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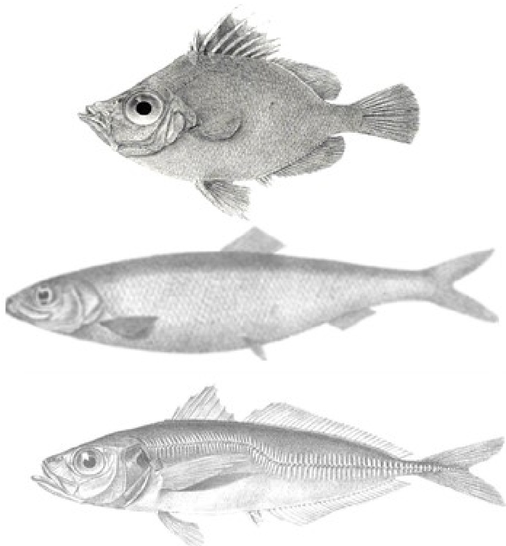
FSS Survey Series: 2022/03

Western European Shelf Pelagic Acoustic Survey (WESPAS)

14 June –24 July, 2022



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Foras na Mara
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1 Introduction

The WESPAS survey program is the consolidation of two existing survey programs carried out by FEAS, the Malin Shelf herring acoustic survey, and the boarfish acoustic survey. The Malin Shelf herring acoustic survey has been carried out annually since 2008 and reports on the annual abundance of summer feeding aggregations of herring to the west of Scotland and to the north and west of Ireland from 53°30'N to 58°30'N. The boarfish survey was conducted from 2011 using a chartered fishing vessel and reported the abundance of spawning aggregations of boarfish from 47°N to 57°N. In 2016 both surveys were combined into the WESPAS survey and have been carried out onboard the RV *Celtic Explorer* over a 42-day period, providing synoptic coverage of shelf waters from 47°30'N northwards to 58°30'N.

Age stratified relative stock abundance estimates of boarfish, herring and horse mackerel within the survey area were calculated using acoustic data and biological data from trawl sampling. Stock estimates of boarfish and horse mackerel were submitted to the ICES assessment Working Group for Widely Distributed Stocks (WGWIDE) meeting in August 2022. Herring estimates are submitted to the Herring Assessment Working Group (HAWG) meeting in March every year. Survey performance will be reviewed at the ICES Planning Group meeting for International Pelagic Surveys (WGIPS) meeting in January 2023.

2 Materials and Methods

2.1 Scientific Personnel

Leg	CE22010	CE22010
Dates	14-04 Jun-Jul	05-25 Jul
Days	20	21
Start	Galway	Galway
End	Galway	Galway
Acou (Chief Sci)	Ciaran O'Donnell	Michael O'Malley
Acou	Cormac Nolan	Eugene Mullins
Acou	Turloch Smith	John Enright
Acou	Thibault Cariou	Artur Opanowski
Bio (Deck Sci)	Marcin Blaszkowski	Grainne Ryan
Bio	Ross Fitzgerald	Helen McCormick
Bio	Sean O'Connor	Rehab Soliman
Bio	Aaron Craig	Llucia Mascorda Cabre
MMO	Mathew Duffy	Justin Judge
SBO	Sharon Sheehan	Sharon Sheehan
Zooplk	Eoin Underwood	Kevin Heeney
eDNA	Maddalena Tibone	
CDOM +	Celine Burin	Rachel Cave
CDOM +		Janina Buescher
CDOM +		Erica Krueger
CDOM +		Patrice Galvin

2.2 Survey Plan

2.2.1 Survey objectives

The primary survey objectives are listed below:

- Collect acoustic density measurements of boarfish, herring and horse mackerel within a pre-determined survey area using a split-beam echosounder (EK60) over multiple frequencies
- Determine an age stratified estimate of biomass and abundance for the above target species from survey data
- Collect biological samples from directed trawling on fish echotraces to determine age structure and maturity state of standing stocks
- Take genetic samples of individual herring within ICES divisions 6a and 7b, c for stock identification analysis
- Use vertical CTD casts to determine hydrographic conditions and the extent of shelf front regions
- Collect plankton samples using dedicated vertical trawls to determine biomass of zooplankton and the spatial extent of areas of concentration

- Carry out visual surveys to determine the abundance and distribution of marine mammals and seabirds
- Collect Omni sonar (Simrad SU92) data on the aggregation morphology and behaviour of target species

2.2.2 Survey design and area coverage

Survey coverage began in the southern Celtic Sea at 47°30'N (northern Biscay) and worked northwards to 58°30'N (northern Hebrides), including the Porcupine Bank (Figure 1). Area coverage was based on the distribution of catches from the previous surveys (e.g. O'Donnell et al. 2007, 2011).

The survey area was stratified based on acoustic sampling effort strata and geographical stock boundaries. Transect start points were randomised within each stratum. Parallel transect spacing was set at 15nmi (nautical miles) for the main body of the survey and 10nmi in 2 strata to the northwest of Ireland (NW coast and North Malin strata). Zigzag transects were used in the Minch region due to geographical and depth constraints. High-intensity small scale surveys were carried out in specific areas of interest using established methods. Coverage extended from the 50 m contour inshore to the shelf-slope (350 m). An elementary distance sampling unit (EDSU) of 1 nmi was used during the analysis of acoustic data throughout the survey area. In total, the planned survey covered 5,084 nmi using 59 transects relating to total area coverage of 58,346 nmi².

The survey was carried out from 04:00–00:00 each day to coincide with the hours of daylight when target species are most often observed in homogenous schools. During the hours of darkness, schools generally disperse into mixed-species scattering layers and are not readily available to acoustic sampling techniques.

Survey design and analysis methods for the WESPAS survey adhere to guidelines laid out in the Manual for International Pelagic Surveys (ICES, 2015).

2.3 Fisheries acoustics

2.3.1 EK60 Calibration

All frequencies of the Simrad EK60 were calibrated in March in Dunmanus Bay. Calibration procedures followed methods laid out in Demer *et al.* (2015). The results of the 38 kHz calibration are provided in Table 1.

2.3.2 Acoustic array

Equipment settings for the acoustic equipment were determined before the start of the survey program, and based on established settings employed by FEAS on previous surveys (O'Donnell *et al.,* 2004, ICES, 2015).

Acoustic data were collected using the Simrad EK60 scientific echosounder. 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 below sea 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. During fishing operations normal two-engine operations were employed to provide sufficient power to tow the net.

2.3.3 Acoustic data acquisition

Acoustic data were recorded onto the hard-drive of the processing unit. The "RAW files" were logged via a continuous Ethernet connection to the vessels server and the EK60 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. Echoview® Echolog (Version 12) 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 schools. 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.

2.3.4 Echogram scrutinisation

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 one of the target species (herring, boarfish and horse mackerel) were identified 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 monospecific schools. For scattering layers or mixed schools containing target species the total NASC (Nautical Area Scattering Coefficient) was split using Target Strength (TS) to provide a species specific NASC value. This process was conducted within the StoX program (Johnsen et al., 2019).

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 (s_A (NASC, m^2/nmi^2) 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 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 boarfish is from Fässler et al. (2013):

Boarfish TS = 20logL – 66.2 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)

2.3.5 Calculation of acoustic abundance

Acoustic data were analysed using the StoX (V 3.4.0 and R StoX V3.4) software package (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).

2.4 Biological sampling

A single pelagic midwater trawl with the dimensions of 85 m in length (LOA) and a fishing circle of 420 m was employed during the survey (Figure 22). Mesh size in the wings was 2.4 m through to 10 cm in the cod-end. The net was fished with a vertical mouth opening of approximately 25 m and 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/boarfish/horse mackerel/mackerel 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, boarfish, sprat and pilchard were taken to the nearest 0.5 cm below. Horse mackerel and mackerel were taken to the nearest 1.0 cm below. Age, length, weight, sex and maturity data were recorded for individual herring, boarfish and horse mackerel within a random 50 fish sample from each trawl haul, where applicable. Length and weight measurements were taken of a further 100 random fish, and for the remainder a random sub-sample of length only fish were measured until 60 fish in one length class was reached. 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 from the bottom to be taken in areas of clean ground.

2.4.1 Herring stock identification

A sample of 96 individual herring were taken from each haul in the Malin Shelf area (6a and 7b, c) for genetic analysis to determine the stock identification of herring in this area. Following the benchmark that was carried out in 2022 (ICES 2022), herring abundance and biomass from this survey (when combined with the Scottish effort in 6aN), will be split into 6aS/7b c and 6aN. Stock identification of herring on the Malin Shelf uses genetic baseline information from spawning fish from numerous areas and is based on sampling work initiated in 2014 (Farrell et al. 2021). The 2022 benchmark resulted in a split for this survey going back as far as 2014, when genetic sampling of herring on this survey first began. All fish sampled for genetics were also fully sampled for length, weight, age, sex, maturity. When less than 96 herring were available to sample from a haul, all the herring were sampled for genetics from the haul.

2.5 Hydrography and biogeochemical data collection

Oceanographic stations were carried out during the survey at predetermined locations along the survey track using a calibrated SeaBird 911 rosette sampler. Data were collected from 1 m subsurface and 3-5 m above the seabed.

2.5.1 Hydrography and water sampling

Seawater samples were collected from up to 6 depths on the up cast of the profile by triggering Niskin bottles at predetermined depths related to the hydrography observed during the down cast. The CTD data comprises continuous downcast and up casts records of the pressure, temperature, conductivity (salinity), dissolved oxygen, chlorophyll fluorescence and turbidity. The raw CTD data are processed according to GO-SHIP guidelines via the Seabird software and incorporated into ODV files for the continuous downcast data and the discrete bottle data collected during the up cast.

2.5.2 Coloured Dissolved Organic Matter (CDOM)

Samples for the analysis of CDOM absorption were collected from the CTD cast directly from the Niskin bottles. They were then immediately filtered through an 0.2 µm syringe filter and part of the filtrate used for CDOM analysis onboard and the rest frozen at -20° C for later nutrient and FDOM analysis. CDOM measurements were performed using an Ocean Optics Maya spectrophotometer coupled to a 1m liquid wave guide capillary cell (LWCC), supplied by World Precision Instruments, and an Ocean Optics DH-mini light source.

2.5.3 Nutrient (NO2-, NO3-, PO43-, Si(OH)4) sampling

Seawater samples are collected from the CTD and immediately filtered through 0.2 µm syringe filters. The filtrate is then frozen at -20° C until analysis in the laboratory in Galway. For analysis in the laboratory samples are thawed overnight and then analysed for Nitrite, Nitrate, Phosphate and Silicate using specially adapted low volume methods based on standard green chemistry methods for nutrient analysis in seawater. Selected stations will also be analysed for urea and ammonia as we look to increase our capacity for measuring nitrogen species in connection with a related EPA/Marine Institute funded project, 'Nuts and Bolts' which is focused on the marine transitional zones.

2.5.4 Bacteria, Heterotrophic nanoflagellates, Pico and nanoplankton abundance

Unfiltered seawater samples collected directly from the CTD were run on an Accuri C6 flow cytometer while at sea according to established protocols (Marie et al., 1997; Marie et al., 2014). Briefly we initially run an untreated raw sample to identify the phytoplankton by size and fluorescence, Synechococcus species can be identified at this step by their unique combination of cell size and phycoerythrin fluorescence. A second raw sample is treated with Lysotracker Green to determine heterotrophic nanoplanktonic protists (Rose et al., 2004). While a third sample is fixed with glutaraldehyde and then treated with the DNA stain Syber Green to enumerate marine bacteria and phytoplankton via the combination of chlorophyll fluorescence (red) and the dna stain (green). We also use the Syber Green staining to identify heterotrophic flagellates (Christaki et al., 2011).

2.5.5 Hyperspectral measurements

In order to more directly compare field data with satellite data, a pair of hyperspectral sensors were mounted above the bridge of the *Celtic Explorer*. The sensor pair incorporated an irradiance and radiance sensor for the purposes of determining the hyperspectral reflectance from the surface of the ocean for comparison to the reflectance measured by the ocean colour satellites.

Particulate absorption of fresh water and seawater can be determined by filtering a known amount of sample through a Glass Fibre Filter (GF/F) and measuring the particulate absorption coefficient $a_p(\lambda)$ concentrated on the filter. This technique is called quantitative filter technique (QFT) and corrects for the path length amplification, an effect of scattering. Measurements were made shipboard using a QFT-1 filter holder (WPI) after filtering 200-1000 mL of seawater through a 25 mm GF/F filter. An Ocean Optics Maya spectrophotometer was coupled to the QFT-1 using 600 µm diameter fibre optical cable with a DH mini light source.

2.5.6 Chlorophyll measurements and Ocean Colour (Chlorophyll)

The frozen filters previously measured onboard for the QFT-1 measurements were analysed in the laboratory for chlorophyll a (b & c) concentrations after extraction with 90% acetone after overnight extraction in a -20° C freezer and subsequent measurement of the solution absorbance using an Ocean Optics Flame spectrophotometer with a low volume 10 cm pathlength cell and DT-mini light source. The concentration of chlorophyll a was calculated using the trichromatic equation.

2.6 Zooplankton

2.6.1 Zooplankton

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.

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).

2.7 Marine mammal and seabird surveys

2.7.1 Marine mammal abundance and distribution

The cetacean survey was conducted by a single marine mammal observer (MMOs), with one cetacean observer deployed per survey leg.

Cetacean watches were conducted using a standard single platform line transect survey design while the vessel was travelling at a consistent speed and heading. When the vessel was stationary at oceanographic stations, cetacean watches were conducted using a standard single platform point sampling survey design. Visual watches were undertaken from the vessel's crow's nest, located 17.45 m above sea level, during all daylight hours, when weather conditions permitted. During periods of unfavourable weather conditions, observations were carried out from the bridge (10.63 m above sea level).

Survey effort was concentrated in periods of sea state 6 or less, and in moderate or good visibility. Survey effort conducted outside of these parameters was conducted at the discretion of the observers. Survey effort for cetaceans was concentrated within an arc of 60° either side (i.e., to port and to starboard) of the vessel's track-line but all sightings to 90° both side of the track-line and further aft were also recorded. Searching for cetaceans was predominantly done with the naked eye, however, Nikon Prostaff 7 8x42 binoculars and a Canon EOS 7D DSLR camera with a Sigma 100-400 mm zoom lens was used to confirm species identification and group size, and assess behaviour. Survey effort was also carried out during hauls and when at CTD stations.

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.

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 time-stamped 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.

The distance of each sighting from the ship was estimated using a fixed interval range finder (Heinemann, 1981), while the bearing from the ship was estimated with an angle board. This data, along with data such as species identification, group size, composition, heading, sighting cues, surfacing interval, behaviour and any associations with birds or other cetaceans was also recorded on the time stamped Cybertracker sighting record page. Where species identification could not be confirmed, sightings were recorded at an appropriate taxonomic/confidence level (i.e. probable, possible, unidentified whale, unidentified dolphin etc.). Auxiliary and incidental sightings were also recorded.

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

2.7.2 Seabird abundance and distribution

The seabird survey was conducted from the 10/06/21 to the 19/07/21 using a single seabird surveyor on each survey leg. The seabird observer conducted visual survey effort, while also collecting and recording all survey data. 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. Observations for seabirds were conducted from the monkey island (deck height 12 m above sea level) or the bridge (deck height 10 m above sea level). Observations were conducted from the monkey island preferably, however, as in previous surveys aboard the RV *Celtic Explorer*, access to the monkey island was dependent on weather conditions.

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 be 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: 0-50 m, B: 50-100 m, C: 100-200 m, 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 track line (Camphuysen *et al.* 2004). Seabirds occurring outside of this survey strip were recorded as 'off-transect' and assigned to separate sub-band (E: >300 m). 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 300 m x 300 m 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.,* 1997, 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 100-400 mm 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 3.501) 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.

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 time-stamped 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 time-stamped 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.

3 Results

3.1 Malin Shelf herring (6.a.S, 7.b, c and 6.a.N south of 58°30'N)

3.1.1 Biomass and abundance

Herring	Abund ('000)	Biomass (t)
Total stock (TSB)	1,985,643	276,378
Spawning stock (SSB)	1,565,694	248,551

The Malin Shelf Herring total stock biomass (TSB) was 276,378 t and total stock numbers (TSN) was 1,985,643,000. The spawning stock biomass (SSB) was 248,551 t and spawning stock numbers (SSN) was 1,565,694,000. The CV for the survey was 0.43.

The Malin Shelf survey area was divided into 6 strata representing a total area coverage of 23,206 nmi^2 (Figure 2 & Table 5). A breakdown of herring stock abundance and biomass by age, maturity and stratum is detailed in Table 3 and Figure 4. The Malin Shelf survey time series is provided in Table 4.

3.1.2 Stock distribution

In the Malin Shelf area 8 hauls contained herring and 4 hauls contained >50% herring by weight of catch (Figure 1 and Table 2). A total of 303 echotraces were assigned to herring compared to 659 in 2021 in this area.

The area covered by the RV *Celtic Explorer* in 2022 was similar to the 2021 survey. The area of 6.a.N to the north of 58°30'N was covered by RV *Scotia* in 2022; the overall estimate of the survey for the stock assessment of herring in 6.a and 7.b c will therefore be complete when both surveys are combined at WGIPS 2022 (the overall abundance and biomass estimate of herring for the two surveys will also be split based on genetics into component stocks at this stage). Herring were distributed in four of the six WESPAS strata (Table 5), this is a contraction of the stock compared to 2021 where all strata had herring distributed. A total of 49 EDSUs (1nmi. long) contained herring in the Malin Shelf survey area in 2022, compared to 211 in 2021. This included a number of high NASC value EDSUs, with areas of high density occurring particularly to the northwest of Tory Island, northwest of the mouth of Lough Swilly in 6.a.S, and south of St. Kilda in 6.a.N (Figure 3). Herring were again found south of 56 ˚N in 2022, similar to the historical distribution of herring found during this time series. There were adult herring distributed south of the 56°N in 2022 similar to recent years (herring had been largely absent for a number of years prior to 2019). Herring school morphology was mixed in 2022, with schools found in midwater as fast-moving pillars, in dispersed marks in close proximity to the seabed and very tight to the seabed (e.g. Figures 11c, 11m and 11n). Overall the stock was distributed throughout a similar area to 2021 but it was more contracted in smaller areas (Figures 3). The distribution of herring during the survey period is usually observed in 3 particular regions; north of 57°N (west of the Hebrides), between 56-57°N (south and west of Barra Head) and south of 56°N (north and west of Donegal and Stanton Bank). The survey in 2022 largely followed a similar distribution, but more contracted.

3.1.3 Stock composition

A total of 432 herring were aged from survey samples with 2,223 length measurements and 829 length-weights recorded. Herring age samples ranged from 1-8 year olds (Table 3 & Figure 4). Samples of flesh (~1cm^3) were also taken from all 432 herring for genetic analysis to establish stock identification.

The 2022 survey estimate was dominated by 3-wr (32% TSB and 30% TSN) and 4-wr (31% TSB and 25% TSN) (Table 3). The third most dominate age group was 5-wr herring contributing 14% to the TSB and 11% to TSN. Combined these three age classes represented 77% of TSB and 66% of TSN.

Maturity analysis of herring samples in 2022 indicated overall 90% of herring (TSB) were mature. In 2021, 74% of herring (TSB) were mature. Maturity analysis by age class (TSN) showed that 0% of 1-wr, 70% of 2-wr, 99% of 3-wr fish, and 100% of fish of 4-wr and older were mature (Table 3).

3.2 Boarfish

3.2.1 Biomass and abundance

Boarfish	Abund ('000)	Biomass (t)
TSB estimate	18,613,756	451,415
SSB estimate	17,672,827	442,722

Boarfish TSB (total stock biomass) and abundance (TSN) estimates were 451,415 t and 18,613,756,000 individuals (CV 0.24) respectively. The 2022 estimate of TSB saw an increase of 2% compared to 2021, while TSN saw a reduction of 15%. Spawning stock biomass (SSB) was higher than 2021 (26%).

The boarfish survey area was divided into six strata representing a total area coverage of 49,988 nmi^2 (Figure 2). A breakdown of boarfish stock abundance and biomass by age, maturity and stratum is detailed in Table 6 & 7 and Figures 5 & 6. The boarfish survey time series is provided in Table 8.

3.2.2 Stock distribution

Forty trawl hauls were carried out during the survey (Figure 1), with 20 hauls containing >50% boarfish by weight (Table 2).

A total of 1,060 echotraces were assigned to boarfish compared to 976 in 2021. Boarfish were present in all of the strata surveyed (Table 7). Geographical range was comparable to previous years with the greatest biomass occurring in the Celtic Sea (61.5 % of TSB and 66.6% of TSN), followed by the Irish west coast (32.5% TSB & 28.1% TSN). Within the Celtic Sea, the highest density of fish was observed in the southern survey area, south of 50°N. Mixed catches of mature and immature fish dominated catches in the Celtic Sea. Overall, TSB was lower in the Celtic Sea than observed in 2021 for comparable effort. The west coast stratum ranked second contributing 32.5%

of TSB (28.1% TSN). The biomass of fish observed in this stratum is comparable to 2021. However, abundance (TSN) is lower, driven by the older age profile of catches in 2022.

The distribution of boarfish north of 55°N (South and West Hebrides strata), was characterised by medium and high density aggregations in close proximity to the shelf edge. The West Hebrides (northernmost) contained the largest proportion of older fish (Figure 6). The North Stanton strata (located on-shelf) contained an aggregation composed almost entirely of small fish of mixed maturity (ages 1-3 years). The stratum contributed 1.1% of TSB and 2.0% TSN. Although the contribution to the total estimate was small, this stratum has previously contained aggregations of immature fish.

3.2.3 Stock composition

A total of 1,270 boarfish were aged from survey samples in addition to 6,575 length measurements and 2,498 length-weights recorded. Boarfish age samples ranged from 1-15+ years (Table 6 & Figure 6). The age structure of the stock was determined using an established age length key.

The 3-year age class dominated the 2022 estimate contributing over 32% of TSB and 40.5% of TSN (Table 6). Ranked second and third were the 4-year old and 2-year old fish (27.2% TSB & 22.9% TSN and 9.3% TSB & 17.4% TSN) respectively. Combined, these three age classes represented 68.6% of TSB and 80.7% of TSN. The 15+ age class represented 3% of TSB and 0.8% of TSN.

The 2022 survey estimate is dominated by young fish from the recent period of strong recruitment that have now matured and contribute to the spawning stock. The remaining strong year classes will continue to recruit over the next two years, further bolstering the reproductive capability of the stock.

Maturity analysis of boarfish indicated 94.9% of observed biomass was mature (98.1% total abundance) compared to 79.3% biomass and 39.7% abundance in 2021. Immature fish were observed in fewer numbers than in 2021 and would indicate that these age cohorts were under represented in this year estimate.

3.3 Horse mackerel

3.3.1 Biomass and abundance

Horse mackerel	Abund ('000)	Biomass (t)
TSB estimate	100,448.6	28,180.1
SSB estimate	100,448.6	28,180.1

Horse mackerel TSB (total stock biomass) and abundance (TSN) estimates were 28,180.1 t and 100,448,600 individuals (CV 0.40) respectively. The 2022 estimate is 21% lower in terms of biomass and 22% lower in terms of abundance compared to 2021.

The horse mackerel survey area was composed of 7 strata relating to an area coverage of 49,988 nmi^2 as shown in Figure 2. A breakdown of horse mackerel stock abundance and biomass by age, maturity and stratum is detailed in Tables 9 & 10 and Figures 7 & 8.

3.3.2 Stock distribution

A total of 40 trawl hauls were carried out during the survey (Figure 1), with no hauls containing >50% horse mackerel by weight. Fifteen hauls contained horse mackerel (Table 2).

A total of 24 echotraces were assigned to horse mackerel (59 in 2021). Horse mackerel were observed in the Celtic Sea and west coast strata (Figure 7). No echotraces were assigned to horse mackerel north of 53°N or the Porcupine Bank. Observations of horse mackerel along the west coast and Celtic Sea were comparable to previous years but lower in number and acoustic density. The overall acoustic density is the lowest in the time series (Table 11).

Of the seven strata surveyed, two contained horse mackerel; the Celtic Sea (33.9% of TSB) and the west coast stratum (66.1%). Overall, aggregations of horse mackerel were of low density. No monospecific horse mackerel aggregations were targeted during trawling and biological samples were taken as part of mixed species catches.

3.3.3 Stock composition

A total of 215 horse mackerel were aged from survey samples including length/weight/sex and maturity. Horse mackerel age samples ranged from 2-24 years (Table 9 & Figure 8). Age structure of the standing stock was determined using aged survey samples.

The 8-year-old fish dominated this year's survey estimate representing 36.9% of TSB and 36.3% of TSN (Table 9). Fourteen -year-old fish ranked second representing 7.6% of TSB and 7.8% of TSN and 5-year-old fish ranked third (5.5% to TSB & 7.6% TSN), Table 9. Combined these three age classes represented 56.8% of TSB and 56% of TSN.

Maturity analysis of horse mackerel samples indicated 100% maturity.

3.4 Celtic Sea herring (7g and j)

3.4.1 Biomass and abundance

CS Herring	Abund ('000)	Biomass (t)
Total stock	1,696,356.0	205,329.8
Spawning stock	1,696,356.0	205,329.8

The estimate of Celtic Sea (CS) herring TSB (total stock biomass) and relative abundance (TSN) estimates were 205,329.8 t and 1,696,356,000 individuals (CV 0.91) respectively.

The herring survey area was composed of a single stratum in the Celtic Sea, representing an area of over 30,646 nmi² and was surveyed using the standard survey transect spacing of 15 nmi. A breakdown of CS herring stock abundance and biomass by age, maturity and stratum is detailed in Tables 12 & 13 and Figures 9 & 10.

Estimates of Celtic Sea herring biomass are not comparable to the stock index survey carried out in October and should not be used for comparative purposes due to differences in survey design and area coverage.

3.4.2 Stock distribution

Eight echotraces of various sizes and acoustic density were assigned to herring (42 in 2021) in the Celtic Sea. Individual herring were caught as part of mixed species catches in low numbers (Table 2). Three high-density herring echotraces were observed but were not fished due to proximity to poor ground. Biological data from a commercial discard sample taken nearby was used to supplement the age and length profile during the analysis. Herring were observed in one area; on the Labadie Bank (Figure 11i-j) and Figure 9). Samples were retained for genetic analysis to assist in stock origin studies.

3.4.3 Stock composition

A total of 73 CS herring were aged from samples including length/weight/sex and maturity. CS herring age samples ranged from 1-8 winter rings (wr) (Table 12 & 13 and Figure 10). Age structure of the stock was determined from survey aged otoliths.

Four winter ring fish dominated the total estimate, representing 32.2% of TSB and 35.4% of total abundance (Table 12). Five winter ring fish ranked second contributing 31.8% and 31.2% respectively. Ranked third were 6 winter ring fish (16.1% TSB & 14.6% TSN). In terms of age structure, the survey has tracked the strong 2018-year class successfully into 2022.

Maturity analysis of Celtic Sea herring samples indicated 100% of fish sampled (n=73) were mature.

3.5 Hydrography and biogeochemical sampling

3.5.1 Hydrography and water sampling

In total, 71 CTD casts were carried out (Figure 12). Horizontal temperature and salinity maps for the survey area are provided for depths 5 m, 20 m, 50 m and at the seabed in Figures 13-16 respectively.

Seawater samples were collected from up to 6 depths on the up cast of the profile by triggering Niskin bottles at predetermined depths related to the hydrography observed during the down cast. The CTD data comprises continuous downcast and up casts records of the pressure, temperature, conductivity (salinity), dissolved oxygen, chlorophyll fluorescence and turbidity. The raw CTD data are processed according to GO-SHIP guidelines via the Seabird software and incorporated into ODV files for the continuous downcast data and the discrete bottle data collected during the up cast.

34 CTD stations were occupied on Leg 1 and water samples were collected at 16 of these (Table 16a). Samples were filtered for nutrients, chlorophyll and CDOM and unfiltered samples were collected for flow cytometry (nano- and pico-plankton). Chlorophyll fluorescence was measured on the filter papers on board using the QFT system with an LWCC 4100 spectrophotometer, and the filter papers were then frozen for fur-

ther analysis back at the lab. CDOM was measured on the LWCC 4100 spectrophotometer on board for both raw and filtered samples.

Water samples were collected at 32 CTD stations across the shelf on Leg 2 for Dissolved Inorganic Carbon (DIC), Total Alkalinity (TA), Particulate Organic Matter (POM), Coloured Dissolved Organic Matter (CDOM), Particulate Organic Carbon (POC), Dissolved Organic Carbon (DOC), Dissolved Inorganic Nutrients (DIN, i.e. nitrate, phosphate and silicate), Chlorophyll (Chl), Salinity, and for nano- and pico-plankton. Four to six depths were sampled at each CTD station, depending on water depth and the variability of the TS profiles, though not all parameters were sampled at every depth (Table 16b).

3.5.2 CDOM measurements

The filtered samples frozen at -20° C will also be analysed, after thawing, back in the laboratory in Galway for nutrients and 3D EEM FDOM analysis (Horiba Aqualog). The 3D EEM FDOM dataset will be analysed using PARAFAC (Murphy et al., 2013) will allow the determination of independent fluorophore components in seawater which can be used to identify sources of FDOM from terrestrial or marine processes.

3.5.3 Nutrient (NO2-, NO3-, PO43-, Si(OH)4) sampling

Analysis of samples requires further processing and was carried out back at the laboratory.

3.5.4 Bacteria, Heterotrophic nanoflagellates, Pico and nanoplankton abundance

Unfortunately, during WESPAS 2022 shipboard flow cytometer was not carried out due to an issue with the instrument during Leg 1 which prevented the instrument from being run at sea. The flow cytometer was returned to the lab in Galway at the end of leg 1, and while the repair was minor, the replacement part did not arrive in time for the instrument to go on leg 2.

3.5.5 Hyperspectral analysis

Ocean colour images for the WESPAS region and time period for WESPAS 2022, have been downloaded from CMEMS and are currently being analysed.

3.5.6 Chlorophyll measurements and Ocean Colour (Chlorophyll)

Analysis of samples requires further processing and was carried out back at the laboratory.

3.6 Zooplankton biomass

3.6.1 Zooplankton

Plankton samples were collected at 62 stations during the survey (Figure 20). Overall, the sample sizes from individual stations in the Celtic Sea were notably smaller than observed in previous recent years. Stations along the west coast, occurring east and west of the Irish Shelf Front, showed equally low catch rates. For stations north of 52°N, a similar pattern was observed, with most stations showing lower catch rates than in 2021. Stations where catch rates were similar to 2021 occurred in areas to the north of Ireland where herring were co-located.

3.7 Marine mammals and seabirds

3.7.1 Marine mammal visual abundance survey

Marine mammal observations were conducted during leg 2 of the 2022 survey only. In total, 17 days were spent surveying with 301 hours of survey time logged. Sea state varied between 1 and 6 across the survey duration with <5 accounting for 93.5% of surface conditions.

A total of 30 separate sightings of cetaceans were recorded. Seven species were observed consisting of: grey seal (*Halichoerus grypus*); short-beaked common dolphin (*Delphinus delphis*); bottlenose dolphin (*Tursiops truncates*); Risso's dolphin (*Grampus griseus*); minke whale (*Balaenoptera acutorostrata*); humpback whale (*Megaptera novaeangliae*); fin whale (*Balaenoptera physalus*). Other non-cetacean species recorded were: ocean sunfish (*Mola mola)*; porbeagle shark *(Lamna nasus)* and tuna species (Table 14, Figure 21).

Additional sightings were made of unidentified dolphins and whales (thought to be various dolphin species) at various locations on the continental shelf as well as at the shelf edge. Sightings of dolphin species, humpback and minke whales occurred on the continental shelf, whereas fin whale sightings occurred at the continental shelf edge, which is considered one the preferred habitats for this species.

Common dolphins (*Delphinus delphis*) were the most abundant species recorded on the survey (170 animals recorded accounting for 79.1% of all animals counted across all species). Sightings of common dolphins and occurred primarily in coastal waters with the furthest record from the coast logged at 60km. The observed group size for common dolphins ranged from 3 to 50 individuals.

The second most frequently observed species was the bottlenose dolphin (*Tursiops truncates*) accounting for 7% of recordings (2 recordings of the species totalling 15 animals). Sightings of bottlenose dolphins occurred primarily in offshore habitats at various locations off the west of Ireland.

Unidentified dolphins made up 4.7% of all sightings with 10 animals recorded. These observations were all logged offshore in excess of 50km from coastal areas. Animals could not be identified due to their brief surfacing behaviour or because they were at too far distances.

Risso's dolphins (*Grampus griseus*) and minke whales (*Balaenoptera rostrate*) made up 3.3% of sightings each, in terms of individual animals sighted. A total of 7 Risso's were seen in a single pod, whereas 7 minke whales were seen at individual sightings (with the exception of a single pair).

Fin whales (*Balaenoptera physalus*) made up 1.4% of sightings with 3 individual records. These records were made in the same area, along the continental shelf edge suggesting the animals were congregating.

A single sighting of two humpback whales (*Megaptera novaeangliae*) made up 1% of sightings. These observation was recorded in shelf waters, close to an area where humpbacks have regularly been seen – Stanton Banks.

A single grey seal (*Halichoerus grypus*) was observed offshore during the survey, making up 0.5% of sightings.

3.7.2 Seabird abundance and distribution

In total, 161 hours and 8 minutes of survey effort were conducted over the course of WESPAS 2022. Of which, 143 hours and 15 minutes of survey effort were conducted using a line transect methodology, while 5 hours and 19 minutes of effort were conducted using the point sampling methodology. A further 12 hour and 34 minutes of effort were conducted as a casual watch.

A total of 2,632 seabird observations were recorded throughout the survey, totalling 7,478 individuals (Table 15a). In total, 1,763 seabirds were recorded as “in transect”, while 5,715 were recorded “off transect”. The species encountered included 21 species from seven families. A further 11 sightings of terrestrial/migratory birds were also recorded, comprising of 31 individuals (Table 15b).

Gannet (*Morus bassanus*) were the most frequently encountered and most abundant species recorded on the survey. Gannet were encountered on 882 separate occasions, accounting for 33.5% of all records. Gannet records comprised of a total of 2,248 individuals (30.1% of all individuals), of these, only 218 individuals were recorded as ‘in transect’.

Fulmar (*Fulmarus glacialis*) were both the second most frequently encountered and the second most abundant species, accounting for 741 records (28.2% of all encounters) and comprising of 1613 individuals in total (21.6% of all encountered individuals.) Of these, 238 individuals were recorded as ‘in transect’.

Guillemot (*Uria aalge*) were the third most frequently sighted and the third most abundant species accounting for 171 sightings (6.5% of all sightings) and comprising of 893 individuals in total (11.9% of all encountered individuals.) Of these, 652 individuals were recorded as ‘in transect’.

A number of terrestrial/ migratory birds were encountered during the survey. A total of 11 sightings of terrestrial/ migratory bird species were recorded during the survey (Table 15b). These sightings comprised of 31 individuals from 7 species’ or species groups. Species recorded included a pectoral sandpiper (*Charadrius melanotos*), a collared dove (*Streptopelia decaocto*) and a juvenile white-tailed eagle (*Haliaeetus albicilla*).

4 Discussion and Conclusions

4.1 Discussion

Overall, weather conditions were poor for a period during the survey resulting in over 72 hrs of lost time. One entire transect was dropped, and two further transects were cut short in the Celtic Sea strata. During Leg 2, further transects were dropped in the west coast and Porcupine Bank strata.

Malin Shelf herring distribution was concentrated in an area to the north and west of Tory Island (north and south of 56˚N) and north of the mouth of Lough Swilly in 6.a.S and to the west of the Hebrides in 6.a.N, south of St. Kilda (Figure 3). There was an approximately 16% decrease in overall the SSB in 2022 compared to 2021 in the survey area (O'Donnell et al 2021),

Herring were distributed in fewer areas and in fewer strata. The stock appeared to be contracted compared to recent years. Herring were found in mostly deeper and colder areas, and temperatures overall appeared to be up compared to recent years, with bottom temperatures rarely getting below 10°C on the CTD casts.

The final estimate of herring in 6.a (combined 6.a.S, 7.b, c and 6.a.N) will be completed by including the biomass and abundance of herring from the survey of 6.a.N to the north of 58˚30N and west of 4˚W carried out by the RV *Scotia*. This final estimate will be presented at WGIPS in 2023. There have been issues with stock identification and containment with this survey in the past, particularly in relation to the boundary of the North Sea stock at the 4˚W line, and the distribution of herring north and south of the 56˚N line (6.a.N and 6.a.S), for example. Prior to the benchmark (WKNSCS 2022), fish distributed either side of these boundary lines influenced the respective survey estimates annually. From 2022 onwards (and retrospectively back to 2014) genetic discrimination of the stocks distributed within the survey area (6.a.N and 6.a.S/7.b c) is possible and will be applied to the abundance and biomass estimates of herring from this survey. There are still issues with spring spawning fish and other stocks that may be found in this area during the survey, however, further work is ongoing to improve the identification of these stocks using genetics.

There were some signs of young and immature herring in the Malin Shelf area again in 2022 particularly in 6.a.S in the area to the north of Lough Swilly, but less than recent years. This survey is not generally a good design for juvenile herring (e.g. 0-wr and 1-wr fish) but immature fish can show up in some years. The age profile of survey samples in 2022 is dominated by 3-wr and 4-wr herring dominate the survey (combined 62% in terms of biomass, and 55% in terms of abundance). The CV estimate for the 2022 survey is higher than recent years (0.42), primarily due to the relatively low number of EDSUs that have herring and the fewer transects where herring were found.

The geographical distribution of boarfish was comparable to earlier years in the time series in terms of latitudinal range. Within this range, clusters of individual schools were most frequently found towards the shelf margin in the northern and western strata and more widespread across the shelf in the Celtic Sea. During this year's survey, mature fish were observed on-shelf in the Hebrides area over 40 nmi from the shelf break, where only aggregations of immature fish have previously been observed. Overall, the most notable feature was the lack of immature fish observed in the Celtic Sea as compared to 2021 when immature fish dominated the estimate.

The number of echotraces of boarfish was comparable to 2021. However, acoustic survey effort was lower, with a reduction of survey miles of 10% compared to 2021 due to poor weather.

Total biomass increased by 2% and total abundance decreased by 15% compared to 2021. The decrease in abundance is driven by the lack of immature fish that contributed to the TSN estimate in 2021. Spawning stock biomass increased by 26% compared to last year, and can be attributed to recruitment of young fish from strong 2020 and 2021 year classes to the spawning stock. Of the six survey strata, all but one saw an increase in biomass compared to 2021. The Celtic Sea saw a decrease of 16% in observed biomass. Reports from the PELGAS survey indicate increased numbers of boarfish in the mid and northern Bay of Biscay, indicating the stock was not fully contained on the southern boundary and a portion of fish present in the Celtic Sea during 2021 were located in Biscay during 2022. Strata north of the Celtic sea saw an increase in reported biomass compared to 2021, most notably in the northern strata northward of 56°N (Western and South Hebrides), where reported biomass was three times that observed in 2021.

The 3-year age class dominated the 2022 estimate contributing over 32% of TSB and 40.5% of TSN (Table 6). Ranked second and third were the 4-year old and 2-year old fish (27.2% TSB & 22.9% TSN and 9.3% TSB & 17.4% TSN respectively). Combined these three age classes represented 68.6% of TSB and 80.7% of TSN. The 15+ age class represented 3% of TSB and 0.8% of TSN. In 2021, this age group dominated the stock estimate. Maturity analysis of boarfish indicated 94.9% of observed biomass was mature (98.1% total abundance) compared to 79.3% biomass and 39.7% abundance in 2021. Immature fish were under represented during the 2022 survey.

Horse mackerel were found distributed along the Irish west coast and Celtic Sea in low numbers. Geographical distribution was comparable to previous years. However, no fish were observed northward of 54°N consistent from 2020 onwards. The 2022 estimate is 21% lower in terms of biomass and 22% lower in terms of abundance compared to 2021. The 2022 estimate is the lowest in the current time series. No monospecific echotraces of horse mackerel were observed during the survey and biological samples were taken as part of mixed species by-catch.

Aggregations of Celtic Sea herring were encountered around the Labadie Bank area. Three high-density herring echotraces were observed but were not fished due to proximity to poor ground, instead biological samples (age/length composition) were provided from a commercial discard sample taken nearby. Small amounts of herring were observed as by-catch in mixed trawl catches further west but no aggregations were identified. Four winter ring (wr) fish dominated the total estimate followed by 5 and 6 wr fish respectively. In terms of age structure, the survey has tracked the strong 2018-year class successfully into 2022.

Estimates of Celtic Sea herring biomass are not comparable to the stock index survey carried out in October and should not be used for comparative purposes due to differences in survey design and area coverage.

4.2 Conclusions

- Malin Shelf herring SSB in the WESPAS survey area was ~16% lower in 2022 compared to 2021 (SSB_{2022} = 248,551 t, SSB_{2021} = 297,027 t)
- The Malin Shelf herring TSB in 2022 was ~ 31% lower than 2021. There were fewer young herring in 2022, in particular there were less 1-wr and 2-wr fish found on the survey compared to recent years and the survey was dominated by 3- and 4-wr fish (TSB_{2022} = 276,378 t, TSB_{2021} = 401,884 t).
- Herring were distributed in fewer areas and in fewer strata. The stock appeared to be contracted compared to recent years. Herring were distributed in four of the six WESPAS strata, this is a contraction of the stock compared to 2021 where herring were distributed in all strata.
- Herring were found in mostly deeper and colder areas, and temperatures overall appeared to be higher compared to recent years, with bottom temperatures rarely getting below 10°C.
- The CV on the survey for Malin Shelf herring in 2022 was higher than recent years (0.42); similar to 2019 (0.37) when there was also an issue with fewer schools and less transects where herring were distributed.
- Malin Shelf herring were distributed in the south again in 2022, similar to 2019, 2020 and 2021 with adult herring again found south of 56°N. This is the fifth year in a row in recent years that herring were found in this area. For instance, there was very little herring distributed south of 56°N in both 2016 and 2017.
- The 2022 survey estimate was dominated by 3-wr (32% TSB and 30% TSN) and 4-wr (31% TSB and 25% TSN). This compares well to the 2021 Malin Shelf herring survey estimate which was dominated by 2-wr (44% TSB and 53% TSN) and 3-wr (30% TSB and 26% TSN). There were some signs of young immature Malin Shelf herring but fewer than recent years.
- Boarfish distribution showed a similar pattern to previous years.
- Boarfish TSB (total stock biomass) and abundance (TSN) estimates were 451,415 t and 18,613,756,000 individuals (CV 0.24) respectively.
- The 2022 estimate of TSB was 2% higher than observed in 2021, while TSN was 15% lower, largely driven by the lack of immature fish observed.
- Maturity analysis of boarfish indicated 94.9% of observed biomass was mature (98.1% total abundance) compared to 79.3% biomass and 39.7% abundance in 2021.
- The 3-year age class dominated the 2022 estimate contributing over 32% of TSB and 40.5% of TSN. Ranked second and third were the 4-year old and 2-year old fish (27.2% TSB & 22.9% TSN and 9.3% TSB & 17.4% TSN) respectively. Combined these three age classes represented 68.6% of TSB and 80.7% of TSN.
- The southern Celtic Sea and northern Biscay region continues to be an important nursery area for boarfish during the recent successful spawning period (2017-2022).

- Horse mackerel were found distributed along the Irish west coast and Celtic Sea. Geographical distribution was comparable to previous years. However, the number of echotraces and acoustic density remains low.
- Horse mackerel TSB (total stock biomass) and abundance (TSN) estimates were 28,180 t and 100,449,000 individuals (CV 0.40) respectively. Compared to 35,506 t and 129,431,000 individuals (CV 0.54) in 2021.
- The 2022 horse mackerel estimate was 21% lower in terms of biomass and 22% lower in terms of abundance compared to 2021. The 2022 estimate is the lowest in the current time series.
- Of the 7 strata surveyed, two contained horse mackerel; the west coast contained the largest proportion of biomass observed (66% of TSB) and the Celtic Sea stratum (34%).
- The 8-year-old fish dominated this year's survey estimate representing 36.9% of TSB and 36.3% of TSN. Fourteen -year-old fish ranked second representing 7.6% of TSB and 7.8% of TSN and 5-year-old fish ranked third (5.5% to TSB & 7.6% TSN), Table 9. Combined these three age classes represented 56.8% of TSB and 56% of TSN.
- Maturity analysis of horse mackerel samples indicated 100% of the total standing stock was mature.
- Aggregations of Celtic Sea herring were observed around a traditional feeding area in the mid-Celtic Sea.
- The estimate of Celtic Sea (CS) herring TSB (total stock biomass) and relative abundance (TSN) estimates were 205,329.8 t and 1,696,356,000 individuals (CV 0.91) respectively.
- Four winter ring fish dominated the total estimate, representing 32.2% of TSB and 35.4% of total abundance. Five winter ring fish ranked second contributing 31.8% and 31.2% respectively. Ranked third were 6 winter ring fish (16.1% TSB & 14.6% TSN). In terms of age structure, the survey has tracked the strong 2018-year class successfully into 2022.
- All herring sampled were mature. Further review will be carried out during the spawning stock survey in October.

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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 :	24.03.2022
Echo sounder : EK60 PC		Locality :	Dunmanus Bay
Type of Sphere : WC-38,1	TSSphere: -42.40 dB (Corrected for Soun vel)	Depth(btm) :	34 m

Calibration Version 2.1.0.12

Comments:
IBWSS 2022_Dunmanus Bay- WC38.1mm

Reference Target:

TS	-42.30 dB	Min. Distance	19.00 m
TS Deviation	5.0 dB	Max. Distance	22.00 m

Transducer: ES38B Serial No. 30227

Frequency	38000 Hz	Beamtype	Split
Gain	25.63 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	7.01 deg	Along. Beam Angle	6.96 deg
Athw. Offset Angle	-0.03 deg	Along. Offset Angl	-0.06 deg
SaCorrection	-0.64 dB	Depth	8.80 m

Transceiver: GPT 38 kHz 009072033933 2-1 ES38B

Pulse Duration	1.024 ms	Sample Interval	0.192 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.	9.48dB/km	Sound Velocity	1499.4 m/s

Beam Model results:

Transducer Gain =	25.64 dB	SaCorrection =	-0.65 dB
Athw. Beam Angle =	7.05 deg	Along. Beam Angle =	6.97 deg
Athw. Offset Angle =	-0.01 deg	Along. Offset Angle=	-0.05 deg

Data deviation from beam model:
RMS = 0.13 dB
Max = 0.55 dB No. = 69 Athw. = 3.6 deg Along = 3.1 deg
Min = -0.60 dB No. = 317 Athw. = -0.8 deg Along = 4.7 deg

Data deviation from polynomial model:
RMS = 0.09 dB
Max = 0.39 dB No. = 69 Athw. = 3.6 deg Along = 3.1 deg
Min = -0.52 dB No. = 71 Athw. = 3.4 deg Along = 3.8 deg

Comments :
Dunmanus Bay
Wind Force : 14 kn **Wind Direction :** SW
Raw Data File: E:\CE22009_IBWSS2022\Calibration\38 kHz Cal\IBWSS2022-D20190705-T090459.raw
Calibration File: E:\CE22009_IBWSS2022\Calibration\38 kHz Cal\Cal 38 kHz.txt

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)	Boarfish %	Mackerel %	Herring %	H Mack %	Others^ %
1	17.06.22	47.57	-6.48	08:40	174	170	8,000	7.2			3.2	89.5
2	17.06.22	47.59	-7.07	14:00	177	100	2,500	97.6			2.4	
3	18.06.22	48.08	-6.16	11:20	130	75	53	99.8			0.2	
4	21.06.22	48.33	-7.46	06:29	172	60	3,500	100.0				
5	21.06.22	48.58	-7.93	16:45	162	40	2,300	100.0				
6	22.06.22	48.83	-9.43	10:00	160	30	1,200	100.0				
7	23.06.22	49.08	-10.26	15:31	158	50	3,000	100.0				
8	24.06.22	49.33	7.96	16:45	140	0	15					100.0
9	25.06.22	49.59	-9.31	08:55	142	0	3,000	3.1	4.1		5.5	88.0
10	27.06.22	50.33	-9.76	18:52	136	100	9	1.0	40.5	1.4	51.3	6.0
11	29.06.22	50.83	-9.17	09:14	120	115	500		0.0	0.3		99.3
12	30.06.22	51.08	-10.61	08:05	190	40	2,000	100.0				
13	30.06.22	51.08	-10.19	13:44	134	75	135	87.4	5.1	1.1	4.9	1.6
14	02.07.22	51.33	-10.61	05:57	166	160	109	1.2	1.1	0.3	4.4	93.0
15	02.07.22	51.33	-11.00	10:25	181	90	500	98.6	0.7		0.7	
16	02.07.22	51.60	-10.57	19:31	129	45	3,500	97.8			2.2	
17	03.07.22	52.34	-10.87	13:01	123	30	200	99.7			0.3	
18	06.07.22	53.09	-10.82	07:28	130	120	200					100.0
19	06.07.22	53.09	-11.25	11:33	138	90	3,500	100.0				
20	07.07.22	53.34	-13.90	12:27	161	140	105		1.8		1.4	97.0
21	08.07.22	53.35	-11.58	07:22	174	60	2,000	91.3	1.8		6.9	
22	09.07.22	54.64	-9.02	14:28	87	60	100					100.0
23	10.07.22	54.89	-9.68	06:31	100	60	2,000	99.0	0.9			
24	10.07.22	55.06	-10.07	18:19	194	75	2,000	100.0				
25	11.07.22	55.37	-9.56	12:52	162	150	19	53.0				47.0
26	12.07.22	55.55	-8.81	19:24	100	80	59	99.2			0.4	0.4
27	13.07.22	55.72	-7.63	09:45	65	35	1,000		0.2	87.2		12.6
28	14.07.22	55.89	-8.17	10:16	176	160	1,500		1.6	82.3		16.1
29	14.07.22	55.89	-8.53	13:16	126	115	34		88.9	9.1		2.1
30	14.07.22	56.06	-8.52	21:59	135	120	200	74.0	1.4	0.3		24.3
31	15.07.22	56.23	-7.45	11:46	93	60	1,500	99.9	0.1			
32	15.07.22	56.23	-8.68	18:43	135	125	1,000	92.5				7.5
33	16.07.22	56.48	-8.74	04:32	146	130	1,500	9.0	2.2	88.5		0.3
34	17.07.22	57.24	-9.06	14:29	138	125	161	18.6	0.9		0.6	79.9
35	17.07.22	57.49	-8.46	22:15	162	155	250		1.0	89.4		9.7
36	19.07.22	58.24	-8.79	10:21	195	75	1,000					
37	20.07.22	58.59	-5.64	12:51	128	120	99		94.4	0.3		5.3
38	20.07.22	58.34	-5.86	20:07	104	80	10		2.8			97.2
39	21.07.22	57.88	-6.01	09:22	97	45	10					100.0
40	22.07.22	55.90	-8.19	11:44	179	175	42		7.5	0.3	2.7	89.5

Table 3. Malin Shelf herring stock estimate 2022 (6.a.S, 7.b, c and 6.a.N (south of 58°30'N) in the WESPAS 2022 survey area.

	Age (years)													Numbers	Biomass	Mn Wt	Mature
Length	0	1	2	3	4	5	6	7	8	9	10	11	12+	(*10-3)	(t)	(g)	(%)
5.5		-	-	-	-	-	-	-	-	-	-	-	-				
6		-	-	-	-	-	-	-	-	-	-	-	-				
6.5		-	-	-	-	-	-	-	-	-	-	-	-				
7		-	-	-	-	-	-	-	-	-	-	-	-				
7.5		-	-	-	-	-	-	-	-	-	-	-	-				
8		-	-	-	-	-	-	-	-	-	-	-	-				
8.5		-	-	-	-	-	-	-	-	-	-	-	-				
9		-	-	-	-	-	-	-	-	-	-	-	-				
9.5		-	-	-	-	-	-	-	-	-	-	-	-				
10		-	-	-	-	-	-	-	-	-	-	-	-				
10.5		-	-	-	-	-	-	-	-	-	-	-	-				
11		-	-	-	-	-	-	-	-	-	-	-	-				
11.5		-	-	-	-	-	-	-	-	-	-	-	-				
12		-	-	-	-	-	-	-	-	-	-	-	-				
12.5		-	-	-	-	-	-	-	-	-	-	-	-				
13		-	-	-	-	-	-	-	-	-	-	-	-				
13.5		-	-	-	-	-	-	-	-	-	-	-	-				
14		-	-	-	-	-	-	-	-	-	-	-	-				
14.5		-	-	-	-	-	-	-	-	-	-	-	-				
15		-	-	-	-	-	-	-	-	-	-	-	-				
15.5		-	-	-	-	-	-	-	-	-	-	-	-				
16		-	-	-	-	-	-	-	-	-	-	-	-				
16.5		5034.6	-	-	-	-	-	-	-	-	-	-	-	5035	206	41.00	0
17		15104	-	-	-	-	-	-	-	-	-	-	-	15104	593	39.24	0
17.5		46031	-	-	-	-	-	-	-	-	-	-	-	46031	1181	25.66	0
18		46750	-	-	-	-	-	-	-	-	-	-	-	46750	2211	47.29	0
18.5		58257	-	-	-	-	-	-	-	-	-	-	-	58257	3018	51.81	0
19		44592	-	-	-	-	-	-	-	-	-	-	-	44592	2460	55.16	0
19.5		38212	-	-	-	-	-	-	-	-	-	-	-	38212	2354	61.62	0
20		43246	-	-	-	-	-	-	-	-	-	-	-	43246	3004	69.46	0
20.5		25892	-	-	-	-	-	-	-	-	-	-	-	25892	1878	72.52	0
21		6488	7178	-	-	-	-	-	-	-	-	-	-	13665	1091	79.84	28
21.5		3014	7746	-	-	-	-	-	-	-	-	-	-	10760	885	82.22	52
22		-	14590	-	-	-	-	-	-	-	-	-	-	14590	1274	87.31	0
22.5		-	14974	2090	-	-	-	-	-	-	-	-	-	17064	1737	101.82	93
23		-	38216	3364	-	-	-	-	-	-	-	-	-	41580	4463	107.34	63
23.5		-	39321	21729	-	-	-	-	-	-	-	-	-	61050	6977	114.29	74
24		-	63005	47156	2012	-	-	-	-	-	-	-	-	112173	13856	123.52	86
24.5		-	34769	74111	8231	-	-	-	-	-	-	-	-	117111	15627	133.43	97
25		-	20967	75894	24330	5598.58	-	-	-	-	-	-	-	126789	18351	144.74	92
25.5		-	12858	133147	41512	23454	-	-	-	-	-	-	-	210972	31868	151.05	100
26		-	-	121913	112659	21068	6168	-	-	-	-	-	-	261808	42300	161.57	98.9814
26.5		-	-	78639	116275	70647	6036	-	5831	-	-	-	-	277428	47131	169.89	100
27		-	-	17266	114923	38968	14913	2783	-	-	-	-	-	188853	33960	179.82	98.1149
27.5		-	-	11651	58332	26766	21626	-	3717	-	-	-	-	122092	23042	188.72	100
28		-	-	-	19750	15078	23669	-	-	-	-	-	-	58496	11183	191.18	100
28.5		-	-	-	-	12562	-	7207	-	-	-	-	-	19769	4121	208.46	100
29		-	-	-	-	6197	-	-	-	-	-	-	-	6197	1222	197.21	100
29.5		-	-	-	-	-	-	-	2126	-	-	-	-	2126	385	181.00	100
30		-	-	-	-	-	-	-	-	-	-	-	-				
30.5		-	-	-	-	-	-	-	-	-	-	-	-				
31		-	-	-	-	-	-	-	-	-	-	-	-				
31.5		-	-	-	-	-	-	-	-	-	-	-	-				
32		-	-	-	-	-	-	-	-	-	-	-	-				
32.5		-	-	-	-	-	-	-	-	-	-	-	-				
33		-	-	-	-	-	-	-	-	-	-	-	-				
33.5		-	-	-	-	-	-	-	-	-	-	-	-				
34		-	-	-	-	-	-	-	-	-	-	-	-				
34.5		-	-	-	-	-	-	-	-	-	-	-	-				
35		-	-	-	-	-	-	-	-	-	-	-	-				
35.5		-	-	-	-	-	-	-	-	-	-	-	-				
36		-	-	-	-	-	-	-	-	-	-	-	-				
36.5		-	-	-	-	-	-	-	-	-	-	-	-				
37		-	-	-	-	-	-	-	-	-	-	-	-				
TSN (1000)		332620	253623	586960	498025	220339	72411.3	9990.05	11674.4					1985643			
TSB (t)		17662.2	29899.6	88094.6	84489.6	38559.7	13592	2044.69	2035.02						276378		
Mean length (cm)		18.80	23.63	25.41	26.48	26.80	27.35	28.08	27.36								
Mean weight (g)		53.1003	117.89	150.086	169.649	175.002	187.706	204.673	174.315							139.11	
SSB (t)		0	21529.9	86938.7	84489.6	38559.7	12953.6	2044.69	2035.02						248551		
% mature		0	70	99	100	100	95	100	100								

Table 4. Malin Shelf herring survey time series 2008-2022. Survey coverage: - ^ 6.a.S & 7.b, c; *6.a.S, 7.b,c & 6.a.N (south of 58°28’N) ** 6.a & 7.b,c. *Survey known as WESPAS since 2016.*

Age	2008^	2009^	2010*	2011*	2012*	2013*	2014*	2015**	2016*	2017*	2018*	2019*	2020*	2021*	2022*
0	-	-	-	-	-	-	-	-	-	-	264.6				
1	6.1	416.4	524.8	82.1	608.3	-	1,115.4	4.9	-	-	395.8	21.6	1541.7	150.0	332.6
2	75.9	81.3	504.3	202.5	451.5	96.2	214.7	162.1	9.7	11.0	339.2	212.4	1059.2	1590.0	253.6
3	64.7	11.4	133.3	752.0	444.6	254.3	166.3	291.7	102.3	273.4	112.5	174.5	506.8	777.8	587.0
4	38.4	15.1	107.4	381.0	516.1	265.8	380.0	580.7	91.4	111.0	314.1	86.3	191.1	218.8	498.0
5	22.3	7.7	103.0	110.8	180.3	78.7	352.1	487.3	91.4	71.6	137.5	55.3	82.8	92.3	220.3
6	26.2	7.1	83.7	124.0	115.4	26.9	125.0	513.4	58.2	94.4	43.7	29.1	175.9	31.1	72.4
7	9.1	7.5	57.6	118.4	116.9	18.5	18.9	143.9	46.5	28.0	59.5	3.4	33.2	70.5	10.0
8	5.0	0.4	35.3	70.7	83.8	10.8	9.7	33.4	2.7	9.9	16.8	11.7	15.7	9.6	11.7
9	3.7	0.9	17.5	41.6	56.3	4.1	4.7	-	0.5	2.6	8.2	3.8	9.3	41.4	
10+	-	-	-	25.6	42.0	1.2	-	8.3	-	-	6.4			6.2	
TSN (mil)	251.4	547.7	1,566.9	1,908.7	2,615.0	756.6	2,386.8	2,225.5	402.8	601.8	1,698.3	598.0	3,615.8	2,987.6	1,985.6
TSB (t)	44,611.0	46,460.0	192,979.0	313,305.0	397,797.0	118,946.0	294,200.0	449,343.0	70,745.0	107,900.0	183,187.5	86,641.1	370,048.2	401,883.6	276,378.0
SSB (t)	43,006.0	20,906.0	170,154.0	284,632.0	325,835.0	92,700.0	200,200.0	425,392.0	69,269.5	106,657.0	129,740.0	68,607.0	177,493.7	297,026.8	248,551.0
CV	34.2	32.2	24.7	22.4	22.8	21.5	28.6	28.6	31.3	46.6	28.3	37.3	24.9	24.8	42.9

^ Survey coverage: 6aS & 7bc

* Survey coverage: 6aS,7bc and 6aN (south of 58˚28’)

** Survey coverage: 6a & 7bc

Table 5. Malin Shelf herring SSB and SSN by strata in the WESPAS survey area 2022.

Strata	Name	Area (nmi^2)	Transects	SSN (‘000)	SSB (t)
1	Minches	3204	8	2,911	456
2	W Hebrides	5849	6	673,574	111,050
3	SW Hebrides	4682	5	364,181	58,382
4	NW Coast	2181	3	0	0
5	W Coast	4344	6	0	0
6	N Malin	2946	3	525,027	78,664
	Total	23,206	31	1,565,694	248,551

Table 6. Total boarfish stock estimate.

Length (cm)	Age (years)																Numbers (000's)	Biomass (t)	Mn Wt (g)	Mature (%)
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+				
3.5																				
4																				
4.5																				
5																				
5.5		9193.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9193.7802	45.9689		0
6		59740.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	59740.545	398.5194		0
6.5		186518.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	186518.12	1195.354		22.4
7		148496.1	89698.9	0	0	0	0	0	0	0	0	0	0	0	0	0	238195.02	1862.744		0
7.5		183178.6	162335.6	0	0	0	0	0	0	0	0	0	0	0	0	0	345514.28	3162.836		28.7
8		0	1576022.7	0	0	0	0	0	0	0	0	0	0	0	0	0	1576022.7	19064.14		95.7
8.5		0	504680.5	2019885.9	0	0	0	0	0	0	0	0	0	0	0	0	2524566.4	36786.88		95.7
9		0	901492.7	1664077.5	0	0	0	0	0	0	0	0	0	0	0	0	2565570.2	43352.29		98.2
9.5		0	0	1472155.6	0	0	0	0	0	0	0	0	0	0	0	0	1472155.6	29061.3		100
10		0	0	2131837.5	0	0	0	0	0	0	0	0	0	0	0	0	2131837.5	50024.76		100
10.5		0	0	248607.1	2030735.7	78459.6	0	0	0	0	0	0	0	0	0	0	2357802.3	63441.79		100
11		0	0	0	2033214.4	91472.5	0	0	0	0	0	0	0	0	0	0	2124686.9	64764.14		100
11.5		0	0	0	101761.7	386071.4	508754.7	99369.8	0	0	0	0	0	0	0	0	1095957.7	37766.9		100
12		0	0	0	92796.8	62585.6	0	479826.2	0	0	0	0	0	0	0	0	635208.64	25350.81		100
12.5		0	0	0	0	0	0	61053.4	169261.6	38392.7	0	0	0	0	0	0	268707.66	11883.09		100
13		0	0	0	0	0	0	24920.0	50668.7	124350.9	20532.9	0	0	0	0	0	220472.5	10635.56		100
13.5		0	0	0	0	0	0	66117.7	45637.4	51004.4	22322.3	0	0	0	0	0	185081.9	9265.182		100
14		0	0	0	0	0	0	20301.3	0	88337.3	79143.0	0	0	0	0	0	187781.58	10787.39		100
14.5		0	0	0	0	0	0	0	0	0	0	41203.6	23352.4	67616.7	15947.1	0	148119.79	9486.467		100
15		0	0	0	0	0	0	0	0	0	0	0	0	47866.8	40166.4	52830.0	140863.26	10797.75		100
15.5		0	0	0	0	0	0	0	0	0	0	0	0	11181.5	33861.0	42025.2	87067.681	7170.13		100
16		0	0	0	0	0	0	0	0	0	0	0	0	0	0	25301.8	25301.827	2325.652		100
16.5		0	0	0	0	0	0	0	0	0	0	0	0	0	0	22034.0	22034.04	2191.937		100
17		0	0	0	0	0	0	0	0	0	0	0	0	0	0	4785.4	4785.4365	521.7603		100
17.5		0	0	0	0	0	0	0	0	0	0	0	0	0	0	570.8	570.84877	71.92694		100
18																				
18.5																				
19																				
TSN (10^{-3})		587,127	3,234,230	7,536,564	4,258,509	618,589	508,755	751,588	265,568	302,085	121,998	41,204	23,352	126,665	89,975	147,547	18,613,756			
TSB (t)		4,292.4	42,148.7	144,450.6	123,009.7	20,883.2	18,160.8	31,152.3	12,244.2	15,537.7	6,970.0	2,538.1	1,487.7	8,550.8	6,640.6	13,348.3	451,415.3			
% mature*		6.3	92.8	98.9	100	100	100	100	100	100	100	100	100	100	100	100				
SSB (t)		272.3	39,111.9	142,814.2	123,009.7	20,883.2	18,160.8	31,152.3	12,244.2	15,537.7	6,970.0	2,538.1	1,487.7	8,550.8	6,640.6	13,348.3	442,722.0			

Table 7. Boarfish biomass and abundance by strata.

Strata name	Area (nmi²)	Transects	Abundance ('000)	Biomass (t)
W Hebrides	2,321.7	7	126,888	6,292
S Hebrides	1,933.6	5	344,601	11,345
N Stanton	1,468.1	4	375,979	5,123
W Coast	11,195.2	19	5,227,664	146,772
Porcupine Bank	2,423.1	3	140,058	4,113
Celtic Sea	30,646.2	15	12,398,567	277,770
Total	49,987.7	53	18,613,757	451,415.1

Table 8. Boarfish survey time series.

Age (Yrs)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
0	-	-	-	-	-	-	-	-	-	1083.9	259.0	
1	5.0	21.5	-	-	198.5	4.6	110.9	76.7	782.3	896.5	9522.8	587.1
2	11.6	10.8	78.0	-	319.2	35.7	126.7	31.2	389.1	1156.7	3391.8	3234.2
3	57.8	174.1	1,842.9	15.0	16.6	45.5	344.6	115	96.8	966.5	2955.2	7536.6
4	187.4	64.8	696.4	98.2	34.3	43.6	367.3	68.3	93.1	112.6	1315.5	4258.5
5	436.7	95.0	381.6	102.3	80.0	6.0	156.0	106.7	88.2	157.3	462.8	618.6
6	1,165.9	736.1	253.8	104.9	112.0	10.0	209.0	165.9	105.9	183.3	149.9	508.8
7	1,184.2	973.8	1,056.6	414.6	437.4	169.0	493.1	320.7	445.7	912.9	953.3	751.6
8	703.6	758.9	879.4	343.8	362.9	112.6	468.3	197.7	182.6	884.5	207.0	265.6
9	1,094.5	848.6	800.9	341.9	353.5	117.6	397.2	293.4	288	720.7	378.4	302.1
10	1,031.5	955.9	703.8	332.3	360.0	96.6	285.8	624.7	290.1	330.9	248.5	122.0
11	332.9	650.9	263.7	129.9	131.7	17.0	120.9	339.2	49.5	80.6	151.3	41.2
12	653.3	1,099.7	202.9	104.9	113.0	32.0	82.1	264.1	192.2	194.9	187.9	23.3
13	336.0	857.2	296.6	166.4	174.0	48.7	74.4	198.4	79.1	298.7	81.0	126.7
14	385.0	655.8	169.8	88.5	108.0	18.3	220.4	116.5	57.2	266.7	326.9	90.0
15+	3,519.0	6,353.7	1,464.3	855.1	1,195.0	400.1	931.0	302.4	758.9	1641.0	1213.3	147.5
TSN (10^{-3})	11,104	14,257	9,091	3,098	3,996	1,157	4,387	3,221	3,899	9,888	21,805	18,614
TSB (t)	670,176	863,446	439,890	187,779	232,634	69,690	223,860	186,252	179,156	399,872	443,777	451,415
SSB (t)	669,392	861,544	423,158	187,654	226,659	69,103	218,810	184,235	169,216	357,871	351,955	442,722
CV	0.21	0.11	0.18	0.15	0.17	0.16	0.22	0.20	0.25	0.35	0.31	0.24

Table 9. Horse mackerel stock estimate.

	Age (years)																							Numbers	Biomass
Length	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	(000's)	(t)
11																										
12																										
13																										
14																										
15		3859	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3859.0	115.8
16		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17		3859	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3859.0	169.8
18		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23		0	0	291	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	290.8	38.1
24		0	0	0	133	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	132.9	17.5
25		0	291	291	872	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1454.0	229.7
26		0	0	1723	1023	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2746.1	452.8
27		0	0	0	1587	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1586.9	288.0
28		0	0	0	1199	734	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1932.4	384.1
29		0	0	0	1199	0	0	493	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1692.6	384.0
30		0	0	0	559	182	353	1817	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2910.7	701.0
31		0	0	0	1225	1396	576	4800	0	0	0	0	0	212	0	0	0	0	0	0	0	0	0	0	8207.9	2196.7
32		0	0	0	0	5274	414	17909	3812	193	0	193	0	3332	0	0	0	0	0	0	0	0	0	0	31126.1	8953.4
33		0	0	0	0	0	182	8935	354	2078	0	0	0	2110	0	0	0	0	0	0	0	0	0	0	13659.2	4125.6
34		0	0	0	0	0	0	1588	0	1621	0	0	473	1344	0	0	0	153	0	0	0	0	0	0	5178.9	1709.5
35		0	0	0	0	0	0	479	712	1251	383	712	0	1118	0	905	233	0	0	0	1915	0	0	0	7708.2	2657.6
36		0	0	0	0	0	0	480	0	508	1028	452	587	1625	978	0	0	0	0	587	1624	0	0	0	7868.8	2986.2
37		0	0	0	0	0	0	0	184	184	0	0	0	1056	0	231	0	0	0	958	479	0	0	224	3316.8	1282.8
38		0	0	0	0	0	0	0	0	0	0	0	0	0	0	440	0	0	133	440	0	0	0	0	1012.3	440.9
39		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	268	0	0	0	0	0	267.6	138.9
40		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41		0	0	0	0	0	0	0	0	0	0	0	0	1199	0	0	0	0	0	0	0	440	0	0	1638.3	907.6
42																										
TSN (10^{-3})		7718.0	290.8	2304.3	7797.1	7585.2	1525.2	36499.8	5061.9	5836.7	1411.1	1356.7	1060.0	11995.4	977.8	1576.3	232.8	152.8	400.5	1984.1	4018.5	439.7	0	224	100,448.6	
TSB (t)		285.6	45.9	360.9	1557.9	2195.8	400.9	10391.0	1706.7	1957.4	541.2	464.5	367.0	4047.2	361.2	609.9	83.6	55.8	200.3	758.6	1462.4	233.9	92.5	0		28180.1

Table 10. Horse mackerel biomass and abundance by strata.

Strata name	Area (nmi²)	Transects	Abundance ('000)	Biomass (t)
W Hebrides	3,921.6	7	0	0
S Hebrides	2,234.5	5	0	0
N Stanton	1,468.1	4	0	0
S Stanton	1,615.3	2	0	0
W Coast	13,215.8	19	60,509	18,619
Porc Bank	2,423.1	3	0	0
Celtic Sea	30,646.2	15	39,934	9,561
Minch	3,322.0	3	0	0
Total	58,346.4	63	100,444	28,180

Table 11. Horse mackerel survey time series.

Age (Yrs)	2016	2017	2018	2019	2020	2021	2022
0							
1	1.1	11.7	1.0	63.7			
2	100.2	181.8	72.4	14.3	6.2	0.1	7.7
3	4.9	147	243.3	9.2	91.9	10.0	0.3
4	43.5	45.4	85.3	46.4	51.5	9.7	2.3
5	19.0	16.2	10.5	30.9	24.3	8.1	7.8
6	7.6	46	7.6	18.5	27.0	7.3	7.6
7	40.6	113	49.3	29.8	35.1	21.9	1.5
8	66.6	67.7	13.3	6.2	5.2	7.5	36.5
9	8.5	25.4	10.0	26.7	13.1	29.7	5.1
10	1.8	33.2	1.5	0.4	1.5	3.1	5.8
11	9.5	32.6	1.5	1.9	0.5	3.6	1.4
12	10.6	37.7	7.4	3.9		4.10	1.4
13	4.7	37.6	8.5	0.6	0.6	0.1	1.1
14	21.1	160.8	27.5	23.2	5.5	9.8	12.0
15	6.5	8.6		10.0		5.5	1.0
16	1.6	5.2		28.4	2.1	8.6	1.6
17	5.3		0.3			0.3	0.2
18				17.7			0.2
19							0.4
20							2.0
21	1.1						4.0
22							0.4
23							
24							0.2
TSN (10^{-3})	354.5	969,655	540,422	333,501	264,314	129,431	100,449
TSB (t)	69,267	228,116	92,932	79,026	47,553	35,506	28,180
SSB (t)	65,194	227,395.6	89,050	77,529	43,527	35,478	28,180
CV	0.42	0.26	0.37	0.34	0.31	0.54	0.40

Table 12. Celtic Sea herring stock estimate.

Length (cm)	Age (years) 1	2	3	4	5	6	7	8	9	10	11	Ukn	Numbers (10^{-3})	Biomass (t)
11.5														
12														
12.5														
13														
13.5														
14														
14.5														
15														
15.5														
16														
16.5														
17														
17.5														
18														
18.5														
19														
19.5														
20														
20.5														
21														
21.5														
22														
22.5			0	70681.5	0	0	0	0					70681.5	6502.7
23			70681.5	0	0	0	0	0					70681.5	6361.3
23.5			0	106022.2	35340.7	0	0	0					141363.0	14843.1
24			70681.5	141363.0	35340.7	0	0	0					247385.2	27283.1
24.5			0	212044.5	70681.5	0	0	0					282726.0	32160.1
25			0	35340.7	141363.0	35340.7	0	0					212044.5	25869.4
25.5			0	35340.7	141363.0	70681.5	0	0					247385.2	31877.4
26			0	0	106022.2	106022.2	0	0					212044.5	28908.7
26.5			0	0	0	35340.7	35340.7	35340.7					106022.2	15196.5
27			0	0	0	0	35340.7	70681.5					106022.2	16327.4
27.5														
28														
28.5														
29														
29.5														
30														
30.5														
31														
31.5														
TSN (10^{-3})			141,363.0	600,792.7	530,111.2	247,385.2	70,681.5	106,022.2					1,696,356.0	
TSB (t)			14,419.0	66,016.5	65,309.7	33,078.9	10,814.3	15,691.3						205,329.8
% mature*			100.0	100.0	100.0	100.0	100.0	100.0						
SSB (t)			14,419.0	66,016.5	65,309.7	33,078.9	10,814.3	15,691.3						205329.8

Table 13. Celtic Sea herring total stock biomass and total abundance by strata.

Strata name	Area (nmi²)	Transects	Abundance ('000)	Biomass (t)
Celtic Sea	30,646.2	15	1,696,356	205,330
Total	30,646.2	15	1,696,356	205,330

Table 14. Marine mammal and megafauna sightings, counts and group size ranges for cetaceans sighted during the survey (includes on and off effort).

Common name	Scientific name	No. of sightings	No. of individuals	Group size range
Common dolphin	*Delphinus delphis*	12	213	3-50
Bottlenose dolphin	*Tursiops truncatus*	2	15	7-8
Risso's dolphin	*Grampus griseus*	1	7	7
Minke whale	*Balaenoptera rostrata*	6	7	1-2
Humpback whale	*Megaptera novaeangliae*	1	2	2
Fin whale	*Balaenoptera physalus*	2	3	1
Grey seal	*Halichoerus grypus*	1	1	1
Unidentified dolphin		5	7	1-4

Table 15a. Totals for all seabird bird species recorded.

Common Name	*Species name*	*No. of Sightings*	*No. of Seabirds*	*In Tran-sect*	*Off Transect*
Fulmar	*Fulmarus glacialis*	741	1613	238	1375
Great Shearwater	*Ardenna gravis*	2	2	0	2
Sooty Shearwater	*Ardenna grisea*	12	14	4	10
Manx Shearwater	*Puffinus*	122	520	17	503
Wilson's Storm Petrel	*Oceanites oceanicus*	1	1	0	1
European Storm Petrel	*Hydrobates pelagicus*	90	154	2	152
Storm Petrel sp.	*Hydrobatidae sp.*	47	102	19	83
Gannet	*Morus bassanus*	882	2248	218	2030
Pomarine Skua	*Stercorarius pomarinus*	2	3	0	3
Arctic Skua	*Stercorarius parasiticus*	1	1	0	1
Great Skua	*Stercorarius skua*	14	14	3	11
Common Gull	*Larus canus*	2	2	0	2
Black-headed Gull	*Chroicocephalus ridibundus*	1	1	0	1
Lesser Black-backed Gull	*Larus fuscus*	103	223	24	199
Herring Gull	*Larus argentatus*	16	38	1	37
Great Black-backed Gull	*Larus marinus*	20	24	0	24
Kittiwake	*Rissa tridactyla*	102	285	56	229
Gull sp.	*Laridae sp.*	4	28	0	28
Commic tern sp.	*Sterna hirundo/ paradisaea*	3	4	2	2
Guillemot	*Uria aalge*	171	893	652	241
Razorbill	*Alca torda*	62	172	72	100
Razorbill / Guillemot	*Alca torda/ Uria aalge*	18	155	151	4
Puffin	*Fratercula arctica*	105	271	117	154
Auk sp.	*Alcidae sp.*	33	504	179	325
Shag	*Gulosus aristotelis*	5	6	0	6
	Total	**2,634**	**7,478**	**1,,763**	**5,715**

Table 15b. Totals for all terrestrial bird species recorded.

Common Name	***Species name***	***No. of Sightings***	***No. of Individuals***
Collared Dove	*Streptopelia decaocto*	1	1
Feral/ racing pigeon	*Columba livia domesticus*	5	6
Oystercatcher	*Haematopus ostralegus*	1	1
Pectoral Sandpiper	*Calidris melanotos*	1	1
Unidentified Geese	*Anatidae sp.*	1	20
White-tailed Eagle	*Haliaeetus albicilla*	1	1
Woodpigeon	*Columba palumbus*	1	1
	Total	**11**	**31**

Table 16a. Water samples by type collected during leg 1. Coloured Dissolved Organic Matter (CDOM), Nutrients (DIN, i.e. nitrate, phosphate and silicate).

Parameter	**No. at Surface**	**No. at Bottom**	**No. at other depths**	**Total no. samples**
Nutrients/CDOM	16	16	64	96
Chlorophyll	16	16	64	96
Nano/pico plankton	14	14	52	80

Table 16b. Water samples by type collected during leg 2. Inorganic Carbon (DIC), Total Alkalinity (TA), Particulate Organic Matter (POM), Coloured Dissolved Organic Matter (CDOM), Particulate Organic Carbon (POC), Dissolved Organic Carbon (DOC), Nutrients (DIN, i.e. nitrate, phosphate and silicate).

Parameter	**No. at Surface**	**No. at Bottom**	**No. at other depths**	**Total no. samples**
DIC	32	32	0	64
TA	32	32	0	64
Salinity	32	32	0	64
POM	32	32	6	70
POC	32	32	11	75
DOC	32	32	11	75
Nutrients/CDOM	32	32	113	177
Chlorophyll	32	32	113	177
Nano/pico plankton	32	32	113	177

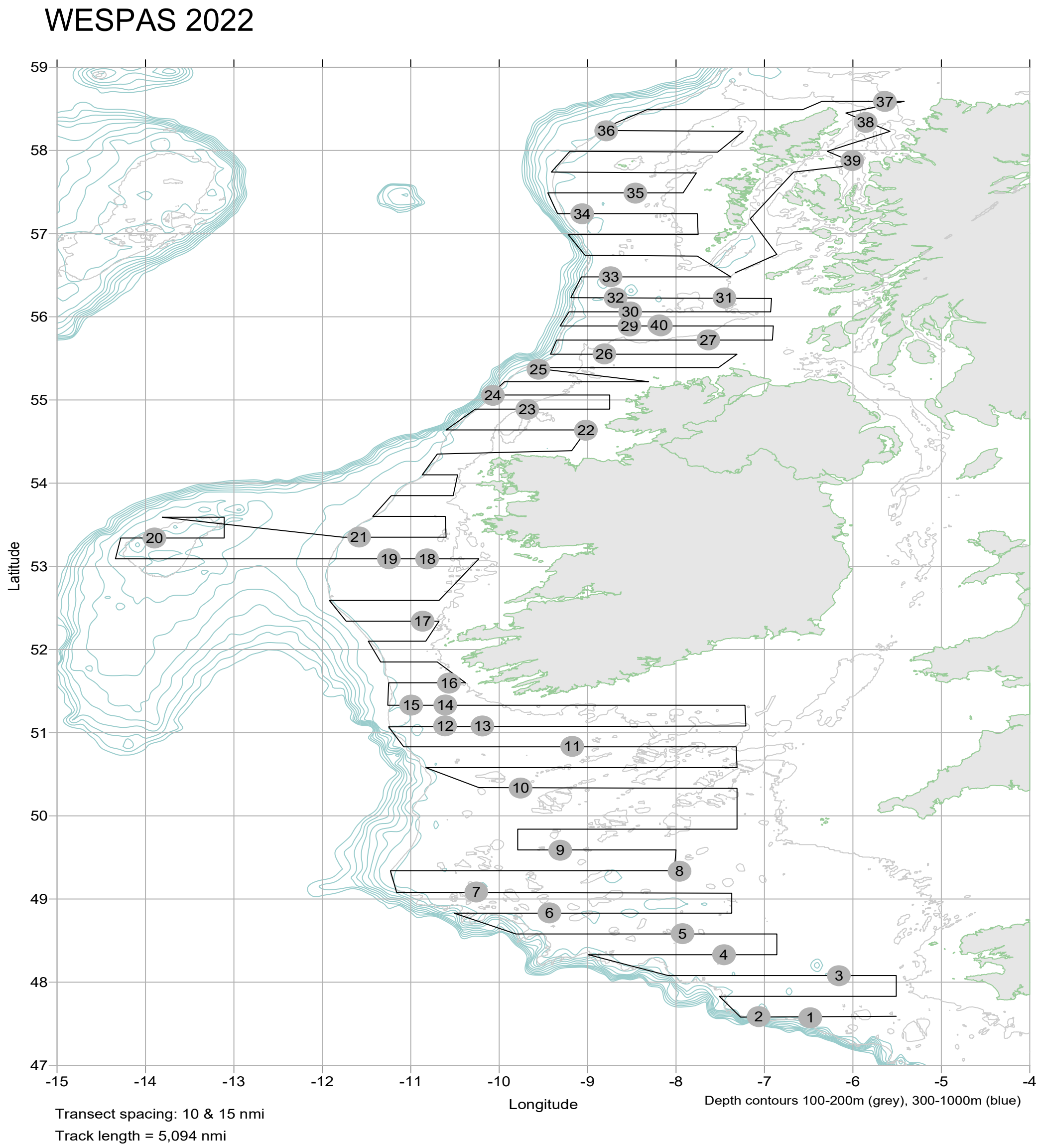


Figure 1. WESPAS 2022 survey cruise track (grey line) and numbered directed pelagic trawl stations. Corresponding catch details are provided in Table 2.

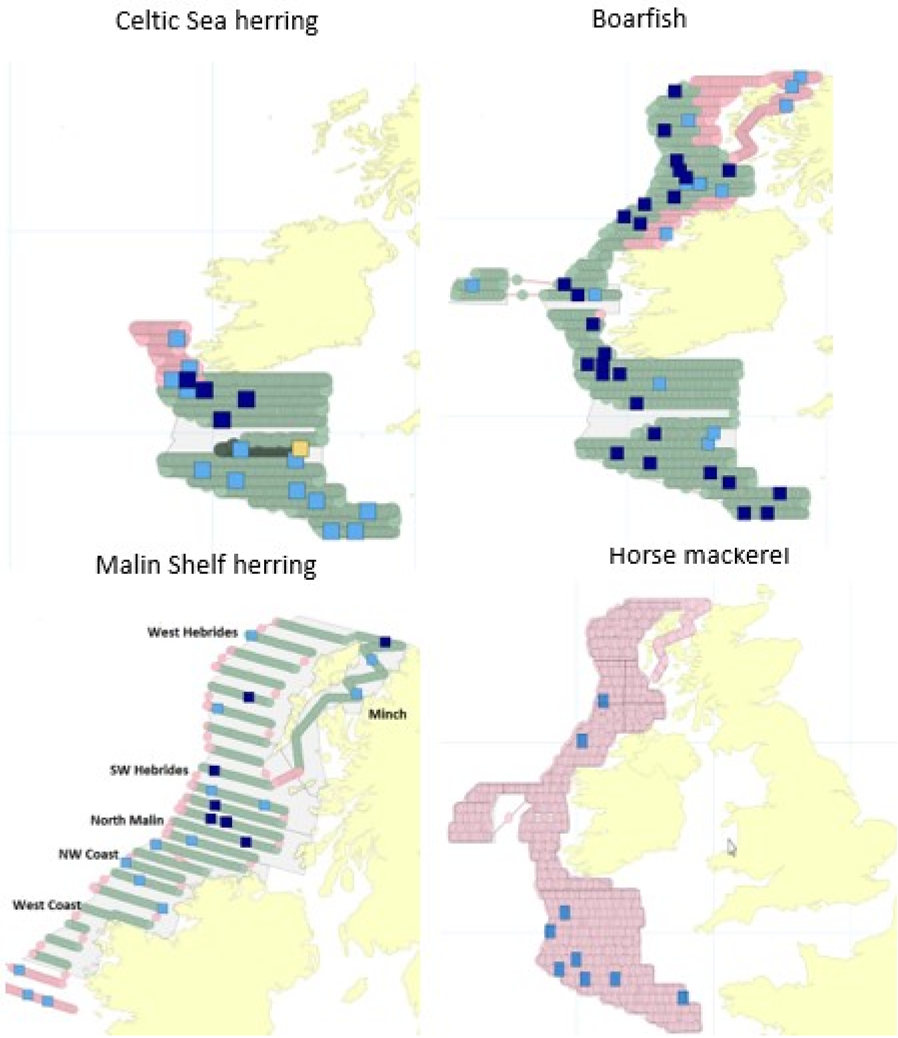


Figure 2. Species specific acoustic sampling stratification taken from StoX

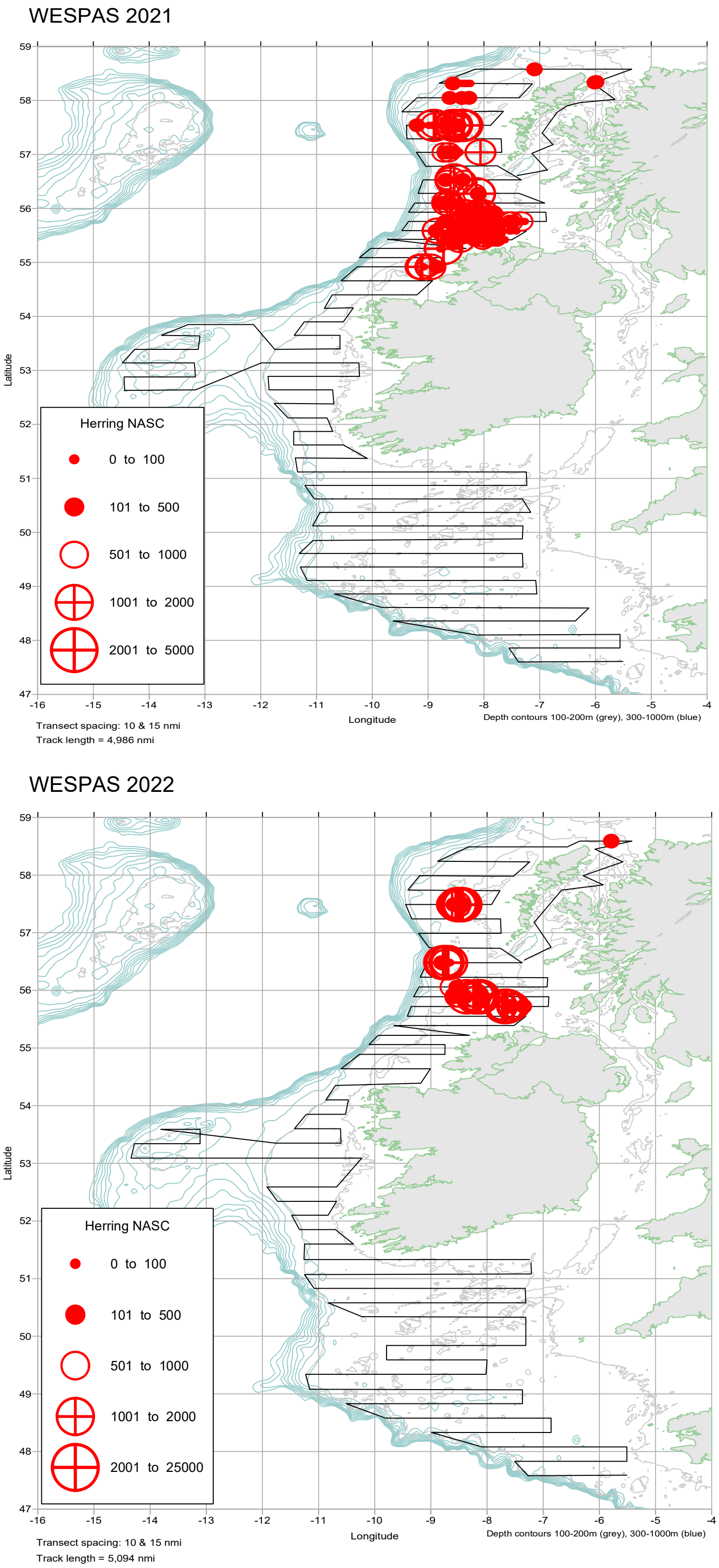


Figure 3. WESPAS Malin Shelf (north of 54°N) herring distribution by weighted acoustic density. Top panel 2021, bottom panel 2022.

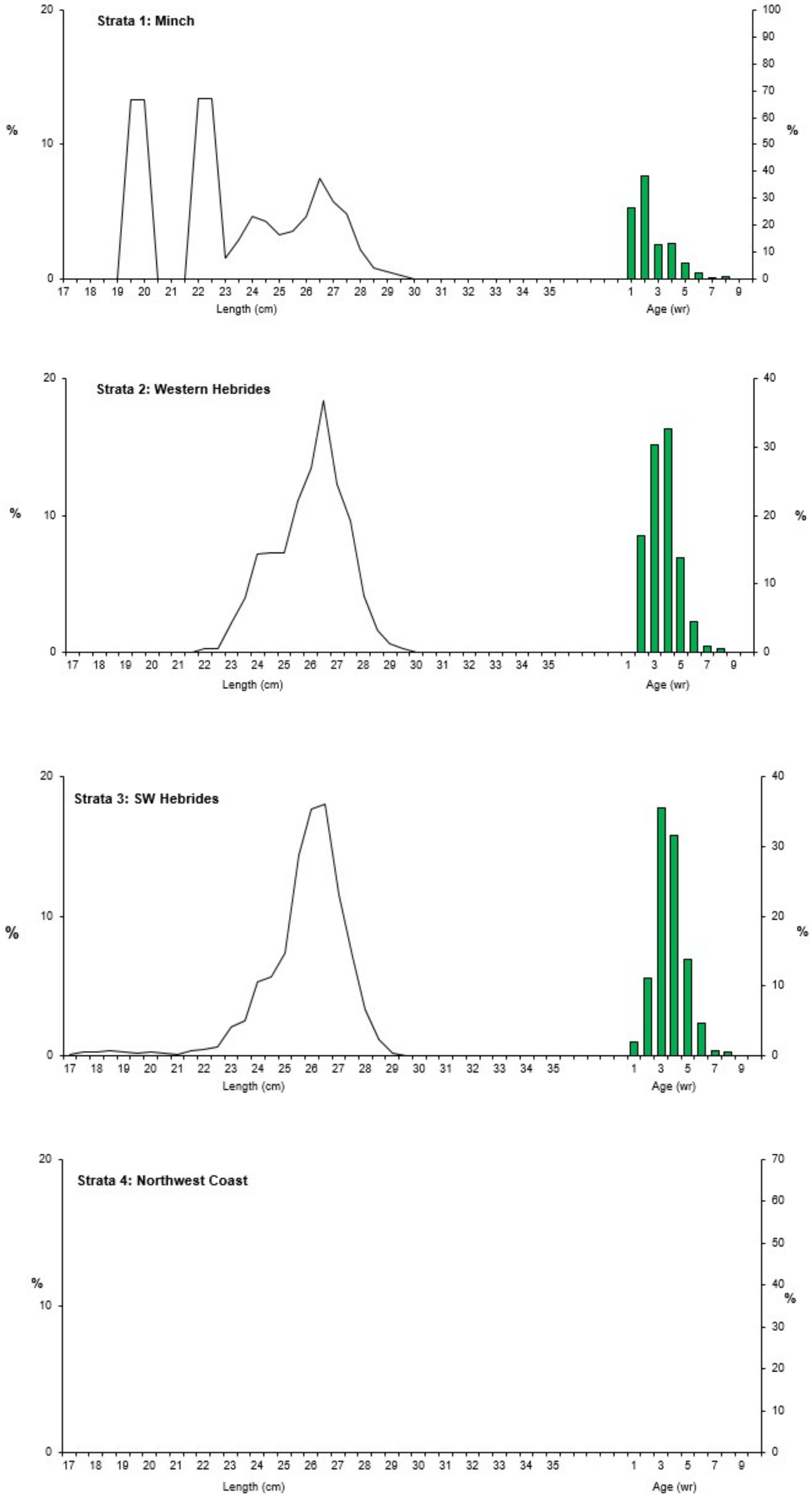
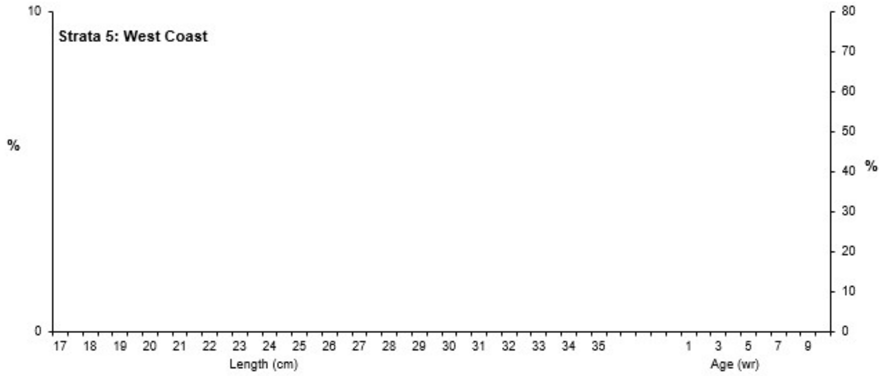
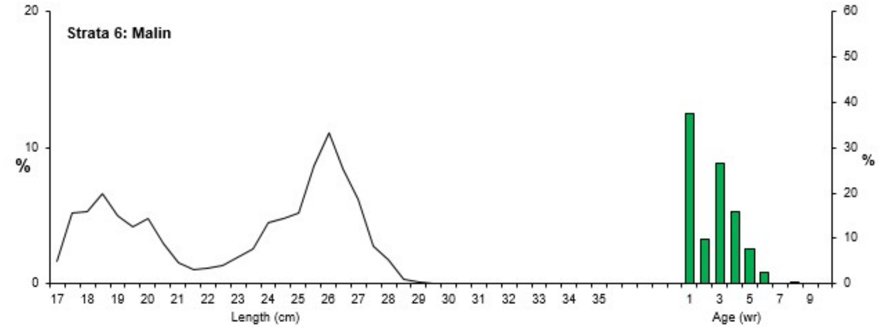


Figure 4. Length and age distribution of Malin Shelf herring by stratum and total survey area during WESPAS 2022 (*no herring found in Northwest Coast and West Coast strata in 2022*).





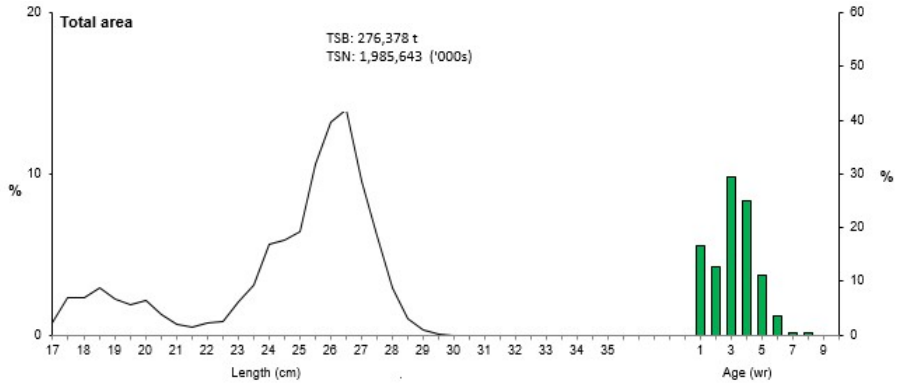


Figure 4. c*ontinued.* Length and age distribution of Malin Shelf herring by stratum and total survey area during WESPAS 2022 (*no herring found in Northwest Coast and West Coast strata in 2022*).

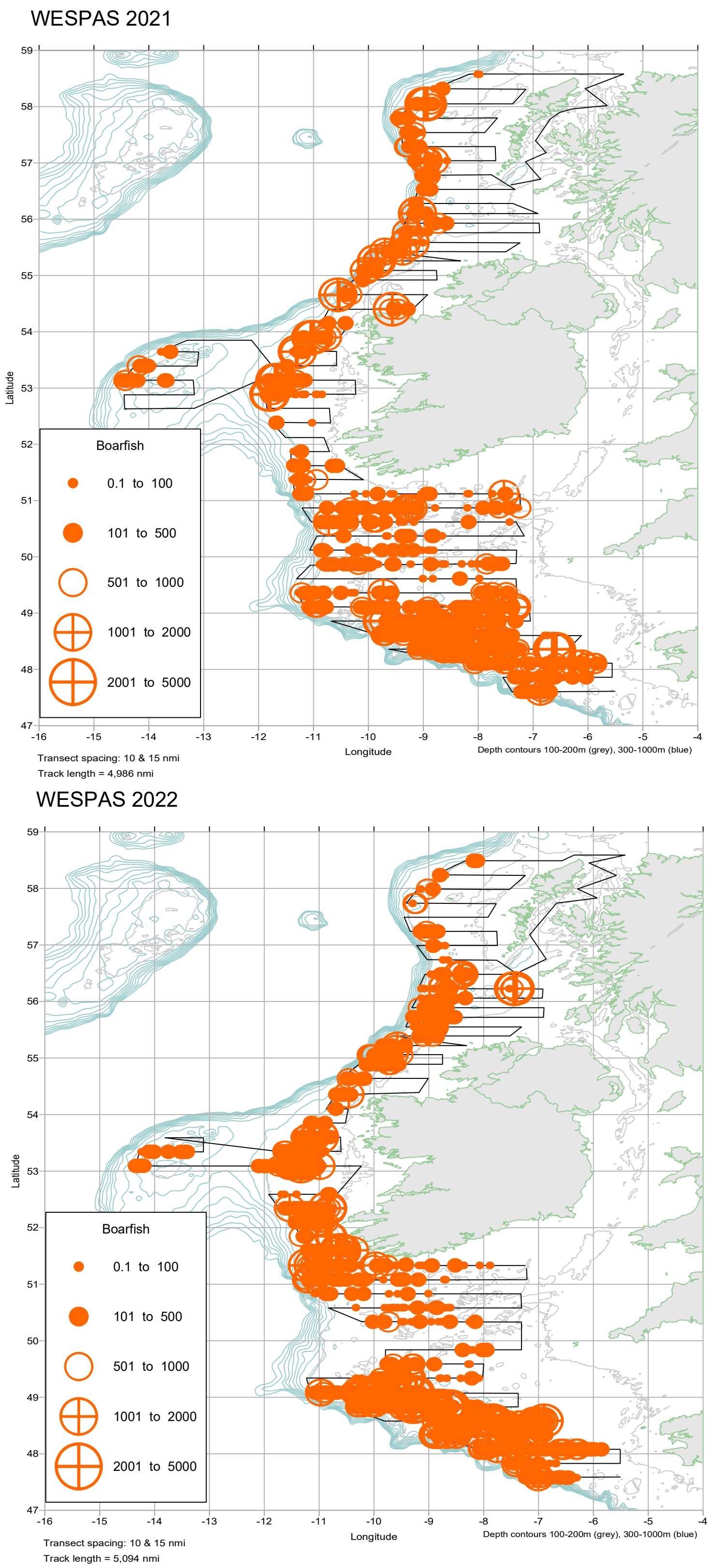


Figure 5. Boarfish distribution by weighted acoustic density. Top panel 2021, bottom panel 2022.

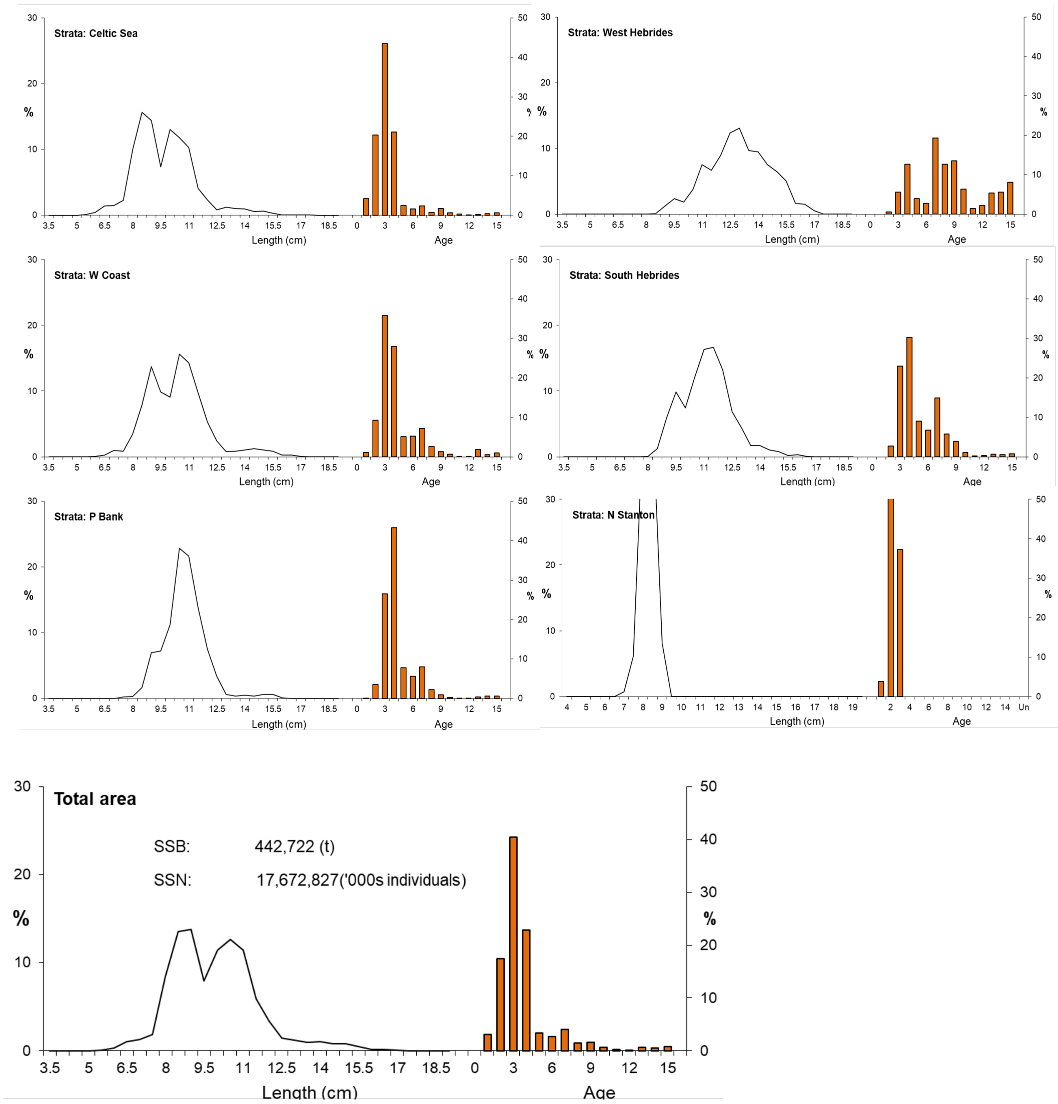
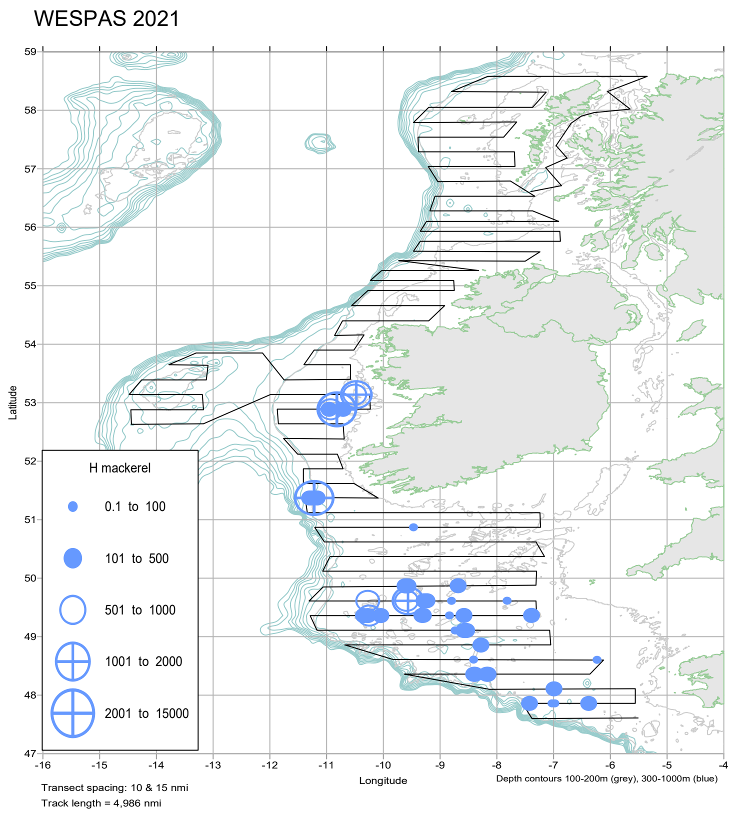


Figure 6. Abundance at length and age distribution of boarfish by stratum and total survey area.



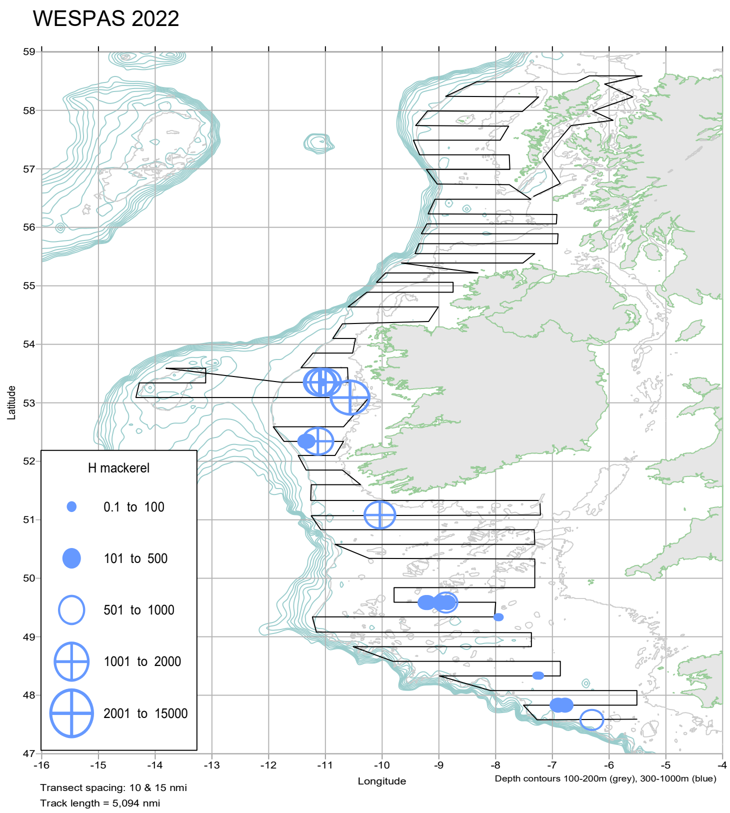


Figure 7. Horse mackerel distribution by weighted acoustic density. Top panel 2021, bottom panel 2022.

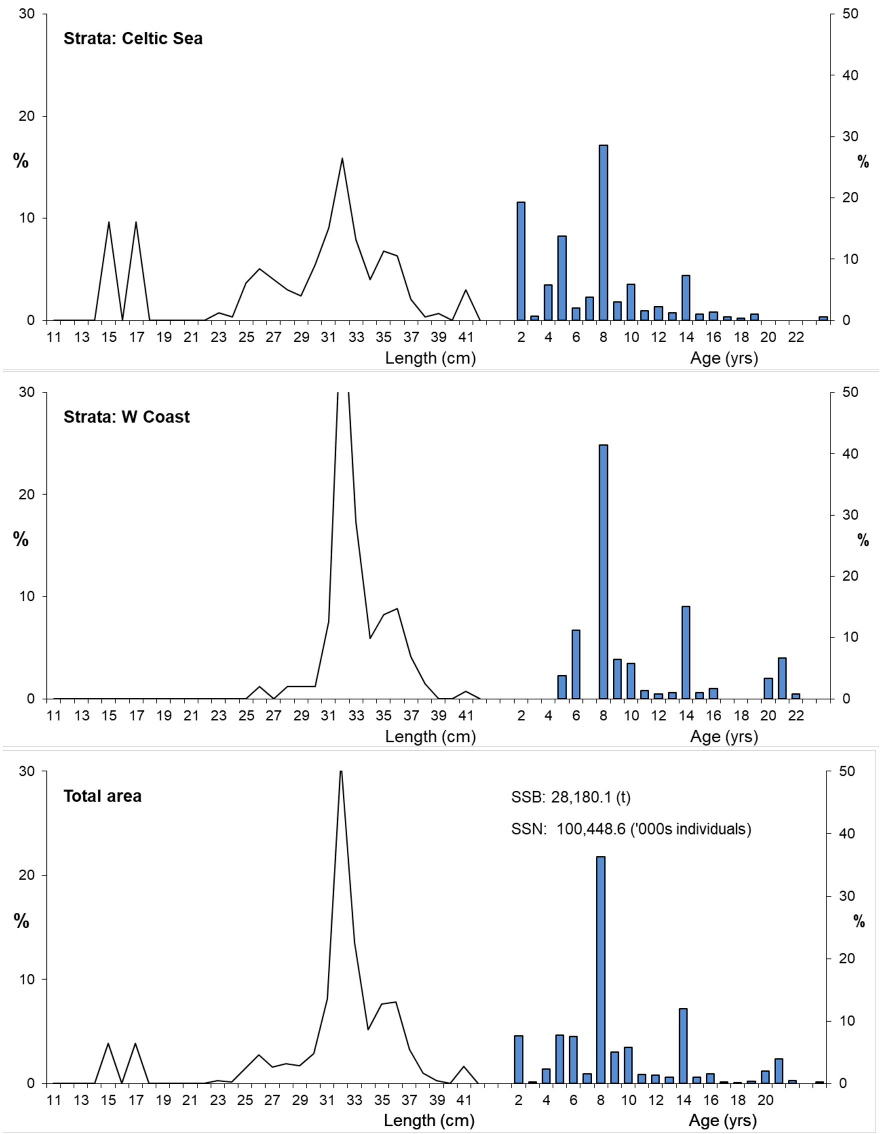


Figure 8. Length and age distribution of horse mackerel by stratum and total survey area.

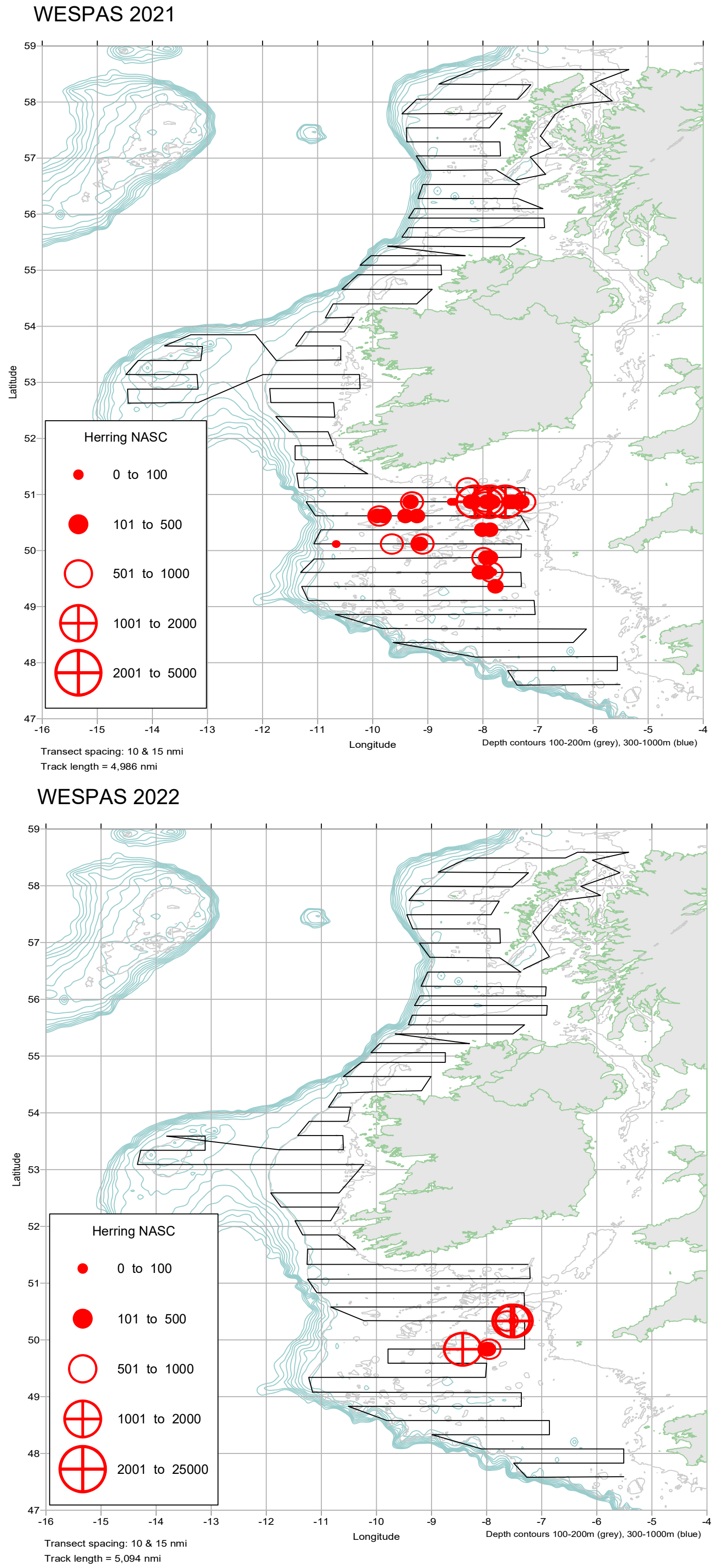


Figure 9. Celtic Sea herring distribution by weighted acoustic density. Top panel 2021, bottom panel 2022.

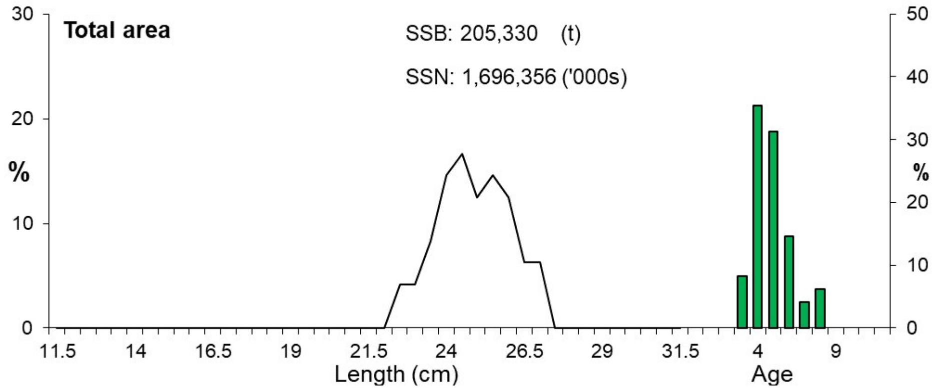
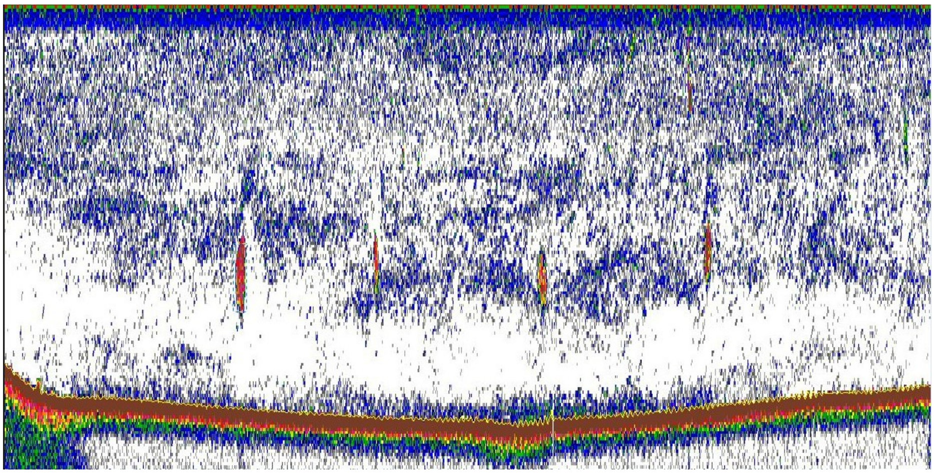
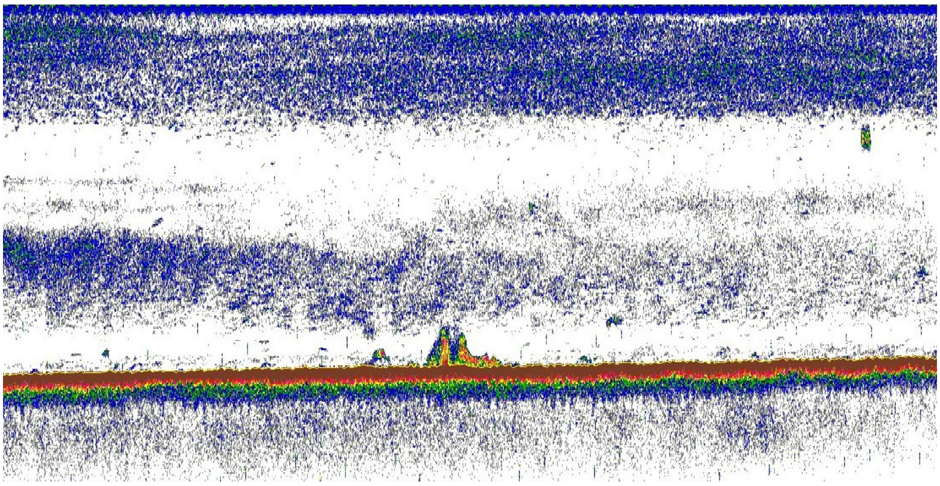


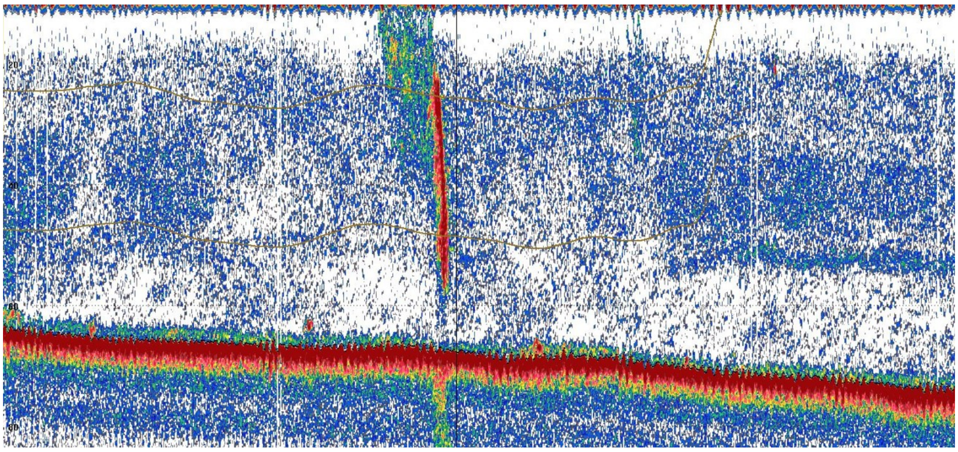
Figure 10. Length and age distribution of Celtic Sea herring within the Celtic Sea stratum (Total survey area).



a). Haul 22. Midwater sprat marks west of Rathlin O'Beirne Island in 6aS. Water depth 90 m. Recorded at 18 kHz.

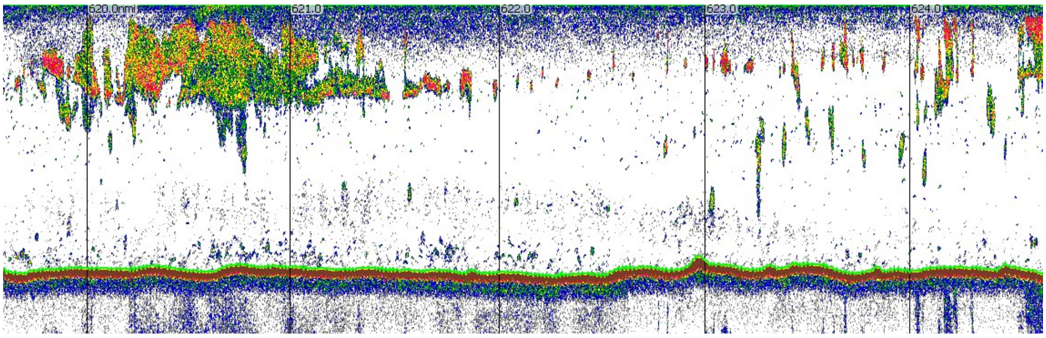


b). Haul 25. Possible herring mark west of Tory Island. Water depth 160 m. Missed mark while fishing. Recorded at 18 kHz.

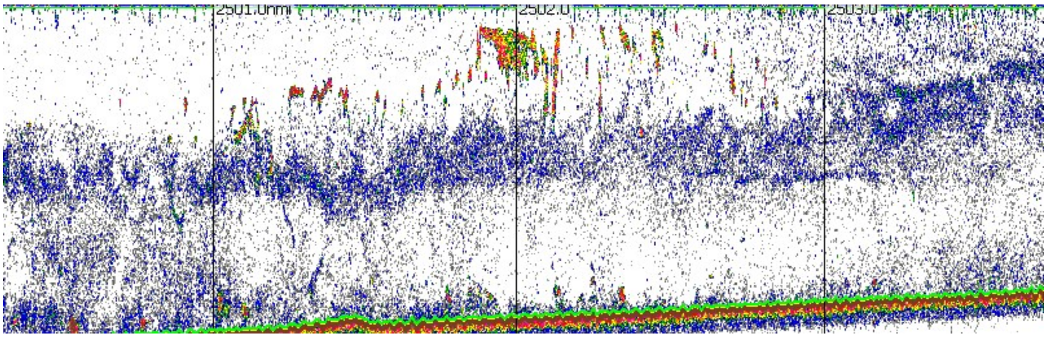


c). Haul 27. Good midwater pillar mark of young herring north of Lough Swilly. Water depth 75m.

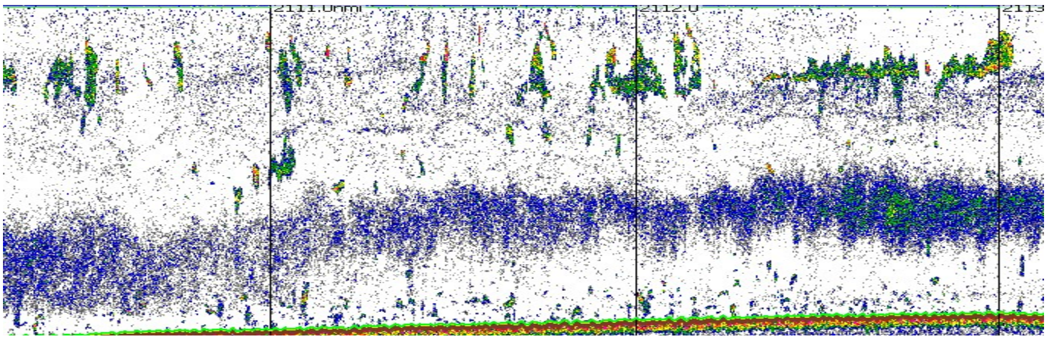
Figures 11a-n. Echotraces recorded on an EK60 echosounder (38 kHz, unless otherwise stated) with images captured from Echoview. Note: Vertical bands on echogram represent 1nmi (nautical mile) intervals.



d). *Haul 05. South Celtic Sea. High density surface echotraces of boarfish recorded on 18 kHz. Water depth 162 m.*

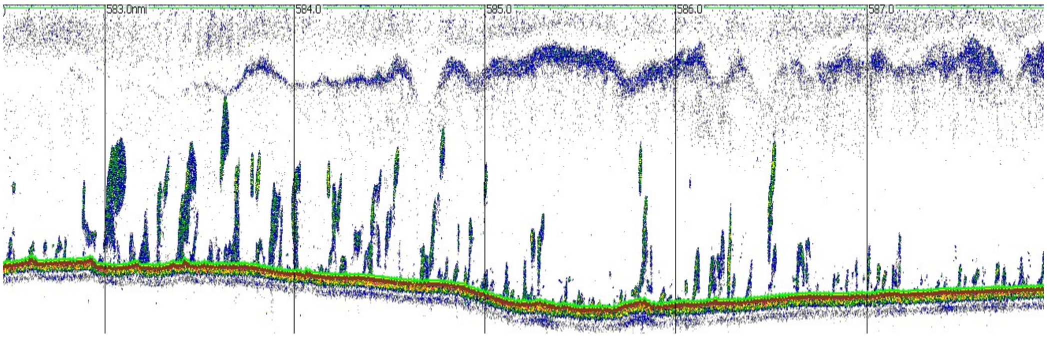


e). *Haul 16. West coast. High density surface echotraces of boarfish recorded on 18 kHz. Water depth 129 m.*

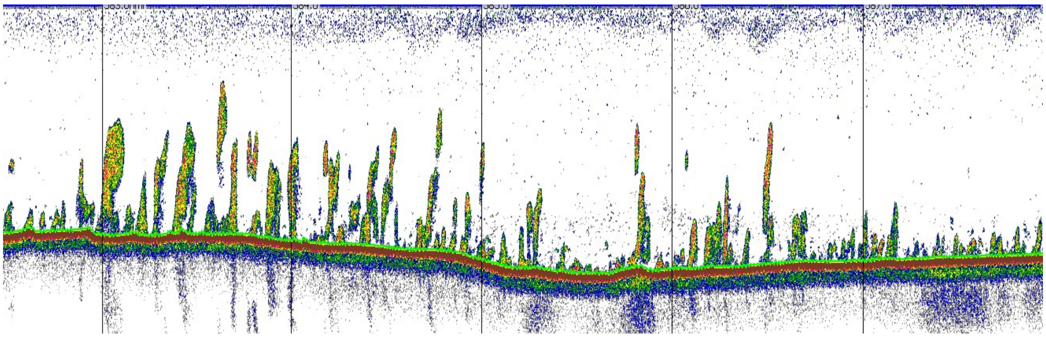


f). *Haul 12. Southwest coast. High density surface echotraces of boarfish recorded on 38 kHz. Water depth 190 m.*

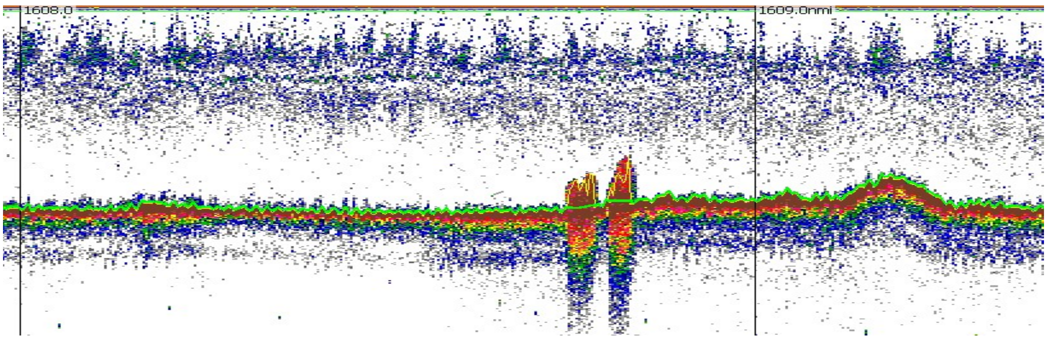
Figures 11a-n. continued



g). *Widespread echotraces of boarfish in the southern Celtic Sea (18 kHz), water depth 121 m.*

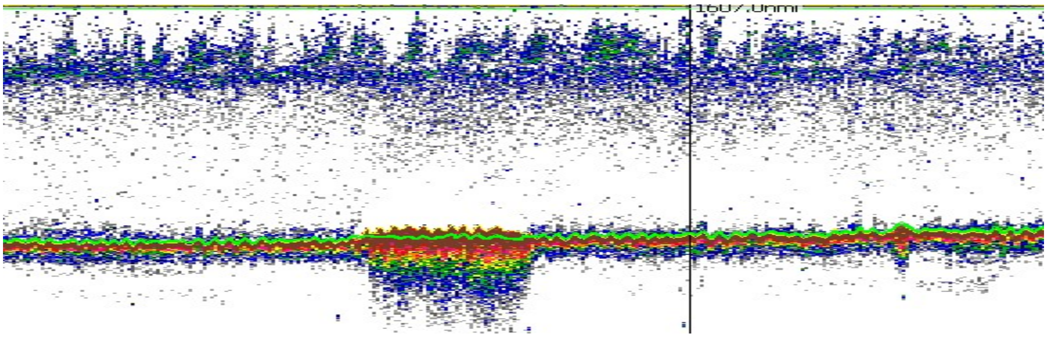


h). *Representation of the same echogram as above at 18 kHz, water depth 121 m.*

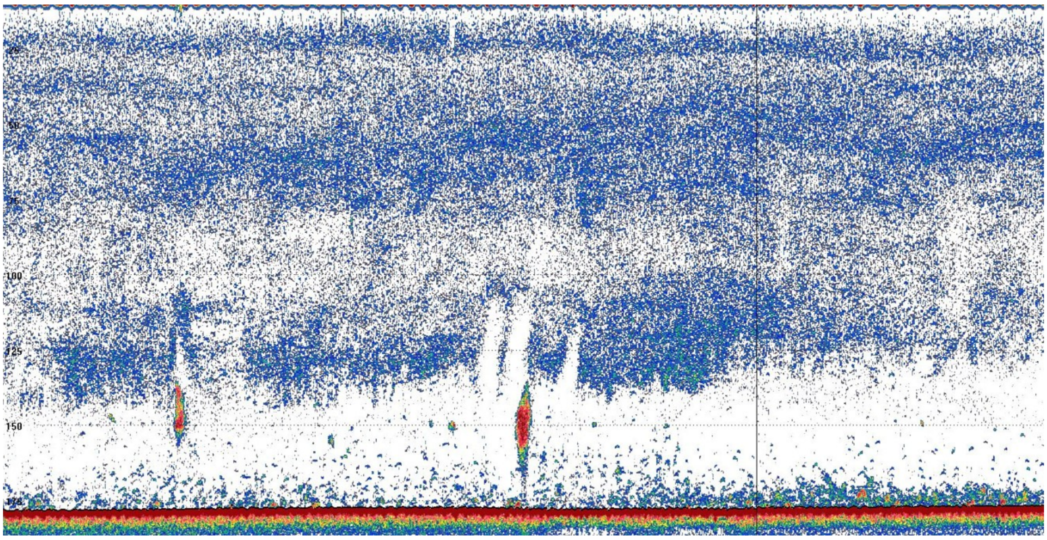


i). *High density herring echotraces located on the Labadie Bank, Celtic Sea. Water depth 90 m.*

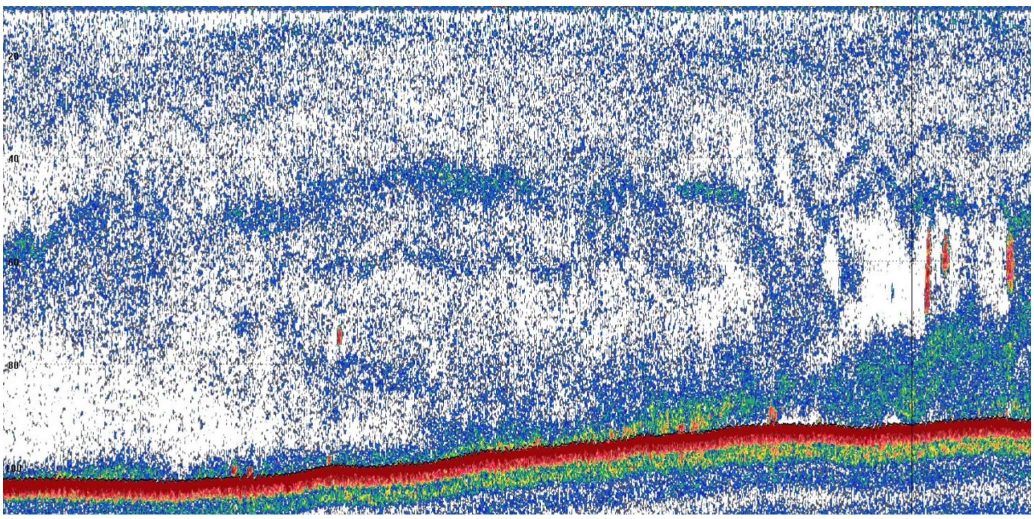
Figures11a-n. continued.



J). *High density herring echotraces located on the Labadie Bank, Celtic Sea. Water depth 93 m.*

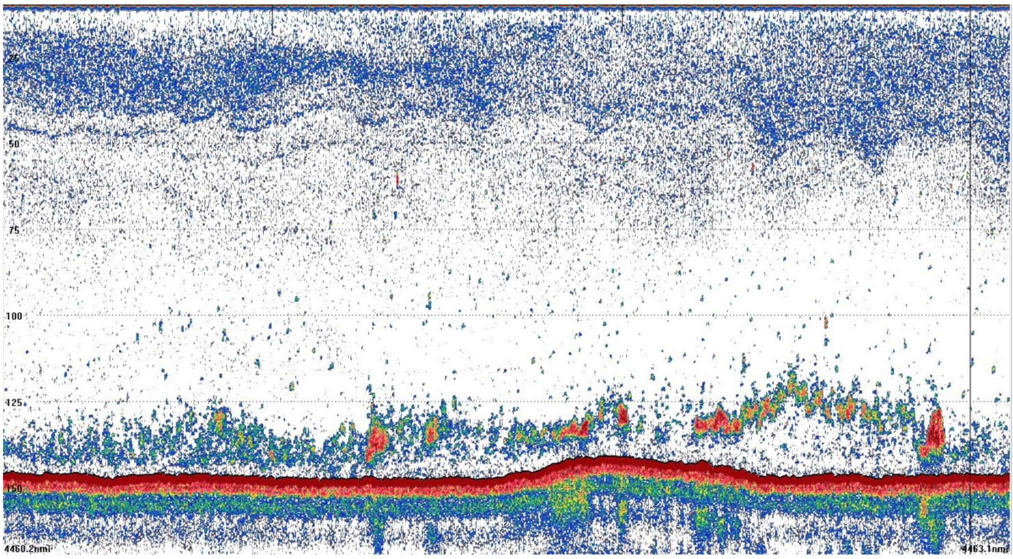


k). *Haul 28. Herring SW of Stanton Bank just south of the 56° line, water depth ~175 m.*

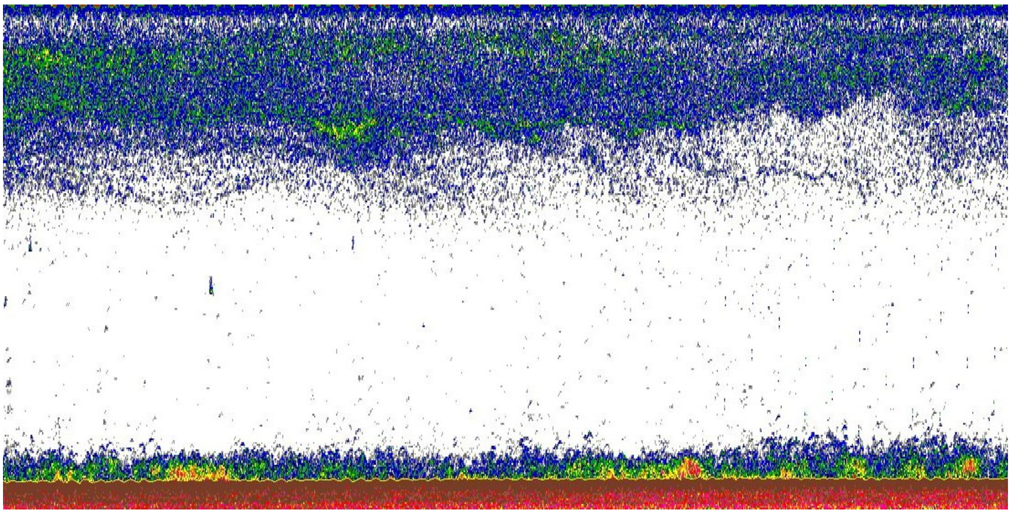


l). *Haul 31. Midwater marks of juvenile BOC to the SW of Tiree in 6aN, water depth ~92 m.*

Figures11-l. continued.



m). *Haul 33. Very strong series of herring marks close to the bottom near the shelf edge NW of Tory, water depth ~146 m.*



n). *Haul 35. Very tight herring marks on the bottom SE of St. Kilda, water depth ~161 m.*

Figures11-n. continued.

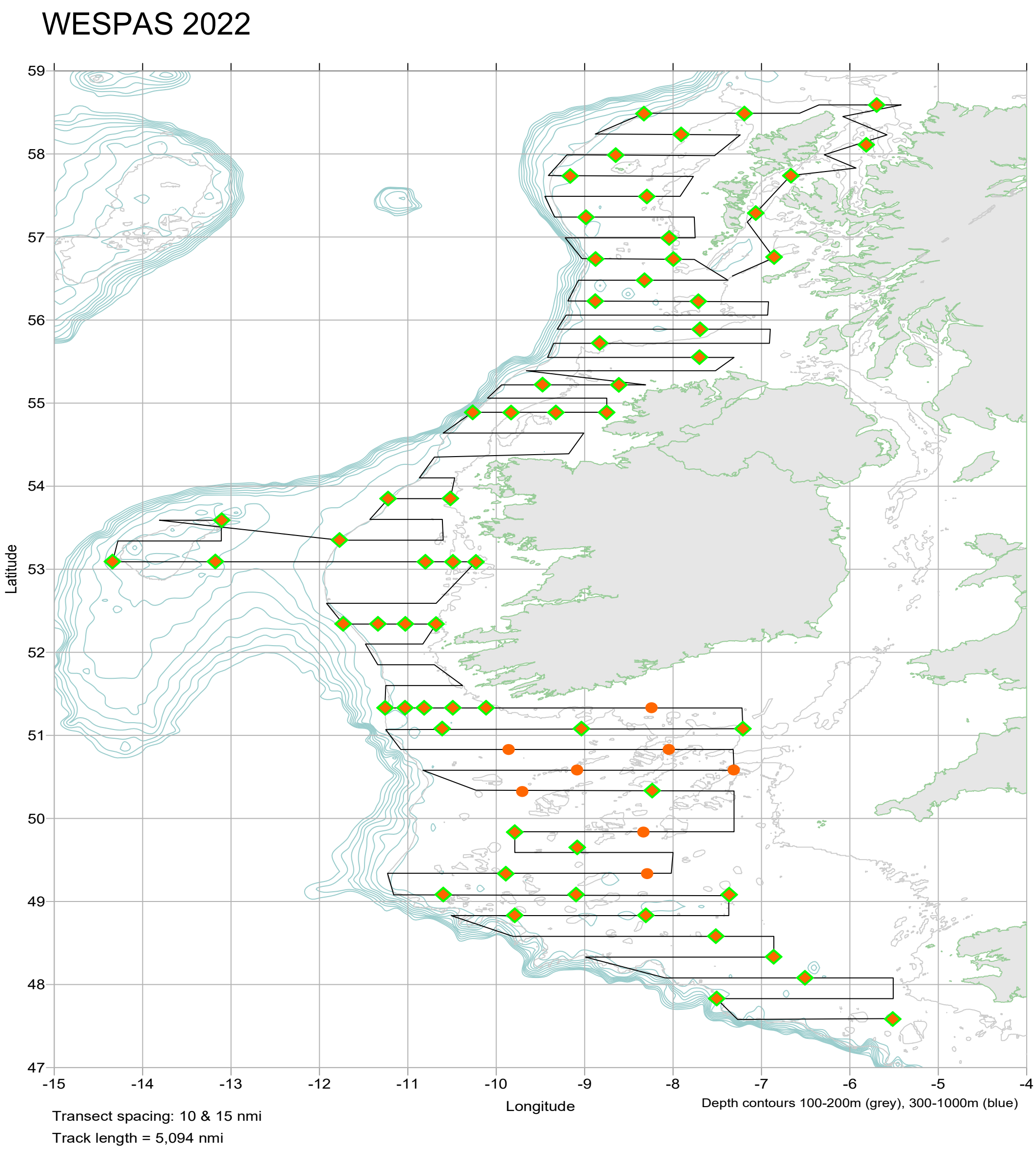


Figure 12. Position of hydrographic (orange circle) and zooplankton sampling stations (green ring) (CTD=71, Zooplankton =62).

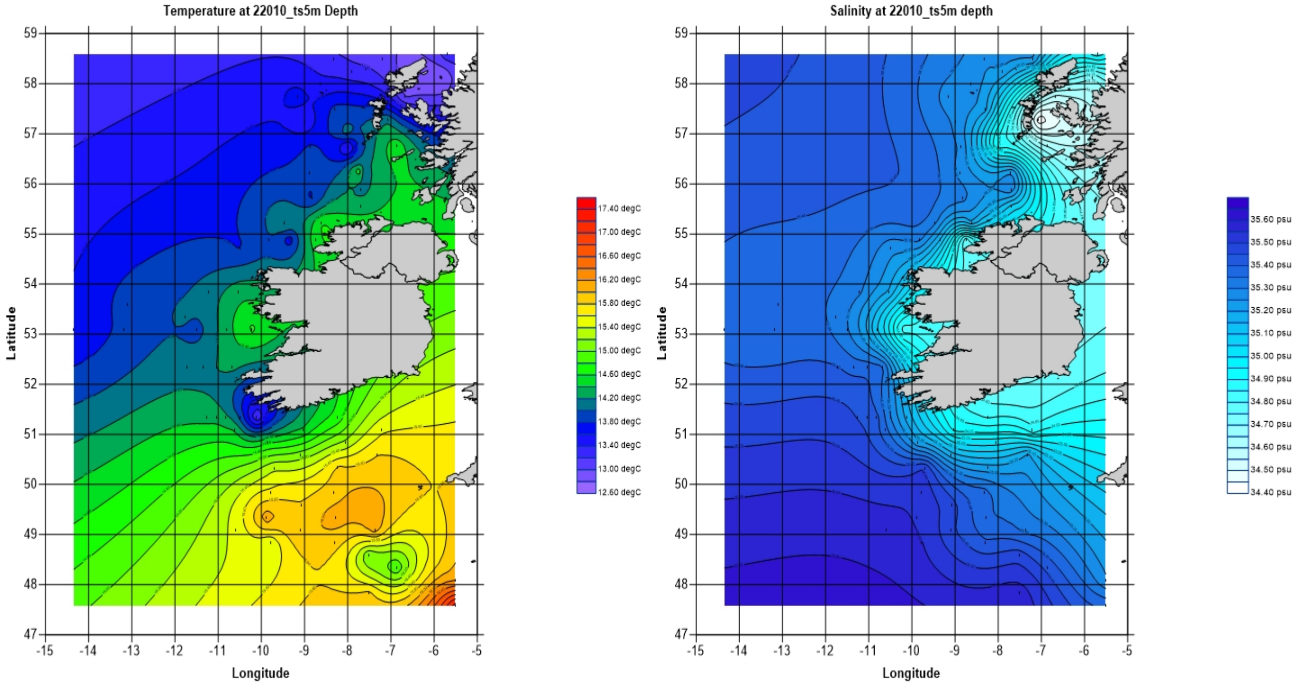


Figure 13. Surface (5m) plots of temperature and salinity compiled from CTD cast data. Station positions with valid data shown as block dots (n=84).

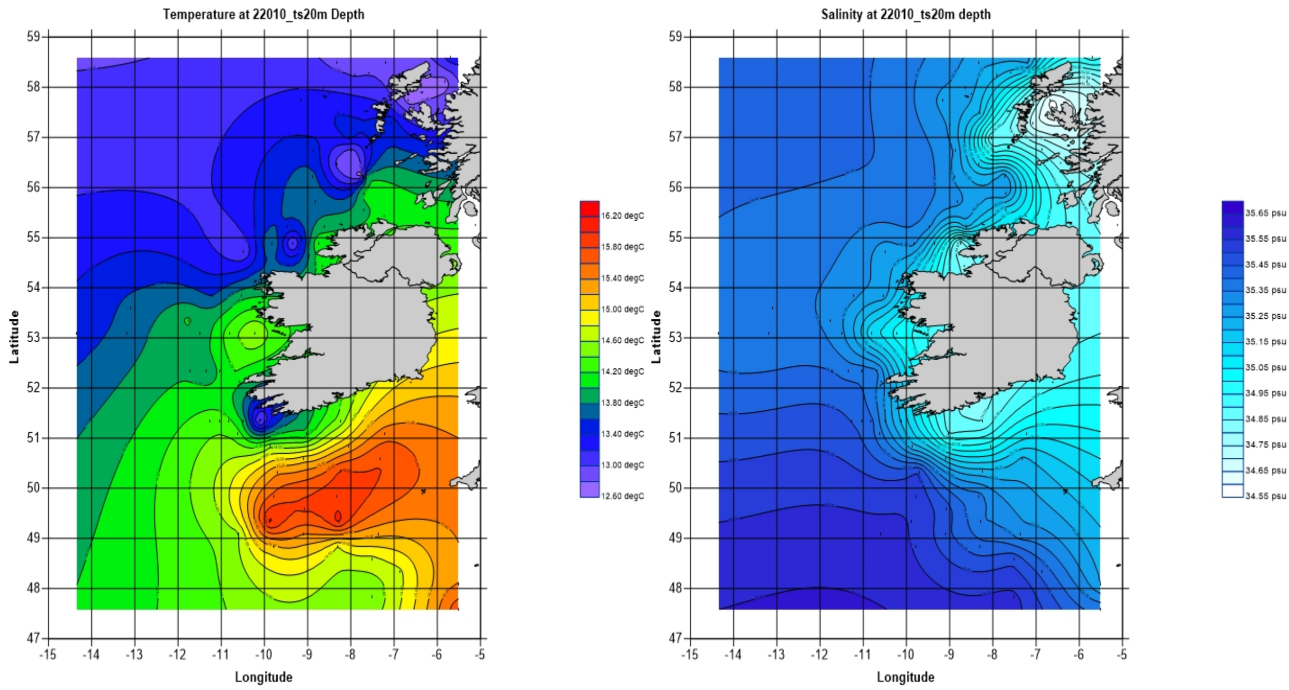


Figure 14. Plots of temperature and salinity compiled from CTD cast data at 20m depth. Station positions with valid data shown as block dots (n=84).

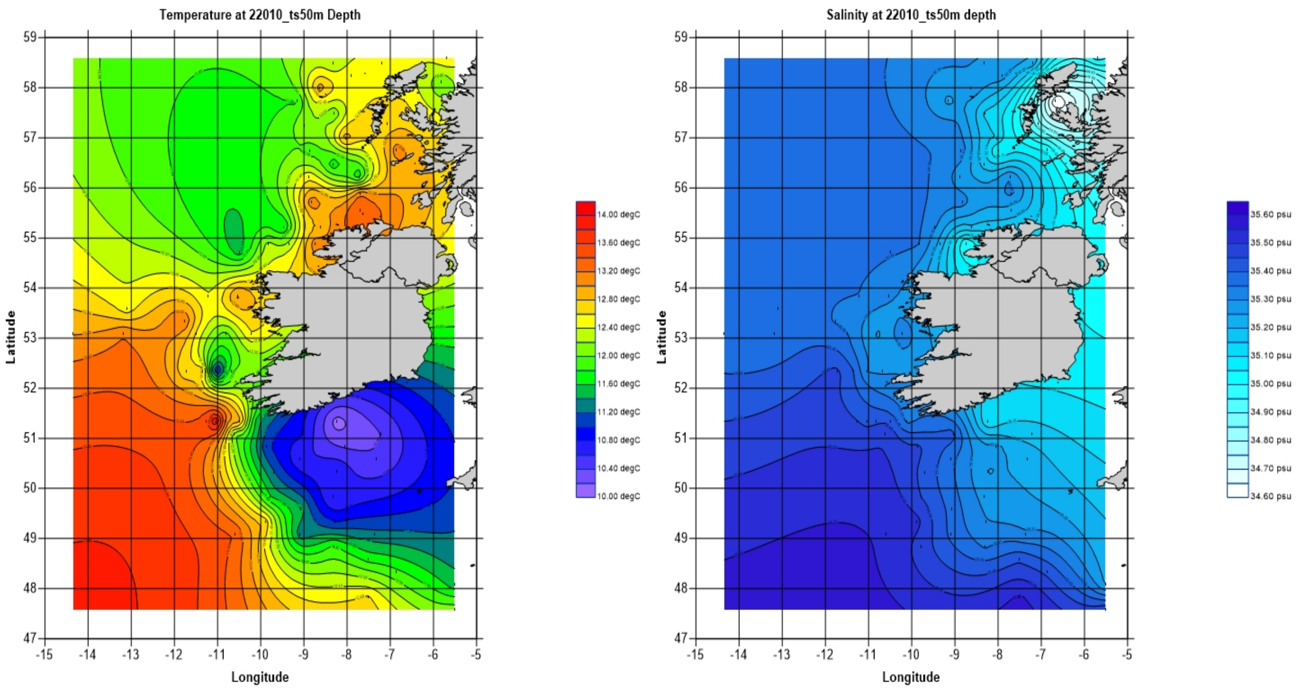


Figure 15. Plots of temperature and salinity compiled from CTD cast data at 50m depth. Station positions with valid data shown as block dots (n=84).

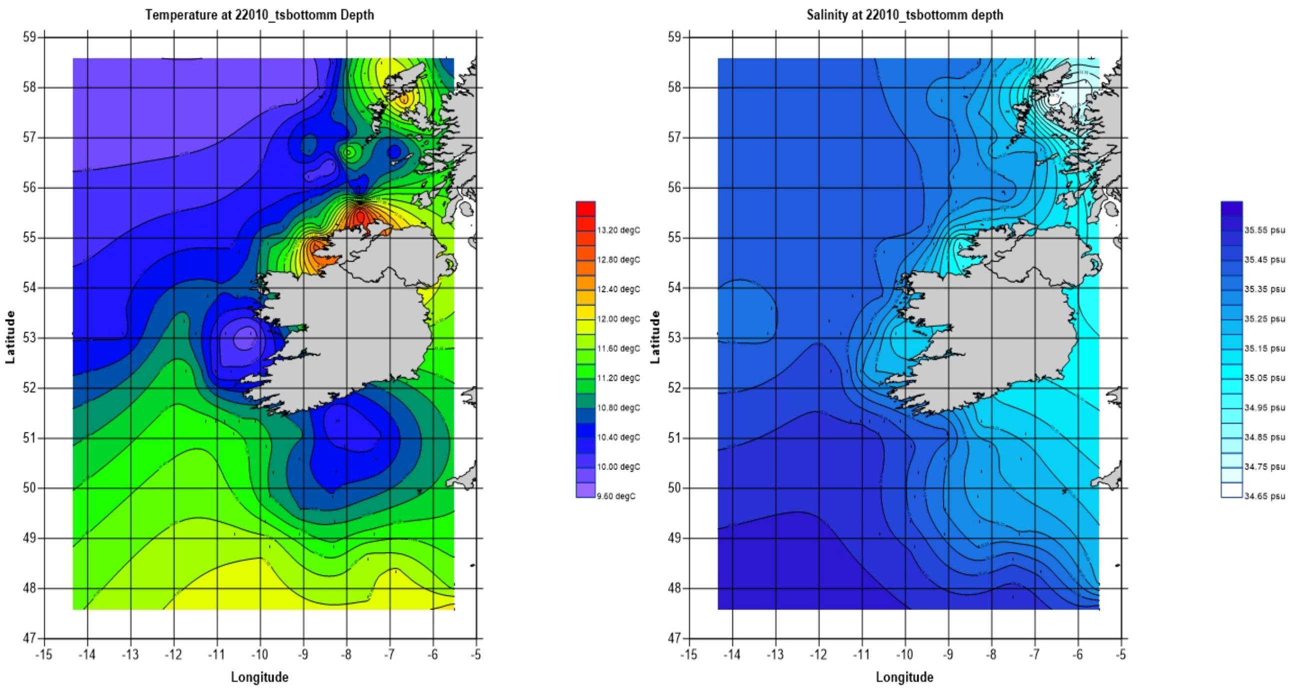


Figure 16. Plots of temperature and salinity compiled from CTD cast data at the seabed (+3-5m). Station positions with valid data shown as block dots (n=84).

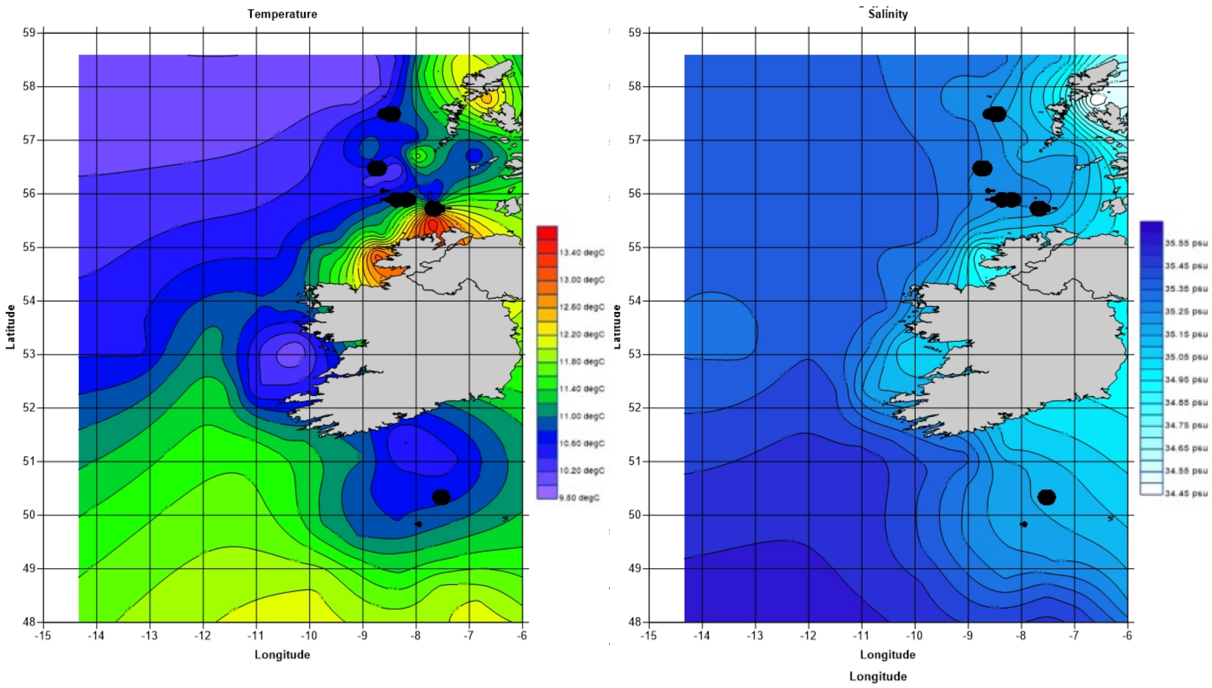


Figure 17. Habitat plots of temperature and salinity with herring distribution. Sea floor values overlaid with herring NASC values (black circles).

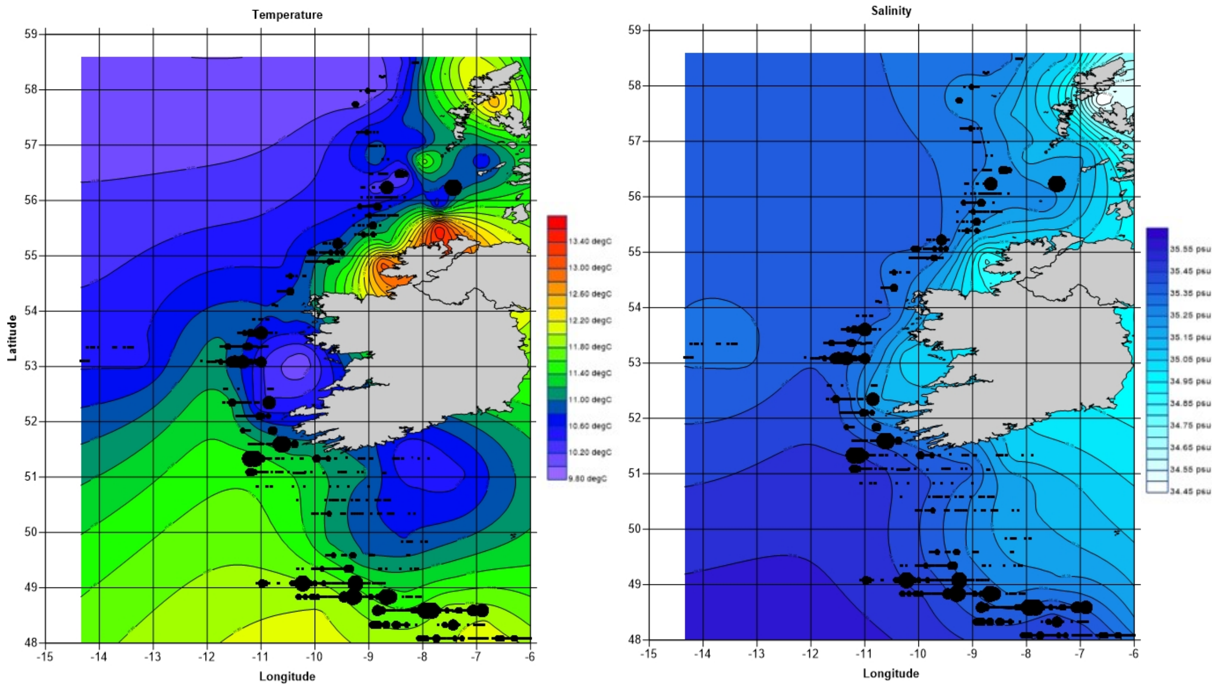


Figure 18. Habitat plots of temperature and salinity with boarfish distribution. Sea floor values overlaid with boarfish NASC values (black circles).

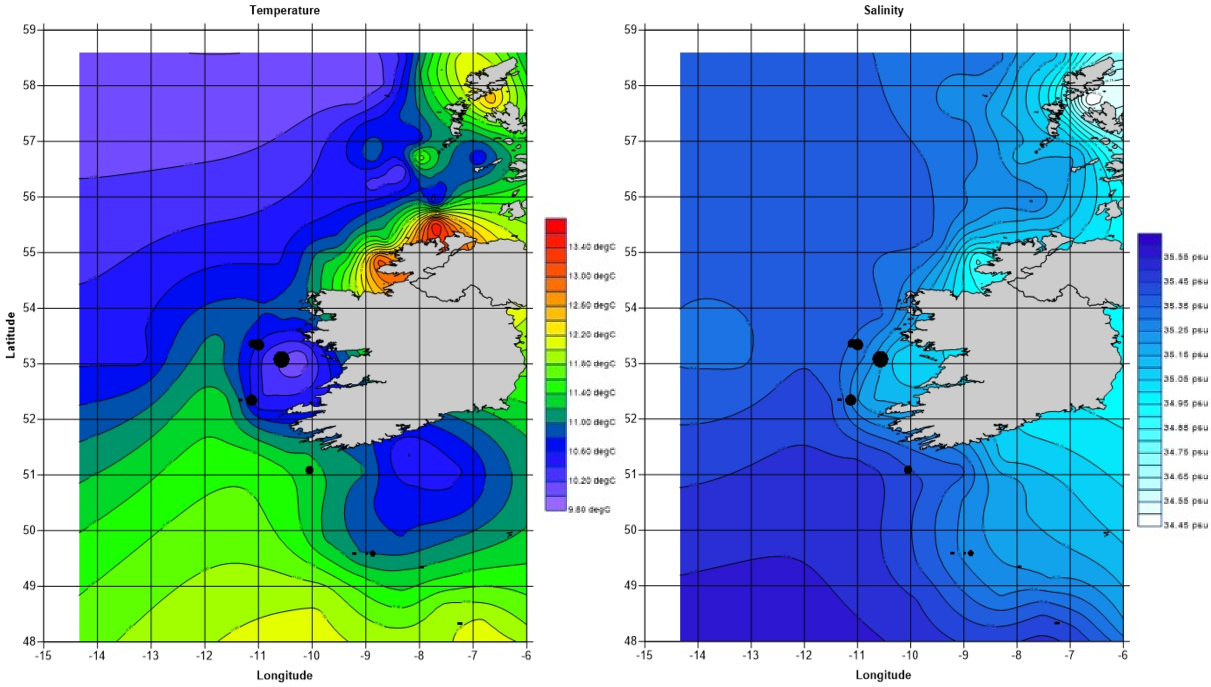


Figure 19. Habitat plots of temperature and salinity with horse mackerel distribution. Sea floor values overlaid with horse mackerel NASC values (black circles).

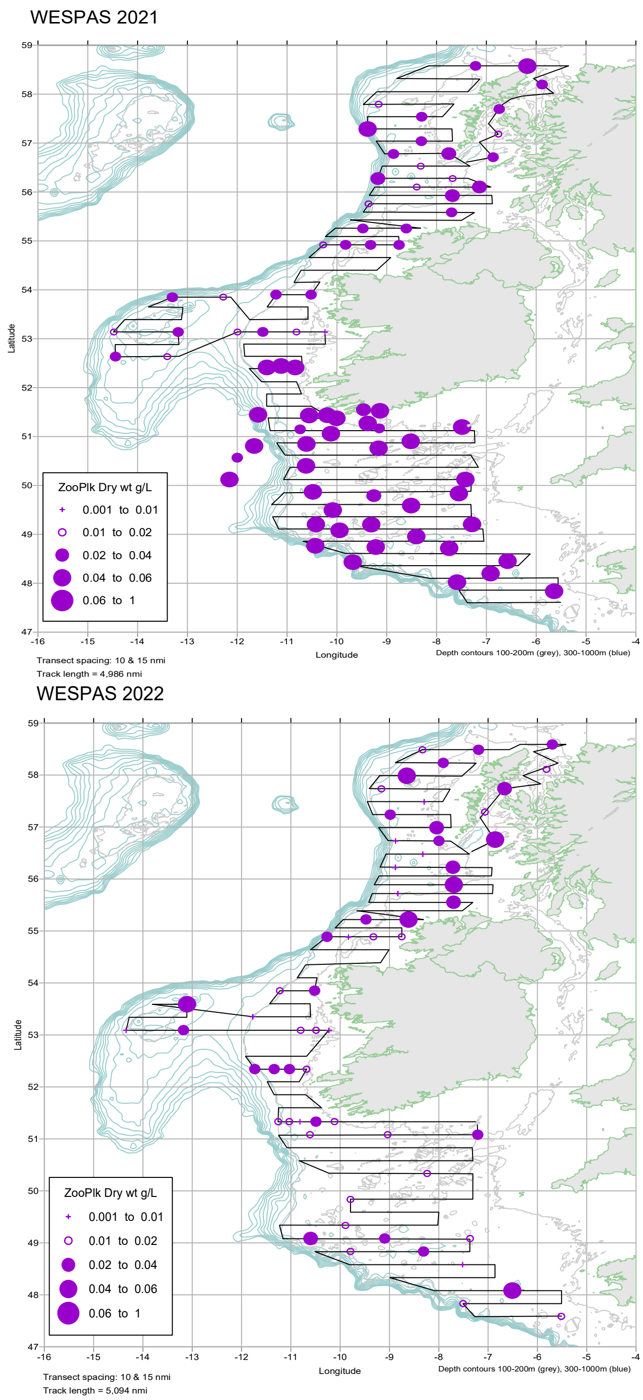


Figure 20. Zooplankton dry weight biomass by station (g dry Wt. m³) 2021-2022.

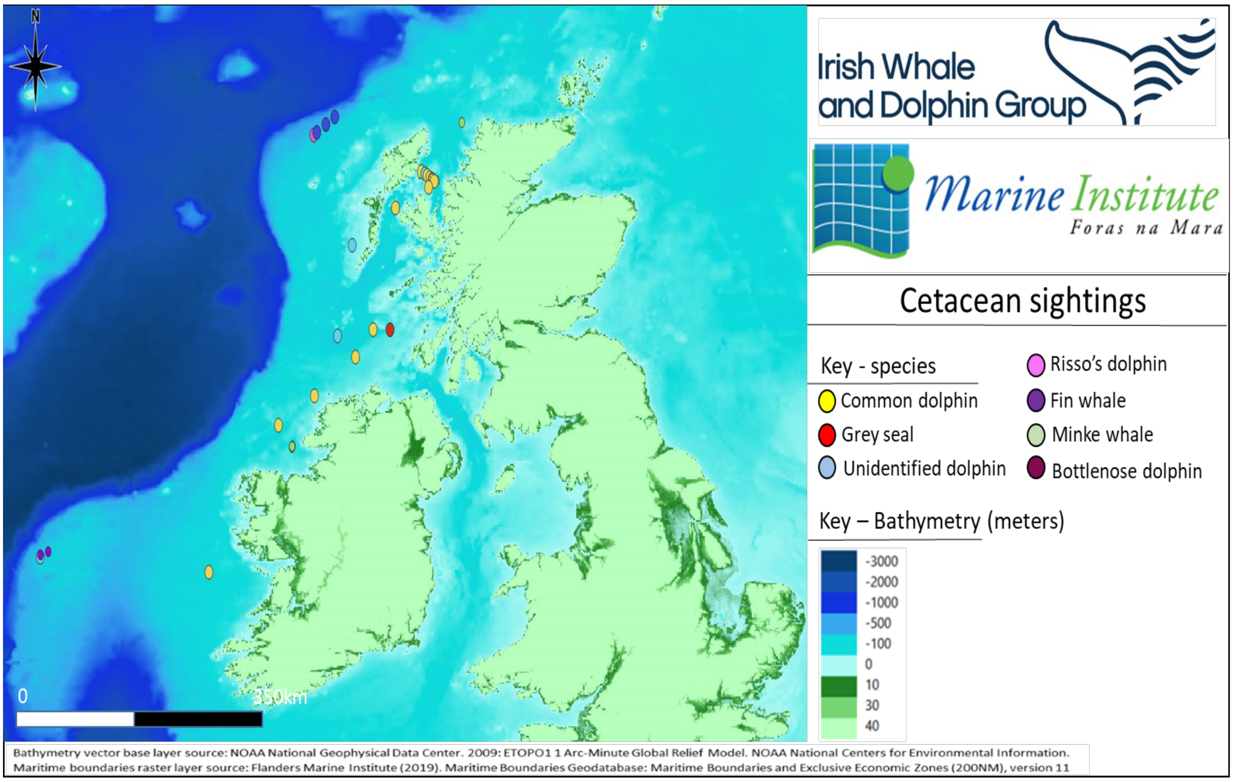


Figure 21. Sightings of all marine mammal species encountered during Leg 2 north, WESPAS 2022. No coverage was undertaken during Leg 1 south.

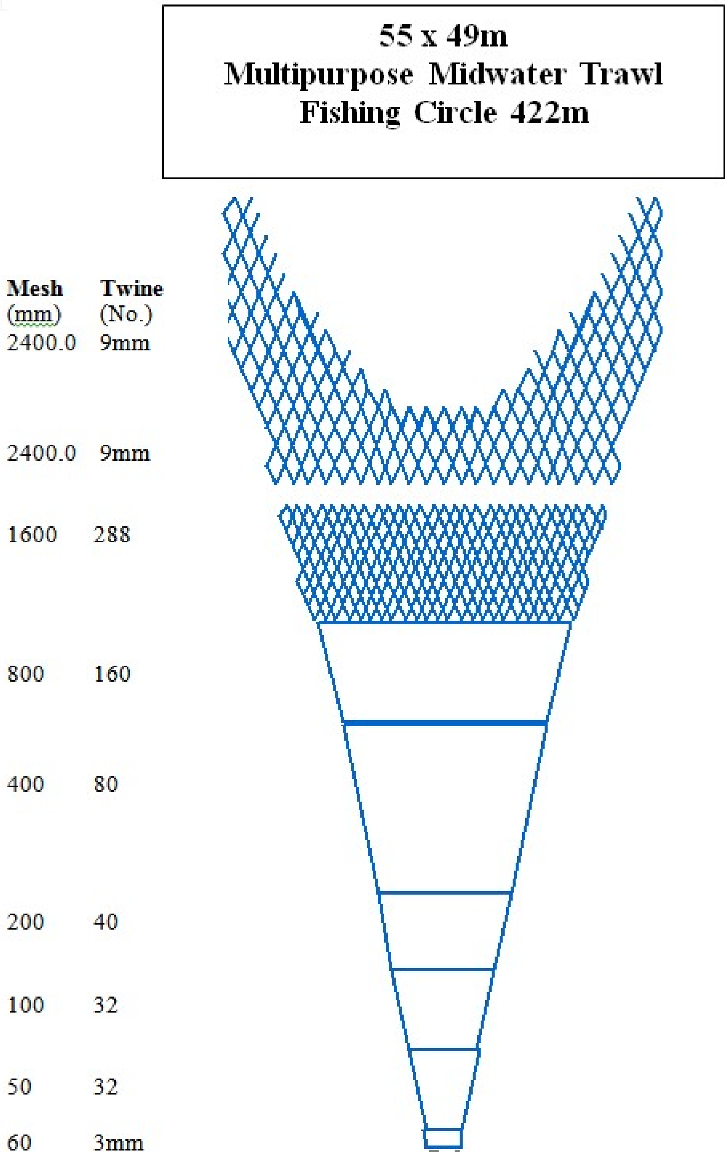


Figure 22. Single multipurpose midwater trawl net plan and layout.

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