

Marine Institute Cetacean Monitoring

During the Blue Whiting Acoustic Survey

March - April 2018

Lead Agency: Marine Institute

Lead Partners: National Parks and Wildlife Service,

Authors: Emerald Marine

Citation: Power, J. and O'Sullivan, C (2018). Cetacean Monitoring undertaken during the Blue Whiting Acoustic Survey (BWAS) March-April 2018

Operational Programme	European Maritime and Fisheries Fund (EMFF) Operational Programme 2014-2020
Priority	Union Priority 1 Sustainable Development of Fisheries Union Priority 6 Fostering the implementation of the Integrated Maritime Policy
Thematic Objective	TO 6 - Preserving and protecting the environment and promoting resource efficiency
Specific Objective	UP1 SO1 - Reduction of the impact of fisheries and aquaculture on the marine environment, including the avoidance and reduction, as far as possible, of unwanted catch. UP1 SO2 - Protection and restoration of aquatic biodiversity and ecosystems. UP6 SO1 - Development and implementation of the Integrated Maritime Policy
Measure	Marine Biodiversity Scheme
Project No.	MB/2019/09
EMFF Certifying Body	Finance Division, Department of Agriculture, Food and the Marine
Managing Authority	Marine Agencies & Programmes Division, Department of Agriculture, Food and Marine
Specified Public Beneficiary Body	Marine Institute
Grant Rate	100%
EU Co-Financing Rate	50%
Legal Basis	Article 29, 40 & 80 EMFF
Details	Report to the Marine Institute Emerald marine

This project or operation is part supported by the Irish government and the European Maritime & Fisheries Fund as part of the EMFF Operational Programme for 2014-2020



An Roinn Talmhaíochta,
Bia agus Mara
Department of Agriculture,
Food and the Marine



EUROPEAN UNION
This measure is part-financed
by the European Maritime
and Fisheries Fund



Foras na Mara
Marine Institute



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Executive Summary

Irish waters represent one of the most important marine habitats for cetaceans in Europe and are utilized by a wide range of cetacean species. However, the abundance, distribution and conservation status of many of the cetacean species occurring in Irish waters remains poorly understood. Under the EU Habitats Directive, there is a requirement on member states to conduct surveillance of cetaceans occurring within their waters. The Department of Arts, Heritage and the Gaeltacht (DAHG), through the Marine Institute, commissioned a cetacean survey from the MRV Celtic Explorer during the annual Blue Whiting Acoustic Survey (BWAS), running from 20th of March to 9th April 2018.

A standard, single platform line transect survey methodology was employed by the cetacean survey team with additional visual point sampling at oceanographic sampling stations. Survey transects were undertaken at speeds of 5-10 knots, with fishing activity being conducted at speeds of 2-3 knots. The cetacean observer's survey effort was maximized and optimized during periods of sea state less than or equal to sea state 6 and with visibility of greater than 1km. A total of 159 hours and 16 minutes of visual cetacean survey effort were recorded over the duration of the survey. 147 hours and 45 minutes of survey effort were conducted using a line transect methodology, while 11 hours and 31 minutes of effort were conducted using the point sampling methodology.

A total of 54 sightings were recorded on the survey. Of these 54 sightings, 50 were recorded while conducting line transect watches, while 4 were recorded while conducting point sampling watches. 48 cetacean sightings were recorded during the survey and included 3 dolphin species, 1 species of porpoise, 1 species of baleen whale, 2 species of toothed whale, including 1 species of beaked whale, and a number of sightings which could not be identified to species level. Five pinniped sightings were recorded on the survey, and included both species of pinniped occurring in Irish waters. A single basking shark was also recorded during the survey.

Introduction

Irish waters represent one of the most important marine habitats for cetaceans in Europe (Berrow, 2001) and are utilized by a wide range of cetacean species. The waters of the Irish EEZ consist of an area high in biological productivity within the North-East Atlantic and include widespread areas over shallower continental shelf, deep oceanic waters and waters overlying the continental slope (DEHLG, 2009), providing diverse habitats for a range of cetaceans. At present, there are twenty-five species of cetaceans known to occur in Ireland (Whooley, 2016), along with two species of seals (NPWS, 2013).

In 1937, legal protection for marine mammals in Ireland began with the enactment of the Whale Fisheries Act. The 1976 Wildlife Act provides a legal framework for the conservation of Irish wildlife and their habitats, conferring specific protection on seals, whales, dolphins and porpoises up to 12nmi from the coast (NPWS, 2014). In 1991, the Irish government acknowledged the importance of Irish waters for cetaceans and declared all Irish waters a whale and dolphin sanctuary. The sanctuary covers all waters within the Irish Economic Exclusive Zone (EEZ) which extends 200nmi from the coast (Rogan & Berrow, 1995).

Marine mammals in Ireland are also protected under EC Council Directive (92/43/EEC) on the conservation of natural habitats, and of wild flora and fauna commonly referred to as the EU Habitats Directive. All cetaceans are listed under Annex IV of the Habitats Directive as species requiring strict protection in their natural range (Article 12, EC Council Directive 92/43/EEC). The harbour porpoise (*Phocoena phocoena*) and the bottlenose dolphin (*Delphinus delphis*), together with both seal species occurring in Irish waters, the grey seal (*Halichoerus grypus*) and the common seal (*Phoca vitulina*), are listed in Annex II and further protected under Article 3 of the Directive, as species whose conservation requires the designation of Special Areas of Conservation (SAC).

Despite accounting for 48% of all native mammal species (DEHLG, 2009), the abundance, distribution and conservation status of many of the cetacean species occurring in Irish waters remains poorly understood (NPWS, 2013; *Table 1*). Under the EU Habitats Directive, there is a requirement on member states to conduct surveillance of cetaceans occurring within their waters.

Table 1: Marine mammal species occurring in Irish waters and their conservation status (Sources: Wall et al., 2013; Whooley, 2016; Temple, et al., 2007)

Common name	Scientific name	Occurrence	Conservation Status (IUCN Europe)
Baleen whales			
Humpback whale	<i>Megaptera novaeangliae</i>	May-Aug	Least concern
Blue whale	<i>Balaenoptera musculus</i>	July-March	Endangered
Fin whale	<i>Balaenoptera physalus</i>	All year	Near threatened
Sei whale	<i>Balaenoptera borealis</i>	All year	Endangered
Northern minke whale	<i>Balaenoptera acutorostrata</i>	All year	Least concern
Northern right whale	<i>Eubalaena glacialis</i>	Vagrant	Critical
Bowhead whale	<i>Balaena mysticetus</i>	Data deficient	Not assessed
Toothed whales and dolphins			
Sperm whale	<i>Physeter macrocephalus</i>	All year	Vulnerable
Pygmy sperm whale	<i>Kogia breviceps</i>	Vagrant	Not assessed
Killer whale	<i>Orcinus orca</i>	All year	Data deficient
False killer whale	<i>Pseudorca crassidens</i>	June-Nov	Not assessed
Long-finned pilot whale	<i>Globicephala melas</i>	All year	Data deficient
Cuvier's beaked whale	<i>Ziphius cavirostris</i>	May-Aug	Least concern
Northern bottlenose whale	<i>Hyperoodon ampullatus</i>	May-Aug	Data deficient
Gervais' beaked whale	<i>Mesoplodon europaeus</i>	Vagrant	Data deficient
Sowerby's beaked whale	<i>Mesoplodon bidens</i>	All year	Data deficient
True's beaked whale	<i>Mesoplodon mirus</i>	All year	Data deficient
Beluga	<i>Delphinapterus leucas</i>	Vagrant	Not assessed
Risso's dolphin	<i>Grampus griseus</i>	March-July	Data deficient
Common bottlenose dolphin	<i>Tursiops truncatus</i>	All year	Data deficient
Short-beaked common dolphin	<i>Delphinus delphis</i>	All year	Data deficient
Striped dolphin	<i>Stenella coeruleoalba</i>	May-Sept	Data deficient
White-beaked dolphin	<i>Lagenorhynchus albirostris</i>	All year	Least concern
Atlantic white-sided dolphin	<i>Lagenorhynchus acutus</i>	All year	Least concern
Porpoises			
Harbour porpoise	<i>Phocoena phocoena</i>	All year	Vulnerable
Seals			
Grey seal	<i>Halichoerus grypus</i>	All year	Least concern
Common (harbour) seal	<i>Phoca vitulina</i>	All year	Least concern

Since 1994, several dedicated studies on cetaceans have been conducted in Ireland, providing data on the presence, distribution and abundance of the numerous cetacean species in coastal and offshore waters (e.g. Pollock et al. 1997; Ó Cadhla et al. 2004; Wall et al., 2013; O'Brien, et al., 2016). In recent years, the Marine Institute has facilitated the surveillance of cetaceans in Irish waters by providing berths for cetacean observers onboard the national research vessels, MRV Celtic Explorer and MRV

Celtic Voyager, during oceanographic and fisheries surveys (Oudejans, 2014). Fisheries acoustic surveys are particularly suited to the conduction of cetacean surveys as the vessel spends the majority of the survey travelling at a steady speed along pre-determined survey tracks.

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 (O'Donnell, *et al.*, 2017). Since 2004, Ireland has participated in an International coordinated survey program along with vessels from Norway, Russia, the Netherlands and the Faroes (O'Donnell, *et al.*, 2017). Owing to the highly migratory nature of the stock a large geographical area along the Atlantic margin of the British Isles is surveyed annually, with surveys timed to coincide with peak spawning of the blue whiting stock (O'Donnell, *et al.*, 2017).

The blue whiting acoustic survey provides a unique opportunity for surveillance of cetaceans in the deep water habitats along Ireland's Atlantic margins which can be difficult to reach by other means. The waters of Ireland's Atlantic margin are highly productive owing to the upwelling of nutrient rich oceanic waters, and support large and diverse species' assemblages (Mackey *et al.*, 2004). The availability and distribution of prey is a key factor affecting the distribution of cetaceans, and the complex bathymetry and hydrology of the Atlantic margin maintain a heterogeneous marine environment (MCR, 2011), making it an ideal habitat for cetaceans (Wall *et al.*, 2006).

In order to contribute to its current monitoring regime, the Department of Arts, Heritage and the Gaeltacht (DAHG), through the Marine Institute, commissioned the conduction of a cetacean survey from the MRV Celtic Explorer during the annual Blue Whiting Acoustic Survey (BWAS), running from 20th of March to 9th April 2018.

Methodology

Given the presented survey transects (*Figure 1*), a standard, single platform line transect survey methodology in passing mode was determined to be most suitable and was employed by the cetacean survey team. Survey transects were undertaken at speeds of 5-10 knots, with fishing activity being conducted at speeds of 2-3 knots. The cetacean observer's survey effort was maximized and optimized during periods of sea state less than or equal to sea state 6 and with visibility of greater than 1km. Additional visual point sampling at oceanographic sampling stations and incidental recording was also employed; however line transect survey effort was prioritised by the observers.

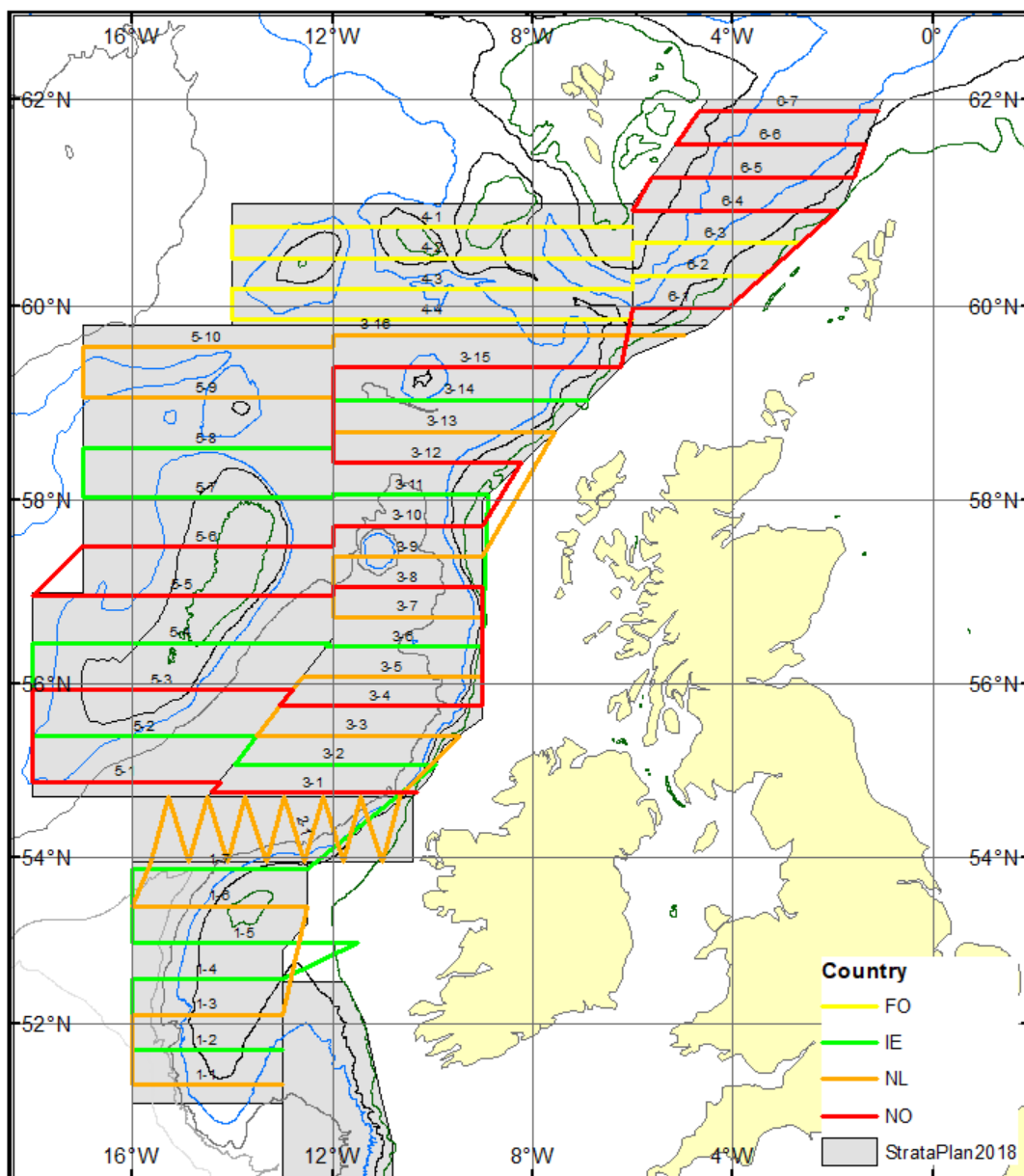


Figure 1: The planned 2018 survey trackline showing individual tracks for participating vessels from Ireland (IE), the Netherlands (NL), Norway (NO) and the Faroes (FO) (Source: Marine Institute, 2017).

Line transect survey methodology

The data collection methodology employed was based on that originally proposed by Tasker *et al.* (1984). Although originally developed as a method for counting seabirds at sea, the method has been adapted to the surveying of cetaceans (Ó Cadhla *et al.* 2004) and has been used extensively in cetacean surveys (Berrow, S. *et al.*, 2011, Hammond, 2013, Ó Cadhla *et al.* 2004, O'Donnell, C., *et al.*, 2015; 2016; 2017; Pollock, *et al.*, 1997, Ryan *et al.* 2010). The method used a standard single platform line transect survey design where one or two, experienced cetacean observers conducted visual watches from an elevated platform during daylight hours.

The observer's survey effort was maximized and optimized during the prevailing hours of daylight. Regular breaks were taken by the observers to avoid observer fatigue and its associated negative consequences. When possible, two observers were preferably 'on effort' conducting visual watches to maximize detection probability, however, this aim was secondary to the optimization of daylight hours and provision of sufficient rest periods.

Survey effort was concentrated in periods of sea state 6 or less and in moderate or good visibility. Survey effort conducted outside of these parameters was recorded as auxiliary effort. Observations for cetaceans was conducted from the crow's nest (deck height 17 m above sea level) or the bridge (deck height 10 m above sea level) depending on weather conditions. Observations were preferably conducted from the crow's nest, as greater platform height increases detection probability (Cominelli, *et al.*, 2016) however, as in previous surveys aboard the R.V. Celtic Explorer, access to the crow's nest was dependent on weather conditions (O'Donnell, *et al.*, 2015; 2016). Survey effort for cetaceans was concentrated within an arc of 60° either side (i.e., to port and to starboard) of the vessel's track-line but all sightings to 90° both side of the track-line and further aft were also recorded. Searching for cetaceans was, predominantly, done with the naked eye, however, Nikon Prostaff 7s 8x42 binoculars and a Canon EOS 7D DSLR camera with a Sigma AF 100-400mm F5-6.3 DG OS HSM telephoto lens were used to confirm parameters such as species identification, group size and behaviour, following Ó Cadhla *et al.* 2004.

Data collection and recording

The IFAW Logger 2000™ (IFAW, 2000) data collection software was configured for optimum use on the survey. Logger was used to record all positional, environmental and sightings data. Using a portable GPS receiver with USB connection, the Logger software automatically recorded the ships position directly into a Microsoft Access database every 10 seconds. The input of environmental data was automatically prompted by Logger every 15 minutes, at which point the cetacean observer input data such as; wind speed, wind direction, sea state, swell, visibility, cloud cover and precipitation. The data was then time stamped by Logger and saved in the Access database. If environmental conditions changed at any point, the cetacean observer on watch input an environmental update of the above listed data. Survey effort start- and end- points, together with any waypoints or other ancillary information (such as line changes, changes in survey activity, other vessel activity, etc.) were also recorded using Loggers' environmental update tab.

The GPS position of each cetacean sighting was time stamped and digitally marked using Logger. The distance of each sighting from the ship was estimated using a fixed interval range finder (Heinemann, 1981), while the bearing from the ship (where the ship's heading = 0°) was estimated with the aid of an appropriately positioned angle board. This data, along with data such as species identification, group size, composition, heading, sighting cues, surfacing interval, behaviour and any associations with birds or other cetaceans (Ó Cadhla *et al.* 2004), was also recorded on the time

stamped Logger sighting record page. Where species identification could not be confirmed, sightings were recorded at an appropriate taxonomic/ confidence level (i.e. probable, possible, unidentified whale, unidentified dolphin etc.).

Sightings were classified in one of the three following categories; 1) Primary Sighting: Any sighting which is initially detected by the observer while 'on effort', 2) Auxiliary Sighting: Any sighting occurring while the cetacean observer is 'on effort' which is initially detected by someone other than the cetacean observer and reported to the cetacean observer at the time of sighting. For all auxiliary sightings, the distance, angle and species identification was confirmed by the cetacean observer, or 3) Incidental sighting: Any sighting recorded while the cetacean observer is 'off effort' or any sighting occurring while the cetacean observer is 'on effort' which has not been independently detected by the cetacean observer and which was not reported to the cetacean observer at the time of the sighting.

Additional visual point sampling was conducted at oceanographic sampling stations. Observation and data recording methodology remained similar for both point sampling and line transect methods, however, as the vessel was stationary, point sampling was conducted irrespective of the ships heading. Survey effort for cetaceans was concentrated within an arc of 180° per observer but all sightings outside this arc were also recorded. The positioning of the 180° arc was selected to minimize environmental factors affecting detection probability (e.g. sun glare) (Palka, 1996; Cominelli, et al., 2016). When the observers were conducting simultaneous point sampling watches, it was possible to cover a full 360° arc around the vessel.

Results

Effort

A total of 159 hours and 16 minutes of visual cetacean survey effort were recorded over the duration of the survey. 147 hours and 45 minutes of survey effort were conducted using a line transect methodology, while 11 hours and 31 minutes of effort were conducted using the point sampling methodology. When possible, continuous watches were conducted from first light until sunset, allowing up to 12 hours and 45 minutes of survey effort daily. No effort watches were conducted on the 27th of March and the 2nd and 3rd of April due to weather conditions exceeding the specified weather limits for observations. Poor weather conditions on the 22nd, 26th and 28th of March and 5th of April resulted in reduced visual survey effort. During these periods of unsuitable environmental conditions, casual 'off effort' watches were conducted by the observers. A graph of daily effort is provided in *Figure 2* below.

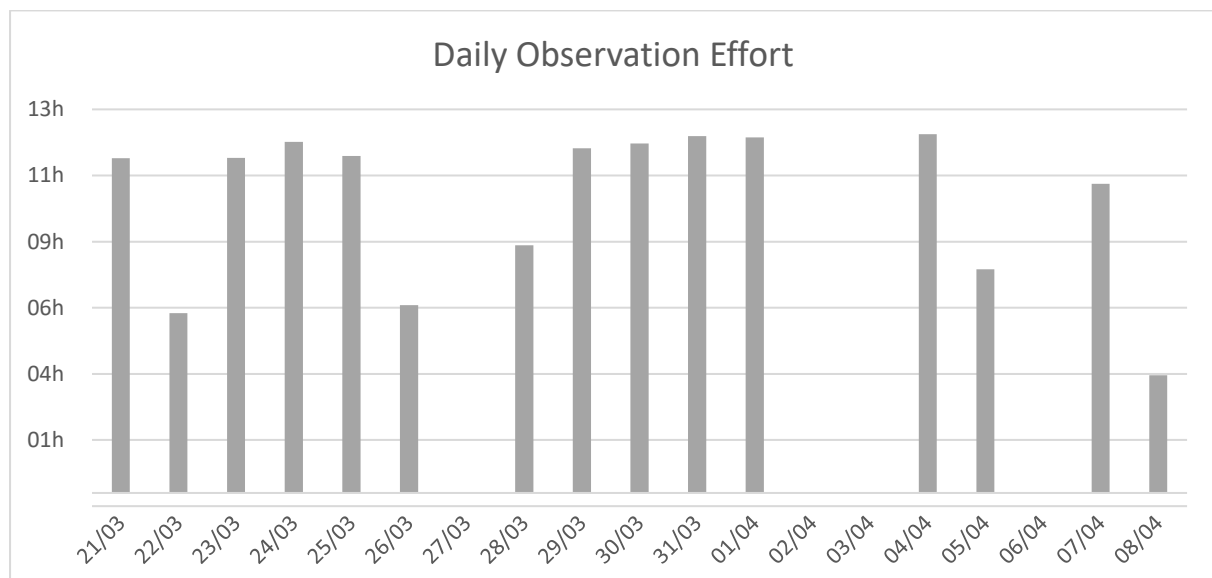


Figure 2: Daily visual effort undertaken during the survey.

Environmental Conditions

Environmental conditions were generally moderate to poor throughout the survey, and on a number of occasions restricted the amount of cetacean survey effort which could be undertaken.

Environmental conditions were recorded a total of 785 times over the course of the survey. A breakdown of key environmental factors recorded during the survey is provided hereunder.

Sea State

Sea state was recorded using both the World Meteorological Organisation (WMO) sea state scale and the Beaufort scale. The WMO scale differs from the Beaufort scale in that it takes account of the

effect of wind, swell and currents (WMO, 2011) on the sea conditions and is judged in terms of height in meters. Beaufort sea state was recorded in terms of Beaufort wind force and was judged based on the effect of the wind and currents on the sea surface. The true wind speed and direction was also recorded hourly using the ships anemometer, the results of which are not presented here.

The most frequently recorded WMO sea state was 4, accounting for over 94 hours (59%) of observation effort. WMO sea state 5 accounted for over 40 hours (26%) of observation effort (Fig. 3).

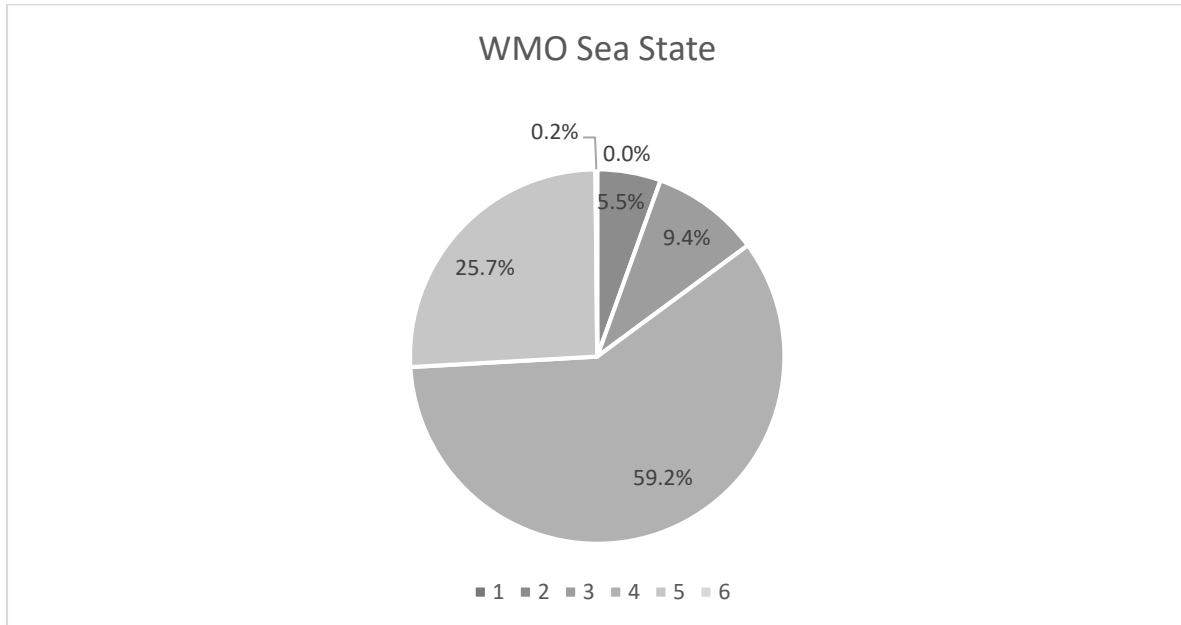


Figure 3: WMO sea state recorded during survey effort.

The most frequently recorded Beaufort sea state was also a sea state 4, accounting for over 56 hours (36%) of survey effort, while sea state 5 accounted for 47 hours (30%) of survey effort. Sea states 3 and 6 were also frequently recorded, accounting for 22 hours (14%) and 23 hours (15%) of recorded conditions respectively (Fig. 4).

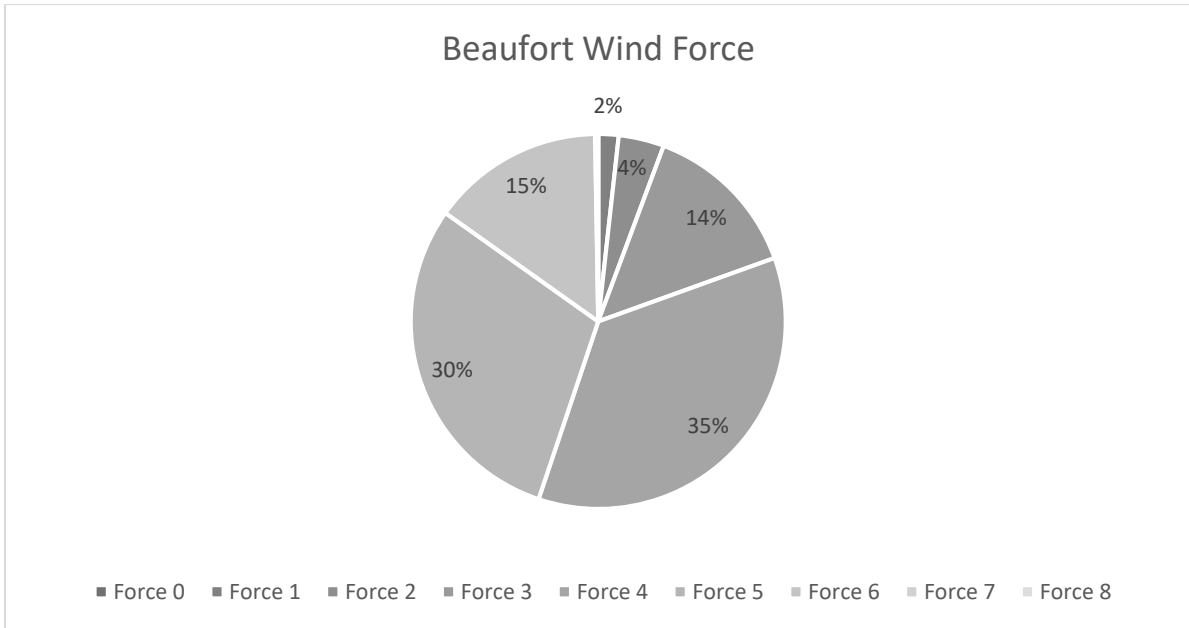


Figure 4: Beaufort sea state recorded during survey effort.

Swell

A swell height of greater than 2 meters was most frequently recorded throughout the survey, being recorded on over 93 hours (59%) of survey effort. A swell height of 1-2 meters accounted for the majority of the remaining survey hours (45 hours / 28%) (Fig. 5).

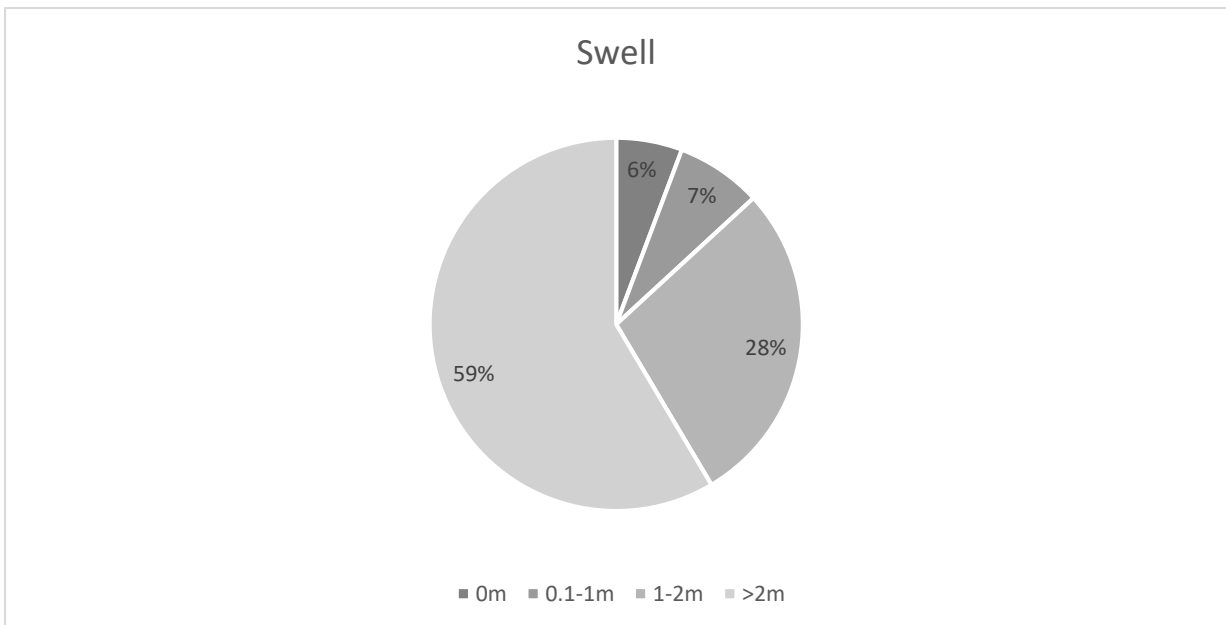


Figure 5: Swell height recorded during survey effort.

Visibility

Visibility was generally very good during cetacean survey effort. The most frequently recorded visibility was 16-20km, being recorded over 72 hours (46%) of survey effort, while visibility of 11-15km was recorded over 67 hours (42%) of survey effort (*Fig. 6*).

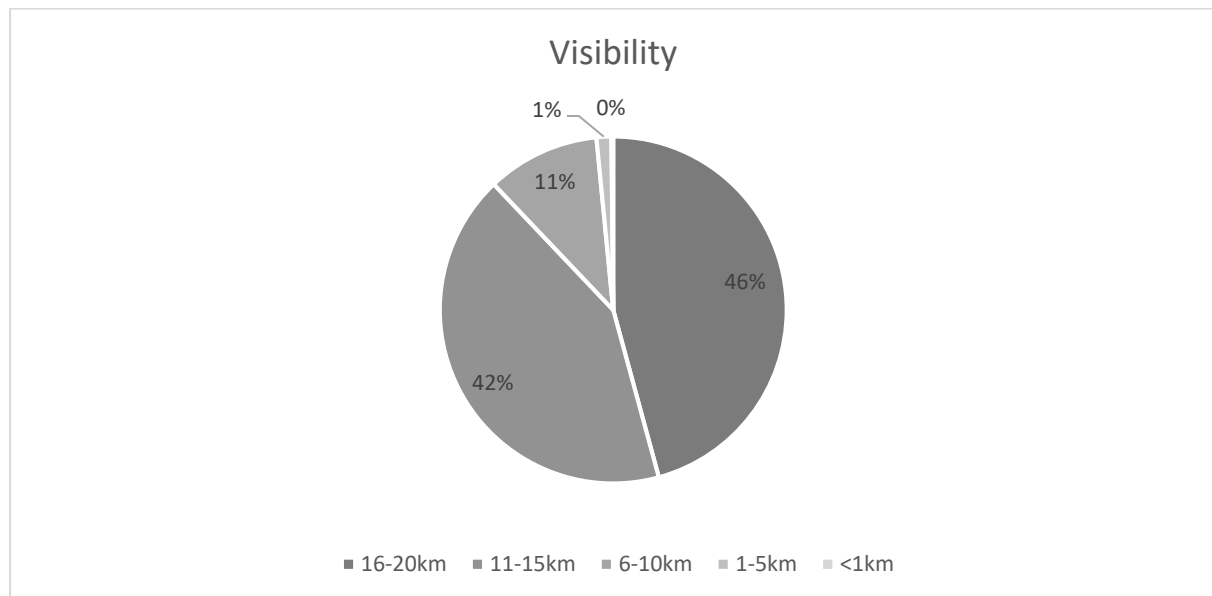


Figure 6: Visibility recorded during survey effort.

Sightings

A total of 54 sightings were recorded on the survey. Of these 54 sightings, 50 were recorded while conducting line transect watches, while 4 were recorded while conducting point sampling watches. A summary of all sightings recorded on the survey is presented in *Table 2* and includes primary, auxiliary and incidental sightings of all megafaunal groups. The distribution of the sightings can be seen in *Figures 7* and *8*.

48 cetacean sightings were recorded during the survey and included 3 dolphin species, 1 species of porpoise, 1 species of baleen whale, 2 species of toothed whale, including 1 species of beaked whale, and a number of sightings which could not be identified to species level.

Five pinniped sightings were recorded on the survey, and included both species of pinniped occurring in Irish waters. 1 species of other marine megafauna, a single basking shark (*Cetorhinus maximus*), was recorded during the survey.

Table 2: Summary of all sightings recorded on the survey, including primary, auxiliary and incidental sightings of all megafaunal groups

Species	Scientific Name	No. of Sightings	No. Of Individuals	Group Size Range
Common dolphin	<i>Delphinus delphis</i>	18	150	1-50
Cuvier's beaked whale	<i>Ziphius cavirostris</i>	1	1	1
Grey seal	<i>Halichoerus grypus</i>	2	2	1
Harbour porpoise	<i>Phocoena phocoena</i>	1	1	1
Long-finned pilot whale	<i>Globicephala melas</i>	6	62	5-25
Minke whale	<i>Balaenoptera acutorostrata</i>	3	3	1
Risso's dolphin	<i>Grampus griseus</i>	1	1	1
Sperm whale	<i>Physeter macrocephalus</i>	9	11	1-2
Unidentified beaked whale		1	2	1
Unidentified cetacean		2	2	1
Unidentified dolphin		5	14	1-8
Unidentified large baleen whale		1	1	1
Phocids				
Common seal	<i>Phoca vitulina</i>	3	3	1
Grey seal	<i>Halichoerus grypus</i>	2	2	1
Other Megafauna				
Basking shark	<i>Cetorhinus maximus</i>	1	1	1
Total		54	254	

The majority of sightings (50) were detected when conducting line transect watches, this included all seal sightings and the basking shark sighting (Table 3). A number of auxiliary sightings occurred during line transect watches. This was the result of a number of other crew members, e.g. sea bird observers, conducting simultaneous watches and reporting observations to the cetacean team. Some incidental sightings were also recorded as line transect sightings, many of these were recorded by the cetacean team during periods of poor weather when casual 'off-effort' watches were conducted.

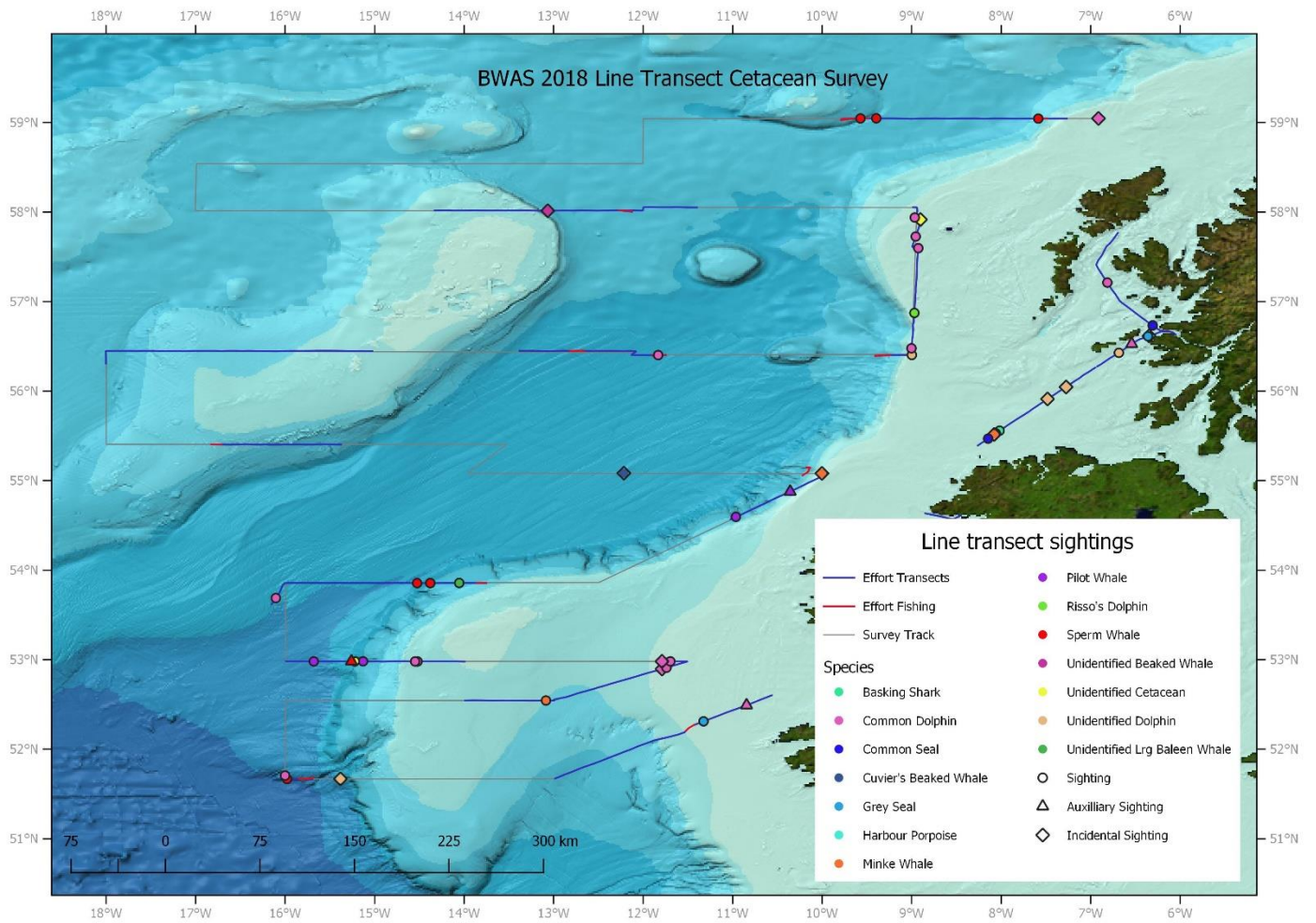
Point sampling was conducted at 15 oceanographic stations (Figure 8). A further 4 sightings were recorded during point sampling watches (Table 4), with no more than 1 sighting being recorded at any single point sampling station. The sightings recorded included 2 primary sightings and 2 auxiliary sightings. Both auxiliary sightings occurred during a point sampling watch where only one cetacean observer was on watch. In these scenarios, the cetacean observer concentrated their effort in an arc of 180° in a direction determined by the observer to be most conducive to observations.

Table 3: Summary of all sightings recorded during line transect effort on the survey, including primary, auxiliary and incidental sightings.

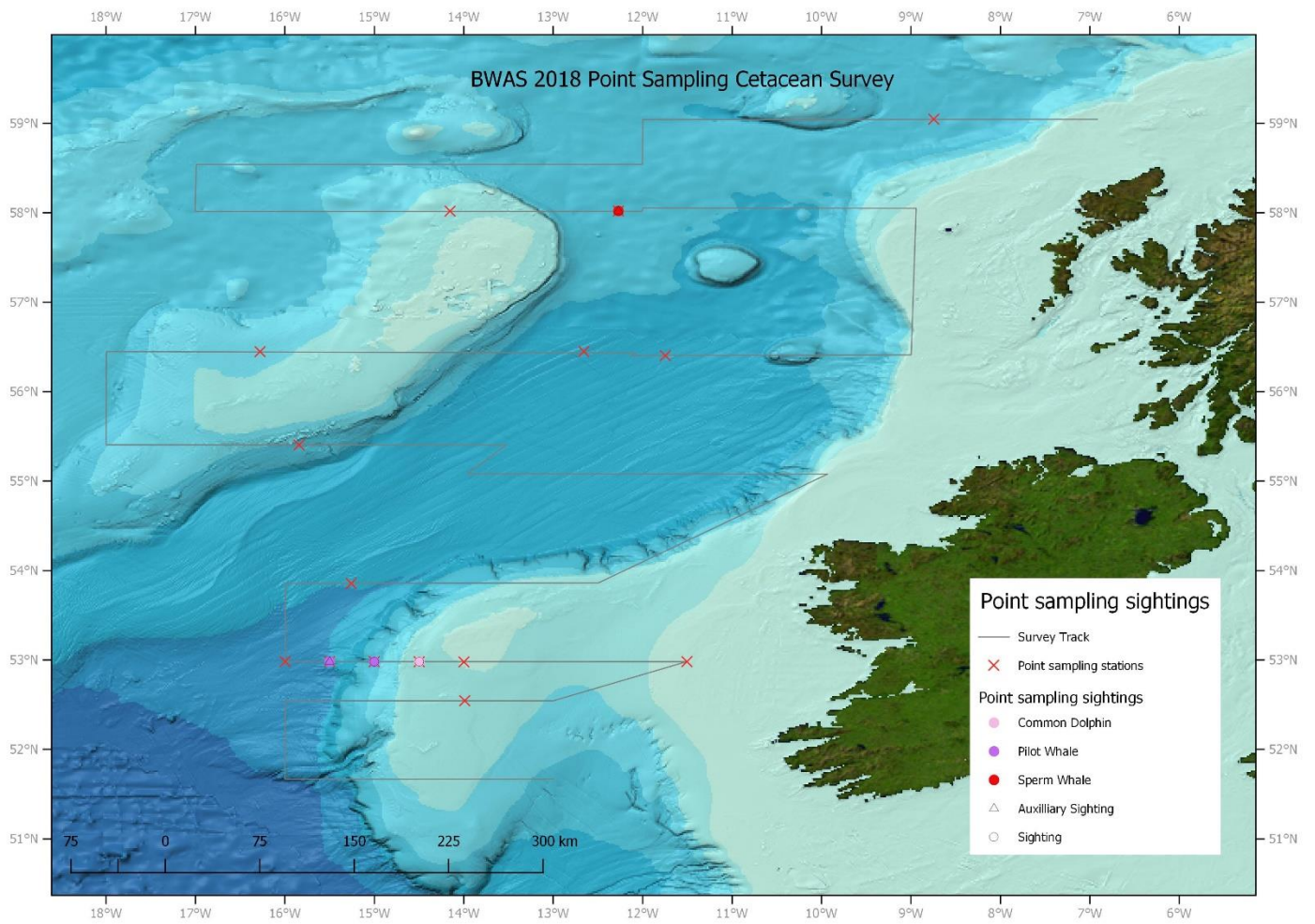
Species	Scientific name	Primary Sightings	Auxiliary Sightings	Incidental Sightings	Total no sightings	Total no. individuals
Common dolphin	<i>Delphinus delphis</i>	12	2	3	17	141
Cuvier's beaked whale	<i>Ziphius cavirostris</i>			1	1	1
Harbour porpoise	<i>Phocoena phocoena</i>			1	1	1
Minke whale	<i>Balaenoptera acutorostrata</i>	1		2	3	3
Long-finned pilot whale	<i>Globicephala melas</i>	3	1		4	29
Risso's dolphin	<i>Grampus griseus</i>	1			1	1
Sperm whale	<i>Physeter macrocephalus</i>	7	1		8	10
Unidentified beaked whale				1	1	2
Unidentified cetacean		1		1	2	2
Unidentified dolphin		2		3	5	14
Unidentified large baleen whale		1			1	1
Phocids						
Common seal	<i>Phoca vitulina</i>	3			3	3
Grey seal	<i>Halichoerus grypus</i>	2			2	2
Other Megafauna						
Basking shark	<i>Cetorhinus maximus</i>	1			1	1

Table 4: Summary of all sightings recorded during point sampling effort on the survey, including primary, auxiliary and incidental sightings.

Species	Scientific name	Primary Sightings	Auxiliary Sightings	Total no sightings	Total no. individuals
Common dolphin	<i>Delphinus delphis</i>	1		1	9
Long-finned pilot whale	<i>Globicephala melas</i>	1	1	2	33
Sperm whale	<i>Physeter macrocephalus</i>		1	1	1



Figures 7: Distribution of all sightings recorded during line transect watches on the survey, including primary, auxiliary and incidental sightings of all megafaunal groups. Transects are categorised as effort conducted while on a standard line transect or effort conducted during fishing operations, and are overlaid on the survey track line.



Figures 8: The location of point sampling stations and the distribution of all sightings recorded during point sampling watches on the survey, including primary, auxiliary and incidental sightings of all megafaunal groups.

Common dolphins (*Delphinus delphis*) were the most frequently encountered and abundant species accounting for 18 sightings (38%), comprising of 150 individuals (60% of all individuals counted). Sightings of common dolphins occurred primarily in continental shelf waters in water depths of less than 200 meters, however a number of sightings were also recorded in deeper waters west of the Porcupine bank and also in the Rockall trough. The observed group size for common dolphins ranged from 1 to 50 individuals, with a mean group size of 8 individuals.

Sperm whales (*Physeter macrocephalus*) were the second most frequently observed species, accounting for 17% of all sightings. Nine sightings were recorded, consisting of a total of 11 individuals. Sperm whales were encountered along continental shelf slopes and also in the deeper waters of the Rockall trough, usually occurring alone or in pairs.

Pilot whales (*Globicephala melas*) were the third most frequently encountered species, accounting for 6 sightings (11%), and the second most abundant species encountered, accounting for 24% of all individuals counted (62 individuals). The observed group size for pilot whales ranged from 5 to 25 individuals, with a mean group size of 10 individuals.

Minke whales (*Balaenoptera acutorostrata*) were encountered on 3 occasions, with each consisting of a single loan individual.

A single sighting of a lone harbour porpoise (*Phocoena phocoena*) was also recorded.

Beaked whales were sighted on 2 separate occasions. One of these sightings was positively identified as a single Cuvier's beaked whale, while the other sighting consisted of a pair of unidentifiable animals. A number of sightings of unidentified dolphin species' also were recorded, as well as a single sighting of an unidentified large baleen whale.

Both species of native pinniped were sighted during the survey. The common seal (*Phoca vitulina*) was sighted on 3 occasions, each sighting comprising of a single individual, while the grey seal (*Halichoerus grypus*) was sighted on 2 occasions, again each sighting comprising of a single individual.

A single basking shark (*Cetorhinus maximus*) was also recorded during the survey.

Discussion

Despite a considerable amount of down time (up to 100 hours of potential survey effort) due to unfavourable weather conditions, a large number of sightings were recorded across a broad range of species' groups. 54 sightings (48 cetacean sightings) were recorded on the survey, consisting of 11 identified species' from taxa including pinnipeds, dolphins, porpoise, baleen whales, toothed whales and elasmobranchs. The poor environmental conditions prevalent during survey effort may have also affected the detection probability of some cetaceans, particularly those with inconspicuous surfacing behaviours (Palka, 1996; Ryan, *et al.*, 2012; Cominelli, *et al.*, 2016). The adverse weather conditions, at times, also hindered the identification to species level of some sightings, as it was often difficult to re-acquire animals following an initial sighting.

The blue whiting survey differs from other annual acoustic surveys in that it is primarily focused on areas west of the continental shelf. As such, it provides a unique opportunity for data collection and surveillance of cetaceans in these deep water environments, which can be difficult to reach by other means.

Despite the amount of time spent in deeper waters, common dolphin remained the most commonly encountered and most abundant species observed. The majority of common dolphin sightings were recorded in shallow shelf

waters, and sightings showed a somewhat clustered distribution. A particularly high density of sightings were recorded in the vicinity of St. Kilda. These sightings were associated with high bird activity, suggesting high prey availability in the area.

Pilot whales were frequently recorded in deeper waters along the continental shelf margins and over the abyssal planes but showed a particularly strong association with the shelf slopes. Continental shelf slopes are known to be highly productive, owing to the upwelling of nutrient rich oceanic waters, and support large and diverse species' assemblages (Mackey et al., 2004). These dynamic areas are likely an important habitat for pilot whales (Wall *et al.*, 2006).

Common dolphins and pilot whales have been frequently recorded on previous blue whiting surveys and have dominated the sightings tally in all previous reports available. The results of this survey concur with previous reports. It should be noted, however, that both common dolphins and pilot whales are known to display attractive movement in response to survey vessels (e.g. SCANS-II), increasing their detection probability. The curious nature of pilot whales was particularly evident at one point sampling station, where a large group of 25 pilot whales remained with the stationary vessel for 45 minutes, frequently spy hopping. The sighting only ended when the vessel moved off on the survey track.

In keeping with previous surveys (*Table 5*), sperm whales were again frequently encountered. A number of the recorded sperm whale sightings occurred in a relatively small area and within a short period of time. On one occasion, 3 sightings consisting of a total of 4 animals were recorded within an area of approximately 10km². These sightings were associated with the continental shelf slope, the presence of the commercial blue whiting fleet, and a substantial blue whiting mark detected, and fished on, by the Celtic Explorer. Sperm whales in the North East Atlantic have been recorded to prey heavily on a range of teleost species (Kawakami, 1980). Sperm whales in these latitudes have been shown to display plasticity in feeding behaviours, indicating they can adapt to food resources, allowing them to exploit wide and variable trophic niches (Teloni, *et al.*, 2004). It is possible that the sperm whales we observed may have been using this seasonally abundant resource as a prey item, either directly or indirectly. However, owing to sperm whales' feeding behaviour, it was not possible to identify feeding behaviours from the observed surface behaviours. Thus further research is required to investigate this possibility.

Beaked whales were encountered on two occasions on this survey, one of these sightings was successfully identified as a Cuvier's beaked whale. Beaked whales have been recorded frequently in low numbers on previous blue whiting surveys. Their detection, however, is severely impacted by adverse sea states (MCR, 2011), thus these species' are likely under recorded. At-sea identification to species level of beaked whales is also difficult (Ryan, *et al.*, 2012) resulting in them often being recorded at higher taxonomic levels.

The recording of 3 individual minke whales was unusual for blue whiting surveys, with only 1 previous record of a minke whale occurring in 2017 (*Table 5*).

The blue whiting survey provides an excellent opportunity for the collection of data on the abundance, distribution and behaviour of cetaceans in Irish waters, particularly the less frequently encountered deep diving species. However, the amount and quality of data collected is confounded by factors such as environmental conditions and cetacean survey design. Poor weather reduced the total number of cetacean survey hours undertaken but also likely affected the detection probability of many species, particularly those with inconspicuous surfacing behaviours (Palka, 1996; Cominelli, *et al.*, 2016). While variation in the number of observers on-watch over survey years, together with variable weather conditions, complicates direct comparison of the reported species abundances. The use of a larger dedicated cetacean team on future surveys could improve data collection and contribute to a more robust dataset, to better inform policy decisions and advance the scientific understanding of cetaceans in Ireland's deep water habitats. The additional use of PAM could have a positive effect on the detection rate and could help over-come some of the issues surrounding the visual detection of beaked whales in poor sea states (MCR, 2011; Ryan, *et al.*, 2012).

Table 5: Cetacean sighting records from Blue Whiting Acoustic Survey from 2004-2018 (O'Donnell et al., 2017; 2015; Oudejans, 2014)

Year	2018	2017	2015	2014	2013	2011	2009	2008	2006	2005
Species										
Common dolphin	18 (150)	6 (37)	6 (215)	3 (10)	7 (103)	23 (78)	5 (46)	2 (151)		1 (150)
Long-finned pilot whale	6 (62)	2 (9)	6 (35)	16 (97)	9 (67)	3 (20)	1 (15)	16 (132)	5 (53)	4 (40)
Bottlenose dolphin		1 (8)	2 (14)	1 (10)	3 (26)			1 (7)		
Sperm whale	9 (11)	2 (5)		6 (7)	3 (17)		7 (14)	3 (5)		1 (1)
Fin whale		2 (3)			1 (1)					
Killer whale					1 (6)					
Minke whale	3 (3)	1 (1)								
Sowerby's beaked whale					1 (3)			1 (3)		
Cuvier's beaked whale	1 (1)				1 (5)		1 (1)			
Northern bottlenose whale										1 (2)
Risso's dolphin	1 (1)					1 (5)				
White-beaked dolphin										2 (-)
White-sided dolphin		1 (1)						3 (18)		
Harbour porpoise	1 (1)				1 (4)	1 (1)	2 (5)			
Unidentified large baleen whale	1 (1)	1 (1)			7 (8)	1 (1)		1 (1)		
Unidentified whale								1 (2)		
Unidentified beaked whale	1 (2)	1 (1)		1 (1)						1 (1)
Unidentified dolphin	5 (14)		1 (1)	2 (11)	2 (11)	2 (8)		3 (18)		
Unidentified small whale				1 (1)	2 (2)			2 (2)		
Unidentified cetacean	2 (2)				1 (3)					2 (-)
Total	48 (248)	20 (70)	15 (265)	31 (138)	39 (256)	32 (114)	16 (81)	33 (339)	5 (53)	12 (193)

Recommendations

An increase to the number of cetacean observers on-board would be recommended for this survey. Four cetacean observers on-board would be more a more suitable number in order to cover full daylight hours, Four cetacean observers would be able to provide the services of two cetacean observers on-effort at all times, while one observer records data and the fourth is on a break. This would facilitate more sufficient coverage, which should increase the chances of detecting animals, while also ensure that all cetacean observers get sufficient breaks/periods of rest when covering full daylight hours. Sufficient breaks/periods of rest are highly important for cetacean observers for maintaining full concentration during all effort times and not becoming at risk of suffering fatigue.

It would also be recommended to incorporate PAM into the survey design. Given the survey tracks, the BWAS is an ideal survey for collecting data on deep diving species such as beaked whales and sperm whales. However, given the time of year, weather conditions are not always conducive to visual observations, particularly for inconspicuous beaked whales. The addition of PAM would be an excellent supplement to visual observations and would remove all down time due to weather as PAM can collect data irrespective of all but the most severe weather. Furthermore, the use of PAMguards Logger forms would allow a single cetacean observer to act as both PAM operator and data recorder simultaneously. The quantity and quality of data collected could thereby be greatly increased with the use of only four cetacean observers.

Acknowledgments

The cetacean observers would like to thank Captain Anthony Hobin, and chief scientist, Graham Johnston, along with the crew of the Celtic Explorer for their support and professional conduct during the survey.

The cetacean observers would also like to thank the marine, and galley crew, for their hospitality, and also the marine crew for providing the cetacean observers with access to the bridge.

Finally, the cetacean observers wish the RV *Celtic Explorer*, the Explorer crew and the Marine Institute staff all the best for future surveys. Both, the Explorer crew and the Marine Institute staff have been a pleasure to work with and the cetacean observers look forward to future collaborations.

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This project or operation is part supported by the Irish government and the European Maritime & Fisheries Fund as part of the EMFF Operational Programme for 2014-2020



An Roinn Talmhaíochta,
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Department of Agriculture,
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EUROPEAN UNION
This measure is part-financed
by the European Maritime
and Fisheries Fund



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