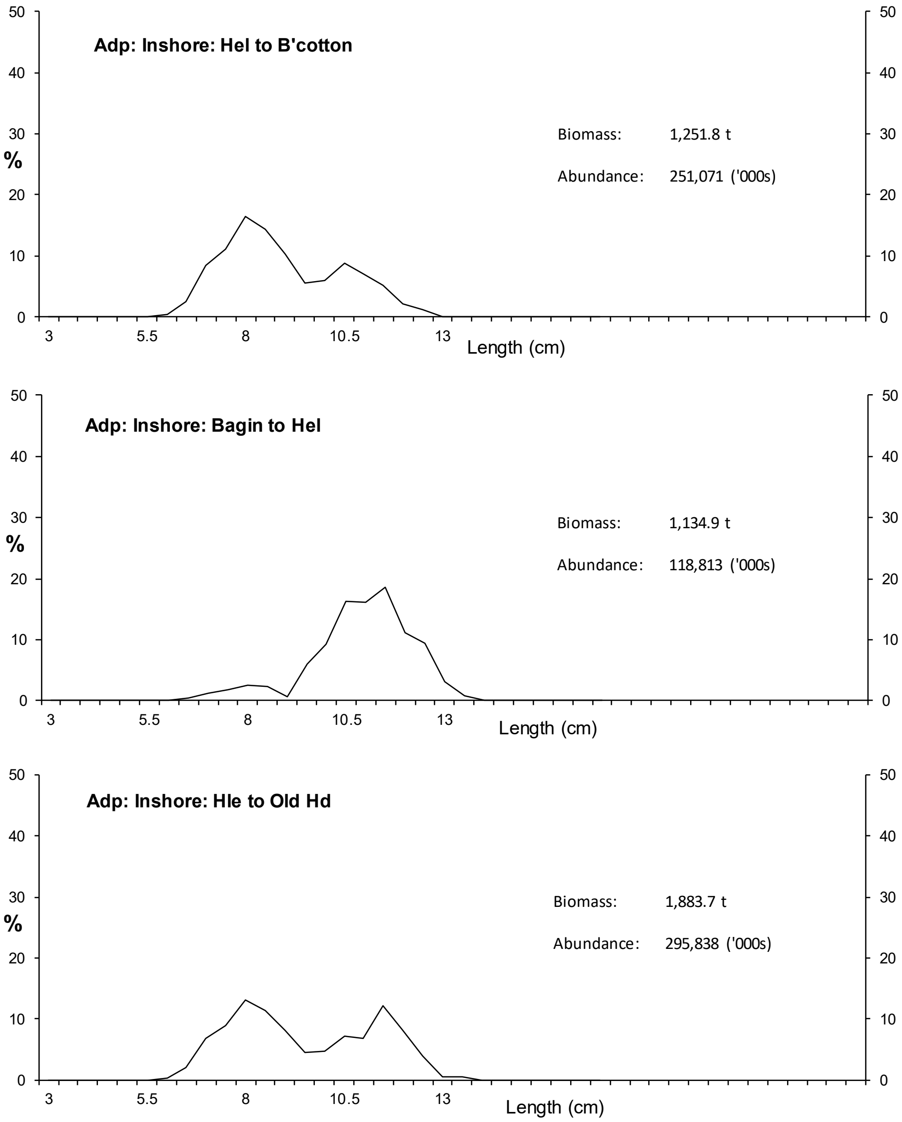
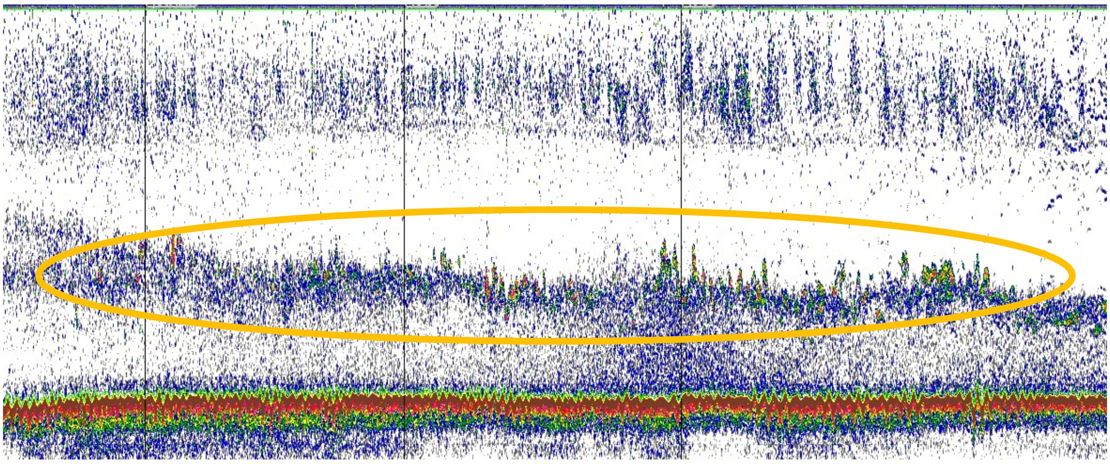
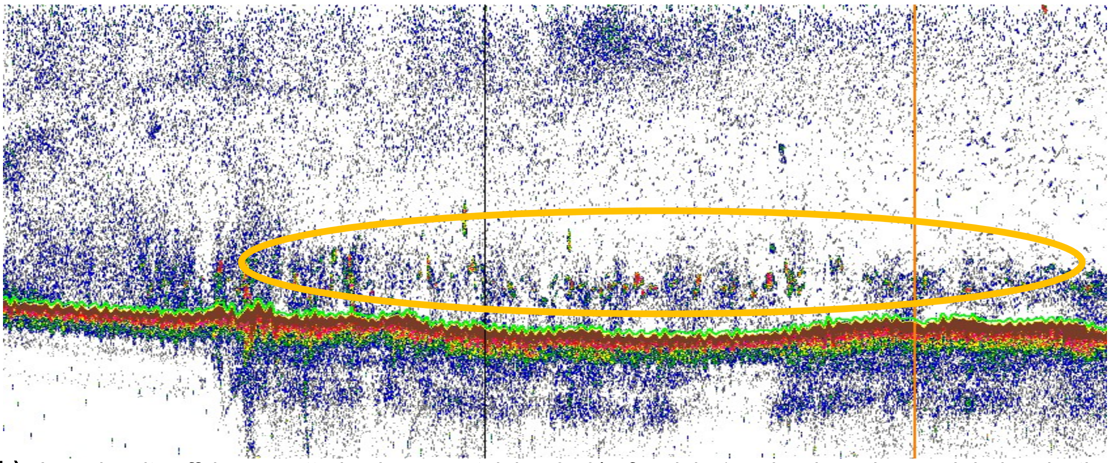


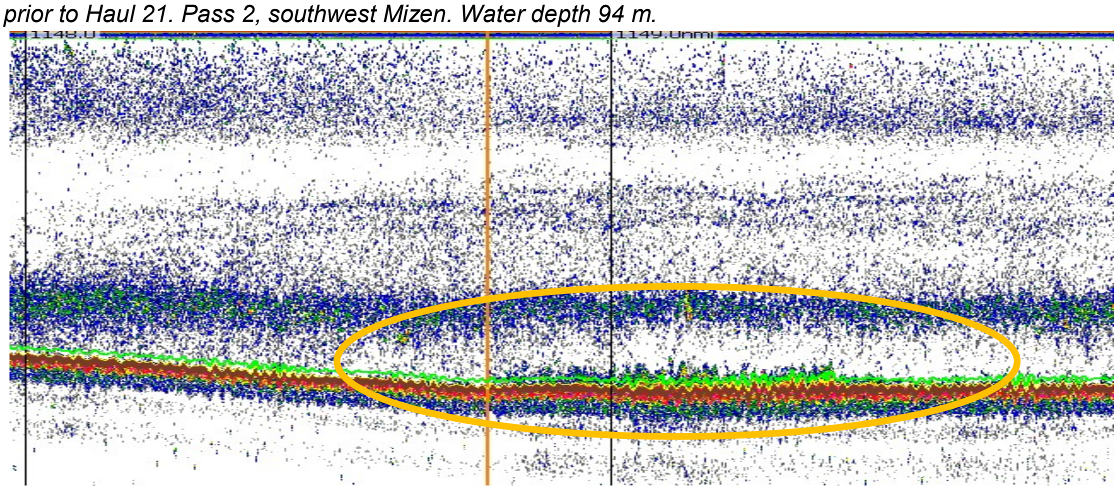
Figure 7. continued.



a). *Low density echotrace containing 2.5 % of 0 & 1-wr herring observed during daylight prior to Haul 02. Recorded inshore during Pass 1 south of Cork. Water depth 85 m*

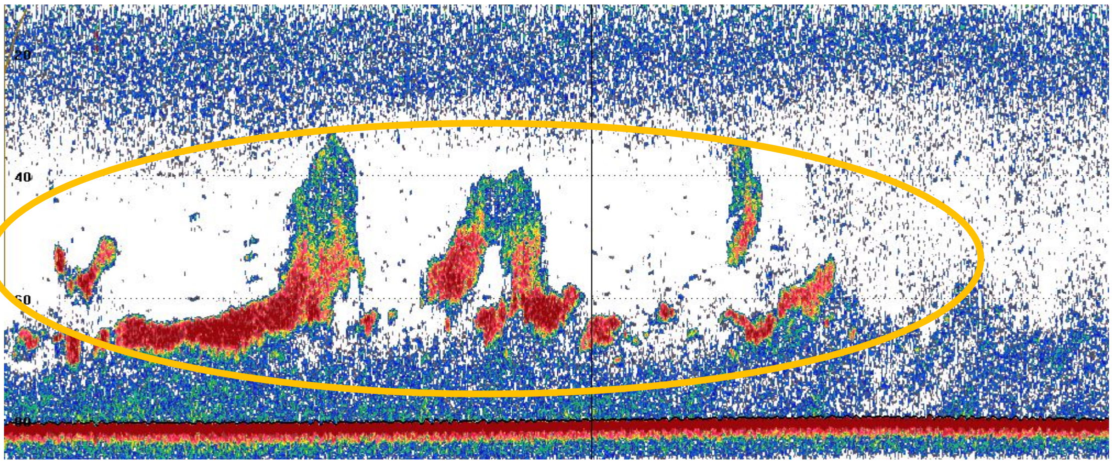


b). *Low density offshore scattering layer containing 6.7% of mainly 1-wr herring, observed during daytime prior to Haul 21. Pass 2, southwest Mizen. Water depth 94 m.*

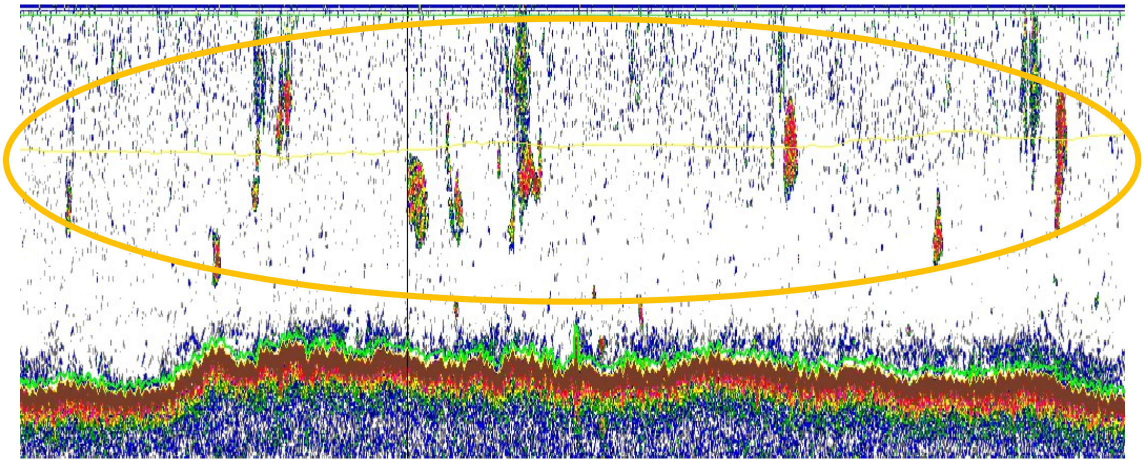


c). *Low density echotrace containing 60% herring by weight, observed during the daylight prior to Haul 10. Recorded during the 'Smalls' offshore adaptive survey. Water depth 79 m.*

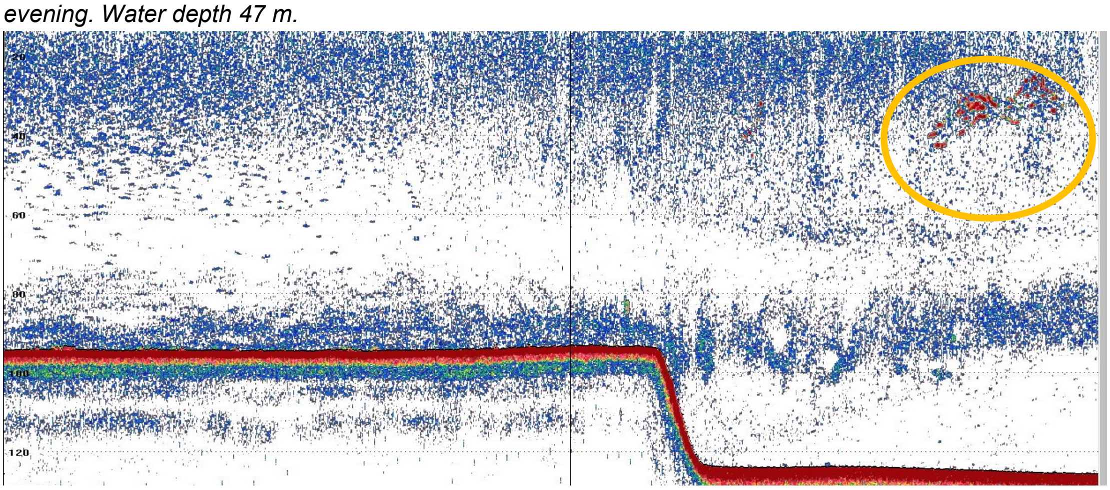
Figure 8. EK60 echograms (38 kHz) recorded prior to directed trawl stations.



d). *High density and extensive sprat echotraces observed during offshore adaptive survey around the 'Smalls', morning prior to Haul 09. Water depth 80 m.*



e). *High density echotraces containing sprat, pilchard and anchovy located outside Cork Haul 20, Early evening. Water depth 47 m.*



f). *Active feeding aggregation of bluefin tuna, recorded offshore during in daylight during 'Trench' scouting survey. Water depth is 126 m.*

Figure 8a-f. Continued

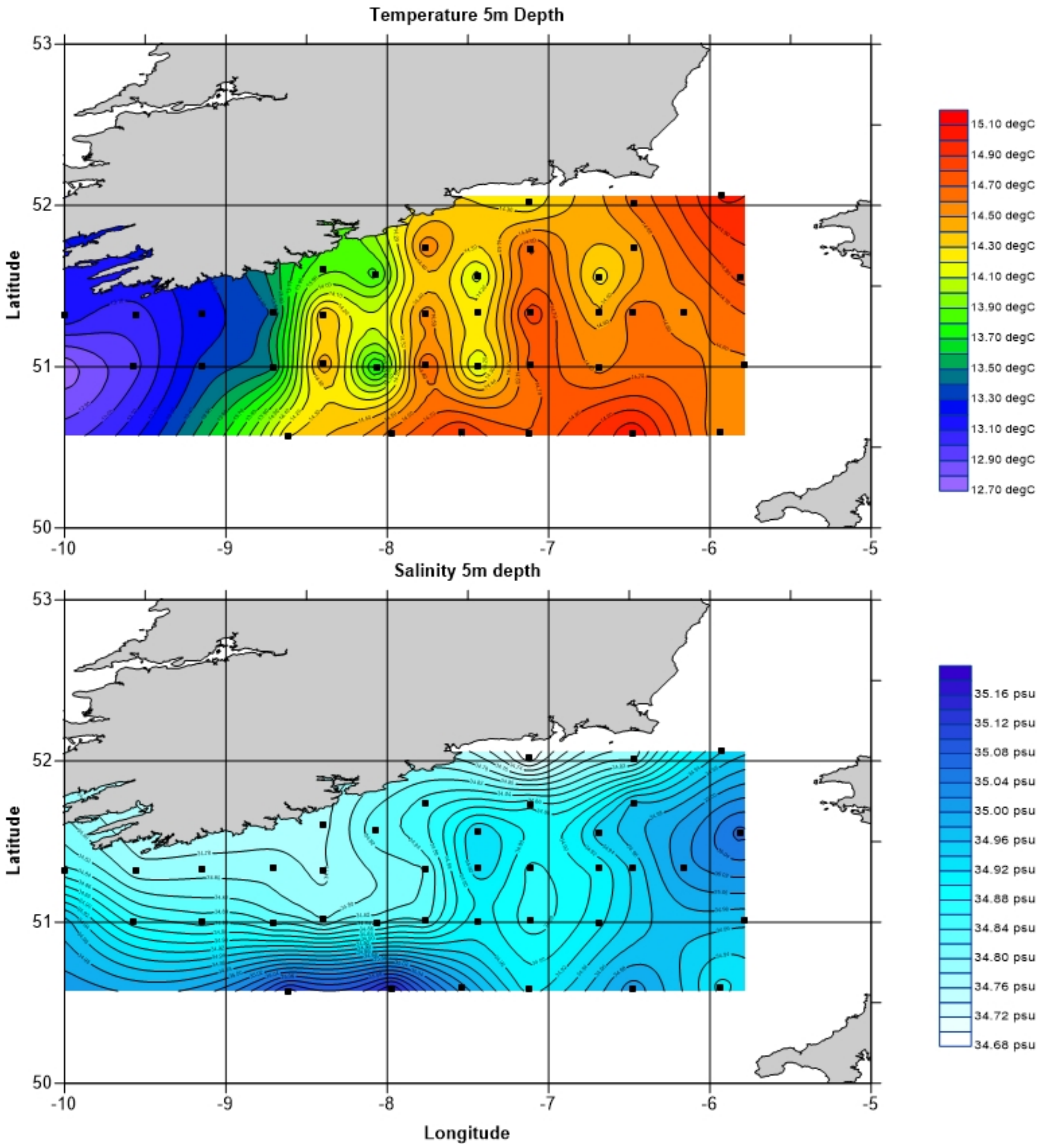


Figure 9. Surface (5 m) plots of temperature and salinity compiled from CTD cast data. Station positions shown as black circles (n=40).

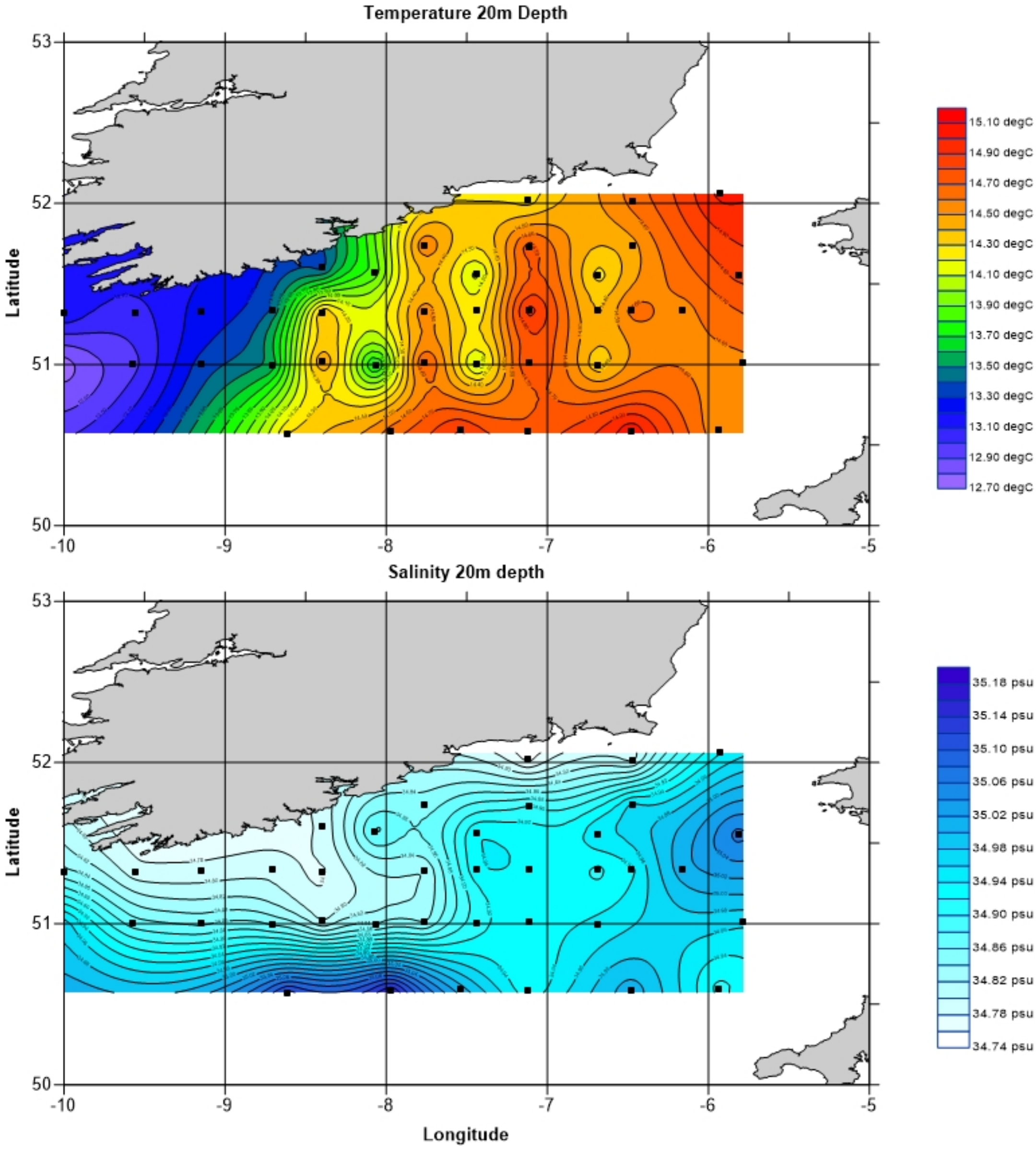


Figure 10. Surface (20 m) plots of temperature and salinity compiled from CTD cast data. Station positions shown as black circles (n=40).

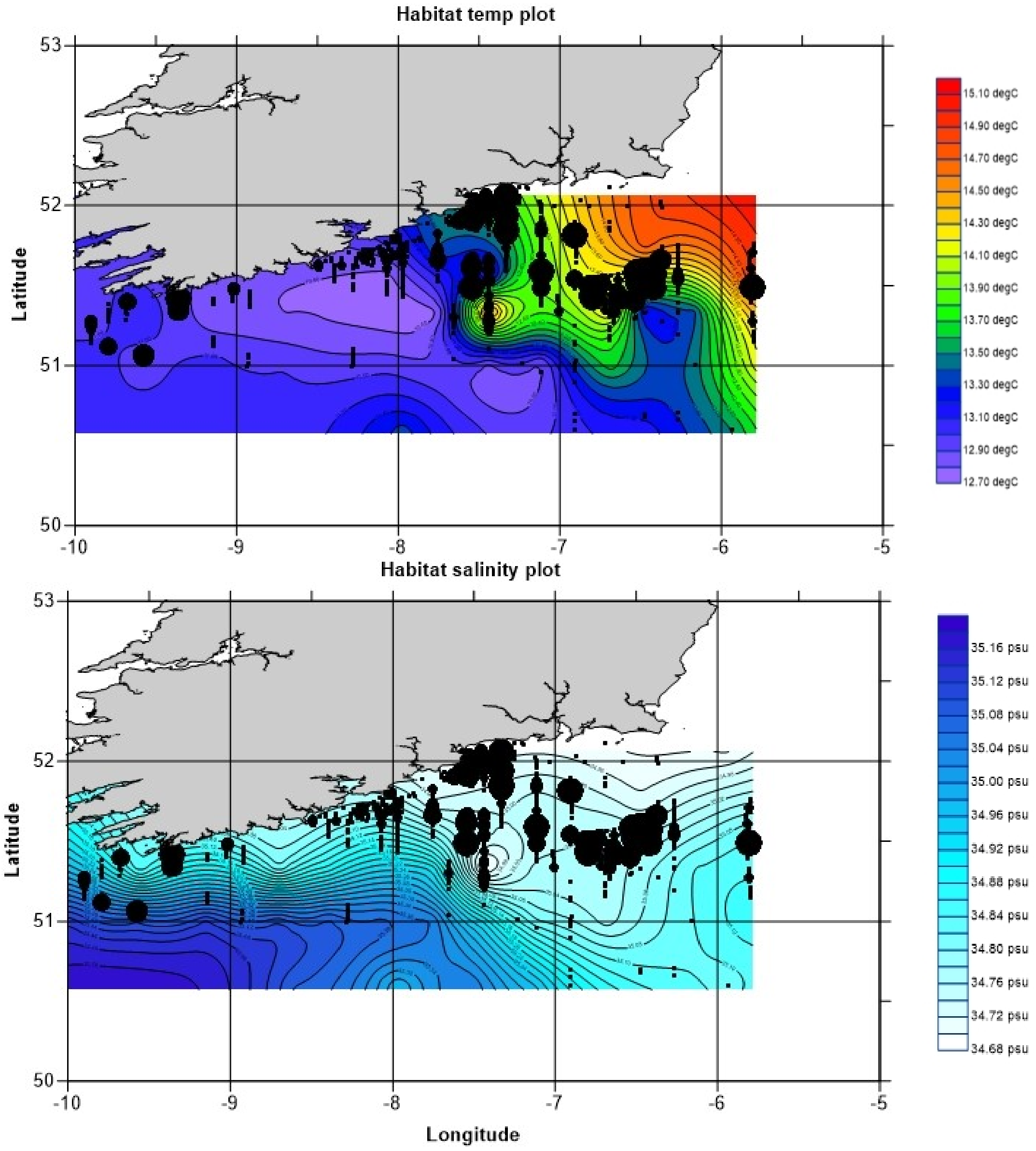


Figure 11. Habitat plots of temperature and salinity at 60 m overlaid with sprat NASC values (black circles).

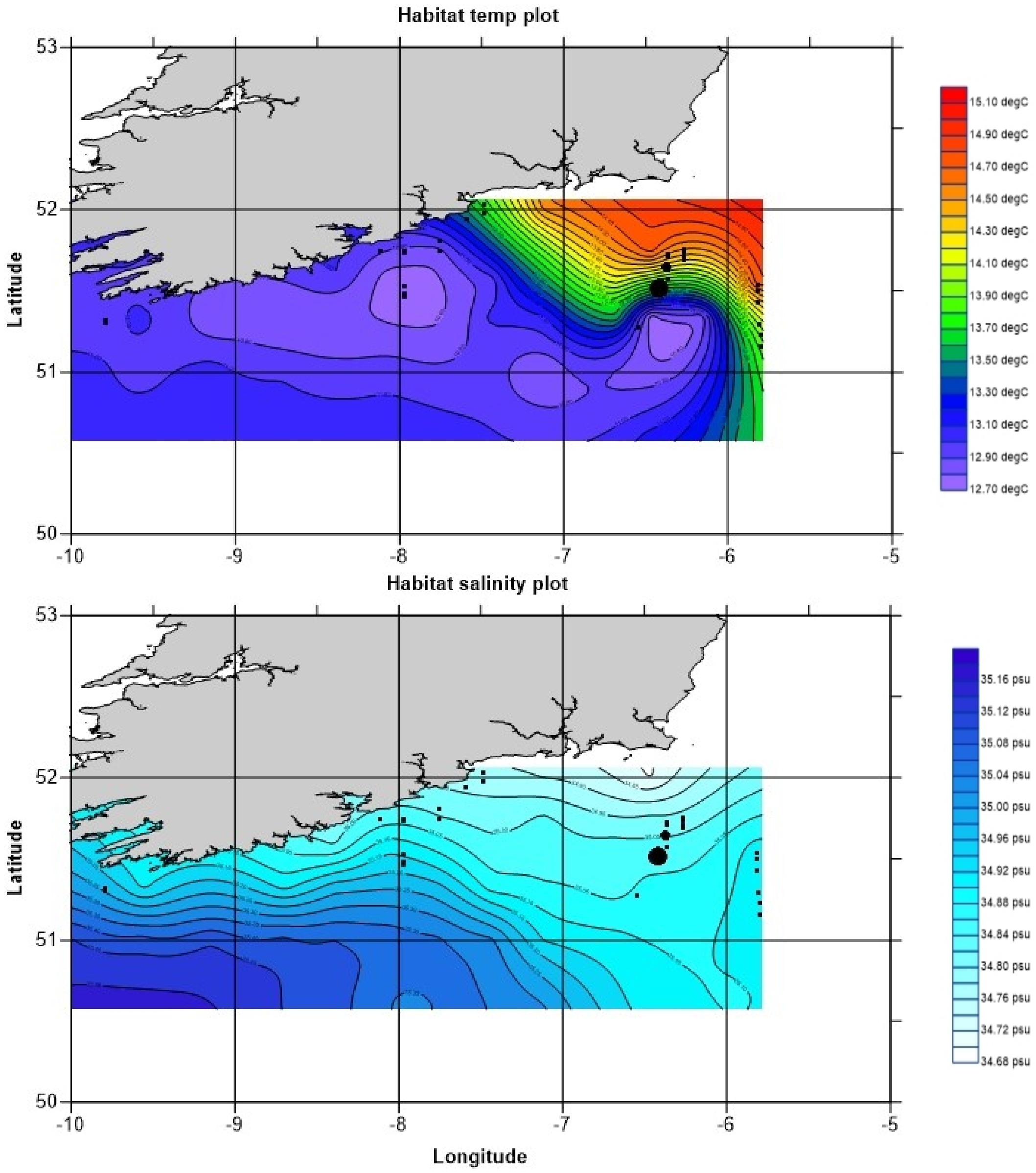


Figure 12. Habitat plots of temperature and salinity at the seabed overlaid with herring NASC values (acoustic density) shown as black circles.

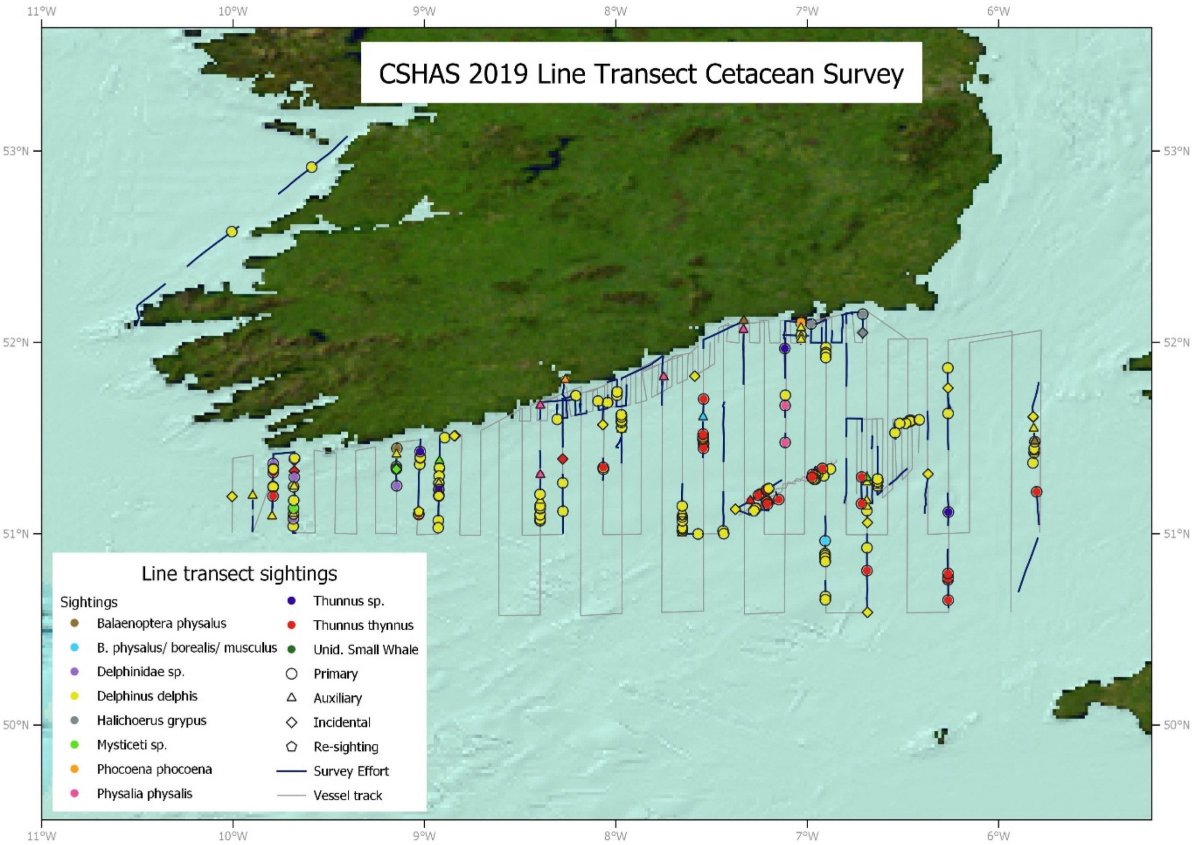


Figure 13. Distribution of all sightings during the survey, profiled with observer effort.

HERRING MIDWATER TRAWL

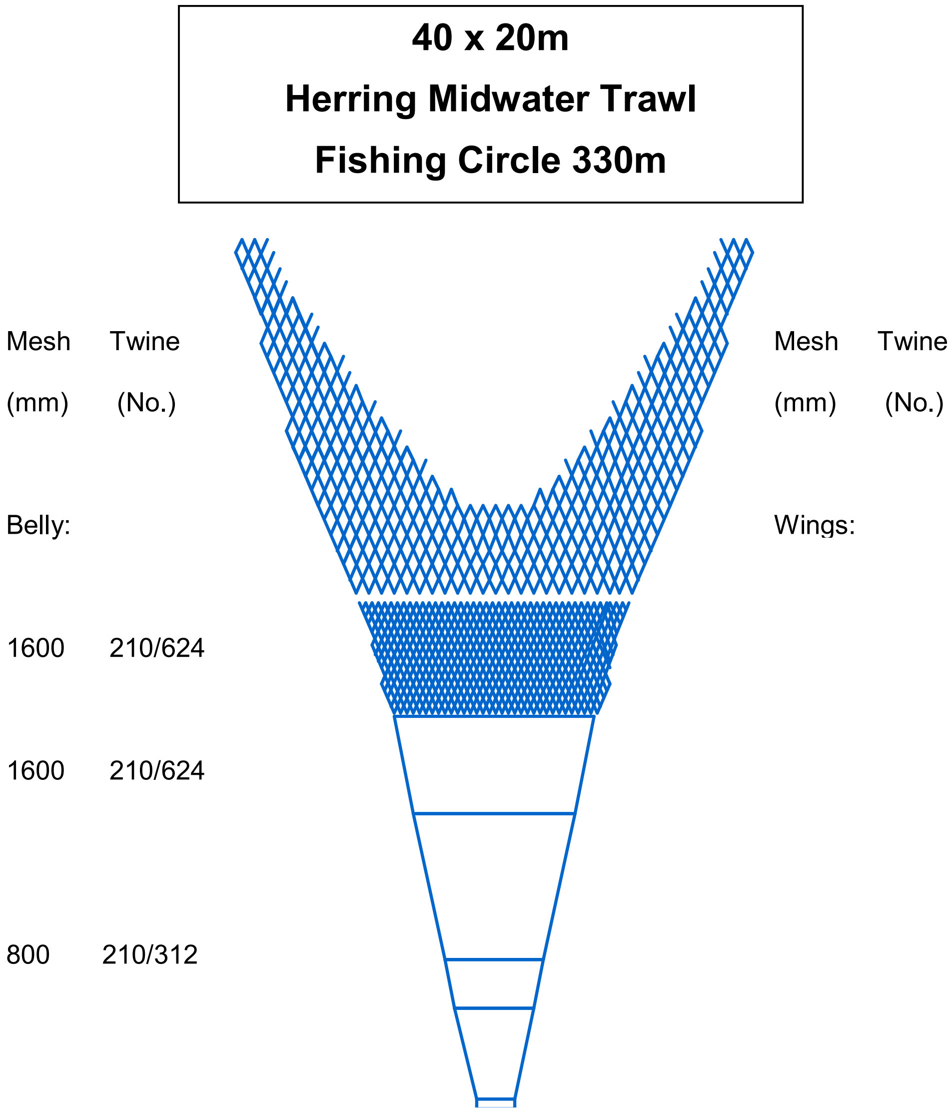


Figure 14. Single herring midwater trawl net plan and layout. Celtic Sea herring acoustic survey.

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

8 Appendix

Core:	Pass 1													
	Age (years)										Numbers	Biomass	Mn Wt	Mature
(cm)	0	1	2	3	4	5	6	7	8	9	(*10^{-3})	(t)	(g)	(%)
9														
9.5														
10														
10.5														
11										2.5	273	2.5	9	0.0
11.5	23.3										2265	23.3	10.27	0.0
12	62										5309	62	12	0.0
12.5	233.1										17245	233.1	14	0.0
13	233.4										14797	233.4	16	0.0
13.5	434.3										24277	434.3	18	0.0
14	274.5										13935	274.5	20	0.0
14.5	193.8										8799	193.8	22	0.0
15	3.6										140	3.6	25	0.0
15.5										1	28	1	36	0.0
16														
16.5														
17		31.9									878	31.9	36	0.0
17.5		150.8									3619	150.8	42	0.0
18		487.8									13185	487.8	37	0.0
18.5		47.2									963	47.2	49	71.6
19	11.1	35.4									906	46.5	51.25	20.3
19.5		6.2									112	6.2	55	44.8
20		1.9									28	1.9	66	56.0
20.5			1.8								28	1.8	65	62.9
21		2	2.1								56	4.1	73.5	83.6
21.5			2.1								28	2.1	76	93.8
22														
22.5														
23		2.9									28	2.9	105	100.0
23.5														
24														
24.5														
25														
25.5														
26														
26.5														
27														
27.5														
28														
28.5														
29														
TSN (*10^{-3})	86993	19522	84							301	106900			
TSB (t)	1468.9	766.1	6							3.5		2244.5		
Mean length (cm)	13.27	17.94	21							11.42				
Mean weight (g)	16.88	39.24	71.67							11.52			21	
% Mature	0	0	67											
SSB (t)	0.0	5.0	4.2									9.2		

Figure 1. Biomass and abundance at length and age for Core survey: Pass 1.

Core:	Pass 2													
	Age (years)										Numbers	Biomass	Mn Wt	Mature
(cm)	0	1	2	3	4	5	6	7	8	9	(*10-³)	(t)	(g)	(%)
9														
9.5														
10														
10.5														
11										1.2	128	1.2	9	
11.5	10.7										1065	10.7	10	
12	29.2										2496	29.2	12	
12.5	110.6										8107	110.6	14	
13	125.4										7961	125.4	16	
13.5	203.7										11413	203.7	18	
14	187.5										9566	187.5	20	
14.5	115.8										5216	115.8	22	
15	1.7										66	1.7	26	
15.5										0.5	13	0.5	36	
16														
16.5														
17		15									413	15	36	
17.5		70.9									1701	70.9	42	
18		228.1									6198	228.1	37	
18.5		35.1									677	35.1	52	
19	4.1	68.5									1324	72.6	54.81	
19.5		119.2									1998	119.2	59.63	
20		162									2482	162	65.26	
20.5		124	4.7								1809	128.7	71.16	
21		77.1									999	77.1	77.13	
21.5		49.5									612	49.5	80.89	
22		12.7									150	12.7	85	
22.5														
23		8.8									88	8.8	99.5	
23.5														
24														
24.5														
25														
25.5														
26														
26.5														
27														
27.5														
28														
28.5														
29														
TSN (*10-³)	45972	18297	72							142	64482			
TSB (t)	788.7	970.8	4.7							1.6		1765.9		
Mean length (cm)	13.34	19.03	20.5							11.42				
Mean weight (g)	17.16	53.06	65							11.52			27.39	
% Mature	0	24	0											
SSB (t)	0.0	312.5	0.0									312.5		

Figure 2. Biomass and abundance at length and age for Core survey: Pass 2.

Adaptive: Smalls 2

(cm)	Age (years) 0	1	2	3	4	5	6	7	8	Ukn	Numbers (*10-³)	Biomass (t)	Mn Wt (g)	Mature (%)
9														
9.5														
10														
10.5														
11														
11.5														
12														
12.5														
13														
13.5														
14														
14.5	67.3										5607	67.3	12	0
15	15.7										1121	15.7	14	0
15.5	34.8										2243	34.8	16	0
16	22.9										1143	22.9	20	0
16.5	24.7										1121	24.7	22	0
17														0
17.5														0
18											44			0
18.5														72
19		5.6									131	5.6	43	20
19.5		12.6									349	12.6	36	45
20		12.1	255								6043	267.1	44	56
20.5		15.9	6.2								480	22.1	46	63
21			15.7								327	15.7	48	84
21.5		10.6									196	10.6	54	94
22			10.8								175	10.8	62	100
22.5		26.6									393	26.6	67.72	100
23		10	18.7								393	28.7	73.17	100
23.5			43.6	5.3							611	48.9	80.11	100
24		12.8	32.6	5.5							589	51	86.52	100
24.5			25.1	3.9							327	29.1	88.8	100
25		16.9									175	16.9	97	100
25.5				25.4							240	25.4	106	100
26										17.5	153	17.5	114.67	100
26.5				12.5							109	12.5	114.6	100
27					30.4						240	30.4	126.55	100
27.5					3	5.8					65	8.8	134.33	100
28					3.1						22	3.1	142	100
28.5						9.7					65	9.7	148.67	100
29										4.2	22	4.2	194	100
TSN (*10-³)	11236	2164	7850	524	284	131				240	22427			
TSB (t)	165.3	123.2	407.8	52.7	36.5	18.5				21.7		825.7		
Mean length (cm)	13.1	19.4	18.79	23.19	25.12	26.33				23.27				
Mean weight (g)	14.71	56.92	51.95	100.71	128.54	141.67				124.58			36.93	
% Mature	0	65	27	100	100	100								
SSB (t)	0.0	92.9	152.8	52.7	36.5	18.5					353.4			

Figure 3. Biomass and abundance at length and age for Adaptive survey: Smalls #2 (Offshore).

Adaptive: Helvick to Ballycotton (Inshore)

	Age (years)										Numbers	Biomass	Mn Wt	Mature
(cm)	0	1	2	3	4	5	6	7	8	UKN	$(*10^{-3})$	(t)	(g)	(%)
9														
9.5														
10														
10.5														
11														
11.5	0.6										68	0.6	10	0
12	1.1										98	1.1	11	0
12.5	1.4										105	1.4	13	0
13	3.8										260	3.8	15	0
13.5	8.2										529	8.2	15	0
14	3.2										181	3.2	18	0
14.5	1.2										65	1.2	19	0
15														
15.5														
16														
16.5														
17		0.9									28	0.9	31	0
17.5														
18		3									85	3	36	0
18.5		1.1									28	1.1	38	0
19	1.4										28	1.4	49	0
19.5														
20														
20.5														
21														
21.5														
22														
22.5														
23														
23.5														
24														
24.5														
25														
25.5														
26														
26.5														
27														
27.5														
28														
28.5														
29														
TSN $(*10^{-3})$	1335	142									1477			
TSB (t)	20.9	5										25.9		
Mean length (cm)	13.35	17.9												
Mean weight (g)	15.66	35.2											17.53	
% Mature	0	0												
SSB (t)	0.0	0.0									0.0			

Figure 4. Biomass and abundance at length and age for Adaptive survey: Helvick to Ballycotton (Inshore).