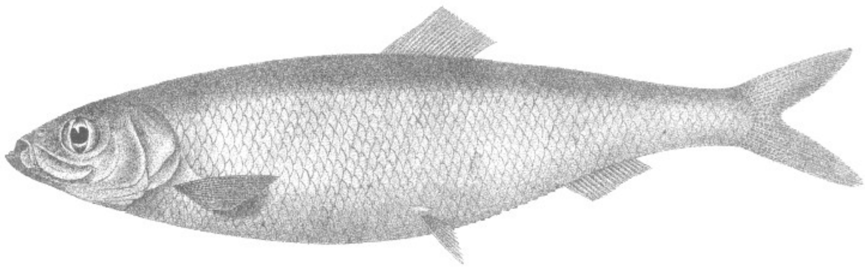
FSS Survey Series: 2022/04

RV Tom Crean

Celtic Sea Herring Acoustic Survey Cruise Report 2022

09 - 29 October, 2022



Ciaran O'Donnell[1], Eugene Mullins[1], Eoghan Daly[2], Niall Keogh*[3] and Andrew Shine*[3]

[1]The Marine Institute, Fisheries Ecosystems Advisory Science Services,

Rinville, Oranmore, Co. Galway.

[2]The Marine Institute, Ocean Climate and information Services

[3] Under contract to National Parks and Wildlife Service

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Foras na Mara
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1 Introduction

In the southwest of Ireland and the Celtic Sea (ICES Divisions VIIaS, g and 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. However, 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 and 1980s, 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.* This year, the survey was conducted onboard the RV Tom Crean.

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	Dingle	09.10.22	Dublin	20.10.22
End	Dublin	20.10.22	Galway	29.10.22

Organisation	Name	Name	Capacity
FEAS	Ciaran O'Donnell	Ciaran O'Donnell	Acou (Chief Sci)
FEAS	Graham Johnston	Graham Johnston	Acou
FEAS	Turloch Smith	Eugene Mullins	Acou
FEAS	John Enright	Tobi Rapp	Acou
FEAS	Dermot Fee	David Tully	Bio (Deck Sci)
FEAS	Sean O'Connor	Cormac Nolan	Bio
FEAS	Grainne Ni Conchuir	Ross Fitzgerald	Bio
Student	Kate O'Regan		CTD/Zoo
MMO	Andrew Shine	Andrew Shine	MMO
SBO	Niall Keogh	Niall Keogh	SBO

SBO- Seabird observer, MMO- marine mammal observer, SmartSea student placement

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
- Carry out additional adaptive surveys as required in areas of interest
- Collect biological samples from directed trawling on insonified fish echotraces
- Collect biological data on the age, length and maturity of herring and sprat
- Determine an age stratified estimate of relative abundance of herring within the survey area (ICES Divisions VIIj, VIIg and VIIaS)
- Determine an estimate of relative abundance of sprat within the survey area (ICES Divisions VIIj, VIIg and VIIaS)
- Collect physical oceanography data from vertical profiles from a deployed sensor array
- Collect biological samples of sprat and herring for genetic analysis on stock origin studies.
- Visual surveys to determine the distribution and abundance of apex predators (marine mammals, tuna and seabirds)

2.2.2 Area of operation

The autumn 2022 survey covered the area from Mizen Head and extended along the south coast into the Celtic Sea (Divisions VIIj, VIIg and 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 two 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 transect 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 represents an independent estimate of abundance.

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 1,752 nmi of transects covering an area of over 12,898 nmi^2.

2.2.3.2 Adaptive survey

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

Arears of specific interest are surveyed using adaptive techniques such as high intensity and/or replicate coverage. Offshore candidate areas were 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 an individual survey basis. The EK80 split beam data is supplemented with Omni sonar data (Simrad SX92) 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.

Two adaptive surveys were carried out (both inshore) and accounted for 319 nmi of transects and an area coverage of 817 nmi^2. No scouting surveys were undertaken.

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 EK80 38 kHz transducer are shown in Table 1.

Acoustic data were collected using the Simrad EK80 scientific echosounder. The Simrad split-beam transducers are mounted within the vessel's drop keel and lowered to the working depth of 3.0 m below the vessel's hull or 8.0 m sub surface. Four operating frequencies were used during the survey (18, 70, 38 and 120) for trace recognition purposes and analysis, with the 38 kHz data used to generate the abundance estimate. A 200 kHz transducer was available but was not operational during the survey.

While on survey track the vessel operates in silent mode (ICES 2002). During fishing operations normal two-engine operations were employed to provide sufficient power to tow the net.

2.3.2 Calibration of acoustic equipment

A calibration of the EK80 was carried out at the beginning of the survey in Dunmanus Bay. The procedure followed methods described by Demer et al. (2015). Calibration results and settings (38 kHz) 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 EK80 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® 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 stratum. 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 18). 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 13 m, which was observed using a cable linked Simrad FS70 netsonde. Spread between the trawl doors was monitored using Marport distance sensors.

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 observation deck located 12.9 m above sea level).

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

2.4.4.2 Seabird sighting survey

A single seabird surveyor worked each leg of the 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.

The seabird observer conducted visual survey effort while simultaneously recording all data. The observer's survey effort was maximized and optimized during periods of sea state less than or equal to sea state 6 and with visibility of greater than 300m. Additional visual point sampling (e.g., at oceanographic sampling stations or fishing stations) and incidental recording were also employed; however, line transect survey effort was prioritised by the observer. Seabird watches were conducted using a standard single platform line transect survey design while the vessel was travelling at a consistent speed and heading. All observations for seabirds were conducted from the observation deck located 12.9 m above sea level.

The data collection methodology was based on that originally proposed by Tasker et al. (1984) with later adaptations applied to allow correction factors to be applied for missed birds (Camphuysen et al., 2004). The method employed used a single platform line transect survey design with sub-bands to survey birds associated with the water, while flying birds were surveyed using a 'snapshot' technique. Observer effort was concentrated in a bow-beam arc of 90^{o} to one side (i.e., to port or starboard) of the vessel's track-line, however, all seabirds observed outside this area were also recorded.

Survey effort for seabirds associating with the water were concentrated within a survey strip of 300m running parallel and adjacent to the vessels track-line and extending to the horizon. All birds surveyed within this region were be recorded as 'in-transect' and assigned to one of four distance sub-bands (A: 0-50m, B: 50-100m, C: 100-200m, D: 200-300m) according to their perpendicular distance from the track-line. This approach allows for the evaluation of biases caused by specific differences in detection probability with increasing distance from the trackline (Camphuysen et al. 2004). Seabirds occurring outside of this survey strip were recorded as 'off-transect' and assigned to a separate sub-band (E: >300m). The perpendicular distance to an animal was estimated using a fixed interval range finder (Heinemann, 1981), ensuring each animal is allocated to the correct distance sub-band.

Flying birds were surveyed using 'snapshots', where instantaneous counts of flying birds within a survey quadrant of 300m x 300m were conducted. The periodicity of these 'snapshots' was vessel speed dependent but timed to allow counts to occur as the vessel passes from one survey quadrant to the next. This method minimises biases in counts of flying birds relative to the movement of the vessel (Pollock et al*.,* 2000, Camphuysen et al. 2004).

Seabirds remaining with the vessel for more than 2 minutes were deemed to be associating with the vessel (Camphuysen et al. 2004) and were recorded as such. Seabirds seen associating with other vessels (i.e. fishing vessels) were also recorded as such.

Searching for seabirds was done with the naked eye, however, Leika Ultravid 8x42 HD binoculars were used to confirm parameters such as species identification, age, moult, group size and behaviour (Mackey et al. 2004). A Canon EOS 7D Mark II DSLR camera with a Canon EF 100-400mm F4.5-5.6 IS II USM telephoto lens was used to visually document other information of scientific interest. Data was also collected on all migratory/ transient waterfowl and terrestrial birds encountered.

The Cybertracker (http://www.cybertracker.org/) data collection software package (Version 3.514) 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.

Each line transect was assigned a unique transect number, and a new transect was started anytime the vessel activity changed (i.e. changing from on-transect to inter-transect). Each subsequent sighting was also assigned to this unique transect number.

Environmental data was timestamped and recorded with GPS data at the beginning and end of each line transect and also as soon as any change in environmental conditions occurred. Environmental data recorded included; wind speed, wind direction, sea state, swell, visibility, cloud cover and precipitation.

Each sighting was timestamped and recorded with GPS data using Cybertracker. Sighting data such as; species identification, distance band, group size, composition, heading, age, moult, behaviour and any associations with cetaceans or other vessels were also recorded on the time stamped Cybertracker sighting record page. Where species identification could not be confirmed, sightings were recorded at an appropriate taxonomic level (i.e. large gull sp., Larus sp., Common tern, etc.).

Ancillary data such as line changes, changes in survey activity (e.g. fishing/CTD cast) and fishing vessel activity were also recorded.

2.4.5 Zooplankton sampling

Zooplankton sampling was carried out alongside CTD stations. A weighted 1 m diameter Hydro-bios ring net was used with a 200 µm mesh size and the net was fitted with a Hydro-Bios® calibrated mechanical flow meter to determine the volume of water filtered. Vertical plankton tows were carried out to within 5 m of the seabed for stations where total depth was less than 100 m and to a 100 m maximum for all other stations depths.

Station samples were split in 50:50 for wet and dry processing for stations 1-44 (Celtic Sea and SW coast). Sample splitting was carried out using a Hydro-Bios® sample splitter. The wet component was fixed for further analysis back at the lab. Fixing was carried using a 4% fix volume of buffered formalin.

Dry processing was carried out with each sample filtered through 2000 µm, 1000 µm and 125 µm sieves. For finer gauge samples (1000 and 125 µm) dry weight analysis was carried out. Samples were transferred to petri-dishes and dried onboard (70 °C oven) for a minimum of 24 hrs before sealing and freezer storage. Back in the lab dry weight analysis was carried out on defrosted frozen samples using a Sartorius MSE225S-000-DA fine scale balance (uncertainty of +/- 0.00016 g).

2.5 Analysis methods

2.5.1 Echogram partitioning

Acoustic data was backed up every 24 hrs and scrutinised using Echoview® (V 12) 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 is provided by Johnsen *et al.* (2019). 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 strata are provided in Table 3. The biomass presented below was determined using Pass 2 (core survey).

Herring	Abund ('000)	Biomass (t)
Total stock	113,367.7	12,533.0
Spawning stock	101,533.8	12,353.9

3.1.2 Herring distribution

A total of 20 trawl hauls were carried out during the survey (Figure 1). Of which, 12 contained herring (Table 2).

Core Surveys

Two core surveys were carried out; Pass 1 and Pass 2. A total of 20 herring echotraces were identified (Pass 1: 17, Pass 2: 03). Herring were predominantly observed as immature individuals mixed catches with sprat, where sprat represented the major component of the catch by weight and number. Mixed sprat and herring scattering layers were observed within 30 nmi of the coast. One large aggregation of mature herring was located offshore during Pass 2 of core survey effort (Figure 2, Figure 8 d & e). Seven hauls contained immature herring from 1-14% of the catch by weight during core survey effort (Table 2).

Adaptive Surveys

Two adaptive surveys were conducted in coastal waters (Figure 3) The first was conducted inshore (Inshore #1) along the south coast from 1-10 nmi using a 4 nmi transect spacing from the 17-18th October. The second adaptive survey took place in Dingle Bay on the 27th October and utilised a zig-zag transect design. Immature herring were observed during the Inshore #1 survey off the south coast occurring as part of mixed species aggregations dominated by sprat.

Inshore survey effort (Inshore #1) was conducted as a single survey conducted over 32 hours using 15 transects covering 251 nmi of sampling effort. Seven herring echotraces composed of immature fish were identified as part of mixed species aggregations dominated by sprat. Inshore effort covered from Kinsale in the west, working eastwards to Hook Head (Figure 3).

3.1.3 Herring stock composition

A total of 374 herring were aged from survey samples, in addition to 619 length measurements and 534 length-weights. Herring age samples ranged from 0-7 winter-rings

(Figures 4 and 5, Tables 3 and 4). Length at age and maturity by strata are presented in Figures 1-3 in Appendix 1.

Core survey

The Pass 1 survey estimate was dominated by immature fish (97.3% of TSB & 99.2% of TSN). This estimate was not used as the stock estimate due to the lack of mature fish. Pass 1 represented a total biomass of 1,404.9 t and a total abundance of 113,411.6 (‘000s) individuals (CV 0.70).

The Pass 2 survey estimate represents the 2022 survey stock estimate. This stratum contained the only large offshore monospecific aggregation of mature herring observed during the survey. Pass 2 represented a total biomass of 12,533 t and a total abundance of 113,367.7 (‘000s) individuals (CV 1.24). The high coefficient of variance (CV) measurement is a result of the low number of herring echotraces (n=3) used to calculate abundance.

Age composition was dominated by 3-wr, followed by 4-wr, 5-wr and immature 0-wr fish by weight. The dominant 3-wr fish contributed 52.2% to the TSB and 50.6%, followed by 4-wr fish (40.5% TSB & 34.5% TSN), then 5-wr fish (3.8% TSB & 3.0% TSN) and 0-wr fish (1.1% TSB & 10% TSN). Mature fish (2-7-wr fish) represented 98.9% of TSB and 90% of TSN.

The proportion of immature fish was less than observed in 2021 survey accounting for 1.1% of TSB (179.1 t of TSB) and 10% of TSN (11,833.9 (‘000s) individuals). In 2021, immature fish accounted for 32.8% TSB (3.242.7 t of TSB) and 42.2% of TSN.

Adaptive surveys

Two adaptive surveys carried out, one of which contained herring (Inshore #1). Estimates of biomass and abundance by strata are presented in Table 3 and Figure 4 respectively.

The Inshore adaptive stratum estimate was dominated by immature fish (98.2% of TSB & 99.6% of TSN) and yielded a TSB of 381.3 t and TSN of 27,174.9 (‘000s) individuals (CV 0.55).

3.2 Other pelagic species

3.2.1 Sprat

Sprar	Abund ('000)	Biomass (t)
Total stock	5,235,755.0	34,508.4

Pass 1 represented a total biomass of 34,508.4 t and a total abundance of 5,235,755 (‘000s) individuals (CV 0.67).

Aggregations of sprat were found widely distributed across the survey area, both inshore and offshore (Figure 6). During the 2020 and 2021 surveys, sprat were more clearly distributed close inshore.

In total, 2,918 individual length measurements and 1,542 length/weight measurements were recorded. Mean length was 8.8 cm and mean weight was 5.45 g (8 cm and 3.78

g in 2021). Individuals ranged from 6 to 13.5 cm in length and 2 to 18 g in weight. Biomass and abundance by survey strata is presented in Table 5 and the survey time series in Table 6.

A total of 401 (275 in 2021) individual sprat echotraces were identified from combined survey effort (Figure 6). Distribution of sprat was more widespread than compared to 2020 and 2021 (predominantly inshore), with high density aggregations observed both inshore and in offshore areas. High density aggregations were observed in the eastern survey area indicating non-containment in the eastern boundary.

3.2.2 Anchovy

A total of three anchovy echotraces were identified offshore during the survey (6 echotraces in 2019, verses 26 in 2020, 0 in 2021). One offshore aggregation was targeted but unsuccessfully sampled as the main body of the school evaded capture. This yielded around 30 Kg of clean anchovy and allowed for positive allocation to anchovy (Figures 13, 14 & 8b). The number of schools and distribution of anchovy observed during the survey is highly variable. High abundance years are likely driven by hydrographic (temperature gradients) and associated feeding opportunities.

In total, 72 individual length/weight measurements were recorded. Mean length was 16.5 cm and mean weight was 29.8 g (6.7 cm and mean weight was 2.53 g in 2021). Individuals ranged from 14 to 19 cm in length and 16 to 39 g in weight.

No estimate of anchovy biomass or abundance was calculated in 2022 due to the low acoustic density encountered.

3.2.3 Sardine

A total of 45 medium and high density echotraces were identified as sardine during the survey, all of which were encountered within 10 nmi of the coast within the Pass 1, Pass 2 and Inshore adaptive stratum (Figures 15,16 & 8f). Individual sardines were observed as components of mixed catches dominated by sprat (weight and number) and as monospecific schools. Sardine are particularly difficult to target during daylight hours with a pelagic trawl.

Total sardine biomass (TSB) and abundance (TSN) estimates by strata are provided in Table 7.

In total, 911 individual length measurements and 400 length/weight measurements were recorded. Mean length was 16.2 cm and mean weight was 43 g. Individuals ranged from 9.5 to 23.5 cm in length and 10 to 121 g in weight.

3.3 Oceanography

A total of 21 CTD stations were carried out during the survey area. Surface plots of temperature and salinity are presented using 5 m and 20 m depth profiles (Figures 9 and 10), while near bottom profiles are overlaid with sprat and herring acoustic density respectively (Figures 11 and 12).

Horizontal plots of temperature and salinity at 5 and 20 m depths showed relatively uniform near surface conditions (Figures 9 and10). The water column was stratified, as evident from the thermocline extending to c.45 m subsurface at offshore stations.

Bottom temperature at offshore stations were lower than during the same time last year (2021: 12°C & 2020: 14°C). Offshore aggregations of mature herring were observed to be distributed in the 10-11°C temperature range, whereas immature fish were located inshore in the warmer mixed coastal waters (Figure 12). High density sprat aggregations were observed temperature boundary areas in the eastern survey area (Figure 11).

The influence of cooler and more saline Atlantic water is evident south of 51°N compared to the warmer and slightly less saline conditions further north towards the coast.

3.3.1 Zooplankton

No zooplankton sampling was undertaken during the survey.

3.4 Marine mammal and seabird observations

3.4.1 Marine mammal abundance and distribution survey

Survey effort

Mammal monitoring was conducted for 76 hours across 13 days, with 10 full days' and three partial day's monitoring. There were five days with no monitoring due to weather or visiting port.

Environment

During monitoring, sea state (SS) was in the SS2 to SS3 range 41.7% of 126 stations recorded, in the SS4 to SS5 range 47.7% of stations, and SS6 or higher 10.6% of stations. Swell was <1 m 58% of stations, 1 - 2 m 38% of stations and 2 - 3 m at 11% of stations. Of the 126 stations, or 41.7%, in the SS2 to SS3 range. 144 stations, or 47.7%, were in the SS4 to SS5 range. 32 stations, or 10.6%, were SS6 or higher.

Visibility was recorded on 301 stations, with data not entered on station 296 through human error. Visibility was classed as High 19.3% of stations, Good 51.5% of stations, Medium 25.9% of stations and Poor 3.3% of stations, where heavy fog or precipitation was an issue for effective observation.

Sightings report

In total, 64 sightings were recorded during the survey (Figure 17, Table 8). There were 43 confirmed sightings of Delphinus Delphis (67.2% of total sightings), 7 sightings of Thunnus thynnus, (10.9%), 5 sightings of Balaenoptera physalus (7.8%), 2 sightings of Phocoena phocoena (3.1%). There was 1 sighting each of Balaenoptera acutorostrata, halicheorus grypus and Prionace glauca respectively. There were a further 3 sightings of unconfirmed dolphin species (4.7%), and 1 sightings of an unconfirmed large whale species, (1.6%).

In total, an estimated 587 marine mammals were observed, comprising of 585 cetaceans and 2 seals, along with 2 sharks and multiple feeding groups of tuna.

3.4.2 Seabird abundance and distribution survey

In total, 72 hours and 41 minutes of survey effort were conducted over the course of CSHAS 2022. In total, 60 hours and 17 minutes of survey effort were conducted using a line transect methodology, while 9 hours and 6 minutes of effort were conducted using the point sampling methodology. A further 3 hours and 17 minutes of effort were conducted as a casual watch.

A total of 2,291 seabird observations were recorded throughout the survey, totalling 9854 individuals (Table 9). In total, 2,410 seabirds were recorded as “in transect”, while 7444 were recorded “off transect”. The species encountered included 29 species, species groups, from nine families. A further 43 observations of terrestrial migratory birds were also recorded, comprising of 88 individuals (Table 10).

Gannet (*Morus bassanus*) were the most frequently encountered species, recorded on 649 separate occasions, accounting for 28.3% of all records. Gannet records comprised of a total of 2,826 individuals (28.7% of all individual birds recorded) making gannet the most abundant species recorded on the survey. However, of these, only 471 birds were recorded as ‘in transect’.

Guillemot (*Uria aalge*) were both the second most frequently encountered and the third most abundant species accounting for 455 records (19.9% of all encounters) and comprising of 1,216 individuals in total (12.3% of all encountered individuals.) Of these, 580 individuals were recorded as ‘in transect’.

Kittiwake (*Rissa tridactyla*) were the third most frequently observed species accounting for 429 sightings (18.7% of all sightings). Kittiwake were the second most abundant species comprising of 2,564 individuals in total (26.0% of all encountered individuals.) Of these, 785 birds were recorded as ‘in transect’.

A number of terrestrial/ migratory birds were encountered during the survey. A total of 43 observations of terrestrial/ migratory bird species were recorded during the survey (Table 9). These records comprised of 88 individuals from 20 species’. Species recorded included a little egret (*Egretta garzetta*), a common redstart (*Phoenicurus phoenicurus*), a goldcrest (*Regulus regulus*) and a spotted flycatcher (*Muscicapa striata*).

4 Discussion and Conclusions

4.1 Discussion

The objectives of the survey were carried out with modification to normal operations and area coverage resulting from to time loses due to weather and vessel obligations. Approximately 72 hrs was lost in total.

In terms of survey effort, geographical coverage was less than in 2021 (-28%) and acoustic sampling effort or survey miles was also reduced (-21%). Core effort strata (Pass 1 and Pass 2) were reduced as little as possible and adaptive sampling effort was curtailed to compensate. Coastal effort was also maintained to ensure coverage of nursery areas. Dingle Bay was covered on route back to Galway to collect samples for a sprat genetics program to identify stock origin in the south and southwest.

One large high density aggregation of herring was located offshore during the Pass 2 survey and represented the biomass of the mature component of the stock. Given the stock estimate was based on this single aggregation the uncertainty estimate (CV) is abnormally high. Outside of this, the age profile of this aggregation is representative of the main age cohorts within the stock.

Herring within this area were in close proximity to the seabed. The first pass over the aggregation saw a typical offshore behaviour with fish in close proximity to the seabed making accurate echo-counting difficult. During trawl sampling, the aggregation began to rise from the seabed to show its actual extent, which extended over 1.5 nmi. Estimates of biomass from this site must therefore be treated with a degree of caution and as an underestimate of the quantity of fish present.

For the mature herring observed offshore, the age and length profile is consistent with the dominant three and four winter ring fish from commercial catch data and observations from the WESPAS summer survey, and so is considered representative of the stock profile.

Immature (0-wr) fish were well represented during both the core and the inshore adaptive surveys, albeit in low numbers, occurring as components of mixed catches dominated by sprat. The proportion immature fish in this year’s estimate was lower than in 2021. The numbers of 1-wr and 2-wr fish remain low overall with no obvious signs of emerging strong year classes.

The biomass of sprat in 2022 was higher than observed over the last 2 years (2021: 12,376t and 2020: 4,523t). Over these years the distribution of sprat was highly concentrated in inshore waters. This presents difficulties in regards to containment in within areas that the survey vessel cannot reach due to shallow water. During this year’s survey, sprat were more widespread and therefore more readily available to the ships echosounders.

Anchovy were observed in low abundance across the survey area and a low number of biological samples were caught. As a result, no biomass was calculated. The occurrence of anchovy (and sardine) during the survey is highly variable year-to-year and likely driven by hydrographic conditions and/or feeding opportunities. Schools of sardine were more numerous this year than anchovy and more easily allocated to species level. Aggregations were concentrated in coastal waters and a representative number of biological samples allowed for a calculation of length based biomass and abundance.

4.2 Conclusions

- In terms of survey effort, geographical coverage was lower than in 2021 (-28%) as was acoustic sampling effort or survey miles (-21%). The survey was carried out during the same time period.
- The 2022 TSB estimate (Pass 2) is 12,533 t and 113,367.7 (‘000s) individuals (CV 1.24). Spawning stock biomass (SSB) was 12,353.9 t and spawning stock abundance (SSN) was 101,533.8 (‘000s) individuals
- The 2022 estimate represents an increase of 21% of TSB and a reduction of-174% of TSN compared to 2021. The reduction in abundance (number of fish) is driven by the smaller number of larger individuals contributing to the stock as compared to the more numerous but smaller individuals last year. Spawning stock biomass increased by 46% and SSN increased by 44% compared to 2021.

- Immature herring were widespread throughout the survey area, both offshore and in coastal waters in mixed species aggregations/layers dominated by sprat. Immature herring accounted for over 1.43% of TSB and over 10% of TSN.
- Mature herring were observed in a single high density offshore aggregation during Pass 2 (core). No further adaptive surveying was carried out around this area due to time limitations.
- Age composition of Pass 2 was dominated by 3-wr fish that contributed 52.2% to the TSB and 50.6% to TSN, followed by 4-wr fish (40.5% TSB & 34.5% TSN), then 5-wr fish (3.8% TSB & 3.0% TSN) and 0-wr fish (1.1% TSB & 10% TSN). Mature fish (2-7-wr fish) represented 98.9% of TSB and 90% of TSN.
- The numbers of 1-wr and 2-wr fish remain low overall with no obvious signs of emerging strong year classes.
- The abundance of sprat observed this year was higher than that observed in 2020 or 2021 and more consistent with the medium term time series.
- The length profile of survey samples of sprat was dominated by smaller, 0-group fish and is comparable to the 2021 survey.
- The amount of anchovy observed is highly variable from year-to-year. High abundance years are likely driven by hydrographic (temperature) and/or feeding opportunities
- Sardine schools were observed along the south coast, with several length cohorts visible in the biological samples, representing immature and mature individuals.

5 Acknowledgements

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7 Tables and Figures

Table 1. Calibration report: Simrad EK80 echosounder at 38 kHz.

Echo Sounder System Calibration

Vessel : R/V Tom Crean		Date : 10.10.2022	
Echo sounder : EK80		Locality : Dunmanus Bay	
Type of Sphere : WC-38,1	TS Sphere: -42.40 dB (Corrected for soundvel	Depth(Sea fl	32 m

Calibration Version 2.1.0.12

Comments:
Dunmanus_CSHAS_2022

Reference Target:

TS	-42.40 dB	Min. Distance	14.00 m
TS Deviation	5.0 dB	Max. Distance	16.00 m

Transducer: ES38-7 Serial No. 400206

Frequency	38000 Hz	Beamtype	Split
Gain	26.56 dB	Two Way Beam Angle	-20.7 dB
Athw . Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw . Beam Angle	6.59 deg	Along. Beam Angle	6.53 deg
Athw . Offset Angle	0.05 deg	Along. Offset Angl	-0.05 deg
SaCorrection	-0.05 dB	Depth	8.0 m

Transceiver: WBT 38 kHz Narrow ES38-7

Pulse Duration	1.024 ms	Sample Interval	0.192 m
Power	2000 W	Receiver Bandwidth	2.43 kHz

Sounder Type:
EK80 Version 21.15.1.0

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.	9.4 dB/km	Sound Velocity	1498.2 m/s

Beam Model results:

Transducer Gain =	265.71 dB	SaCorrection =	-0.10 dB
Athw . Beam Angle =	6.53 deg	Along. Beam Angle =	6.57 deg
Athw . Offset Angle =	0.04 deg	Along. Offset Angle=	-0.06 deg

Data deviation from beam model:
RMS = 0.06 dB

Comments :
Dunmanus Bay
Wind Force : 13 Kts **Wind Direction :** SW
Raw Data File: E:\TC22010_CSHAS 2022\Calibration\38 kHz Cal\
Calibration File: E:\TC22010_CSHAS 2022\Calibration\38 kHz Cal

Calibration: Ciaran O'Donnell

Table 2. Catch table from directed trawl hauls.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target btm (m)	Bulk Catch (Kg)	Herring %	Mackerel %	Scad %	Sprat %	Pilchard %	Others* %
1	10.10.22	51.55	-9.70	19:03	41	30	18.2				72.5		
2	11.10.22	51.58	-8.25	15:25	85	65	26.2	15.9	1.5	0.7		27.6	54.4
3	12.10.22	51.77	-8.04	08:10	41	20	13.9					46.0	54.0
4	12.10.22	51.23	-7.82	14:52	95	95	27.1	0.1	3.4	21.3			75.3
5	12.10.22	51.63	-7.61	23:20	85	20	96.6			2.0	95.0		3.0
6	13.10.22	51.82	-7.39	23:55	80	20	183.63		12.2	1.7	75.9		10.3
7	13.10.22	51.86	-7.17	19:34	74	30	16.4	0.2	0.7	26.7	36.4		36.0
8	14.10.22	51.50	-6.76	13:00	78	60	101.0	0.4	4.7		81.6		13.3
9	14.10.22	51.63	-6.76	16:16	71	71	35.9		3.8		5.6	58.9	31.8
10	15.10.22	51.53	-6.34	12:30	100	80	51.3	25.5		0.2	67.0		7.3
11	16.10.22	51.05	-5.81	09:00	90	70	91.8	2.6	0.1	0.6	93.5		3.2
12	16.10.22	51.56	-5.81	13:30	90	90	228.4	2.5	7		88.04		2.1
13	17.10.22	51.04	-7.47	09:00	52	40	42.1	0.4	5.3		82.1		12.1
14	17.10.22	51.99	-7.14	17:30	60	60	350.0	0.8			1.3	87.4	10.6
15	22.10.22	51.74	-6.43	08:30	70	60	75.8	5.2	12.6	3.1	75.0		4.1
16	23.10.22	51.27	-7.08	11:40	90	90	2.5	1.2		0.5	7.6		90.8
17	23.10.22	51.48	-7.1	14:10	81	81	32.7				86.8		13.2
18	24.10.22	51.48	-7.5	11:48	83	83	0.0						
19	25.10.22	51.20	-7.9	01:35	98	98	3500.0	99.7					0.3
20	27.10.22	51.06	-10.4	17:00	54	54	55.0				100.0		

Table 3. Herring biomass and abundance by strata. Pass 2 (blue) presented as total stock biomass estimate for 2022.

Strata	Name	Type	Area (nmi²)	Transects	TSN ('000)	TSB (t)	SSN ('000)	SSB (t)	CV (Abun)
1	Pass 1	Core	6,667.4	13	113,411.6	1,404.9	335.9	15.4	0.70
2	Pass 2	Core	5,414.2	15	113,367.7	12,533.0	101,533.8	12,353.9	1.24
6	Inshore 1	Adaptive	698.6	14	27,174.9	381.3	100.5	6.9	0.55
7	Dingle Bay	Adaptive	117.9	zig zag	-	-	-	-	-
	Total		12,898.1	42					

Table 4. Celtic Sea herring survey time series.

Age (wr) Year	0	1	2	3	4	5	6	7	8	9	TSN (mils)	SSB ('000t)	Design	CV
2002	0	42	185	151	30	7	7	3	0	0	423	41	AR	0.49
2003	24	13	62	60	17	2	1	0	0	0	183	20	AR	0.34
2004	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2005	2	65	137	28	54	22	5	1	0	0	312	33	ARS	0.48
2006	0	21	211	48	14	11	1	0	0	0	305	36	ARS	0.35
2007	1	106	70	220	31	9	13	4	1	0	454	46	ARS	0.25
2008	2	63	295	111	162	27	6	5	0	0	671	93	ARS	0.20
2009	239	381	112	210	57	125	12	4	6	1	1147	91	ARS	0.24
2010	5	346	549	156	193	65	91	7	3	0	1414	122	ARS	0.20
2011	0.1	342	479	299	47	71	24	33	4	2	1300	122	ARS	0.28
2012	31	270	856	615	330	49	121	25	23	3	2322	246	ARS	0.25
2013	3.8	698	291.4	197.4	43.7	37.9	9.8	4.7	0	0.2	1286	71	ARS	0.28
2014	0	41	117	112	69	20	24	7	17	1	408	48	ARM	0.59
2015	0	0	40	48	41	38	7	6	5	0	184	25	ARM	0.18
2016	0	125	21	43	40	36	25	5	6	0	301	30	CRM	0.33
2017	0	0	6	3	7	5	4	0	1	0	27	4	CRM	NA
2018	109	56	16	27	6	0	0	0	0	0	213	8	CRM	0.50
2019	87	19.5	0.1	0	0	0	0	0	0	0	106.9	0.009	CRM	0.55
2020	1	27.7	32.2	5	1	0	0	0	0	0	67	3.1	CRM	0.51
2021	25.3	0	1.7	3.5	0.3	0.1	0	0.1	0	0	310	6.6	CRM	0.44
2022	11.3	0	0.8	57.3	39.1	3.36	0.9	0.52	0	0	113	12.3	CRM	1.24

Table 5. Sprat biomass and abundance by strata.

Strata	Name	Type	Area (nmi²)	Transects	TSN ('000)	TSB (t)	CV (Abun)
1	Pass 1	Core	6,667.4	13	5,235,755	34,508.4	0.67
2	Pass 2	Core	5,414.2	15	2,325,323	13,283.9	0.47
6	Inshore 1	Adaptive	698.6	14	841,206	5,002.0	0.34
7	Dingle Bay	Adaptive	117.9	zig zag	112,932	653.9	0.71
	Total		12,898	42			

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

	Pass1		Pass 2	
Year	**Abundance (Mils)**	**Biomass (t)**	**Abundance (Mils)**	**Biomass (t)**
2004	5,646	50,810		
2005	2,571	29,017		
2007	132	1,918		
2008	540	5,493		
2009	1,418	16,229		
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	3,396	17,747
2017	4,189	13,442	13,285	52,473
2018	6,934	47,806	73,955	51,039
2019	10,344	60,608	74,282	42,787
2020	354	4,523	14,819	18,918
2021	3,018	12,376	7,255	28,081
2022	5,235	34,508	2,325	13,283

Table 7. Sardine biomass and abundance by strata

Strata	Name	Type	Area (nmi²)	Transects	TSN ('000)	TSB (t)	CV (Abun)
1	Pass 1	Core	6,667.4	13	240,033	5,508.6	0.73
2	Pass 2	Core	5,414.2	15	397,668	9,184.5	0.68
6	Inshore 1	Adaptive	698.6	14	240,249	8,643.8	0.75
7	Dingle Bay	Adaptive	117.9	zig zag	-	-	-
	Total		12,898	42			

Table 8. Marine mammal sightings, counts and group size ranges for cetaceans sighted.

Species	# sight-ings	% sight-ings	Est. Total individuals	Est. # adults	Est. # juveniles	Est. # calves
B. acutorostrata	1	1.6	1	1	-	-
B. physalus	5	7.8	22	-	-	-
D. delphis	43	67.2	545	332	104	63
H. grypus	1	1.6	2	1	1	-
P. glauca	1	1.6	2	-	-	-
P. phocoena	2	3.1	9	7	1	-
T. thynnus	7	10.9	n/a	-	-	-
Unidentified cetacean	1	1.6	1	-	-	-
Unidentified dolphin spp.	3	4.7	7	-	-	-
Totals	**64**	**100**	**589**	**341**	**106**	**63**

Table 9. Totals for all seabird species recorded.

Common Name	Scientific name	No. of Records	No. of Individuals	On Transect	Off Transect
Fulmar	*Fulmarus glacialis*	64	272	31	241
Great Shearwater	*Ardenna gravis*	14	82	32	50
Sooty Shearwater	*Ardenna grisea*	29	120	17	103
Manx Shearwater	*Puffinus puffinus*	21	30	8	22
Storm Petrel	*Hydrobates pelagicus*	2	3	0	3
Gannet	*Morus bassanus*	649	2826	471	2355
Pomarine Skua	*Stercorarius pomarinus*	2	2	0	2
Arctic Skua	*Stercorarius parasiticus*	9	11	5	6
Long-tailed Skua	*Stercorarius longicaudus*	1	1	0	1
Great Skua	*Stercorarius skua*	13	14	2	12
Mediterranean gull	*Ichthyaetus melanocephalus*	3	3	1	2
Common Gull	*Larus canus*	13	25	2	23
Sabine's gull	*Xema sabini*	2	2	1	1
Black-headed Gull	*Chroicocephalus ridibundus*	8	14	1	13
Lesser Black-backed Gull	*Larus fuscus*	88	601	60	541
Herring Gull	*Larus argentatus*	51	345	17	328
Yellow-legged gull	*Larus michahellis*	1	1	0	1
Great Black-backed Gull	*Larus marinus*	121	234	67	167
Kittiwake	*Rissa tridactyla*	429	2564	785	1779
Arctic Tern	*Sterna paradisaea*	1	1	0	1
Guillemot	*Uria aalge*	455	1216	580	636
Razorbill	*Alca torda*	215	770	286	484
Razorbill / Guillemot	*Alcidae*	20	312	3	309
Puffin	*Fratercula arctica*	58	142	25	117
Shag	*Gulosus aristotelis*	17	54	16	38
Cormorant	*Phalacrocorax carbo*	1	5	0	5
Great Northern Diver	*Gavia immer*	1	1	0	1
Total		**2291**	**9854**	**2410**	**7444**

Table 10. Totals of migrant terrestrial bird species recorded.

Common Name	Scientific name	No. of Individuals	No. of Sightings
Racing Pigeon	*Columba livia*	1	1
European Golden Plover	*Pluvialis apricaria*	2	4
Eurasian Curlew	*Numenius arquata*	1	1
Ruddy Turnstone	*Arenaria interpres*	1	1
Little Egret	*Egretta garzetta*	1	1
Common Kestrel	*Falco tinnunculus*	1	1
Eurasian Skylark	*Alauda arvensis*	2	3
Barn Swallow	*Hirundo rustica*	2	7
Eurasian Blackcap	*Sylvia atricapilla*	4	4
Goldcrest	*Regulus regulus*	1	1
Eurasian Wren	*Troglodytes troglodytes*	1	1
Common Starling	*Sturnus vulgaris*	2	15
Song Thrush	*Turdus philomelos*	1	1
Redwing	*Turdus iliacus*	2	2
Spotted Flycatcher	*Muscicapa striata*	1	1
Common Redstart	*Phoenicurus phoenicurus*	1	1
Grey Wagtail	*Motacilla cinerea*	2	2
Pied/White Wagtail	*Motacilla alba*	1	1
Meadow Pipit	*Anthus pratensis*	12	33
Rock Pipit	*Anthus petrosus*	1	4
Total		**41**	**88**

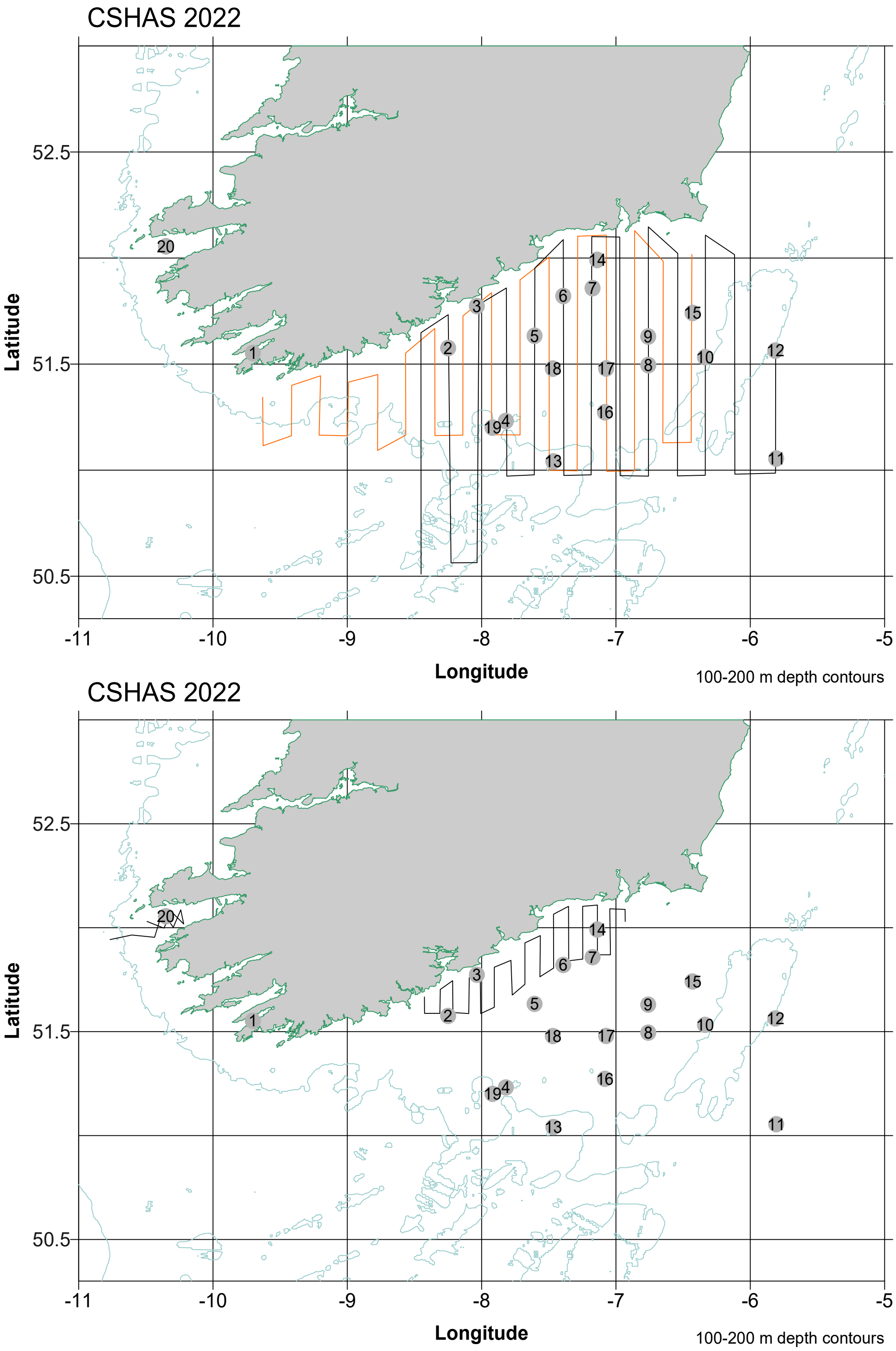


Figure 1. Top panel: Core replicate survey effort cruise tracks and numbered haul stations. (Pass 1: black track, Pass 2: orange track). Bottom panel: Adaptive survey effort mini surveys: Inshore and Dingle Bay.

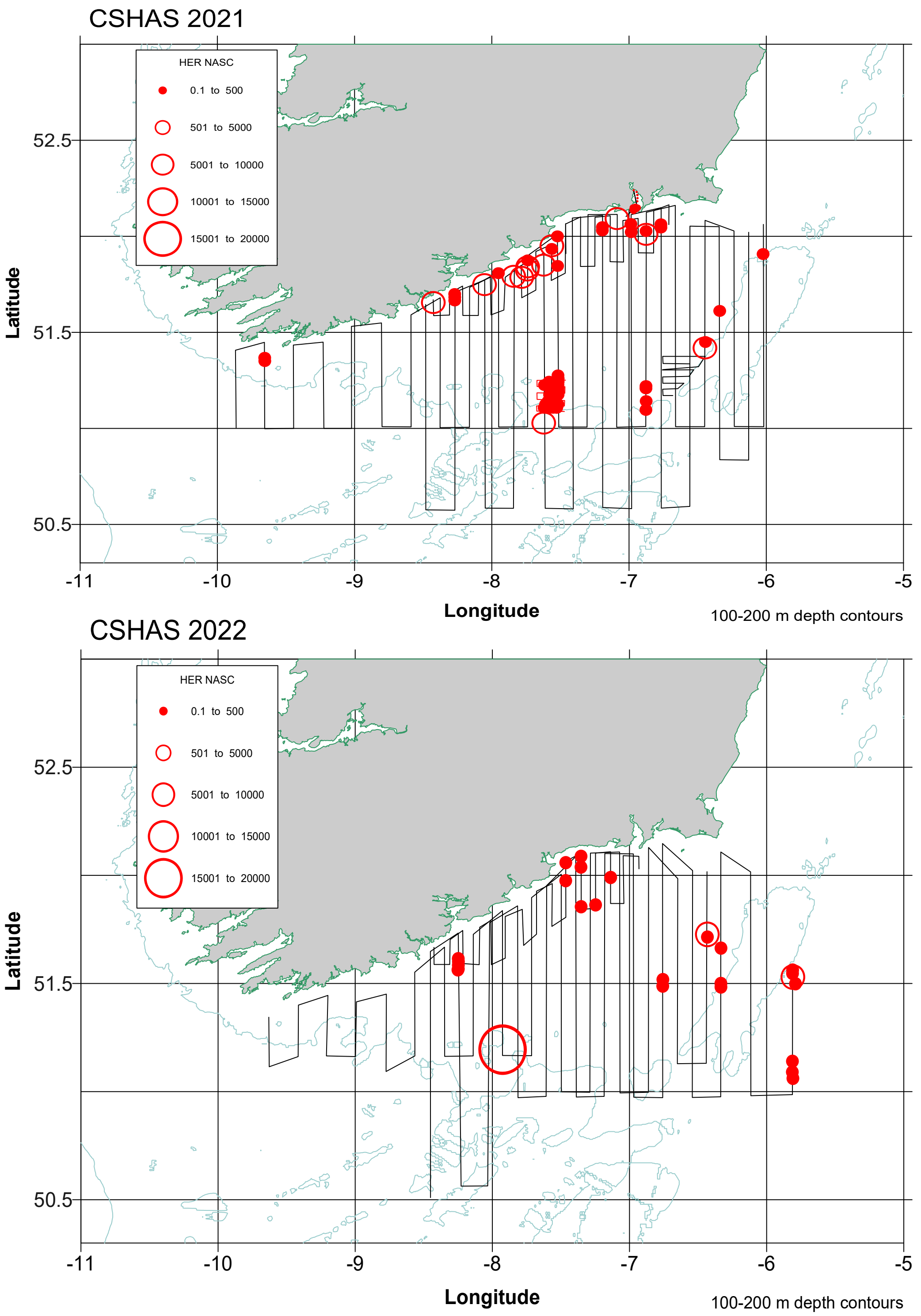


Figure 2. Herring NASC (Nautical area scattering coefficient) plot of herring distribution 2021 and 2022 from combined survey effort.

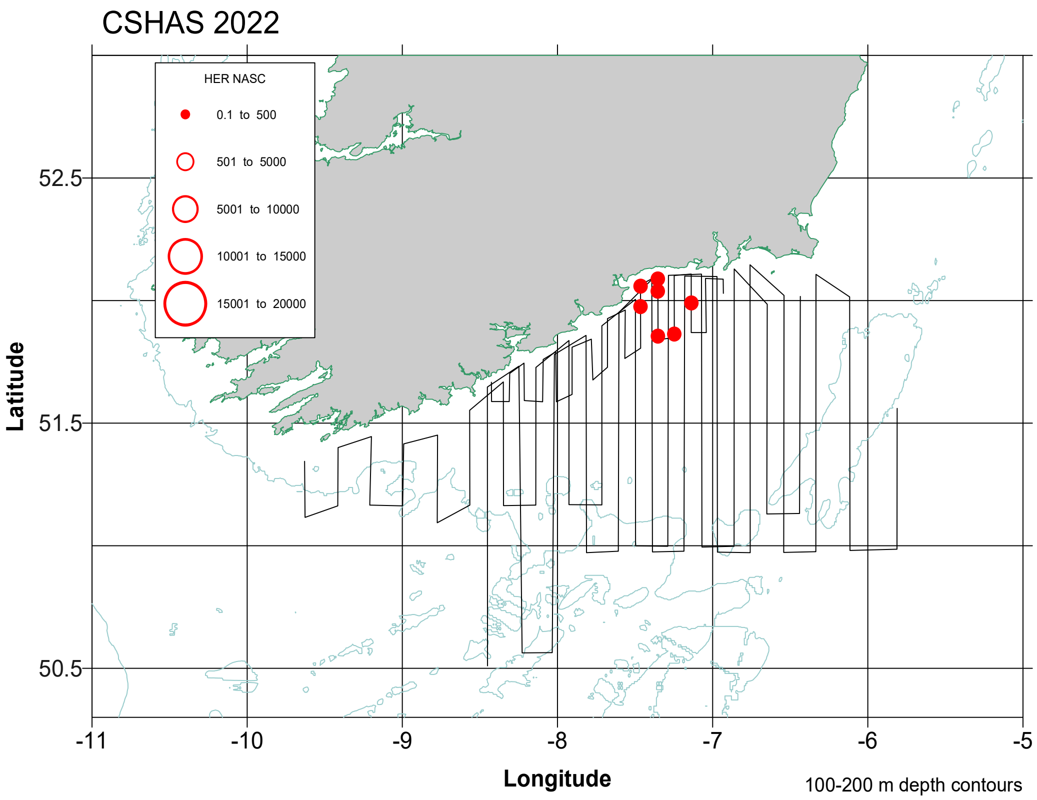


Figure 3. Herring NASC (Nautical area scattering coefficient) plot of the distribution from adaptive survey effort Inshore 1: Kinsale to Hook Head.

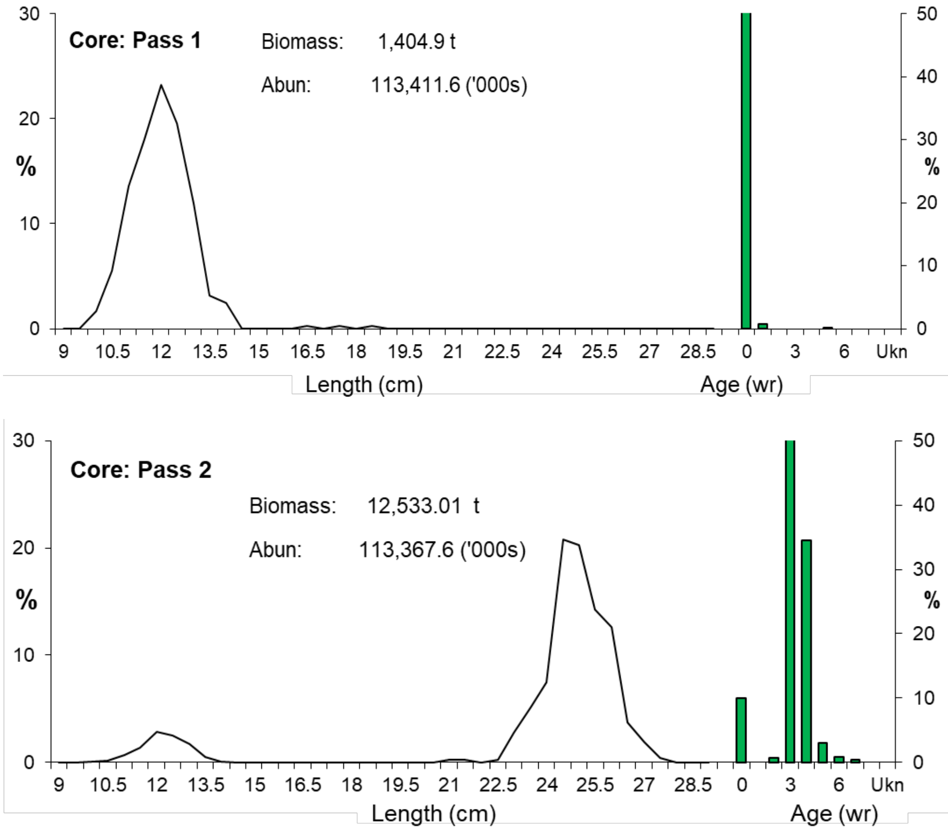


Figure 4. Age and length composition of herring from core survey strata in 2022.

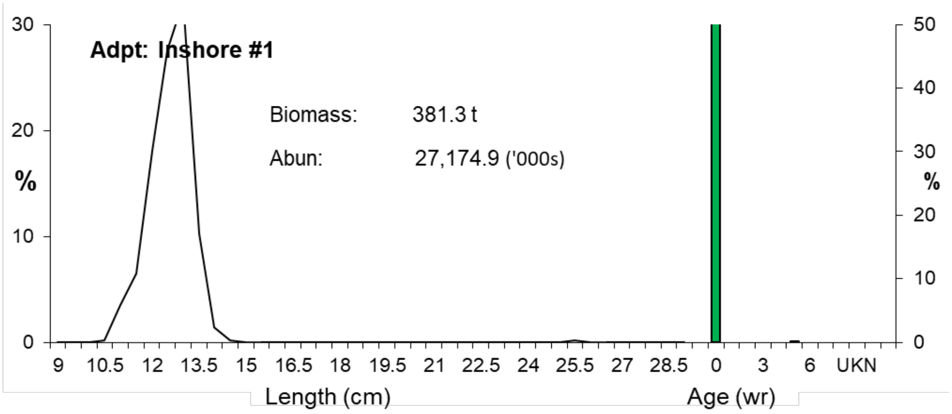


Figure 5. Age and length composition of herring from adaptive survey strata in 2022.

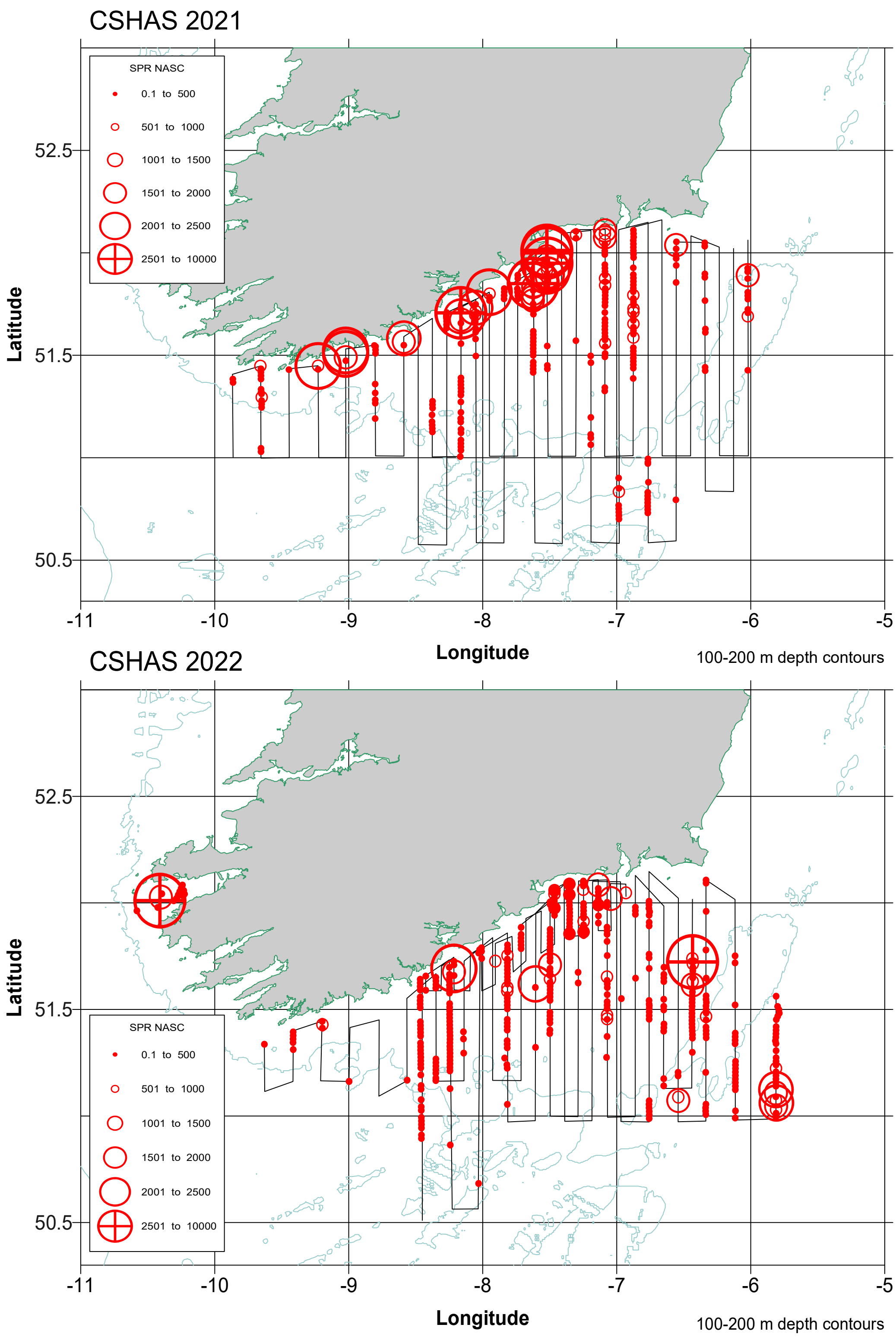


Figure 6. Sprat NASC (Nautical area scattering coefficient) plot of the distribution from combined survey effort, top 2021, bottom 2022.

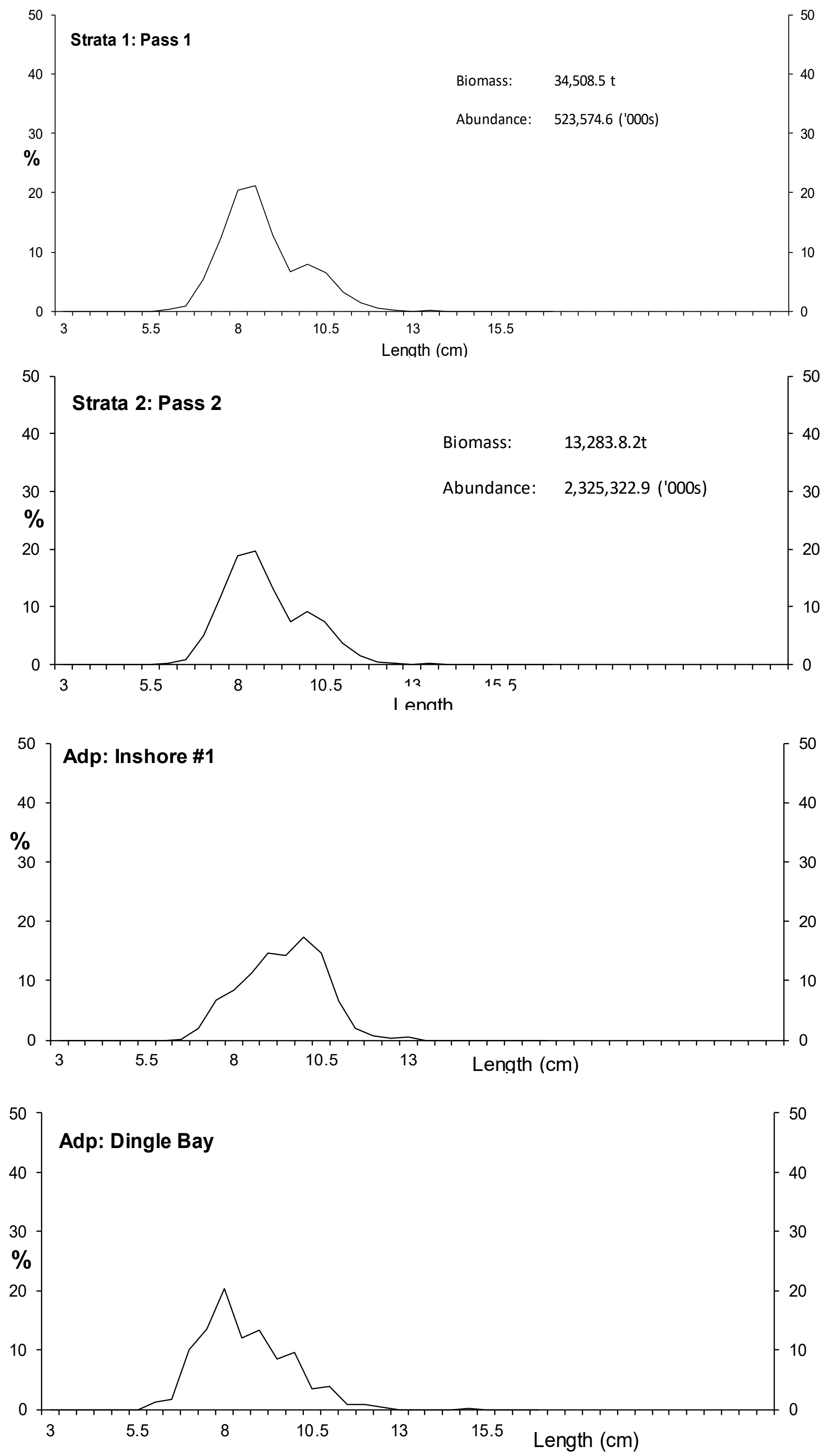
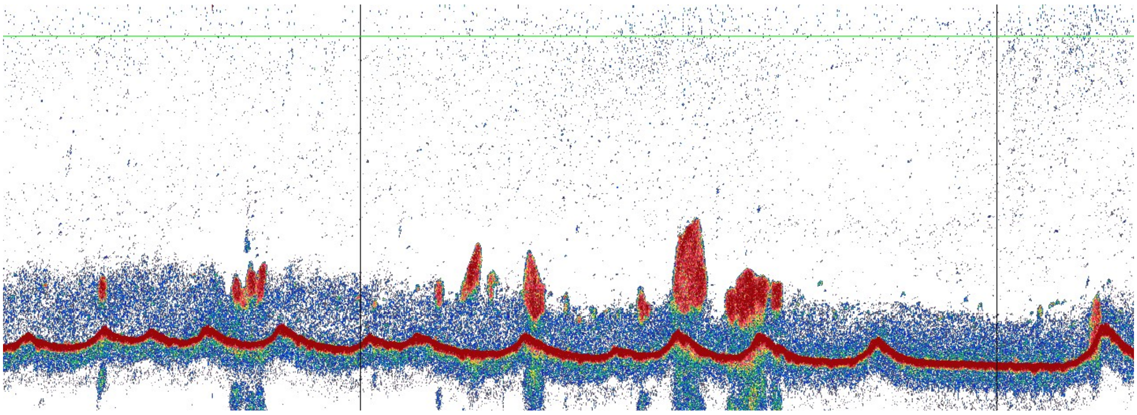
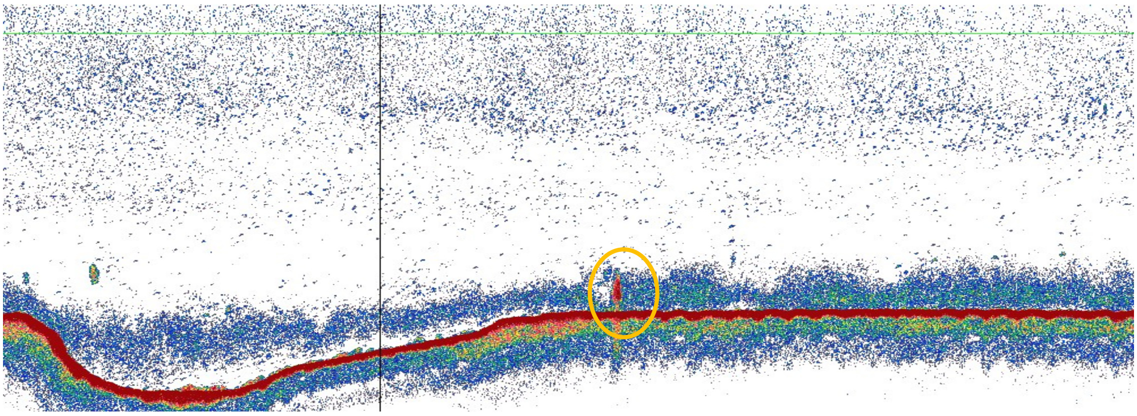


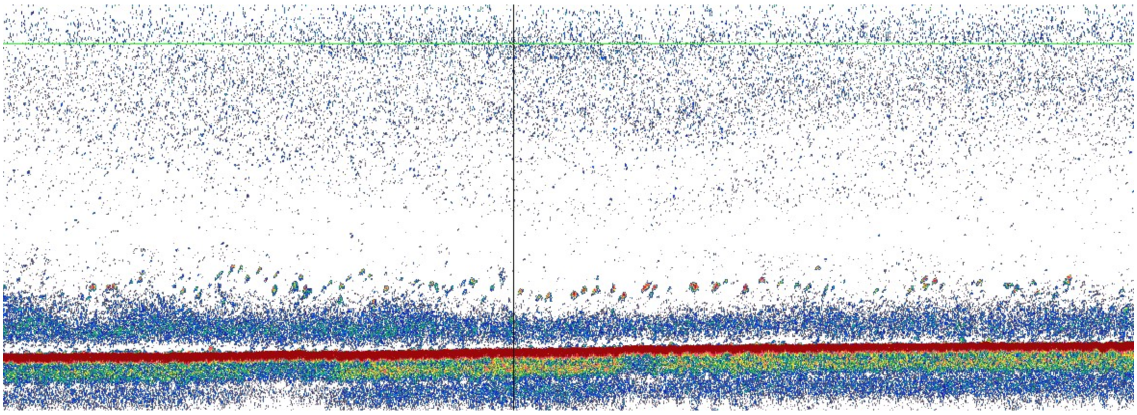
Figure 7. Length composition of sprat by strata and combined survey effort in 2022.



a). *Very high density echotraces composed primarily of sprat (97.5%) and some immature herring (2.5%). Recorded in daylight hours prior to Haul 12. Water depth 90 m*

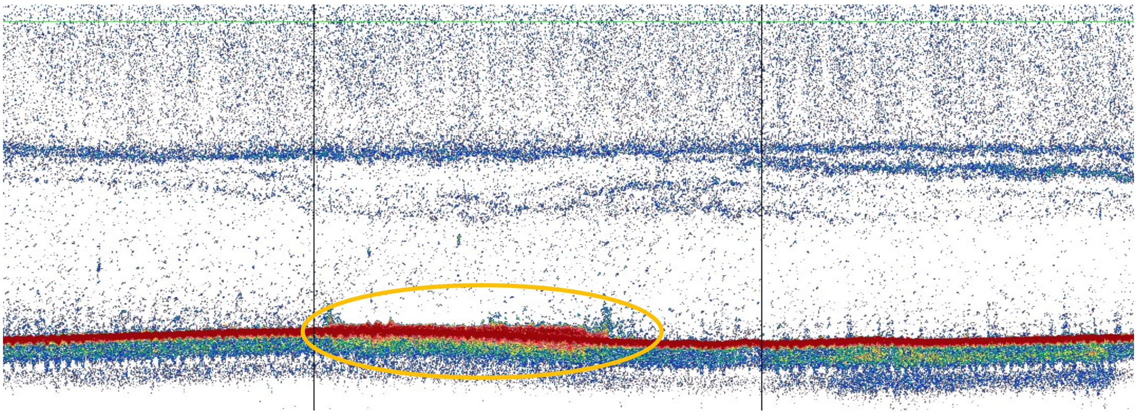


b). *Medium density anchovy echotrace. Observed during daylight hours, located offshore prior Haul 16. Water depth 90 m. Primary school evaded capture but some individuals were captured.*

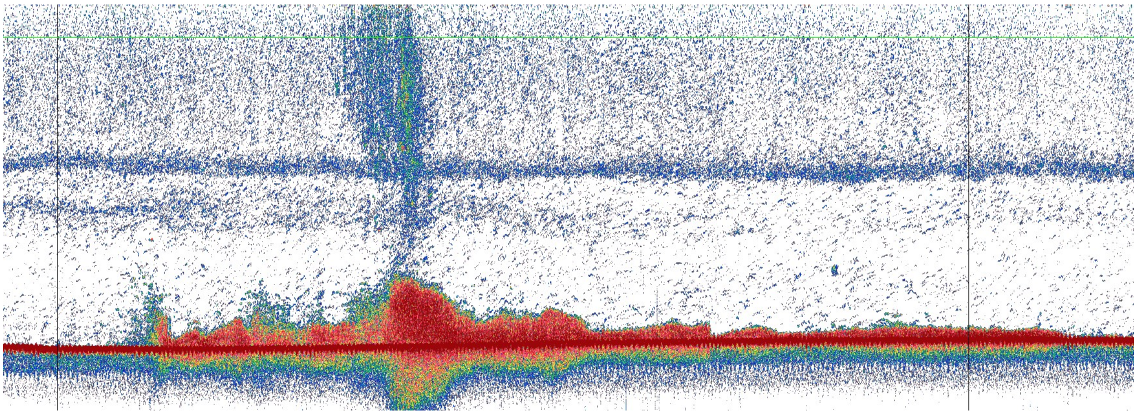


c). *Day time offshore scattering layer containing immature herring and sprat. Recorded prior to Haul 08. Water depth 78 m.*

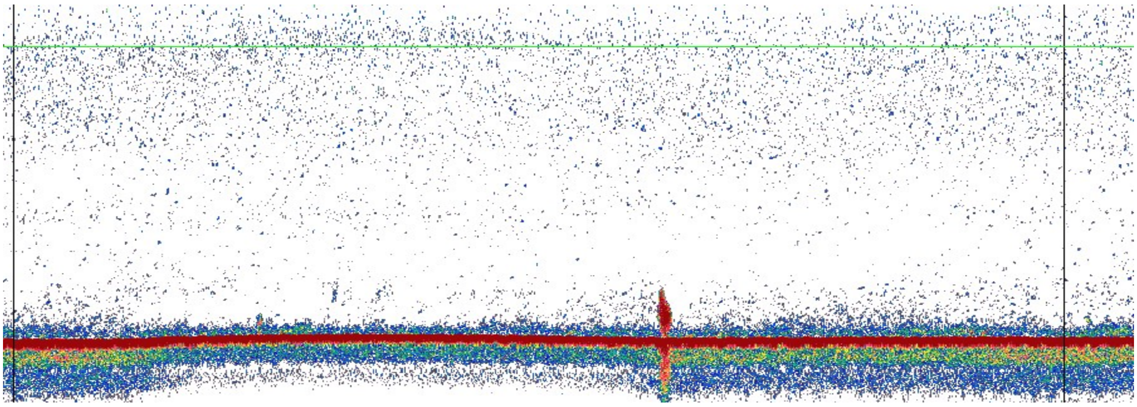
Figure 8. EK60 echograms (38 kHz) recorded prior to directed trawl stations.



d). *High density herring echotrace recorded prior to fishing operations (Haul 19). Water depth 98 m.*



e). *Same herring echotrace recorded during fishing operations conducted along the same line and heading (Haul 19). Water depth 98 m.*



f). *High density offshore pilchard echotrace recorded prior to Haul 14. Water depth is 60 m.*

Figure 8a-f. Continued

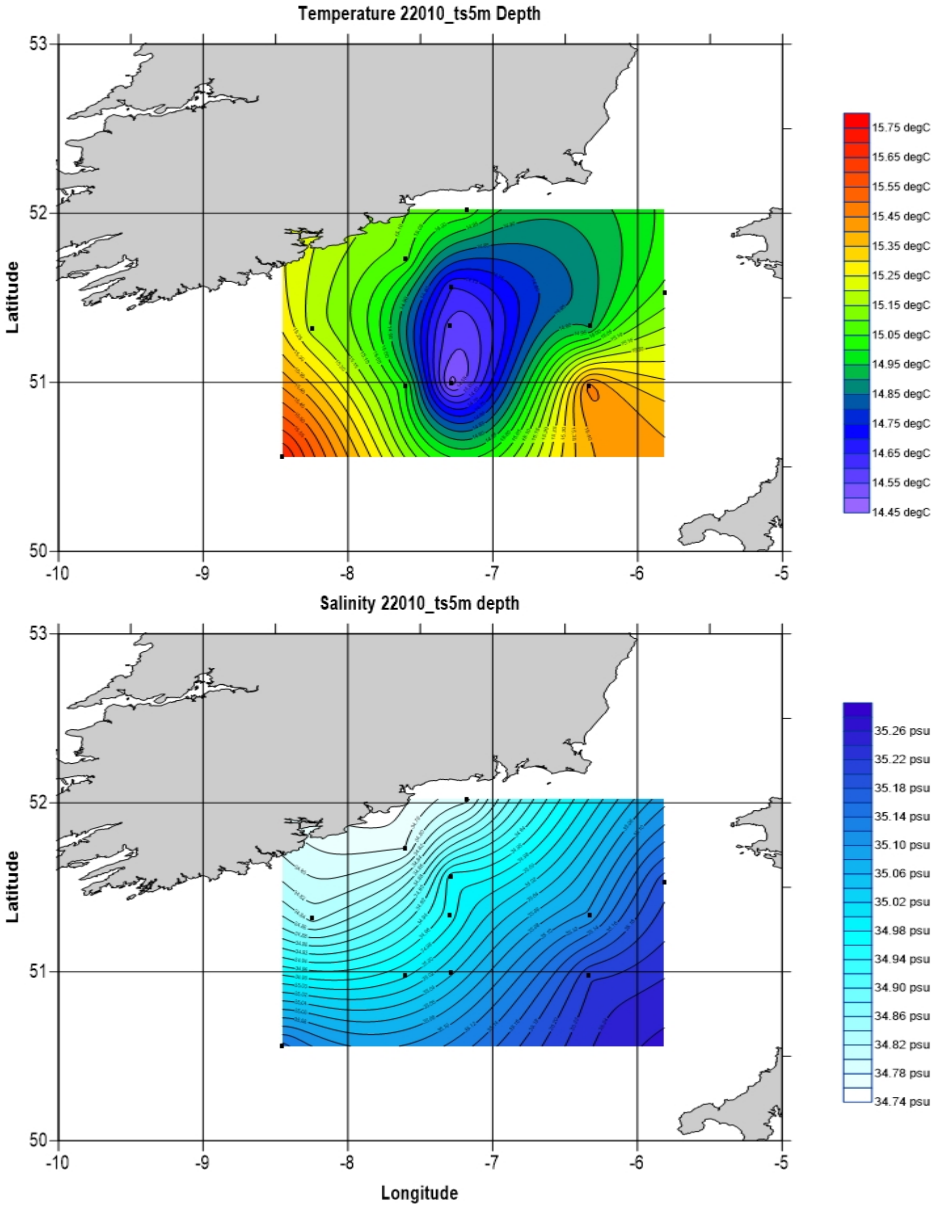


Figure 9. Surface (5 m) plots of temperature and salinity compiled from CTD cast data. Station positions shown as black circles (n=21).

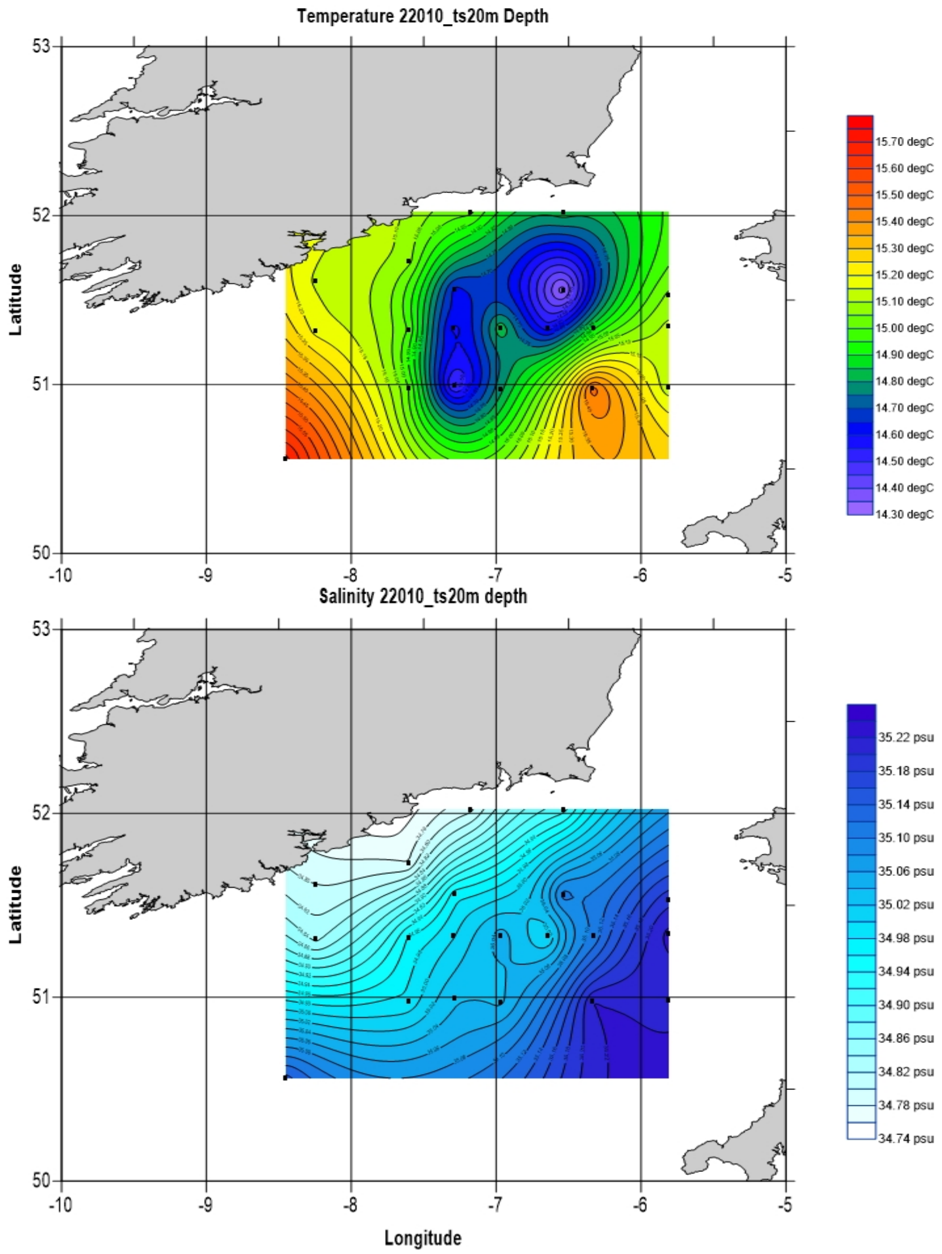


Figure 10. Surface (20 m) plots of temperature and salinity compiled from CTD cast data. Station positions shown as black circles (n=21).

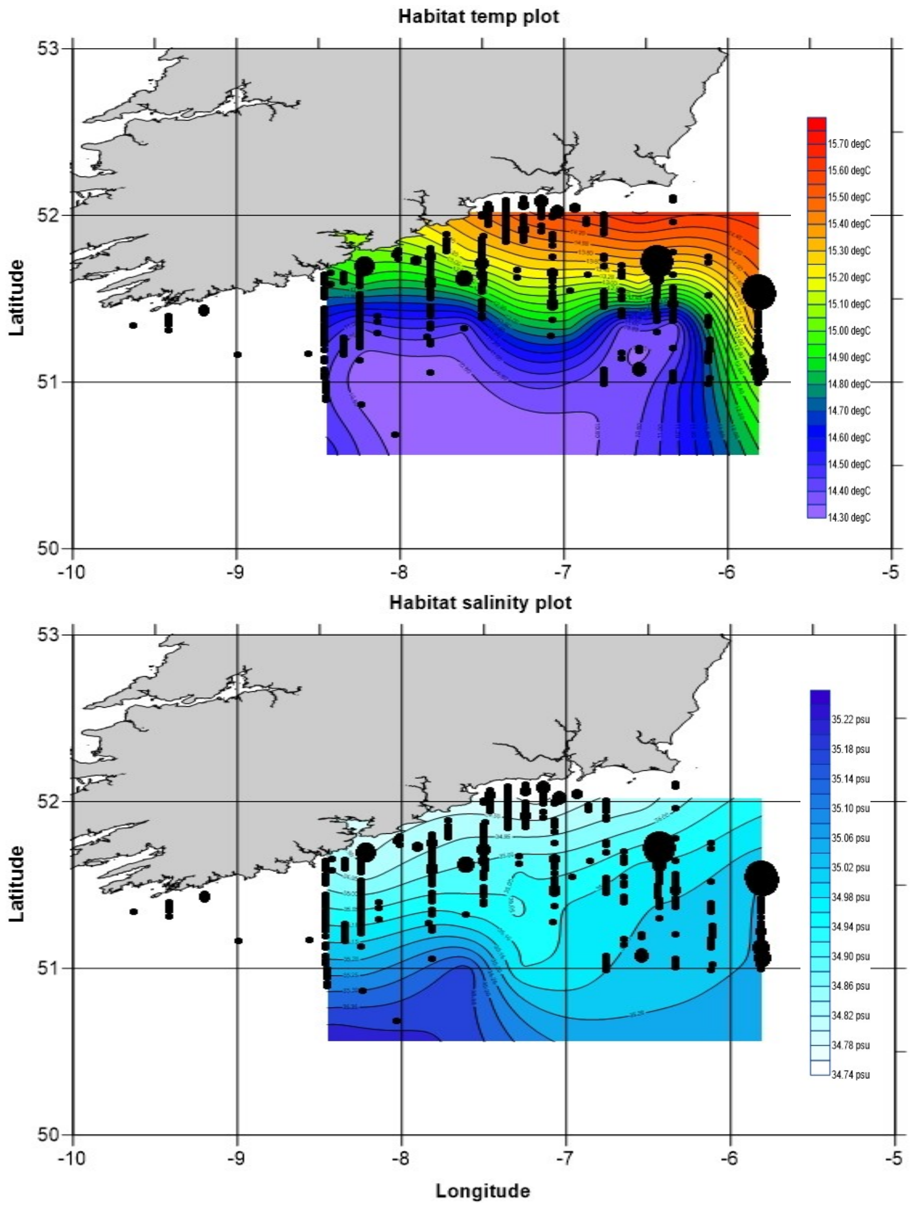


Figure 11. Habitat plots of temperature and salinity at the seabed overlaid with sprat NASC values (black circles).

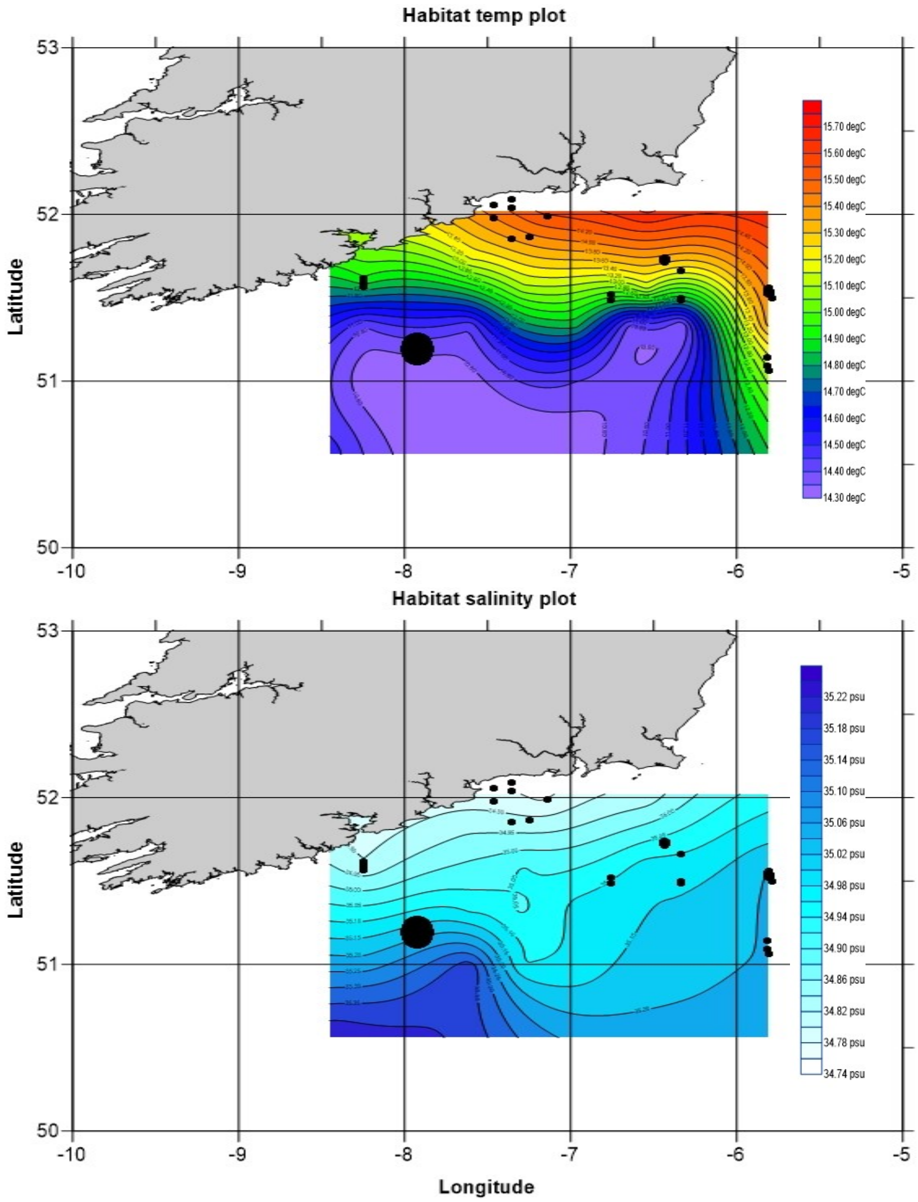


Figure 12. Habitat plots of temperature and salinity at the seabed overlaid with herring NASC values (acoustic density) shown as black circles.

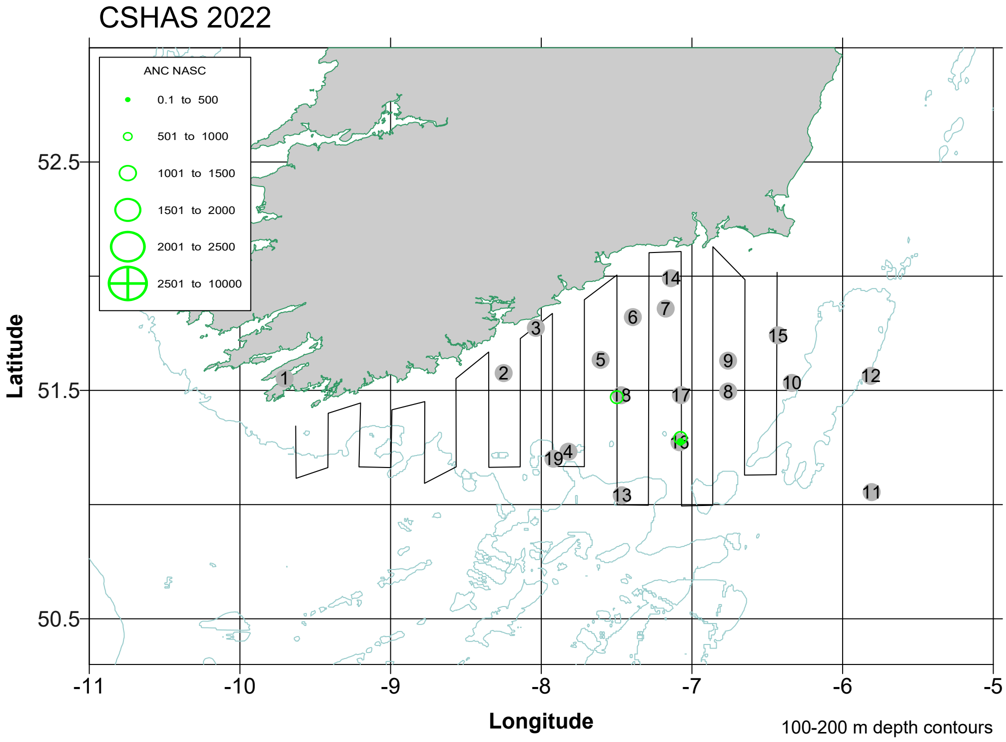


Figure 13. Anchovy NASC (Nautical area scattering coefficient) plot of the distribution from combined survey 2022.

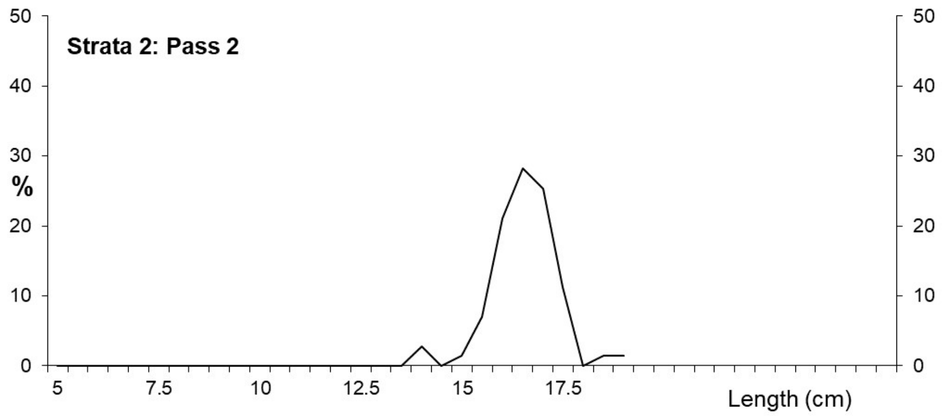


Figure 14. Length composition of anchovy by strata and combined survey effort in 2022.

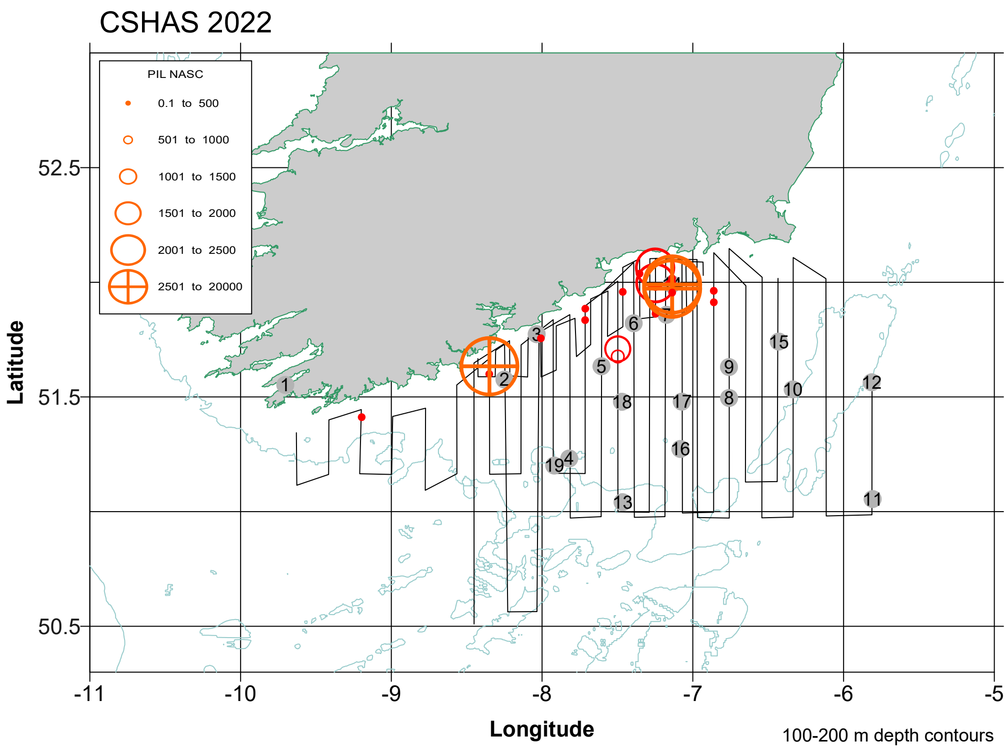


Figure 15. Sardine NASC (Nautical area scattering coefficient) plot of the distribution from combined survey 2022.

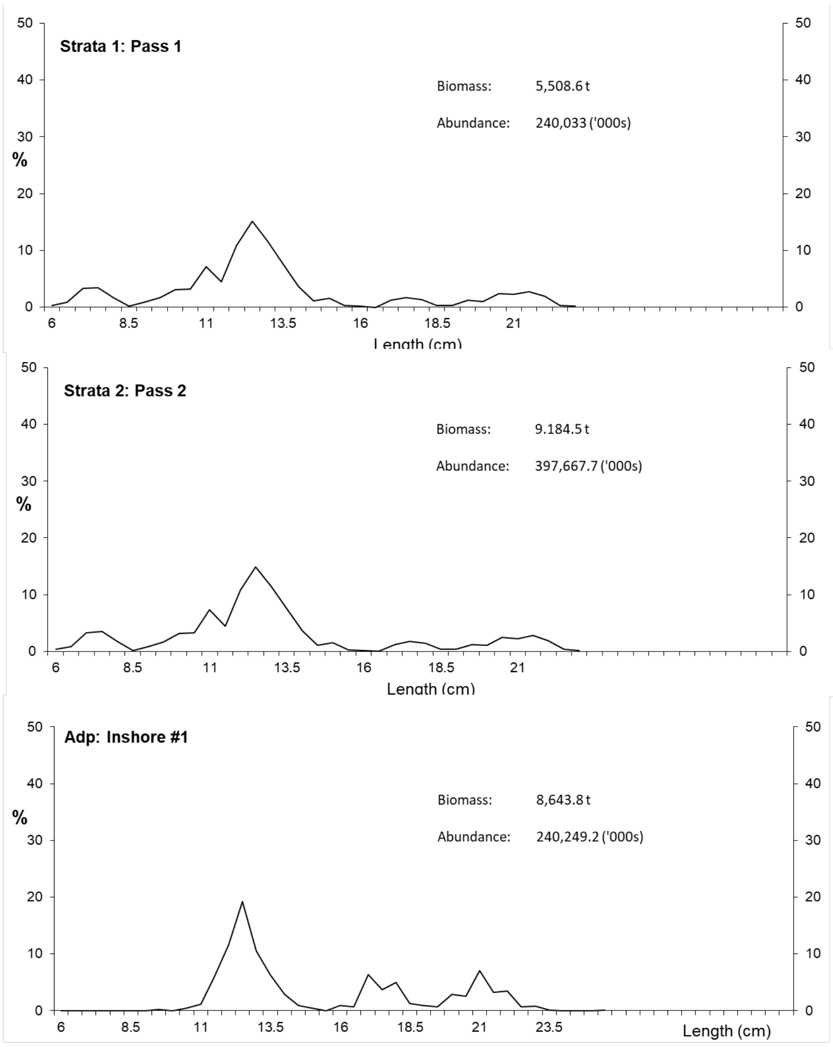


Figure 16. Length composition of sardine by strata.

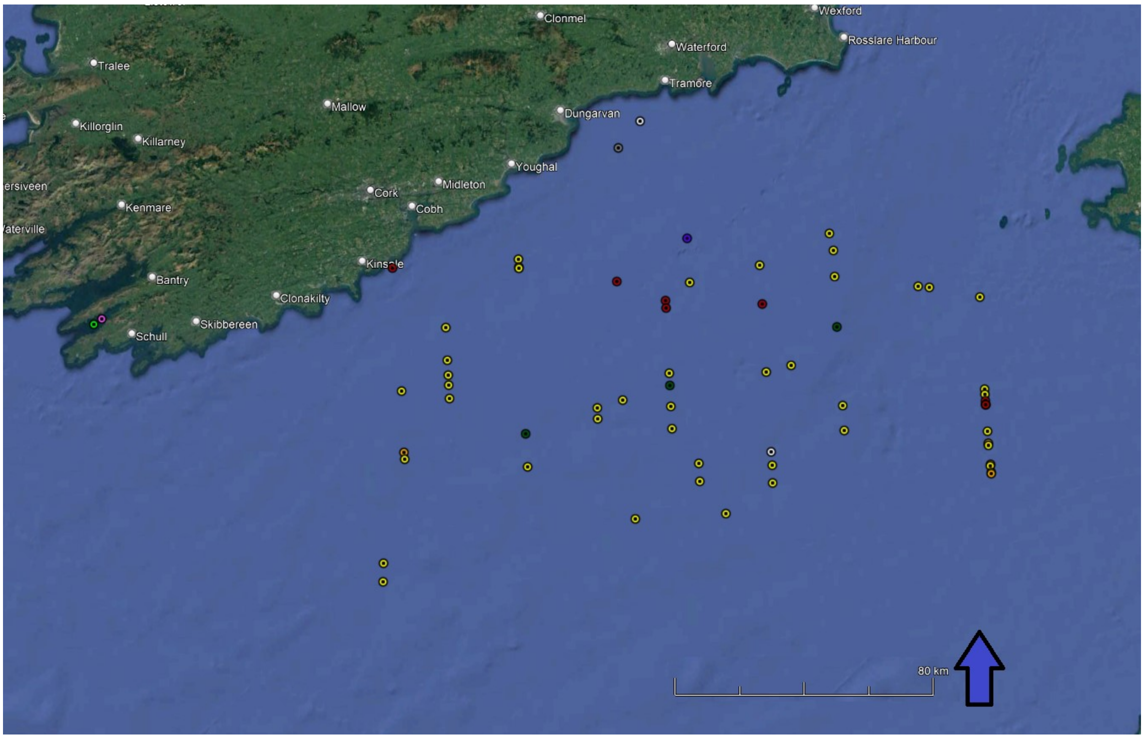


Figure 17. Distribution of all marine mammal sightings during the survey. B. acutorostrata, Purple – H. grypus, Red – T. thynnus, Yellow – D. delphis Orange - B. physalus, White – P. phocoena, Blue - P. glauca, Green – Unidentified Dolphin Spp., Grey – Unidentified Cetacean Spp. Animals observed in Dumanus bay were observed during acoustic survey calibration before acoustic survey began.

HERRING MIDWATER TRAWL

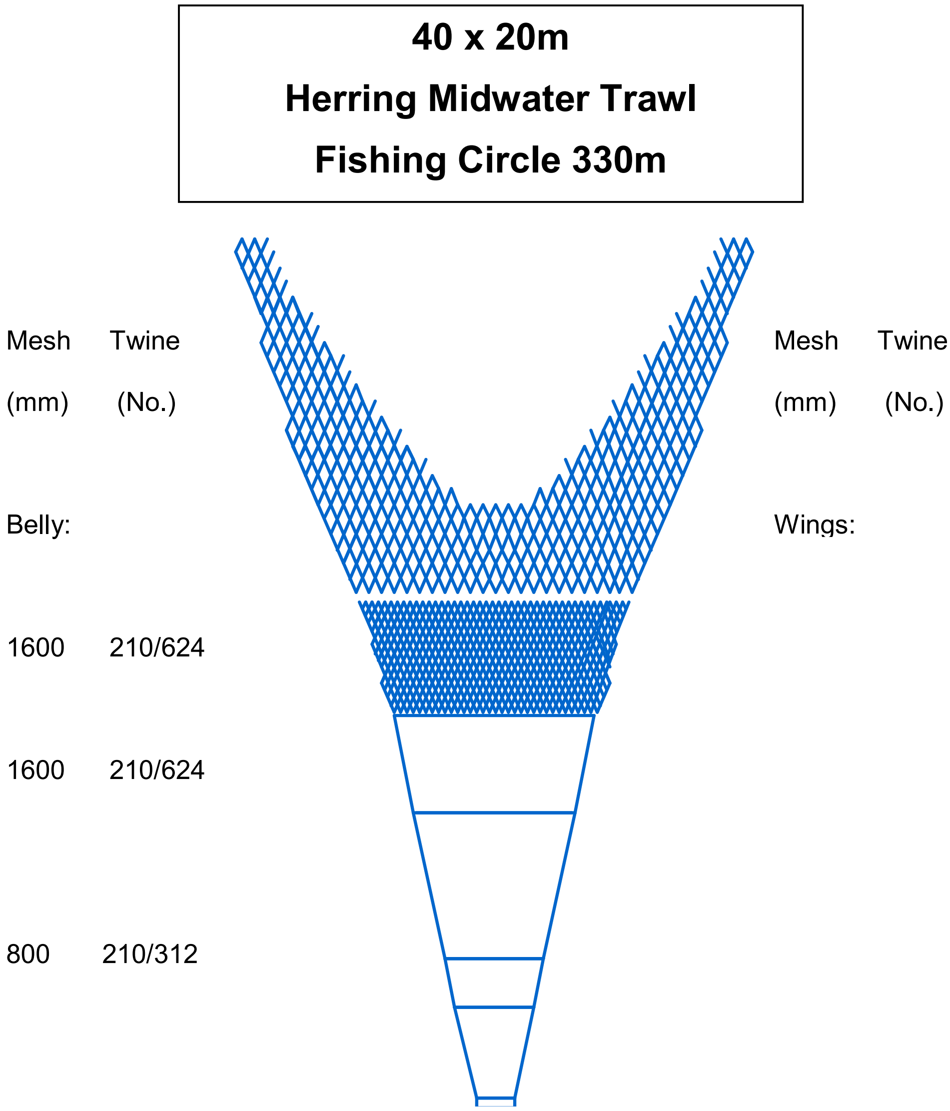


Figure 18. Single herring midwater trawl net plan and layout. Celtic Sea herring acoustic survey.

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

8 Appendix

	Age (years)										Numbers	Biomass	Mn Wt
Length	0	1	2	3	4	5	6	7	8	Ukn	(*10^{-6})	(t)	(g)
9													
9.5													
10	1941.7										1941.70786	15.6	7.6
10.5	6288.0										6288.00252	53.1	8.69
11	15372.5										15372.4504	147.7	9.54
11.5	20533.0										20533.013	216.9	10.6
12	26313.4										26313.4228	321.5	12
12.5	22172.0										22171.954	296.8	13
13	13504.4										13504.3683	203.9	15
13.5	3608.2										3608.21286	59.2	16
14	2769.5										2769.54961	52.3	19
14.5	24.6										24.5766108	0	
15													
15.5													
16													
16.5		286.6									286.602628	9.2	31
17													
17.5		286.6									286.602628	12.0	37
18													
18.5		286.6									286.602628	13.5	44
19													
19.5													
20													
20.5													
21													
21.5													
22													
22.5													
23													
23.5													
24													
24.5													
25													
25.5						24.577					24.5766108	3.4	131
26													
26.5													
27													
27.5													
28													
28.5													
29													
TSN (*10^{-3})	112,527.3	859.8				24.6					113,411.6		
TSB (t)	1,366.8	34.7				3.4						1,404.9	
Mean length (cm)	12.39	17.57				25.87							
Mean weight (g)	13.18	37.26				138.85							

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

Length	Age (years) 0	1	2	3	4	5	6	7	8	Ukn	Numbers (*10-³)	Biomass (t)	Mn Wt (g)
9													
9.5													
10	83.4										83.4	0.6	7.6
10.5	233.1										233.1	2.0	8.69
11	826.3										826.3	8.1	9.54
11.5	1525.9										1525.9	15.6	10.6
12	3256.4										3256.4	39.7	12
12.5	2831.0										2831.0	37.7	13
13	1951.5										1951.5	29.1	15
13.5	548.1										548.1	8.9	16
14	49.3										49.3	0.9	19
14.5													
15													
15.5													
16													
16.5													
17													
17.5													
18													
18.5													
19													
19.5													
20													
20.5													
21			264.4								264.4	18.0	68
21.5			264.4								264.4	18.5	70
22													
22.5			264.4								264.4	0.0	
23				3172.9							3172.9	298.8	94.5
23.5				5817.0							5817.0	559.9	95.5
24				8461.1							8461.1	911.5	106.6
24.5				18156.8	5375.8						23532.6	2721.6	115.3
25				12379.7	10624.0						23003.7	2837.6	122.6
25.5				5018.0	10950.7	160.3					16129.1	2110.2	131
26				4314.4	8098.6	1865.2					14278.2	1946.5	137
26.5					2890.41	1340.2					4230.6	587.2	139.1
27					1206.69		908.6				2115.3	297.2	142
27.5								528.8			528.8	83.6	158
28													
28.5													
29													
TSN (*10-³)	11,305.1		793.2	57,319.9	39,146.3	3,365.7	908.6	528.8			113,367.7		
TSB (t)	142.6		36.5	6,584.7	5,078.5	478.6	128.6	83.6				12533.0	
Mean length (cm)	12.39		21.25	24.67	25.55	25.85	27	27.5					
Mean weight (g)	13.18		69	116.16	130.73	138.85	140	162					

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

	Age (years)										Numbers	Biomass	Mn Wt
Length	0	1	2	3	4	5	6	7	8	Ukn	(*106)	(t)	(g)
9													
9.5													
10													
10.5	61.1										61.1	0.5	7.6
11	950.4										950.4	9.0	8.69
11.5	1755.6										1755.6	17.1	9.54
12	4902.0										4902.0	61.5	11
12.5	7480.8										7480.8	100.7	12
13	8750.4										8750.4	132.8	13
13.5	2802.0										2802.0	46.0	15
14	372.5										372.5	6.7	16
14.5	50.06905										50.1	0	19
15													
15.5													
16													
16.5													
17													
17.5													
18													
18.5													
19													
19.5													
20													
20.5													
21													
21.5													
22													
22.5													
23													
23.5													
24													
24.5													
25													
25.5						50.069					50.1	6.9	131
26													
26.5													
27													
27.5													
28													
28.5													
29													
TSN (*10^3)	27074.37					50.1					27174.90		
TSB (t)	374.4					6.9						381.3	
Mean length (cm)	12.39					25.87							
Mean weight (g)	13.18					138.85							

Figure 3. Biomass and abundance at length and age for Adaptive survey: Inshore #1.