



**An Roinn Tithíochta,
Rialtais Áitiúil agus Oidhreachta**
Department of Housing,
Local Government and Heritage

Seabird Monitoring undertaken during
the Celtic Sea Herring Acoustic Survey
(CSHAS)
8th – 28th October 2021

Report to the 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, 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 Housing, Local Government and Heritage (DHLGH), through the Marine Institute, commissioned a seabird survey from the RV *Celtic Explorer* during the annual the Celtic Sea Herring Acoustic Survey (CSHAS), running from 8th - 28th October 2021.

A standard line transect survey methodology was employed by the seabird observer 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 71 hours and 26 minutes of survey effort were conducted over the course of CSHAS 2021. In total, 66 hours and 14 minutes of survey effort were conducted using a line transect methodology, while 5 hours of effort were conducted using the point sampling methodology. A further 12 minutes of effort were conducted as a casual watch.

A total of 2879 seabird observations were recorded throughout the survey, totalling 14797 individuals. In total, 4181 seabirds were recorded as "in transect", while 10616 were recorded "off transect". The species encountered included 29 species, hybrids or species groups, from eight families. A further 42 observations of terrestrial/migratory birds were also recorded, comprising of 151 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). Note: All counts are of pairs unless otherwise stated.

<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>
Northern 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>Hydrobates leucorhous</i>	0	310	310	48,357	
Northern Gannet	<i>Morus bassanus</i>	0	32,758	32,758	259,311	39%
Great Cormorant	<i>Phalacrocorax carbo</i>	663	4,548	5,211	13,681	7%
European Shag	<i>Gulosus 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>Ichthyaeus 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%
Black-legged Kittiwake	<i>Rissa tridactyla</i>	13,060	36,100	49,160	415,995	-23%
Sandwich Tern	<i>Thalasseus 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>Sternula 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>Alca 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 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.*, 2016; 2017; 2018; 2019, 2020). 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.*, 2020).

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.*, 2016; 2017; 2018; 2019, 2020).

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 Housing, Local Government and Heritage (DHLGH), through the Marine Institute, commissioned the undertaking of a seabird survey from the RV *Celtic Explorer* during the annual Celtic Sea Herring Acoustic Survey (CSHAS), running from the 8th to the 28th of October 2021.

Methodology

The seabird survey was conducted across two survey legs from the 9th - 18th October and the 18th - 26th October 2021, using a single seabird observer per survey leg. The seabird observer conducted visual survey effort while also recording all survey data. Given the presented survey transects for the 2021 survey (*Figure 1*), a standard line transect survey methodology was determined to be most suitable and was employed by the seabird surveyor. Survey transects were undertaken at speeds of 5-10 knots, with fishing activity being conducted at speeds of 2-3 knots.

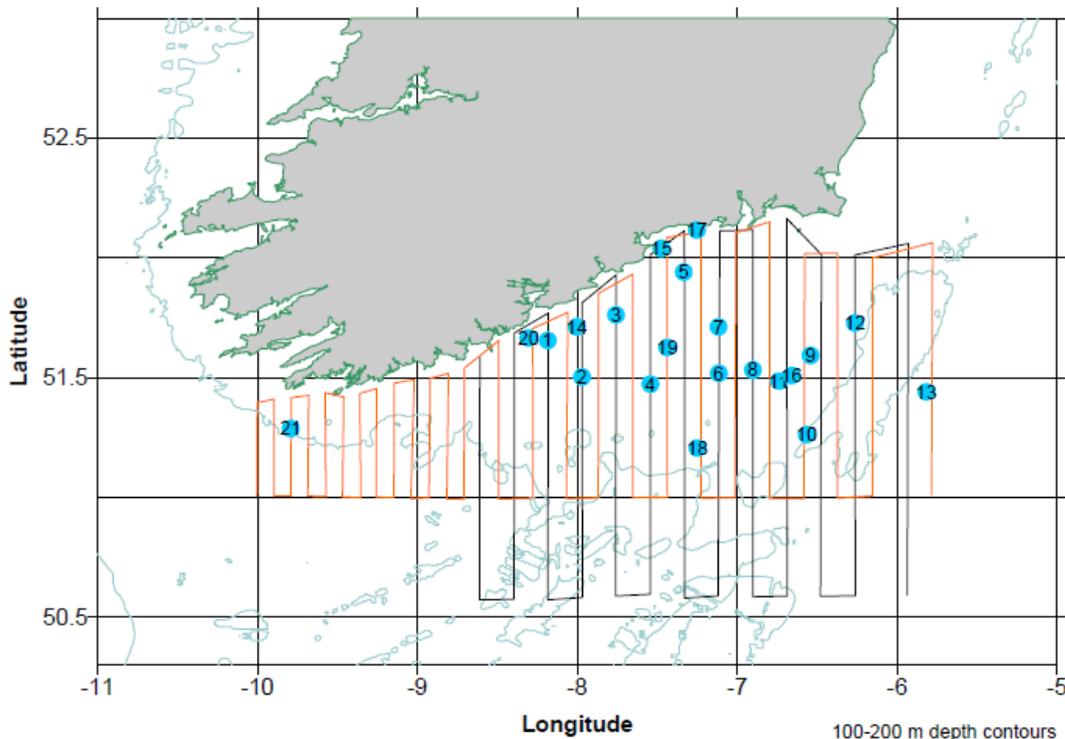


Figure 1: Representative cruise track of the Celtic Sea Herring Acoustic Survey (Source: Marine Institute, 2021).

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 13 m above sea level), however, as in previous surveys aboard the *RV 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 were conducted within a survey quadrant of 300m x 300m. 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, Swarovski NL 10x32 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 I DSLR camera with a Sigma EF 100-400mm F5-6.3 DG DN OS telephoto lens was used to visually document other information of scientific interest. Data were 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 3.515) was configured for optimum use on the survey. Cybertracker was used to record positional, environmental and seabird observation 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 observer 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 seabird observation 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 record was time stamped and digitally marked using Cybertracker. Observational 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, observations were recorded at an appropriate taxonomic level (i.e. large gull sp., *Larus sp.*, commic 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

The seabird survey was conducted across 18 days from the 9th - 26th October. Due to port calls at the beginning/end of the survey it was not possible to conduct the seabird survey for the full 21 day duration of the cruise.

A total of 71 hours and 26 minutes of survey effort were conducted over the course of CSHAS 2021. In total, 66 hours and 14 minutes of survey effort were conducted using a line transect methodology, while 5 hours of effort were conducted using the point sampling methodology. A further 12 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 daily survey effort recorded over the course of the survey was 7 hours and 22 minutes while the average daily survey effort was 3 hours and 58 minutes.

Seabird survey effort was greatly reduced on the 17th and 21st of October and to a lesser extent on the 19th, 18th and 20th October due to weather conditions exceeding the specified weather limits for observations. Survey effort was also reduced on the 11th, 12th and 13th of October as variable vessel activity limited the possibility of conducting line transect watches. Survey effort was also limited on the 9th of October as the vessel was in Dunmanus Bay for calibration of the vessels acoustic equipment. A graph of daily effort is provided in *Figure 2* below.

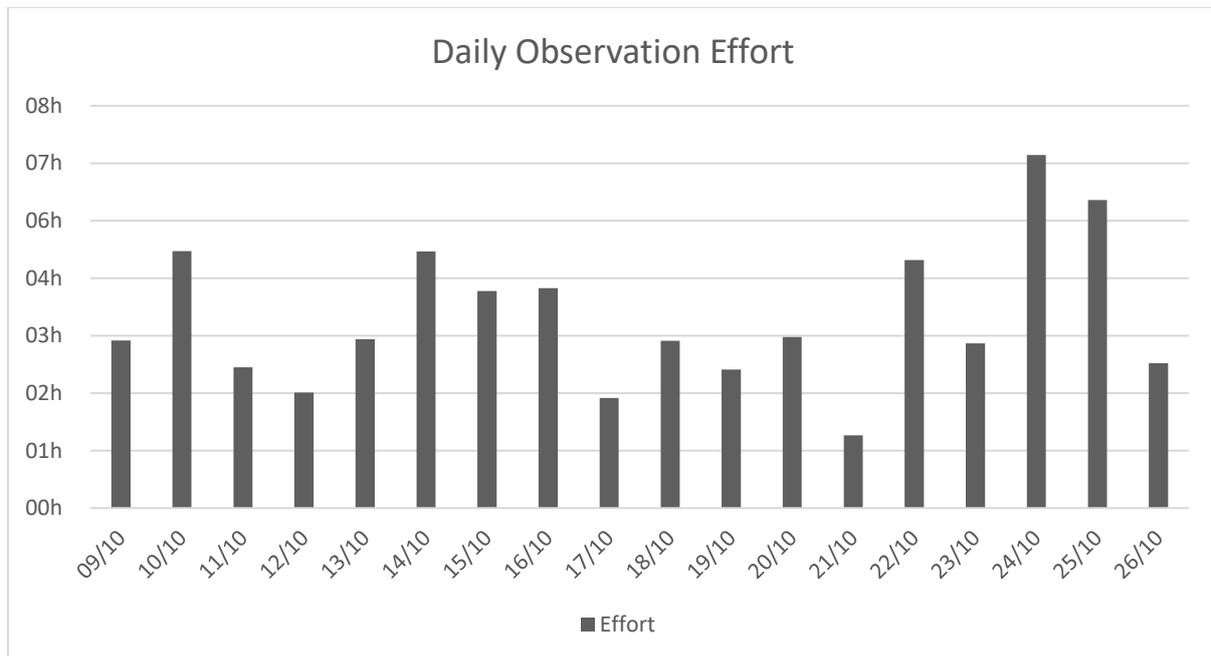


Figure 2: Daily visual effort undertaken during the survey.

Environmental Conditions

Weather conditions throughout the survey were generally favourable during leg 1, however leg 2 saw a significant deterioration, with high wind speeds recorded. On a number of occasions seabird survey effort was restricted due to poor environmental conditions. 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 number of casual watches were undertaken during periods where the environmental conditions exceeded these parameters. A breakdown of key environmental factors recorded during the survey is provided hereunder.

Sea State

Sea state was recorded both in terms of the World Meteorological Organisation (WMO) sea state scale and the Beaufort scale. The WMO sea state was judged based on the total state of agitation of the sea, taking into account the effect of wind, swell and currents (WMO, 2011) on the sea conditions, with wave height in meters used as an additional guide. Beaufort wind force/ sea state and was judged based on the effect of the wind on the sea surface.

Sea states 4 and 5 were the most common sea states recorded. The most frequently recorded WMO sea state was 5, accounting almost 27 hours (37%) of observation effort, while WMO sea state 4 accounted for over 15 hours (22%). WMO sea state 2, 3 and 6 each accounted for approximately 8-9 hours (11-12%) of observation effort (*Fig. 3a*).

The most frequently recorded Beaufort wind force/ sea state was a sea state 5, accounting for 28.5 hours (40%) of survey effort. Beaufort wind force/ sea state 2 was recorded over 12 hours (17%) of observation effort, while Beaufort wind force/ sea state 4 accounted for almost 8.5 hours (12%) of observation effort (*Fig. 3b*).

Swell

A swell height of 0.1-1 meter was most frequently recorded throughout the survey, being recorded over almost 26 hours (37%) of survey effort. A swell height of 1.1-2 meters was recorded across 24 survey hours (33%), while swell of over 2 meters was recorded during almost 14 hours (19%) of survey effort. No swell was also recorded across over 7 hours (11%) of survey effort (*Fig. 3c*).

Visibility

Visibility was generally very good during seabird survey effort; however, a number of periods of reduced visibility were also recorded. The most frequently recorded visibility was 16-20km, being recorded for almost 33 hours (46%) of survey effort. Visibility of 11-15km was recorded during 22 hours (31%) of survey effort, while visibility of 6-10km was recorded for 5 hours (7%) of survey effort. Visibility of 1-5km was recorded during 11 hours (15%) of survey effort. Visibility of less than 1km was recorded during 11 minutes (>0%) of survey effort, however, survey effort generally ceased if visibility reduced below 300m (*Fig. 3d*).



Figure 3: Summary of environmental conditions recorded on the WESPAS 2021; a) WMO sea state, b) Beaufort sea state/ wind force, c) Swell height (meters), d) Visibility (kilometres).

Seabird records

A total of 26 species from eight families were encountered during the survey. Of the 26 seabird species recorded during the survey, 24 were recorded during line transect survey effort, while 15 species were recorded during point counts.

In total, 2879 seabird observations were recorded throughout the survey, totalling 14797 individuals, with flock size ranging from one up to 800 for some species (*Table 2*). A summary of all seabirds recorded on the survey is presented in *Table 2* and includes birds recorded during both line transect and point sampling watches.

Of the 2879 seabird observations recorded during the survey, 2821 were recorded during line transect effort. In total, 13038 seabirds were recorded during line transect effort, with 4181 of these recorded as 'in-transect'. The remaining 10616 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 observations of seabird species recorded as 'in-transect' during line transect survey effort is presented in *Figures 4- 10*. For clarity, and brevity, seabirds recorded during point sampling watches, or those recorded as 'off-transect' are not displayed.

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

<i>Common Name</i>	<i>Species name</i>	<i>No. of records</i>	<i>No. of Seabirds</i>	<i>Flock size</i>
Northern Fulmar	<i>Fulmarus glacialis</i>	160	274	1-25
Great Shearwater	<i>Ardenna gravis</i>	5	11	1-7
Sooty Shearwater	<i>Ardenna griseus</i>	96	499	1-120
Manx Shearwater	<i>Puffinus puffinus</i>	38	169	1-50
European Storm Petrel	<i>Hydrobates pelagicus</i>	16	53	1-13
Leach's Petrel	<i>Hydrobates leucorhous</i>	1	1	1
Northern Gannet	<i>Morus bassanus</i>	1006	5667	1-800
Pomarine Skua	<i>Stercorarius pomarinus</i>	5	5	1
Arctic Skua	<i>Stercorarius parasiticus</i>	5	5	1
Great Skua	<i>Stercorarius skua</i>	37	51	1-6
Mediterranean Gull	<i>Ichthyiaetus melanocephalus</i>	14	53	1-25
Common Gull	<i>Larus canus</i>	24	50	1-10
Black-headed Gull	<i>Larus ridibundus</i>	16	32	1-5
Lesser Black-backed Gull	<i>Larus fuscus</i>	65	1157	1-300
Herring Gull	<i>Larus argentatus</i>	44	269	1-30
Yellow-legged Gull	<i>Larus michahellis</i>	1	1	1
Great Black-backed Gull	<i>Larus marinus</i>	102	366	1-30
Black-legged Kittiwake	<i>Rissa tridactyla</i>	316	1398	1-200
IN x LB*	<i>L. delawarensis</i> x <i>L. fuscus</i>	1	1	1
Large gull sp.	<i>Larus sp.</i>	4	230	1-100
Arctic Tern	<i>Sterna paradisaea</i>	2	3	1-2
Guillemot	<i>Uria aalge</i>	644	2257	1-60
Razorbill	<i>Alca torda</i>	133	392	1-15
Razorbill/Guillemot	<i>Alca torda/Uria aalge</i>	42	1647	1-300
Black Guillemot	<i>Cepphus grylle</i>	3	3	1
Atlantic Puffin	<i>Fratercula arctica</i>	89	174	1-11
European Shag	<i>Gulosus aristotelis</i>	5	24	1-10
Great Cormorant	<i>Phalacrocorax carbo</i>	1	1	1
Great Northern Diver	<i>Gavia immer</i>	4	4	1
Total		2879	14797	

* Hybrid Ring-billed x Lesser Black-backed Gull.

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

<i>Common Name</i>	<i>Species name</i>	<i>No. of records</i>	<i>No. of Seabirds</i>	<i>In Transect</i>	<i>Off Transect</i>
Northern Fulmar	<i>Fulmarus glacialis</i>	157	268	28	240
Great Shearwater	<i>Ardenna gravis</i>	5	11	2	9
Sooty Shearwater	<i>Ardenna griseus</i>	94	495	137	358
Manx Shearwater	<i>Puffinus puffinus</i>	38	169	9	160
European Storm Petrel	<i>Hydrobates pelagicus</i>	16	53	40	13
Leach's Petrel	<i>Hydrobates leucorhous</i>	1	1	1	0
Northern Gannet	<i>Morus bassanus</i>	997	5454	758	4696
Pomarine Skua	<i>Stercorarius pomarinus</i>	5	5	1	4
Arctic Skua	<i>Stercorarius parasiticus</i>	5	5	1	4
Great Skua	<i>Stercorarius skua</i>	35	49	9	40
Mediterranean Gull	<i>Ichthyæetus melanocephalus</i>	13	52	14	38
Common Gull	<i>Larus canus</i>	24	50	26	24
Black-headed Gull	<i>Larus ridibundus</i>	16	32	19	13
Lesser Black-backed Gull	<i>Larus fuscus</i>	60	1043	47	996
Herring Gull	<i>Larus argentatus</i>	38	172	20	152
Yellow-legged Gull	<i>Larus michahellis</i>	1	1	0	1
Great Black-backed Gull	<i>Larus marinus</i>	93	311	29	282
Black-legged Kittiwake	<i>Rissa tridactyla</i>	309	1210	379	831
Large gull sp.	<i>Larus sp.</i>	4	230	0	230
Arctic Tern	<i>Sterna paradisæa</i>	2	3	0	3
Guillemot	<i>Uria aalge</i>	644	2257	1904	353
Razorbill	<i>Alca torda</i>	133	392	268	124
Razorbill/Guillemot	<i>Alca torda/Uria aalge</i>	38	597	380	217
Atlantic Puffin	<i>Fratercula arctica</i>	89	174	107	67
European Shag	<i>Gulosus aristotelis</i>	1	1	1	0
Great Northern Diver	<i>Gavia immer</i>	3	3	1	2
Total		2821	13038	4181	8857

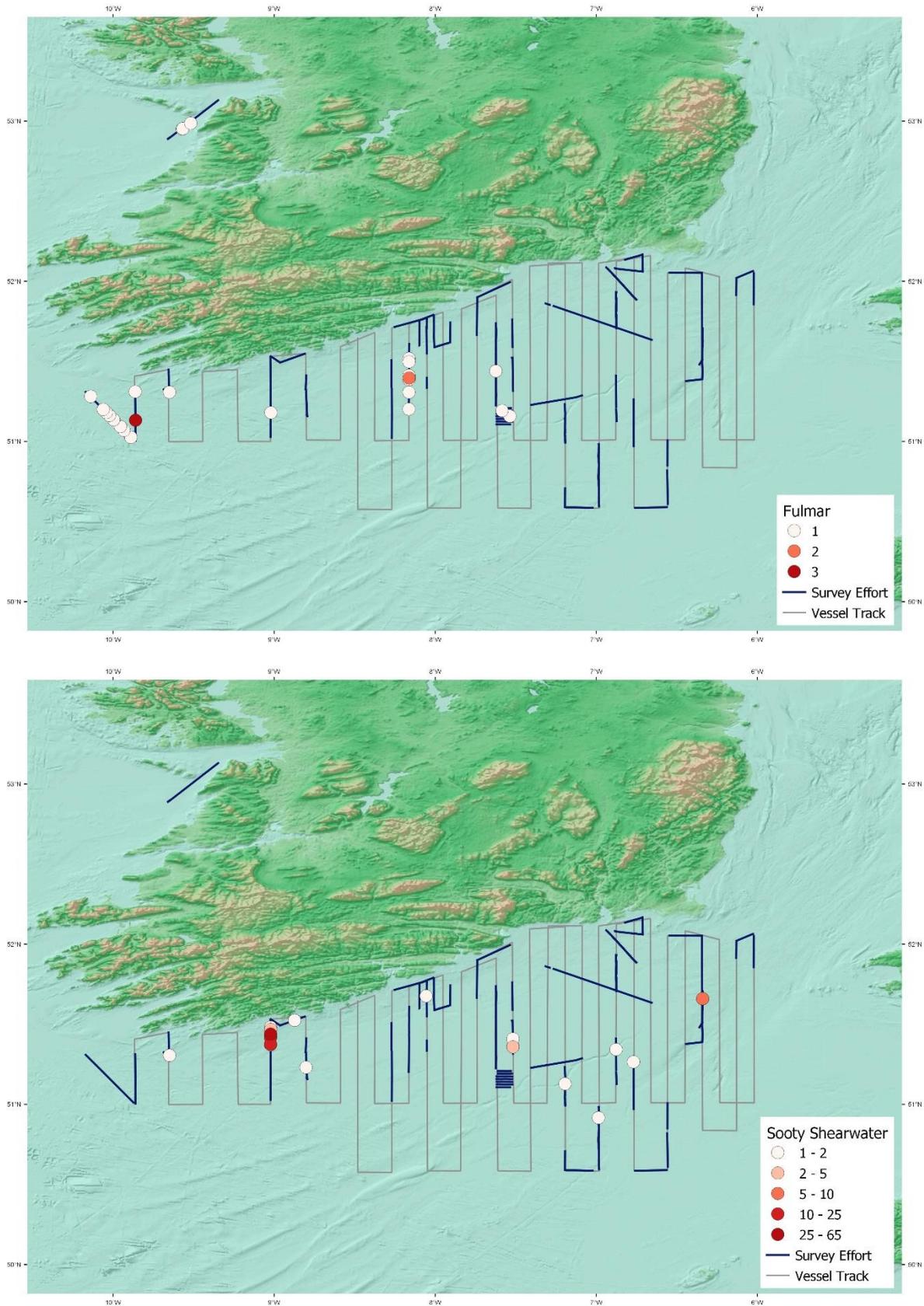


Figure 4: Distribution of a) Fulmar and b) Sooty Shearwater recorded as 'in-transect' during line transect survey effort.

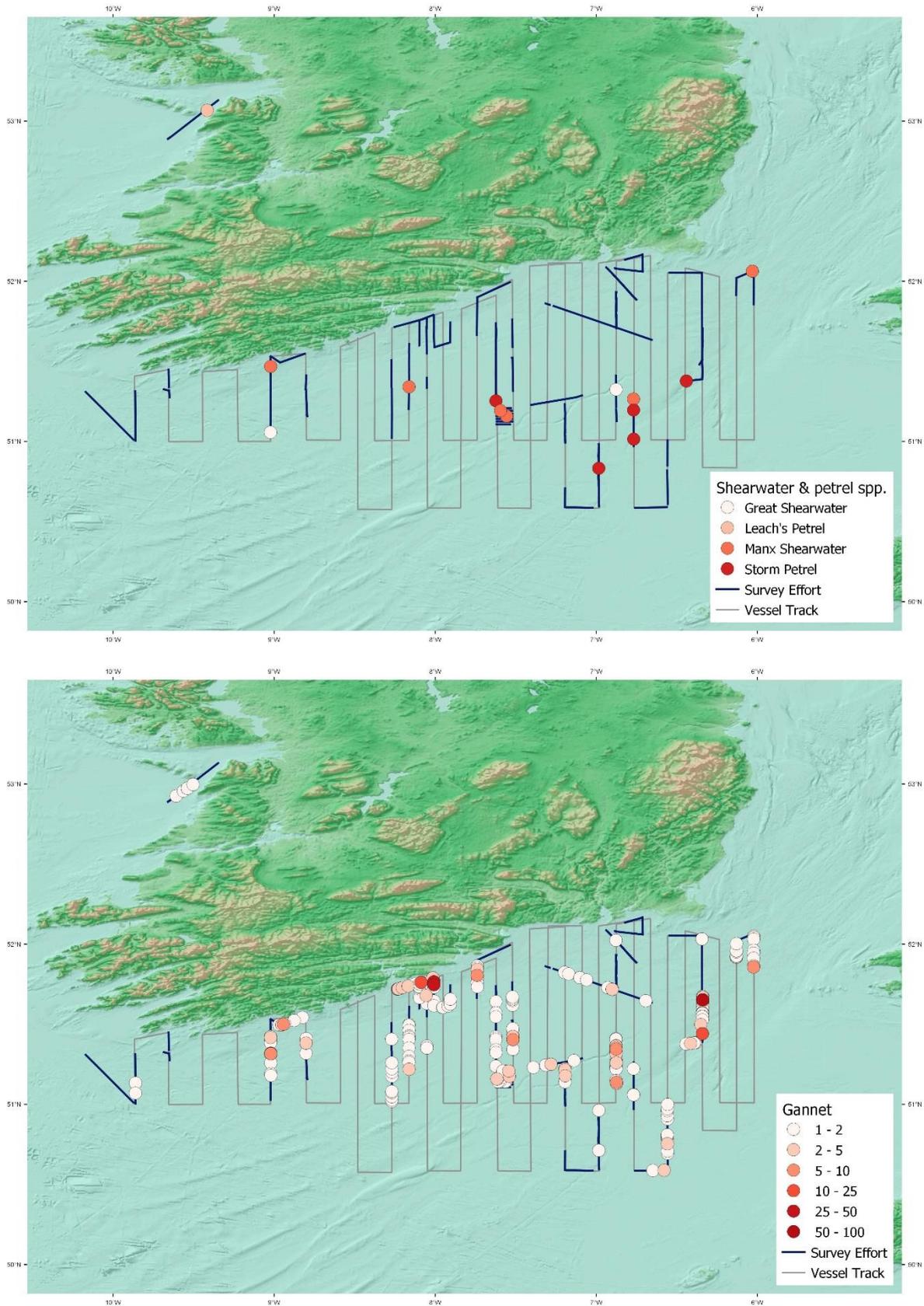


Figure 5: Distribution of a) Shearwater & Storm Petrel spp. and b) Gannet recorded as 'in-transect' during line transect survey effort.

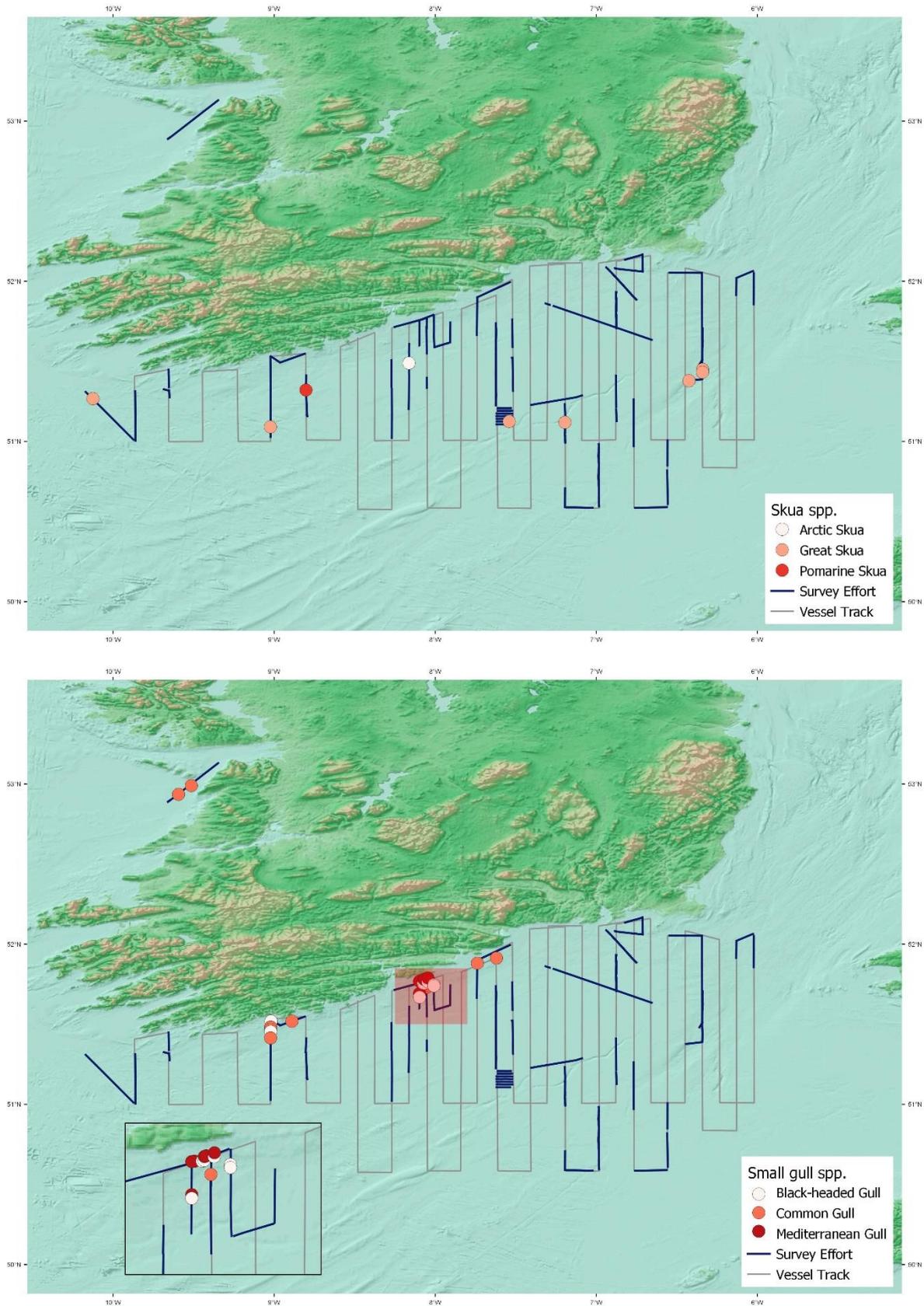


Figure 6: Distribution of a) Skua spp. and b) small gull spp. recorded as 'in-transect' during line transect survey effort.

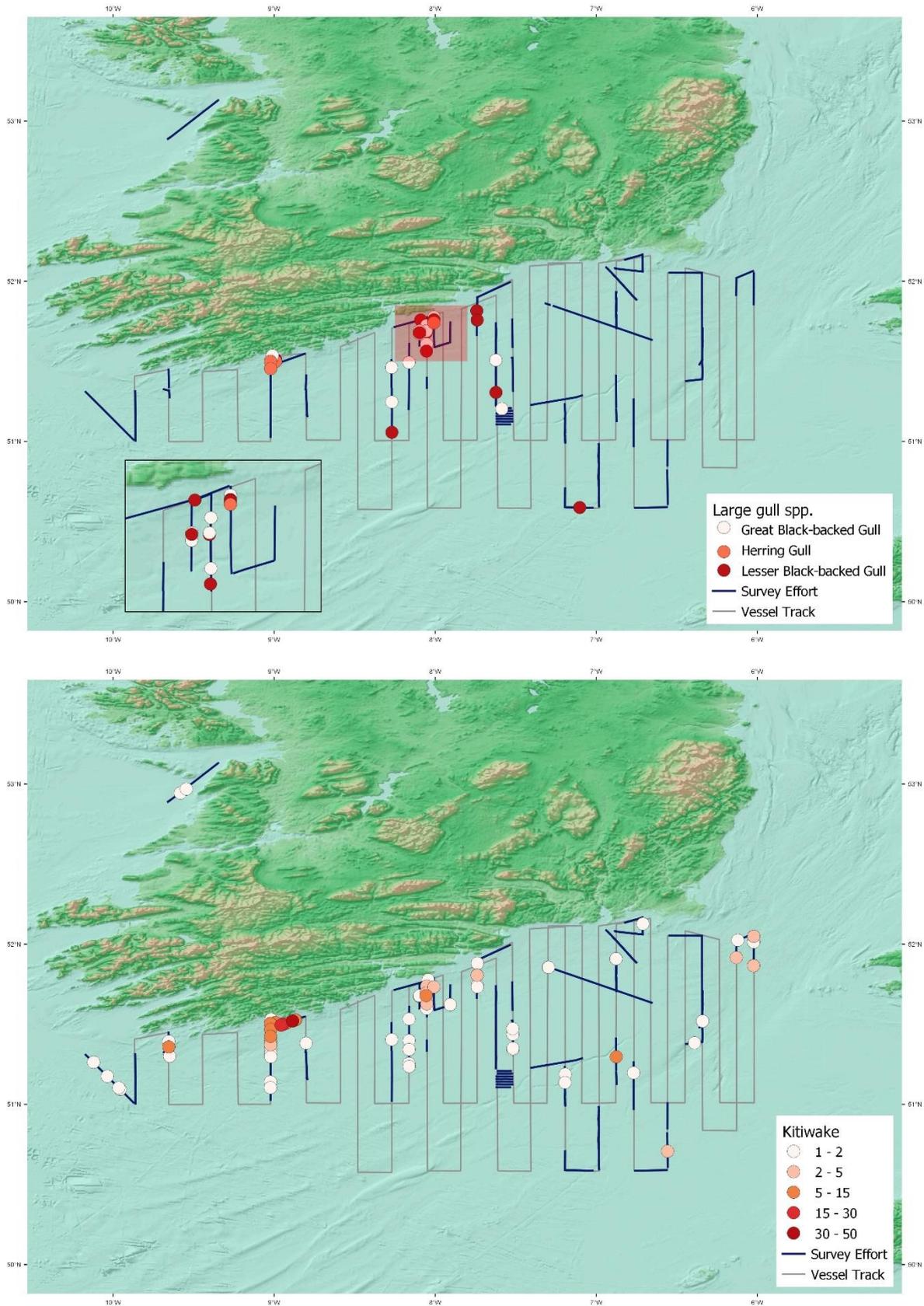


Figure 7: Distribution of a) large gull spp. and b) Kittiwake recorded as 'in-transect' during line transect survey effort.

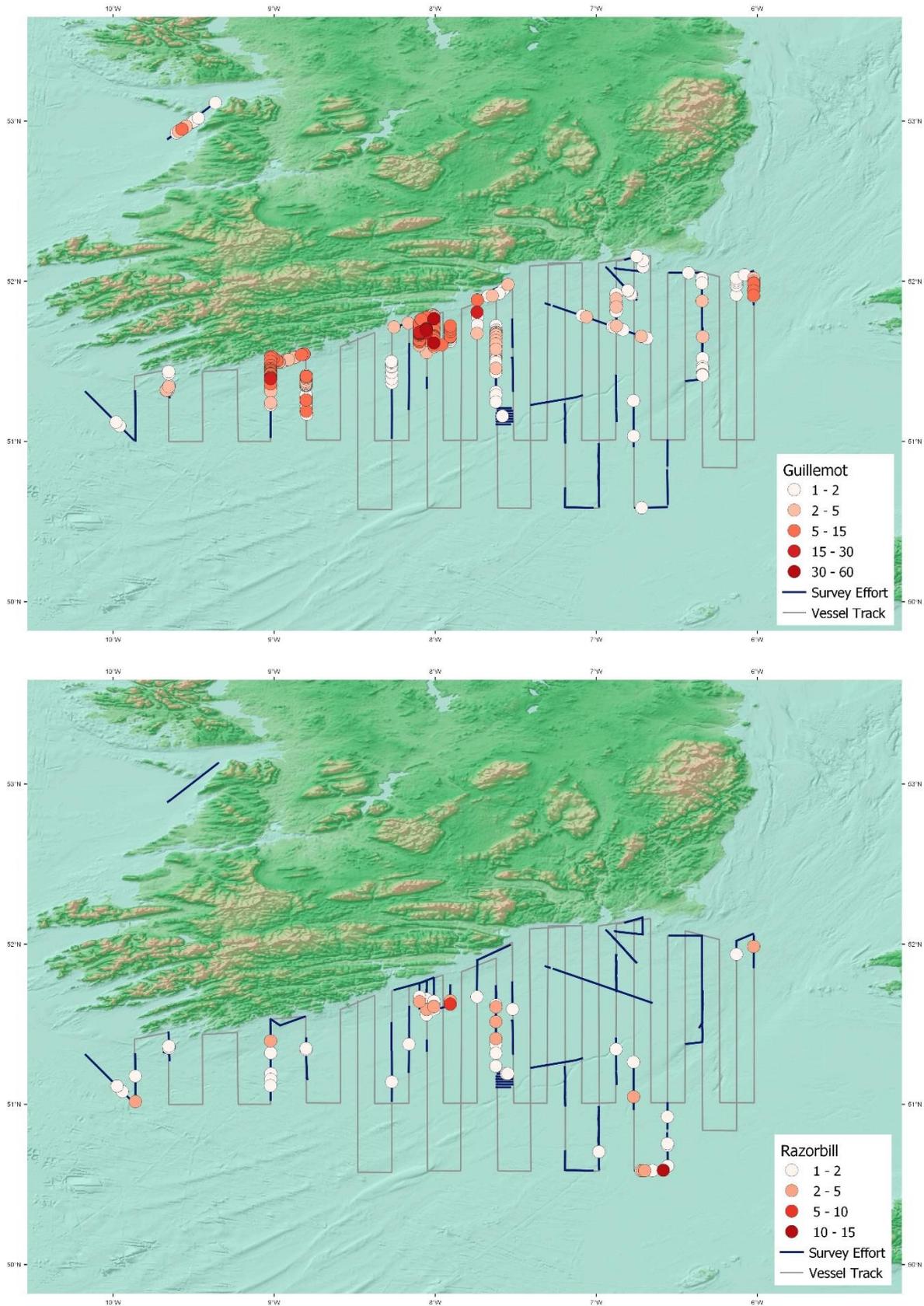


Figure 8: Distribution of a) Guillemot and b) Razorbill recorded as 'in-transect' during line transect survey effort.

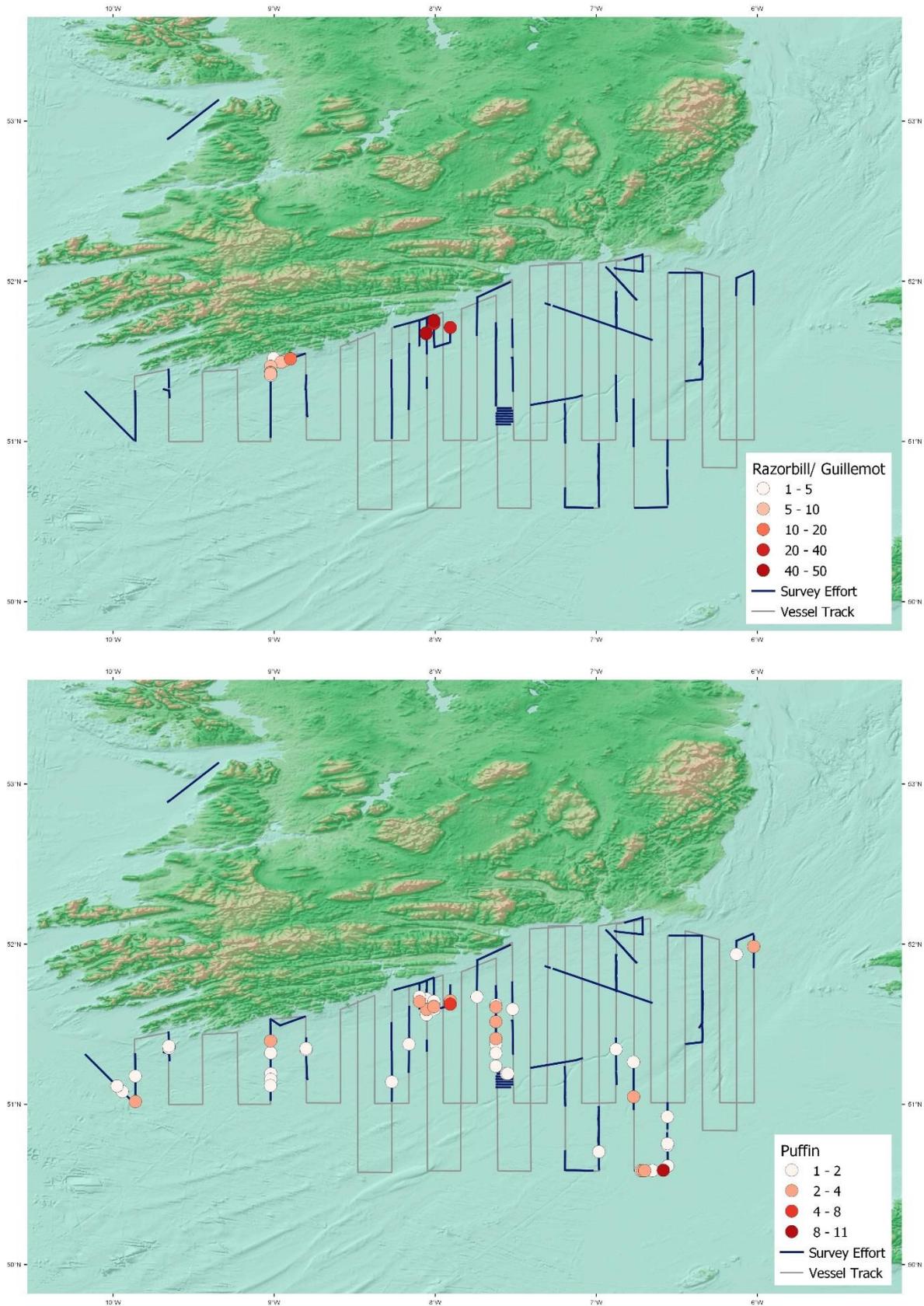


Figure 9: Distribution of a) unidentified Razorbill/Guillemot and b) Puffin recorded as 'in-transect' during line transect survey effort.

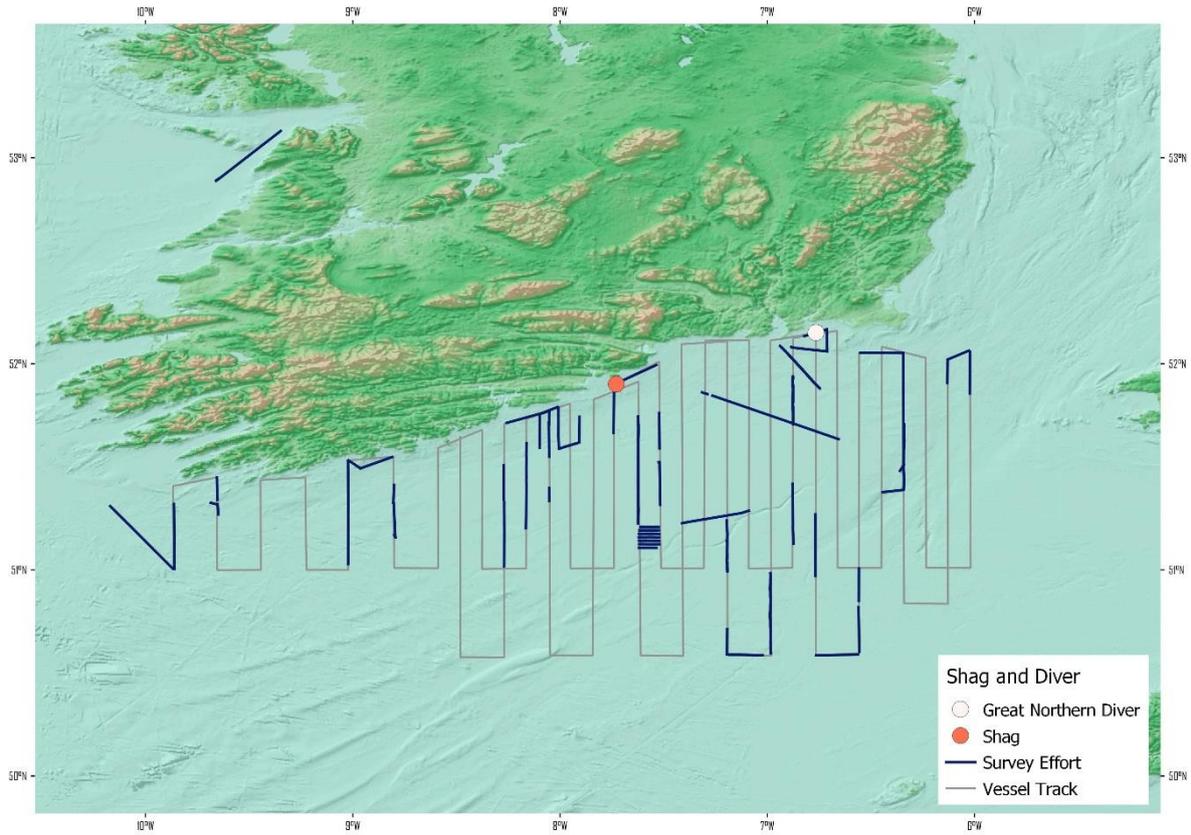


Figure 10: Distribution of Shag and Great Northern Diver recorded as 'in-transect' during line transect survey effort.

Seven point counts were conducted at oceanographic or fishing stations. A total of 51 seabird observations were recorded during point sampling effort, comprising 1670 individuals from 14 species (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.

<i>Common Name</i>	<i>Species name</i>	<i>No. of records</i>	<i>Off transect</i>
Northern Fulmar	<i>Fulmarus glacialis</i>	3	6
Sooty Shearwater	<i>Ardenna griseus</i>	2	4
Northern Gannet	<i>Morus bassanus</i>	8	198
Great Skua	<i>Stercorarius skua</i>	1	1
Mediterranean Gull	<i>Ichthyaetus melanocephalus</i>	1	1
Lesser Black-backed Gull	<i>Larus fuscus</i>	4	64
Herring Gull	<i>Larus argentatus</i>	5	87
Great Black-backed Gull	<i>Larus marinus</i>	8	45
Black-legged Kittiwake	<i>Rissa tridactyla</i>	5	185
IN x LB*	<i>L. delawarensis x L. fuscus</i>	1	1
Razorbill/Guillemot	<i>Alca torda/Uria aalge</i>	4	1050
Black Guillemot	<i>Cepphus grylle</i>	3	3
European Shag	<i>Gulosus aristotelis</i>	4	23
Great Cormorant	<i>Phalacrocorax carbo</i>	1	1
Great Northern Diver	<i>Gavia immer</i>	1	1
	Total	51	1670

Northern Fulmar

Northern Fulmar (*Fulmarus glacialis*) were frequently encountered on the survey, being recorded on 160 occasions and totalling 274 individuals. In total, 157 observations of 268 individuals were recorded during line transect watches, with 28 individual birds recorded as 'in-transect'. All birds seen were of the double light morph (LL) plumage type, with no High Arctic 'Blue' Fulmars recorded. Fulmar were found to be patchily distributed in low numbers within the survey area. During line transect effort, Fulmar were more frequently encountered on the westerly lying transects, with higher abundances recorded 'in-transect' over fishing grounds such as the Rigs, Galley, the Trench and Fastnet grounds (Fig. 4a), and large aggregations were recorded west of Hags Head. A number of Fulmar observations, including a flock of 25 birds, were also recorded as 'off-transect' over the Trench fishing grounds, however these birds recorded and are not presented graphically here.

Shearwaters

Three species of shearwater were encountered on the survey: Great Shearwater (*Ardenna gravis*), sooty shearwater (*Ardenna griseus*) and Manx Shearwater (*Puffinus puffinus*). All three species were recorded during line transect effort, however, only Sooty Shearwater were recorded point sampling watches.

Sooty Shearwater were recorded on 96 occasions, totalling 499 individuals. Sooty Shearwater were recorded on 94 occasions (495 individuals) during line transect effort with 137 individuals recorded as 'in-transect'. Sooty Shearwater 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, off Toe head and west of Hags Head (Fig. 4b).

Manx Shearwater were recorded on 38 occasions with 169 individual birds recorded. Of these records. All Manx Shearwater were recorded during line transect effort, with 9 birds recorded as 'in-transect'.

Five records of Great Shearwater, totalling 11 birds, were obtained during line transect effort, with 2 Great Shearwater recorded as 'in-transect'.

The distribution of Manx and Great Shearwater recorded as 'in-transect' during line transect effort are presented in Figure 5a.

Storm petrels

Two species of storm petrel were recorded during the survey: European Storm petrel (*Hydrobates pelagicus*) and Leach's Storm petrel (*Hydrobates leucorhous*).

European Storm petrel were recorded exclusively during line transect effort, being recorded on 16 occasions and numbering 53 birds in total. Of these, 40 Storm petrels were recorded as 'in transect'.

A single record of a lone Leach's Storm petrel was obtained during line transect effort in outer Galway Bay, and recorded as 'in-transect'. This bird was recorded during a period of strong south-westerly winds and thus was likely blown inshore from its expected offshore habitat, and is a typical record for this location and time of year.

The distribution of Leach's and European Storm petrel recorded as 'in-transect' during line transect effort are presented in Figure 5a.

Northern Gannet

Overall, Northern Gannet (*Morus bassanus*) were the most frequently observed seabird species on the survey, being recorded on 1006 occasions and totalling 5667 individuals. In total, 997 observations of 5454 birds were recorded during line transect watches, with 758 Gannets recorded as 'in-transect', making Gannet the second most abundant species recorded during line transect effort. Gannet were found to be broadly distributed in low numbers across the entire survey area, although, as with many other species, a number of large aggregations were also recorded. These larger aggregations were observed in areas such as off Galley Head and the Smalls (*Fig. 5a*). Particularly large feeding aggregations of 500-800 Gannet were recorded over the Smalls and the Trench fishing grounds, however, these aggregations were recorded as 'off-transect' and are not presented graphically here.

Skuas

Three species of skua were encountered on the survey including Great Skua (*Stercorarius skua*), Pomarine Skua (*Stercorarius pomarinus*) and Arctic Skua (*Stercorarius parasiticus*). All skua species were recorded as 'in-transect' during line transect survey effort. Of the three species, Great Skua were the only species recorded during point counts. The distribution of skua species recorded as 'in-transect' during line transect effort are presented in *Figure 6a*.

Great Skua were regularly encountered in low numbers throughout the survey (37 records of 51 individual birds). During line transect survey effort, Great Skua were encountered on 35 occasions, totalling 49 individual birds. Of these, only 9 Great Skua were recorded as 'in-transect'. Great Skua were patchily distributed across much of the survey area in low numbers, however, the waters over the Smalls and the Trench fishing grounds held some higher numbers. These were largely recorded as 'off-transect'.

Five records of solitary Pomarine Skua were noted during line transect effort on the survey; with one Pomarine Skua recorded as 'in-transect'. Similarly, five records of solitary Arctic Skua were noted during line transect effort on the survey; with one Arctic Skua also recorded as 'in-transect'.

Gulls

Eight species of gull were encountered on the survey including; Mediterranean Gull (*Ichthyaetus melanocephalus*), Common Gull (*Larus canus*), Black-headed Gull (*Larus ridibundus*), Lesser Black-backed Gull (*Larus fuscus*), Herring Gull (*Larus argentatus*), Yellow-legged Gull (*Larus michahellis*), Great Black-backed Gull (*Larus marinus*) and Black-legged Kittiwake (*Rissa tridactyla*). Of these eight species, all but Common Gull, Black-headed Gull and Yellow-legged Gull were recorded as 'in-transect' during line transect survey effort. A number of observations of gulls which could not be identified to species level were recorded 'off-transect' during line transect survey effort, these gulls were recorded as "large gull species (*Larus spp.*)". One adult presumed hybrid Ring-billed x Lesser Black-backed Gull was also identified during a point count on the survey.

Although less common than some of the other gull species recorded, Mediterranean Gull (14 birds 'in-transect) Common Gull (26 birds 'in-transect) and Black-headed Gull (19 birds 'in-transect') were recorded on a number of occasions during line transect effort. Each of these species displayed a highly patchily distribution with Toe Head and Ballycotton accounting for the majority of records (*Fig. 6b*).

Lesser Black-backed Gull were the third most frequently encountered gull species on the survey with a total of 1157 individuals recorded during 65 observations. Lesser Black-backed Gull were the second

most abundant species of gull recorded, being recorded on 60 occasions, amounting to 1043 birds, during line transect effort. Of these, 47 birds were recorded as 'in-transect'.

Great black-backed gull were the second most frequently encountered gull species on the survey being encountered on 102 occasions and with a total of 366 individuals recorded. Great Black-backed Gull were the third most abundant species of gull recorded, being recorded on 60 occasions, amounting to 1043 birds, during line transect effort. Of these, 47 birds were recorded as 'in-transect'.

Herring Gull were also regularly encountered during the survey, with 44 observations of 269 birds reported. During line transect effort, Herring Gull were recorded 38 times, amounting to 172 individual birds, 20 of which were recorded as 'in-transect'.

Lesser Black-backed Gull, Great Black-backed Gull and Herring Gull were each broadly distributed in low numbers across the survey area, however as with many other species, some patchiness was also evident in these three species. Large aggregations of each of these species were recorded on the Trench and the Smalls fishing grounds, however the majority of the birds were recorded as 'off-transect'. In terms of 'in-transect' records, Toe Head and Ballycotton accounted for the majority records (*Fig. 7a*).

A solitary Yellow-legged Gull (1 bird 'off-transect') was also encountered on one occasion during line transect effort in the vicinity to the Trench fishing grounds.

Kittiwake were the most frequently encountered and most abundant gull species on the survey with a total of 316 individuals recorded during 1398 observations. During line transect survey effort, Kittiwake were encountered on 309 occasions, totalling 1210 individual birds. Of these, 379 birds were recorded as 'in-transect'. Kittiwake were found to be broadly distributed in low numbers across the entire survey area, however, a somewhat patchy distribution was also noted with higher numbers of 'in-transect' birds noted in areas such as Toe Head and Ballycotton (*Fig. 7b*). Kittiwake were well represented on the Trench and the Smalls fishing grounds, however the majority of these encounters were recorded as 'off-transect'.

The hybrid Ring-billed x Lesser Black-backed Gull was identified among a flock of gulls approximately 25 nautical miles southeast of Ballycotton Lighthouse. The bird was superficially like a Ring-billed Gull but was quite large (just smaller than the accompanying Lesser Black-backed Gulls), with a hint of red/warmth to the gonys. The darker upperpart colour made for a strong contrasting tertial crescent and well defined trailing edge to the wing with unusual leg colour also evident. A mix of characters of both species was noted. This individual was similar looking in many respects to other birds thought to be of this pairing seen in the midlands of England (2012 to 2021), Norfolk (March 2019) and Madrid (Nov 2008, 2009 and 2010). This record constitutes the first record of this hybrid type for Ireland. The bird was photographed and ID was independently confirmed by Irish, UK and European gull experts.

Terns

One species of tern were encountered over the course of the survey: Arctic Tern (*Sterna paradisaea*). Arctic Tern were recorded on 2 occasions during line transect effort the survey, totalling 3 birds, all of which recorded as 'off-transect'.

Auks

Four of the five species of auk known to occur in Irish waters were encountered on the survey. These were Guillemot (*Uria aalge*), Black Guillemot (*Cepphus grylle*), Razorbill (*Alca torda*) and Atlantic Puffin (*Fratercula arctica*). Of the auks identified to species level, all bar Black Guillemot were recorded during line transect effort only. A number of observations of auks identified only as Guillemot/Razorbill were recorded during both line transect and point sampling survey effort.

Guillemot were the most frequently encountered of the auk species and were both the second most frequently encountered and the second most abundant species overall. In total, 644 observations of 2257 individual Guillemot were recorded during line transect watches, with 1904 birds recorded as 'in-transect'. Guillemot 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 particularly high abundances recorded in areas such as off Toe Head and Ballycotton (*Fig. 8a*).

Razorbill were the second most frequently encountered during the survey. In total, 133 observations of 392, individuals were recorded during line transect watches, with 368 individuals recorded as 'in-transect'. Although less abundant, Razorbill showed a very similar distribution pattern to that of Guillemot with highest numbers recorded off Toe head and Ballycotton (*Fig. 8b*). The distribution of auks identified as Guillemot/Razorbill is also consistent with the distribution of Guillemot and Razorbill (*Fig. 9a*).

Puffin were the third most frequently encountered of the auk species. In total, 89 records of 174 Puffin were recorded during line transect watches, with 107 birds recorded as 'in-transect'. Puffin were broadly distributed across much of the survey area and showed a more even distribution than many other species (*Fig. 9b*).

Three records of solitary Black Guillemot were obtained while conducting point sampling watches in Dunmanus Bay while the vessel was calibrating acoustic equipment.

Cormorants, Shags and Divers

Both Great Cormorant and European Shag were recorded during this years' CSHAS. Shag were recorded during both line transect and point sampling survey effort, however, Cormorant were recorded solely during point sampling survey effort.

Shag were recorded on 5 occasions totalling 24 birds, of these only 1 Shag was recorded as 'in-transect'. Shag were recorded off Ardmore Head and in Dunmanus Bay, with the single 'in-transect' Shag occurring off Ardmore Head (*Fig. 10*).

The single 'off-transect' Cormorant recorded on the survey was also encountered in Dunmanus Bay.

Great Northern Diver were recorded on 4 occasions during the survey, each record consisted on a solitary bird. Three of the Great Northern Diver records were noted during point sampling counts, the remaining observation was recorded as 'in-transect' during line survey effort east of Hook Head (*Fig. 10*).

Terrestrial/migratory birds

A number of terrestrial/migratory birds were encountered during the survey. A total of 42 observations of terrestrial/migratory bird species were recorded during the survey (Table 2). These observations comprised of 151 individuals from 20 species. Species recorded included a Siberian chiffchaff (*Phylloscopus collybita tristis*), a black redstart (*Phoenicurus ochruros*), a wren (*Troglodytes troglodytes*) and a lone juvenile whooper swan (*Cygnus cygnus*). The distribution of terrestrial records is presented in Figure 11 below.

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

Common Name	Species name	No. of records	No. of individuals
Black Redstart	<i>Phoenicurus ochruros</i>	1	1
Blackcap	<i>Sylvia atricapilla</i>	1	1
Chiffchaff	<i>Phylloscopus collybita</i>	1	1
Dunlin	<i>Calidris alpina</i>	1	1
Goldcrest	<i>Regulus regulus</i>	3	3
Goldfinch	<i>Carduelis carduelis</i>	1	4
Grey Wagtail	<i>Motacilla cinerea</i>	1	1
House Martin	<i>Delichon urbica</i>	1	1
Linnet	<i>Linaria cannabina</i>	1	1
Meadow Pipit	<i>Anthus pratensis</i>	13	113
Merlin	<i>Falco columbarius</i>	3	3
Pied Wagtail	<i>Motacilla alba</i>	3	3
Redwing	<i>Turdus iliacus</i>	2	3
Robin	<i>Erithacus rubecula</i>	1	1
Rock Pipit	<i>Anthus petrosus</i>	1	2
Siberian Chiffchaff	<i>Phylloscopus collybita tristis</i>	1	1
Skylark	<i>Alauda arvensis</i>	2	3
Swallow	<i>Hirundo rustica</i>	3	6
Whooper Swan	<i>Cygnus cygnus</i>	1	1
Wren	<i>Troglodytes troglodytes</i>	1	1
	Total	42	151

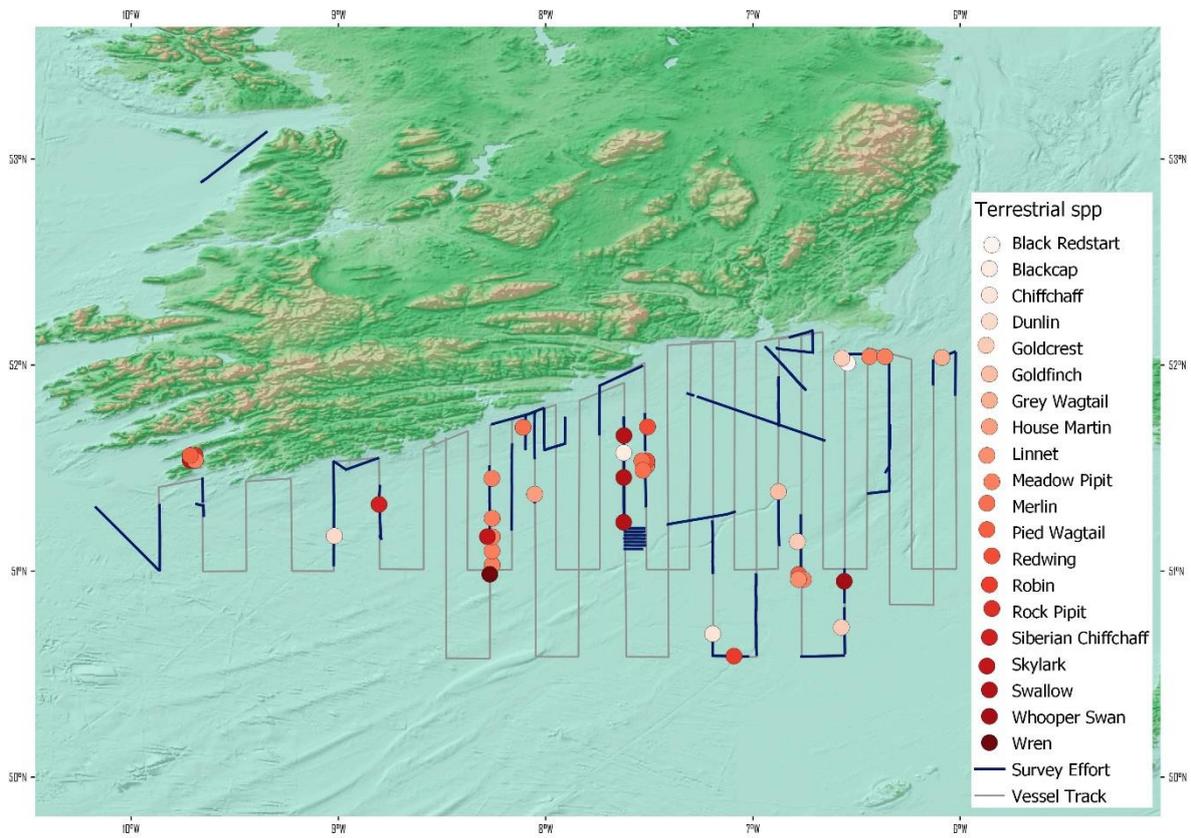


Figure 11: Distribution of terrestrial species recorded during survey effort.

Discussion

Since 2016 the Celtic Sea Herring Acoustic 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 (O'Donnell, et al., 2020). 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 71 hours and 26 minutes of survey effort was conducted. In 2022, 117 hours and 34 minutes of survey effort was conducted, very close to the total survey effort of 117 hours and 33 minutes recorded in 2019. 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 (O'Donnell, et al., 2016; 2017; 2018; 2019, 2020). The variation in the survey effort overtaken across years can largely be attributed to variable weather conditions at this time of year.

The seabird survey during this year's CSHAS and CSHAS 2020 differed from other recent CSHAS seabird surveys in that only a single seabird surveyor was deployed for the duration of the survey (Connaughton & Power, 2020). This was due to crewing restrictions put in place as a mitigation measure against the impacts of the COVID 19 pandemic. As a result the level of data collected on both surveys was affected in a number of ways (Connaughton & Power, 2020). COVID control measures meant that access to the bridge was restricted to bridge crew the chief scientist only. As access to the monkey island is weather dependent, the bridge access restriction limited the ability of the observer to conduct survey effort in suboptimal weather conditions. The use of a single observer meant that it was not always possible to collect all relevant seabird data in areas of high activity. This resulted in survey effort being curtailed on a number of occasions or restricted to focus on the correct identification, enumeration, distance estimation and recording of species encountered while ancillary data such as age, moult stage and behaviour were de-prioritised.

As in previous surveys, a large number of records, from a broad range of taxa and species groups were observed over the course of the survey. In total, 26 species of seabird and 20 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 2020, 27 species of seabird and 19 species of terrestrial bird were recorded. In 2019, 30 species of seabird and 16 species of terrestrial bird were recorded, and in 2018, 23 species of seabird and 12 species of terrestrial bird were recorded. During the 2017 survey, 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 (O'Donnell, et al., 2016; 2017; 2018; 2019, 2020).

Despite some inter-annual variation, the overall assemblage of seabird species recorded has remained relatively consistent over the years since 2016 (O'Donnell, et al., 2016; 2017; 2018; 2019, 2020), with no seabird species recorded in the present survey which had not been previously encountered. However, this year did see the notable addition of hybrid Ring-billed x Lesser Black-backed Gull to the records.

Some variance in the reported occurrence of species has been noted across the survey time series (O'Donnell, et al., 2016; 2017; 2018; 2019, 2020), however, it is not possible to directly compare species abundance without further analysis. A reduction in the numbers of birds recorded on the

present survey was evident for a number of species when compared to last year's survey. This was particularly evident for species such as Gannet, Guillemot, Razorbill, Fulmar and a number of gull species. In contrast, the number of Sooty Shearwater and Puffin recorded this year were substantially higher than recorded in 2020, while Mediterranean Gull and Black-headed Gull also saw a marked increase in occurrence. This year's survey also recorded 11 Great Shearwater, 2 of which were 'in-transect', whereas no Great Shearwater were recorded last year (Connaughton & Power, 2020), and have been generally scarce across the time series (O'Donnell, et al., 2016; 2017; 2018; 2019, 2020). This level of variation between years is not uncommon on the Celtic Sea herring acoustic survey, for example, 2017 also showed a reduced numbers of records for a number of species when compared to the preceding or following years (O'Donnell, et al., 2016; 2017; 2018). This variation may be down to any number of factors including; environmental conditions, survey design, observer effects or prey distribution.

The hybrid Ring-billed x Lesser Black-backed Gull record was a noted addition to the bird records for this survey series and is also of national significance, as it is the first record of this hybrid type for Ireland. The bird was photographed and identity was independently confirmed by Irish, UK and European gull experts. This year also saw the addition of two terrestrial birds which had not been reported in recent previous Celtic Sea Herring Acoustic Surveys; Wren and Siberian Chiffchaff.

Gannet, Guillemot, Kittiwake and Fulmar were the most abundant and widespread species' in the present survey, with Guillemot 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, the Trench, Ballycotton and Fastnet grounds. These same areas were also noted as 'hotspots' during the 2020 survey (Connaughton & Power, 2020).

The high levels of seabird activity and feeding behaviour observed in these 'hotspots' suggests abundant feeding opportunities and high prey availability for seabirds in these locations. 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 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. Weather conditions throughout the survey were generally favourable during leg 1, however leg 2 saw a significant deterioration, with high wind speeds recorded persistently. The total number of seabird

survey hours was reduced on a number of occasions due to conditions exceeding the environmental parameters for surveying. Environmental conditions, particularly elevated sea states, also likely affected the detection probability of certain inconspicuous species. The use of a larger ESAS qualified 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 autumn abundance and distribution of seabirds in Ireland's Celtic Sea 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 due to COVID 19 restrictions, however recent surveys have also 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 observer wishes 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 observer looks forward to future collaborations.

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