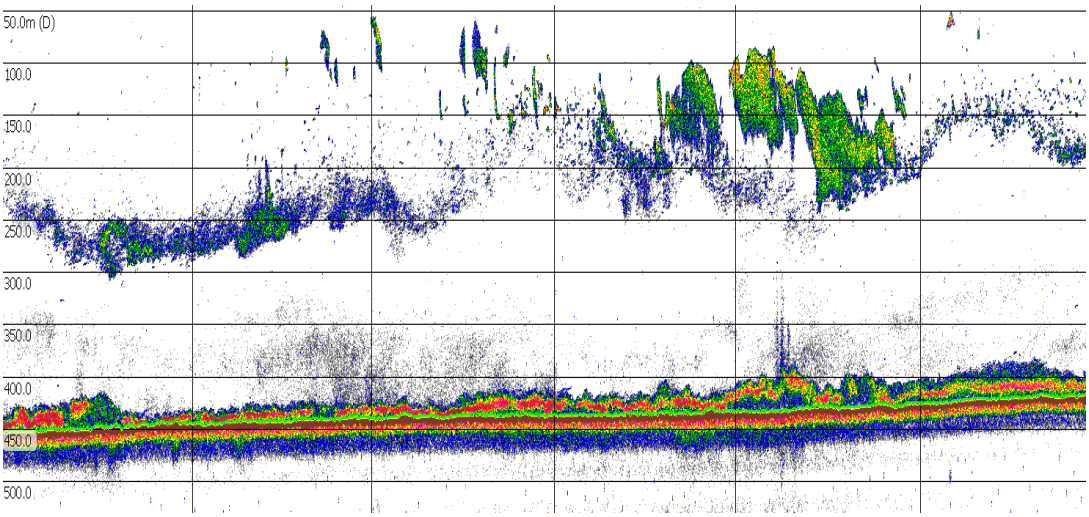
FSS Survey Series: 2017/01

Blue Whiting Acoustic Survey Cruise Report

March 19- April 11, 2017



Ciaran O'Donnell[1], Graham Johnston[1], Eugene Mullins[1],

Niall Keogh[2], Sean O'Callaghan[3]

[1]The Marine Institute, Fisheries Ecosystems Advisory Services

[2] Galway Mayo Institute of technology

[3]Irish Whale and Dolphin Group

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 2017 survey was part of an international collaborative survey using the vessels RV *Celtic Explorer* (Ireland), RV *Tridens* (Netherlands), FV Kings Bay (Norway) 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 1°-17° 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.

2 Materials and Methods

2.1 Scientific Personnel

Name	Organisation	Role
Graham Johnston	FEAS	SIC/Acoustics
Eugene Mullins	FEAS	Acoustics
Marcin Blaszkowski	FEAS	Acoustics
Tobi Rapp	FEAS	Acoustics
Ian Murphy	FEAS	Wetlab
Jan Pedersen	DTU Aqua	Wetlab
Sean O'Callaghan	IWDG	MMO
Aude Benhemma	IWDG	PAM
Carlota Vialcho Miranda	IWDG	MMO/SBO
Niall Keogh	GMIT	SBO
Ciara Hunt	GMIT	Student

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 2017
- 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 visual abundance surveys of marine mammals and seabirds in conjunction with passive acoustic monitoring of marine mammals

2.2.2 Survey design and area coverage

The survey covered core spawning area of blue whiting to the southwest and 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 2017. A parallel transect design was used to allow transect interlacing in co-surveyed target areas. Offshore, transects extended to 17° W. Transect spacing was set at 30 nmi for individual vessels and maintained throughout the survey.

In total, the Irish survey covered 67,209 nmi² using 1,493 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 shown in Table 1.

Acoustic data were collected using the Simrad EK60 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 Galway Bay on 19 March at the start of the survey. Calibration procedure followed methods laid out in Demer *et al.* (2015). The results of the calibration (38 kHz transducer) are shown 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 2017.

2.3.4 Acoustic data acquisition

EK60 "RAW files" were logged via a continuous Ethernet connection to the vessel's 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 continuously monitored the equipment. 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 vessel's 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
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 11). 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 Simrad FS70 (120 & 200 kHz). The net was fitted with a MarPort depth sensor. Spread between the trawl doors was monitored using Scanmar distance sensors and all sensors were 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 also taken. All blue whiting were aged immediately after the survey ended. 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 6). 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

Acoustic data were analysed using the StoX software package as the standard adopted for WGIPS coordinated surveys. A description of StoX can be found here: http://www.imr.no/forskning_/prosjekter/stox/nb-no. Estimation of abundance from acoustic surveys with StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990). Pre-determined survey strata, established in 2016, were adjusted within in StoX based on survey effort and observations in 2017. This occurred mainly in the western fringes where some transects were shortened due to zero registrations of blue whiting (Figure 1). The strata used in StoX are shown in Figure 1. All trawl stations within a given stratum with catches of blue whiting where assigned to all transects within the stratum, and the length distributions where weighted equally within the stratum (Figure 1).

Following the decisions made at the Workshop on implementing a new TS relationship for blue whiting abundance estimates (WKTSBLUES) , the following target strength (TS)-to-fish length (L) relationship (Pedersen et al. 2011) used is:

$$TS = 20 \log10 (L) - 65.2$$

In StoX a super-individual table is produced where abundance is linked to population parameters like age, length, weight, sex, maturity etc. (exact name: 1_FillMissingData_SuperIndividuals.txt). This table was used to split the total abundance estimate by any combination of population parameters. The IBWSS StoX project folder for 2017 is available on request.

.

2.5 Marine mammal and seabirds

2.5.1 Marine mammal sighting and Passive acoustic monitoring surveys (PAM)

2.5.1.1 Visual surveys

One marine mammal observer (MMO) was present on board during the survey and conducted watches (when conditions allowed) from the ships crow's nest located 19m above sea level or alternatively from the monkey island 14m above sea level or in bridge of the vessel 11m above sea level when environmental conditions prevented access to the upper levels.

Each day surveys commenced at approximately 08:30am (where fishing or a CTD station was not taking place) and concluded in the evening when light conditions were not suitable to continue the watch (after 19:00 before 26/03/17 and after 20:00 after this date). All data was collected using UTC time. Visual surveying effort was postponed during incumbent weather (sea state 6, 2m+ high swell or visibility <1km) and also when stations such as fishing trawls or CTD's (conductivity, temperature and depth measurements) were taking place.

Observer effort focused on a 180-degree arc ahead of the ship; however sightings located up to 90 degrees to port and starboard were also included. The observer scanned the area by eye and while using 10 X 50 binoculars (HAWKE Endurance ED) when required. Bearings to sightings were measured using an angle board and distances were estimated with the aid of a distance measuring stick (Heinemann, 1981).

Sightings were recorded using Logger 2000 software (IFAW 2000) where the species sighted, identification confidence level, number of animals present, group dynamics (adults, juveniles and calves), distance (m), bearing (˚), heading (˚) in relation to the ship were made in addition to the initial cue for the sighting and observed behaviours.

Environmental data was also recorded every 30 minutes using Logger 2000 where the sea state (Beaufort scale), swell height (m), visibility (km), cloud cover (out of 8), wind speed (kn) and direction (˚) along with precipitation and intensity were logged. Automated position data was obtained continuously while on effort through a laptop computer linked to GPS receiver.

2.5.1.2 PAM surveys

As cetaceans are often vocally active and their sound can travel far underwater, monitoring acoustically can be advantageous in addition to or instead of visual observations. When weather conditions are undesirable or during hours of darkness/low light, Passive Acoustic Monitoring (PAM) can be used for detection of cetaceans. During visual surveys, a towed hydrophone array was deployed on a 200 m cable and towed behind the vessel. The array contained two hydrophone elements situated 25 cm apart in a fluid filled tube towards the end of the cable. The hydrophone connected to a MAGREC HP-27 buffer box which ran through a laptop computer and was connected to a National Instruments NI 9222 ADC (high frequency) and a Tascam US-144 MKII ADC USB soundcard. This allowed for the detection of sounds outside the capability of the computers soundcard (i.e. harbour porpoise high frequency echolocation clicks). Detection software used during survey was PAMGuard 32 (v1.12.05 beta) and IFAW´s, Logger. GPS data was recorded via an external GPS receiver linked to the Logger software. On 28 March, a technical error resulted in the high frequency setup being shut down. For the remainder of the survey, only the low frequency channels (0-20 kHz) were operational.

A rotation system was implemented during every survey day where the primary MMO would spend 3 hours broken into two 1.5 hour time periods (once in the morning and once in the evening) on PAM (passive acoustic monitoring) and Logger while the primary PAM operator would maintain visual surveying effort. Any vocalisation event detected by the operator was noted and stored in a database along with a time stamp and GPS location of the event. This method reduced the amount of post processing and allowed for species identification of detections where visual sightings occurred. The hydrophone was removed from the water during activities such as trawling, Conductivity, Temperature, Depth sampling, plankton hauls

and fishing. The Survey track of acoustic effort and cetacean detections were mapped using ArcGIS 10.2.

2.5.2 Seabirds

Surveys of seabirds at sea were conducted from the R.V. Celtic Explorer between 21st March and 3rd April 2017. While on transect, the ship travelled at an average speed of 10 knots, except when increased swell prohibited this. A standardised line transect method with sub-bands to allow correction for species detection bias and 'snapshots' to account for flying birds was used (following recommendations of Tasker et al. 1984; Komdeur et al.1992; Camphuysen et al. 2004), as outlined below.

Two observers (a primary observer and a scribe, who also acted as a secondary observer) surveyed while the ship was travelling along transect lines during daylight hours, between 08:00 to 20:30 each day. Surveying ceased when the ship broke track during sample tows, deployment of CTD etc. Environmental conditions, including wind force and direction, sea state, swell height, visibility, precipitation and cloud cover as well as the ship's speed and heading were noted at the start of each survey period and when significant changes occurred thereafter. No surveys were conducted out on deck in conditions greater than sea state six, when high swell made working on deck unsafe. During such periods of inclement weather or heavy seas, surveying was conducted from inside the bridge. Survey effort was also stopped when visibility was reduced to less than 300m due to heavy rain or sea fog.

The seabird observation platform was the bridge deck, which is 10m above the waterline and provided a good view of the survey area. The survey area was defined as a 300m wide band operated on one side (in a 90˚ arc from the bow) and 300m 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 check distance estimates for birds sitting on the water or those flying birds which were recorded during 'snapshot' counts. The area was scanned by eye, with binoculars used only to confirm species identification or count the number of birds present in a flock. All birds seen within the survey area were counted, and those recorded sitting on the water in survey bands A to D 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 when the ship passed from one survey area to the next (every 300m). Any bird recorded within the survey area that was regarded as being associated 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 ad hoc counts of birds not occurring in the survey area were also recorded and added to the database for the research cruise, but are not included in abundance or density analysis.

During the 2017 survey, a series of point counts were made of seabirds associating with the vessel during fishing operations. These began as soon as the towed net began to appear near the surface of the water and finished once the fishing operation was complete, with the net back on board and any surplus fish cleared from the deck. Date, time, location and details of the haul (gross tonnage, species present etc.) were noted for each of these point counts.
In this report, we present our daily total count data for each species along with the daily survey effort. It is envisaged that this data will be analysed in the future and the seabird abundance (birds per km travelled), and seabird density (birds per km²) will be mapped per ¼ ICES square (15˚ latitude x 30˚ longitude), allowing comparison to the results of previous seabird surveys in Irish waters (e.g. Hall et al. in press, Mackey et al. 2004, Pollock et al. 1997). Through further analysis, species-specific correction factors will be applied to birds observed on the water. The binomial species names for the birds recorded are presented in the results section, for which taxonomy and nomenclature follows that of the Irish Rare Birds Committee (2015).

3 Results

3.1 Blue whiting distribution and age structure

No estimate of abundance has not been calculated for this survey. This survey forms part of a coordinated multi vessel effort and as a result a single vessel estimate is not considered a representative measure of the stock.

The combined survey estimate of biomass and abundance for the IBWSS survey 2017 is available here: http://hdl.handle.net/10793/1318

3.1.2 Blue whiting distribution

In total 1068 echotraces were positively identified as blue whiting over the 3 strata surveyed (Figures 1 & 2). Blue whiting aggregations were most frequently encountered between 350-550 m with a range extending from 250 to 650 m. The Porcupine Bank (stratum 1) was characterised by medium to low density aggregations with the bulk of the stock having already migrated northwards. Further north along the northern flank of the Porcupine Bank, (stratum 2) numerous high density schools of blue whiting were observed in open water and along the shelf edge contour extending from 11° to 16°W (Figure 3a). Within stratum 3 (Rockall Trough) the continuation of these aggregations was evident both along the shelf edge and extending westward into open water by up to 60 nmi. This stratum contained the three largest single acoustic density registrations observed during the survey, all of which occurred in open water (Figure 3b-d). Extensive blue whiting aggregations continued in high density northwards to the Anton Dhorn seamount and to limit of Irish coverage at 59°‘30N.

3.1.4 Blue whiting stock structure

A total of 16 directed blue whiting trawls were carried out during the survey (Figures 1 & Table 2).

The second most frequently encountered group of species were the Myctophidae present in all survey hauls (Table 2 & 3). High density mesopelagic echotraces were observed in a number of areas during daylight hours (Figure 3e). 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 (70-200 m) to the target blue whiting layer (250-650 m).

During the survey 1,430 individual lengths and weights recorded for blue whiting and 749 fish were aged. Age analyses of otiliths showed individuals from 1 to 13-years old from trawl samples (Figure 4 & 5).

3.2 Oceanography

Overall 27 CTD casts were carried out during the survey (Figure 6). Open water stations were conducted to a maximum of 1,000 m. Horizontal profiles of temperature and salinity from 10 m subsurface to 600 m is shown in Figures 7-10.

Surface water conditions (10 m) indicate relatively stable conditions south of 60°N in terms of temperature and salinity. The most prominent feature is an area of cooler, less saline water than the surrounding area to the west of the Hebrides, which could be the influence of Arctic surface waters (Figure 7).

At 200 and 400 m the influence of warmer Atlantic water is evident from the northern Porcupine Bank and further south (Figure 8 & 9). Profile taken at 600 m is dominated by warmer Atlantic water origin (Figure 10). Uniform temperatures and salinity regions of Atlantic origin water 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 Environmental data and survey effort

Visual surveying began on the 21st March and concluded on the 2nd April. A total of 94hrs and 50 minutes (5,690 mins) of surveying effort was completed across twelve days where 67.7% (64.2 hrs) of surveying effort was spent in the crow's nest, 28.5% (24.47 hrs) in the bridge and 6.5% (6.17 hrs) on the monkey Island.

A total of 242 environmental stations took place during the survey. The weather conditions were generally good with 68.2% of stations ≤ sea state 4 while the remaining sea states were between 5 and 6 at 33.1%. Swell height was recorded as being moderate (1-2m) 47.5% of the time while 28.9% of the swell was 1 or 0m in height. Heavy swell height occurred 23.6% during effort. Visibility was very good for the majority of the survey with 61.6% at 16-20km to the horizon. Poor visibility (<1-5km) occurred 7.4% while surveying. Overall precipitation did not occur 94.6% of the time spent on effort but rain was present at 4.1% while the remaining precipitation types (fog/mist, hail and sleet) were all noted at 0.4% each. When precipitation did occur, intensity varied from 23.1% for continuous light to 38.5% for both intermittent light and continuous heavy.

3.3.2.1 Sightings and Acoustic detection (PAM)

Six species were observed within the Irish EEZ namely common dolphins, sperm whales, pilot whales, fin whales, bottlenose dolphins and an unidentified beaked whale. Two additional species were sighted in Scottish waters; a minke whale and an Atlantic white-sided dolphin (Figure 12).

A total of 20 cetacean sightings were made while on effort comprising of 70 individuals were made (see table 1). An additional four off effort sightings were recorded of 35 long-finned pilot whales where the group size ranged from 4 to 20 while a solitary bottlenose dolphin was also observed. Three sightings were made outside the Irish EEZ in Scottish waters (Figure 12).

The most frequently sighted and abundant species was the short-beaked common dolphin at 30% (N = 6) of the sightings and 52.9% (37) of the individual species seen. Common dolphins were recorded on five of the twelve survey days followed by unidentified whale species on four days while long-finned pilot whales, sperm whales and fin whales were present on two survey days while on effort. The remainder of the species sighted were on single days.

The most numerous large whale species recorded was the sperm whale with five individuals observed or 7.1% of the total animals sighted. 25% of all sightings were not identified to species level and were either unidentified whales (N = 4) or an unidentified beaked whale species (N = 1). The most numerous Mysticeti (baleen) whale species sighted was the fin whale with three individuals while Long-finned pilot whales were the most abundant large Odontoceti (toothed) whale species with 9 individuals on effort or 44 in total including auxiliary sightings (Table 4).

Dolphins were the most numerous Cetcea sighted. The three dolphin species recorded comprised of 40% of the surveys total sightings, the two large toothed whales recorded were 20% of the sightings while baleen whales were at 15% of the total.

PAM data was recorded and will be analysed at a later date.

3.3.2 Seabirds

3.3.2.1 Effort

A total of 69 hours and 21 minutes (4,161 minutes) of dedicated seabird surveys was conducted across thirteen dates between 21st March and 3rd April 2017. Casual observations

were made on 20th March while in transit to the survey track lines and no surveys were conducted on 29th March due to inclement weather.

A total of nine point counts were made during fishing tow operations during the survey between 24th March and 1st April.

3.3.2.2 Sightings

A cumulative total of 6,349 individual seabirds of 15 species were recorded, of which 2805 were noted as 'off survey', outside of dedicated survey time or associating with the vessel (including during fishing operations point counts) and as such will be excluded from future analysis of abundance and density. A synopsis of daily totals for all seabird species recorded is presented in Table 5. In addition, daily totals for two species of migrant terrestrial birds recorded on or around the vessel are also presented (Table 6).

4 Discussion and Conclusions

4.1 Discussion

Overall, the survey objectives were carried out as planned with little weather downtime recorded (<24hrs). Communication between vessels was good. A temporal time gap developed between the vessels due to the acoustic sampling effort in the northern Porcupine stratum. However, this was not thought to adversely affect the overall precision of the estimate.

The distribution of the bulk of the stock in the mid latitudes indicated that peak spawning was comparable to 2016. The TSB estimates from the combined survey are comparable to 2016. However, the proportion of immature (1 year old fish) was much lower in 2017 as these fish had recruited to the spawning stock as 2 year olds. The low number of 1 year old fish observed during the combined survey may be an indication of a weaker emerging year class. However, this will not become evident until next year.

4.2 Conclusions

The distribution of the bulk of the stock follows a similar pattern of distribution as in in 2016 with the bulk of the stock located in the mid region. The westward continuation of spawning/post spawning aggregations extending into the Rockall Trough would indicate favourable spawning habitat in the mid Rockall Trough.

The 2017 international survey was considered a good representation of the stock with the dominant year classes represented. The survey was carried out during the same time and with the same geographical coverage and shows an increase in the standing stock from 2016. Overall, the combined survey estimate is one of the highest in the international survey time series.

Acknowledgements
We would like to express our thanks and gratitude to Dennis Rowan (Captain) and crew of the *Celtic Explorer* for their good will and professionalism during the survey.

Our thanks also go to our visiting scientists from GMIT and to Jan Pederssen (DTU Aqua, Denmark) for their help and expertise during the survey.

References

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

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

Demer, D. A., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., Domokos, R., et al. 2015. Calibration of acoustic instruments. ICES Cooperative Research Report No. 326.

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

Hatun H., Payne, M. and Jacobsen, J.A. (2009). The North Atlantic subpolar gyre regulates the spawning distribution of blue whiting (*Micromesistius poutassou*). Can. J. Aquat. Sci. 66: 759-770.

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

ICES. (Monstad et al), 1982. Report of the International acoustic survey on blue whiting in the Norwegian Sea, July/August 1982. ICES, Doc.CM. 1982/ H.5.

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

ICES. (O'Donnell et al.) 2012. Report of the Workshop on implementing a new TS relationship for blue whiting abundance estimates (WKTSBLUES), 23–26 January 2012, ICES Headquarters, Copenhagen, Denmark. ICES CM 2012/SSGESST:01. 27 pp.

ICES. 2015. Manual for International Pelagic Surveys (IPS). Series of ICES Survey Protocols SISP 9 – IPS. 92 pp.

IFAW (2000) Logger 2000 software. International Fund for Animal Welfare, London.

IWDG (2009) Irish Whale and Dolphin Group sightings database (Republic of Ireland and Northern Ireland). www.iwdg.ie/Iscope (accessed April 2013)

Irish Rare Birds Committee (2011) List of the Birds of Ireland www.irbc.ie/topbar/categories.php (accessed April 2013)

Jolly, G. M., and I. Hampton. 1990. A stratified random transect design for acoustic surveys of fish stocks. Canadian Journal of Fisheries and Aquatic Sciences 47(7): 1282-1291.

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

Mackey, M., Ó Cadhla, O., Kelly, T.C., Aguilar de Soto, N. and Connolly, N. (2004) Cetaceans and Seabirds of Ireland's Atlantic Margin. Volume 1 – Seabird distribution, density and abundance. Report on research carried out under the Irish Infrastructure Programme (PIP): Rockall Studies Group (R SG) projects 98/6 and 00/13, Porucpine Studies Group project P00/15 and Offshore Support Group (OSG) project 99/38. University College Cork.

MacLennan, D and Simmons, J. 2005. Fisheries Acoustics. Theory and Practice. Second edition. Blackwell publishing. 325-328pp.

Monstad, T. 2004. Blue Whiting. *In* The Norvegian Sea Ecosystem. *Edited by* H.R. Skjoldal.540 Tapir, Trondheim. pp. 263-288.

O'Donnell, C., Mullins, E., Monstad, T., Macualay, G., Power, G. and Ullgren, J. 2004 .Blue Whiting Acoustic Survey Cruise Report. Marine Institute, Ireland. Survey series 04:01

O'Donnell, C., Mullins, E., Johnston, G., Lyons., K., Saunders, R., Brkic, Z. and O'Leary., E. 2009. Blue whiting Acoustic Survey cruise Report. Marine Institute, Ireland. Survey series 09:01

Pedersen, G., Godo, R.O., Ona, E., Macaulay, G.J. (2011). A revised target strength estimate for blue whiting (*Micromesistius poutassou*): implications for biomass estimates. ICJM: (2011), 68(10), 2222-2228. 10.1093/icesjms/fsr142

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

Shirihai H. and Jarrett B. (2006) *Whales, Dolphins and Seals. A Field Guide to the Marine Mammals of the World*. A&C Black, London.
Simmonds, J. and Mac Lennan D. 2007. Fisheries acoustics, theory and practice. Second edition. Blackwell publishing

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

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

Toresen, R., Gjøsæter, H. and Barros de, P. 1998. The acoustic method as used in the abundance estimation of capelin (*Mallotus villosus* Müller) and herring (*Clupea harengus* Linné) in the Barents Sea. Fisheries Research, 34: 27–37.

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

Echo Sounder System Calibration

Vessel :	RV Celtic Explorer	Date :	19.03.17
Echo sounder :	EK60 PC	Locality :	Dunmnaus Bay
Type of Sphere :	Cu-60.1mm	TS_{Sphere}: -33.50 dB (Corrected for soundvelocity)	Depth(Sea floor) : 30 m

Calibration Version 2.1.0.11

Comments:
CE17004.BWAS. Black Head

Reference Target:

TS	-33.5 dB	Min. Distance	16.00 m
TS Deviation	5.0 dB	Max. Distance	25.00 m

Transducer: ES38B Serial No. 30227

Frequency	38000 Hz	Beamtype	Split
Gain	26.5 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	7.10 deg	Along. Beam Angle	7.10 deg
Athw. Offset Angle	- 0.04 deg	Along. Offset Angl	-0.04 deg
SaCorrection	-0.64 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.	9.4 dB/km	Sound Velocity	1486.0 m/s

Beam Model results:

Transducer Gain =	25.9dB	SaCorrection =	-0.60 dB
Athw. Beam Angle =	6.88 deg	Along. Beam Angle =	6.82 deg
Athw. Offset Angle =	-0.02 deg	Along. Offset Angle=	-0.03 deg

Data deviation from beam model:
RMS = 0.19 dB
Max = 0.58 dB No. = 281 Athw. = 4.2 deg Along = 3.1 deg
Min = -0.73 dB No. = 314 Athw. = -4.4 deg Along = 1.5 deg

Data deviation from polynomial model:
RMS = 0.15 dB
Max = 0.51 dB No. = 89 Athw. = -4.0 deg Along = -3.3 deg
Min = -0.66 dB No. = 334 Athw. = -1.7 deg Along = -3.9 deg

Comments :

Wind Force : 3 **Wind Direction :** SW
Raw Data File: \\C\EK60_Data\BWAS_2017\RAW ER60 Files\Calibration\BWAS_2017
Calibration File: \\C\EK60_Data\BWAS_2017\RAW ER60 Files\Calibration\BWAS_2017

Calibration : Graham Jonston

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	23.03.2017	53.207	-14.634	20:04:00	500	450	1,100.0	112.9	99.3	0.3	0.4		
2	24.03.2017	52.409	-14.712	14:54:00	3000	320	1.4	1.4			100.0		
3	25.03.2017	54.508	-14.499	16:24:00	2700	520	23.5	23.5	32.2		67.8		
4	25.03.2017	53.928	-14.461	23:12:00	1000	440	1,200.0	121.8	99.6		0.4		
5	26.03.2017	54.088	-13.501	16:12:00	1600	520	1,800.0	126.9	99.7		0.3		
6	27.03.2017	53.926	-12.507	12:08:00	410	400	400.0	120.3	90.4		0.1		9.5
7	28.03.2017	54.575	-11.504	00:44:00	1800	450	135.9	120.9	96.3		3.7		
8	28.03.17	55.264	-10.080	22:35:00	800	450	350.0	116.1	98.5		1.5		
9	29.03.2017	55.263	-12.093	08:06:00	2000	420	1,000.0	121.3	99.6		0.4		
10	30.03.2017	55.934	-9.922	10:01:00	1250	500	900.0	114.4	99.7		0.3		
11	30.03.2017	56.929	-9.903	22:39	1100	500	800.0	122.8	97.3		2.8		
12	31.03.2017	56.929	-11.573	07:46	2000	500	1000.0	113.6	99.4		0.6		
13	31.03.2017	57.922	-10.623	22:04	2000	520	800.0	113.6	98.8		1.2		
14	01.04.2017	58.594	-9.004	13:43	1200	460	400.0	132.6	91.8		8.2		
15	02.04.2017	59.262	-10.621	03:18	1000	520	1000.0	110.8	99.1		0.9		
16	02.04.2017	59.263	-7.181	15:57	700	500	1000.0	139.2	96.8		3.2		

Note: “Others” was used to represent fish and non-fish species occurring in the catch.

Table 3. Species occurrence from trawl stations.

Category	Common Name	Scientific Name	Occurrence
Pelagic	Blue Whiting	*Micromesistius poutassou*	15
	Mackerel	*Scomber scombrus*	1
	Horse mackerel	*Trachurus trachurus*	0
	Hake	*Merluccius merluccius*	0
Mesopelagics	None	Arctozenus rissoi	13
	Greater Argentine	*Argentina silus*	14
	Hatchet Fish (small)	*Argyropelecus hemigymnus*	12
	Myctophidae(combined)		0
	Hatchet Fish (large)	*Argyropelecus olfersi*	0
	None	*Astronethus gemmifer*	0
	Myctophidae	*Benthosema glaciale*	16
	Alfonsino	*Beryx decadactylus*	0
	Ray's bream	*Brama brama*	0
	None	*Bathylagus euryops*	3
	Blackfish	*Centrophagus niger*	0
	Sloanes Viper fish	*Chauliodus sloani*	9
	Myctophidae	*Diaphus raffinesqui*	0
	Myctophidae	*Diaphus metapoclampus*	0
	Myctophidae	*Diaphus effulgens*	1
	None	*Diretmus argentus*	1
	None	*Echiostoma barbatum*	0
	Myctophidae	*Electrona rissoi*	0
	Pipefish	*Entelurus aequoreus*	0
	Balbo sabretooth	*Evermanella balbo*	0
	None	*Gonastoma elongatum*	0
	None	*Howella sherborni*	1
	None	*Lampadena speculigera*	0
	Myctophidae	*Lampanyctus crocodilus*	0
	Myctophidae	*Lobianchia gemallari*	0
	Searsids	*Maulisia*	0
	Pearlside	*Maurolicus muelleri*	2
	None	*Melanostomias tentaculatus*	1
	Myctophidae	*Myctophum punctatum*	0
	None	*Maulisia microlepis*	3
	None	*Melamphaes longivelis*	1
	None	*Melanstomias bartonbeani*	1
	Greenland Argentine	*Nansenia groenlandica*	0
	Forgotten argentine	*Nansenia oblita*	0
	Slender snipe-eel	*Nemichthys scolopaceous*	1
	Multipore Searside	*Normichthys operosus*	0
	None	*Notolepis rissoi*	0
	Myctophidae	*Notoscopelus krokeyeri*	0
	None	*Opisthoproctus soleatus*	0
	Shrimps	*Pandalidae*	15
	Silver Pomfret	*Pterycombus brama*	0
	Schnakenbeck's searside	*Sagamichthys schnakenbecki*	2
	None	*Scopelosaurus lepidus*	1
	None	*Searsia koefoedi*	0
	Bean's sawtoothed eel	*Serrivomer beani*	1
	None	*Sternoptyx diaphana*	0
	Scaly dragonfish	*Stomias boa*	0
	Myctophidae	*Symbolophoros veranyi*	0
	Greater Pipefish	*Syngnathus acus*	0
	Dealfish	*Trachipterus arcticus*	0
	Bluntsnout smooth-head	*Xenodermichthys copei*	3
	None	*Pseudoscopelus altipinnis*	0
	None	*Argyropelecus olfersi*	12
Demersal	Grey Gurnard	*Eutrigla gurnardus*	0
	Silvery Pout	*Gadiculus argentus*	0
	Norway Pout		0
	saithe	*Pollachius Virens*	0
Squid	Lesser flying squid	*Todaropsis elbanae*	0
	Northern flying squid	*Todarodes sagittatus*	0
	Short finned squid	*Omnastrephidae*	0
	Unknown squid		10
			0
Other	Jellyfish		2
	Octopus		0
	Grey Gurnard		0
		Total Number of Trawls	**16**
		Total number of Species:	**25**

Table 4. Sightings, counts and group size ranges for cetacean species recorded during the survey.

Species common name	Scientific name	No. of sightings	No. of animals	Group size range
Short-beaked common dolphin	*Delphinus delphis*	6	37	1 - 15
Long-finned pilot whale	*Globicephala melas*	2	9	4 - 5
Sperm whale	*Physeter macrocephalus*	2	5	2 - 3
Fin whale	*Balaenoptera physalus*	2	3	1 - 2
Common bottlenose dolphin	*Tursiops truncatus*	1	8	8
Minke whale	*Balaenoptera acutorostrata*	1	1	1
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	1	1	1
Unidentified whale	Cetacean sp.	4	5	1 - 2
Beaked whale species	Ziphiidae sp.	1	1	1
Total number of sightings			20	
Total number of individuals			70	

Table 5. Totals for all seabird species.

Vernacular Name	Scientific Name	On Survey	Off Survey	Total
Fulmar	*Fulmarus glacialis*	1541	1599	3140
Sooty shearwater	*Ardenna griseus*	0	3	3
Great shearwater	*Ardenna gravis*	0	1	1
Manx shearwater	*Puffinus puffinus*	24	2	26
Gannet	*Morus bassanus*	1263	576	1839
Cormorant	*Phalacrocorax carbo*	3	0	3
Kittiwake	*Rissa tridactyla*	357	328	685
Great black-backed gull	*Larus marinus*	19	126	145
Glaucous gull	*Larus hyperboreus*	0	1	1
Lesser black-backed gull	*Larus fuscus graellsii*	99	74	173
Unidentified large gull sp.	*Larus sp.*	0	40	40
Great skua	*Stercorarius skua*	59	42	101
Little auk	*Alle alle*	4	2	6
Guillemot	*Uria aalge*	68	0	68
Razorbill	*Alca torda*	19	0	19
Puffin	*Fratercula arctica*	88	11	99
Total		3544	2805	6349

Table 6. Totals of migrant terrestrial bird species.

Vernacular Name	Scientific Name	Total
Oystercatcher	*Haematopus ostralegus*	2
Redwing	*Turdus iliacus*	2
Total		4

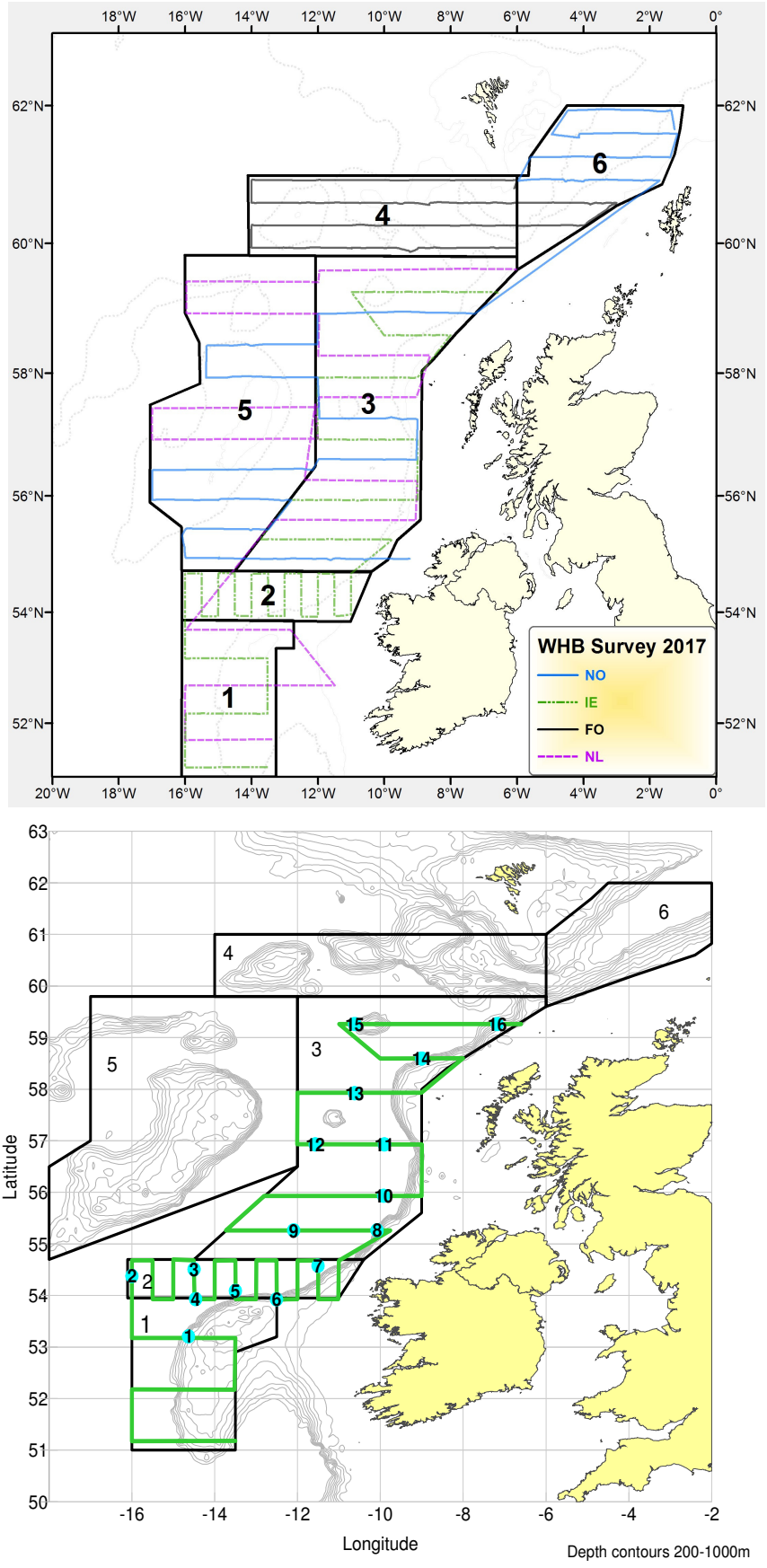


Figure 1. International survey effort (top panel) and Irish effort with trawl station positions (bottom panel).

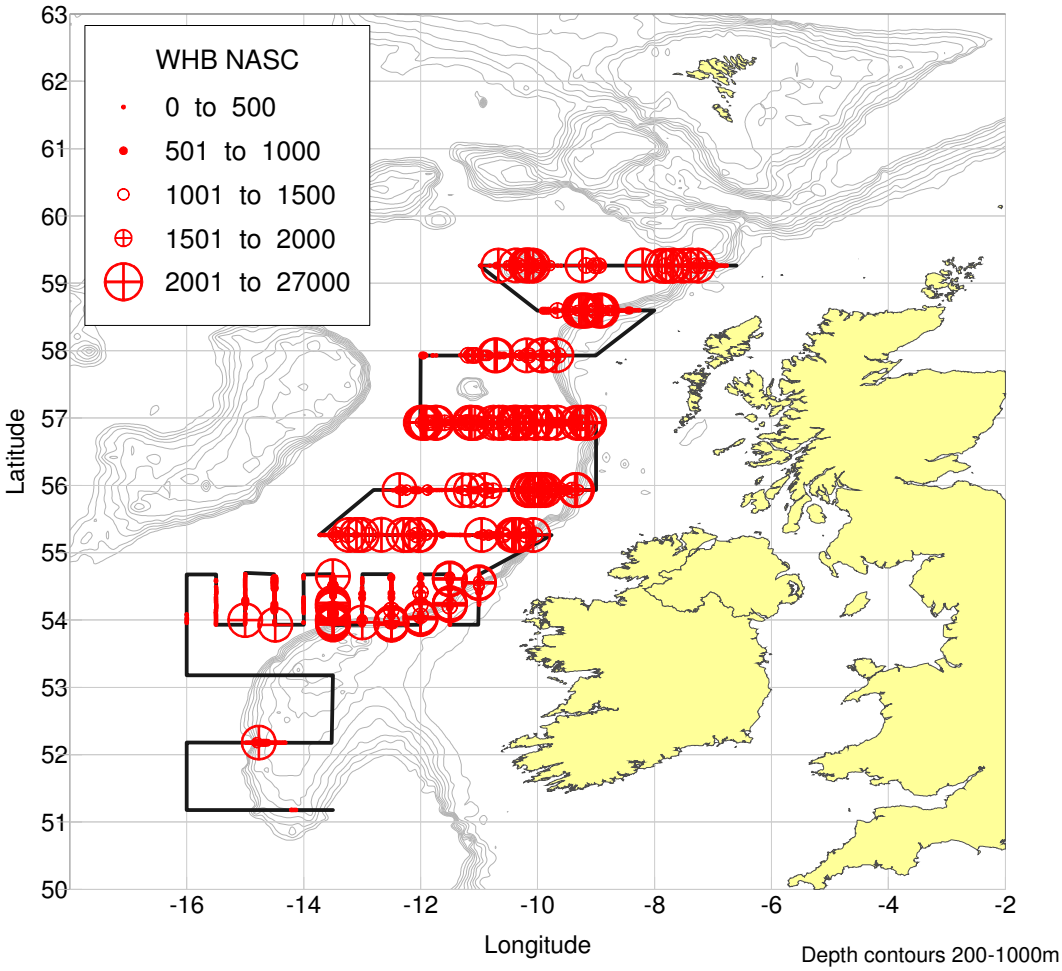
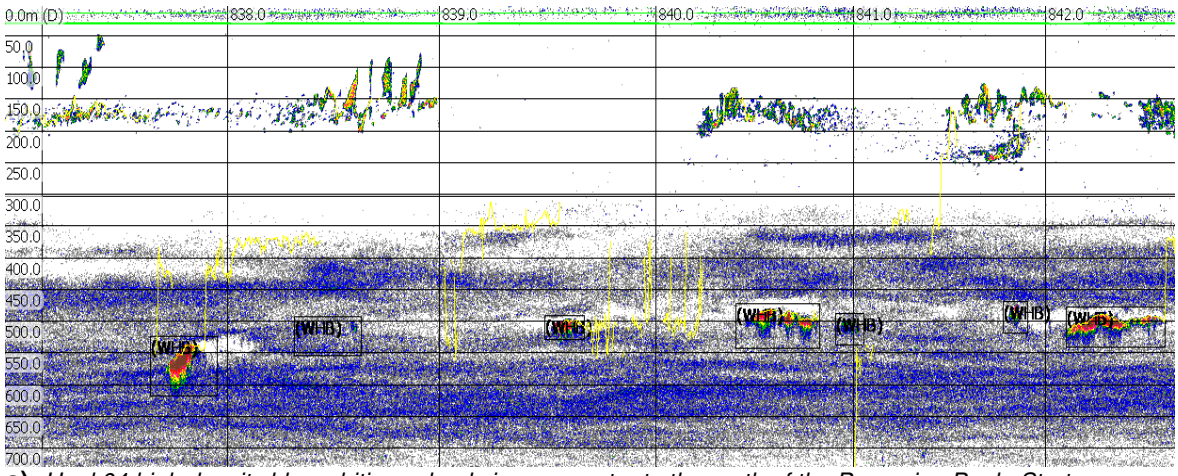
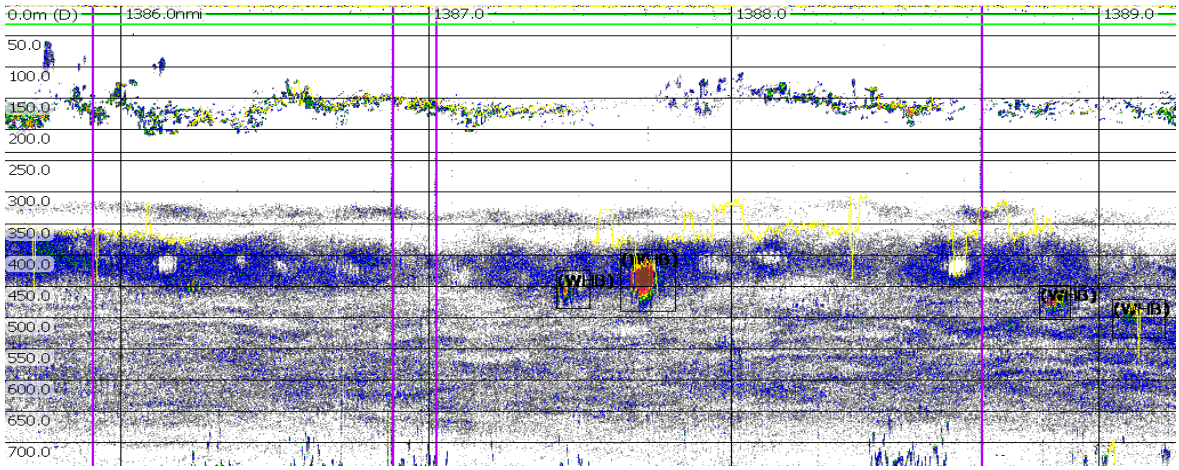


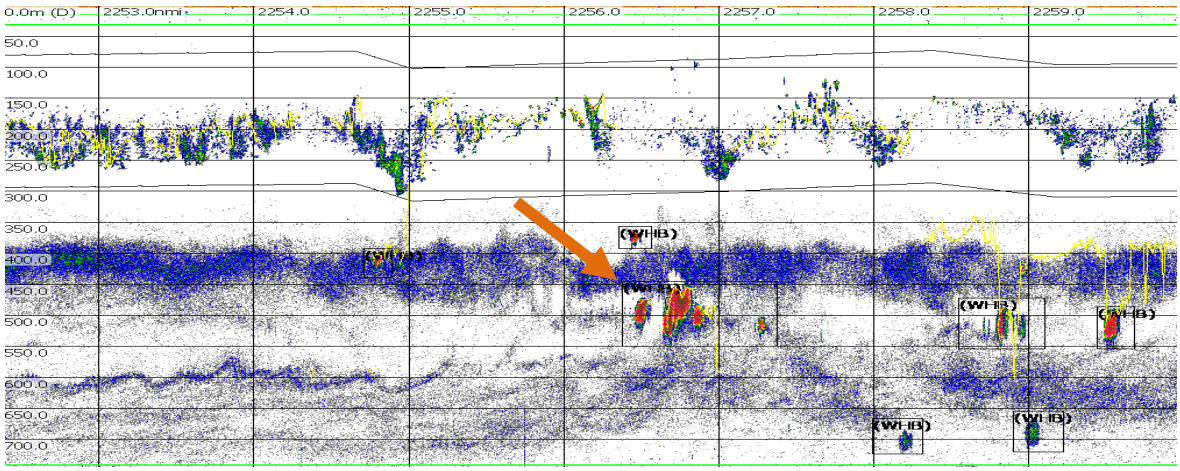
Figure 2. Blue whiting distribution (NASC values) by strata.



a). *Haul 04 high density blue whiting schools in open water to the north of the Porcupine Bank. Stratum 2-north Porcupine.*

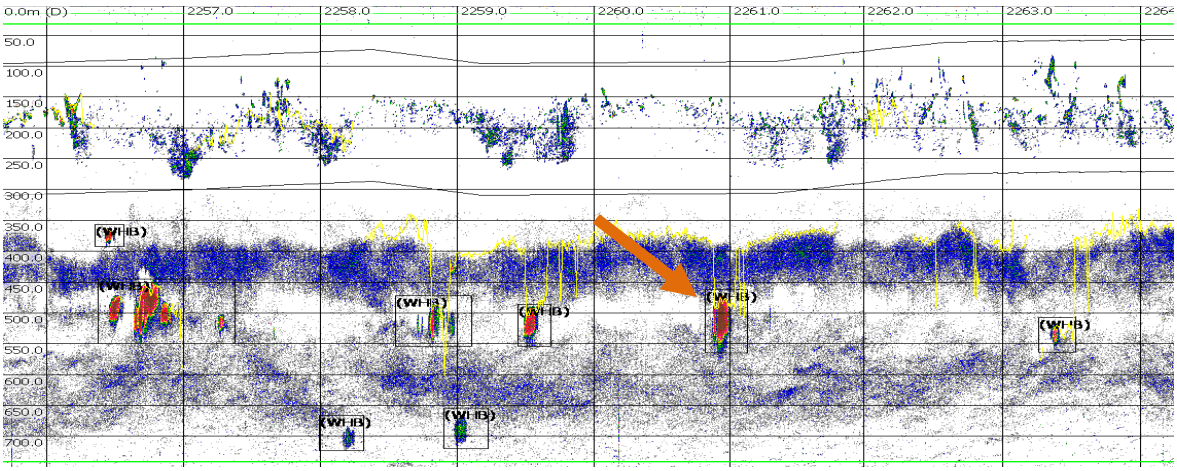


b). *Haul 09, Stratum 3- Rockall Trough. High density single schools in open water.*

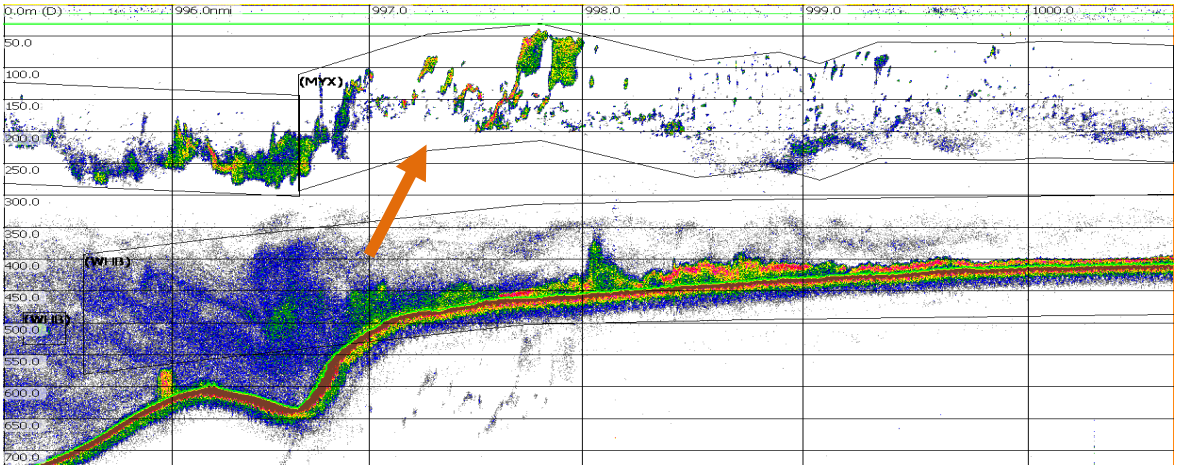


c). *Stratum 3- Rockall Trough. Single highest acoustic density school (orange arrow) observed during the survey. Open water blue whiting aggregation in the Rockall Trough close to Haul 09.*

Figures 3 a-e. 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.



d). *Stratum 3- Rockall Trough. Second single highest acoustic density school (orange arrow) observed during the survey. This school was observed in close proximity to the previous largest school (~4 nmi away).*



e). *Stratum 2- northern Porcupine. High density day light aggregations of mesopelagics (orange arrow) from 50-250m depth layer.*

Figures 3 a-e. continued.

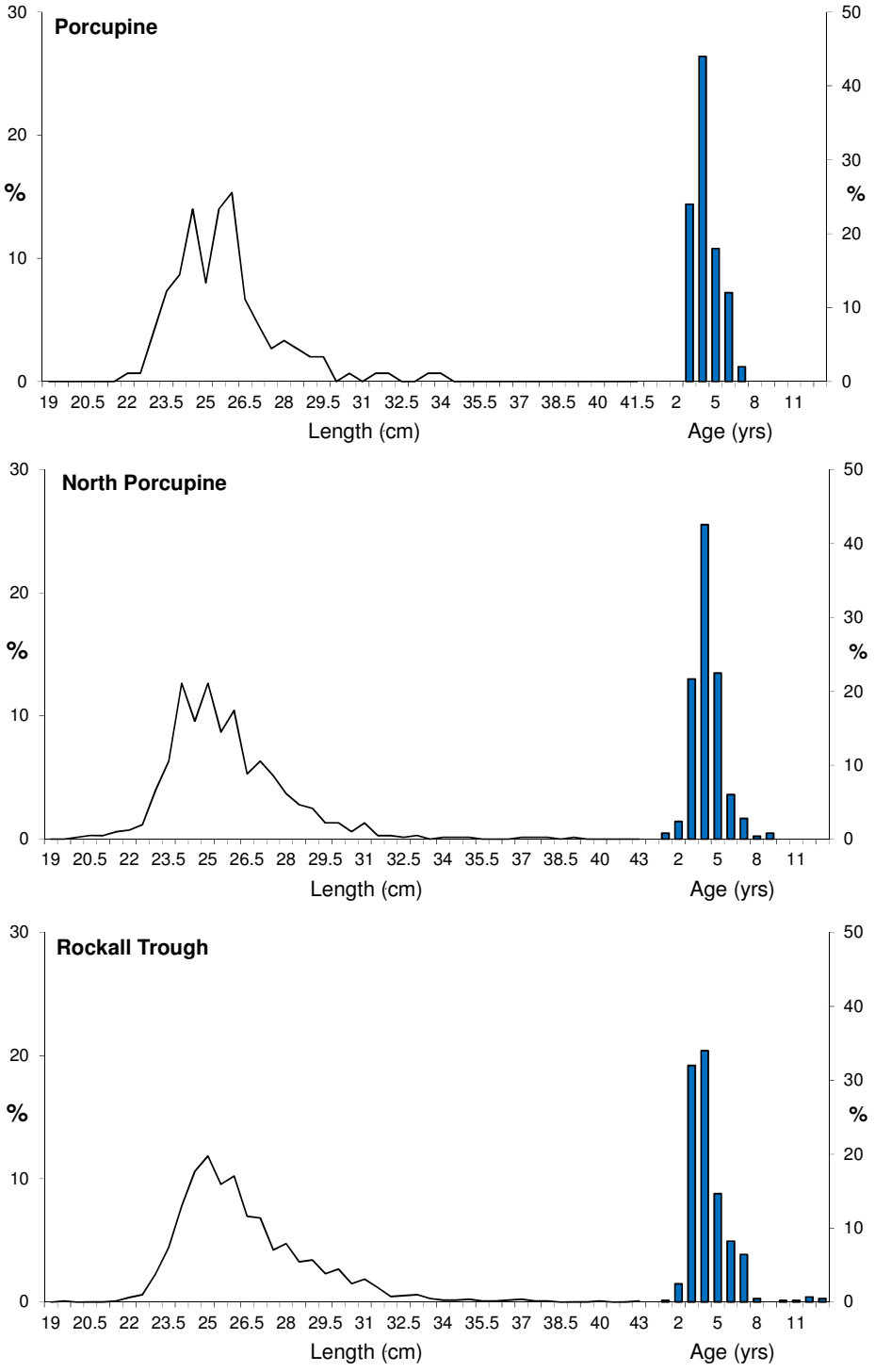


Figure 4. Length and age composition of blue whiting from trawl samples presented by stratum.

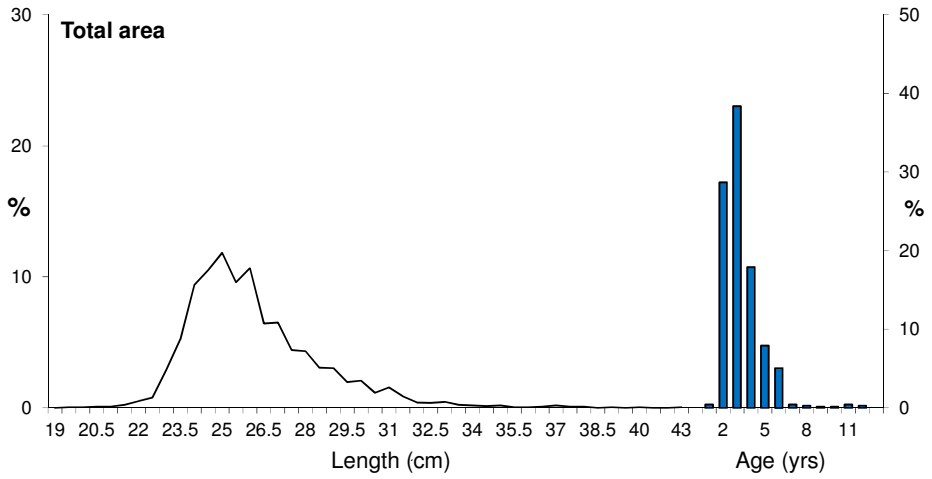


Figure 5. Length (n= 2,178) and age (n=732) composition of blue whiting from trawl samples presented for the total area surveyed.

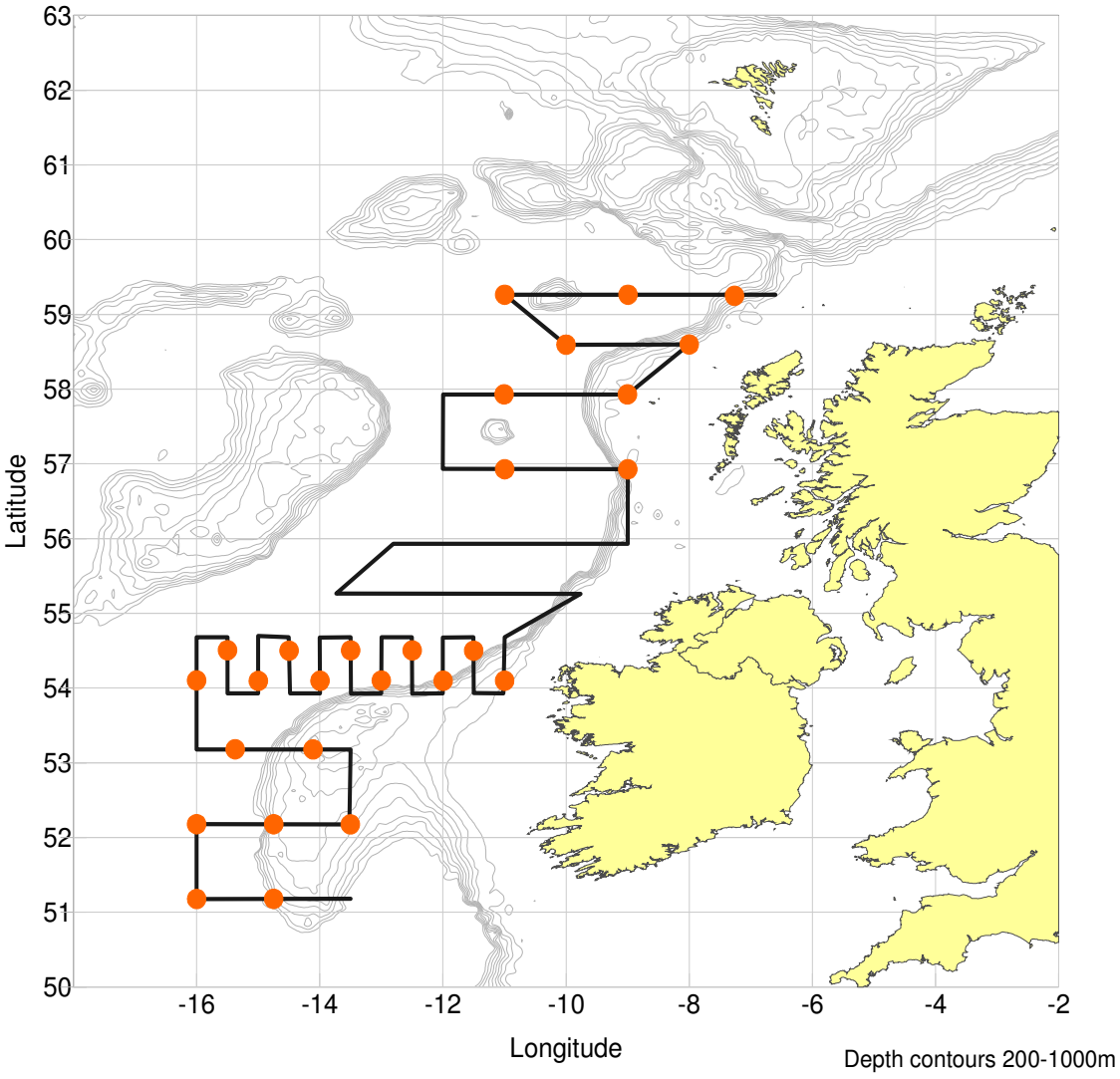


Figure 6. Position of hydrographic stations (orange dots). Note: Open water stations were carried out to a maximum depth of 1000m.

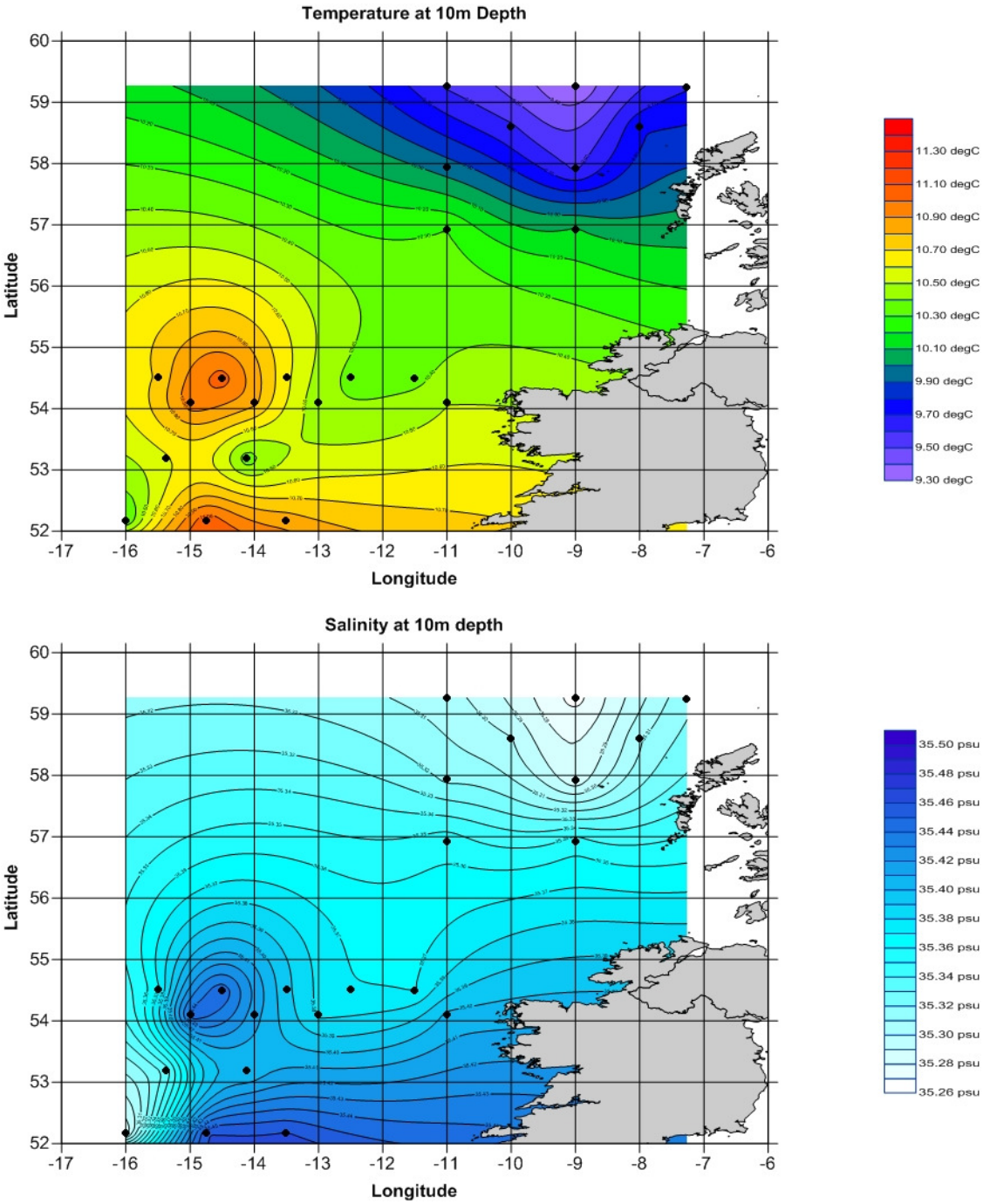


Figure 7. Horizontal temperature (top) and salinity (bottom) at 10m as compiled from Irish CTD stations (black dots).

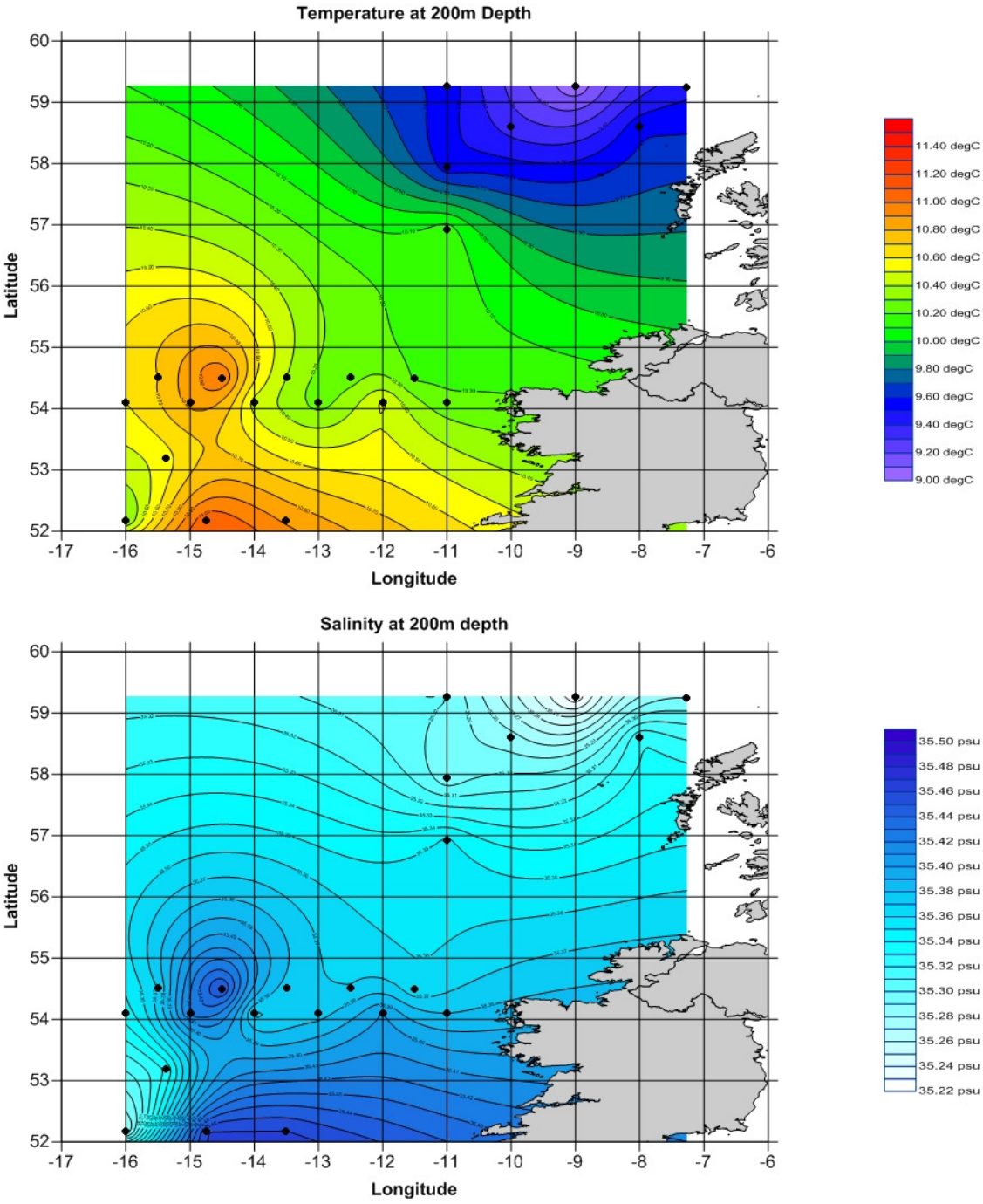


Figure 8. Horizontal temperature (top) and salinity (bottom) at 200m as compiled from Irish CTD stations (black dots).

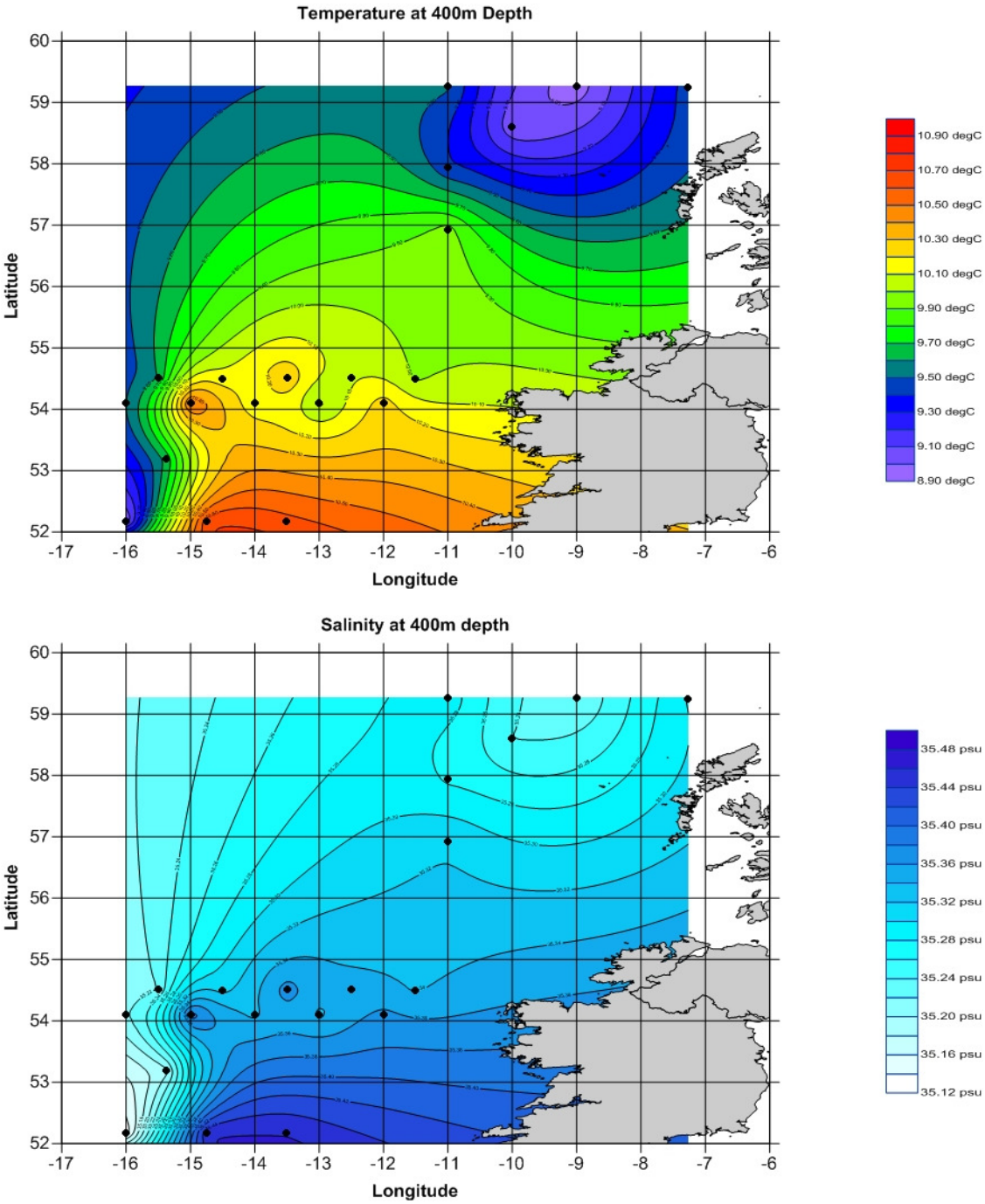


Figure 9. Horizontal temperature (top) and salinity (bottom) at 400m as compiled from Irish CTD stations (black dots).

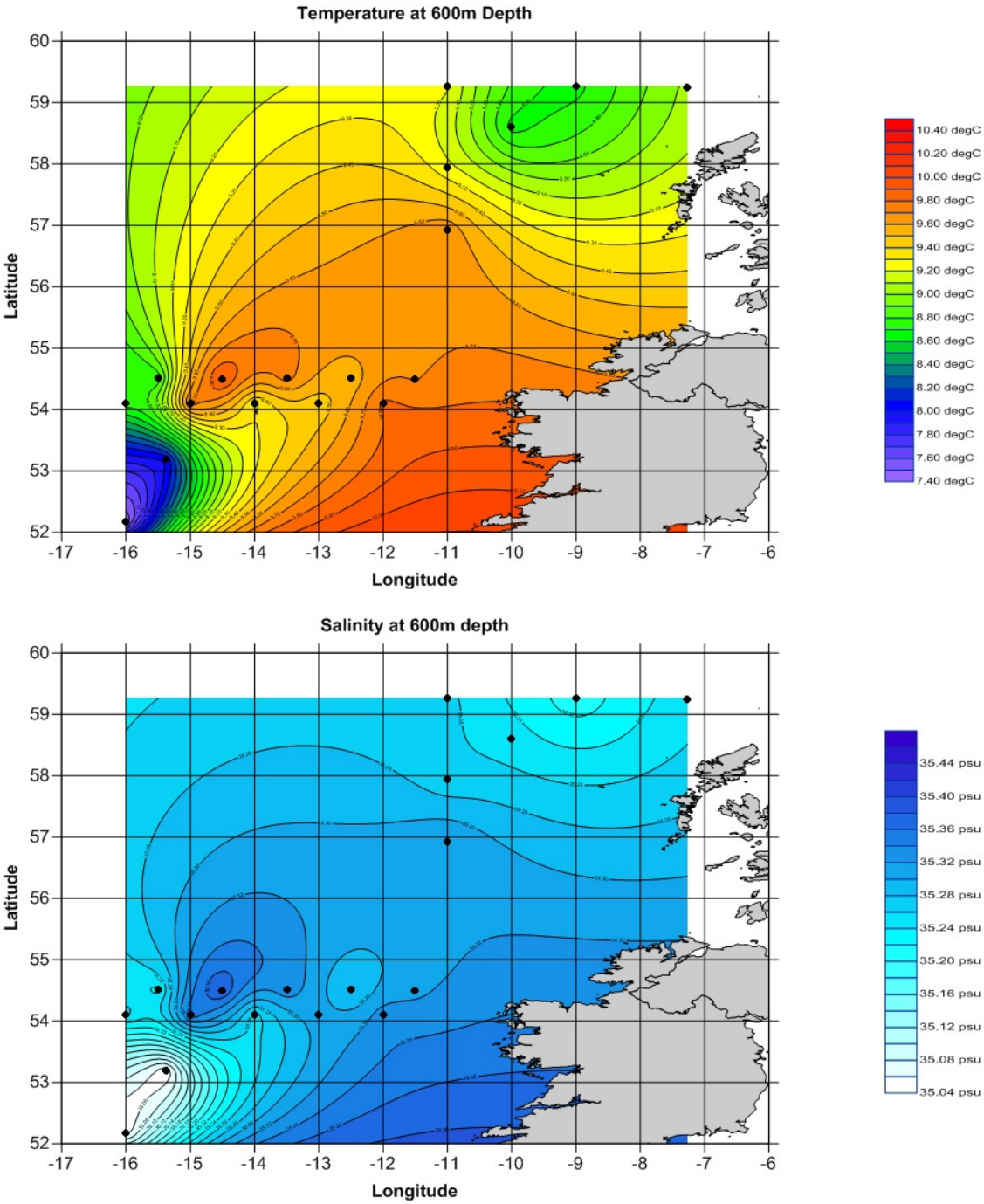
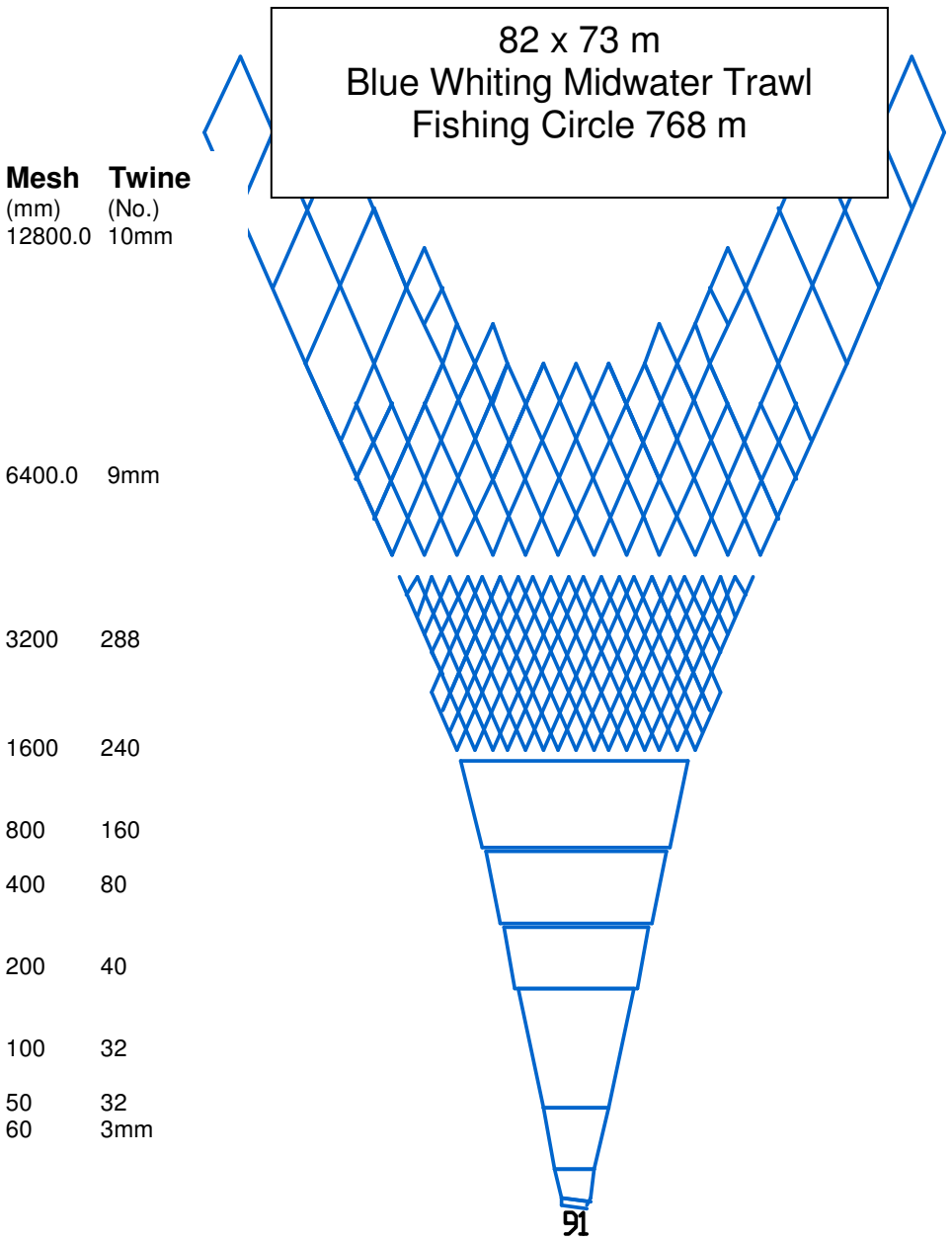


Figure 10. Horizontal temperature (top) and salinity (bottom) at 600m as compiled from Irish CTD stations (black dots).



Net specifics	
Clump weights:	1000 Kg per side
Trawl doors:	Polyice pelagic 6 m^2 (750 Kg weight in air)
Bridle length:	80 m
Door spread:	170 m
Vertical net opening:	50 m

Figure 11. Pelagic midwater trawl employed during the survey.

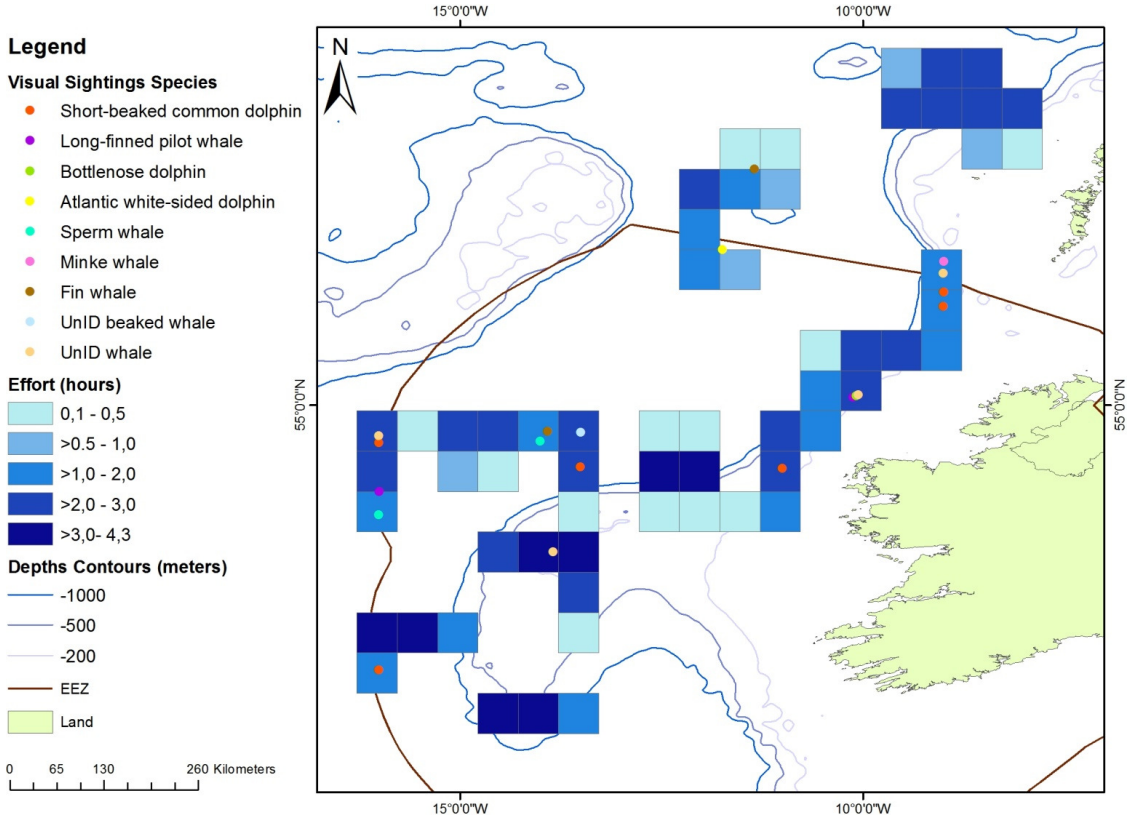


Figure 12. Map of the visual survey effort (survey track), and the sighting locations of the marine mammals.