

Marine Institute Seabird Monitoring

During the Celtic Sea Herring Acoustic Survey

10th - 28th October 2019

Lead Agency: Marine Institute

Lead Partners: National Parks and Wildlife Service,

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Executive Summary

Irish waters represent one of the most important marine habitats for seabirds in Europe and are utilized by a wide range of seabird species. However, the at-sea abundance and distribution of many of the seabird species occurring in Irish waters remains poorly understood. Under the EU Birds Directive, there is a requirement on member states to conduct surveillance of seabirds occurring within their waters. The Department of Arts, Heritage and the Gaeltacht (DAHG), through the Marine Institute, commissioned a seabird survey from the MRV Celtic Explorer during the annual Celtic Sea Herring Acoustic Survey (CSHAS), running from the 10th to the 28th of October 2019.

A standard line transect survey methodology was employed by the seabird survey team with additional visual point sampling at fishing locations and 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 seabird observer's survey effort was maximized and optimized during periods of sea state less than or equal to sea state 6 and with visibility of greater than 300m. A total of 117 hours and 33 minutes of survey effort was conducted over the course of the CSHAS 2019 survey. In total, 96 hours and 9 minutes of survey effort were conducted using a line transect methodology, while 15 hours and 42 minutes of effort were conducted using the point sampling methodology. A further 5 hours and 41 minutes of effort were conducted as a casual watch.

A total of 4219 seabird sightings were recorded throughout the survey, totalling 28110 individuals, with flock size ranging from 1 up to 1000 for some species. In total, 12476 seabirds were recorded as "in transect", while 15634 were recorded "off transect". The species encountered included 32 species from 9 families. A further 25 sightings of terrestrial birds were also recorded, comprising of 85 individuals.

Introduction

Irish waters represent one of the most important marine habitats for seabirds in Europe and are utilized by a wide range of seabird species (Mackey, *et al.*, 2004; Mitchell, *et al.*, 2004; Pollock, *et al.*, 1997). 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 seabirds. Ireland's rugged and exposed coastline provide ample and diverse nesting habitats for a range of seabirds, and Ireland's coast hosts a number of large seabird colonies of significance at a European level (Mackey, *et al.*, 2004). At present, there are twenty-four species of seabirds known to breed in Ireland (Mitchell, *et al.*, 2004; *Table 1*).

In 1930, legal protection for birds, including most seabird species, in Ireland began with the enactment of the Wild Birds (Protection) Act. The 1976 Wildlife Act provides a legal framework for the conservation of Irish wildlife and their habitats, conferring specific protection on all bird species, including seabirds, from death, injury or disturbance at nest sites.

Seabirds in Ireland are also protected under EC Council Directive (2009/147/EEC) on the conservation of birds commonly referred to as the EU Birds Directive. The Birds Directive relates to the conservation of all wild bird species occurring in EU member states, it covers the protection and management of the birds, their nests, eggs and habitat, and mandates the creation of Special Protection Areas (SPAs) (Article 3, EC Council Directive 2009/147/EEC). A number of seabirds are listed under Annex I of the Birds Directive as species requiring special conservation measures concerning their habitat in order to ensure their survival in their natural range (Article 4, EC Council Directive 2009/147/EEC). Since 1993 the EU has funded Species Action Plans for species listed in Annex 1 of the Birds Directive, including the Balearic shearwater (*Puffinus mauretanicus*) and roseate tern (*Sterna dougallii*), providing key information on the status, ecology and threats to species as well as key steps to ensure their conservation. Seabirds gain further protection under the 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, through the establishment of the 'Natura 2000' network; a coherent network of SPAs and Special Areas of Conservation (SACs). Article 6 of the Habitats Directive defines how Natura 2000 sites are managed and protected, and establishes the requirement to conduct appropriate assessments in Natura 2000 sites before plans or projects likely to impact the site are conducted.

Ireland is also a signatory to the Bern convention on the conservation of European wildlife and natural habitats, the Bonn convention on the conservation of migratory species of wild animals, and the OSPAR convention for the protection of the marine environment in the North-East Atlantic, each affording further protection to seabirds.

Despite the importance Ireland holds for nesting and feeding seabirds, quantitative data on the population status and distribution, particularly the at sea distribution, of many of the seabird species occurring in Ireland remains poorly understood (Mackey, *et al.*, 2004). Under the EU Birds Directive, there is a requirement on member states to identify and classify habitats for the establishment of SPAs for seabirds, including foraging habitats within their waters.

Table 1: Breeding seabird numbers in Ireland and Britain 1998-2002 as recorded during the Seabird 2000 census and percentage change in numbers since The Seabird Colony Register (SCR) 1985-1988 (Source: Mitchell, et al., 2004).

<i>Species</i>	<i>Latin name</i>	<i>Northern Ireland</i>	<i>Republic of Ireland</i>	<i>All- Ireland total</i>	<i>GB & Ireland Total</i>	<i>Percentage change since SCR Census (1985-88)¹</i>
Fulmar	<i>Fulmarus glacialis</i>	5,992	32,918	38,910	537,991	0%
Manx Shearwater ²	<i>Puffinus puffinus</i>	4,633	32,545	37,178	332,267	
European Storm petrel ²	<i>Hydrobates pelagicus</i>	0	99,065	99,065	124,775	
Leach's Storm petrel ²	<i>Oceanodroma leucorhoa</i>	0	310	310	48,357	
Gannet	<i>Sula bassana</i>	0	32,758	32,758	259,311	39%
Cormorant	<i>Phalacrocorax carbo</i>	663	4,548	5,211	13,681	7%
Shag	<i>Phalacrocorax aristotelis</i>	301	3,426	3,727	32,306	-25%
Arctic Skua	<i>Stercorarius parasiticus</i>	0	0	0	2,136	-37%
Great Skua	<i>Stercorarius skua</i>	0	1	1	9,635	26%
Mediterranean Gull	<i>Larus melanocephalus</i>	2	3	5	113	
Black-headed Gull	<i>Larus ridibundus</i>	10,107	3,876	13,983	141,890	2%
Common Gull	<i>Larus canus</i>	557	1,060	1,617	49,780	39%
Lesser Black-backed Gull	<i>Larus fuscus</i>	1,973	2,876	4,849	116,684	42%
Herring Gull	<i>Larus argentatus</i>	714	5,521	6,235	149,177	-17%
Great Black-backed Gull	<i>Larus marinus</i>	76	2,243	2,319	19,713	-6%
Kittiwake	<i>Rissa tridactyla</i>	13,060	36,100	49,160	415,995	-23%
Sandwich Tern	<i>Sterna sandvicensis</i>	1,954	1,762	3,716	14,252	-11%
Roseate Tern	<i>Sterna dougallii</i>	4	734	738	790	44%
Common Tern	<i>Sterna hirundo</i>	1,704	2,485	4,189	14,497	-2%
Arctic Tern	<i>Sterna paradisaea</i>	767	2,735	3,502	56,123	-29%
Little Tern	<i>Sterna albifrons</i>	0	206	206	2,153	-25%
Guillemot	<i>Uria aalge</i>	98,546	138,108	236,654	1,559,484	32%
Razorbill ³	<i>Alea torda</i>	24,084	27,446	51,530	216,087	23%
Black Guillemot ⁴	<i>Cephus grylle</i>	1,174	3,367	4,541	42,683	
Atlantic Puffin	<i>Fratercula arctica</i>	1,610	19,641	21,251	600,751	19%

¹ inland colonies were not surveyed during the SCR Census (1985-88)

² not surveyed during the SCR Census (1985-88)

³ counts of individuals

⁴ counts of pre-breeding adults; pre-breeding surveys were not conducted in the Republic of Ireland during the SCR Census (1985-88).

Since 1994, a number of dedicated studies on seabirds have been conducted in Ireland, providing data on the presence, distribution and abundance of the numerous seabird species in coastal and offshore waters (e.g. Pollock et al. 1997; Mackey, et al., 2004; O'Brien, et al., 2016). In recent years, the Marine Institute has facilitated the surveillance of seabirds in Irish waters by providing berths for seabird observers on-board the national research vessels, *RV Celtic Explorer* and *RV Celtic Voyager*, during oceanographic and fisheries surveys (O'Donnell, et al., 2016a; 2017a; 2018a). Fisheries acoustic surveys are particularly suited to the conduction of seabird surveys as the vessel spends the majority of the survey travelling at a steady speed along pre-determined survey tracks.

The CSHAS is an acoustic survey undertaken by the Fisheries Ecosystems Advisory Services (FEAS) department of the Marine Institute of Ireland to determine an age stratified relative abundance of herring (*Clupea harengus*) within the survey area as part of a national stock assessment. CSHAS also aims to determine estimates of biomass and abundance of sprat (*Sprattus sprattus*) within the survey area (O'Donnell, et al., 2018a).

The survey has been undertaken annually since 1989 and since 2004 has been fixed in October and carried out on the *RV Celtic Explorer*. Since 2016 the CSHAS survey has used an updated survey design, covering an extended area of the Celtic sea with each survey employing parallel transects spaced equally at 8 nautical miles, beginning in an east-west fashion for an initial pass of the survey area before a second pass is conducted in a west-east fashion at a 4 nautical mile offset. The survey also incorporates secondary high resolution adaptive surveys focusing on areas of high abundance (O'Donnell, et al., 2016a; 2017a; 2018a).

The CSHAS provides a unique opportunity for surveillance of the autumn distribution of seabirds in shelf water habitats along Ireland's Celtic sea 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 seabirds, and the complex bathymetry and hydrology of the Atlantic margin maintain a heterogeneous marine environment, making it a key habitat for seabirds (Mackey et al., 2004).

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 seabird survey from the *RV Celtic Explorer* during the annual Celtic Sea Herring Acoustic Survey (CSHAS), running from the 10th to the 28th of October 2019.

Methodology

The seabird survey was conducted from the 10/10/19 to the 28/10/19 using a team of two seabird surveyors per survey leg. The lead seabird observer conducted visual survey effort, while the other seabird observer was responsible for data collection and recording. Given the presented survey transects for the 2018 survey (*Figure 1*), a standard line transect survey methodology was determined to be most suitable and was employed by the seabird survey team. Survey transects were undertaken at speeds of 5-10 knots, with fishing activity being conducted at speeds of 2-3 knots.

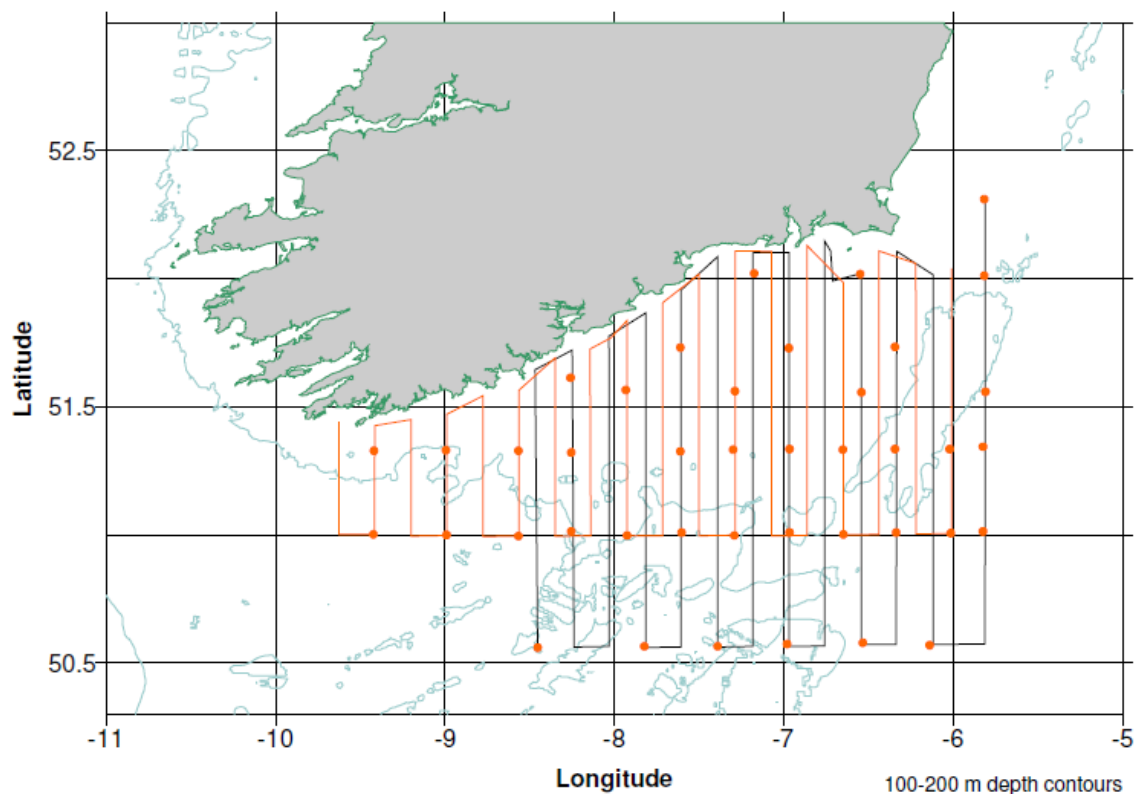


Figure 1: The CSHAS 2018 cruise track (Source: Marine Institute, 2019).

Visual survey watches were conducted using a standard line transect survey design while the vessel was travelling at a consistent speed and heading. Additional visual point sampling (e.g., at oceanographic sampling stations or fishing stations) was also employed, however line transect survey effort was prioritised by the observer. The observer's survey effort was maximized and optimized during periods of sea state less than or equal to sea state 6 and with visibility of greater than 300m. Regular breaks were taken by the observer to avoid observer fatigue and its associated negative consequences.

Observations for seabirds were conducted from the monkey island (deck height 12 m above sea level) or the bridge (deck height 10 m above sea level). Observations were conducted from the monkey island preferably, however, as in previous surveys aboard the R.V. Celtic Explorer, access to the monkey island was dependent on weather conditions.

Line transect survey methodology

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

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

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

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

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

Data collection and recording

The Cybertracker (<https://cybertracker.org>) data collection software package (Version 3.501) was configured for optimum use on the survey. Cybertracker was used to record all positional, environmental and sightings data. Using a portable GPS receiver with USB connection, the Cybertracker software automatically recorded the ships position directly into a Microsoft Access database every 5 seconds.

Environmental data was regularly recorded using Cybertracker, including at the start of each seabird survey transect, and included data such as; wind speed, wind direction, sea state, swell, visibility, cloud cover and precipitation. The data was time stamped with GPS data by Cybertracker and saved

in the Access database. If environmental conditions changed at any point, the seabird observers recorded an environmental update of the above listed data. Each line transect was assigned a unique transect number, and a new transect was started anytime the vessel activity changed (i.e. changing from on-transect to inter-transect). Each subsequent sighting was also assigned to this unique transect number. Ancillary information (such as line changes, changes in survey activity, other vessel activity, etc.) were also recorded on Cybertracker.

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

Additional visual point sampling was conducted at oceanographic sampling stations and fishing shoot/haul locations. Point sampling survey effort for seabirds was conducted in 360° arc around the vessel. Data recording methodology remained similar for both point sampling and line transect methods.

Results

Effort

A total of 117 hours and 33 minutes of survey effort was conducted over the course of CSHAS 2019. In total, 96 hours and 9 minutes of survey effort were conducted using a line transect methodology, while 15 hours and 42 minutes of effort were conducted using the point sampling methodology. A further 5 hours and 41 minutes of effort were conducted as a casual watch.

The observer's survey effort was maximized and optimized during the prevailing hours of daylight. The maximum recorded daily survey effort was 7 hours and 27 minutes while the average daily survey effort was 6 hours and 4 minutes. No effort watches were conducted on the 19th of October due to a port call for a crew change. Seabird survey effort was greatly reduced on the 18th of October due to weather conditions exceeding the specified weather limits for observations. Seabird survey effort was also restricted on the 28th of October due to transiting from the survey area in the Celtic sea back to port in Galway. During this transit a number of casual watches were conducted by the observers. A graph of daily effort is provided in *Figure 2* below.

On a number of occasions throughout the survey, the vessel conducted intensive mini surveys over key herring habitats. During these mini surveys the seabird survey methodology was adjusted to accommodate the shorter and more closely spaced transect lines by reducing the transect strip width and/or decreasing the snap shot frequency.

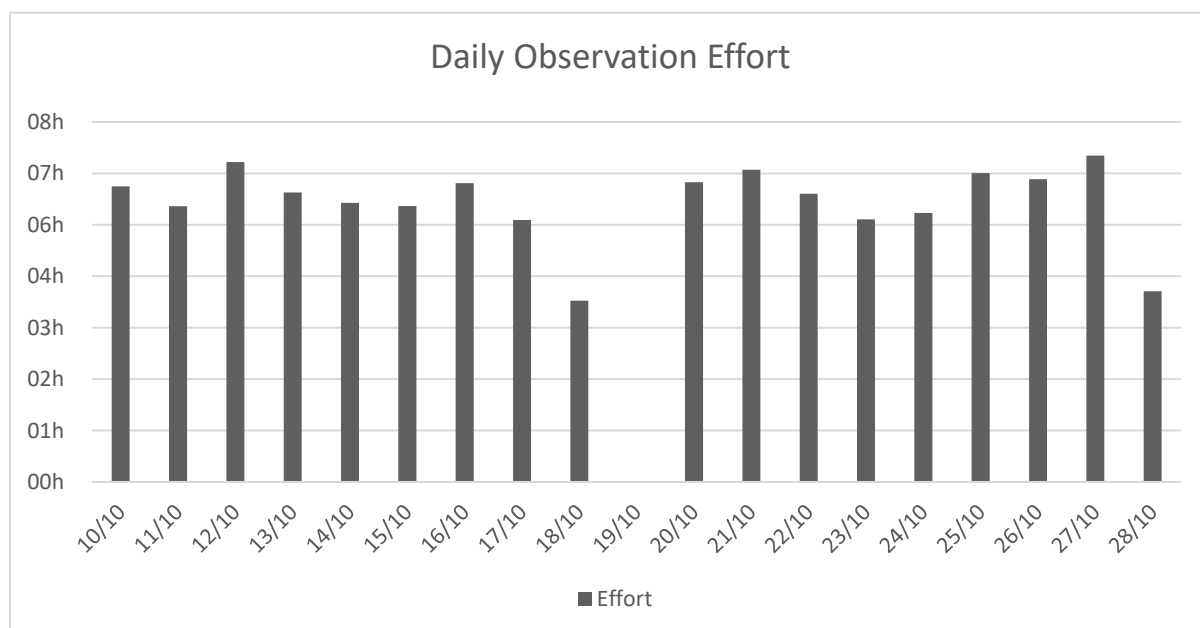


Figure 2: Daily visual effort undertaken during the survey.

Environmental Conditions

Environmental conditions were generally moderate to good throughout the survey, however, on a number of occasions seabird survey effort was restricted due to environmental conditions. 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 takes account of the effect of wind, swell and currents (WMO, 2011) on the sea conditions and was judged in terms of the total state of agitation of the sea with wave height in meters used as an additional guide. Beaufort sea state was recorded in terms of Beaufort wind force and was judged based on the effect of the wind on the sea surface.

WMO sea states 2, 3 and 4 were the most common sea states recorded. The most frequently recorded WMO sea state was 4 (moderate), accounting for over 48 hours (41%) of observation effort. WMO sea state 3 accounted for over 25 hours (21%) of observation effort, while WMO sea state 2 accounted for over 20 hours (17%) (*Fig. 3a*).

The most frequently recorded Beaufort sea state was a sea state 3, accounting for over 33 hours (29%) of survey effort, while sea state 2 accounted for 23 hours (20%) of survey effort. Beaufort sea state 4 was also frequently recorded, accounting for 18 hours (16%) of survey effort (*Fig. 3b*).

Swell

A swell height of 1.1-2 meter was most frequently recorded throughout the survey, being recorded on over 46 hours (39%) of survey effort. A swell height of 0.1-1 meters was recorded over almost 38 survey hours (32%), while swell of over 2 meters was recorded over 27 hours (24%) (*Fig. 3c*).

Visibility

Visibility was generally very good during seabird survey effort. The most frequently recorded visibility was 11-15km, being recorded over 89 hours (76%) of survey effort, while visibility of 6-10km was recorded over 13 hours (11%) of survey effort (*Fig. 3d*).

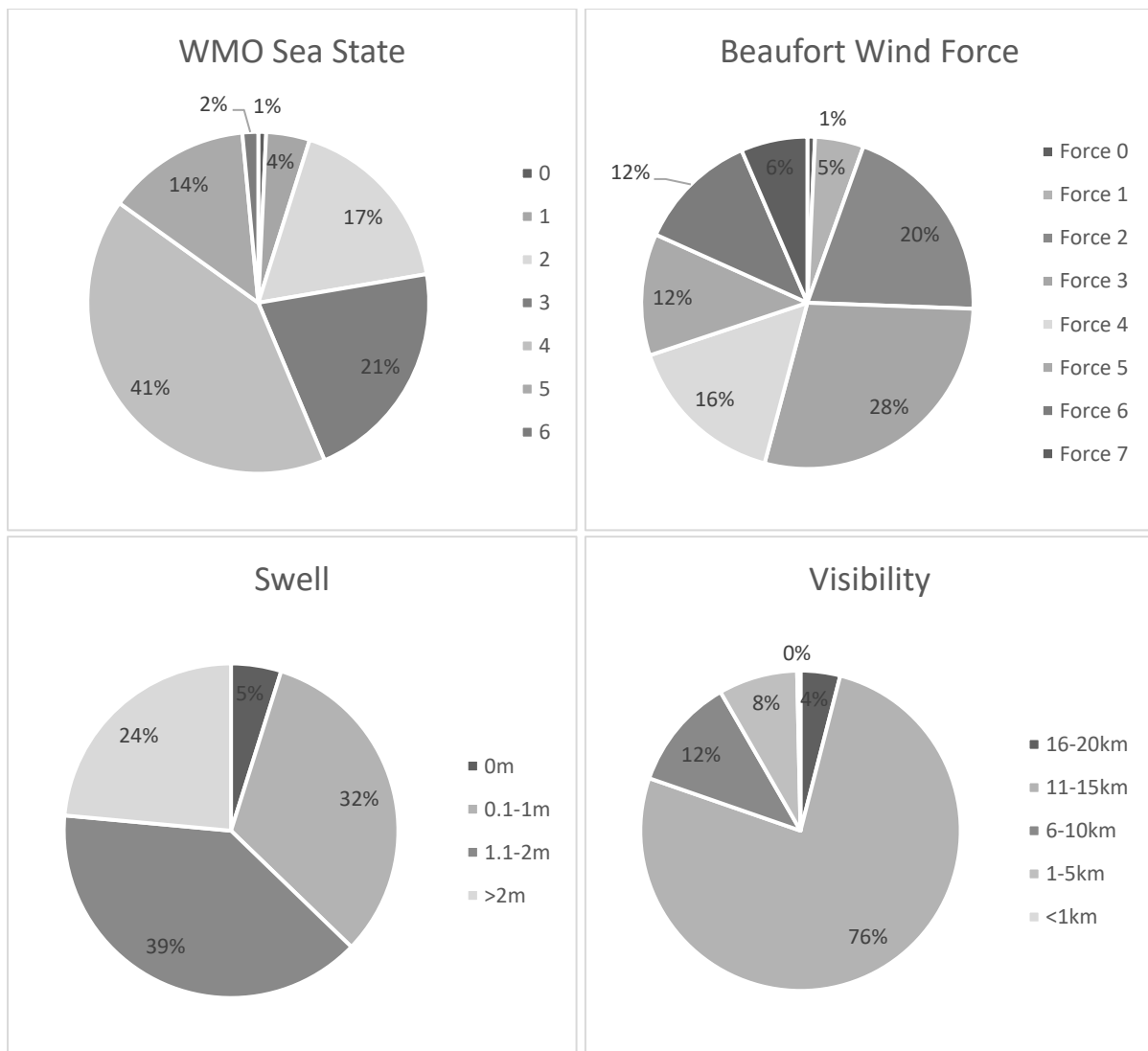


Figure 3: Summary of environmental conditions recorded on the CSHAS 2019; a) WMO sea state, b) Beaufort sea state/ wind force, c) Swell height (meters), d) Visibility (kilometres).

Sightings

A total of 4219 seabird sightings were recorded throughout the survey, totalling 28110 individuals, with flock size ranging from 1 up to 1000 for some species (*Table 2*). In total, 12476 seabirds were recorded as “in transect” during line transect survey effort. A summary of all sightings recorded on the survey is presented in *Table 2* and includes sightings recorded during both line transect and point sampling watches. A total of 30 species of seabird were encountered during the survey. A further 25 sightings of terrestrial birds were also recorded, comprising of 85 individuals belonging to 16 species’.

Of the 4219 sightings recorded during the survey, 3935 were recorded during line transect effort. All 32 seabird species recorded during the survey were recorded during line transect survey effort. In total, 23629 seabirds were recorded during line transect effort, with 12473 of these recorded as ‘in-transect’. The remaining 11156 seabirds were recorded as ‘off-transect’. A breakdown of all species encountered during line transect effort watches is presented in *Table 3*.

The distribution of all sightings of seabird species recorded during line transect survey effort can be seen in *Figures 4 to 6*.

Table 2: Summary of all seabird sightings recorded on the survey during both line transect and point sampling watches.

Common Name	Species name	No. of Sightings	No. of Individuals	Group Size
Fulmar	<i>Fulmarus glacialis</i>	403	2605	1-1000
Balearic Shearwater	<i>Puffinus mauretanicus</i>	4	4	1
Great Shearwater	<i>Puffinus graves</i>	2	2	1
Sooty Shearwater	<i>Puffinus griseus</i>	46	83	1-10
Manx Shearwater	<i>Puffinus puffinus</i>	42	77	1-8
Storm Petrel	<i>Hydrobates pelagicus</i>	13	19	1-3
Petrel sp.	<i>Hydrobatidae sp.</i>	1	1	1
Gannet	<i>Morus bassanus</i>	861	6903	1-800
Pomarine Skua	<i>Stercorarius pomarinus</i>	18	24	1-5
Arctic Skua	<i>Stercorarius parasiticus</i>	28	32	1-2
Long-tailed Skua	<i>Stercorarius longicaudus</i>	2	3	1-2
Great Skua	<i>Stercorarius skua</i>	139	205	1-14
Mediterranean gull	<i>Larus melanocephalus</i>	6	7	1-2
Common Gull	<i>Larus canus</i>	63	282	1-100
Sabine's gull	<i>Larus sabini</i>	2	2	1
Black-headed Gull	<i>Larus ridibundus</i>	7	10	1-3
Lesser Black-backed Gull	<i>Larus fuscus</i>	115	1320	1-500
Herring Gull	<i>Larus argentatus</i>	35	103	1-30
Yellow-legged gull	<i>Larus michahellis</i>	5	5	1
Great Black-backed Gull	<i>Larus marinus</i>	90	366	1-50
Kittiwake	<i>Rissa tridactyla</i>	623	7001	1-600
Gull sp.	<i>Laridae sp.</i>	7	319	1-200
Sandwich tern	<i>Sterna sandvicensis</i>	2	7	3-4
Common Tern	<i>Sterna hirundo</i>	2	3	1-2
Arctic Tern	<i>Sterna paradisaea</i>	2	2	1
Guillemot	<i>Uria aalge</i>	1331	7027	1-200
Razorbill	<i>Alea torda</i>	321	1027	1-40
Razorbill / Guillemot	<i>Alea torda / Uria aalge</i>	20	616	9-60
Little Auk	<i>Alle alle</i>	1	1	1
Atlantic Puffin	<i>Fratercula arctica</i>	21	39	1-6
Cormorant	<i>Phalacrocorax carbo</i>	3	3	1-3
Great Northern Diver	<i>Gavia immer</i>	3	11	1-9
Red-throated diver	<i>Gavia stellata</i>	1	1	1
	Total	4219	28110	

Table 3: Summary of all seabird sightings recorded during line transect effort on the survey.

Common Name	Species name	No. of Sightings	No. of Seabirds	In Transect	Off Transect
Fulmar	<i>Fulmarus glacialis</i>	385	2407	496	1911
Balearic Shearwater	<i>Puffinus mauretanicus</i>	1	1	0	1
Great Shearwater	<i>Puffinus graves</i>	1	1	1	0
Sooty Shearwater	<i>Puffinus griseus</i>	39	66	24	42
Manx Shearwater	<i>Puffinus puffinus</i>	37	68	32	36
Storm Petrel	<i>Hydrobates pelagicus</i>	12	18	9	9
Petrel sp.	<i>Hydrobatidae sp.</i>	1	1	0	1
Gannet	<i>Morus bassanus</i>	813	4640	1723	2917
Pomarine Skua	<i>Stercorarius pomarinus</i>	13	19	7	12
Arctic Skua	<i>Stercorarius parasiticus</i>	19	21	8	13
Long-tailed Skua	<i>Stercorarius longicaudus</i>	2	3	3	0
Great Skua	<i>Stercorarius skua</i>	117	165	42	123
Mediterranean gull	<i>Larus melanocephalus</i>	6	7	3	4
Common Gull	<i>Larus canus</i>	59	238	39	199
Sabine's gull	<i>Larus sabini</i>	1	1	1	0
Black-headed Gull	<i>Larus ridibundus</i>	3	3	0	3
Lesser Black-backed Gull	<i>Larus fuscus</i>	96	494	142	352
Herring Gull	<i>Larus argentatus</i>	30	69	15	54
Yellow-legged gull	<i>Larus michahellis</i>	2	2	0	2
Great Black-backed Gull	<i>Larus marinus</i>	76	265	95	170
Kittiwake	<i>Rissa tridactyla</i>	588	6409	2555	3854
Gull sp.	<i>Laridae sp.</i>	6	318	75	243
Sandwich tern	<i>Sterna sandvicensis</i>	2	7	3	4
Common Tern	<i>Sterna hirundo</i>	2	3	1	2
Arctic Tern	<i>Sterna paradisaea</i>	2	2	1	1
Guillemot	<i>Uria aalge</i>	1298	6874	6094	780
Razorbill	<i>Alea torda</i>	278	864	505	359
Razorbill / Guillemot	<i>Alea torda / Uria aalge</i>	20	616	586	30
Little Auk	<i>Alle alle</i>	1	1	0	1
Atlantic Puffin	<i>Fratercula arctica</i>	19	32	12	20
Cormorant	<i>Phalacrocorax carbo</i>	2	2	0	2
Great Northern Diver	<i>Gavia immer</i>	3	11	1	10
Red-throated diver	<i>Gavia stellata</i>	1	1	0	1
	Total	3935	23629	12473	11156

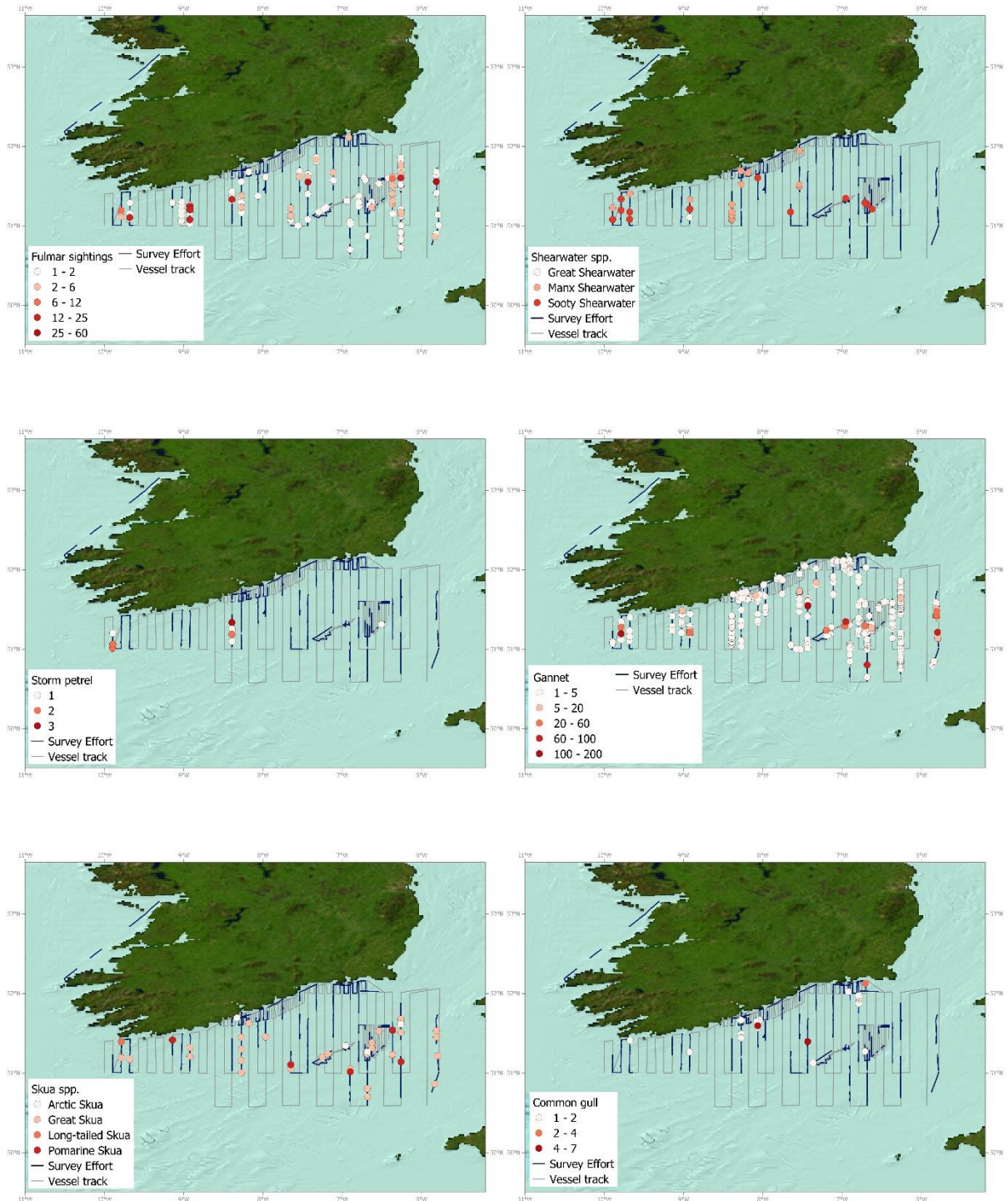


Figure 4: Distribution and abundance of seabird sightings recorded as 'In transect' during line transect effort on the survey; a) fulmar, b) shearwater spp., c) European storm petrel, d) gannet, e) skua spp., f) common gull. Seabird survey effort transects are overlaid on the survey track line.

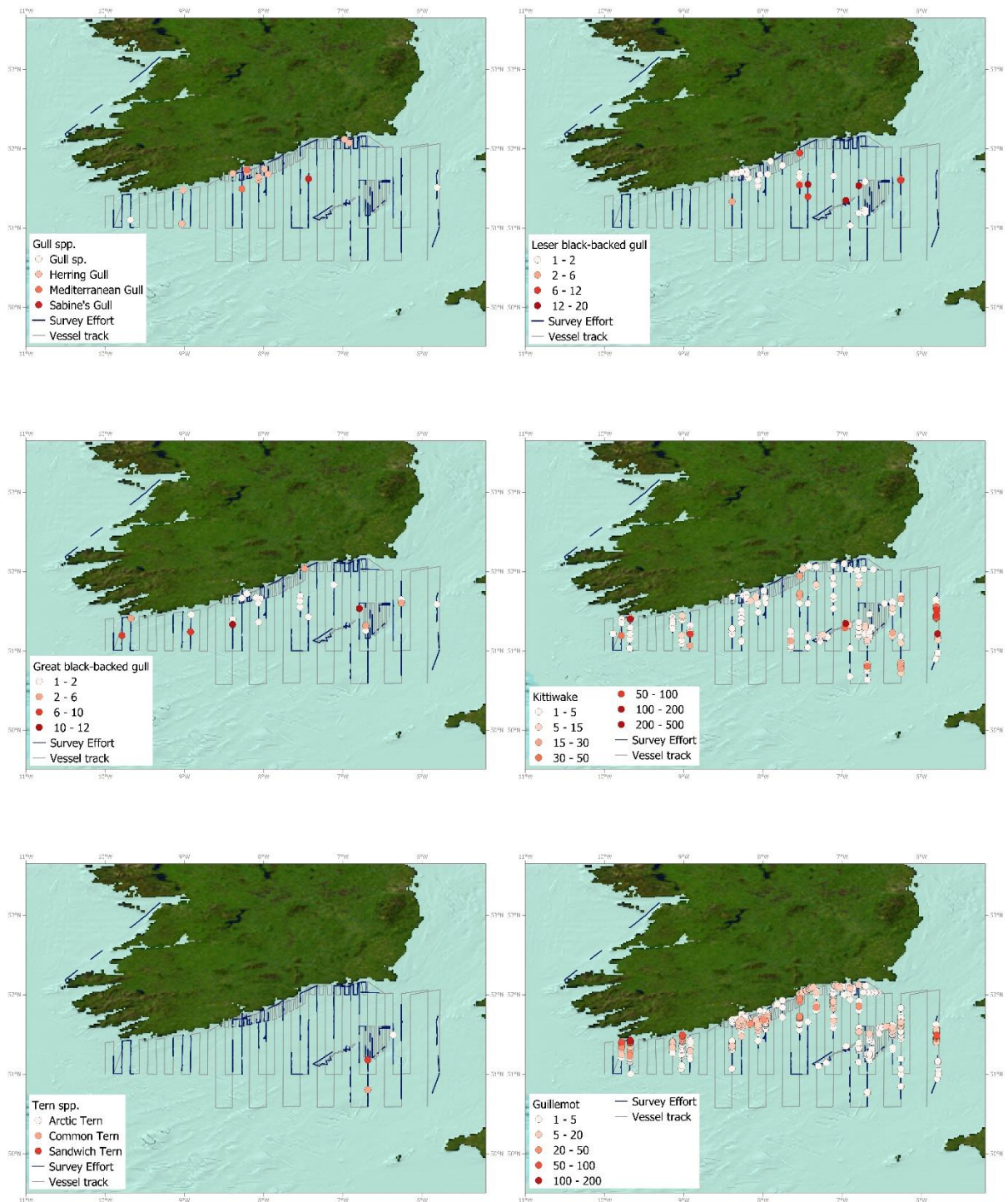


Figure 5: Distribution and abundance of seabird sightings recorded as 'In transect' during line transect effort on the survey; a) gull spp., b) lesser black-backed gull, c) greater black-backed gull, d) kittiwake, e) tern spp., f) guillemot. Seabird survey effort transects are overlaid on the survey track line.

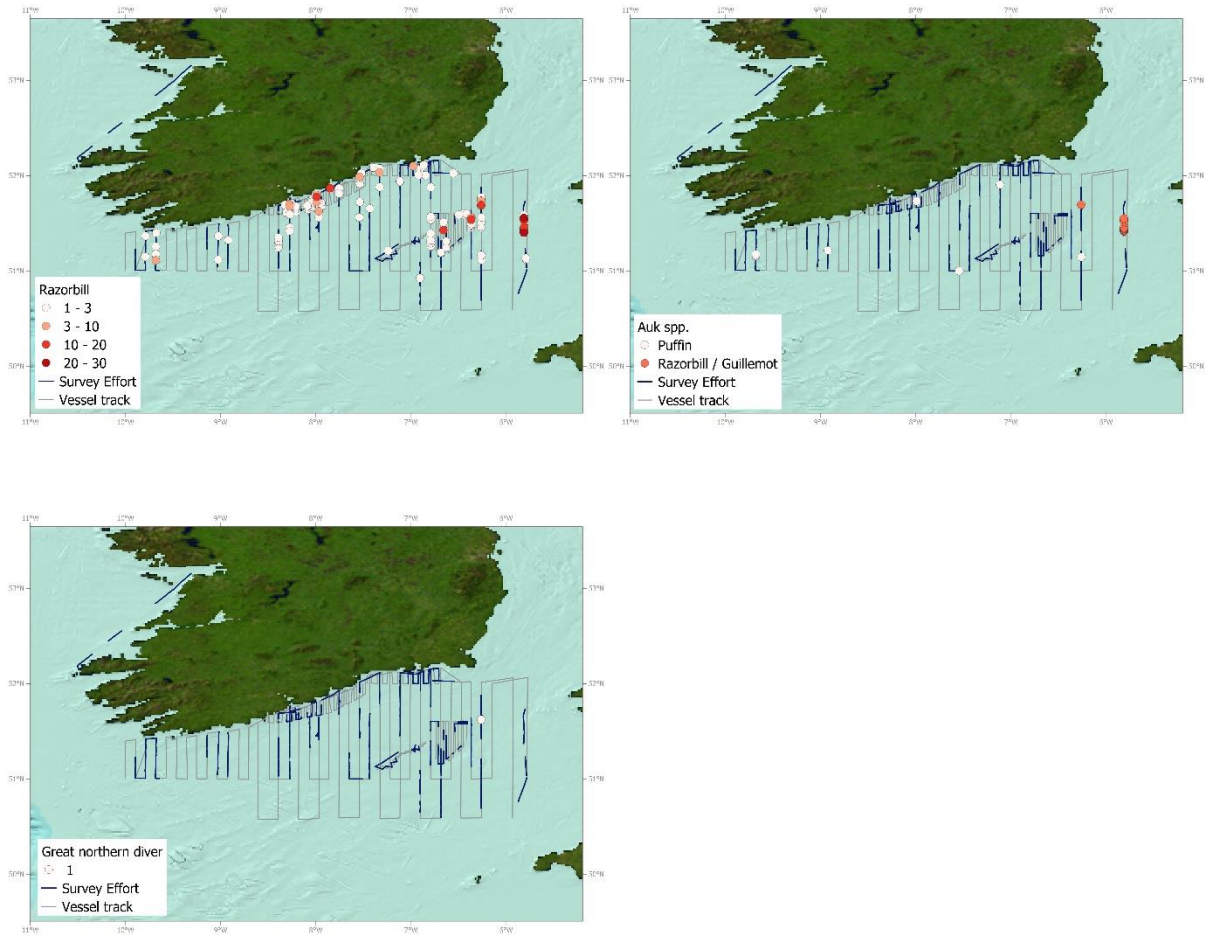


Figure 6: Distribution and abundance of seabird sightings recorded as 'In transect' during line transect effort on the survey; a) razorbill, b) auk spp., c) great northern diver. Seabird survey effort transects are overlaid on the survey track line.

Point sampling was conducted at 19 oceanographic or fishing stations (*Figure 9*). A total of 182 sightings were recorded during point sampling effort, comprising 4210 individuals belonging to 20 species or species groups (*Table 4*). All sightings recorded during point sampling watches were recorded as 'off transect'.

Table 4: Summary of all sightings recorded during point sampling effort on the survey.

Common Name	Species name	No. of Sightings	No. of Individuals 'Off Transect'
Fulmar	<i>Fulmarus glacialis</i>	18	198
Balearic Shearwater	<i>Puffinus mauretanicus</i>	3	3
Great Shearwater	<i>Puffinus graves</i>	1	1
Sooty Shearwater	<i>Puffinus griseus</i>	7	17
Manx Shearwater	<i>Puffinus puffinus</i>	5	9
Storm Petrel	<i>Hydrobates pelagicus</i>	1	1
Gannet	<i>Morus bassanus</i>	27	2230
Pomarine Skua	<i>Stercorarius pomarinus</i>	4	4
Arctic Skua	<i>Stercorarius parasiticus</i>	9	11
Great Skua	<i>Stercorarius skua</i>	21	39
Common Gull	<i>Larus canus</i>	2	41
Black-headed Gull	<i>Larus ridibundus</i>	1	1
Lesser Black-backed Gull	<i>Larus fuscus</i>	19	826
Herring Gull	<i>Larus argentatus</i>	2	30
Yellow-legged gull	<i>Larus michahellis</i>	3	3
Great Black-backed Gull	<i>Larus marinus</i>	14	101
Kittiwake	<i>Rissa tridactyla</i>	26	579
Guillemot	<i>Uria aalge</i>	13	102
Razorbill	<i>Alea torda</i>	4	7
Puffin	<i>Fratercula arctica</i>	2	7
	Total	182	4210

Fulmar

Northern fulmar (*Fulmarus glacialis*) were one of the most frequently encountered seabird species on the survey, being recorded on 403 occasions and totalling 2605 individuals. In total, 385 sightings of 2407 individuals were recorded during line transect watches, with 496 individuals recorded as 'in-transect', making fulmars the fourth most abundant species recorded during line transect effort.

Fulmars were found to be broadly distributed in low numbers across the entire survey area but were also found to display a somewhat patchy distribution with higher abundances recorded in areas such as the Smalls and Fastnet fishing grounds.

Shearwaters

Four species of shearwater were encountered on the survey including; Balearic shearwater (*Puffinus mauretanicus*), great shearwater (*Puffinus graves*), sooty shearwater (*Puffinus griseus*) and Manx shearwater (*Puffinus puffinus*). All four species were recorded during line transect survey effort, however, Balearic shearwater were not recorded as 'in-transect' All four species were also recorded during point sampling watches.

Manx and sooty shearwaters were the most frequently encountered shearwater species on the survey, while Balearic and great shearwaters were recorded on a single occasion.

Manx shearwaters were recorded on 42 occasions, totalling 77 individuals. Manx shearwaters were recorded on 37 occasions (68 individuals) during line transect effort with 32 individuals recorded as 'in-transect'. Sooty shearwaters were recorded on 46 occasions, totalling 83 individuals. Sooty shearwaters were recorded on 39 occasions (66 individuals) during line transect effort with 24 individuals recorded as 'in-transect'.

Both sooty and Manx shearwaters were patchily distributed in the Celtic sea, showing a distribution clustered around fishing grounds such as Fastnet, Galley grounds, Ballycotton and the Celtic Deep. When Manx or Sooty shearwater were encountered, they were recorded in low numbers with a maximum flock size for either species recorded as 10 individuals.

Storm petrels

The European storm petrel (*Hydrobates pelagicus*) was the only species of storm petrel identified during the survey. Another sighting of a storm petrel was recorded but this could not be identified to species level due to sighting conditions at the time. The European storm petrel was recorded during both line transect and point sampling watches, while the petrel sp. was recorded during a line transect watch.

European storm petrels were infrequently encountered on the survey, totalling 13 sightings of 19 individuals. In total, 12 sightings of 18 individuals were recorded during line transect watches, with 9 individuals recorded as 'in-transect'.

European storm petrels were also patchily distributed with all sightings recorded on the fishing grounds; Fastnet, Galley grounds, and the Celtic Deep.

Gannet

Overall, Gannet (*Morus bassanus*) were the second frequently observed seabird species on the survey, being recorded on 861 occasions and totalling 6903 individuals. In total, 813 sightings of 4640 individuals were recorded during line transect watches, with 1723 individuals recorded as 'in-transect', making gannets one of the most abundant species recorded during line transect effort.

Gannets were found to be broadly distributed in low numbers across the entire survey area, although they were found to display a somewhat patchy distribution with slightly high abundances recorded over many of the fishing grounds in the Celtic sea.

Skuas

Four species of skua were encountered on the survey including; Arctic skua (*Stercoratius parasiticus*), great skua (*Stercoratius skua*), long-tailed skua (*Stercoratius longicaudus*) and pomarine skua (*Stercoratius pomarinus*). All four species were recorded as 'in-transect' during line transect survey effort, however, only the great skua was recorded, and all but long-tailed skua were also recorded during point sampling watches.

Great skuas were regularly encountered in low numbers throughout the survey (139 sightings of 205 individuals). During line transect survey effort, great skuas were encountered on 117 occasions, totalling 165 individuals. Of these, 42 individuals were recorded as 'in-transect'. Pomarine, Arctic and long-tailed skuas were each also recorded as 'in-transect', with 7, 8 and 3 individuals recorded 'in-transect' respectively.

All skua species were patchily distributed in the Celtic sea, their distribution showing clustering around fishing grounds such as Fastnet, Galley grounds, the Trench, the Smalls and the Celtic Deep.

Gulls

Nine species of gull were encountered on the survey including; Mediterranean gull (*Larus melanocephalus*), Common Gull (*Larus canusgreat*), Sabine's gull (*Larus sabini*), black-backed gull (*Larus marinus*), lesser black backed gull (*Larus fuscus*), herring gull (*Larus argentatus*), Yellow-legged gull (*Larus michahellis*), greater black backed gull (*Larus marinus*) and black-legged kittiwake (*Rissa tridactyla*). A number of individuals were also encountered which could not be identified to species level. All of the nine species successfully identified were recorded during line transect survey effort, with all but yellow-legged and black-headed gull recorded as 'in-transect'. All species other than Mediterranean and Sabine's gull were also recorded during point sampling survey.

Kittiwakes were the most frequently encountered gull species on the survey with a total of 7001 individuals recorded during 623 sighting events. They were also the most abundant species of gull and one of the most abundant seabird species with 6409 individuals recorded during 588 sightings while conducting line transect watches. Of these, 2555 birds were recorded as 'in-transect'.

Kittiwakes were found to be broadly distributed across the entire survey area, although they were found to display a somewhat patchy distribution with particularly high abundances recorded over the main fishing grounds in the Celtic sea.

Although less common overall, common gull (39 birds 'in-transect'), lesser black-backed gulls (142 birds 'in-transect') and greater black-backed gulls (95 birds 'in-transect') gulls were regularly recorded during line transect effort in the Celtic sea. Each of these species showed a strong association with fishing grounds, particularly Ballycotton, the Rigs and Celtic deep.

Terns

Three species of tern were encountered on the survey including; Arctic tern (*Sterna paradisaea*), common tern (*Sterna hirundo*) and sandwich tern (*Sterna sandvicensis*). All three species were recorded as 'in-transect' during line transect survey effort, while none of the three species were recorded during point sampling watches. Each species was encountered twice during the survey.

Sandwich terns were the most abundant tern species with 3 birds recorded as 'in-transect' during line transect effort, a second sighting of 4 sandwich terns was recorded as 'off-transect'. Only a single common tern was recorded as 'in-transect'. The same was true of Arctic tern. All tern sightings occurred offshore in the Celtic Deep area.

Auks

Four species of auk were encountered on the survey including; Atlantic puffin (*Fratercula arctica*), little auk (*Alle alle*), guillemot (*Uria aalge*) and razorbill (*Alea torda*). All but little auk were recorded during both line transect and point sampling survey effort. All but little auk were also recorded as 'in-transect' during line transect watches. A number of sightings of auks identified only as guillemot/razorbill were also recorded during line transect survey effort.

Guillemots were the most frequently encountered of the auk species and one of most frequently encountered species on the survey (1331 sightings of 7027 individuals). In total, 1298 sightings of 6874 individuals were recorded during line transect watches, with 6094 individuals recorded as 'in-transect', making guillemots the most abundant species recorded during line transect effort by a large margin. Guillemots were recorded in high numbers in the inshore waters along the breadth of Irelands Celtic sea coast. Guillemot were also recorded in high numbers in the Smalls and Celtic Deep areas but were notably less common in much of the remaining offshore waters.

Razorbills were the second most infrequently encountered of the auk species (321 sightings of 1027 individuals). In total, 278 sightings of 864 individuals were recorded during line transect watches, with 505 individuals recorded as 'in-transect'. Although less abundant, razorbills showed a similar distribution pattern to that of the guillemot

Puffins were less frequently encountered during the survey (21 sightings of 39 individuals). In total, 19 sightings of 32 individuals were recorded during line transect watches, with 12 individuals recorded as 'in-transect'. In contrast to guillemot and razorbill, puffin were observed to be broadly distributed in low numbers across the Celtic Sea.

A single little auk was also recorded as 'off-transect' during line transect survey effort.

Cormorants and Divers

Two sightings of dingle cormorants (*Phalacrocorax carbo*) were recorded as 'in-transect' during line transect effort south of Barra. A number of great northern diver (*Gavia immer*) sightings were recorded, including a sighting of 9 great northern diver off Dunmore East. A single sighting of a red-throated diver (*Gavia stellata*) was also recorded during the survey. None of the divers encountered were recorded as 'in-transect' during line transect survey effort.

Terrestrial/ migratory birds

A number of terrestrial/ migratory birds were encountered during the survey. A total of 25 sightings of terrestrial/ migratory bird species were recorded during the survey (Table 5). These sightings comprised of 85 individuals from 16 species. Notable sightings included a red-breasted flycatcher (*Ficedula parva*), a ring ousel (*Turdus torquatus*), 2 sightings of individual grey phalarope (*Phalaropus fulicarius*), and a pair of tufted duck (*Aythya fuligula*).

All terrestrial/ migratory bird species recorded during the survey were recorded as 'off transect'. The distribution of these sightings can be seen in Figure 7.

Table 5: Summary of all terrestrial/ migratory bird sightings recorded during the survey.

Common Name	Species name	No. of Sightings	No. of Individuals
Blackcap	<i>Sylvia atricapilla</i>	1	1
Brambling	<i>Fringilla montifringilla</i>	1	1
Buzzard	<i>Buteo buteo</i>	1	1
Common Scoter	<i>Melanitta nigra</i>	1	9
Fieldfare	<i>Turdus pilaris</i>	1	1
Grey Phalarope	<i>Phalaropus fulicarius</i>	2	2
Meadow Pipit	<i>Anthus pratensis</i>	6	11
Red-breasted flycatcher	<i>Ficedula parva</i>	1	1
Redwing	<i>Turdus iliacus</i>	2	31
Ring Ousel	<i>Turdus torquatus</i>	1	1
Shelduck	<i>Tadorna tadorna</i>	1	1
Snipe	<i>Gallinago gallinago</i>	1	1
Starling	<i>Sturnus vulgaris</i>	3	18
Tufted Duck	<i>Aythya fuligula</i>	1	2
Wheatear	<i>Oenanthe oenanthe</i>	1	1
Whimbrel	<i>Numenius phaeopus</i>	1	3
	Total	25	85

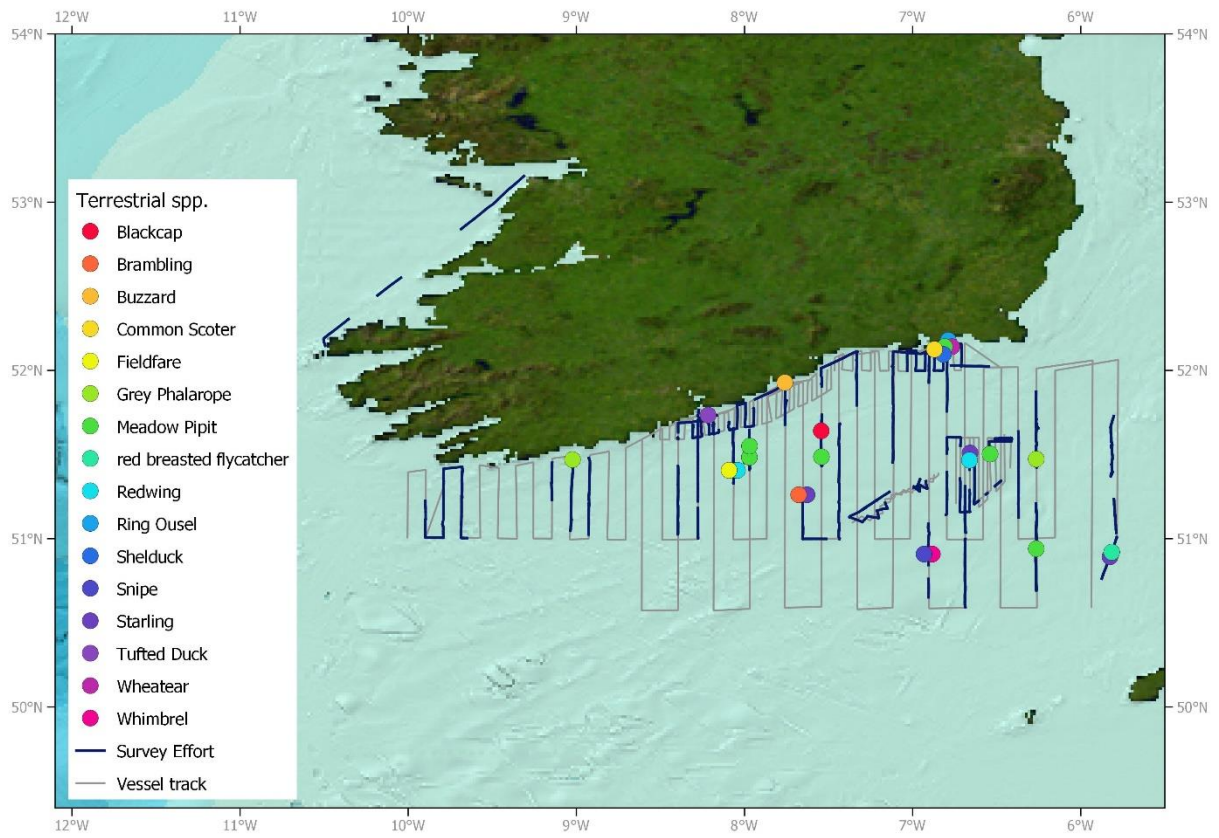


Figure 7: Distribution of terrestrial/ migratory bird sightings recorded on the survey.

Discussion

Since 2016 the CSHAS survey has used an updated survey design, covering an extended area of the Celtic sea employing parallel transects spaced equally at 8 nautical miles. The survey conducts two passes of the survey area offset at 4 nautical miles, while also conducting high resolution adaptive surveys within the bounds of the main survey area. A seabird survey has been conducted each year since the updated survey design was implemented. Seabird survey effort has varied across the time series of surveys since 2016. During the present survey a total of 117 hours and 33 minutes of survey effort was conducted. A total of 62 hours and 31 minutes of survey effort were recorded in 2018, and 66 hours and 14 minutes of survey effort were recorded in 2017, while 73 hours and 35 minutes of survey effort were recorded in 2016.

As in previous surveys, a large number of sightings, from a broad range of taxa and species groups, and a high abundance of seabirds were observed over the course of the survey. In total, 30 species of seabird and 16 species of terrestrial bird were recorded during the present survey. This is broadly consistent with the species totals from previous seabird surveys during CSHAS. In 2018, 23 species of seabird and 12 species of terrestrial bird were recorded, in 2017, 26 species of seabird and 26 species of terrestrial bird were recorded, while in 2016, 26 species of seabird and 24 species of terrestrial bird were recorded.

The assemblage of seabird species recorded has remained relatively consistent over the years since 2016, with no species recorded in the present survey which had not been previously encountered. There has been some variance in the reported occurrence of some species however it is not possible to directly compare species abundance without further analysis.

This year did see the addition of a number of terrestrial birds which had not been reported in recent previous surveys, for example; ring ousel, tufted duck and red-breasted flycatcher.

Guillemot, kittiwake, gannet and fulmar were the most abundant and widespread species' in the present survey, with fulmar and gannet being the most widely distributed. Despite their abundance and generally broad distribution, these species, along with many other species' recorded, displayed a somewhat patchy distribution. A number of areas of very high seabird density and diversity were observed over the course of the survey, usually in vicinity of commercial fishing grounds. These included areas such as; the Smalls, Celtic Deep, the Trench, the Rigs, Galley grounds, Ballycotton and Fastnet.

The high levels of seabird activity and feeding behaviour observed in these 'hotspots' suggests abundant feeding opportunities and high prey availability for seabirds. This was further confirmed on the survey by the presence of feeding tuna and dolphins at some of these locations together with sprat 'marks' detected near the surface using the ships acoustic survey equipment. Many of the areas noted as holding a high diversity and abundance of seabirds are within foraging range of important seabird colonies. For instance, Little Skellig has the largest population of gannets in Ireland, and the cliffs of Moher hold the largest population of fulmars in Ireland (9% of the total population of Ireland and Britain), and the largest colony of kittiwakes in Ireland, as well as having large colonies of both razorbill and guillemot. The Saltee islands are also home to some of Ireland's largest kittiwake, guillemot and razorbill colonies (Cummins, *et al.*, 2019; Mitchell, *et al.*, 2004).

Given the outstanding international importance of the multi-species seabird colonies found in the British Isles (Kober, *et al.*, 2010), it is important to recognise the important role played by the winter foraging areas utilised by the seabirds that reside there. The availability and distribution of prey are known to be vital for the breeding success, and thus long term stability, of many seabird populations

(Mackey, *et al.*, 2004). As such, the identification and management of key hotspots for foraging seabirds, both during the breeding and non-breeding seasons, are important steps in guarding the long term health and stability of seabird colonies (Kober, *et al.*, 2010). Protecting seabirds in their offshore foraging habitats through the designation of SPAs would also further assist Ireland in meeting its obligation under the EU Birds Directive.

The CSHAS provides an excellent opportunity for the collection of data on the autumn distribution, abundance and behaviour of seabirds in the Celtic sea. However, the amount and quality of data collected is confounded by factors such as environmental conditions and seabird survey design. Although the weather was quite good throughout the survey, poor weather did reduce the total number of seabird survey hours undertaken on a number of occasions. Environmental conditions, particularly elevated sea states, also likely affected the detection probability of certain inconspicuous species. The use of a larger dedicated seabird 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 the at-sea summer abundance and distribution of seabirds in Ireland's shelf water habitats.

Recommendations

An increase to the number of ESAS trained seabird observers on-board would be recommended for this survey. The present survey used a single ESAS trained seabird observer with a second, non-ESAS observer employed as scribe/ secondary observer. The ESAS survey methodology recommends the use of a minimum of two ESAS trained observers. The use of three ESAS seabird observers would allow a rotational system of two seabird observers on-effort (one observing, the other scribing) while the third observer takes a break. This approach would increase effort coverage of the survey area, minimise observer fatigue and allow full coverage of all daylight hours. However, the authors appreciate the constraints on using such a large seabird survey team.

The approach outlined above would facilitate more sufficient coverage, which should increase the chances of detecting seabirds, particularly rare or scarce species, while also ensuring that all seabird observers get sufficient breaks/periods of rest. Sufficient breaks/periods of rest are highly important for seabird observers for maintaining full concentration during all effort times without suffering the ill effects of fatigue.

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Finally, the seabird 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 seabird observers look forward to future collaborations.

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