FSS Survey Series: 2015/01

Blue Whiting Acoustic Survey Cruise Report

March 22- April 08, 2015

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Table of Contents

1 Introduction

Acoustic surveys targeting blue whiting (*Micromesistius poutassou*) spawning and post spawning aggregations in the north east Atlantic have been carried out by the Institute of Marine Research (IMR) Norway since the early 1970s. In the early 1980s a coordinated acoustic survey approach was adopted, with both Russia and Norway participating to estimate the size of this migratory stock within the main spawning grounds to the west of Ireland and Britain. Since 2004, an International coordinated survey program has expanded to include vessels from the EU (Ireland and the Netherlands) and the Faroes.

Due to the highly migratory nature of the stock a large geographical area has to be surveyed. Spawning takes place from January through to April along the shelf edge from the southern Porcupine Bank area northwards to the Faroe/Shetland Ridge including offshore areas as the Rosemary, Hatton and Rockall Banks. Peak spawning occurs between mid-March and mid April and acoustic surveys are timed to occur during this phase. To facilitate a more coordinated spatio-temporal approach to the survey participating countries meet annually to discuss survey methods and define effort allocation at the ICES led Working Group International Pelagic Surveys (WGIPS).

Data from the annual spawning stock abundance survey (March/April, western waters), juvenile surveys (May, Norwegian Sea and January-March, Barents Sea trawl survey) and commercial landings data are presented annually at the ICES Working Group of Widely Distributed Stocks (WGWIDE). Ultimately, combined data inputs into the management and catch advice for this international cross boundary stock.

The 2015 survey was part of an international collaborative survey using the vessels RV *Celtic Explorer* (Ireland), FV *Fridtjof Nansen* (Russia), RV *Tridens* (Netherlands) and the RV *Magnus Heinason* (Faroes). The total combined area coverage extended from the Faroe Islands in the north (62° N) to south of Ireland (51° N), with east -west extension from 4°-18° W.

International survey participants meet shortly after the survey to present data and produce a combined relative abundance stock estimate and report. The combined survey report is presented annually at the WGIPS meeting held in January. The information presented here relates specifically to the Irish survey component.

2 Materials and Methods

2.1 Scientific Personnel

Organsiation	*Name*	*Capacity*
FEAS	Ciaran O'Donnell	Acoustics (SIC)
FEAS	Cormac Nolan	Acoustics
FEAS	Grahan Johnston	Acoustics
FEAS	Robert Bunn	Acoustics
FEAS	Sean O'Connor	Biologist
DTU Aqua	Jan Pedersen	Biologist
Birdwatch Irl	Niall Keogh	SBO
Birdwatch Irl	Mairead O'Donovan	SBO
IWDG	Alexandra Borawska	PAM
IWDG	Inge van der Knaap	MMO

2.2 Survey Plan

2.2.1 Survey objectives

The primary survey objectives are listed below:

- Collect acoustic data on blue whiting spawning aggregations within the pre-determined areas based on terms agreed at the WGIPS meeting 2015
- Collect biological samples from directed trawling on fish echotraces to determine age structure and maturity state of survey stock
- Determine an age stratified estimate of relative abundance of blue whiting within the survey area using acoustic survey techniques
- Collect physical oceanography data as horizontal and vertical profiles from a deployed sensor array
- Submit survey data (acoustic, biological and hydrographic) to the internationally coordinated database
- Conduct a sighting survey of marine mammals and seabirds (ESAS)
- Conduct a passive acoustic (PAM) survey to monitor occurrence of marine mammals

2.2.2 Survey design and area coverage

The survey covered the core spawning area of blue whiting to the west of Ireland and Scotland (Figure 1). Coverage extended from the shelf slopes (250 m) westward into the Rockall Trough and was carried out in continuity from south to north.

Transect design and effort allocation was pre-agreed for each vessel at the WGIPS meeting in 2015. A parallel transect design was used to allow transect interlacing in co-surveyed target areas (east-west orientation). Offshore, transects extended to 16° W. Transect spacing was set at 30 nmi for individual vessels and maintained throughout the survey.

In total, the Irish survey covered 58,569 nmi² using 2,224 nmi of transects. Survey design and methodology adheres to the methods laid out in the WGIPS acoustic survey manual (ICES 2015).

2.3 Equipment and system details and specifications

2.3.1 Acoustic array

Equipment settings for the EK60 are based on established settings employed on previous surveys (O'Donnell *et al.,* 2004) and are detailed in Table 1.

Acoustic data were collected using the Simrad EK 60 scientific echosounder. A Simrad ES-38B (38 kHz) split-beam transducer is mounted within the vessels drop keel and lowered to the working depth of 3.3 m below the vessels hull or 8.8 m below the sea surface. Three other frequencies were used during the survey (18, 120 and 200 kHz) for trace recognition purposes, with the 38 kHz data used solely to generate the abundance estimate.

While on track the vessel is normally propelled using DC twin electric motor propulsion system with power supplied from 1 main diesel engine, so in effect providing "silent cruising" as compared to normal operations (ICES, 2002). Cruising speed is maintained at a maximum of 10 Kts (knots) where possible. During fishing operations normal 2 engine operations were employed to provide sufficient power to tow the net.

2.3.2 Calibration of acoustic equipment

The EK60 was calibrated in Dunmanus Bay on March 22 at the start of the survey. The results (38 kHz transducer) are provided in Table 1.

2.3.3 Inter-vessel calibration

Inter-vessel acoustic calibrations are carried out when participant vessels are working within the same general area and time and weather conditions allow for an exercise to be carried out. The procedure follows the methods described by Simmonds & MacLennan 2007.

No inter-calibration exercise was carried out in 2014.

2.3.4 Acoustic data acquisition

EK60 "RAW files" were logged via a continuous Ethernet connection to the vessels server and the EK60 hard drive as a backup. Sonar Data's Echoview® Echolog (Version 4.8) live viewer was used to display the echogram during data collection to allow the scientists to scroll through echograms noting the locations and depths of fish shoals. A member of the scientific crew monitored the equipment continually. Time and location (GPS position) data was recorded for each transect within each target area. This log was used to monitor the time spent off track during fishing operations and hydrographic stations plus any other important observations.

2.3.5 Echogram scrutinisation

Acoustic data was backed up onto the vessels server every 24 hrs and scrutinised using Echoview.

EK60 "Raw" files were imported into Echoview for post-processing. The echograms were divided into transects. Echo integration was performed on regions defined by enclosing selecting marks or scatter that belonged to one of the target species categories. Echograms were analysed at a threshold of -70 dB and, where necessary, plankton were filtered out by thresholding to –65 dB.

Echograms were scrutinised into one of the following categories:

a). Blue whiting (further classified as; Definitely, Probably, Possibly and Mixed)
b). Mesopelagic fish
c). Plankton
d). Pelagic fish (Including herring and mackerel)

2.3.6 Biological sampling

A single pelagic midwater trawl with the dimensions of 70 m in total length and a fishing circle of 768 m was employed during the survey (Figure 12). Mesh size in the wings was 12.5 m through to 20 mm in the cod-end. The net was fished with a vertical mouth opening of approximately 50 m and was observed using a cable linked “BEL Reeson” netsonde (50 kHz). The net was also fitted with a Scanmar depth sensor. Spread between the trawl doors was monitored using Scanmar distance sensors, all sensors being configured and viewed through a Scanmar Scanbas system.

All components of the catch from the trawl hauls were sorted and weighed; fish and other taxa were identified to species level. Fish samples were divided into species composition by weight. Species other than blue whiting were weighed as a component of the catch. Age, length, weight, sex, stomach fullness and maturity data were recorded for individual blue whiting within a random 50 fish sample from each trawl haul with a further 100 random length and weight measurements were also taken. All blue whiting were aged onboard. The appropriate raising factors were calculated and applied to provide length frequency compositions for the bulk of each haul.

Decisions to fish on particular echo-traces were largely subjective and an attempt was made to target marks in all areas of concentration not just high density shoals. No bottom trawl gear was used during this survey.

2.3.7 Oceanographic data collection

Oceanographic stations were carried out during the survey at predetermined locations along the track (Figure 5). Data on temperature, depth and salinity were collected using a Seabird 911 sampler from 1 m subsurface to 1000 m where depth allowed or to within 10 m of the bottom on shelf slopes.

2.4 Analysis methods

2.4.1 Echogram partitioning and abundance estimates

The recordings of area back scattering strength per nautical mile (NASC) were averaged over one nautical mile elementary distance sampling units. NASC values were allocated to blue whiting and other acoustic targets was based on the composition of the trawl catches and the appearance of the echotraces. To estimate the abundance, the allocated NASC values were averaged for 1° latitude by 2° longitude strata (4 ICES rectangles). For each strata, the unit area density of fish (S_A) in number per square nautical mile ($N{*}nmi^{-2}$) was calculated using standard equations (Foote et al. 1987, Toresen *et al*. 1998).

For blue whiting a target strength (TS) of= 20 $\log_{10}$ – 65.2 dB was applied based on Pedersen *et al,* 2011.

To estimate the total abundance of fish, the unit area abundance for each statistical rectangle was multiplied by the number of square nautical miles in each statistical square and then summed for all statistical rectangles within defined sub areas and for the total area. Biomass estimation was calculated by multiplying abundance in numbers by the average weight of the fish in each statistical rectangle and then sum of all squares within defined sub areas and the total area.

2.5 Marine mammal and seabirds

2.5.1 Marine mammals

Visual observations for cetaceans were conducted during daylight hours from one of two platforms: the crow’s nest (deck height 17 m above sea level) or the bridge (deck height 10 m above sea level). Surveying from the crow’s nest was preferred to surveying from the bridge as the higher platform height provided a better detection probability. Access to the crow’s nest was dependent on weather conditions (wind speed < 20 knots and swell height ≤ 2 m).

Observations were for the most part conducted by a single observer scanning a 180° arc ahead of the vessel (i.e. 90° to port and 90° to starboard of the ship's track line). The position of the ship was recorded directly into an Access database every 10 seconds using IFAW Logger 2000™ (IFAW, 2000) software via a GPS receiver with USB connection. Searching for cetaceans was done with the naked eye, using binoculars only to confirm identification. The distance of any cetacean or group seen was estimated using a range finder (Heinemann, 1981) and this was recorded along with animals' bearing from the ship (where the ship's heading = 0°). The GPS position of each cetacean sighting was digitally marked using Logger 2000™ software. Where species identification could not be confirmed, sightings were recorded as appropriate (i.e. probable, possible, unidentified whale, unidentified dolphin etc.) according to criteria set out by the IWDG for the recording of sightings. Details such as group size and composition, behaviour, animal/group heading were recorded for each sighting.

Aside from sightings periodic records of environmental conditions were inputted every 30 minutes whilst on effort. Other details such as changes in transect direction, changes in survey activity e.g. fishing/CTD cast/plankton net cast were also recorded. Incidental sightings of cetaceans seen outside of dedicated survey effort periods were also entered.

2.5.2 Seabirds

Surveys of seabirds at sea were conducted from R.V. *Celtic Explorer* between 25th March and 7th April 2014. A standardized line transect method with sub-bands to allow correction for species detection bias and 'snapshots' to account for flying birds was used (following the recommendations of Tasker et al. 1984; Komdeur et al. 1992; Camphuysen et al. 2004).

Two observers (a primary observer and a scribe, who also acted as a secondary observer) worked in rotating one hour shifts, surveying between 08:00 and 18:00 hours. Environmental conditions, including wind force and direction, sea state, swell height, visibility and cloud cover, and the ship's speed and heading were noted at regular intervals during surveys. No surveys were conducted in conditions greater than sea state 6, when high swell made working on deck unsafe, or when visibility was reduced to less than 300m.

Seabird surveys were conducted from the platform of the bridge deck. The platform for observation was changed to either the port or starboard side on the basis of suitable viewing conditions at the time (e.g. presence of glare). The platform height was 10.5m above the waterline, providing an uninterrupted view of the survey area. The survey area was defined as a 300m wide band operated on one side (in a 90˚ arc from the bow) and ahead of the ship. This survey band was sub- divided (A = 0-50m from the ship, B = 50-100m, C = 100-200m, D = 200-300m, E = >300m) to subsequently allow correction of species differences in detection probability with distance from the observer. A fixed-interval range finder (Heinemann 1981) was used to periodically check distance estimates. The area was scanned by eye, with binoculars used only to confirm species identification. All birds seen within the survey area were counted, and those recorded on the water noted as 'in transect'. All flying birds within the survey area were also noted, but only those recorded during a 'snapshot' were regarded as 'in transect'. This method avoids overestimating bird numbers in flight (Tasker et al. 1984). The frequency of the snapshot scan was ship-speed dependent, such that they were timed to occur at the moment the ship passed from one survey area (300m long x 300m wide) to the next. Any bird recorded within the survey area that was regarded as being in association with the survey vessel was noted as such (to be excluded from abundance and density calculations). Survey time intervals were set at 1 minute.

Additional bird species observed outside the survey area or during periods of casual observations were also recorded and added to the species list for the duration of the survey. In this report we present our daily total count data for each species across all days along with the daily survey effort.

2.5.3 Passive acoustic monitoring (PAM) survey

An acoustic cetacean survey was conducted using a single array set up containing two high frequency and two low frequency hydrophones towed at 150 metres behind the vessel. Deployment was off the starboard side using a boom to keep the array c.2m from the side of the ship, vertical deployment ranged 1 to10 m below the surface. The signal from the hydrophone array was amplified and digitised by the AMS-DS40 (Acoustic Marine Systems) signal conditioning unit containing a preamplifier and two sound cards: National Instruments DAQ-6255 USB for processing high frequency data (sampling rate up to 500 kHz) and a Tascam 96kHz card, processing low to mid frequency signal. The acoustic data was recorded in raw format and analysed during the monitoring effort using PAMGUARD software (available at www.pamguard.org) on two portable computers, one receiving the low frequency sound and GPS data, the other receiving high frequency sound. The kind assistance of the crew and the fisheries scientists on shifts covering 24h days allowed for maximised deployment time of the hydrophone and nearly continuous recording and storage of the acoustic data, apart from the periods of fishing activity, oceanographic sampling and sharp turns of the vessel. Low frequency sound was recorded and stored continuously from the start of the survey, however due to lack of a sufficiently large capacity storage unit; the high frequency acoustic data was recorded and stored during approximately 60% of the cruise.

Apart from the continuous recording, a monitoring effort was conducted, predominantly during the daylight hours, to maximise the opportunity for simultaneous visual and acoustic sampling. The timing of the active monitoring was dictated first of all by the primary activity of the vessel, blue whiting acoustic survey, and carried out both when on transect and in transit, between 07:00 and 22:00 UTC, for the average of 6h and 22 min per day. This excludes the time when the hydrophone was not deployed: during the oceanographic sampling, trawling, sharp manoeuvres, during the first and last day, when steaming from and to port and mobilising or demobilising, and during one day spent sheltering from inclement weather conditions.

3 Results

3.1 Blue whiting abundance and distribution

A total of 10 directed blue whiting trawls were carried out during the survey (Figure 1, Table 2).

In total 427 echotraces were positively identified as blue whiting over the 21 strata surveyed (Table 9). Blue whiting aggregations were most frequently encountered between 350-550m with a range extending from 250 to 650m.

The second most frequently encountered group of species were the Myctophidae present in 8 of 10 survey hauls (Table 10). High density mesopelagic echotraces were observed in a number of areas during daylight hours. The presence of mesopelagic species in trawl catches is generally regarded as by-catch due to the passage of the trawl through the mesopelagic layer (100-300 m) to the target blue whiting layer (250-650 m).

3.1.2 Blue whiting biomass and abundance

The table below shows the estimated abundance and biomass of each category of blue whiting across the entire survey area. A full breakdown of the survey estimate is presented by distribution, age, length, biomass, abundance and area in Figures 2 & 4 and Tables 3-9.

Blue whiting	Millions	Biomass (t)	% contribution
Total estimate			
Definitely	11,944	1,423,616	100.0
Mixture	0	0	0.0
Probably	0	0	0.0
Total estimate	11,944	1,423,616	100
SSB Estimate			
Definitely	11157	1,375,048	100.0
Probably	0	0	0.0
Mixture	0	0	0.0
SSB estimate	11157	1,375,048	100

3.1.3 Blue whiting distribution

For the purposes of the international survey, spawning areas are broken into target areas ranked according to historic core abundance (Figure 1). Blue whiting distribution represented by NASC is shown in Figure 2.

Four target areas were surveyed with varying degrees of coverage as part of the agreed international effort allocation. Rockall was only partly covered by this survey and as a result it is not considered as a representative estimate outside of the combined international survey effort. Blue whiting distribution in the south Porcupine target area was dominated by a small number of medium to high density echotraces close to the seabed (Table 9, Figure 3c). Within the north Porcupine area two main clusters of echotraces were observed; a small localised area of high density echotraces in the west and a more significant cluster in the northeast. Almost all of the high density echotraces were observed in close proximity to the shelf edge with the exception of one (Figure 3a). The Hebrides, covering the largest geographical area, had patchy areas of high density echotraces of blue whiting and a smaller number of low density echotraces further west in deeper water. The single highest density echotrace was observed in the Hebrides as well as several large expansive schools extending several miles from the shelf edge (Figure 3c).

Overall high density echotraces dominated near shelf regions (c.15nmi) from south to north at depths of between 250-650m (Figure 3b). This year the centre of gravity of the stock was located in the south following a similar pattern to that observed in 2014. The main difference between the two years was that in 2015 the distribution of schools was much more closely confined to the shelf edge than in 2014. The largest single echotrace observed in 2015 was nearly double the acoustic density of that in 2014. However, the actual number observed was much lower (702: 2014 and 427: 2015).

The distribution of biomass within target areas is broken down as follows and detailed in Tables 5 & 6):

South Porcupine Bank contained 4.1% of TSB (58,700 t) and 508.2 million individuals.

North Porcupine Bank contained 28.9% TSB (411,300 t) and 3,744.2 million individuals.

The Hebrides area contained 67% of TSB (953,700 t) and 7,691.5 million individuals.

The Rockall area was covered using only 2 rectangles and contained no blue whiting.

3.1.4 Blue whiting stock structure

During the survey 550 fish were aged with length, weight, sex, maturity and stomach fullness data recorded. A further 1,600 fish were measured and 1,100 length and weights were recorded from individuals. Due to logistical problems it was not possible to use Irish aged fish during the analysis and as a result an ALK (age-length key) made up of data from the International survey was applied. Age using the composite ALK contained individuals from 1 to 13-years (Table 3).

The age structure of survey stock was dominated by 3 strong year classes; the 4 (2010 yr class), 5 (2009 yr class) and 2-year old fish (2012 yr class) respectively. Together these year classes represented 62.1% of the TSB and 70.4% of the TSN.

In terms of biomass the breakdown is as follows: 4-year old fish 33% (469,200t), 5-year old fish 14.6% (207,500 t) and 2-year old fish 14.5% (207,100t). In terms of abundance: 4-year old fish 32.6% (3,892 million individuals), 5-year old fish 12.7% (1,516 million individuals) and 2-year old fish 25.1% (2,996 million individuals).

Maturity analysis (international data) indicates 9% of 1-year old, 66% of 2-year old and 83% of 3-year old fish were mature. Of the mature fish sampled, approximately 46% were found to be spent and a smaller proportion was actively spawning. Over 96% of the surveyed stock was found to be mature with less than 4% immature. Immature fish were found in 12 of the 17 strata where blue whiting were observed with the highest density in the Hebrides area.

3.2 Oceanography

Overall 27 CTD casts were carried out during the survey. Open water stations were conducted to a maximum of 1,000m. Horizontal profiles of temperature and salinity from 10m subsurface to 600m are shown in Figures 8-11.

Surface water conditions (10m) indicate relatively uniform conditions with temperature decreasing from south to north. Salinity follows a similar trend but over a finer scale, with less saline water further north. This pattern is replicated at the 200m, 400 and 600m depth profiles also. Indicating conditions are well mixed. The warmer waters and most saline waters occur across all depth channels around the Porcupine Bank.

Uniform temperatures and salinity regions are the preferred spawning habitat for blue whiting and are often observed when the sub polar gyre is weak allowing the influence of Atlantic water to dominate on the spawning grounds (Monstad 2004). During weak gyre cycles the distribution of spawning aggregations of blue whiting occurs further west into the Rockall Trough and on the Rockall Bank than during strong cycles where spawning is limited predominantly to shelf edge (Hatun *et al* 2009).

3.3 Marine mammal and seabirds

3.3.1 Marine mammals

3.3.1.1 Effort

Visual sighting survey was conducted on 17 days between 23.03.2015 and 10.04.2015 (inclusive) amounting to a total of 87 hours of effort. A total of 42 hrs and 15 mins of observation time were recorded from the crow's nest and the remaining 44 hrs and 45 mins from within the bridge. Confinement of observers to the bridge was due to weather conditions prohibiting access to the crow's nest. Effort averaged 5 hrs and 3 mins per day with a range of 2 hrs to a maximum of 8 hrs. Days with no or little survey effort were due to conditions that were deemed unfavorable for effective visual observation.

Sea state during observation hours ranged from Beaufort sea state 1 to 7. In total 28% of effort was recorded in sea state ≤ 3; sea state 4 accounted for 18%; sea state 5 for 31% of survey time and the remaining 23% of observations were conducted in sea state 6 or greater (Figure 11). Visibility ranged from greater than 20 km to less than 1 km. For the most part visibility was greater than 10 km whilst on survey effort (63%). Visibility was between 6 and 10 km for 18% of the time surveyed and between 1 and 5 km for 12% of the time. Poor visibility (< 1 km) accounted for 6% of the total survey effort. During times of particularly poor visibility due to thick fog the daily survey effort was limited to a few hours during brief periods of clearance (notably on 04 and 05 April). Rain was recorded during six of the days with survey effort but was mainly intermittent and light and its effect on survey conditions would have been reflected in visibility records.

3.3.2.1 Sightings

There was a total of 14 sightings of identified cetacean species and one unidentified dolphin recorded, comprising a minimum of 245 individuals (Figure 12, Table 12). Of these, 11 encounters were recorded during dedicated survey periods and a further four detections (two each of pilot whales and common dolphins) were made off effort and logged as incidental sightings.

<u>Long-finned pilot whale</u> (*Globicephala melas)*

Pilot whales were encountered six times (four sightings 'on effort' and two incidental) over the duration of the survey and a minimum of 35 animals where recorded. On all occasions the animals passed relatively close (within 400 m of the ship) but were swimming fast and didn't noticeably interact with the vessel. Pilot whales were observed in the deeper waters (> 1500 m) of the Rockall trough and west of the Rosemary bank which represents typical habitat for the deep water species (refer to the map in figure 6 above). There were concurrent acoustic detections for three of the encounters and in these cases the animals were detected visually prior to being detected by hydrophones.

<u>Common bottlenose dolphin</u> (*Tursiops truncatus*)

There were two bottlenose dolphin encounters. The colouration of individuals suggested that they were of the species' offshore ecotype. One group was observed on the Porcupine bank relatively close to the shelf edge and the other encounter was adjacent to the north of the Porcupine bank along the shelf slope (Fig. 6). These locations are similar to previous records for the species (Berrow *et al.*, 2010). In both instances the animals appeared to be travelling and passed the ship at a distance of more than 600 m. There were acoustic detections for the second (more northern) of these encounters with the initial detection being acoustic.

<u>Short-beaked common dolphin</u> (*Delphinus delphis*)

Common dolphins accounted for the sightings with largest group sizes and all six sightings (including two incidental sightings that were detected acoustically and then observed visually) were associated with the ship (e.g. bow riding). The largest group had a minimum of 120 individuals and this pod associated with the vessel for more than one hour. With the exception of one sighting southwest of the Rosemary bank all common dolphin sightings were recorded over the relatively shallower depths of the continental shelf (refer to map in figure 6 above). There were simultaneous acoustic and visual detections for all common dolphin encounters except one which occurred off the Cork coast on 23.03.2015 when the hydrophone array was not deployed. On four of these occasions the initial detection was by PAM.

3.3.2 Seabirds

3.3.2.1 Effort

A total of 2,704 minutes (45 hours and 4 minutes) of dedicated seabird surveying was conducted across twelve days between 23rd March and 10th April 2015 with an average of 225 minutes (3 hours and 45 minutes) surveyed per day, ranging from a minimum of 43 minutes to a maximum of 354 minutes. Records of birds observed during casual observation periods from the ships bridge across five days were kept during days when inclement weather or prolonged fishing activity prevented dedicated survey effort from being conducted, details of which are outlined in Table 13. No surveying or casual observations were conducted on 31st March and 1st April while moored in Lough Swilly, Co. Donegal during a period of particularly bad weather.

3.3.2.2 Sightings

An uncorrected, cumulative total of 7,174 individual seabirds of 18 species were recorded (Table 14). A total of 5,446 seabirds were noted as ‘off survey’, outside of dedicated survey time or associating with the vessel and as such will be excluded from future analysis of abundance and density. Thus, the corrected total of seabird recorded during dedicated survey time was 1,728. A synopsis of daily totals for all seabird species recorded is presented in Table 14.

More detail and information can be found in the species accounts, in which taxonomy and nomenclature follows Irish Rare Birds Committee (2012).

3.3.3 PAM survey

Passive acoustic recordings were made during the entire time the hydrophone was in the water. Real time monitoring of the acoustic survey was carried out for a total of 101 hrs and 46 min, spread over 16 days with an average of 6 hrs and 21 min per day.

The acoustic data will be analysed in its entirety in future, the following findings are partial and preliminary results.

A total of 74 acoustic detection events were recorded during real-time monitoring effort, lasting from 1 min to 130 min (Table 15). Ten encounters were recorded both acoustically and visually, out of which four were first detected visually and six were first detected acoustically. Aside from sperm whale (*Physeter macrocephalus)* clicks (identified as “possible” sperm whale), which are characteristic, the identification of the cetaceans based on vocalisations was not attempted, however in eight of the encounters observed visually as well as recorded on PAM, the species were identified with high certainty, and one species classification was classed as “probable”.

Three types of vocalisations were observed: clicks, whistles and buzzes (Figure 13). The majority of acoustic records during the active monitoring effort on PAM occurred near the continental slope or in the deeper waters of the Rockall trough (Figures 14-16).

4 Discussion and Conclusions

4.1 Discussion

Overall, the survey objectives were achieved as planned with some cruise track alteration to allow for the 48 hrs of weather induced downtime. As the survey forms part of a larger synoptic survey effort it is important that all vessels work in close temporal alignment to cover the area with the highest precision. Close communications between vessels allowed for good planning and survey tracks were adjusted as required to maintain optimum geographical coverage in core spawning areas.

Due to unforeseen circumstances it was not possible to use aged samples of blue whiting caught during this year's survey during the analysis. An ALK compiled of international survey data from co-surveyed areas (Norway, Faroes and Netherlands) was used instead and was considered to be more than adequate.

The abundance estimate is considered robust as the stock was well contained within the survey area (international coverage) and good trawl sampling was undertaken in core as well as peripheral abundance areas.

The age composition of the international survey was missing the most dominant year classes from the previous year(s) survey. This was most evident for the 4, 5, and 6 year old fish.

4.2 Conclusions

As this survey is part of a cooperative survey covering the larger spawning range of the stock it is difficult to take the results from the Irish survey as an indicator of the state of the stock over the entire area and this should be considered when reviewing the results.

The distribution of the bulk of the stock within the Hebrides target area is consistent with previous years. The stock was spread along the shelf edge from the northern Porcupine target area north to the Hebrides. Distribution was restricted to a narrow band along the shelf edge and is in contrast to most recent years where schools extended further west into the Rockall Trough.

An annual fishery that takes place prior to the survey and is temporally and spatially different from the survey. This fishery focuses on an area in international waters southwest of the Porcupine in Feb/Mar. Catches this year were reported as higher than average. The age structure of catch samples has yet to be compared to survey data to see if they are comparable.

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Table 1. Survey settings and calibration report for the Simrad ER60 echosounder.

Echo Sounder System Calibration

Vessel : RV Celtic Explorer		Date : 22.03.15	
Echo sounder : EK60 PC		Locality : Dunmnaus Bay	
Type of Sphere : Cu-60.1mm	TS_{Sphere}: -33.50 dB (Corrected for soundvelocity)	Depth(Sea floor)	38 m

Calibration Version 2.1.0.11

Comments:
CE15005.BWAS. Dunmanus Bay

Reference Target:

TS	-33.5 dB	Min. Distance	16.00 m
TS Deviation	5.0 dB	Max. Distance	23.00 m

Transducer: ES38B Serial No. 30227

Frequency	38000 Hz	Beamtype	Split
Gain	25.89 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	6.98 deg	Along. Beam Angle	6.95 deg
Athw. Offset Angle	- 0.05 deg	Along. Offset Angl	-0.06 deg
SaCorrection	-0.80 dB	Depth	8.8 m

Transceiver: GPT 38 kHz 009072033933 1 ES38B

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

Sounder Type:
ER60 Version 2.4.3

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.	9.8 dB/km	Sound Velocity	1490.2 m/s

Beam Model results:

Transducer Gain =	25.96 dB	SaCorrection =	-0.67 dB
Athw. Beam Angle =	6.95 deg	Along. Beam Angle =	6.90 deg
Athw. Offset Angle =	-0.03 deg	Along. Offset Angle=	-0.05 deg

Data deviation from beam model:
RMS = 0.12 dB
Max = 0.35 dB No. = 381 Athw. = -3.1 deg Along = -3.2 deg
Min = -0.54 dB No. = 36 Athw. = -4.3 deg Along = -2.8 deg

Data deviation from polynomial model:
RMS = 0.06 dB
Max = 0.18 dB No. = 35 Athw. = 3.9 deg Along = -3.2 deg
Min = -0.29 dB No. = 36 Athw. = 4.3 deg Along = -2.8 deg

Comments :

Wind Force : 3 **Wind Direction** E
Raw Data File: \\C\EK60_Data\BWAS_2014\RAW ER60 Files\Calibration\BWAS_2015
Calibration File: \\C\EK60_Data\BWAS_2014\RAW ER60 Files\Calibration\BWAS_2015

Calibration : Ciaran O'Donnell

Table 2. Catch composition, time and location of trawl hauls.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target (m)	Bulk Catch (Kg)	Sampled (Kg)	Blue Whiting %	Mackerel %	Meso %	Herring %	Others %
1	25/03/2015	52.413	-14.588	17:11:00	404	0-35	3,500.0	167.7	99.8		0.2		
2	26/03/2015	52.409	-14.712	13:40:00	400	0-45	2,500.0	155.1	99.9		0.1		
3	27/03/2015	54.294	-12.309	14:29:00	2500	470	184.0	184.0	90.6		9.4		
4	28/03/2015	54.805	-10.523	07:59:00	1248	440	4,000.0	130.3	84.8	14.2	1.0		
5	30/03/2015	55.295	-9.974	07:14:00	420	290	3,500.0	130.7	100.0				
6	04/04/2015	56.708	-9.329	14:37:00	1200	600	2,500.0	155.5	99.7		0.3		
7*	04/04/2015	57.707	-11.476	11:41:00	2900	200	1.8	1.8			100.0		
8	05/04/2015	58.211	-9.720	06:53:00	1000	500	4,000.0	173.4	99.7		0.3		
9	05/04/2015	58.708	-8.848	21:35:00	1200	510	1,500.0	149.1	97.5		2.5		
10	08/04/2015	59.211	-7.406	10:29:00	645	580	500.0	172.8	96.2		3.8		

* Dedicated meso trawl

Table 3. Age length key (ALK) used during the analysis of Irish survey data. ALK compiled from international aged survey samples in co-surveyed areas.

Age (yrs) Length (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
12.5	1.0														
13	1.0														
13.5	1.0														
14	1.0														
14.5	1.0														
15	1.0														
15.5	1.0														
16	1.0														
16.5	1.0														
17	1.0														
17.5	1.0														
18	1.0														
18.5	0.9	0.8													
19	1.0														
19.5	1.0														
20	1.0														
20.5	0.8	0.2													
21	1.0														
21.5		1.0													
22		1.0													
22.5		0.9	0.1												
23		0.8	0.2												
23.5		0.8	0.2	0.3											
24		0.9	0.9												
24.5		0.9	0.9	0.2											
25		0.4	0.4	0.2											
25.5		0.5	0.1	0.3	0.5										
26		0.2	0.1	0.7	0.5										
26.5		0.3	0.2	0.6	0.2										
27		0.5	0.2	0.6	0.2										
27.5			0.8	0.5	0.4	0.5									
28			0.1	0.6	0.3	0.4									
28.5			0.7	0.6	0.3										
29			0.7	0.7	0.2	0.4									
29.5				0.6	0.3		0.7								
30				0.4	0.5	0.1									
30.5				0.8	0.2										
31				0.8	0.2										
31.5				0.4		0.3						0.3			
32				0.2	0.2			0.3				0.3			
32.5				0.2	0.1	0.2		0.1	0.2			0.2			
33						0.3	0.2	0.3		0.2					
33.5					0.5			0.3	0.3						
34			0.2		0.3				0.8	0.8	0.2	0.2			
34.5				0.4						0.4	0.2				
35					0.2				0.3	0.3	0.1				
35.5						0.3							0.7		
36							0.4		0.6						
36.5							0.4		0.6						
37						0.5			0.5						
37.5						0.4	0.4		0.2						
38							0.4			0.6					
38.5						1									
39						1									
39.5									1.0						
40									1.0						
40.5									1.0						
41									1.0						
41.5									1.0						
42								0.5			0.5				
42.5										1.0					
43										1.0					
43.5											1.0				
44											1.0				
44.5												1.0			
45												1.0			

Table 4. Blue whiting length at age (years) as abundance (millions) and biomass (000's tonnes).

Length (cm)	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Abund (mils)	Biomass 000's t	Mn wt (g)
12.5	14.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.6	0.1	9.6
13	14.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.6	0.2	10.8
13.5	14.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.6	0.2	12.1
14	25.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25.6	0.4	13.6
14.5	14.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.6	0.2	15.1
15	14.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.6	0.3	16.8
15.5	22.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22.0	0.4	18.6
16	27.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27.7	0.6	20.5
16.5	25.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25.6	0.6	22.5
17	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	0.59	24.7
17.5	29.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29.3	0.8	27.0
18	26.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26.4	0.8	29.4
18.5	25.4	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	27.7	0.9	32.0
19	7.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.3	0.3	34.8
19.5	16.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16.3	0.7	40.8
20	3.1	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-	3.7	0.2	44.0
20.5	14.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.6	0.7	47.4
21	-	105.5	-	-	-	-	-	-	-	-	-	-	-	-	-	105.5	5.4	51.0
21.5	-	298.0	-	-	-	-	-	-	-	-	-	-	-	-	-	298.0	16.3	54.8
22	-	311.8	34.7	-	-	-	-	-	-	-	-	-	-	-	-	346.5	20.4	58.7
22.5	-	573.1	114.6	-	-	-	-	-	-	-	-	-	-	-	-	687.7	43.2	62.9
23	-	362.4	78.2	14.2	-	-	-	-	-	-	-	-	-	-	-	454.8	30.6	67.2
23.5	-	564.7	53.3	-	-	-	-	-	-	-	-	-	-	-	-	617.9	44.3	71.8
24	-	194.7	20.5	5.1	-	-	-	-	-	-	-	-	-	-	-	220.4	16.9	76.5
24.5	-	175.6	204.8	87.8	-	-	-	-	-	-	-	-	-	-	-	468.1	38.1	81.4
25	-	223.2	70.5	164.5	23.5	-	-	-	-	-	-	-	-	-	-	481.6	41.7	86.6
25.5	-	132.6	94.7	549.4	37.9	-	-	-	-	-	-	-	-	-	-	814.7	74.9	92.0
26	-	16.4	115.0	394.4	98.6	-	-	-	-	-	-	-	-	-	-	624.5	60.9	97.6
26.5	-	35.9	125.6	394.7	161.5	-	-	-	-	-	-	-	-	-	-	717.6	74.2	103.4
27	-	-	47.3	330.8	220.5	31.5	-	-	-	-	-	-	-	-	-	630.0	69.0	109.5
27.5	-	-	77.6	336.4	155.3	25.9	-	-	-	-	-	-	-	-	-	595.2	68.9	115.8
28	-	-	23.6	212.8	106.4	-	-	-	-	-	-	-	-	-	-	342.8	41.9	122.3
28.5	-	-	33.8	321.3	101.5	16.9	-	-	-	-	-	-	-	-	-	473.4	61.1	129.1
29	-	-	-	146.0	64.9	-	16.2	-	-	-	-	-	-	-	-	227.1	30.9	136.1
29.5	-	-	-	84.4	96.4	24.1	-	-	-	-	-	-	-	-	-	204.9	29.4	143.4
30	-	-	-	199.3	49.8	-	-	-	-	-	-	-	-	-	-	249.2	37.6	151.0
30.5	-	-	-	295.2	73.8	-	-	-	-	-	-	-	-	-	-	369.0	58.6	158.8
31	-	-	-	142.8	-	95.2	-	-	-	-	-	95.2	-	-	-	333.2	55.6	166.9
31.5	-	-	-	75.5	75.5	-	-	151.0	-	-	-	151.0	-	-	-	453.0	79.4	175.3
32	-	-	-	71.0	35.5	71.0	-	35.5	71.0	-	-	71.0	-	-	-	355.2	65.3	184.0
32.5	-	-	-	-	-	98.7	49.4	98.7	-	49.4	-	-	-	-	-	296.1	57.1	192.9
33	-	-	-	-	87.4	-	-	43.7	43.7	-	-	-	-	-	-	174.9	35.4	202.1
33.5	-	-	38.6	-	77.2	-	-	-	19.3	19.3	38.6	38.6	-	-	-	231.7	49.0	211.7
34	-	-	-	67.0	-	-	-	-	-	67.0	33.5	-	-	-	-	167.6	37.1	221.5
34.5	-	-	-	-	50.7	-	-	-	76.1	76.1	25.4	-	-	-	-	228.2	52.9	231.6
35	-	-	-	-	-	31.3	-	-	-	-	-	-	62.5	-	-	93.8	22.7	242.1
35.5	-	-	-	-	-	-	48.6	-	72.8	-	-	-	-	-	-	121.4	30.7	252.9
36	-	-	-	-	-	-	39.3	-	59.0	-	-	-	-	-	-	98.3	25.9	263.9
36.5	-	-	-	-	-	25.0	-	-	25.0	-	-	-	-	-	-	50.0	13.8	275.3
37	-	-	-	-	-	14.6	14.6	-	7.3	-	-	-	-	-	-	36.6	10.5	287.1
37.5	-	-	-	-	-	-	8.9	-	-	13.3	-	-	-	-	-	22.1	6.6	299.3
38	-	-	-	-	-	17.2	-	-	-	-	-	-	-	-	-	17.2	5.4	311.7
38.5	-	-	-	-	-	12.7	-	-	-	-	-	-	-	-	-	12.7	4.1	324.3
39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
42.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
43.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
44.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SSN (mil)	320.5	2,996.7	1,132.8	3,892.6	1,516.4	464.1	176.9	329.0	374.2	225.0	97.5	355.9	62.5	-	-	11,943.9	-	-
TSB('000s t)	7.6	207.1	105.2	469.2	207.5	88.2	41.2	60.9	86.6	50.1	21.5	63.6	15.1	-	-	-	1,423.6	-
Mn Wt (g)	23.6	69.1	92.9	120.5	136.8	190.1	233.1	185.1	231.3	222.4	220.2	178.7	242.1	-	-	-	-	-
Mn length (cm)	16.4	23.6	25.9	28.2	29.3	32.6	34.9	32.6	34.9	34.5	34.4	32.2	35.5	-	-	-	-	-

Table 5. Total blue whiting biomass at age.

Target area	Strata	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
S por	5112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S por	5114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S por	5214	0	0.2	5.6	4.7	22.4	9.2	3.3	1.6	1.7	1.9	0.7	0.1	1.1	0.6	0	0	53.2
S por	5212	0	0	0.6	0.5	2.3	1	0.3	0.2	0.2	0.2	0.1	0	0.1	0.1	0	0	5.5
N por	5312	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N por	5314	0	0.9	22.6	11.2	45.9	17.6	4	2.2	1.7	3.7	1.3	0.6	2.7	0.7	0	0	115.2
N por	5414	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N por	5412	0	0	10.5	9	50.2	20.5	5.7	1.3	1.9	3.4	1.2	0.8	2.7	0.6	0	0	107.8
N por	5410	0	0	34.1	18.4	73.6	30.9	7.8	2.2	3.8	6.5	3	1.6	5.1	1.2	0	0	188.3
Heb	5512	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heb	5510	0	0.4	2.3	0.6	0.8	0.2	0	0	0	0	0	0	0	0	0	0	4.4
Heb	5508	0	5.9	29.9	7.6	9.9	1.9	0.1	0	0	0	0	0	0	0	0	0	55.3
Heb	5610	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heb	5608	0	0	50.6	29.7	155.8	72.8	32.8	20.5	30.3	37	18.5	8.4	30.8	4.8	0	0	492
Heb	5708	0	0	0.9	0.7	4.4	2.3	1.6	0.6	1	1.6	1.2	0.5	1	0.4	0	0	16.2
Heb	5710	0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0.4
Heb	5810	0	0	0.2	0.1	0.8	0.4	0.3	0.1	0.2	0.3	0.2	0.1	0.2	0.1	0	0	3.1
Heb	5808	0	0	14.1	8.6	49.6	25.9	17.7	6.8	11.1	17.5	12.9	5.2	11.2	3.9	0	0	184.6
Heb	5806	0	0	1.8	0.6	1.6	0.7	0.3	0.1	0.2	0.3	0.3	0.1	0.2	0	0	0	6.2
Heb	5812	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Heb	5910	0	0	24.8	9.8	40.4	19.5	12	4.5	7.7	11.8	9.4	3.7	7.4	2.3	0	0	153.3
Heb	5908	0	0	1.8	0.6	1.7	0.7	0.4	0.1	0.2	0.3	0.3	0.1	0.2	0	0	0	6.5
Heb	5906	0	0	7.4	3.2	9.7	3.7	1.7	0.9	0.9	1.8	0.9	0.3	0.7	0.4	0	0	31.6
Rock	5514	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock	5814	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		0	7.6	207.1	105.2	469.2	207.5	88.2	41.2	60.9	86.6	50	21.5	63.6	15.1	0	0	1423.6
%		0	0.5	14.5	7.4	33	14.6	6.2	2.9	4.3	6.1	3.5	1.5	4.5	1.1	0	0	100

Table 6. Total blue whiting abundance at age.

Target area	Strata	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
S por	5112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S por	5114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S por	5214	0	7.3	77.8	50.0	196.0	75.4	17.8	7.1	9.1	7.9	3.4	0.4	6.2	2.5	0	0	460.7
S por	5212	0	0.8	8.0	5.2	20.3	7.8	1.8	0.7	0.9	0.8	0.4	0.0	0.6	0.3	0	0	47.6
N por	5312	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N por	5314	0	22.4	335.2	122.4	404.6	147.2	24.5	9.2	9.2	15.9	5.9	2.6	15.4	3.0	0	0	1117.4
N por	5414	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N por	5412	0	0	143.7	88.9	422.0	161.8	31.9	6.3	10.3	14.3	5.4	3.6	15.1	2.7	0	0	905.9
N por	5410	0	0	490.4	195.8	641.6	237.5	44.1	9.5	20.5	28.3	12.5	7.5	28.1	5.1	0	0	1720.9
Heb	5512	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heb	5510	0	20.2	34.4	7.7	8.5	1.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	72.7
Heb	5508	0	269.9	449.5	99.5	105.0	18.4	1.1	0	0	0	0	0	0	0	0	0	943.3
Heb	5610	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heb	5608	0	0	729.3	303.5	1250.9	508.4	183.0	89.0	163.9	160.4	86.6	38.4	172.4	19.7	0	0	3705.4
Heb	5708	0	0	11.8	6.8	32.1	15.2	7.6	2.6	5.5	7.0	5.1	2.2	5.8	1.5	0	0	103.2
Heb	5710	0	0	0.3	0.2	0.8	0.4	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.0	0	0	2.5
Heb	5810	0	0	2.2	1.3	6.1	2.9	1.5	0.5	1.0	1.3	1.0	0.4	1.1	0.3	0	0	19.7
Heb	5808	0	0	196.6	89.3	370.1	170.0	82.6	28.4	59.8	76.1	56.8	23.6	63.1	16.3	0	0	1232.6
Heb	5806	0	0	25.9	6.7	13.7	4.8	1.5	0.5	1.2	1.4	1.4	0.5	1.1	0.2	0	0	58.9
Heb	5812	0	0	0.1	0.1	0.3	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0	0	0.9
Heb	5910	0	0	360.1	111.7	319.9	131.5	55.8	18.8	41.4	51.4	41.4	16.5	41.6	9.4	0	0	1199.5
Heb	5908	0	0	26.8	7.0	14.5	5.0	1.6	0.5	1.3	1.5	1.4	0.5	1.1	0.2	0	0	61.3
Heb	5906	0	0	104.7	36.9	86.3	28.4	8.9	3.8	4.8	7.6	3.8	1.2	4.1	1.5	0	0	291.6
Rock	5514	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock	5814	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		0.0	320.5	2996.7	1132.8	3892.6	1516.4	464.1	176.9	329.0	374.2	225.0	97.5	355.9	62.5	0	0	11943.9
%		0.0	2.7	25.1	9.5	32.6	12.7	3.9	1.5	2.8	3.1	1.9	0.8	3.0	0.5	0	0	100.0
CV		0.0	124.7	24.2	17.4	16.5	18.3	25.5	22.5	25.1	28.3	34.0	33.2	25.0	37.7	0	0	18.5

Table 7. Total blue whiting biomass at maturity.

Target area	Strata	Imm	Mature	Spent	Total
S por	5112	0	0	0	0
S por	5114	0	0	0	0
S por	5214	1.3	25.7	26.2	53.2
S por	5212	0.1	2.7	2.7	5.5
N por	5312	0	0	0	0
N por	5314	4.5	57.1	53.6	115.2
N por	5414	0	0	0	0
N por	5412	2.4	47.0	58.4	107.8
N por	5410	7.0	92.4	88.9	188.3
Heb	5512	0	0	0	0
Heb	5510	0.7	2.7	1.0	4.4
Heb	5508	9.1	34.6	11.6	55.3
Heb	5610	0	0	0	0
Heb	5608	12.1	247.9	231.9	492.0
Heb	5708	0.2	8.2	7.7	16.2
Heb	5710	0	0.2	0.2	0.4
Heb	5810	0	1.6	1.5	3.1
Heb	5808	3.5	95.2	86.0	184.6
Heb	5806	0.3	3.6	2.3	6.2
Heb	5812	0	0.1	0.1	0.1
Heb	5910	5	82.7	65.6	153.3
Heb	5908	0	3.7	2.4	6.5
Heb	5906	1.7	16.7	13.2	31.6
Rock	5514	0	0	0	0
Rock	5814	0	0	0	0
Total		48.6	721.9	653.1	1423.6
%		3.4	50.7	45.9	100

Table 8. Total blue whiting abundance at maturity.

Target area	Strata	Imm	Mature	Spent	Total
S por	5112	0	0	0	0
S por	5114	0	0	0	0
S por	5214	18.2	224.1	218.4	460.7
S por	5212	1.9	23.2	22.6	47.6
N por	5312	0	0	0	0
N por	5314	65.1	600.8	451.5	1117.4
N por	5414	0.0	0.0	0.0	0.0
N por	5412	30.7	408.8	466.4	905.9
N por	5410	89.0	900.2	731.8	1720.9
Heb	5512	0	0	0	0
Heb	5510	19.7	42.9	10.1	72.7
Heb	5508	261.1	556.9	125.3	943.3
Heb	5610	0	0	0	0
Heb	5608	155.0	1930.0	1620.5	3705.4
Heb	5708	3.2	52.7	47.3	103.2
Heb	5710	0.1	1.3	1.2	2.5
Heb	5810	0.6	10.1	9.0	19.7
Heb	5808	45.3	649.7	537.5	1232.6
Heb	5806	4.4	36.9	17.6	58.9
Heb	5812	0.0	0.5	0.4	0.9
Heb	5910	67	692.1	440.8	1199.5
Heb	5908	5	38.2	18.5	61.3
Heb	5906	21.5	162.8	107.2	291.6
Rock	5514	0	0	0	0
Rock	5814	0	0	0	0
Total		786.8	6331.1	4826.0	11943.9
%		6.6	53.0	40.4	100

Table 9. Blue whiting biomass and abundance by strata.

Target area	Strata	No. transects	No. schools	Def schools	Mix schools	Prob schools	% zeros	Def Biomass	Mix Biomass	Prob Biomass	Biomass ('000t)	SSB ('000t)	Abundance millions
S por	5112	1	0	0	0	0	100	0.0	0	0	0.0	0.0	0.0
S por	5114	1	0	0	0	0	100	0.0	0	0	0.0	0.0	0.0
S por	5214	1	33	33	0	0	0	53.2	0	0	53.2	51.8	460.7
S por	5212	1	5	5	0	0	0	5.5	0	0	5.5	5.4	47.6
N por	5312	1	0	0	0	0	100	0.0	0	0	0.0	0.0	0.0
N por	5314	1	14	14	0	0	0	115.2	0	0	115.2	110.7	1,117.4
N por	5414	1	0	0	0	0	100	0.0	0	0	0.0	0.0	0.0
N por	5412	2	72	72	0	0	0	107.8	0	0	107.8	105.4	905.9
N por	5410	2	75	75	0	0	0	188.3	0	0	188.3	181.3	1,720.9
Heb	5512	1	0	0	0	0	100	0.0	0	0	0.0	0.0	0.0
Heb	5510	3	21	21	0	0	33	4.4	0	0	4.4	3.7	72.7
Heb	5508	2	19	19	0	0	0	55.3	0	0	55.3	46.2	943.3
Heb	5610	2	0	0	0	0	100	0.0	0	0	0.0	0.0	0.0
Heb	5608	1	48	48	0	0	0	492.0	0	0	492.0	479.9	3,705.4
Heb	5708	1	10	10	0	0	0	16.2	0	0	16.2	15.9	103.2
Heb	5710	1	2	2	0	0	0	0.4	0	0	0.4	0.4	2.5
Heb	5810	2	9	9	0	0	50	3.1	0	0	3.1	3.0	19.7
Heb	5808	2	55	55	0	0	0	184.6	0	0	184.6	181.2	1,232.6
Heb	5806	1	5	5	0	0	0	6.2	0	0	6.2	5.9	58.9
Heb	5812	2	1	1	0	0	50	0.1	0	0	0.1	0.1	0.9
Heb	5910	1	21	21	0	0	0	153.3	0	0	153.3	148.2	1,199.5
Heb	5908	1	9	9	0	0	0	6.5	0	0	6.5	6.2	61.3
Heb	5906	1	28	28	0	0	0	31.6	0	0	31.6	29.9	291.6
Rock	5514	1	0	0	0	0	0	0.0	0	0		0.0	0.0
Rock	5814	2	0	0	0	0	0	0.0	0	0	0.0	0.0	0.0
Total		35	427	427	0	0	31	1,423.7	0	0.0	1,423.7	1,375.2	11,943.9

Table 10. Species occurrence from trawl stations.

Category	Common Name	Scientific Name	Occurrence
Pelagic	Blue Whiting	*Micromesistius poutassou*	9
	Mackerel	*Scomber scombrus*	2
	Horse mackerel	*Trachurus trachurus*	0
	Hake	*Merluccius merluccius*	0
Mesopelagics		Arctozenus rissoi	3
	Greater Argentine	*Argentina silus*	3
	Hatchet Fish (small)	*Argyropelecus hemigymnus*	2
	Myctophidae(combined)		3
	Hatchet Fish (large)	*Argyropelecus olfersi*	3
	None	*Astronethus gemmifer*	1
	Myctophidae	*Benthosema glaciale*	0
	Alfonsino	*Beryx decadactylus*	0
	Ray's bream	*Brama brama*	1
	Blackfish	*Centrophagus niger*	0
	Sloanes Viper fish	*Chauliodus sloani*	1
	Myctophidae	*Diaphus raffinesqui*	0
	Myctophidae	*Diaphus metapoclampus*	0
	None	*Diretmus argentus*	3
	None	*Echiostoma barbatum*	0
	Myctophidae	*Electrona rissoi*	0
	Pipefish	*Entelurus aequoreus*	0
	Balbo sabretooth	*Evermanella balbo*	0
	None	*Gonastoma elongatum*	0
	None	*Howella sherborni*	0
	None	*Lampadena speculigera*	1
	Myctophidae	*Lampanyctus crocodilus*	2
	Myctophidae	*Lobianchia gemallari*	0
	Searsids	*Maulisia*	0
	Pearlside	*Maurolicus muelleri*	1
	None	*Melanostomias tentaculatus*	
	Myctophidae	*Myctophum punctatum*	0
	Greenland Argentine	*Nansenia groenlandica*	1
	Forgotten argentine	*Nansenia oblita*	0
	Slender snipe-eel	*Nemichthys scolopaceous*	0
	Multipore Searside	*Normichthys operosus*	1
	None	*Notolepis rissoi*	1
	Myctophidae	*Notoscopelus krokeyeri*	7
	None	*Opisthoproctus soleatus*	0
	Shrimps	*Pandalidae*	2
	Silver Pomfret	*Pterycombus brama*	0
	Schnakenbeck's searside	*Sagamichthys schnakenbecki*	0
	None	*Scopelosaurus lepidus*	0
	None	*Searsia koefoedi*	0
	Bean's saw toothed eel	*Serrivomer beani*	0
	None	*Sternoptyx diaphana*	0
	Scaly dragonfish	*Stomias boa*	1
	Myctophidae	*Symbolophoros veranyi*	0
	Greater Pipefish	*Syngnathus acus*	0
	Dealfish	*Trachipterus arcticus*	0
	Bluntsnout smooth-head	*Xenodermichthys copei*	0
	None	*Pseudoscopelus altipinnis*	0
Demersal	Grey Gurnard	*Eutrigla gurnardus*	0
	Silvery Pout	*Gadiculus argentus*	0
	Norway Pout		0
	saithe	*Pollachius Virens*	0
Squid	Lesser flying squid	*Todaropsis elbanae*	2
	Northern flying squid	*Todarodes sagittatus*	1
	Short finned squid	*Omnastrephidae*	2
	Unknown squid		0
Other	Jellyfish		1
	Octopus		0
		Total Number of Trawls	**10**
		Total number of Species:	**24**

Table 11. Irish blue whiting survey time series.

Year	2004	2005	2006	2007	2008	2009	2010	2011	2011	2012	2013	2014	2015
Target	2a	1	2b	1	1	1	1	Survey 1	Survey 2	1	1	1	1
areas	2b, 2c	2a, 2b		2a, 2b	2a, 2b	2b	2b	1, 2b	1, 2b	2b	2a, 2c	2a-b, 3a	2a-b, 3a
Age													
1	3.0	37.4	4.4	2.4	13.9	2.2	2.5	21.2	1.0	19.8	53.7	20.8	7.6
2	108.3	64.0	43.2	31.0	12.5	66.7	1.5	28.9	3.7	4.2	113.2	36.2	207.1
3	346.4	500.0	242.5	585.0	128.7	49.9	3.3	35.8	12.6	282.3	346.6	242.4	105.2
4	524.0	911.1	636.7	1681.0	1148.0	236.3	8.6	41.8	19.4	124.3	298.5	462.4	469.2
5	211.5	1010.0	342.6	1424.0	1445.7	1126.8	15.0	15.0	15.5	79.9	472.6	326.1	207.5
6	154.5	311.0	144.7	639.2	762.9	1444.3	81.7	107.3	23.3	155.3	243.4	130.1	88.2
7	72.8	111.0	50.4	219.3	200.0	563.6	143.3	255.3	26.8	86.7	39.4	22.3	41.2
8	34.7	69.9	18.0	126.2	33.1	117.6	104.2	489.5	85.6	212.3	103.8	41.3	60.9
9	4.1	20.5	0.0	14.6	0.0	31.4	19.2	319.2	41.2	514.9	122.8	83.8	86.6
10+	15.6	7.9	0.0	5.4	0.0	12.9	5.6	80.7	5.6	745.9	916.9	209.6	150.3
TSB ("000 t)	1,474.9	3,042.8	1,482.4	4,727.6	3,744.7	3,651.7	385.0	1,394.7	234.6	2,225.5	2,710.9	1,574.8	1,423.6
TSN (millions)	16,029.3	34,268.0	16,344.0	48,746.1	34,179.6	28,512.2	2,365.3	9,057.1	1,590.5	15,530.0	21,577.0	13,666.0	11,944.0
SSB ("000 t)	1,471.9	3,001.0	1,478.1	4,725.2	3,726.4	3,647.9	382.6	1,373.5	233.6	2,203.4	2,464.3	1,509.8	1,375.0

*Note: 2012 onwards survey estimate calculated using the new TS-length relationship.
Target area 1: Hebrides; Target area 2a: north Porcupine Bank; Target area 2b: Rockall; Target area 2c Faroe/Shetland. 3a south Porcupine Bank.

Table 12. Marine mammal sightings, counts and group size ranges for cetacean species recorded during the visual survey.

Species	No. of sightings (incidental)	No. of individuals	No. of calves/juveniles	Group size range
Long-finned pilot whale	6	>35	2/4	2-17
Common bottlenose dolphin	2	14	-/2	6-8
Short-beaked common dolphin	6	≥215	4/2	1-120
Unidentified Dolphin	1	1	-	-
Totals	**15**	**>265**	**6/8**	-

Table 13. Seabird survey detail of daily effort, species richness and approximate location.

Date	Start	End	Effort (mins)	Species	Platform	Area
23/03/2015	CASUAL OBSERVATIONS			9	Crow's Nest	Inshore West Cork
24/03/2015	08:15	17:48	345	8	Bridge/Bridge Deck	Porcupine Seabight/Bank
25/03/2015	08:10	16:00	248	8	Bridge/Bridge Deck	Porcupine Bank
26/03/2015	08:10	13:35	227	7	Bridge	Porcupine Bank
27/03/2015	09:00	14:30	270	8	Bridge Deck	Rockall Trough
28/03/2015	CASUAL OBSERVATIONS			6	Bridge	Rockall Trough
29/03/2015	09:00	17:31	240	4	Bridge/Bridge Deck	Rockall Trough
30/03/2015	14:30	15:30	60	10	Bridge/Bridge Deck	Inshore North Donegal
31/03/2015	NO SURVEY			n/a	n/a	n/a
01/04/2015	NO SURVEY			n/a	n/a	n/a
02/04/2015	09:20	12:00	160	6	Bridge	Rockall Trough
03/04/2015	CASUAL OBSERVATIONS			6	Bridge	Rockall Trough
04/04/2015	08:15	17:15	180	4	Bridge Deck	Rockall Trough
05/04/2015	CASUAL OBSERVATIONS			8	Bridge	Rockall Trough
06/04/2015	08:40	17:40	354	6	Bridge Deck	Rockall Trough
07/04/2015	08:20	18:00	310	6	Bridge Deck	Rockall Trough
08/04/2015	CASUAL OBSERVATIONS			10	Bridge	Rockall Trough
09/04/2015	09:30	18:00	267	12	Bridge/Bridge Deck	The Minch/Offshore Donegal
10/04/2015	08:00	08:43	43	9	Bridge	Inshore West Mayo/Galway
	Total		2,704	18		

Table 14. Daily totals for all seabird species recorded between 23rd March and 10th April 2015. Species codes: ND = great northern diver; F. = fulmar; Blue F. = blue fulmar; MX = Manx shearwater; TL = Leach's Storm-petrel; GX = gannet; NX = great skua; AC = Arctic skua; BH = black-headed gull; LU = little gull; KI = kittiwake; LB = lesser black-backed gull; HG = Herring gull; GB = great black-backed gull; TE = Sandwich tern; GU = guillemot; RA = razorbill; RAGU = unidentified razorbill/guillemot; PU = puffin; LK = little auk. Figures in *italics* represent totals of birds recorded as 'off survey', i.e. in association with the survey vessel or outside of dedicated survey time, thus separate to 'on survey' totals (non-italics) which are to be used for abundance and density estimates.

23rd Mar	24th Mar	25th Mar	26th Mar	27th Mar	28th Mar	29th Mar	30th Mar	2nd Apr	3rd Apr	4th Apr	5th Apr	6th Apr	7th Apr	8th Apr	9th Apr	10th Apr	Total
																	0
1													*1*				*2*
	1	14	7	46		13	30	21		5		3	1		530	36	707
	75	*10*	*30*	*55*	*2000*	*55*	*1000*	*44*	*150*	*3*	*200*	*3*	*1*	*300*		*6*	*3932*
																	0
	2				*4*		*1*		*1*		*3*			*2*			*13*
	4	1		1								4			5	2	17
83				*2*			*1*							*6*	*6*	*1*	*99*
		1															1
																	0
	2		14	7			31	4		2					253	53	366
x	*2*	*1*	*1*		*300*		*200*	*2*	*5*		*50*	*1*	*2*	*100*	*4*	*25*	*693*
	24	4	4	5		9		2		1		4	2		3		58
	9	*5*	*2*	*4*	*4*	*5*	*4*		*2*	*1*		*2*	*5*	*3*	*5*	*2*	*53*
															1		1
																	0
																	0
														2			*2*
																	0
			1														*1*
	33	31	223	31		41	4	13		3		5	12		89	3	488
x	*41*	*10*	*40*	*10*	*50*	*15*	*10*	*2*	*20*	*1*	*10*	*9*	*14*	*20*	*31*		*283*
	1			1				3									5
x	*1*	*1*		*18*	*30*		*50*	*1*	*10*		*10*	*25*	*25*	*30*		*25*	*226*
																	0
x															*1*		*1*
							4										4
x				*1*	*7*		*5*		*2*		*4*			*4*		*10*	*33*
															1		1
																	0
							6								2	1	9
x							*1*				*48*			*31*	*2*		*82*
							1								4	6	11
x							*13*								*2*		*15*
	1	6	1	1		1	1	1							44	3	59
		1		*1*			*2*	*1*			*2*			*1*	*2*		*10*
	1																1
											1						*1*
0	67	57	249	92	0	64	77	44	0	11	0	16	15	0	932	104	1728
84	*130*	*28*	*74*	*91*	*2395*	*75*	*1287*	*50*	*190*	*5*	*328*	*40*	*48*	*499*	*53*	*69*	*5446*

Table 15. Summary of acoustic detections (PAM) recorded during active monitoring.

Species	No. of detection events	Only acoustic	Both visual and acoustic
(Possible) Sperm whale	7	7	0
Pilot whale (incl. 1 “probable” id)	3	0	3
Bottlenose dolphin	1	0	1
Short-beaked common dolphin	5	0	5
Unidentified odontocete	58	57	1
Totals	**74**	**64**	10

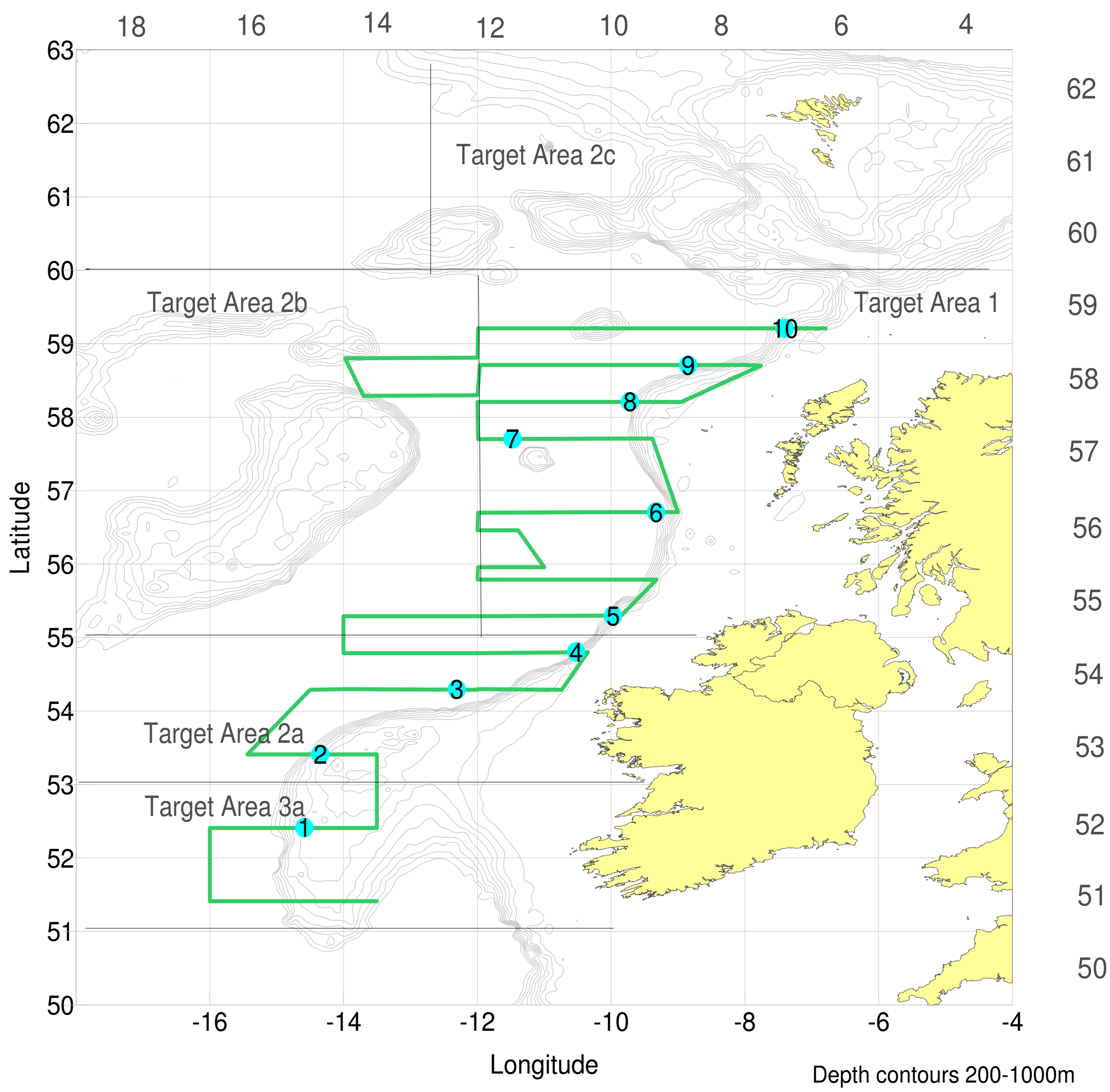


Figure 1. Cruise track (green) with trawl station positions.

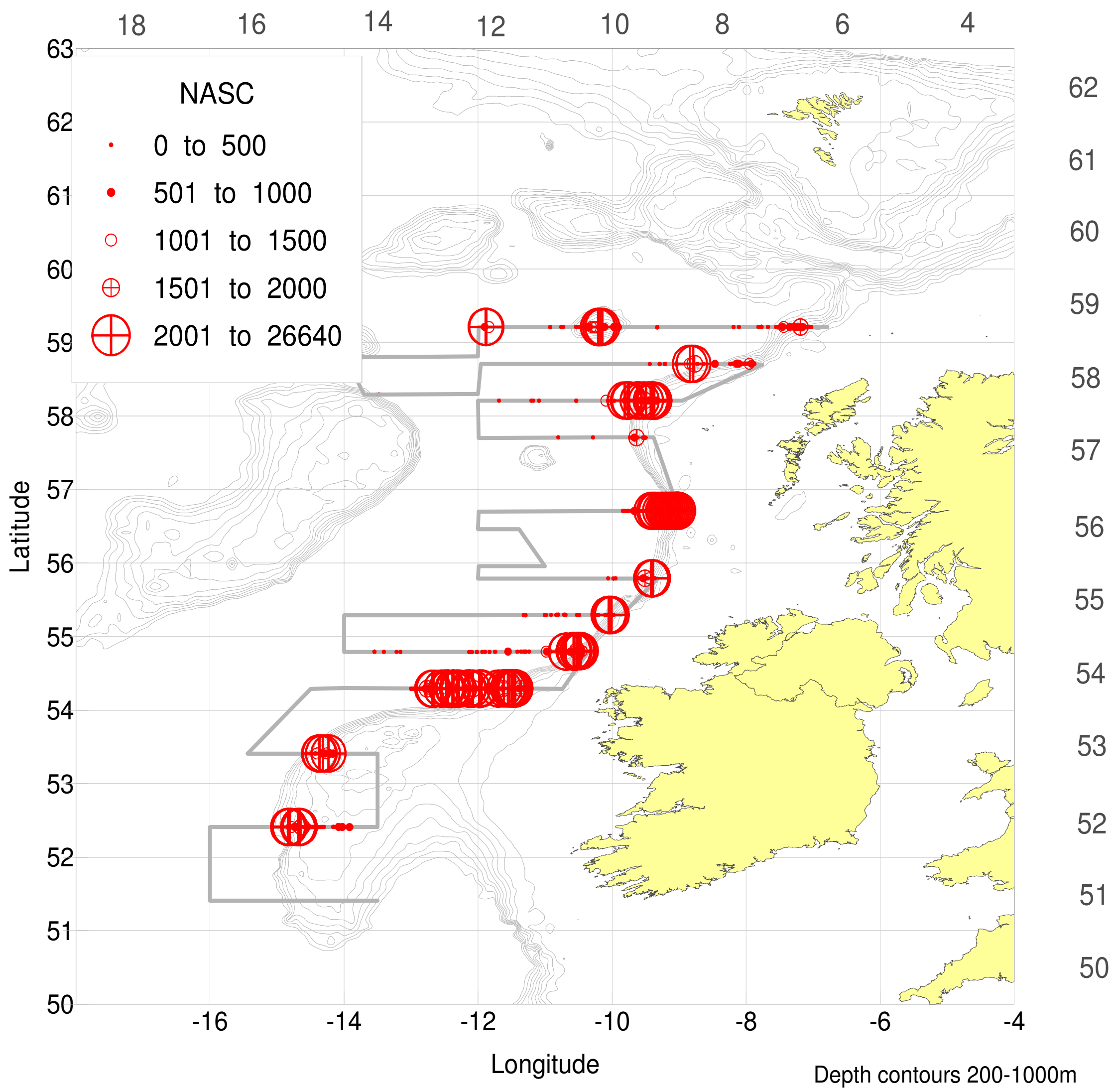
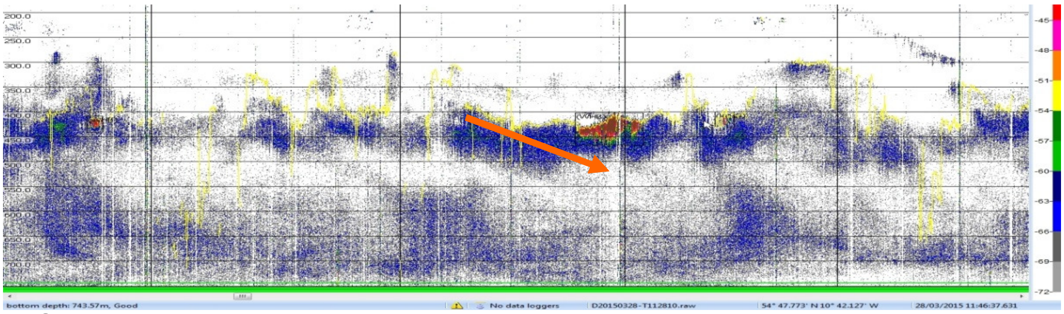
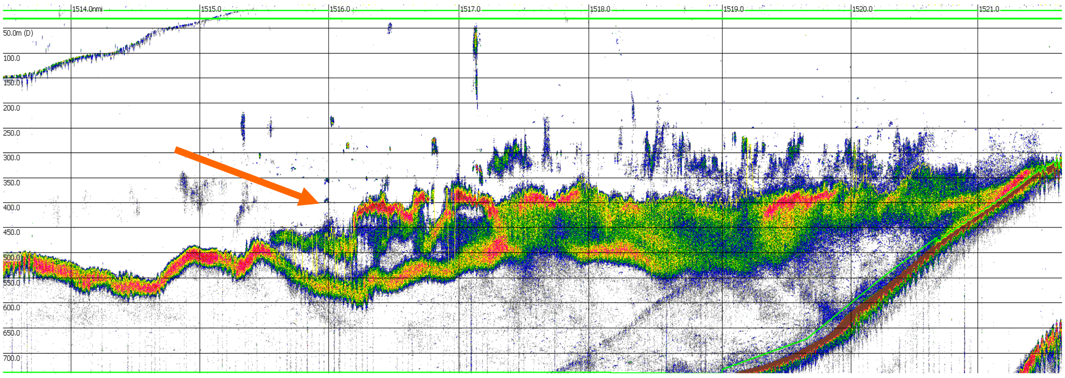


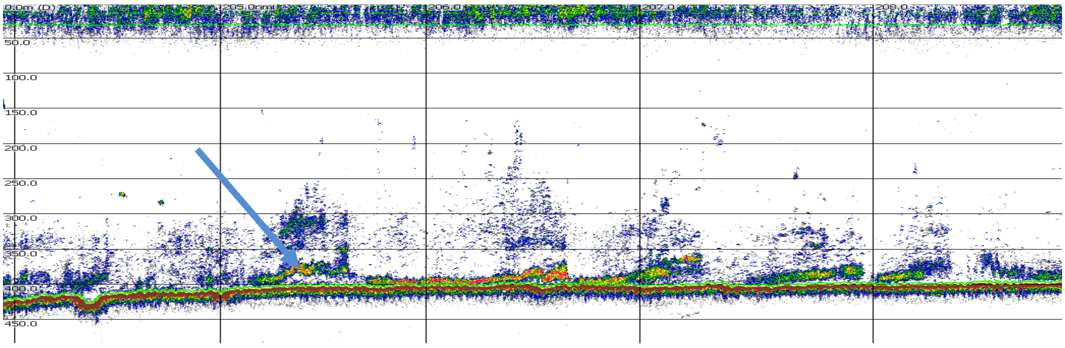
Figure 2. Blue whiting distribution plot of weighted NASC values (red circles).



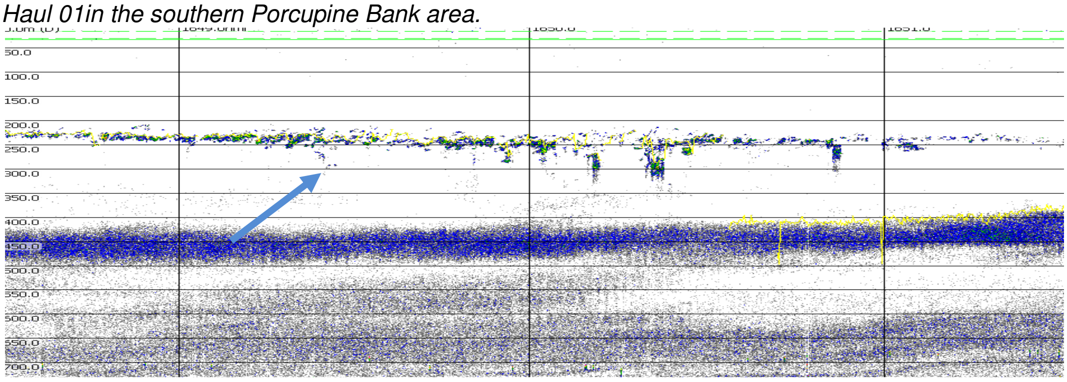
b). Single highest density blue whiting echotrace (orange arrow. s_A = 51,431 $m^2/mile^2$) recorded during the survey in open water to the north of the Porcupine sub area.



c). Large expansive high density blue whiting echotrace (orange arrow) recorded in the Hebrides sub area.



c). *High density echotrace containing blue whiting close to the seabed (blue arrow) sampled during Haul 01in the southern Porcupine Bank area.*



d). *Medium density meso pelagic echotrace (blue arrow) northwest of the Anton Dhorn seamount (Haul 07).*

Figures 3 a-d. Echotraces recorded on an EK60 echosounder (38 kHz) with images captured from Echoview. Note: Vertical bands on echogram represent 1nmi (nautical mile) intervals. Depth scale is shown in 50m intervals.

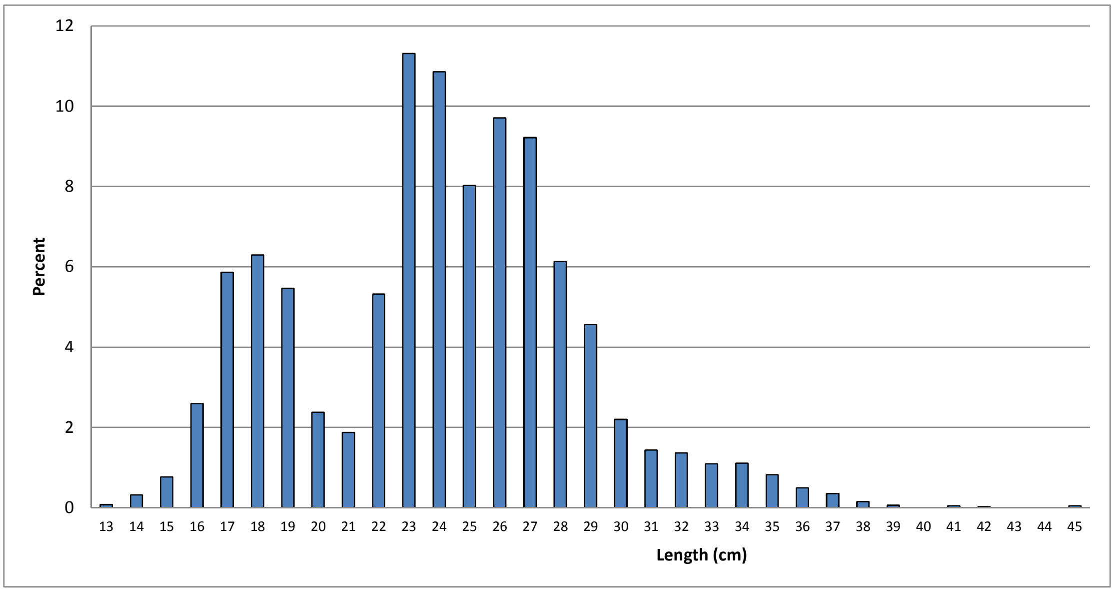


Figure 4. Length composition of combined blue whiting trawl samples.

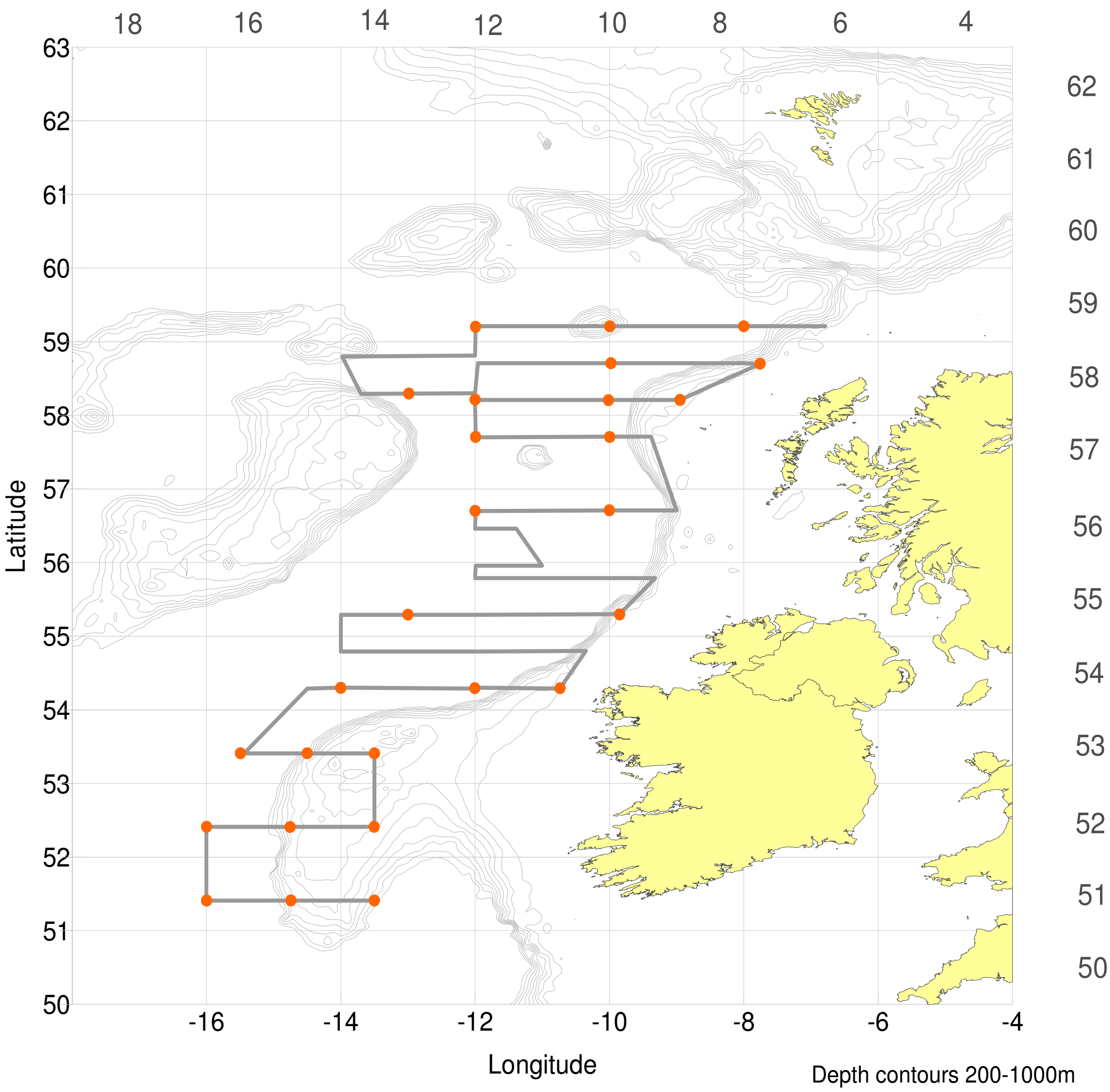


Figure 5. Position of hydrographic stations (orange points). Note: Open water stations were capped at a maximum depth of 1000m

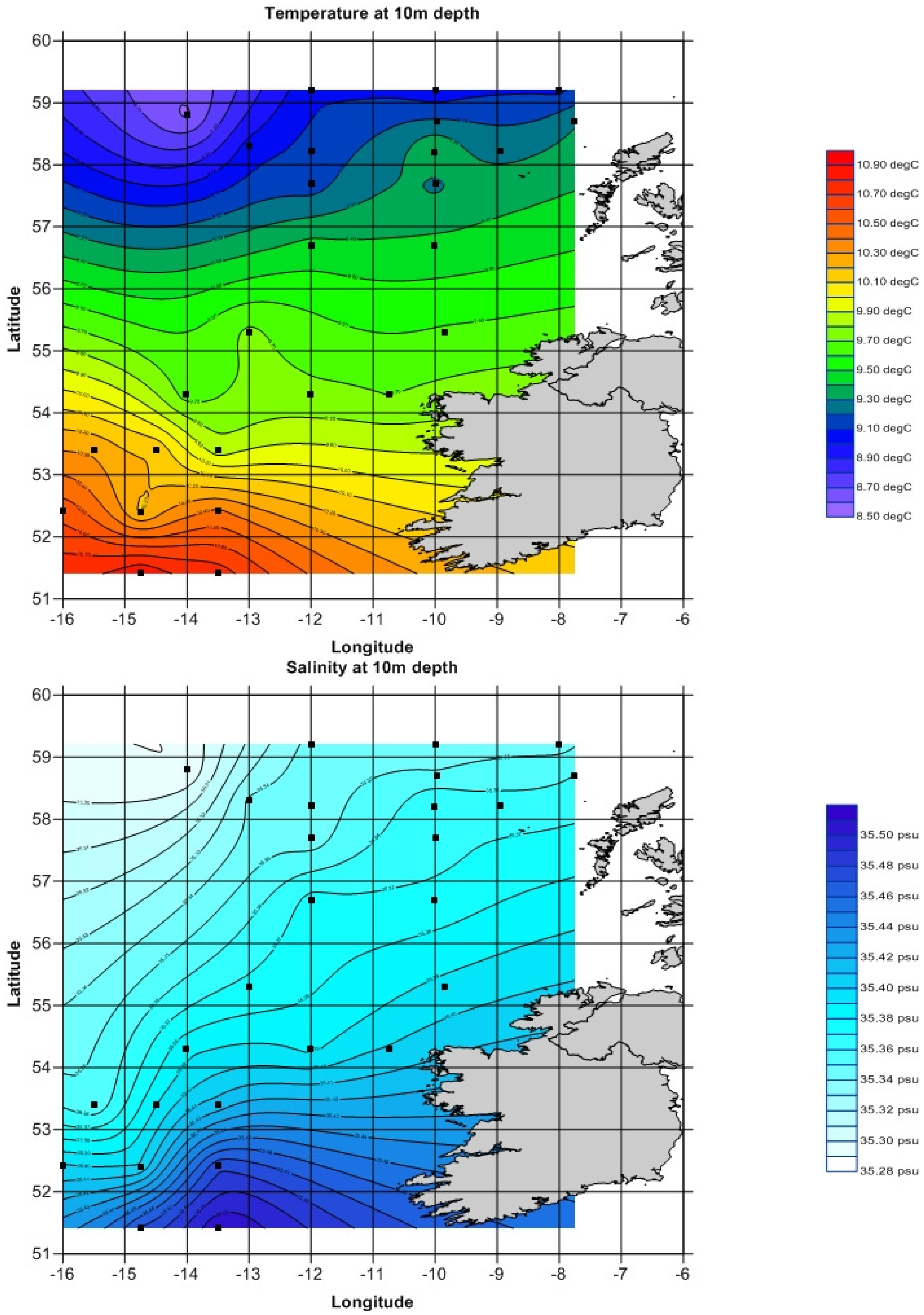


Figure 6. Horizontal temperature (top) and salinity (bottom) at 10m as compiled from Irish CTD stations (black circles).

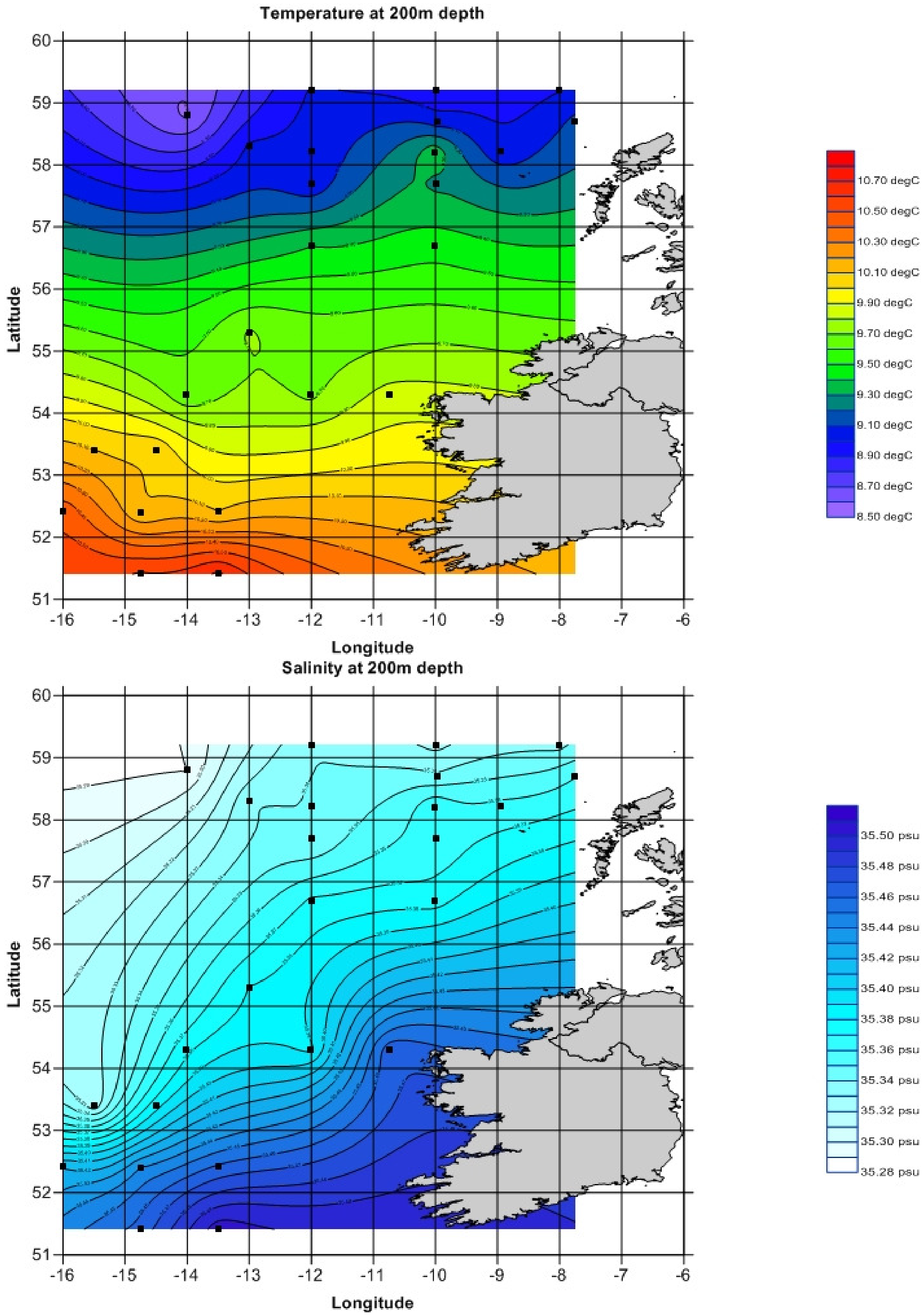


Figure 7. Horizontal temperature (top) and salinity (bottom) at 200m as compiled from Irish CTD stations (black circles).

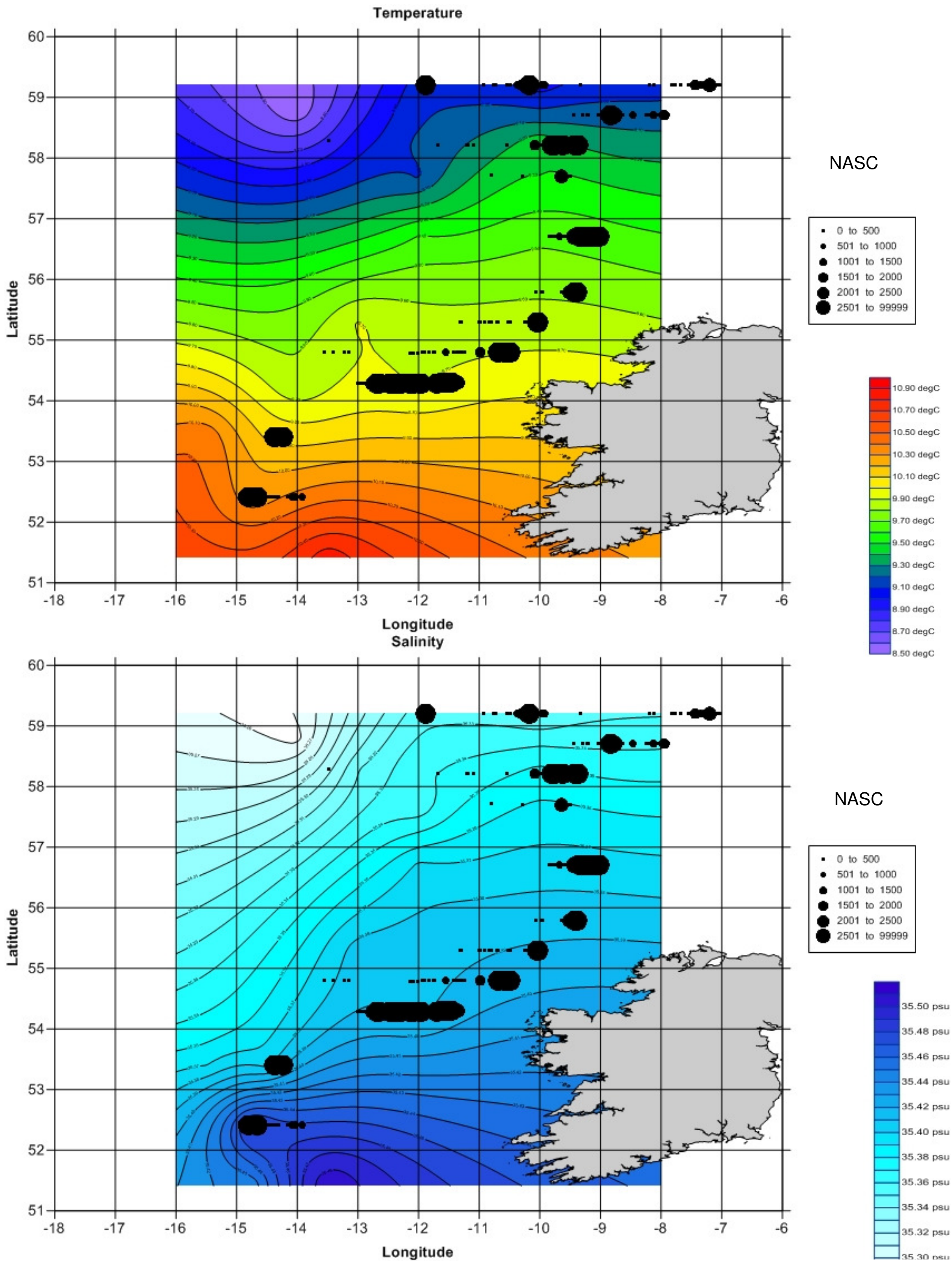


Figure 8. Habitat plot of horizontal temperature (top) and salinity (bottom) at 400m overlaid proportional NASC values from acoustic observations (black circles).

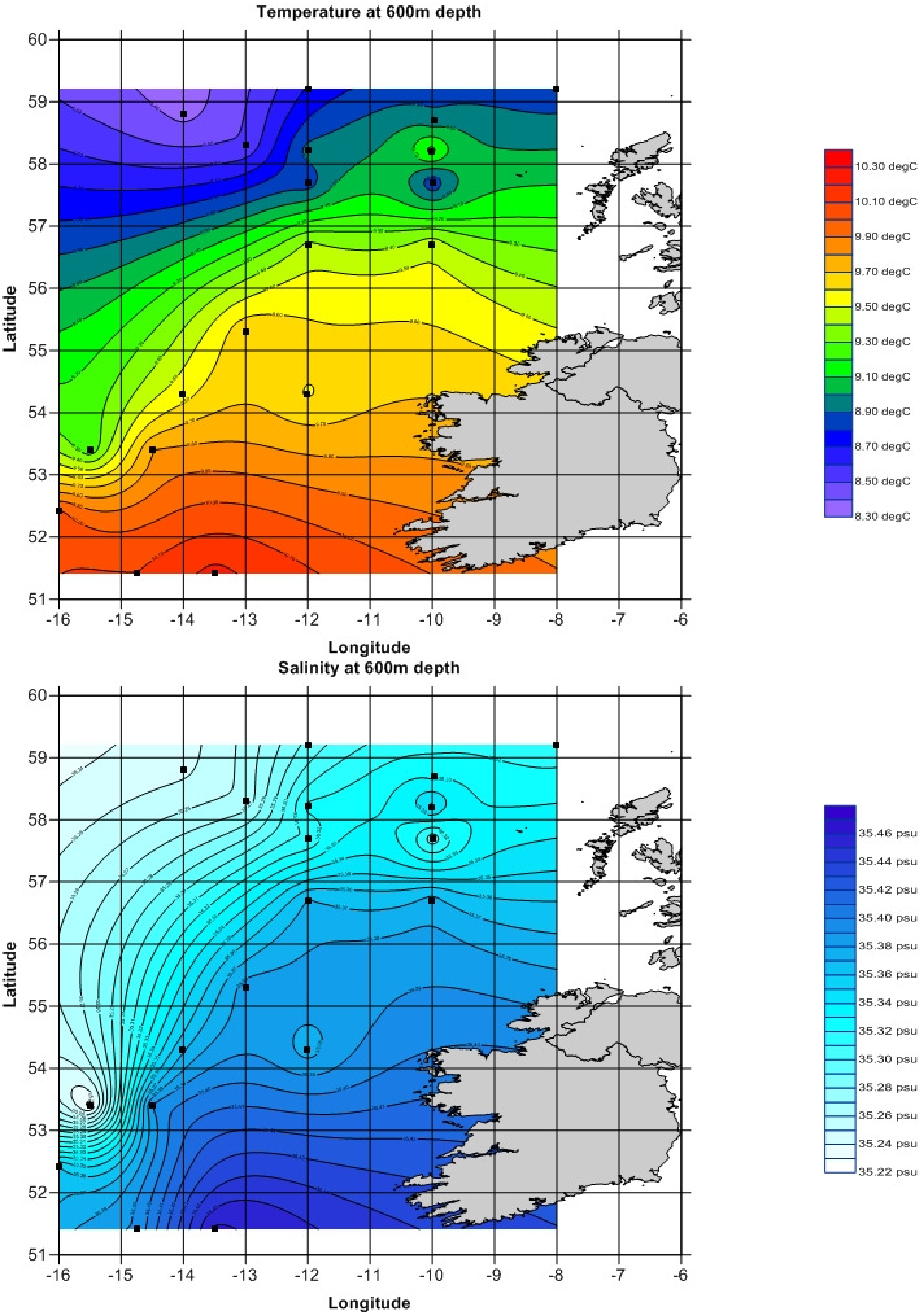
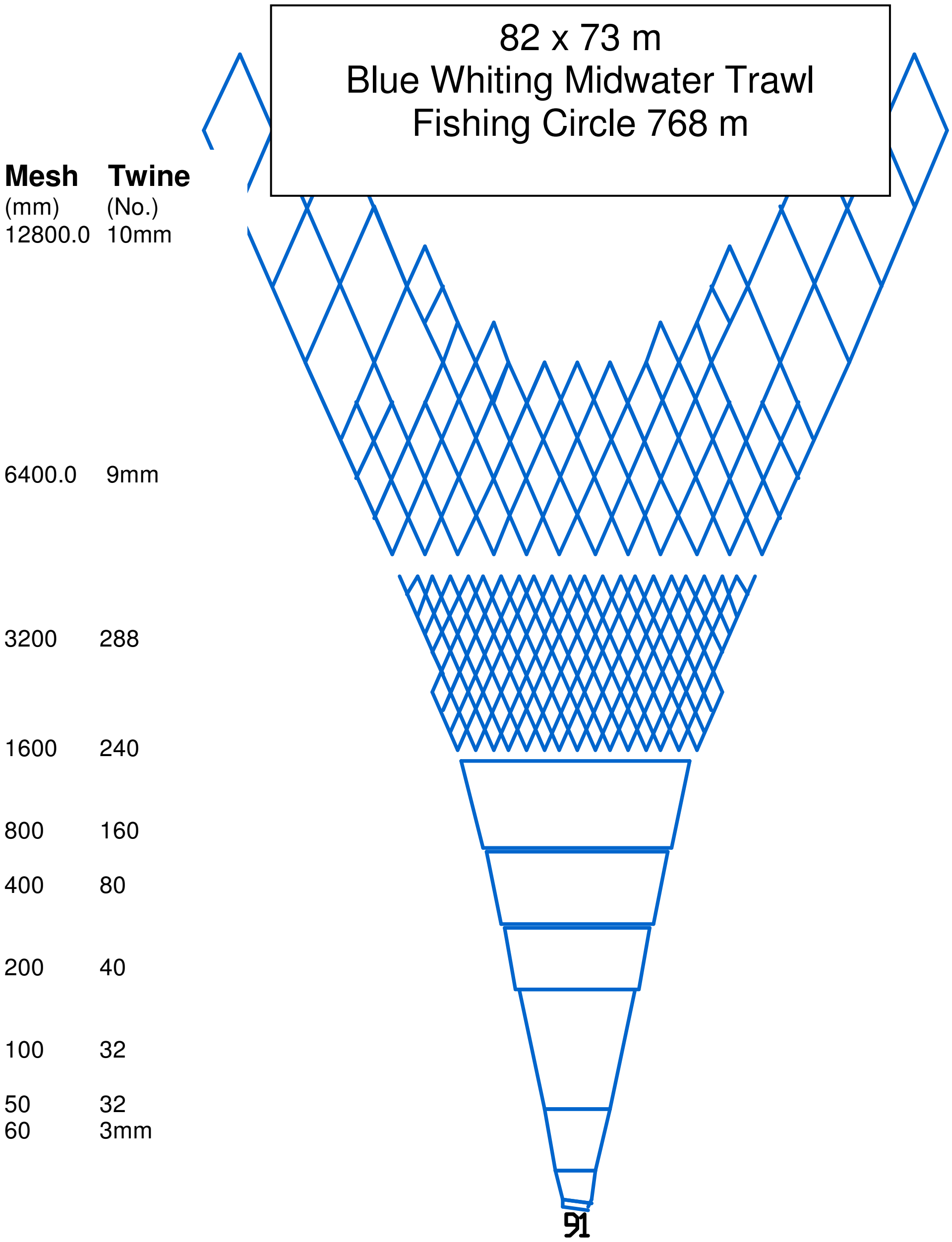


Figure 9. Horizontal temperature (top) and salinity (bottom) at 600m as compiled from Irish CTD stations (black circles).



Net specifics

Clump weights:	1000 Kg per side
Trawl doors:	Polyice pelagic 6m² (750Kg weight in air)
Bridle length:	80m
Door spread:	170m
Vertical net opening:	50m

Figure 10. Pelagic midwater trawl employed during the survey.

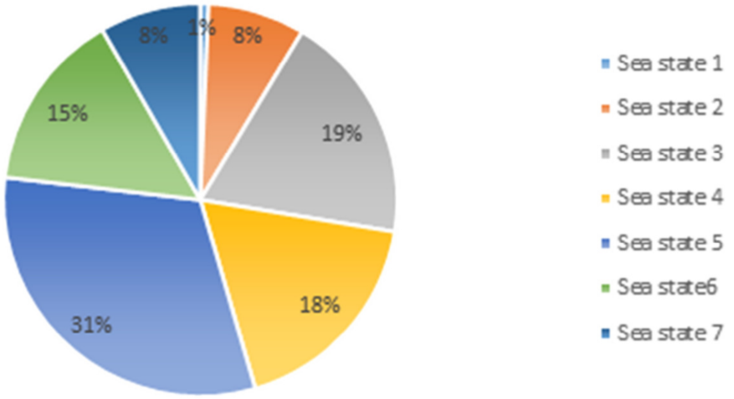


Figure 11. Summary of the visual survey effort and Beaufort sea state

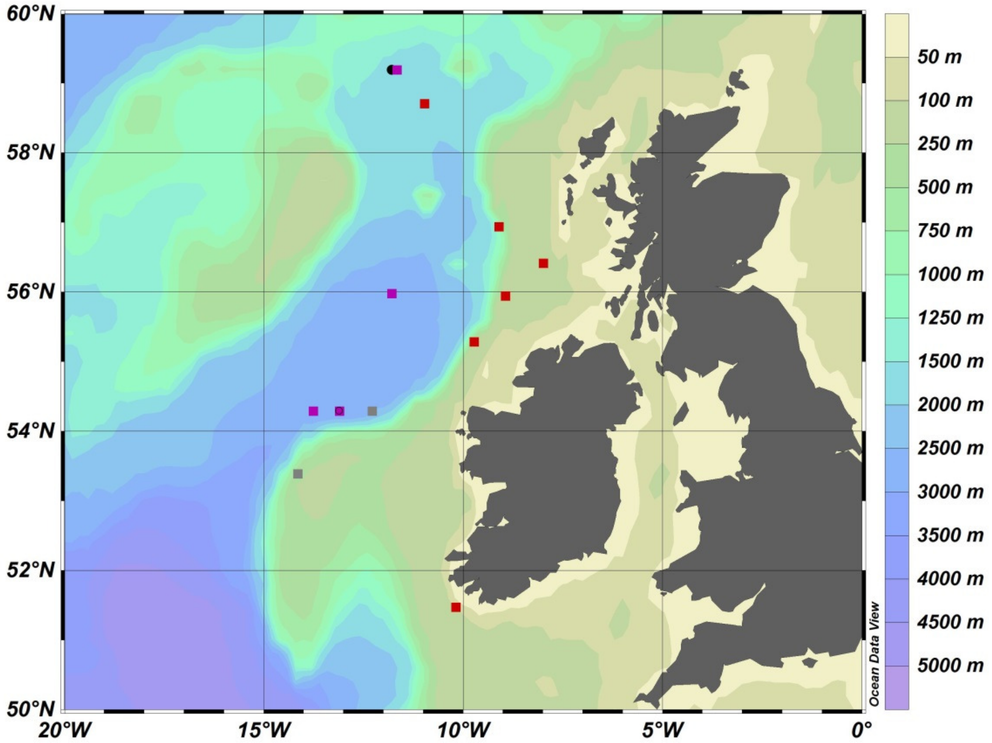


Figure 12. Marine mammal locations (visual observations). Red= common dolphin, grey= bottlenose, purple= pilot whale, black= unidentified dolphin. (Note: locations for 2x opportunistic pilot whale encounters are not shown).

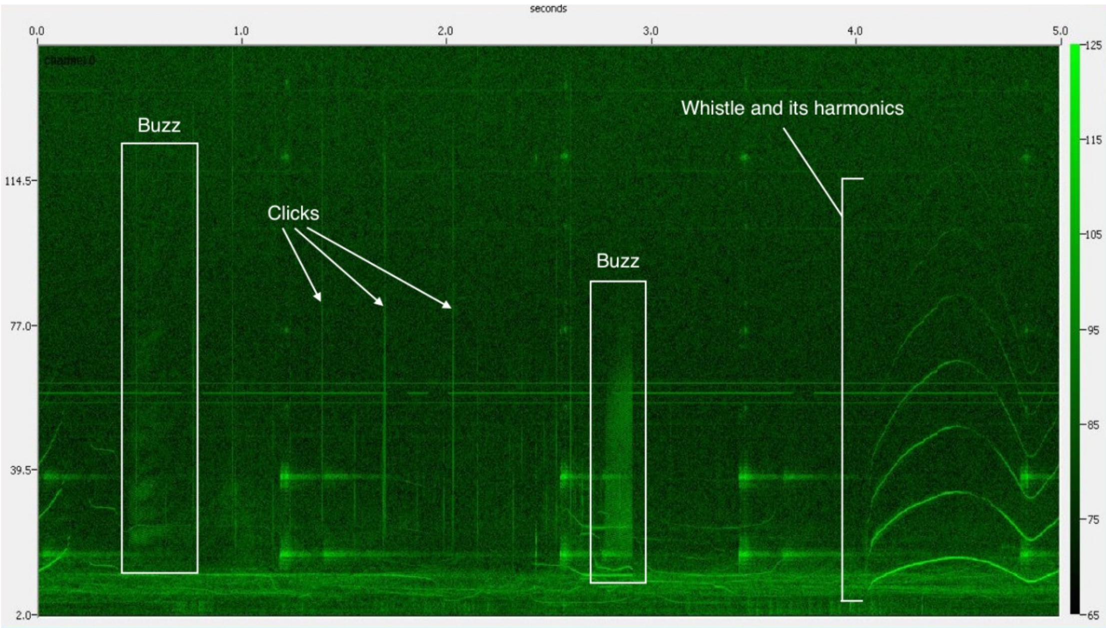


Figure 13. Spectrogram showing 3 different types of cetacean vocalisation recorded during the PAM survey.

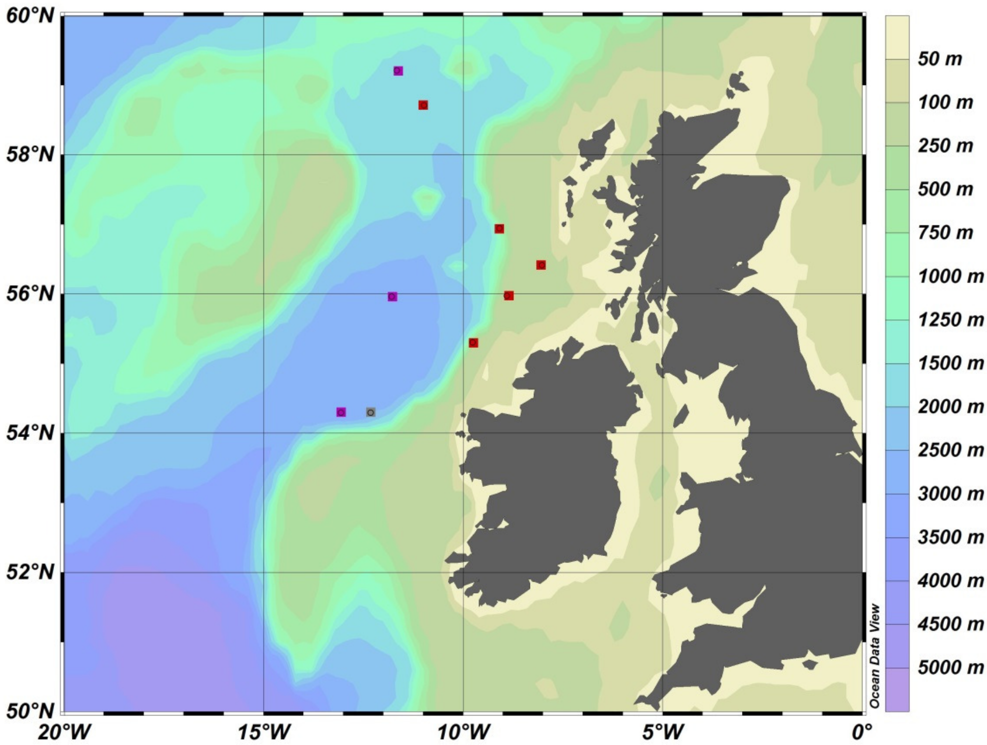


Figure 2. Map illustrating acoustic detection locations of cetaceans which were identified visually, during the active monitoring effort on PAM. Red = common dolphin / grey = bottlenose dolphin / purple = pilot whale.

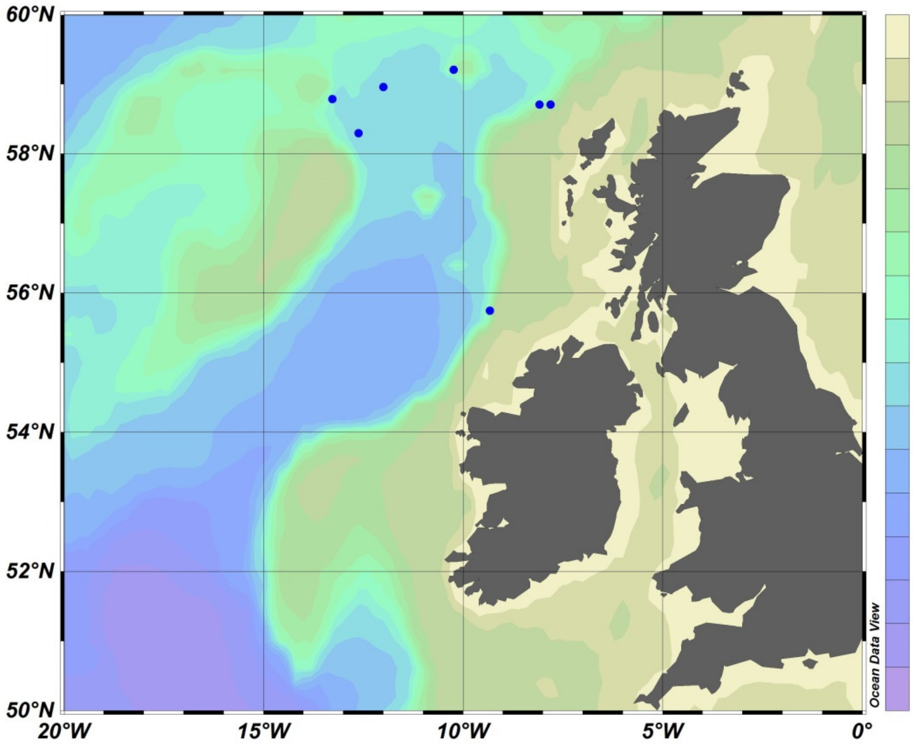


Figure 3. Map illustrating locations of possible sperm whale detections, during active PAM monitoring effort.

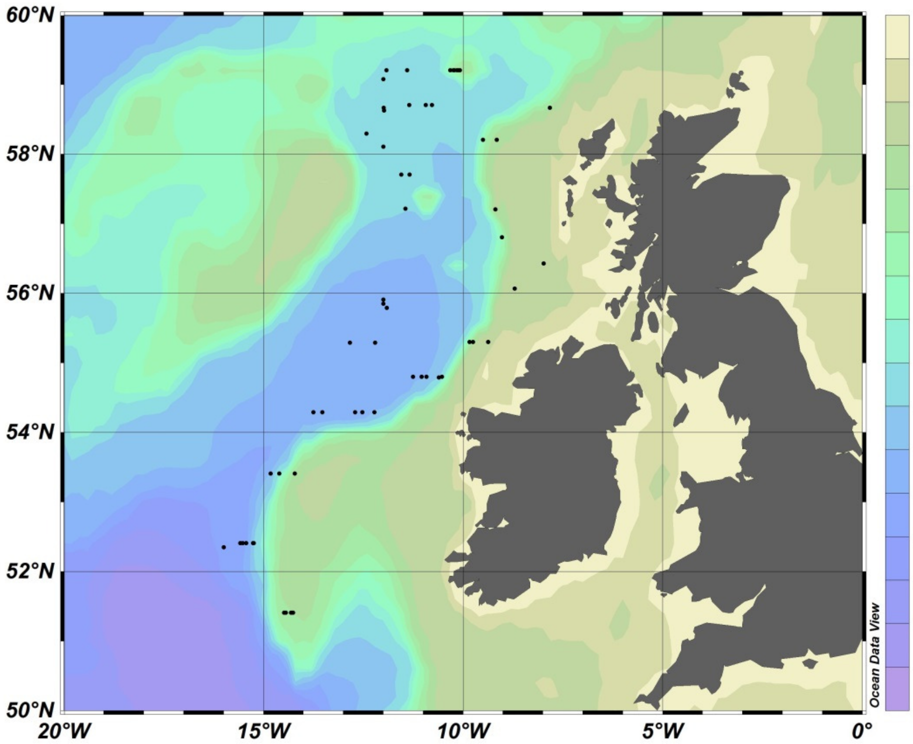


Figure 4. Map illustrating locations of detections of unidentified odontocetes, during active PAM monitoring effort.