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Morlais Project
Environmental Statement

Chapter 11: Marine Ornithology

Volume III

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Appendix 11.1: Bird and Marine Mammal Surveys 24-Month Technical Report (November 2016 - October 2018) (Natural Power, 2019)

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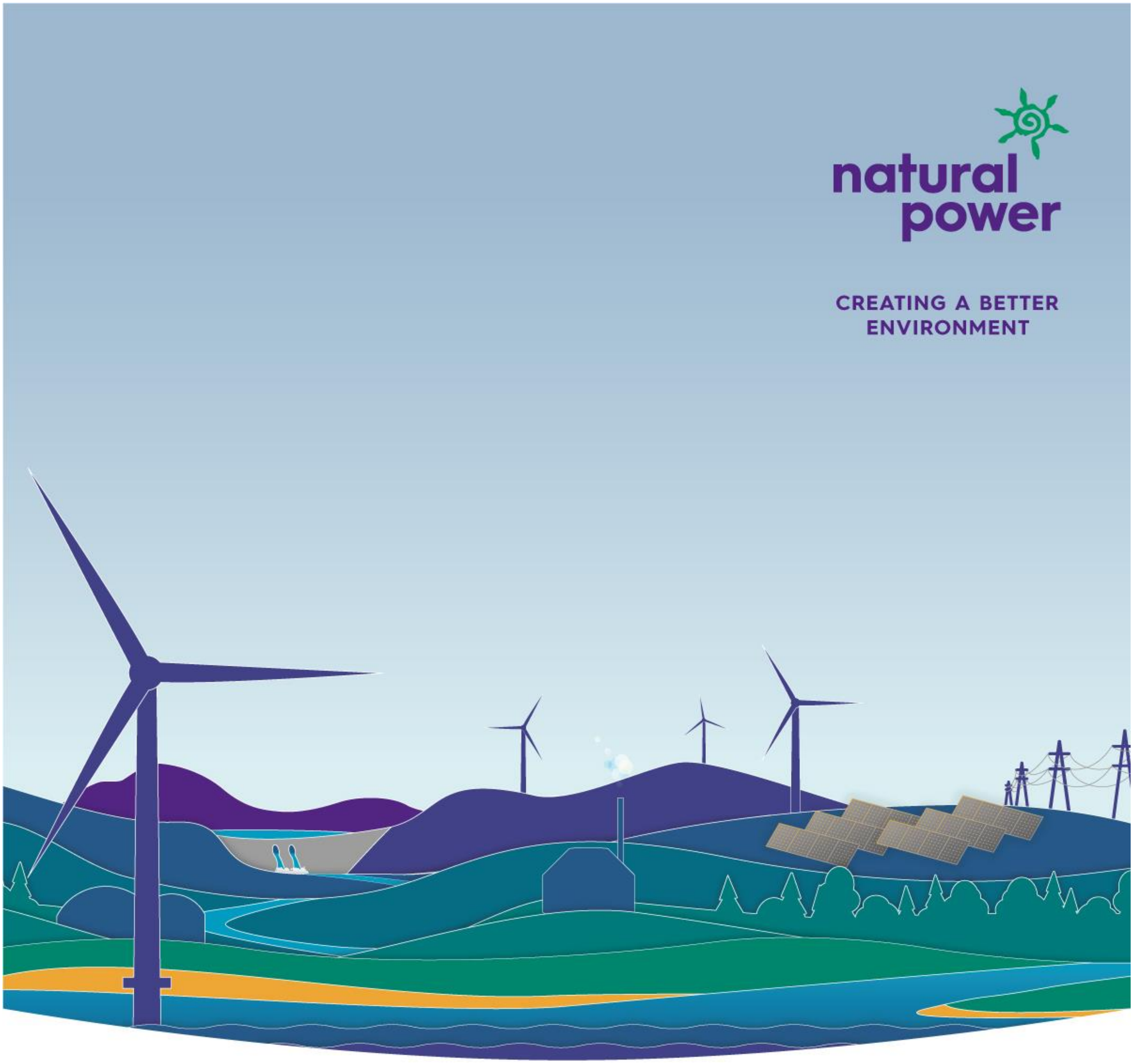

Morlais Demonstration Zone

Bird and Marine Mammal Surveys 24-Month Technical Report (November 2016 - October 2018)

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Executive Summary

Two years of baseline seabird and marine mammal surveys of the Morlais Demonstration Zone were undertaken between November 2016 and October 2018. Twenty-four surveys were carried out and these provided coverage of all ecological seasons.

Surveys were undertaken by means of boat-based visual surveys, using a transect method. Thirteen parallel transects were followed on all surveys, covering the Morlais Demonstration Zone plus a 2 km buffer area.

Weather conditions during surveys were favourable for data recording and analysis.

In total, 34 species of bird were recorded within the survey area. Of these, 23 species were 'seabirds', with the other species considered to be 'land birds' passing over the survey area.

Guillemot was the seabird recorded in the highest numbers within the survey area. Other 'key species' (birds which feed by means of pursuit diving or are seabed foragers) recorded during baseline surveys were eider (*Somateria mollissima*), common scoter (*Melanitta nigra*), red-throated diver (*Gavia stellata*), Manx shearwater (*Puffinus puffinus*), gannet (*Morus bassanus*), shag (*Phalacrocorax aristotelis*), cormorant (*Phalacrocorax carbo*), razorbill (*Alca torda*) and puffin (*Fratercula arctica*). However, common scoter and cormorant were recorded in flight only.

Terns (Sandwich tern (*Thalasseus sandvicencis*), Arctic tern (*Sterna paradisaea*) and common tern (*Sterna hirundo*)) were recorded in small numbers within the Morlais Demonstration Zone.

Most seabirds were recorded in the breeding season: e.g. 78% of the guillemots recorded within the Morlais Demonstration Zone were recorded in the five months of April to August.

Three seabird species were present in numbers sufficient for density analysis to be carried out: guillemot, razorbill and herring gull.

A small proportion of birds were recorded as foraging within the survey area (e.g. 12% of guillemots). The data indicates that the auks present in the survey area are local breeders, but that they mostly use the survey area for resting/ loafing close to the colony rather than as a favoured location for feeding/ foraging.

Four species of marine mammal were recorded in the survey area: harbour porpoise (*Phocoena phocoena*), Risso's dolphin (*Grampus griseus*), bottlenose dolphin (*Tursiops truncates)* and grey seal (*Halichoerus grypus).*

Harbour porpoise was the most frequently sighted marine mammal species and comprised 93% of all marine mammals recorded. This species was recorded in all months of the year; the highest count being on a January survey. Harbour porpoise were present in numbers sufficient for density analysis to be carried out. The highest densities of harbour porpoise were found in the northern-most part of the Morlais Demonstration Zone and the 2 km buffer to the north. The data suggest that the greatest number of porpoises within the survey area were present mid-tide, as the tide was rising.

The two dolphin species were recorded only occasionally, and in small numbers, with only one individual Risso's dolphin recorded within the Morlais Demonstration Zone. Of the small number of grey seals recorded, two individuals were present within the Morlais Demonstration Zone.

1. Introduction

The Morlais Demonstration Zone (MDZ) is located off South Stack, Anglesey. The MDZ is a proposed site for the testing and operation of energy generating tidal devices. In November 2016 Natural Power Consultants (Natural Power) were commissioned by Royal HaskoningDHV, on behalf of Menter Môn, to undertake a programme of seabird and marine mammal surveys (SMMS) across the MDZ. The aim of these surveys was to gather data suitable for describing the baseline conditions of the proposed site in an Environmental Impact Assessment (EIA). This document summarises the survey methods utilised and presents the results of these baseline surveys.

2. Survey Methods

The SMMS were undertaken using a programme of boat-based surveys, undertaken for a period of two years. Twenty-four surveys were carried out between November 2016 and October 2018. The surveys used the following methods.

2.1. Survey Vessel

The SMMS were all undertaken using the vessel *Seekat C*. The vessel is operated by SeeKat Marine Charters of Amlwch, north Anglesey. The *SeeKat C* is a Maritime and Coastguard Agency (MCA) Category 2 survey boat and complies with the Collaborative Offshore Wind Research into the Environment (COWRIE) recommendations for European Seabirds at Sea (ESAS) surveys and guidance (Camphuysen *et al*., 2004, Maclean *et al*., 2009) as she has the following attributes:

- A forward-facing viewing platform with an unobstructed view;
- An observer eye height of greater than 5 m above sea level; and
- Capable of completing surveys at a speed of 5-15 knots (undertaken at 8-12 knots).

Whilst the *SeeKat C* is shorter than COWRIE recommendations (11 m), observer eye height met guidance and it was considered that vessel stability would not be compromised given that the vessel used was a catamaran (as opposed to a less stable, single-hulled vessel) and because surveys were undertaken in sea states of three or less and within inshore waters (11.5 km of land).

2.2. Survey Area

The surveyed area was designed to cover the whole of the MDZ ('the Site') plus a buffer area around the Site of 2 km (1.08 nm) (the 'survey area'). Note, however, that parts of the theoretical buffer on the eastern side of the Site encompassed land, and these areas were therefore excluded from the surveyed area. The survey area was surveyed using 13 parallel transects, of varying length, orientated in a west-east direction. This transect orientation, being approximately perpendicular to the coast, ensured that each transect comprised a similar depth profile. Transects were spaced 0.92 km (0.5 nm) apart, which is the minimum transect separation distance specified by boat-based survey guidelines (Camphuysen *et al*., 2004, Maclean *et al*., 2009; SNH, 2011). Whilst slightly under the 15 transects recommended for robust Distance analysis (Buckland *et al*., 2004), this spacing maximised survey coverage across the MDZ and 2 km buffer and minimised the risk of birds being double-counted as they moved from one transect into another. The total length of all transects was 101.94 km (55.04 nm). The location of the Site, together with the survey transects used, can be seen in Figure 2.1.

2.3. Survey Timing

The SMMS were scheduled to be undertaken on a monthly basis: i.e. one survey per calendar month for two years. On occasion, there were months where a survey was not possible due to poor weather or logistical constraints. Surveys were not undertaken in February, June or October 2017, or in September 2018. These surveys were completed in subsequent months to ensure that the full suite of 24 surveys were carried out within the two year period, and it is considered that each ecological season (breeding, non-breeding and passage) received sufficient survey coverage.

Each survey was carried out on a single day and took between five and six hours to complete (see Appendix A). The direction along which transects were surveyed was alternated from north to south (Transect 1 to 13) and from south to north (Transect 13 to 1), to build temporal variation into the baseline dataset collected.

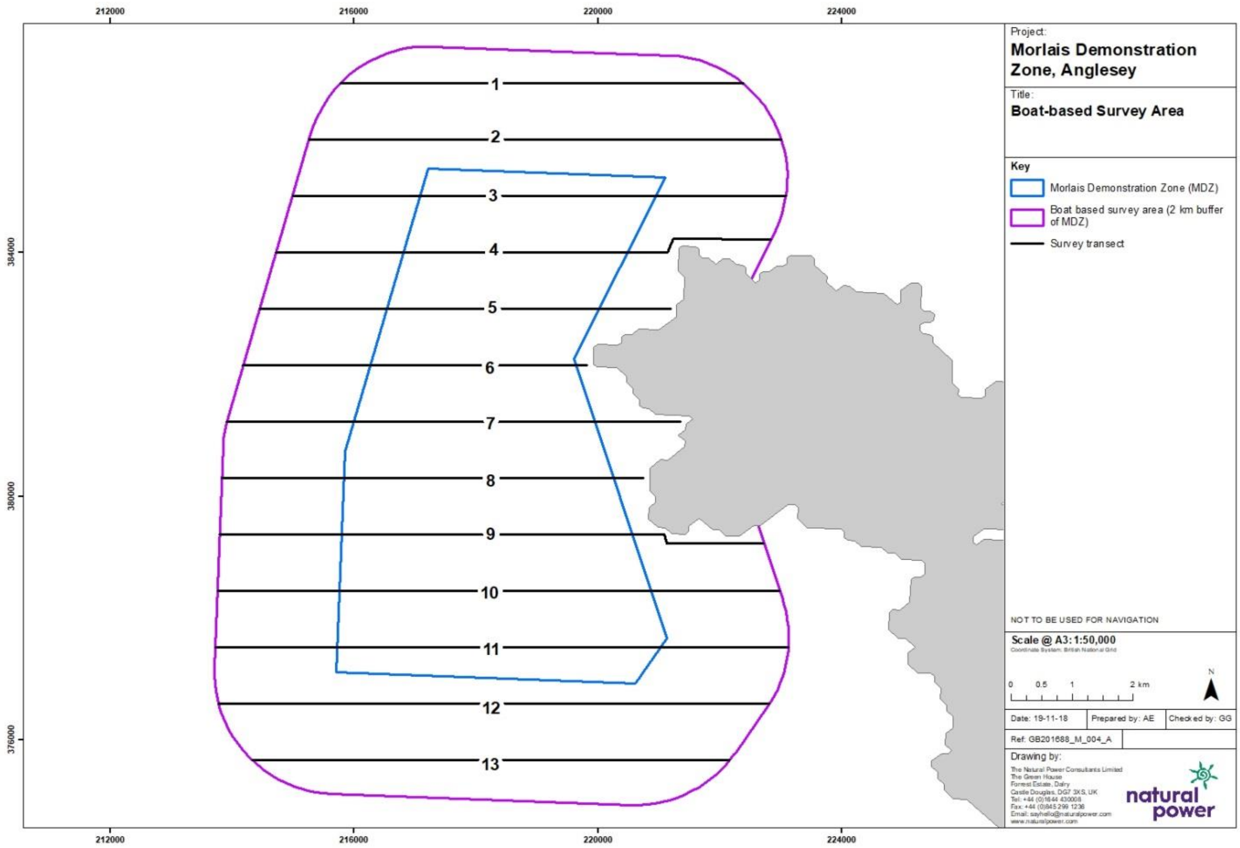

Figure 2.1: **Location of Morlais Demonstration Zone (MDZ), the 2 km buffer survey area and transect layout.**

Surveys were largely undertaken during appropriate weather conditions, considered to be sea state three or less, swell height of <0.5 m or less, and visibility of more than 500 m. Given the tidal nature of the Site, however, small parts of the survey area where tidal flows were particularly pronounced were occasionally surveyed during conditions rougher than sea state three (i.e. sea state four). Such conditions were only encountered for short periods and an analysis of environmental conditions during baseline recording (see Section 3.3) indicates that this did not negatively affect the detection of ecological features. A summary of the environmental conditions during all surveys is provided in Appendix A.

2.4. Seabird Survey

2.4.1. Boat-based Survey Methods

The boat-based seabird survey methods were based on the standard European Seabirds at Sea (ESAS) methodology, as described in guidance by Webb & Durinck (1992) and updated by COWRIE (Camphuysen *et al*.,

2004) and Maclean *et al*. (2009). These methods were adapted to ensure that the data collected are appropriate to inform an EIA for the MDZ, with the surveys focussed on the distribution and behaviour of birds sitting on the sea surface, particularly for those species identified as being vulnerable to 'wet' renewable technologies (Furness *et al*. 2012). Since flying birds are not expected to be at risk from marine renewables, flight height was not recorded in detail. Instead two height bands were used; 'above eye height' and 'below eye height' in order to facilitate any assessment of birds which may interact with the sea versus those transiting through the area.

Two experienced and ESAS-certified surveyors undertook each survey: one surveyor scanned for birds and the other scribed the recordings of the observer. A third surveyor recorded navigational and environmental data and assisted with protecting and storing field sheets. The three surveyors alternated roles to avoid fatigue and to maintain visual acuity.

The following formed key components of the survey method:

- Observers scanned one side of the survey vessel, looking ahead and to 90º to either port or starboard;
- All bird species observed were recorded, whether on the sea or in flight. Only birds within 300 m were recorded as being 'in transect' (see below), with birds beyond 300 m recorded but excluded from subsequent data analysis;
- Birds were detected by the naked eye and identified using binoculars where necessary;
- For each bird observed, surveyors recorded the following:
  - Species (using the British Trust for Ornithology (BTO) two letter code);
  - Number of individuals;
  - Time (each sighting was recorded to the nearest minute using a watch set to the same time as the GPS. This placed each bird within a 300 m x 300 m sampling area);
  - Whether the bird was on the sea or in flight (birds initially seen in flight but that were clearly foraging/feeding were recorded as being on the sea);
  - Distance band (perpendicular to the transect) of birds on the sea, estimated using a range finder (see below);
  - Behaviour of birds on the sea, as categorised after 30 seconds of observation (where possible) (see below);
  - Height of birds in flight (recorded as being either below eye height (≤5 m) or above eye height (≥6 m));
  - Direction of birds in flight; and
  - Age, sex, plumage (where possible).
- The following distance bands were used (where birds in Bands A-D are 'in transect' and E is not in transect):
  - Band A, 0-50 m;
  - Band B, 50-100 m;
  - Band C, 100-200 m;
  - Band D, 200-300 m; and
  - Band E, 300+ m.
- The following behaviour categories were used for birds on the sea:
  - Diving (D), individual was fully submerged;
  - Surface feeding (S), individual appeared to be feeding but was not fully submerged;
  - Carrying prey but not seen diving (F);
  - Preening (P) (or other maintenance behaviours such as bathing); and
  - Resting (R), birds on the water but for which no active behaviour was apparent.
  - Birds were watched for as long as possible to ascertain behaviour, but frequently the number of birds present meant that each individual was only observed briefly, in order to meet the survey requirements of

detecting all individuals present within the survey transect. Where behaviour was not ascertained, or was considered to have been influenced by the presence of the survey vessel, a behaviour code was not applied.

  – Note that these codes are project specific. Standard ESAS behaviour codes were also used where appropriate

- The side of the vessel surveyed was selected to ameliorate the effects of local conditions on observers, such as wind direction, glare etc., and was varied accordingly during the course of the survey;
- Vessel speed was maintained as close as possible to 10 knots (range 8-12 knots depending on local sea conditions); and
- Vessel position was logged every 30 seconds by at least two handheld GPS units.

If numbers of birds encountered were sufficiently large that not all the above data could be recorded, then species, number, whether on the sea or in flight, and distance band, were recorded as priorities.

2.4.2. Data Analysis

Where possible, densities and abundances of key species recorded on the sea were calculated using 'design-based' Distance analysis. Distance analysis is used to correct the numbers of birds observed for imperfect detectability. Distance Version 7.2 (Thomas *et al*., 2010) was used to run the Distance analysis and to calculate the density and abundance of qualifying species within the survey area.

Distance sampling operates on the principle that randomly distributed targets (i.e. individual seabirds) become more difficult to detect with increasing distance from the observer (Buckland *et al*., 2001). As a result, an increasing proportion of individuals that are present will go undetected with increasing distance. In order to account for this decline in detectability, a detection function was fitted to the data. This function allowed estimation of the proportion of individuals present within the survey area which remained undetected. The proportion of 'undetected' individuals was then incorporated into the calculations of density and abundance for each species. Since at least 60-80 observations of any species are required to ensure that a reliable detection function can be fitted (Buckland *et al.,* 2001), seabird species with fewer than 60 observations were not analysed in this way.

One of the assumptions of Distance sampling is that all targets on the line are detected (i.e. the probability of detection on the survey line is 1, in notation, $g(0) = 1$). This assumption is usually accepted by stakeholders for birds since the amount of time during which observers are able to detect them from a vessel is considered to be sufficiently long enough for diving species.

Birds recorded in the final distance Band E (>300 m) were excluded from the Distance analysis because the average distance of counts within an unbounded category cannot be calculated. This truncation is routinely utilised for accurate density estimation using the Distance sampling technique. In order to allow separate analyses of the Site and buffer area, survey transects were divided into lengths falling within the Site and those falling within the 2 km buffer. Thus if transects passed through the Site, they were divided into two separate transect segments: a Site transect and a broken segment representing the length of the transect passing through the buffer to either side of the Site. The result was 22 transect segments (nine falling within the Site and 13 covering the remaining buffer). For each species, a global detection function was fitted based on all data combined across surveys and regions. The function used to model the drop in detectability with distance was selected by minimising Akaike's Information Criterion (AIC), a metric which assesses the suitability of a model based on a trade-off between the goodness-of-fit of the model to the data and the complexity of the model. Estimates of density and abundance were then calculated for the Site and buffer, using the global detection function to estimate undetected individuals. Cluster size was also estimated at the global level while encounter rate was estimated at the stratum level (i.e. separately for each area and survey).

For species where Distance sampling was undertaken, density plots were also produced to show the average density and distribution of seabirds across the survey area over the survey period. For each grid square, density was calculated as:

$$Density\ (birds\ per\ km^2) = \frac{\sum_{n=1}^{n\ obs}(number\ of\ individuals_n\ \times 1/p\ det_n)}{Area\ surveyed}\ x\ Total\ area$$

where *n obs* is the number of observations and *p det* is the probability of detection given the distance band within which the observation was recorded.

For species with fewer than 60 observations, and for birds in flight, densities were calculated per survey per area as:

$$Density\ (birds\ per\ km^2) = \frac{Number\ of\ individuals}{Area\ surveyed}$$

and extrapolated to the Site, the 2 km buffer and survey area as a whole as:

$$Abundance = \frac{Number\ of\ individuals}{Area\ surveyed}\ x\ Total\ area$$

in order to give a crude indication of the numbers of animals likely to be using the Site. These estimates are minimum estimates since drop-off in detectability with distance for the observer has not been accounted for.

2.5. Marine Mammal Survey

2.5.1. Boat-based Visual Survey Methods

A dedicated and experienced marine mammal surveyor, holding Joint Nature Conservation Committee (JNCC) approved certification, carried out marine mammal recording concurrently to the seabird survey using the same 13 transects. However, the marine mammal surveyor operated independently of the seabird surveyors, scanning an area of sea 180° ahead of the vessel. One marine mammal surveyor provided survey coverage for the full duration of each survey; but the ESAS 'third man' (where qualified to do so) periodically took over from the marine mammal surveyor to allow breaks and to maintain the surveyor's visual acuity. Any such change in survey effort was duly noted on the recording form. Marine mammal detection was by naked eye and binoculars. For each marine mammal observed, the following data were recorded:

- Transect;
- Time;
- Species;
- Group size, recording the best estimate plus number of calves (where applicable);
- Distance from the vessel (using reticule binoculars or a range finder)[1];
- Side of vessel and angle (measured in relation to the direction of vessel travel);
- Direction of travel of the marine mammal;
- Behaviour (e.g. normal swim, 'bottling', foraging);
- Cue for sighting (e.g. body, splash); and
- Survey effort (see below).

2.5.2. Survey Effort

For analysis purposes, the marine mammal sightings were classified into one of three categories depending on where an individual was recorded and by which surveyor. This was to enable an estimate of the survey effort for

[1] On the few occasions when the location of an animal close inshore meant that distance was measured against land, rather than the horizon, the distance between the vessel and shore at the time of observation was estimated using GIS and a conversion formula used to estimate the actual distance, based on the range finder/ reticule measurement recorded.

comparison between surveys, as well as to calculate other survey matrices such as detection rates. The three categories were:

- On-effort: sightings recorded by the marine mammal surveyor during the survey and on transect;
- Off-effort: sightings recorded by the ESAS surveyors, but not by the marine mammal surveyor, when inside the survey area, either on- or off-transect; and
- Incidental: sightings recorded by the marine mammal surveyor when the vessel was inside the survey area but off-transect (e.g. during a turn between transects).

Whilst only on-effort sightings can be included in statistical analyses, off-effort and incidental data can also provide useful contextual information, for example in adding to the species list of those mammals recorded on the Site.

2.5.3. Data Analysis

As with the seabird data, densities and abundances of marine mammals were calculated using Distance analysis, where possible. The methods of analysis used were the same as those used for seabirds except that perpendicular distances were calculated from the angles and distances recorded for each observation (distance bands were used for birds). A truncation distance of 300 m was selected for marine mammals as it results in removal of 5% of the data from the right-hand tail of the detection function (following Buckland *et al*., 2001, pp. 104).

As mentioned above, Distance sampling operates on the assumption that all targets on the survey line are detected. This assumption is known not to hold for marine mammals as many individuals are submerged and therefore not available for detection. However, in the absence of any quantitative assessment of g(0), the analysis was carried out assuming g(0) = 1). Therefore, whilst the drop-off in detectability with distance has been accounted for, marine mammal density and abundance estimates are likely to be underestimates of the total individuals using the site.

Only marine mammals recorded on effort by the marine mammal surveyor were included in the analysis. Since sea state is known to affect detectability of harbour porpoise, sea state was initially included as a covariate when fitting the detection function (with sea states 3 and 4 combined due to the low sample sizes in each category). However, the difference in the AIC for the two models was less than 2 meaning that both models are equally supported. (AIC including sea state was 1912.08 and without was 1910.40).The simpler model (excluding sea state) was therefore taken forward for the analysis.

As for birds, estimates of density and abundance were calculated using a global detection function (i.e. a function that was fitted using the entire dataset) to estimate undetected individuals. Cluster size was also estimated at the global level but encounter rate was estimated at the stratum level (i.e. separately for each area and survey).

2.5.4. Environmental Recording

In addition to the above recording, environmental variables (wind direction and speed, sea state, swell height, cloud cover, glare and precipitation) were all frequently noted during surveys. These variables were recorded at the start of each transect and whenever a change in one of the variables occurred, as recommended in Maclean *et al*. (2009).

3. Results

3.1. Seabird Survey Results

3.1.1. Key Species

Since the MDZ is a proposed site for testing tidal devices (i.e. with moving parts within the water column) the emphasis of this Section has been placed on deep diving bird species (e.g. those which are capable of pursuit dives or are seabed foragers) which were recorded using the survey area ('on sea'). It is these species that have the greatest potential for interactions with any tidal turbines (Furness *et al.* 2012). Key diving bird species observed during surveys are considered to be: eider (*Somateria mollissima*), red-throated diver (*Gavia stellata*), gannet (*Morus bassanus*), shag (*Phalacrocorax aristotelis*), puffin (*Fratercula arctica*), razorbill (*Alca torda*) and guillemot (*Uria aalge*).

Manx shearwater (*Puffinus puffinus*) has also been included on this list, as although this is typically a surface feeder, this species is capable of pursuit dives and was one of the more abundant species recorded in the survey area. Also included as key species are the three tern species recorded during baseline surveys: Sandwich tern (*Thalasseus sandvicencis*), Arctic tern (*Sterna paradisaea*) and common tern (*Sterna hirundo*). Although considered to be of 'low vulnerability' to tidal devices (Furness *et al.* 2012) and recorded on the sea in the survey area only in small numbers (and in the case of Sandwich tern, recorded in flight only) these three species are named features of the Anglesey Terns Special Protection Area (SPA), part of which overlaps the survey area.

Two other deep diving/ bottom-feeding species, common scoter (*Melanitta nigra*) and cormorant (*Phalacrocorax carbo*) were recorded within the survey area, but it should be noted that in both cases these birds were only observed transiting over the survey area (recorded 'in flight' only).

Species that shallow dive (e.g. fulmar (*Fulmarus glacialis*)) are not considered to be key species as they do not tend to become fully submerged when foraging, and are, therefore, only likely to use the very top of the water column. Other birds, such as gulls (*Larus* sp.) were recorded sitting on the sea's surface during surveys. These are not considered to be target species, however, herring gull (*Larus argentatus)* was recorded in relatively high numbers during baseline recording and thus density analysis has been undertaken for this species. Other birds recorded on the survey included species such as waders and passerines which were recorded on migration, simply passing over the survey area.

3.1.2. All Birds: Total Counts

This section presents the total numbers of all species recorded during the two years of baseline recording (November 2016 to October 2018). These totals have been filtered to exclude birds not in transect (i.e. those in Band E or highlighted in GIS as not being on a transect line). Presented numbers therefore represent processed, rather than raw counts (i.e. the data underpinning subsequent density analysis).

In total, the surveys identified 34 species of bird, comprising 11,732 individuals. These were very evenly split between birds in flight, 5,834 individuals, and bird on the sea, 5,898 individuals (Table 3.1). Guillemot was the most abundant species (6,132 individuals) and represented 52% of all records.

Within the Site, the number of birds recorded on the sea comprised 18 species/ species groups of 2,755 individuals; and the number of birds in flight comprised 29 species/ species groups of 2,566 individuals. Of the birds seen on the sea, guillemot was the most abundant species (1,585 individuals), comprising almost 58% of records. Of the total number of guillemots recorded in the Site (both on the sea and in flight), 78% were recorded during breeding season surveys (April to August).

Results were similar inside the 2 km buffer with 17 species/ species groups (3,143 individuals) seen on the sea and 31 species/ species groups (3,268 individuals) in flight. The difference in the list of seabird species recorded in the Site compared to the buffer, were that sooty shearwater (*Puffinus griseus*) was only recorded in the Site and cormorant and great skua (*Stercorarius skua*) were only recorded in the 2 km buffer. Guillemot was the most abundant species seen on the sea (1,805 individuals) in the 2 km buffer, comprising almost 61% of records.

The ‘species groups’ described above, refer to those individuals that were not observed well enough to allow species identification. The most numerous of these groups were ‘guillemot/razorbill’ (birds which were either of these two species) (786 individuals), ‘large gull species’ (birds that were either herring gull, lesser black-backed gull (*Larus fuscus*) or great black-backed gull (*Larus marinus*) (60 individuals) and ‘common/ Arctic tern’ (birds which were either common tern or Arctic tern (25 individuals).

Table 3.1: All birds recorded during boat-based surveys (November 2016 to October 2018). Key species are shaded.

	Site			2 km buffer			Site + 2 km buffer		
	On sea	In flight	Total	On sea	In flight	Total	On sea	In flight	Total
Whooper swan (*Cygnus Cygnus*)					2	2	0	2	2
Eider		13	13	1	1	2	1	14	15
Common scoter		40	40		72	72	0	112	112
Red-throated diver	1	7	8	2	10	12	3	17	20
Fulmar	4	13	17	2	24	26	6	37	43
Sooty shearwater		2	2				0	2	2
Manx shearwater	186	277	463	469	446	915	655	723	1378
Gannet	4	44	48	14	71	85	18	115	133
Cormorant					2	2	0	2	2
Shag	5	1	6	12	13	25	17	14	31
Peregrine (*Falco peregrinus*)					1	1	0	1	1
Dunlin (*Calidris alpine*)		4	4		18	18	0	22	22
Whimbrel (*Numenius phaeopus*)					2	2	0	2	2
Great skua					1	1	0	1	1
Mediterranean gull (*Larus melanocephalus)*		2	2		2	2	0	4	4
Black-headed gull (*Chroicocephalus ridibundus*)	9	22	31	76	121	197	85	143	228
Common gull (*Larus canus*)	7	30	37	59	42	101	66	72	138
Common gull/ kittiwake					1	1	0	1	1
Lesser black-backed gull	14	13	27	10	16	26	24	29	53
Herring gull	286	167	453	132	282	414	418	449	867
Great black-backed gull	7	16	23	3	30	33	10	46	56
Kittiwake (*Rissa tridactyla*)	60	124	184	91	138	229	151	262	413
Large gull sp.	20	21	41	3	16	19	23	37	60
Gull sp.				3	1	4	3	1	4
Sandwich tern		3	3		5	5	0	8	8
Common tern		8	8	4	5	9	4	13	17
Arctic tern	17	12	29	14	45	59	31	57	88
Common/ Arctic tern	1	7	8	1	16	17	2	23	25
Guillemot	1585	1259	2844	1805	1483	3288	3390	2742	6132
Razorbill	258	234	492	271	213	484	529	447	976
Puffin	6	17	23	17	12	29	23	29	52
Guillemot/ razorbill	285	213	498	154	134	288	439	347	786
Sand martin (*Riparia riparia)*		1	1				0	1	1
Swallow (*Hirundo rustica)*		12	12		16	16	0	28	28

	Site			2 km buffer			Site + 2 km buffer		
House martin (*Delichon urbicum*)		1	1				0	1	1
Meadow pipit (*Anthus pratensis*)		3	3		12	12	0	15	15
Meadow pipit/ tree pipit (*Anthus trivialis*)					2	2	0	2	2
Pied wagtail (*Motacilla alba)*					1	1	0	1	1
Redwing (*Turdus iliacus*)					2	2	0	2	2
Starling (*Sturnus vulgaris*)					9	9	0	9	9
Passerine sp.					1	1	0	1	1
Grand Total	**2755**	**2566**	**5321**	**3143**	**3268**	**6411**	**5898**	**5834**	**11732**

3.1.3. Diving Birds: Seasonal Variation in Total Counts

The survey identified 13 species of diving bird, comprising 9,775 individuals and representing 83% of all birds recorded within the Site and 2 km buffer (Table 3.2 and 3.3). Guillemot was the most frequently recorded diving species (6,132 individuals), followed by Manx shearwater (1,378 individuals) and razorbill (976 individuals).

These totals refer to records of those birds considered to be diving species. They do not refer to the total number of individuals recorded actively diving during surveys; the proportion of which was low (see Section 3.1.7 for further information).

Within the Site, 12 species of diving bird were seen with guillemot, again, the most frequently recorded species (2,844 individuals); followed by razorbill and Manx shearwater (492 and 463 individuals respectively).

During the first year of baseline surveys (November 2016 to September 2017), guillemot numbers were lowest in the autumn and early winter periods. Numbers began to rise from January until numbers peaked on the survey in July (Figure 3.1). Manx shearwater numbers also showed an obvious peak in July 2017.

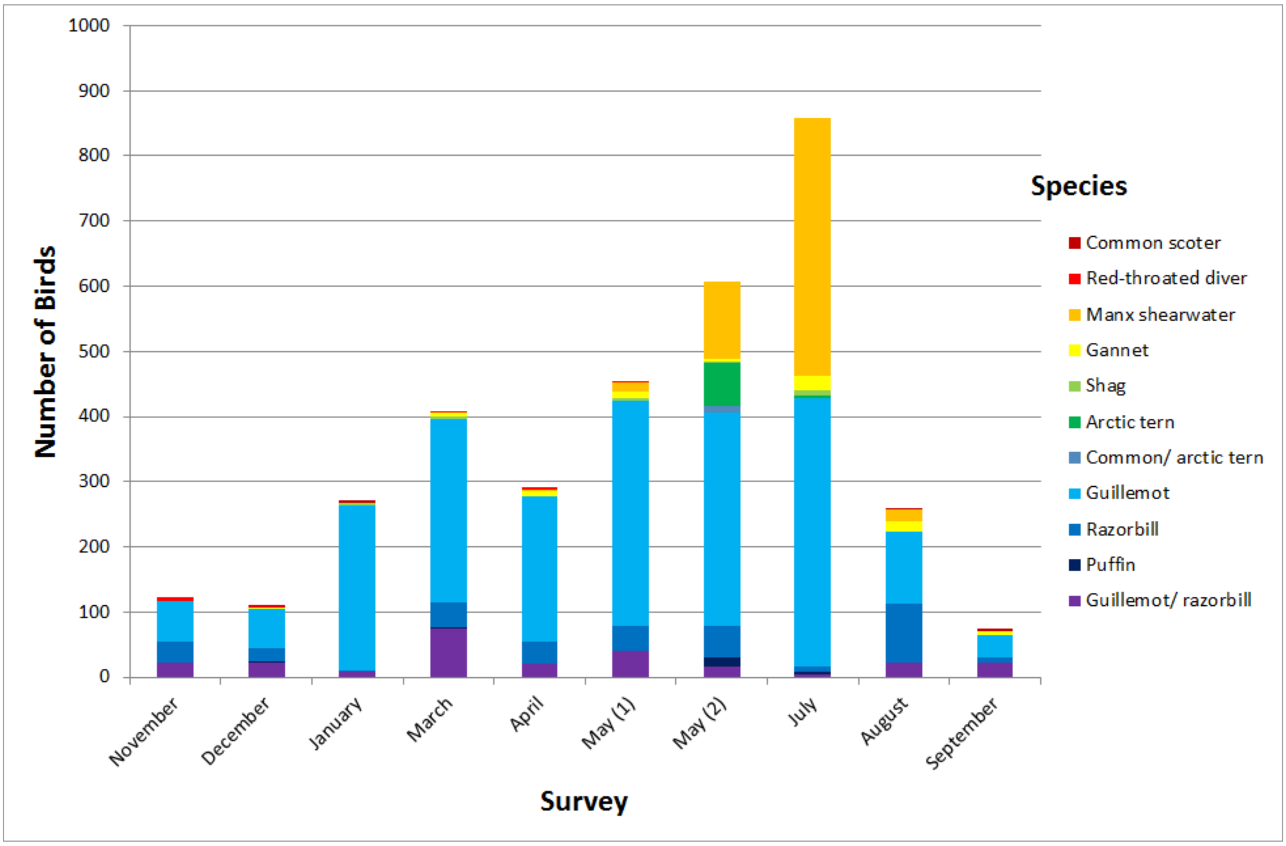

Figure 3.1: Seasonal distribution of key species recorded in the survey area (MDZ plus 2 km buffer), during the first year of baseline surveys (November 2016 to September 2017).

In the second year of baseline recording (November 2017 to October 2018) guillemot numbers showed an isolated increase in early February 2018, followed by a clear increase in the survey area during the main breeding season (April to August), but in this year the greatest numbers were recorded in May 2018 (Figure 3.2). Manx shearwater numbers had an obvious peak in August 2018.

Apart from guillemot, razorbill and Manx shearwater the other diving bird species were recorded in low numbers throughout the survey period (Table 3.2 and 3.3).

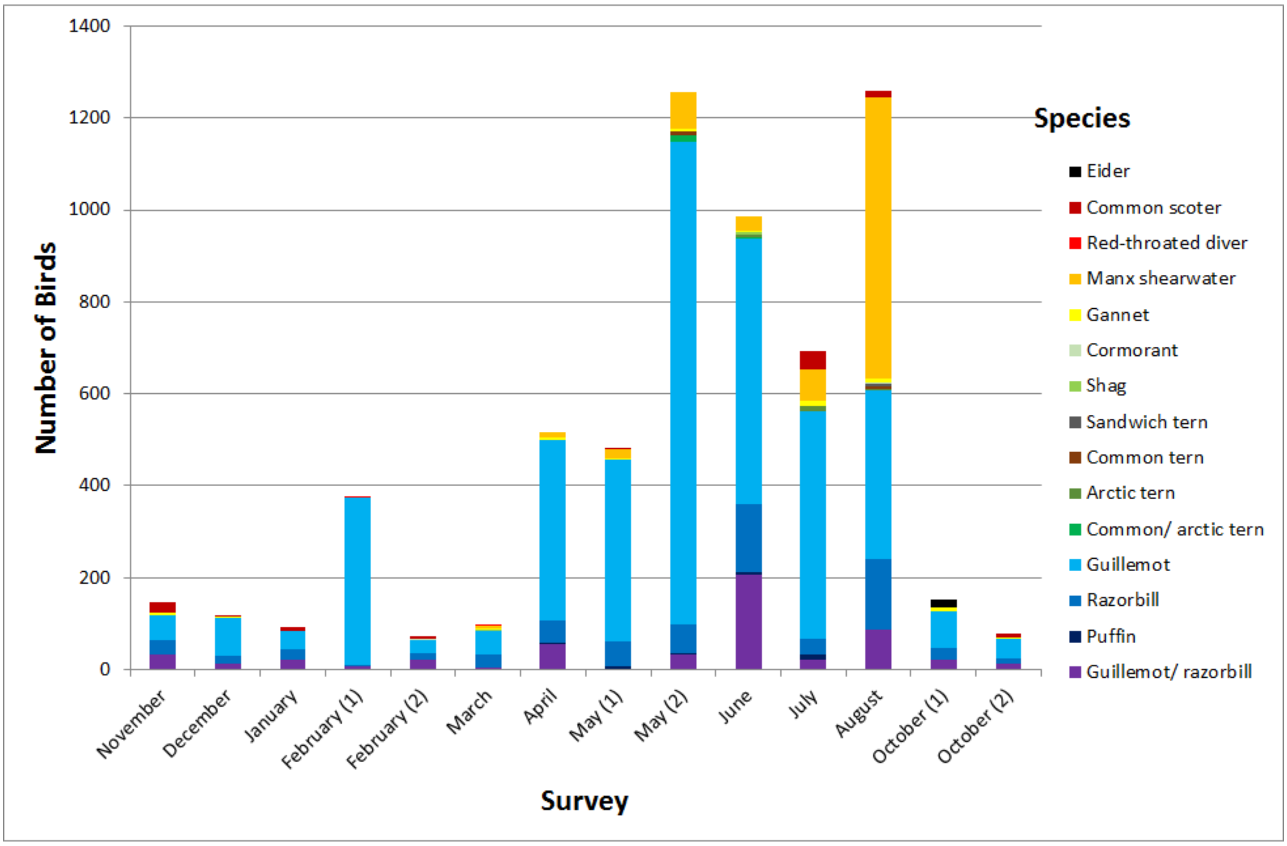

Figure 3.2: Seasonal distribution of key species recorded in the survey area (MDZ plus 2 km buffer), during the second year of baseline surveys (November 2017 to October 2018).

Table 3.2: Seasonal abundance (total counts) of key bird species recorded in the Morlais Demonstration Zone during the boat-based surveys (November 2016-October 2018).

	2016		2017										2018												
Species	**Nov**	**Dec**	**Jan**	**Mar**	**Apr**	**May 1**	**May 2**	**Jul**	**Aug**	**Sep**	**Nov**	**Dec**	**Jan**	**Feb 1**	**Feb 2**	**Mar**	**Apr**	**May 1**	**May 2**	**Jun**	**Jul**	**Aug**	**Oct 1**	**Oct 2**	**Total**
Eider																							13		**13**
Common scoter		2	1								12	1			7			2				14		1	**40**
Red-throated diver	4	1			2									1											**8**
Manx shearwater					1	7	30	137	9		1						6	11	20	3	31	207			**463**
Gannet				2	3	6	2	5	6	2		1			1	4	5	1			2	2	6		**48**
Shag								2												4					**6**
Sandwich tern																			2			1			**3**
Common tern																		1	1			6			**8**
Arctic tern							26													2		1			**29**
Common/ Arctic tern							5												3						**8**
Guillemot	12	15	106	168	139	130	123	135	32	14	23	51	20	129	15	17	232	191	493	337	248	173	30	11	**2844**
Razorbill	10	15		19	23	16	26	4	39	4	19	5	14	2	10	9	19	27	28	92	10	81	12	8	**492**
Puffin				1			4	2										7	1	3	5				**23**
Guillemot/ razorbill	11	16	2	54	19	26	13		10	17	21	8	15	5	7	3	29		30	204	2	1	5		**498**

Table 3.3: Seasonal abundance (total counts) of key bird species recorded in the 2 km buffer during the boat-based surveys (November 2016-October 2018).

	2016		2017										2018												
Species	**Nov**	**Dec**	**Jan**	**Mar**	**Apr**	**May 1**	**May 2**	**Jul**	**Aug**	**Sep**	**Nov**	**Dec**	**Jan**	**Feb 1**	**Feb 2**	**Mar**	**Apr**	**May 1**	**May 2**	**Jun**	**Jul**	**Aug**	**Oct 1**	**Oct 2**	**Total**
Eider																							2		**2**
Common scoter			3						1	3	9		8								40			8	**72**
Red-throated diver	2			2	1	1							1	1		2							2		**12**
Manx shearwater					1	8	89	258	10	1						3	6	9	60	28	36	406			**915**
Gannet	1	2		4	5	4	3	18	9	4	6					1	2	1	4	3	10	6	1	1	**85**
Cormorant															1							1			**2**
Shag			3	3		4	2	6			1					2				1	1	1			**25**
Sandwich tern																						5			**5**
Common tern																			7	1		1			**9**
Arctic tern							39	3										1	1	4	10	1			**59**
Common/ Arctic tern							5	1											9	2					**17**
Guillemot	49	44	147	115	84	216	205	277	80	20	29	33	21	235	15	33	160	205	557	241	247	193	50	32	**3288**
Razorbill	23	6	3	19	11	21	22	4	51	4	14	11	9		4	22	30	26	35	54	23	74	15	3	**484**
Puffin		1					10	2									1		3	5	7				**29**
Guillemot/ razorbill	11	7	6	21	2	15	4	4	12	5	11	5	5	2	14		27		2	1	20	85	15	14	**288**

3.1.4. Species Qualifying for Distance Analysis

From the full list of species recorded during baseline surveys, there were sufficient records of three species (razorbill, guillemot and herring gull) to allow Distance analysis to be undertaken (Table 3.4). For the other species, either no Distance eligible observations were made (i.e. not observed on the sea within the 300 m transect) or too few encounters occurred to allow Distance analysis to be undertaken. Observations recorded as 'guillemot/razorbill' were not included in the analysis as these would be accounted for by the detection function as 'missed detections'. Unidentified 'guillemot/razorbill' records accounted for just 1% of the total number of guillemots, razorbills and guillemot/razorbills recorded in distance Band A and it was assumed that all birds actually on the line (and therefore easiest to see) were correctly assigned to species.

Table 3.4: Number of observations of birds on the sea and eligible for inclusion in Distance analysis. Shading indicates species for which Distance analysis was undertaken.

Species	Number of observations
Guillemot	1544
Razorbill	268
Herring gull	114
Guillemot/razorbill	61
Manx shearwater	40
Kittiwake	35
Common gull	24
Puffin	19
Black-headed gull	18
Gannet	15
Lesser black-backed gull	14
Shag	14
Great black-backed gull	9
Arctic tern	6
Fulmar	5
Common tern	3
Red-throated diver	3
Common/ arctic tern	2
Unidentified gull species	2
Unidentified large gull species	2
Eider	1

Given the frequency with which herring gull was encountered during the surveys, abundance and density estimates were produced using Distance. However, herring gull is not considered to be vulnerable to the effects of tidal turbine devices as, when foraging at sea, this species only feeds at the sea's surface (Furness *et al*. 2012). Therefore, the results for this species are not discussed in detail, and are presented in in Appendix B.

The detection functions selected for modelling the densities of guillemot and razorbill (and herring gull) are shown in Table 3.5. For herring gull, more observations were recorded in Band B than Band A. This may happen as a result of birds being displaced from the band closest to the vessel. For this reason observations in Bands A and B were combined for Distance analysis for this species.

Table 3.5: Detection functions selected to model drop-off in detectability.

Species	Number of observations	Detection function	Goodness-of-fit p-value
Razorbill	268	Half-normal polynomial	0.846
Guillemot	1544	Uniform cosine	0.924
Herring gull	114	Uniform cosine	>0.999

Razorbill and guillemot density and abundance estimates for each survey are shown in Table 3.6 and Table 3.7 respectively. These are estimates of birds on the sea only. Within the Site, razorbills peaked at an estimated 8.9 birds/km^{-2} during the August 2018 survey, whilst guillemots peaked at an estimated 46.93 birds/km^{-2} during May 2018.

Table 3.6: Razorbill abundance and density (birds/km^{-2}) estimates, together with lower 95% confidence limits (LCL) and upper 95% confidence limits (UCL) derived from Distance sampling.

		Abundance			Density			
Survey	Region	Estimate	LCL	UCL	Estimate	LCL	UCL	%CV
November 2016	Buffer	119	68	207	1.82	1.04	3.18	26.39
	Site	11	2	70	0.31	0.05	2.00	97.17
December	Buffer	12	2	69	0.18	0.03	1.06	96.10
	Site	54	26	109	1.53	0.75	3.13	32.21
January 2017	Buffer	12	2	71	0.18	0.03	1.09	98.10
	Site	0	0	0	0.00	0.00	0.00	
March	Buffer	12	2	69	0.18	0.03	1.06	95.97
	Site	32	12	88	0.92	0.33	2.52	46.34
April	Buffer	24	6	90	0.36	0.10	1.38	67.45
	Site	43	10	179	1.22	0.29	5.11	68.65
May (1)	Buffer	12	2	69	0.18	0.03	1.06	95.97
	Site	32	7	141	0.92	0.21	4.02	71.42
May (2)	Buffer	36	9	143	0.55	0.14	2.20	71.35
	Site	32	7	139	0.92	0.21	3.97	70.72
July	Buffer	36	9	146	0.55	0.13	2.24	72.41
	Site	32	7	139	0.92	0.21	3.97	70.73
August	Buffer	225	132	384	3.46	2.03	5.90	25.26
	Site	161	79	329	4.59	2.24	9.40	32.32
September	Buffer	12	2	69	0.18	0.03	1.06	96.10
	Site	0	0	0	0.00	0.00	0.00	
November	Buffer	12	2	75	0.18	0.03	1.15	102.07
	Site	21	5	85	0.61	0.15	2.44	65.93
December	Buffer	47	14	162	0.73	0.21	2.49	61.33
	Site	21	5	87	0.61	0.15	2.47	66.83
January 2018	Buffer	59	27	130	0.91	0.41	2.00	37.54
	Site	54	15	188	1.53	0.44	5.36	58.88
February (1)	Buffer	0	0	0	0.00	0.00	0.00	
	Site	0	0	0	0.00	0.00	0.00	
February (2)	Buffer	12	2	76	0.18	0.03	1.17	103.73
	Site	32	11	94	0.92	0.31	2.69	49.57
March 2018	Buffer	12	2	67	0.18	0.03	1.03	93.81
	Site	0	0	0	0.00	0.00	0.00	
April 2018	Buffer	83	29	240	1.27	0.44	3.68	51.98

Survey	Region	Abundance Estimate	LCL	UCL	Density Estimate	LCL	UCL	%CV
	Site	54	14	206	1.53	0.40	5.87	63.92
May (1)	Buffer	47	16	143	0.73	0.24	2.19	54.24
	Site	54	20	144	1.53	0.57	4.11	45.24
May (2)	Buffer	154	62	383	2.37	0.95	5.88	43.91
	Site	172	50	591	4.90	1.42	16.89	58.08
June	Buffer	201	82	494	3.09	1.26	7.58	43.16
	Site	97	25	376	2.76	0.71	10.75	64.83
July	Buffer	47	22	101	0.73	0.34	1.55	35.93
	Site	21	3	143	0.61	0.09	4.09	98.75
August	Buffer	462	284	753	7.10	4.36	11.57	23.12
	Site	311	148	652	8.88	4.24	18.61	33.40
October (1)	Buffer	95	50	180	1.46	0.77	2.77	30.41
	Site	64	23	181	1.84	0.65	5.16	47.50
October (2)	Buffer	12	2	75	0.18	0.03	1.15	102.14
	Site	0	0	0	0.00	0.00	0.00	

Table 3.7: Guillemot abundance and density (birds km^{-2}) estimates, together with lower 95% confidence limits (LCL) and upper 95% confidence limits (UCL) derived from Distance sampling.

Survey	Region	Abundance Estimate	LCL	UCL	Density Estimate	LCL	UCL	%CV
November 2016	Buffer	214	112	408	3.28	1.72	6.27	30.48
	Site	68	28	161	1.93	0.81	4.59	39.03
December	Buffer	128	62	265	1.97	0.95	4.07	34.38
	Site	68	29	157	1.93	0.83	4.50	38.03
January 2017	Buffer	278	100	769	4.27	1.54	11.81	49.46
	Site	135	57	322	3.86	1.63	9.18	39.02
March	Buffer	150	75	300	2.30	1.14	4.61	32.94
	Site	222	155	318	6.35	4.44	9.09	15.96
April	Buffer	278	154	500	4.27	2.37	7.68	27.57
	Site	329	209	517	9.39	5.96	14.77	20.11
May (1)	Buffer	395	228	686	6.07	3.50	10.53	25.81
	Site	242	143	408	6.90	4.09	11.65	23.22
May (2)	Buffer	492	340	710	7.55	5.23	10.91	17.19
	Site	164	83	325	4.69	2.37	9.29	30.44
July	Buffer	759	487	1182	11.65	7.48	18.15	20.7
	Site	483	334	699	13.80	9.54	19.96	16.41
August	Buffer	620	430	893	9.52	6.61	13.71	17.06
	Site	203	133	311	5.80	3.78	8.88	18.94
September	Buffer	150	77	290	2.30	1.19	4.45	31.12
	Site	97	43	218	2.76	1.22	6.22	36.51
November	Buffer	96	37	252	1.48	0.56	3.87	46.5
	Site	39	16	92	1.10	0.47	2.62	38.91
December	Buffer	85	34	214	1.31	0.52	3.29	44.19
	Site	68	10	442	1.93	0.30	12.63	97.01
January 2018	Buffer	64	23	176	0.98	0.36	2.71	49.12
	Site	58	18	186	1.66	0.52	5.30	53.93

Survey	Region	Abundance Estimate	LCL	UCL	Density Estimate	LCL	UCL	%CV
February (1)	Buffer	299	138	650	4.60	2.12	9.98	36.86
	Site	184	86	394	5.24	2.44	11.26	34.2
February (2)	Buffer	96	48	193	1.48	0.74	2.96	32.9
	Site	29	7	128	0.83	0.19	3.66	71.87
March 2018	Buffer	64	30	136	0.98	0.46	2.10	35.83
	Site	19	5	74	0.55	0.14	2.11	63.58
April 2018	Buffer	524	296	927	8.04	4.54	14.25	26.82
	Site	551	271	1120	15.74	7.74	31.99	31.68
May (1)	Buffer	256	125	525	3.94	1.92	8.07	33.9
	Site	271	110	666	7.73	3.14	19.02	40.71
May (2)	Buffer	2020	1459	2797	31.02	22.41	42.96	15.23
	Site	1644	1222	2211	46.93	34.88	63.13	13.29
June	Buffer	513	323	814	7.88	4.96	12.51	21.62
	Site	532	308	919	15.18	8.79	26.24	24.28
July	Buffer	769	532	1113	11.82	8.17	17.09	17.24
	Site	512	351	748	14.63	10.03	21.35	16.8
August	Buffer	556	248	1247	8.54	3.80	19.16	38.51
	Site	309	134	717	8.83	3.81	20.46	37.81
October (1)	Buffer	363	203	651	5.58	3.12	9.99	27.35
	Site	203	81	509	5.80	2.31	14.53	41.63
October (2)	Buffer	160	100	258	2.46	1.53	3.96	22.24
	Site	58	17	202	1.66	0.48	5.77	58.48

The density plots for razorbill and guillemot are presented in Figures 3.3 and 3.4, together with the associated detection curves. The areas of highest razorbill density were in the southern half of the Site. There is little obvious pattern to guillemot density, but Figure 3.4 indicates most birds were in eastern (inshore) areas, including areas of high density within the south-eastern part of the Site.

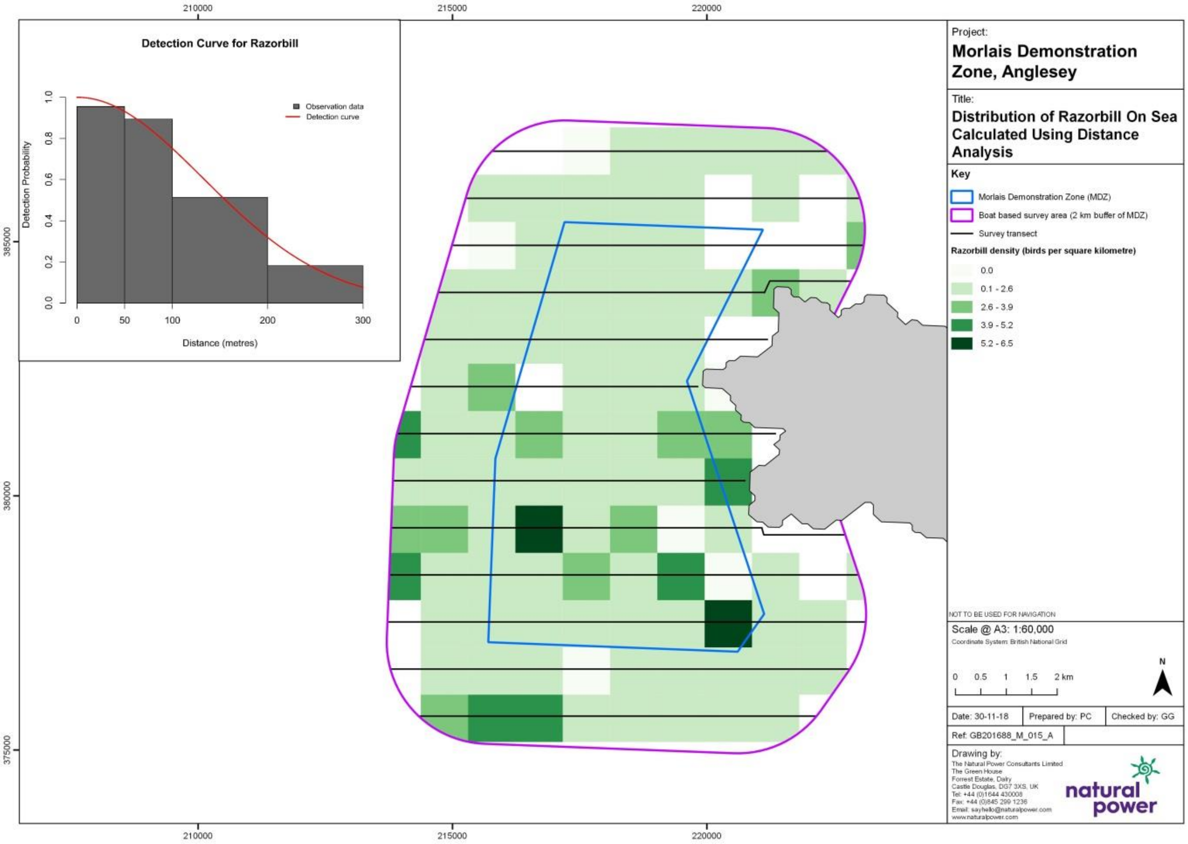

Figure 3.3: **Density of razorbill calculated using Distance analysis (and associated detection curve)**

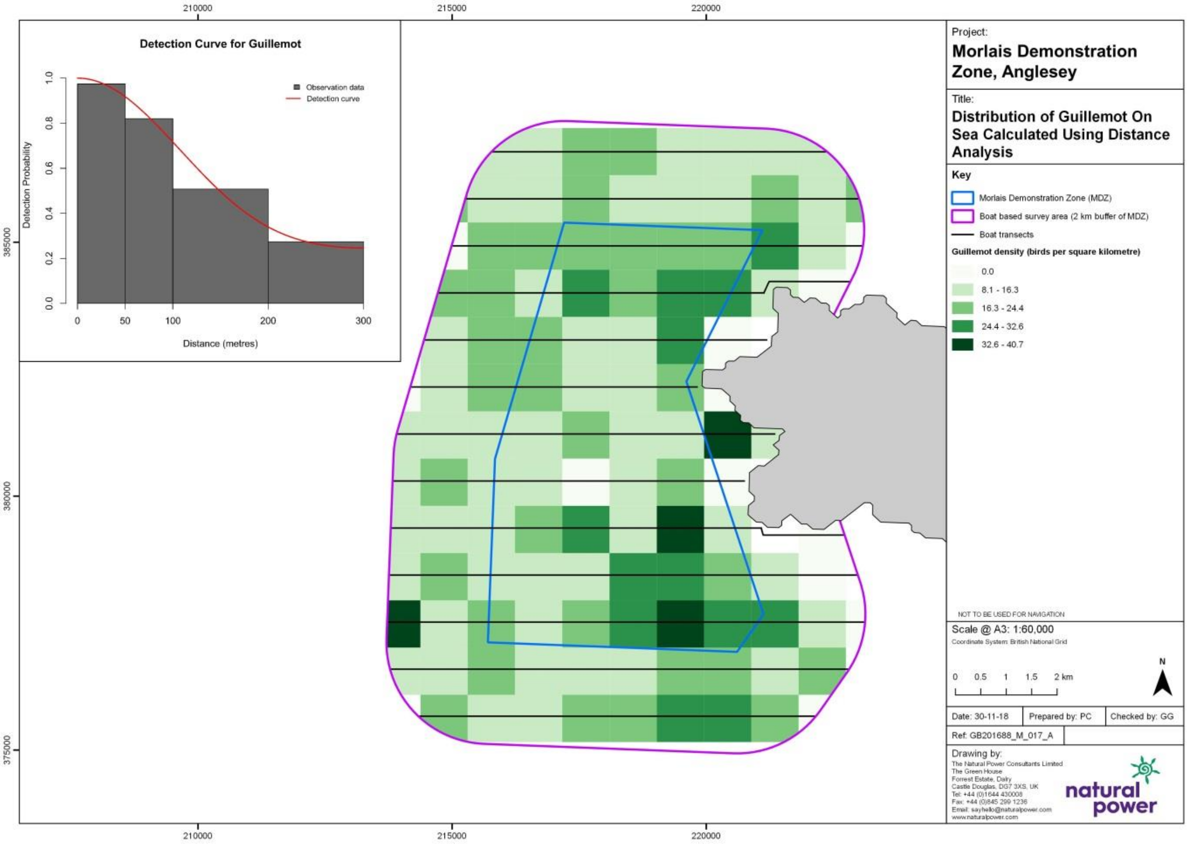

Figure 3.4: **Density of guillemot calculated using Distance analysis (and associated detection curve)**

3.1.5. Density and Abundance Estimates

Mean densities (birds per km^2) and extrapolated abundance indicators across all surveys are shown in Table 3.8. These values were calculated from individual survey estimates which are presented in Appendix C. It should be noted that these numbers are indicative only and are likely to underestimate the total number of birds using the survey area.

During all surveys, guillemots were the most abundant diving species within the Site, with a mean of 4.1 birds km^{-2}, followed by razorbills with 1.1 birds km^{-2}. Densities were lower in the buffer area but guillemots and razorbills were again the most abundant species with 3.8 and 0.9 birds per km^{-2}, respectively.

Table 3.8: **Mean (minimum – maximum) number of species observed on sea (km^{-2}) across all surveys, together with extrapolated abundance indicators.**

	Density of observed individuals			Indication of likely abundance		
Species	Site	Buffer	Study area	Site	Buffer	Study area
Eider	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.03)	0 (0 - 0)	0 (0 - 0)	0 (0 - 3)
Red throated diver	0.00 (0.00 - 0.09)	0.01 (0.00 - 0.09)	0.00 (0.00 - 0.07)	0 (0 - 3)	1 (0 - 7)	0 (0 - 7)
Manx shearwater	0.68 (0.00 - 13.42)	0.33 (0.00 - 2.87)	0.89 (0.00 - 16.68)	24 (0 - 470)	23 (0 - 246)	89 (0 - 1670)
Fulmar	0.01 (0.00 - 0.18)	0.01 (0.00 - 0.09)	0.01 (0.00 - 0.10)	1 (0 - 6)	0 (0 - 3)	1 (0 - 10)
Gannet	0.01 (0.00 - 0.18)	0.04 (0.00 - 0.31)	0.02 (0.00 - 0.20)	0 (0 - 6)	3 (0 - 20)	2 (0 - 20)
Shag	0.02 (0.00 - 0.35)	0.04 (0.00 - 0.21)	0.02 (0.00 - 0.16)	1 (0 - 12)	3 (0 - 16)	2 (0 - 16)

Species	Density of observed individuals			Indication of likely abundance		
	Site	Buffer	Study area	Site	Buffer	Study area
Black-headed gull	0.03 (0.00 - 0.44)	0.19 (0.00 - 3.55)	0.12 (0.00 - 2.22)	1 (0 - 15)	13 (0 - 231)	12 (0 - 223)
Kittiwake	0.22 (0.00 - 4.38)	0.14 (0.00 - 1.30)	0.20 (0.00 - 3.04)	8 (0 - 154)	10 (0 - 85)	20 (0 - 304)
Common gull	0.03 (0.00 - 0.18)	0.11 (0.00 - 2.24)	0.09 (0.00 - 1.44)	1 (0 - 6)	7 (0 - 146)	9 (0 - 144)
Herring gull	1.06 (0.00 - 9.03)	0.76 (0.00 - 3.77)	0.57 (0.00 - 3.47)	37 (0 - 316)	48 (0 - 334)	57 (0 - 347)
Lesser black-backed gull	0.05 (0.00 - 0.88)	0.09 (0.00 - 0.88)	0.03 (0.00 - 0.62)	2 (0 - 31)	5 (0 - 62)	3 (0 - 62)
Great black-backed gull	0.02 (0.00 - 0.18)	0.02 (0.00 - 0.10)	0.01 (0.00 - 0.13)	1 (0 - 6)	1 (0 - 7)	1 (0 - 13)
Unidentified large gull species	0.04 (0.00 - 1.05)	0.06 (0.00 - 1.05)	0.02 (0.00 - 0.39)	2 (0 - 37)	3 (0 - 39)	2 (0 - 39)
Unidentified gull species	0.00 (0.00 - 0.00)	0.01 (0.00 - 0.16)	0.00 (0.00 - 0.10)	0 (0 - 0)	0 (0 - 10)	0 (0 - 10)
Arctic tern	0.06 (0.00 - 1.40)	0.13 (0.00 - 1.40)	0.04 (0.00 - 0.95)	2 (0 - 49)	8 (0 - 95)	4 (0 - 95)
Common tern	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)	0.01 (0.00 - 0.10)	0 (0 - 0)	0 (0 - 0)	1 (0 - 10)
Common/ Arctic tern	0.00 (0.00 - 0.09)	0.01 (0.00 - 0.09)	0.00 (0.00 - 0.03)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)
Guillemot	5.74 (0.18 - 40.16)	3.77 (0.70 - 11.21)	4.60 (0.26 - 29.56)	201 (6 - 1407)	253 (25 - 1018)	461 (26 - 2960)
Razorbill	0.93 (0.00 - 7.10)	0.54 (0.00 - 3.33)	0.72 (0.00 - 5.07)	33 (0 - 249)	34 (0 - 288)	72 (0 - 507)
Guillemot/razorbill	1.01 (0.00 - 17.54)	0.16 (0.00 - 0.70)	0.58 (0.00 - 6.54)	35 (0 - 614)	10 (0 - 65)	58 (0 - 655)
Puffin	0.02 (0.00 - 0.18)	0.04 (0.00 - 0.18)	0.03 (0.00 - 0.20)	1 (0 - 6)	2 (0 - 13)	3 (0 - 20)

3.1.6. Key Species: Spatial Distribution

The spatial distributions of 11 diving bird species are presented in Figure 3.5 (eider), Figure 3.6 (red-throated diver), Figure 3.7 (Manx shearwater). Figure 3.8 (gannet), Figure 3.9 (shag), Figure 3.10 (Sandwich tern), Figure 3.11 (common tern), Figure 3.12 (Arctic tern), Figure 3.13 (common/ Arctic tern), Figure 3.14 (guillemot), Figure 3.15 (razorbill), Figure 3.16 (razorbill/ guillemot) and Figure 3.17 (puffin).

The distribution of eider in flight and on sea is shown in Figure 3.5. Four counts of eider were recorded flying within the Site with a single count within the 2 km buffer. A single bird was recorded on the sea within the 2 km buffer.

Common scoters (no figure: only recorded in flight) were recorded throughout the survey area but mainly within the eastern half of the survey site. All observations were during the autumn through to spring period. A total of 10 observations were recorded within the Site and a further 10 in the 2 km buffer survey area. The majority of records were of groups ranging from one to eight birds with three counts ranging from 12 to 40.

Red-throated divers were recorded throughout the Site and 2 km buffer (Figure 3.6). A total of eight individuals were recorded in flight and a single bird on the sea within the MDZ. A further 10 individuals were recorded in flight with two birds on the sea (within 2 km of the coastline) within the 2 km buffer survey area.

Manx shearwater records were widespread across the Site and 2 km buffer (Figure 3.7). In total, 65% of Manx shearwater records were of single birds, with the large majority of these (95%) being birds in flight. However, there were 14 records of groups of more than 10 birds; 11 of these were on the sea. The majority of these groups, including the largest single flock (170 birds) were in the 2 km buffer. Figure 3.7 indicates that most Manx shearwaters were in the southern half of the survey area and that records had a bias towards being offshore.

Gannets were recorded in flight throughout the survey area (Figure 3.8). Highest aggregations were recorded within the eastern half of the Site with further aggregations of flying birds in the northern half of the 2 km buffer survey area. Fewer gannets were recorded on the sea within the MDZ compared to birds in the 2 km buffer (four and 14 individuals respectively), these being largely offshore.

The majority of shags recorded were within the 2 km buffer and almost all within 2 km of the coast. A total of 12 individuals were recorded on the sea within the 2 km buffer and 13 in flight. Five individuals were recorded on the sea along the inshore boundary of the Site, with the largest aggregation being three birds. A single bird was recorded in flight (Figure 3.9).

The two cormorant records were both of individuals flying over the 2 km buffer area (not mapped).

The four records of Sandwich tern were all of birds in flight in the southern part of the survey area; and comprised three individuals within the Site and five in the 2 km buffer survey area (Figure 3.10).

Small numbers of common tern were recorded in the southern half of the survey area, with eight flying through the Site and five flying within the 2 km buffer (Figure 3.11). A total of four birds were recorded on the sea (surface feeding); these birds were in the 2 km buffer and not within the Site.

Arctic tern was the most recorded tern species with a total of 88 individuals recorded, throughout the survey area. In flight, 12 birds were recorded within the Site and 45 in the 2 km buffer (Figure 3.12). There were 31 individuals recorded on the sea, comprising 17 within the Site, including one group of 16 birds (surface feeding), and 14 in the 2 km buffer.

Guillemots and razorbills were recorded in high numbers throughout the area both on the sea and flying (Figures 3.14 and 3.15). Neither species showed a clear preference for any particular region of the survey area. Large aggregations of guillemots were recorded within the Site with 21 records of groups on the sea ranging from 11 to 50 individuals. Three records of razorbill groups ranging from 11 to 16 individuals were also recorded on the sea, within the Site.

Records of puffins were scattered throughout the Site and the 2 km buffer survey area, with fewer records within the north-western corner of the survey area (Figure 3.17). Birds on the sea ranged from one to two birds with a total of six individuals observed within the Site and 17 within the 2 km buffer. A total of 30 birds were recorded in flight ranging from one to four individuals of which 17 were observed within the MDZ.

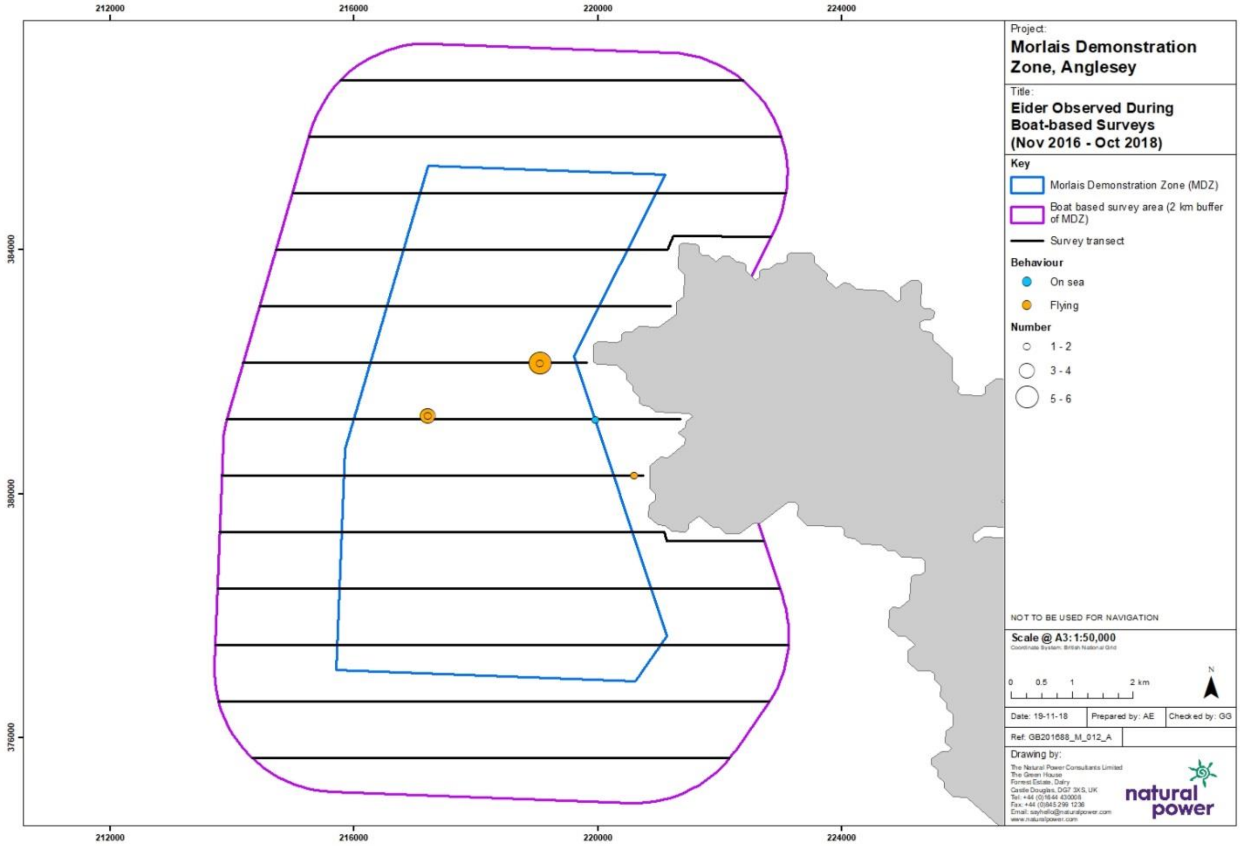

Figure 3.5: **Distribution of eider recorded in flight and on the sea during boat-based surveys (November 2016 to October 2018).**

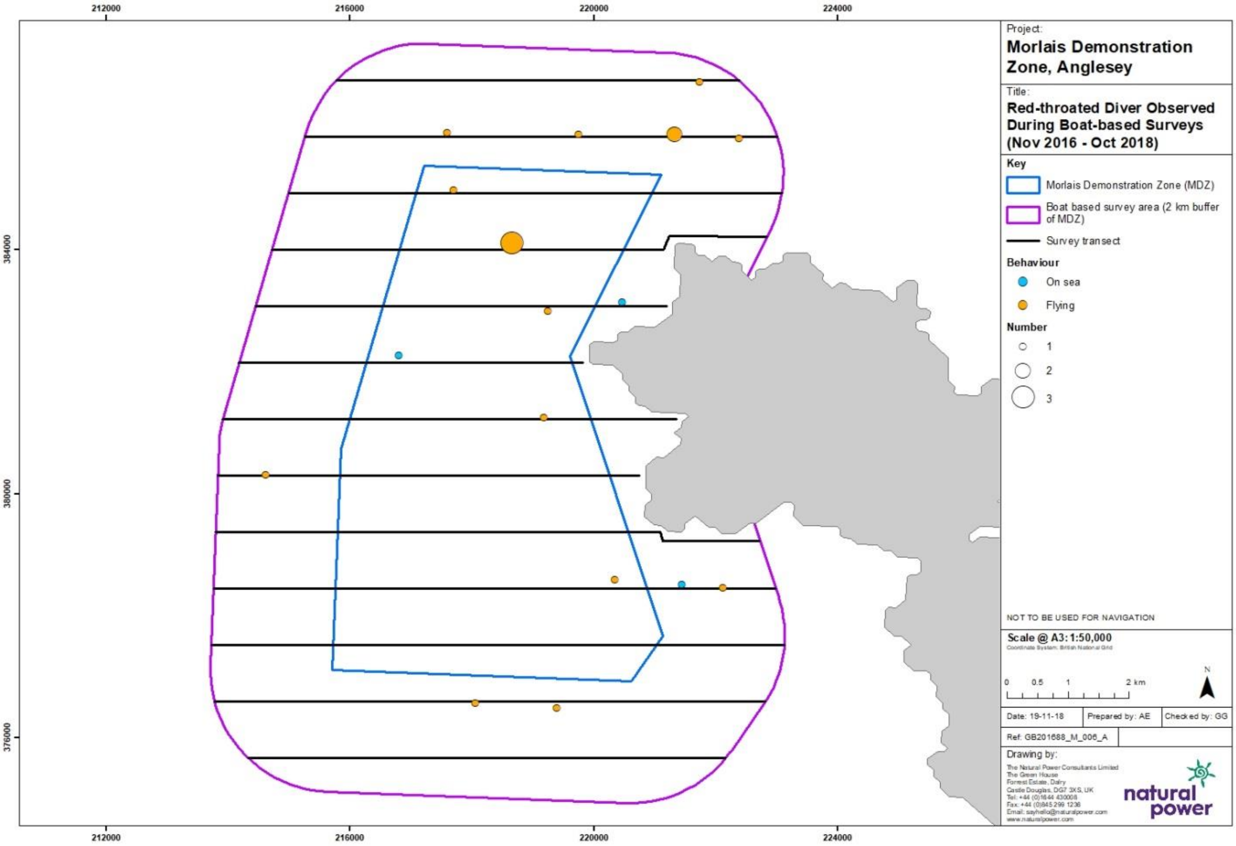

Figure 3.6: **Distribution of red-throated diver recorded in flight and on the sea during boat-based surveys (November 2016 to October 2018).**

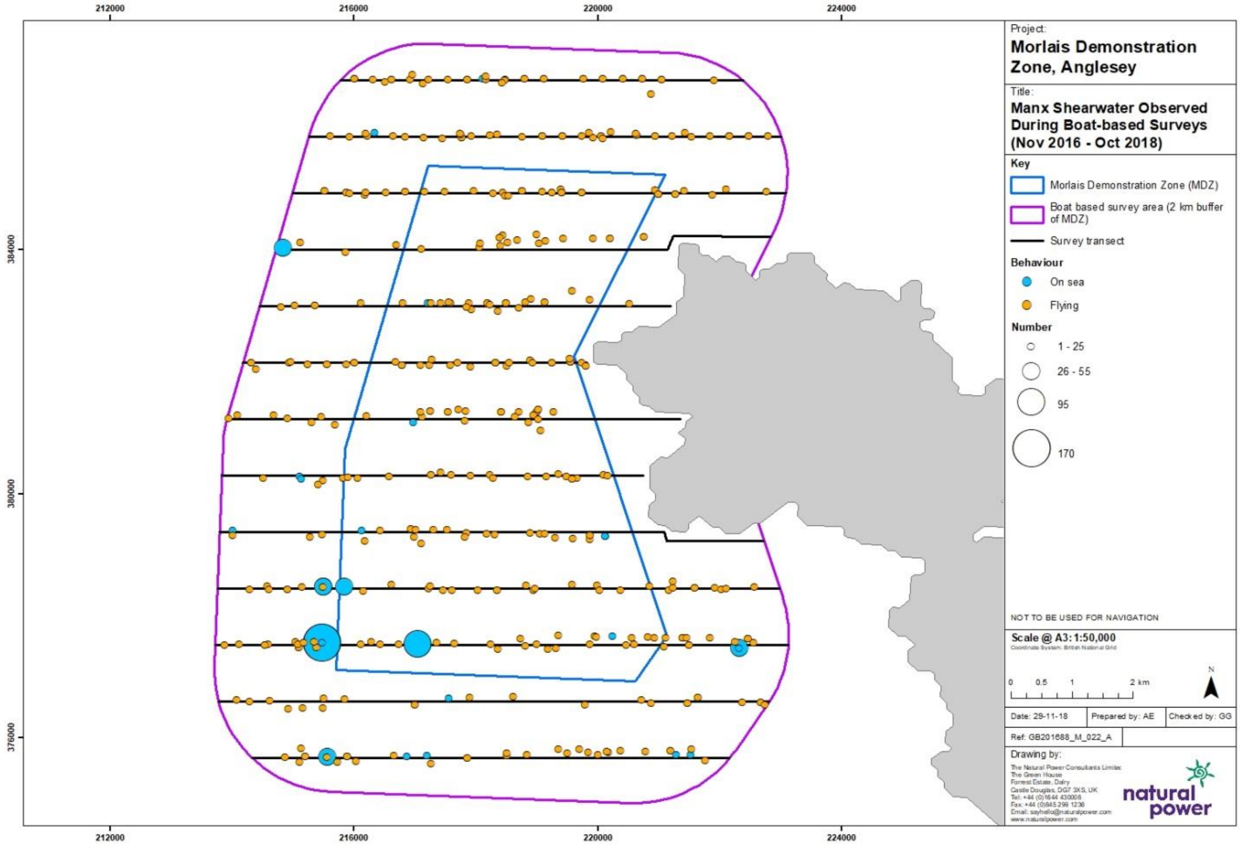

Figure 3.7: **Distribution of Manx shearwater recorded in flight and on the sea during boat-based surveys (November 2016 to October 2018).**

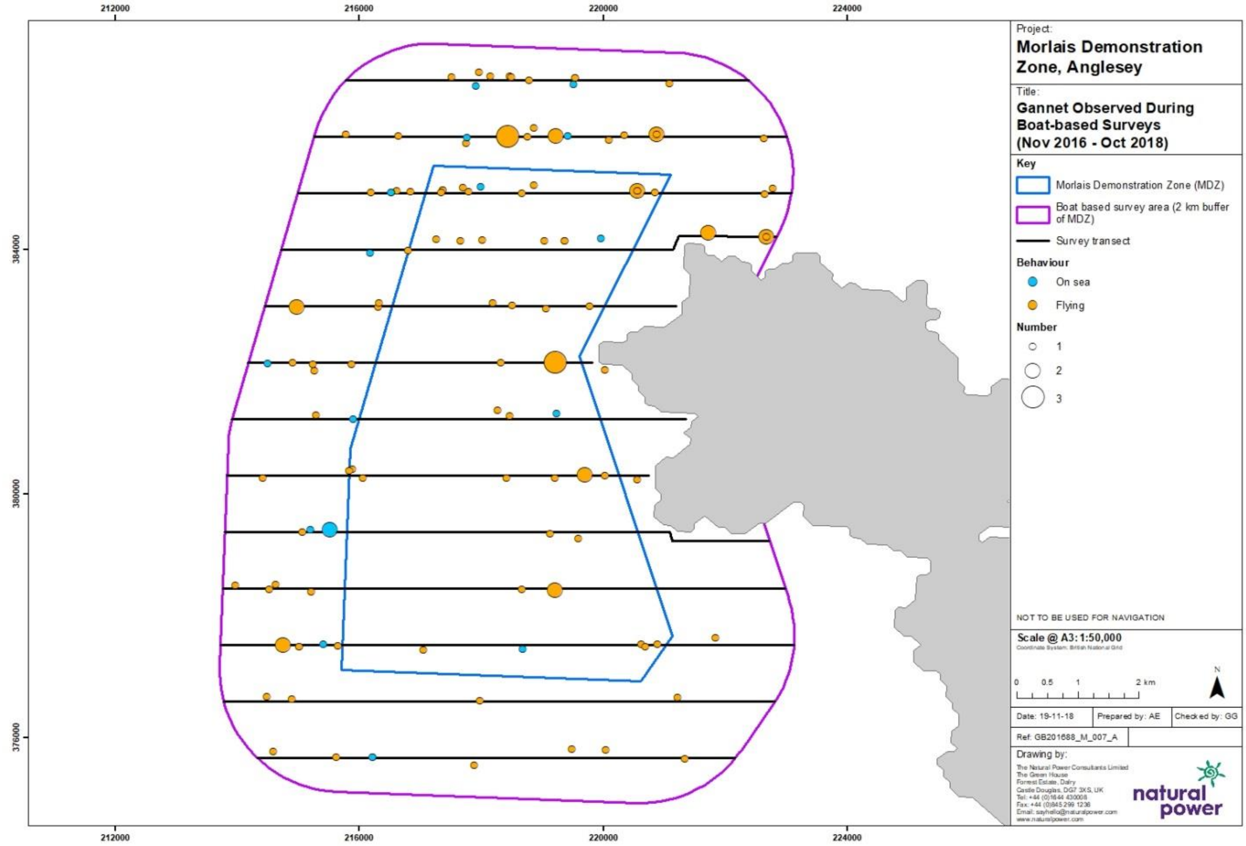

Figure 3.8: Distribution of gannet recorded in flight and on the sea during boat-based surveys (November 2016 to October 2018).

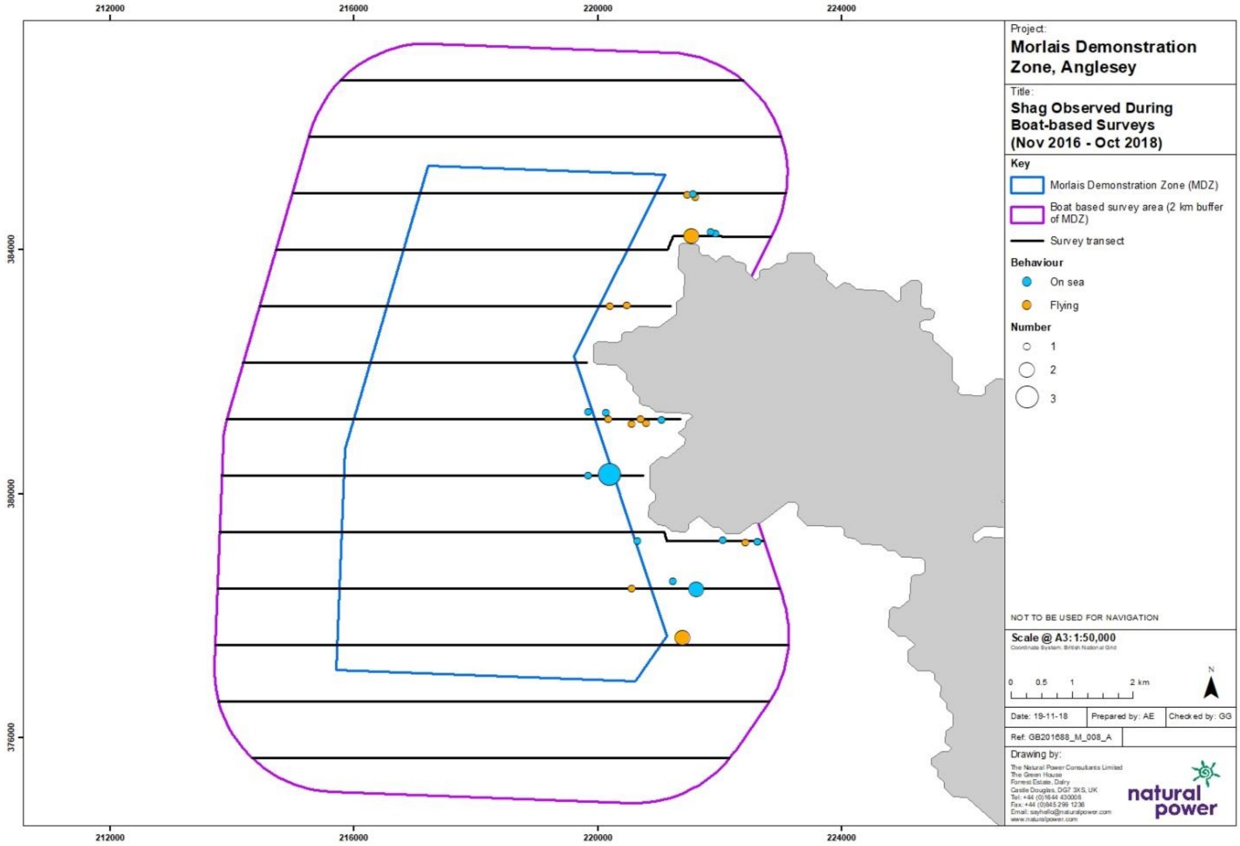

Figure 3.9: Distribution of shag recorded in flight and on the sea during boat-based surveys (November 2016 to October 2018).

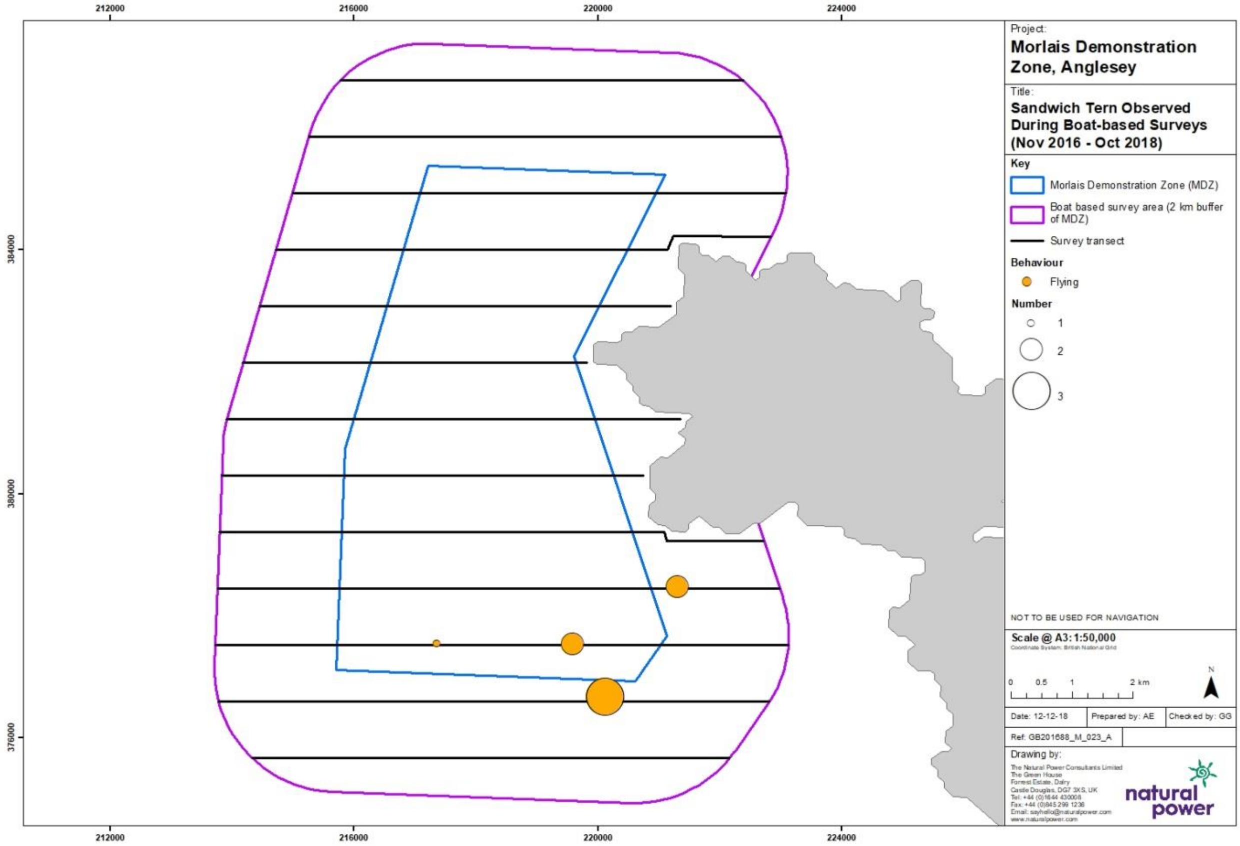

Figure 3.10: **Distribution of Sandwich tern recorded in flight and on the sea during boat-based surveys (November 2016 to October 2018).**

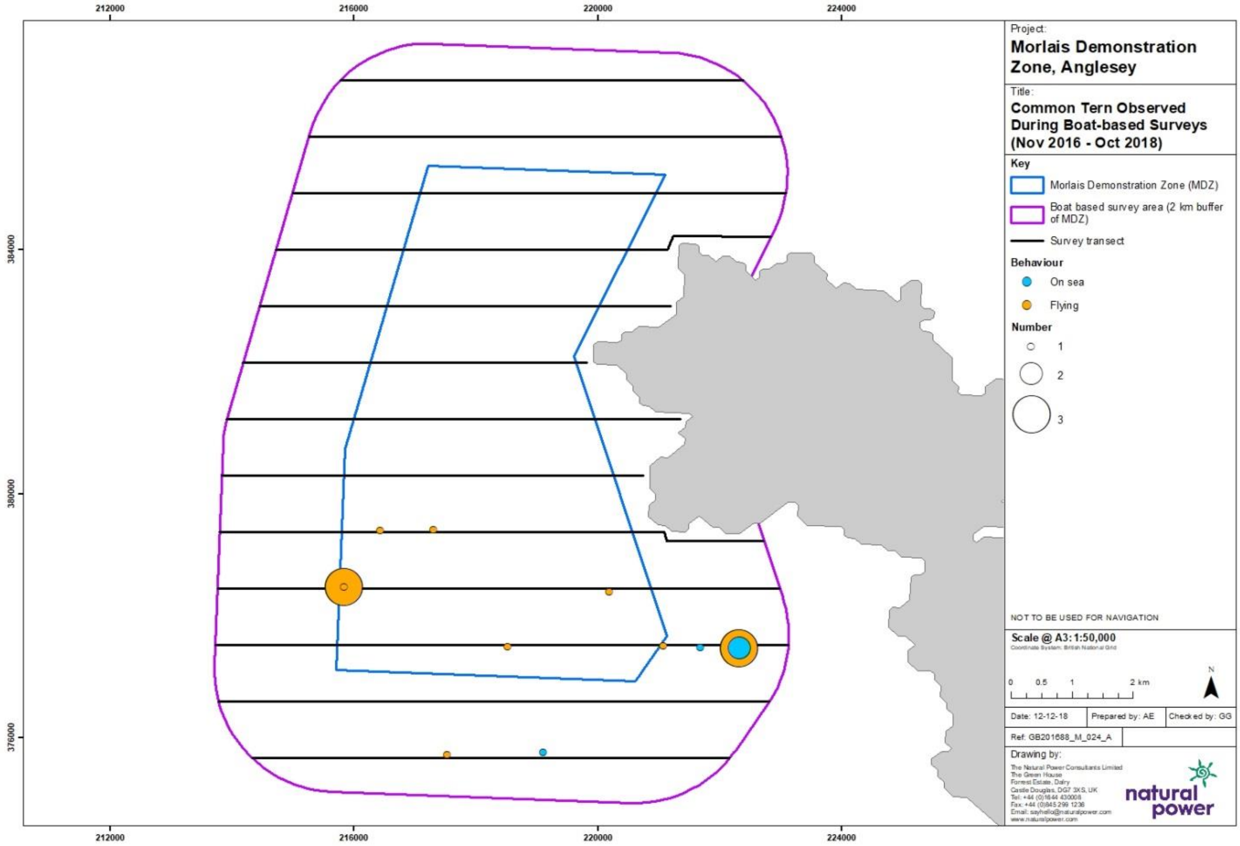

Figure 3.11: **Distribution of common tern recorded in flight and on the sea during boat-based surveys (November 2016 to October 2018).**

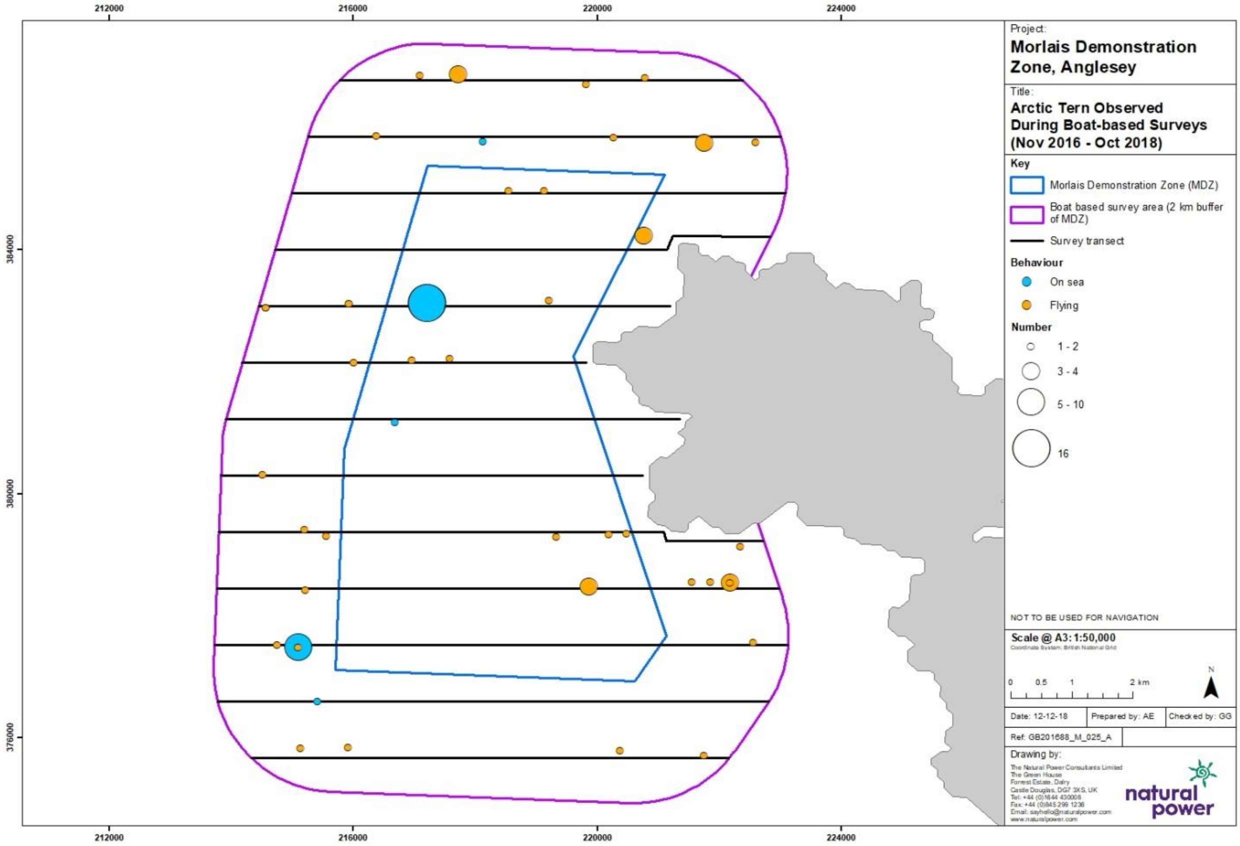

Figure 3.12: Distribution of Arctic tern recorded in flight and on the sea during boat-based surveys (November 2016 to October 2018).

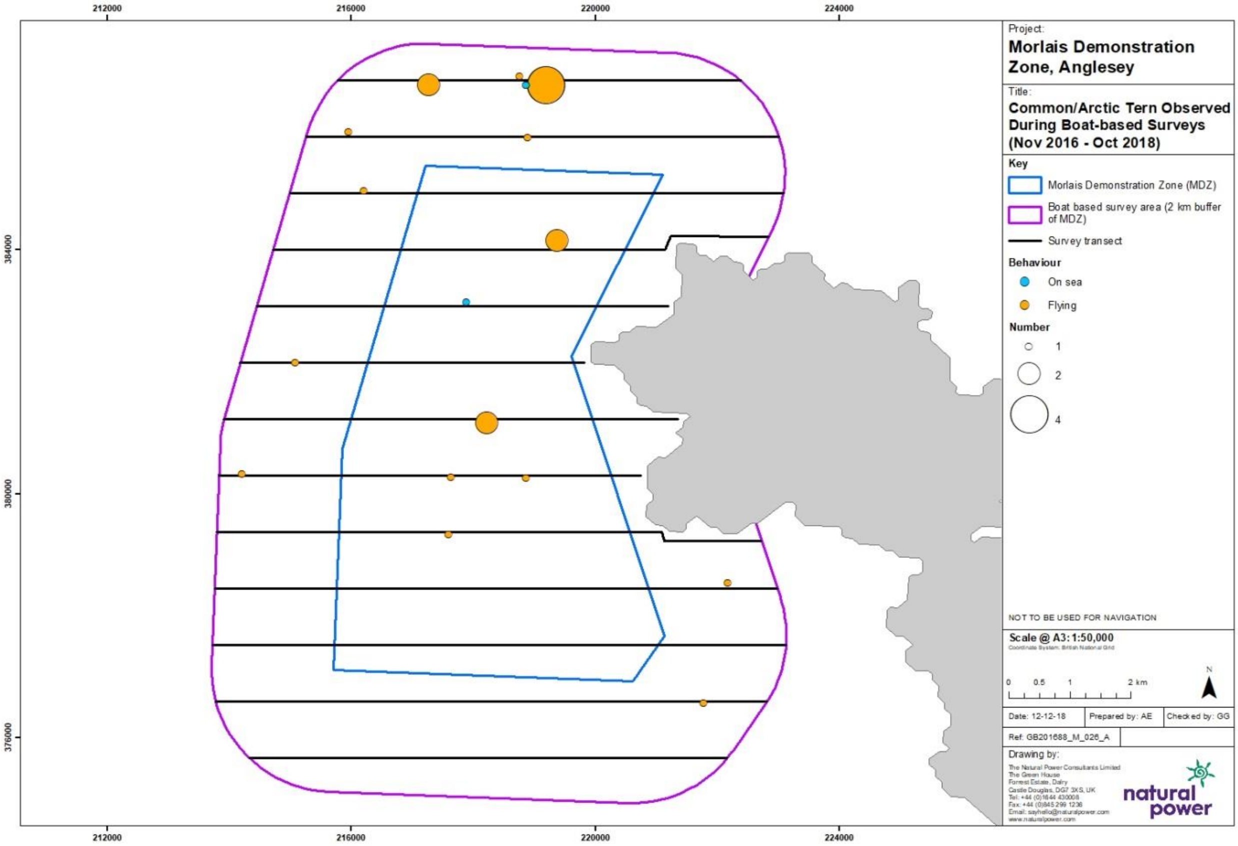

Figure 3.13: **Distribution of 'common/ Arctic tern' recorded in flight and on the sea during boat-based surveys (November 2016 to October 2018).**

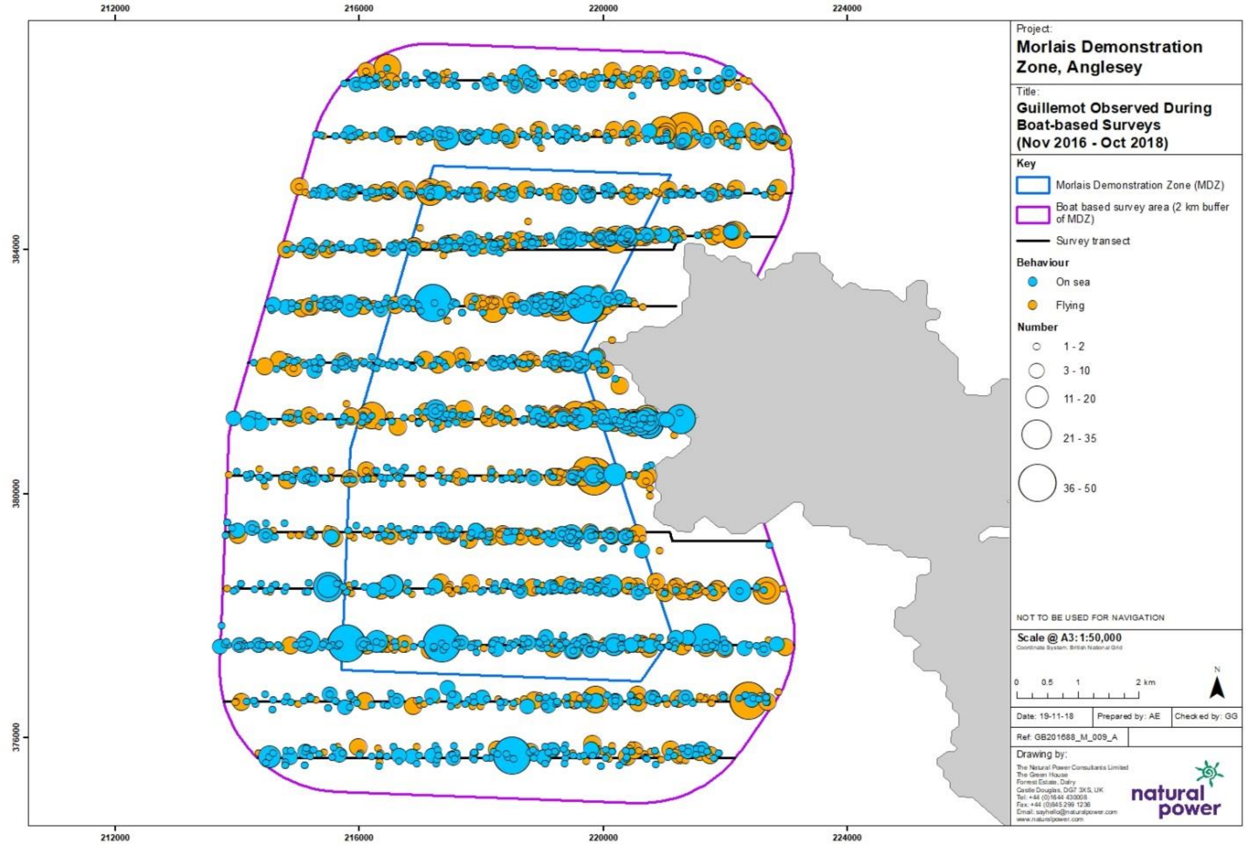

Figure 3.14: **Distribution of guillemot recorded in flight and on the sea during boat-based surveys (November 2016 to October 2018).**

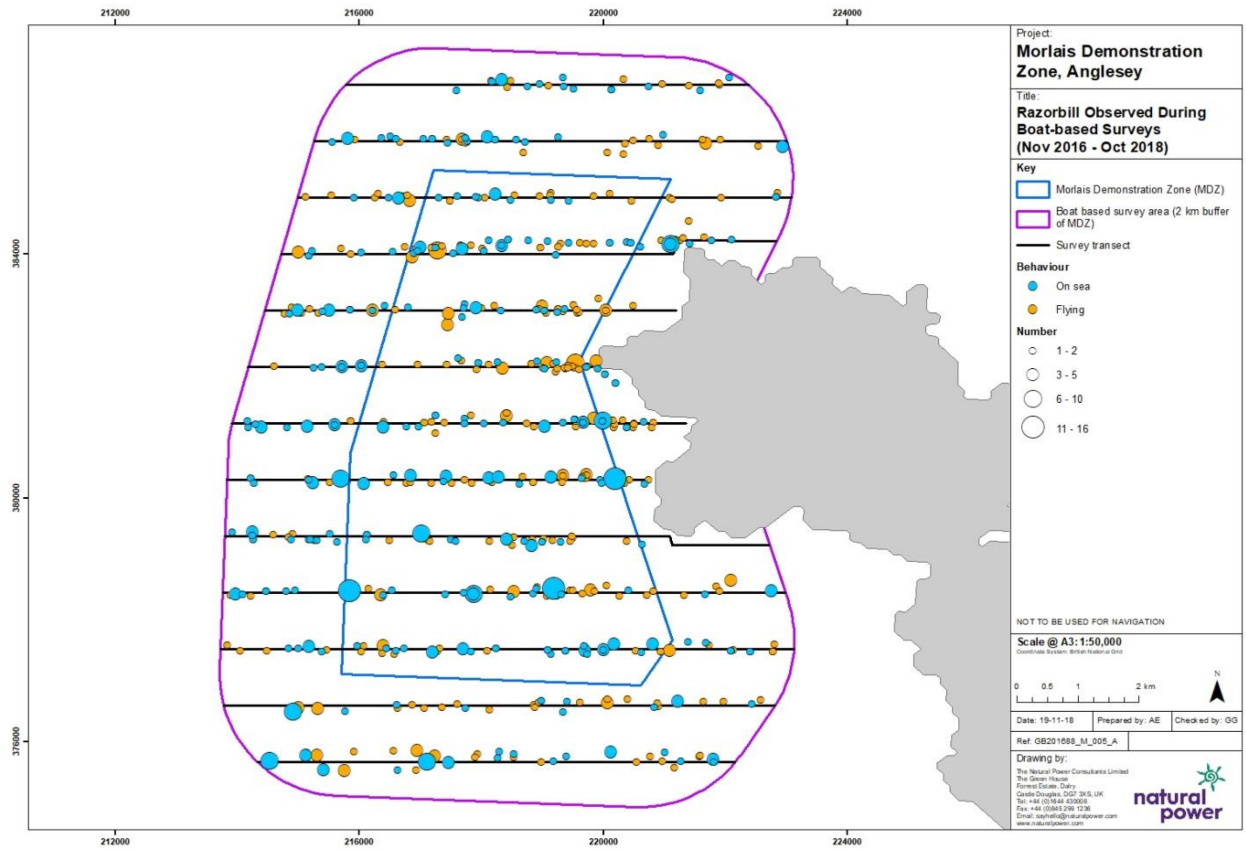

Figure 3.15: Distribution of razorbill recorded in flight and on the sea during boat-based surveys (November 2016 to October 2018).

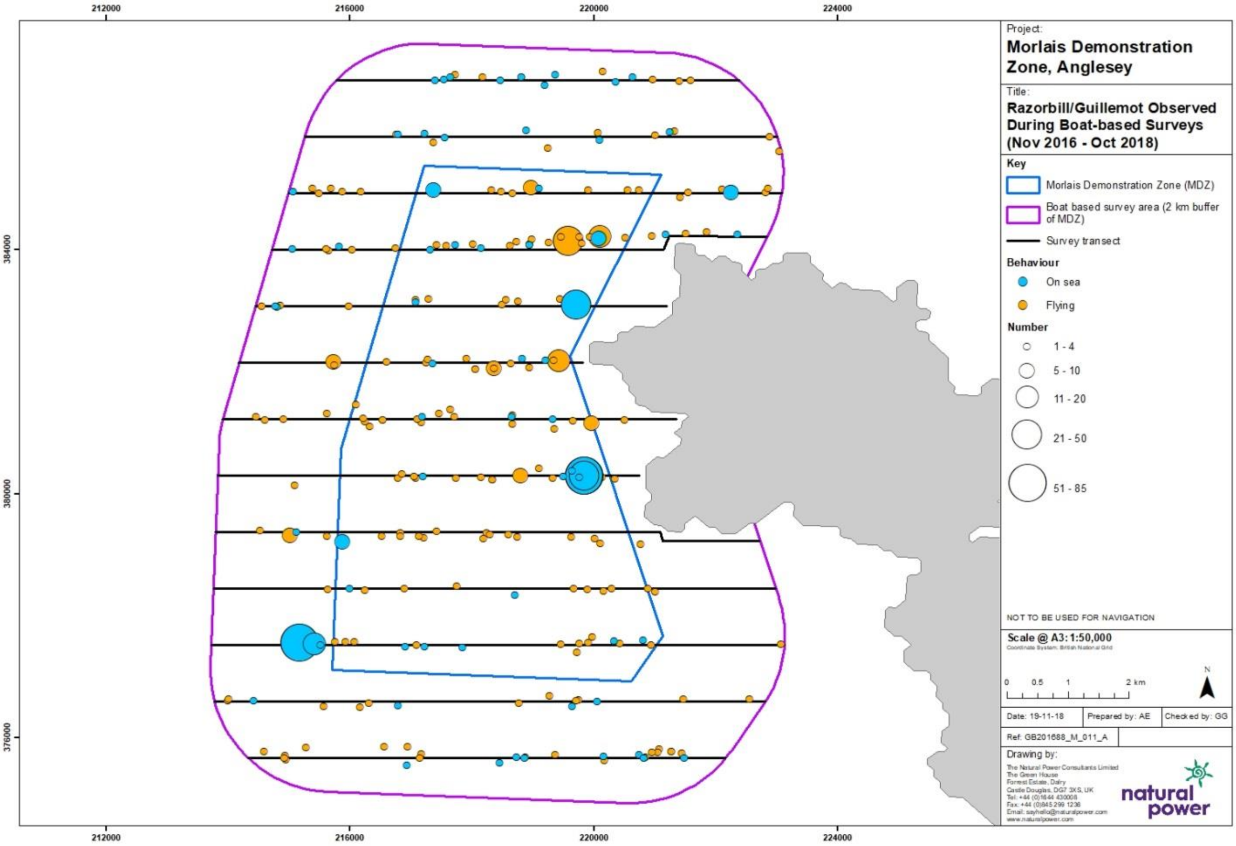

Figure 3.16: **Distribution of 'guillemot/ razorbill' recorded in flight and on the sea during boat-based surveys (November 2016 to October 2018).**

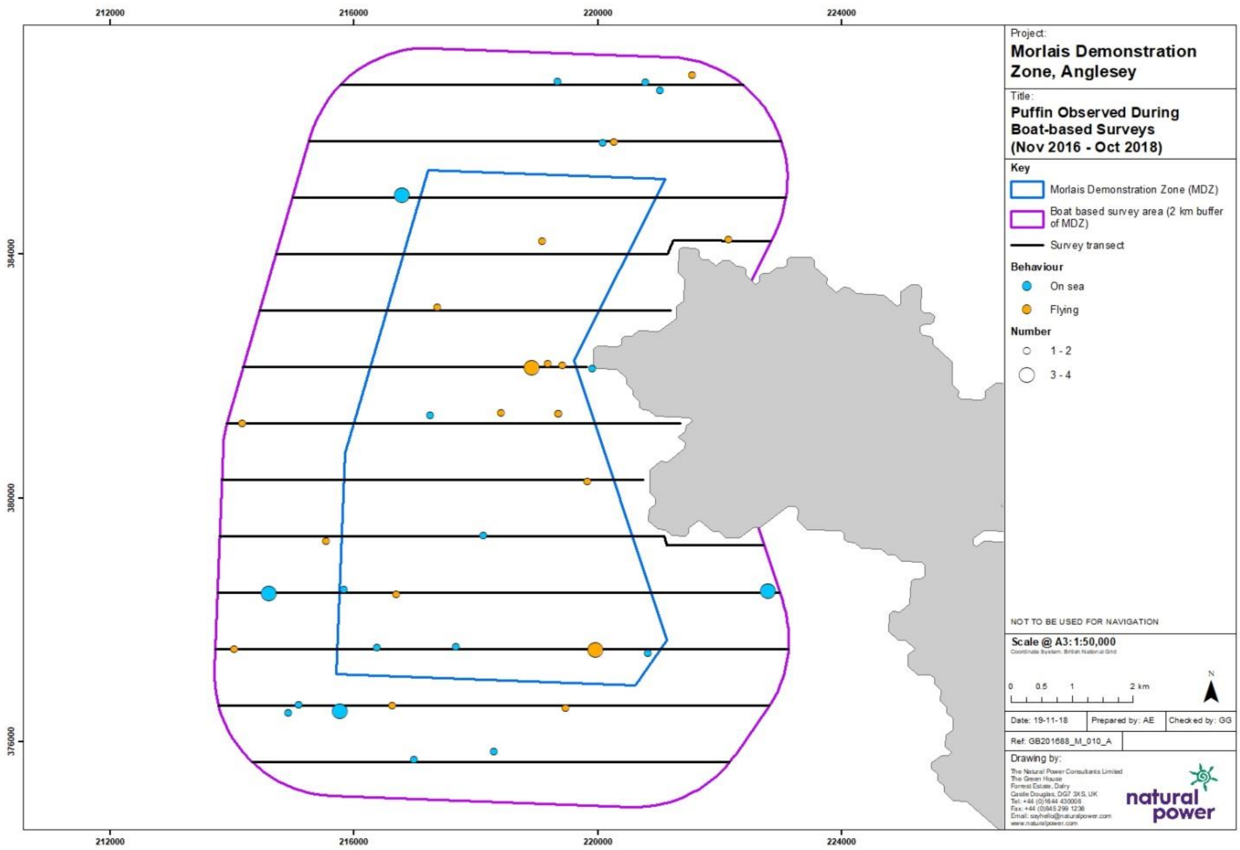

Figure 3.17: Distribution of puffin recorded in flight and on the sea during boat-based surveys (November 2016 to October 2018).

3.1.7. Key Species: Behaviour

Ten key species of diving bird were recorded on the sea and in transect, of which 4,624 individuals had a behaviour code recorded (Table 3.9). This equates to 89% of individuals being allocated a behaviour code. Of this total, 15% were recorded diving/ feeding. The behaviours have been grouped into foraging (deep-diving, surface feeding and carrying prey) and non-foraging (resting and preening). Foraging birds totalled 709 individuals and non-foraging birds totalled 3,915 individuals, of which the large majority were deemed to be resting. Five species engaged in foraging behaviour within the survey area: Manx shearwater, gannet, Arctic tern, guillemot and razorbill.

Note that the number of birds recorded as foraging (deep diving and surface feeding) should be considered to be an underestimate due to the limited duration of each individual observation in which a behaviour was looked for, and the influence of the survey vessel upon a bird's behaviour. Furthermore, 'resting' relates to individuals for which no active behaviour was witnessed.

The distribution of guillemot and razorbill by behaviour, across the survey area, are shown in Figures 3.18 and 3.19.

In addition to the behaviours recorded for birds on the sea, records of behaviour of flying birds included guillemot and razorbill holding fish (20 and two respectively). These were generally flying in an easterly direction during the breeding season, presumably to nesting sites along the neighbouring Anglesey coastline. Of the gannets recorded in flight, some were recorded as 'actively searching': five birds were recorded actively searching in the Site and 10 within the 2 km buffer area. Arctic terns in flight included five birds holding fish and two that were actively searching.

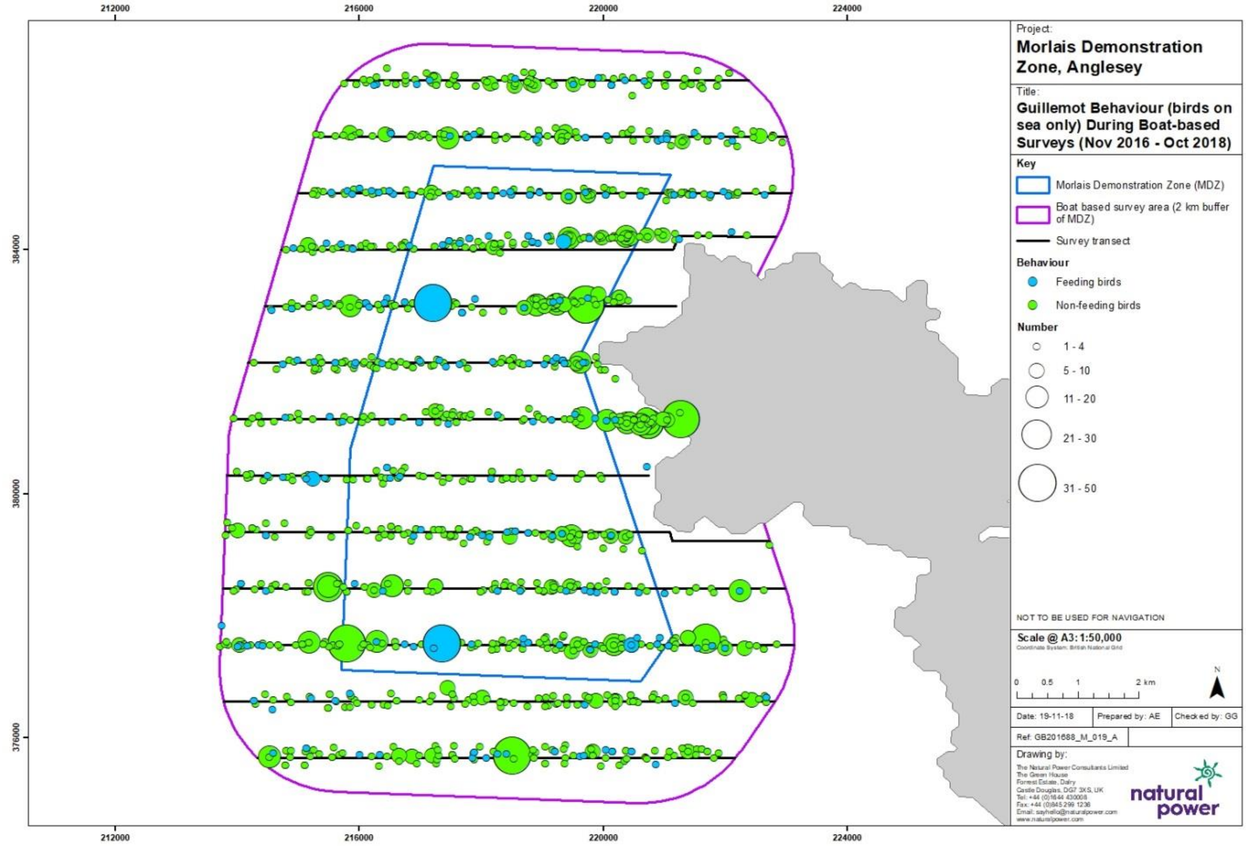

Figure 3.18: Guillemot distribution by behaviour (birds on sea in transect) (November 2016 to October 2018).

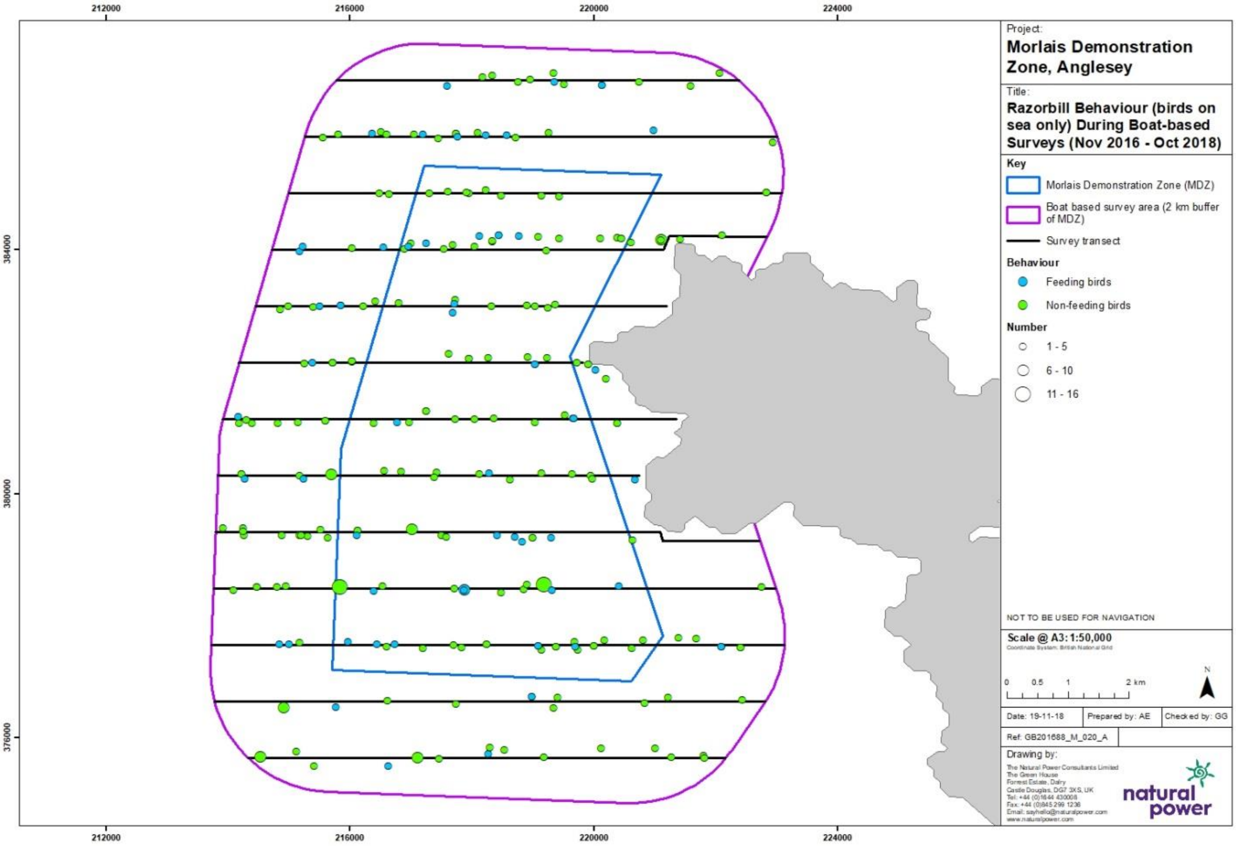

Figure 3.19: Razorbill distribution by behaviour (birds on sea in transect) (November 2016 to October 2018).

Table 3.9: Behaviour of key bird species recorded during all surveys (November 2016 to October 2018); birds recorded both on the sea and within 300 m of the vessel (Foraging = birds deep diving, surface feeding and carrying fish; Non-foraging = resting and preening)

	Site			2 km buffer			Site + 2 km buffer			
Species	Foraging	Non-foraging	Total	Foraging	Non-foraging	Total	Foraging	Non-foraging	Total	Total % foraging
Eider					1	1		1	1	0
Red-throated diver		1	1		2	2		3	3	0
Manx shearwater	120	66	186	5	422	427	125	488	613	20
Gannet	1	4	5		12	12	1	16	17	6
Shag		1	1	3	7	10	3	8	11	27
Common tern				4		4	4		4	100*
Arctic tern	17	1	18	18		18	35	1	36	97
Common/ Arctic tern	1		1	2		2	3		3	100*
Guillemot	231	1236	1467	151	1573	1724	382	2809	3191	12
Razorbill	62	177	239	39	212	251	101	389	490	21
Puffin		6	6	3	12	15	3	18	21	14
Guillemot/ razorbill	41	42	83	11	140	151	55	200	255	22
Total	**473**	**1534**	**2007**	**236**	**2381**	**2617**	**709**	**3915**	**4624**	**15**

3.1.8. All Seabirds: Flight Direction

A summary of flight directions for birds recorded (November 2016 to October 2018) is shown in Table 3.10.

Flight direction was recorded for 5,660 individuals across the survey area. Birds were recorded flying in all directions with the highest numbers recorded flying along a north and south axis (almost 45%).

Table 3.10: Flight direction recorded across the survey area of seabird species/ species groups (November 2016 to October 2018).

Row Labels	E	N	NE	NW	S	SE	SW	W	Total
Eider					7			7	14
Common scoter		10		22	27	40	10	3	112
Red-throated diver		6			5	4	1	1	17
Fulmar	2	8	3	2	5	1	8	9	38
Sooty shearwater		2							2
Manx shearwater	5	153	4	73	273	5	152	65	730
Gannet	1	24	4	10	26	3	19	14	101
Cormorant		1				1			2
Shag	1	4	1	1	2	4		3	16
Great skua				1					1
Mediterranean gull		1	1		1		1		4
Black-headed gull	5	60	12	4	6	30	15	11	143
Common gull	9	9	4	7	14	4	10	9	66
Common gull/ kittiwake				1					1
Lesser black-backed gull	3	3	2	6	1	4	5	5	29
Herring gull	61	37	25	42	42	36	69	73	385
Great black-backed gull	3	4	1	7	6	5	7	6	39
Kittiwake	11	45	5	34	56	7	69	22	249
Large gull sp.	15	1	1	4	4		2	2	29
Gull sp.		1							1
Sandwich tern		1		2	3		2		8
Common tern		2		1	6	4			13
Arctic tern	4	3		10	14	5	9	10	55
Common/ Arctic tern	1	5			2	2	7	4	21
Guillemot	98	765	230	431	543	223	291	173	2754
Razorbill	25	97	41	59	119	20	46	44	451
Puffin	8	2	4	5	3	4	4		30
Guillemot/ razorbill	16	96	24	73	39	19	52	30	349
Total	**268**	**1340**	**362**	**795**	**1204**	**421**	**779**	**491**	**5660**

For those species with more than 100 recorded flight directions (Manx shearwater, gannet, kittiwake, guillemot and razorbill) rose diagrams were produced and these are shown in Figures 3.20-3.24. These diagrams represent the number of flight records (and not the number of actual individuals) flying in each direction.

To determine whether flight directions changed between the breeding and non-breeding seasons for these species, rose diagrams were produced for each season. With the exception of kittiwake there was a definite strong bias for flights along a north to south axis, i.e. approximately parallel to the coast, which became more apparent during the non-breeding season. Kittiwake, however, flew mostly in a south-westerly direction in the non-breeding season.

Overall a high proportion of flights were recorded along the north to south axis; Manx shearwater (58%), gannet (50%), kittiwake (41%), guillemot (47%) and razorbill (48%).

Manx shearwater

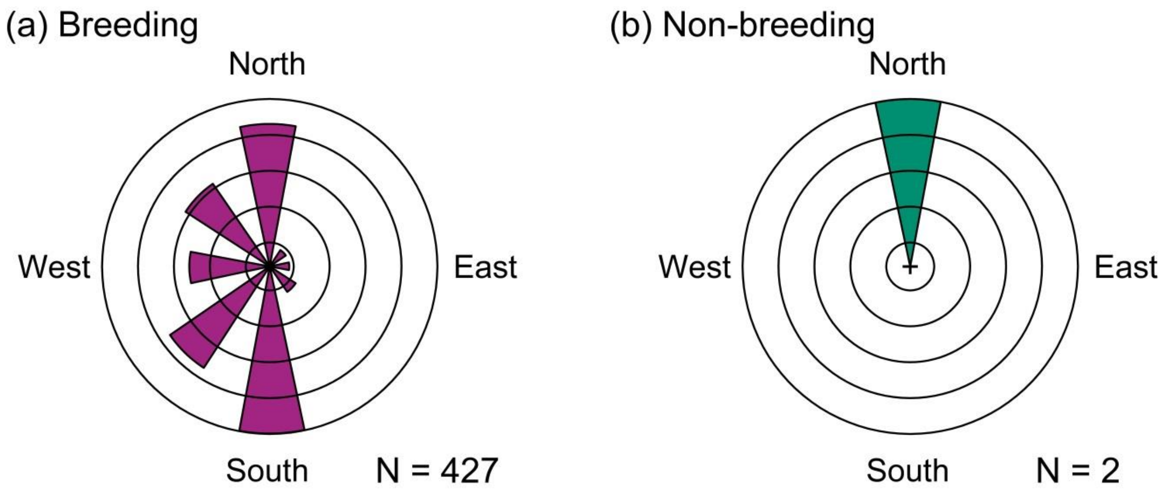

Figure 3.20: Rose diagrams showing flight directions of Manx shearwater during the breeding seasons (April to August) and non-breeding seasons (September to March) within the MDZ and 2 km buffer survey area.

Gannet

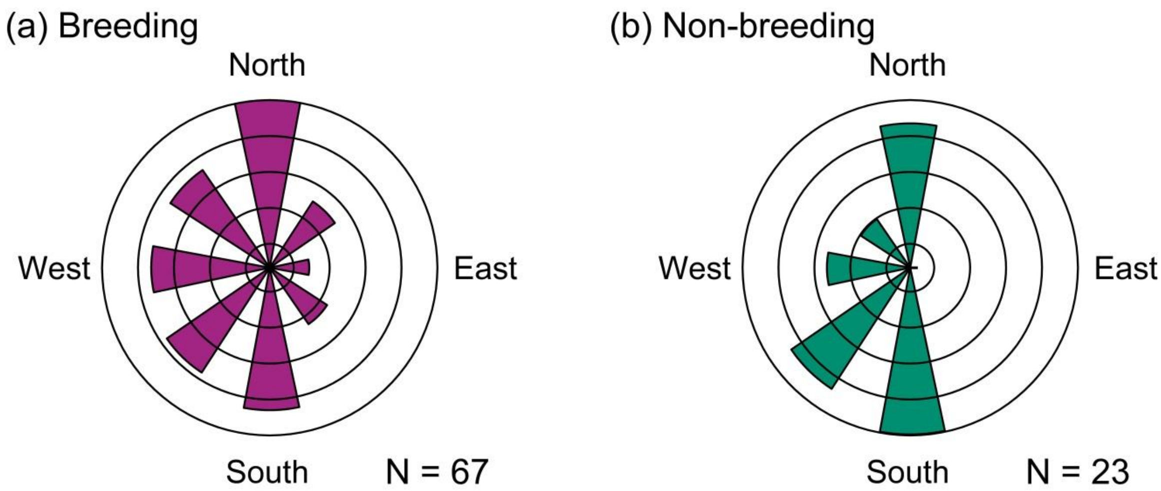

Figure 3.21: Rose diagrams showing flight directions of gannet during the breeding seasons (April to August) and non-breeding seasons (September to March) within the MDZ and 2 km buffer survey area

Kittiwake

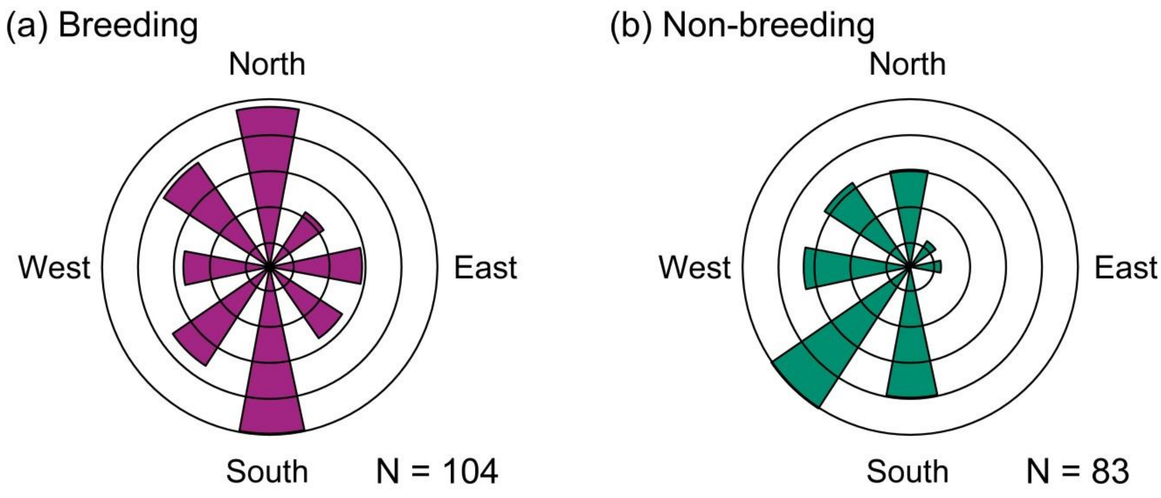

Figure 3.22: Rose diagrams showing flight directions of kittiwake during the breeding seasons (April to August) and non-breeding seasons (September to March) within the MDZ and 2 km buffer survey area

Guillemot

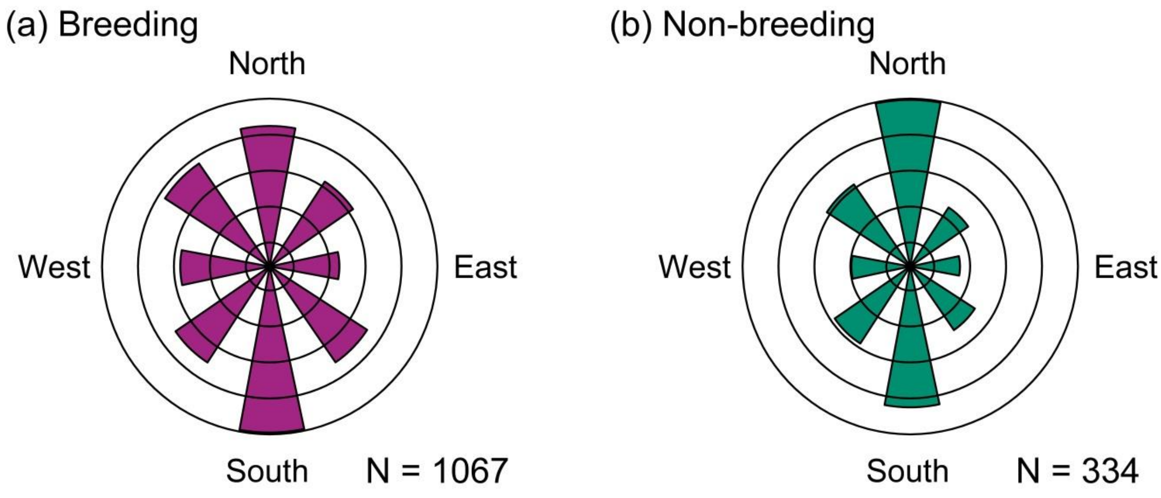

Figure 3.23: Rose diagrams showing flight directions of guillemot during the breeding seasons (April to August) and non-breeding seasons (September to March) within the MDZ and 2 km buffer survey area

Razorbill

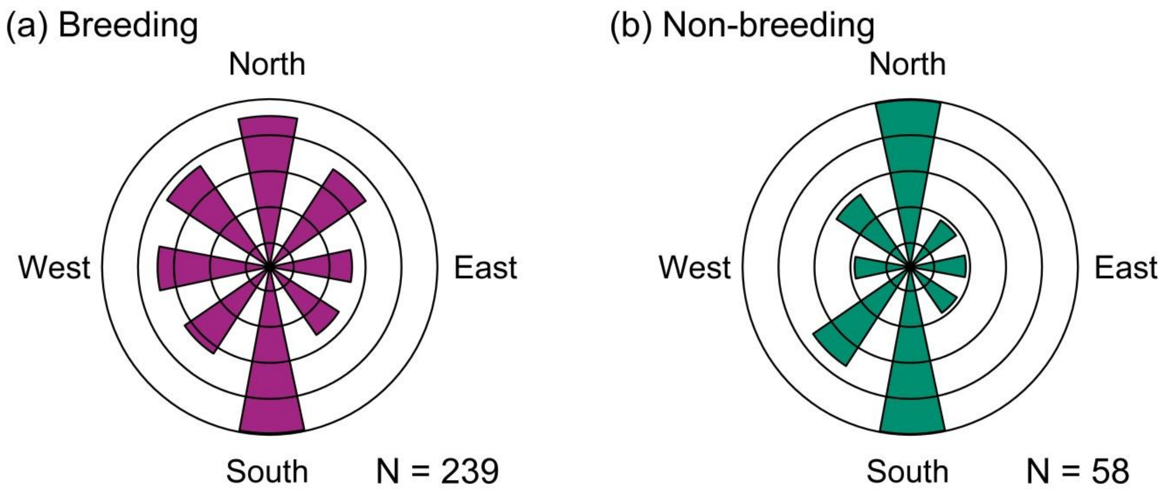

Figure 3.24: Rose diagrams showing flight directions of razorbill during the breeding seasons (April to August) and non-breeding seasons (September to March) within the MDZ and 2 km buffer survey area.

3.2. Marine Mammal Survey Results

3.2.1. Marine Mammal Observations

Over the 24 surveys, a total of 337 observations of marine mammals were recorded (Table 3.11). The total number of individual animals recorded (based on best estimates of group size) was 465 individuals.

Harbour porpoise (*Phocoena phocoena*) was the most frequently sighted cetacean species and comprised 93% of all marine mammals recorded. Other cetaceans observed were Risso's dolphin (*Grampus griseus*) encountered during three surveys (September 2017, May and October 2018) and a group of bottlenose dolphin (*Tursiops truncatus)* on the February 2018 survey. Grey seals (*Halichoerus grypus)* were also recorded throughout the survey period. Five records of unidentified seals were also made, but as no harbour seals (*Phoca vitulina*) were recorded, it is considered likely that these records were also of grey seals.

Most harbour porpoise records were of single animals (73% of sightings) but groups of up to three animals were observed. There were 61 records of two individuals and 11 groups of three individuals recorded. Most of the porpoises recorded were given a behaviour of 'slow swimming'; with eight records (14 animals) recorded as 'foraging', although such behaviour is likely to have been under-recorded.

The group of bottlenose dolphin consisted of an estimated 12 individuals and the behaviour of the group suggested that they may have been feeding. A total of three encounters with Risso's dolphin were observed, ranging from one to seven individuals. All seal sightings were of single individuals.

January 2017 and April 2018 resulted in the highest encounter rates (number of on-effort marine mammal encounters per km survey effort) for harbour porpoise: 0.255 and 0.177 encounters per km survey effort, respectively (see Table 3.13). On the surveys that grey seal was present, this species had 0.010 encounters per km survey effort.

Table 3.11: Marine mammal sightings (on-effort, off-effort and incidental) (November 2016 to October 2018).

Survey	Species	On-effort		Incidental and off-effort		Total number of individuals (minimum count)
		Number of encounters	Number of animals	Number of encounters	Number of animals	
November	Harbour porpoise	10	11	2	4	**15**
December	Harbour porpoise	3	3	9	11	**14**
January	Grey seal	1	1	-	-	**1**
	Harbour porpoise	26	44	23	32	**76**
March	Grey seal	-	-	1	1	**1**
	Harbour porpoise	11	11	9	9	**20**
April	Grey seal	-	-	1	1	**1**
	Harbour porpoise	5	5	1	2	**7**
May (1)	Grey seal	1	1	-	-	**1**
	Harbour porpoise	12	13	7	8	**21**
May (2)	(No sightings)	**-**	**-**	-	**-**	**-**
July	Harbour porpoise	15	22	13	18	**40**
August	Harbour porpoise	7	9	5	5	**14**
September	Grey seal	1	1	-	-	**1**
	Harbour porpoise	2	2	6	7	**9**
	Risso's dolphin	-	-	2	8	**8**
November	Harbour porpoise	5	5	4	5	**10**
December	Harbour porpoise	3	5	3	3	**8**
January	Harbour porpoise	7	9	12	14	**23**
February (1)	Grey seal	1	1	-	-	**1**
	Harbour porpoise	4	4	2	4	**8**
February (2)	Bottlenose dolphin	1	12	-	-	**12**
	Harbour porpoise	3	3	5	6	**9**
	Seal sp.	1	1	1	1	**2**
March	Harbour porpoise	7	10	4	4	**14**
April	Harbour porpoise	18	25	5	6	**31**
May (1)	Harbour porpoise	4	5	1	1	**6**
May (2)	Grey seal	-	-	1	1	**1**
	Harbour porpoise	6	8	1	1	**9**
	Risso's dolphin	2	11	-	-	**11**
	Seal sp.	2	2	-	-	**2**
June	Harbour porpoise	9	12	3	3	**15**
	Seal sp.	-	-	1	1	**1**
July	Grey seal	1	1	-	-	**1**
	Harbour porpoise	6	7	4	5	**12**
August	Harbour porpoise	6	8	5	7	**15**
October (1)	Grey seal	-	-	1	1	**1**
	Harbour porpoise	7	9	3	3	**12**
	Risso's dolphin	3	20	-	-	**20**
October (2)	Grey seal	1	1	2	2	**3**
	Harbour porpoise	7	7	2	2	**9**
Total		**198**	**289**	**139**	**176**	**465**

Table 3.12: Marine mammal encounters (on-effort, off-effort and incidental) (November 2016 to October 2018).

	Number of encounters during boat-based survey			
Species	**On-effort**	**Incidental and off-effort**	**Total**	**% of total sightings**
Harbour porpoise	183	129	312	**93%**
Bottlenose dolphin	1	0	1	**<1%**
Risso's dolphin	5	2	7	**2%**
Grey seal	6	6	12	**3%**
Seal sp.	3	2	5	**1%**

Table 3.13: Marine mammal encounter rates for species for which on-effort sightings were made (November 2016 to October 2018). Values are number of sightings per km*.

Species	Nov	Dec	Jan	Feb	Apr	May (2)	May (2)	Jul	Aug	Sep	Nov	Dec
Harbour porpoise	0.098	0.029	0.255	0.108	0.049	0.118	0	0.137	0.069	0.020	0.049	0.029
Bottlenose dolphin	0	0	0	0	0	0	0	0	0	0	0	0
Risso's dolphin	0	0	0	0	0	0	0	0	0	0	0	0
Grey seal	0	0	0.010	0	0	0.010	0	0	0	0.010	0	0
Seal sp.	0	0	0	0	0	0	0	0	0	0	0	0
	Jan	**Feb (1)**	**Feb (2)**	**Mar**	**Apr**	**May (1)**	**May (2)**	**Jun**	**Jul**	**Aug**	**Oct (1)**	**Oct (2)**
Harbour porpoise	0.069	0.039	0.029	0.069	0.177	0.039	0.059	0.088	0.049	0.059	0.069	0.069
Bottlenose dolphin	0	0	0.010	0	0	0	0	0	0	0	0	0
Risso's dolphin	0	0	0	0	0	0	0.020	0	0	0	0.029	0
Grey seal	0	0.010	0	0	0	0	0	0	0.010	0	0	0.010
Seal sp.	0	0	0.010	0	0	0	0.020	0	0	0	0	0

**Calculations based on 101.9 km survey effort per survey.*

The distribution of marine mammals across the survey area is shown in Figure 3.25 (harbour porpoise) and Figure 3.26 (all other species).

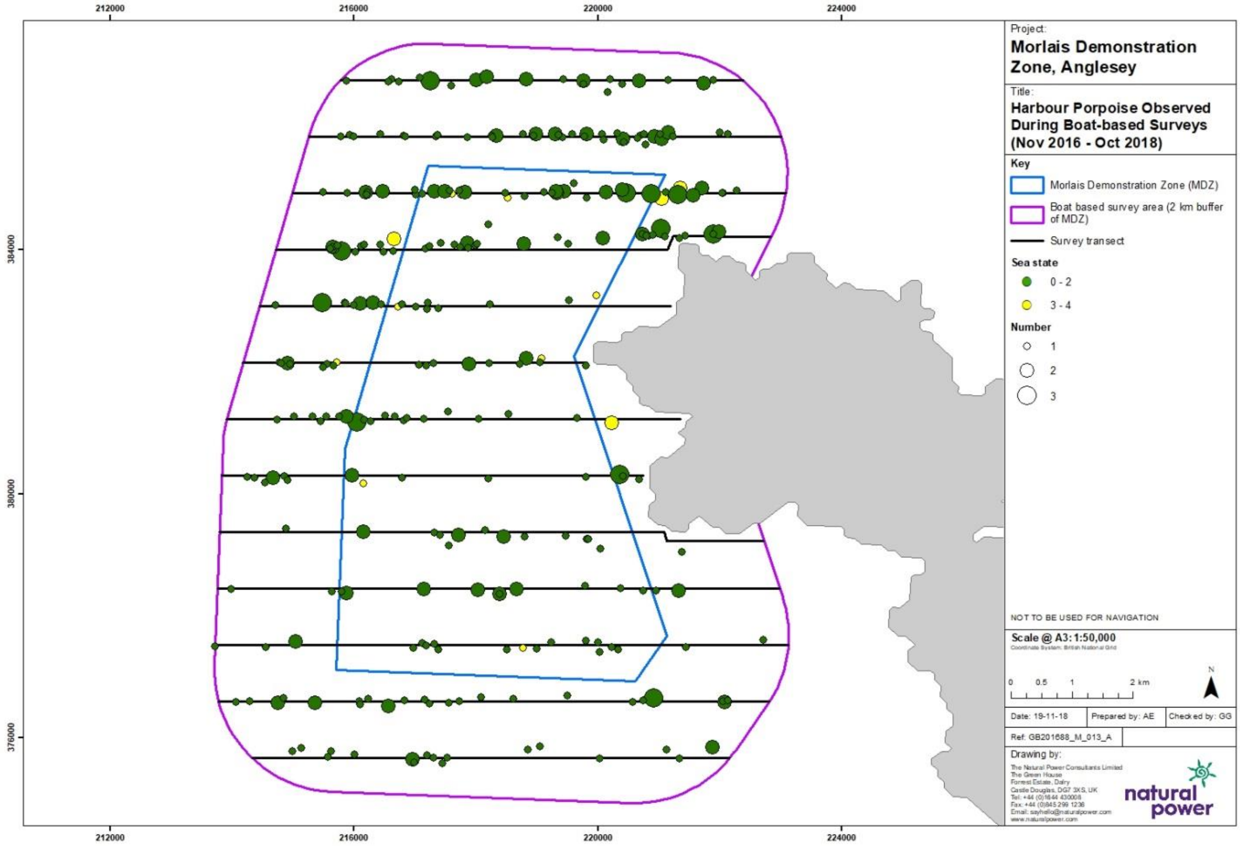

Figure 3.25: **Distribution of all harbour porpoise sightings (on-effort, off-effort and incidental) (November 2016 to October 2018).**

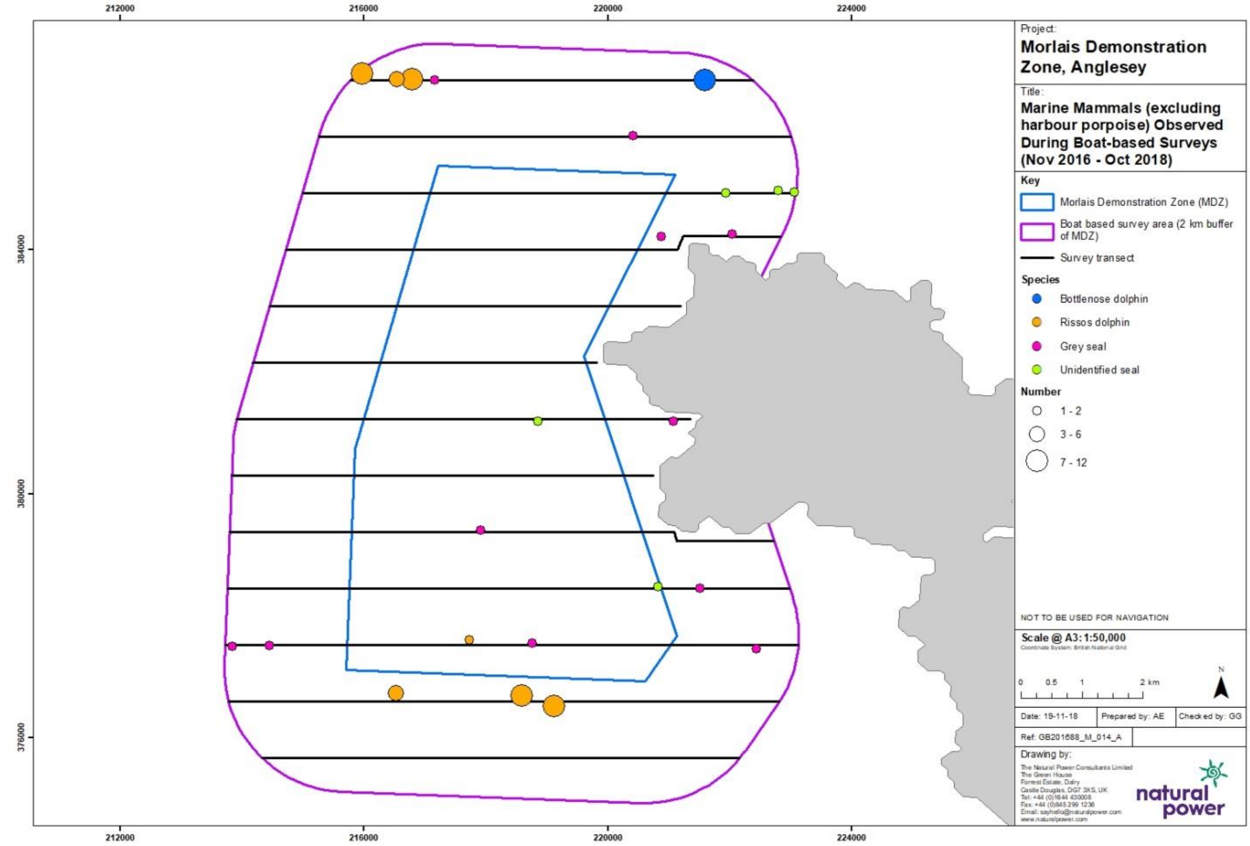

Figure 3.26: Distribution of marine mammal (excluding harbour porpoise) sightings (on-effort, off-effort and incidental) survey (November 2016 to October 2018).

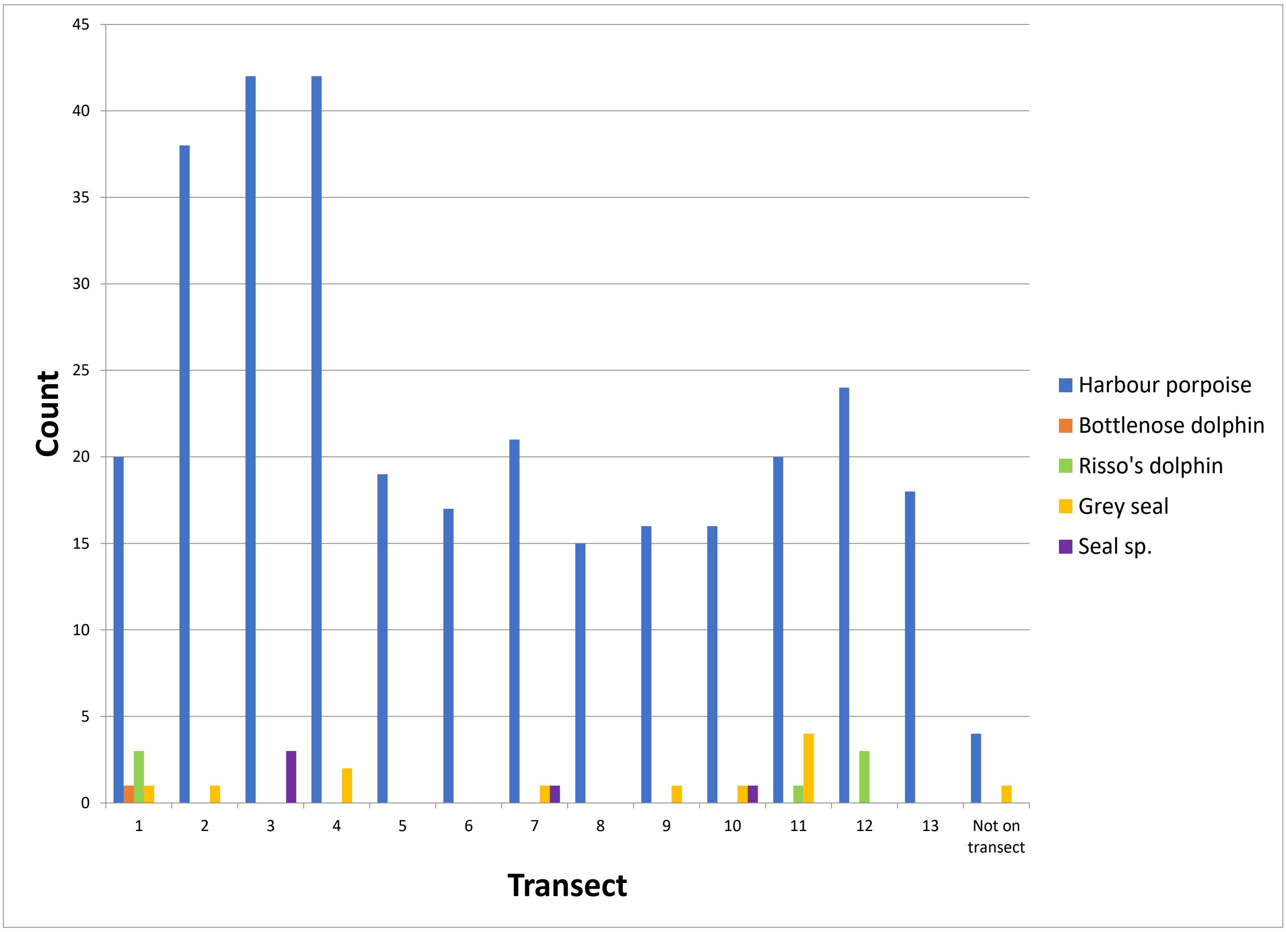

Figure 3.27: Marine mammal encounters per species per transect (including on-effort, off-effort and opportunistic sightings) (November 2016 to October 2018)

3.2.2. Harbour Porpoise: Abundance and Density

There were sufficient records of harbour porpoise to allow Distance analysis to be undertaken (Table 3.14). For the other species, either no Distance eligible observations were made (i.e. observed within 300 m of the track line) or too few encounters occurred to allow Distance analysis to be undertaken.

Table 3.14: Number of observations of marine mammals eligible for inclusion in Distance analysis. Shading indicates species for which Distance analysis was undertaken.

Species	Number of observations
Harbour porpoise	170
Grey seal	6
Risso's dolphin	5
Unidentified seal species	3
Bottlenose dolphin	1

A half-normal polynomial detection function was selected to model harbour porpoise densities. The p-value associated with the goodness-of-fit test comparing observed data with those expected according to the detection is 0.92. A plot of the detection function is shown in Figure 3.28.

Density and abundance estimates for harbour porpoise, across each of the 24 surveys, are shown in Table 3.15. Within the Site, harbour porpoise peaked at an estimated 1.00 animals/km^{-2} during the January 2017 survey. It should be noted that although detectability of animals available for detection is accounted for in this analysis, these figures still represent a minimum estimate since the assumption of g(0) = 1 will certainly be inaccurate (see

Section 2.5.3.). The true g(0) has not been estimated during the surveys but, as an example, Hammond *et al*. (2013) estimated a g(0) of 0.2 for harbour porpoise which, if applicable to this survey area, would mean that true abundances could be around five times those presented here.

Table 3.15 Harbour porpoise abundance and density (animals km^{-2}) estimates, together with the coefficient of variation (%CV), lower 95% confidence limits (LCL) and upper 95% confidence limits (UCL) derived from Distance sampling.

		Abundance			Density			
Survey	**Region**	**Estimate**	**LCL**	**UCL**	**Estimate**	**LCL**	**UCL**	**% CV**
November 2016	Buffer	26	11	63	0.40	0.16	0.96	42.71
	Site	6	1	39	0.17	0.02	1.11	98.78
December 2016	Buffer	10	4	27	0.15	0.05	0.41	49.09
	Site	0			0.00	0.00	0.00	
January 2017	Buffer	42	17	102	0.64	0.26	1.57	42.98
	Site	35	13	97	1.00	0.36	2.76	46.6
February 2017	Buffer	3	1	21	0.05	0.01	0.32	103.75
	Site	18	6	51	0.50	0.17	1.46	49.37
March 2017	Buffer	0			0.00	0.00	0.00	
	Site	9	3	28	0.25	0.08	0.79	53.54
April 2017	Buffer	32	15	68	0.50	0.23	1.05	35.7
	Site	3	0	19	0.08	0.01	0.54	97.19
May 2017	Buffer	0			0.00	0.00	0.00	
	Site	0			0.00	0.00	0.00	
June 2017	Buffer	35	19	67	0.54	0.29	1.03	30.35
	Site	9	3	26	0.25	0.08	0.75	50.63
July 2017	Buffer	13	4	39	0.20	0.07	0.60	54.12
	Site	9	3	26	0.25	0.08	0.75	50.82
August 2017	Buffer	3	1	21	0.05	0.01	0.32	103.39
	Site	3	0	21	0.08	0.01	0.59	102.84
September 2017	Buffer	10	3	27	0.15	0.05	0.41	49.85
	Site	6	1	38	0.17	0.03	1.09	97.19
October 2017	Buffer	3	1	20	0.05	0.01	0.31	102.17
	Site	6	1	25	0.17	0.04	0.71	69.74
November 2017	Buffer	16	5	53	0.25	0.08	0.81	58.94
	Site	6	1	25	0.17	0.04	0.71	69.52
December 2017	Buffer	13	4	41	0.20	0.06	0.63	57.5
	Site	0			0.00	0.00	0.00	
January 2018	Buffer	10	2	41	0.15	0.03	0.63	74.72
	Site	0			0.00	0.00	0.00	
February 2018	Buffer	19	10	36	0.30	0.16	0.56	29.83
	Site	3	0	19	0.08	0.01	0.54	97.19
March 2018	Buffer	32	11	95	0.50	0.17	1.46	53.22
	Site	23	11	50	0.67	0.31	1.42	34.11
April 2018	Buffer	10	2	39	0.15	0.04	0.60	71.01
	Site	3	0	19	0.08	0.01	0.54	97.19
May 2018	Buffer	10	4	25	0.15	0.06	0.39	46.25
	Site	6	1	23	0.17	0.04	0.66	65.34
June 2018	Buffer	10	3	29	0.15	0.05	0.45	54.32
	Site	15	6	37	0.42	0.16	1.06	42.65
July 2018	Buffer	10	3	29	0.15	0.05	0.45	54.92

Survey	Region	Abundance			Density			
		Estimate	LCL	UCL	Estimate	LCL	UCL	% CV
	Site	6	1	24	0.17	0.04	0.67	66.74
August 2018	Buffer	16	7	39	0.25	0.10	0.59	41.9
	Site	3	0	21	0.08	0.01	0.59	102.55
September 2018	Buffer	13	4	42	0.20	0.06	0.64	58.6
	Site	9	3	25	0.25	0.09	0.73	49.26
October 2018	Buffer	6	2	25	0.10	0.03	0.38	68.86
	Site	12	5	28	0.33	0.14	0.81	40.18

The distribution of harbour porpoise across the survey area, as calculated by the Distance analysis, is shown in Figure 3.28. The figure indicates that the greatest abundance of porpoise occurred in the north of the survey area.

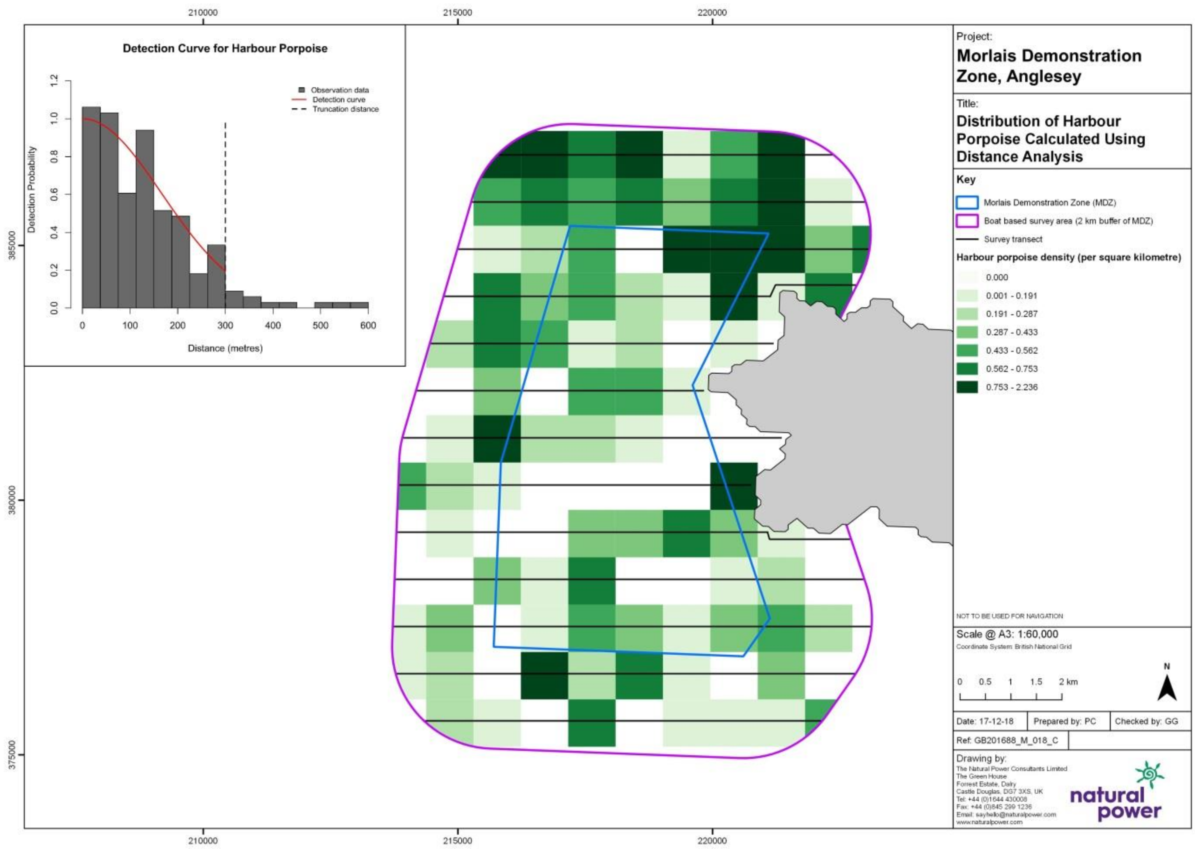

Figure 3.28: Density of harbour porpoise calculated using Distance analysis (and associated detection curve)

3.2.3. Sea State in Relation to Harbour Porpoise Records

The different sea-states during which surveys were undertaken are shown in Table 3.16 along with the number of harbour porpoise sightings (all effort categories) made during the same survey. It is to be expected that as sea state increases, so the detection rate of harbour porpoise (and the resulting density estimate) will decline (Palka, 1995). This pattern is not obvious in the dataset, however. This is considered to be evidence that, overall, the surveys were all undertaken in suitable weather conditions and, therefore, the data has not been obviously negatively impacted upon by environmental factors (see Section 3.3).

Table 3.16: Percentages of each survey conducted at different sea states compared with the total number of harbour porpoise sightings (all effort categories) made during the survey.

	Percentage of each survey spent at different sea states						Percentage of survey conducted at sea state 2 or lower	Total no. porpoise sightings
	Sea state							
Survey	**0**	**0.5**	**1**	**2**	**3**	**4**		
November	0	0	10	88	2	0	98	12
December	0	0	34	64	2	0	98	12
January	0	10	27	63	0	0	100	49
March	7	0	43	48	2	0	98	20
April	0	0	19	56	25	0	75	6
May (1)	0	17	51	32	0	0	100	19
May (2)	0	0	20	32	39	9	52	0
July	19	0	58	23	0	0	100	28
August	0	0	0	90	10	0	90	12
September	0	0	29	71	0	0	100	8
November	0	0	9	71	20	0	80	9
December	0	0	0	100	0	0	100	6
January	0	0	19	81	0	0	100	19
February (1)	0	0	55	45	0	0	100	6
February (2)	28	0	57	15	0	0	100	8
March	0	0	3	65	31	1	68	11
April	0	0	48	52	0	0	100	23
May (1)	0	0	34	66	0	0	100	5
May (2)	92	0	8	0	0	0	100	7
June	28	2	68	2	0	0	100	12
July	24	0	76	0	0	0	100	10
August	20	0	33	47	0	0	100	11
October (1)	0	0	3	33	36	27	36	10
October (2)	0	0	21	46	33	0	67	9

3.2.4. Effect of the Tide

Over the course of the 24 surveys all tidal conditions were encountered within the survey area. Table 3.17 shows the timing of each survey in relation to the tidal cycle on that date. As a supplementary analysis, this is presented alongside the number of harbour porpoise recorded on each survey. The data presented in Table 3.17 indicates that the greatest number of porpoises were present mid-tide, when then the tide was rising.

Table 3.17: **Approximate tidal state and harbour porpoise sightings (on-effort, off-effort and incidental) recorded during the boat-based visual survey (November 2016 to October 2018) (grey cells = duration of survey). Values are the percentage of the porpoise total seen on each survey.**

	Proportion of harbour porpoise on each survey (%) recorded in each tidal phase												Total porpoise sightings (individuals)
Tidal state	**Low**	**L+1**	**L+2**	**H-3**	**H-2**	**H-1**	**High**	**H+1**	**H+2**	**L-3**	**L-2**	**L-1**	
Survey	**Low**	**Rising**		→			**High**	**Falling**		→			
November	-	-	-	-	-	17	33	-	17	17	17	-	12
December	-	17	33	25	-	-	25	-	-	-	-	-	12
January	14	4	8	12	8	47	6	-	-	-	-	-	49
March	-	-	-	-	-	5	10	45	5	25	5	5	20
April	-	-	-	-	33	17	50	-	-	-	-	-	6
May (1)	-	-	11	21	21	-	5	-	32	11	-	-	19
May (2)	-	-	-	-	-	-	-	-	-	-	-	-	0
July	21	11	4	18	18	21	7	-	-	-	-	-	28
August	17	-	25	8	33	8	-	-	-	-	-	1	12
September	-	-	13	63	13	13	-	-	-	-	-	-	8
November	11	-	-	-	-	-	-	22	11	11	11	33	9
December	-	-	-	-	-	-	17	17	67	-	-	-	6
January	11	11	16	42	16	-	-	-	-	-	5	-	19
February (1)	-	-	33	67	-	-	-	-	-	-	-	-	6
February (2)	-	-	-	63	25	-	13	-	-	-	-	-	8
March	18	9	-	9	36	9	-	-	-	-	-	18	11
April	-	-	17	22	39	22	-	-	-	-	-	-	23
May (1)	-		20	-	-	20	-	60	-	-	-	-	5
May (2)	-	14	14	14	14	-	28	14	-	-	-	-	7
June	25	25	-		-	-	-	-	-	-	25	25	12
July	30	10	20	10	-	-	-	-	-	-	10	20	10
August	-	36	-	18	18	18	9	-	-	-	-	-	11
October (1)	10	40	10	10	10	20	-	-	-	-	-	-	10
October (2)	-	22	22	22	22	11	-	-	-	-	-	-	9
Total HP sightings	**27**	**25**	**31**	**54**	**44**	**47**	**23**	**16**	**14**	**10**	**9**	**12**	**312**
% of HP sightings	**9**	**8**	**10**	**17**	**14**	**15**	**7**	**5**	**5**	**3**	**3**	**4**	**100%**
Sightings / no. times tidal state surveyed	1.92	1.56	1.55	2.84	2.09	2.35	1.27	1.23	1.55	1.66	1.28	1	

3.3. Sea Conditions During Surveys

The final set of results presented here aim to provide a brief review of the environmental conditions in which the baseline surveys were undertaken (see also Sections 3.2.3 and 3.2.4.). ESAS guidance (Camphuysen *et al*., 2004) recommends that seabird data not be used when observations are made in sea state 5 and above, and marine mammal data not be used when observations are made in sea state 3 or above. Therefore, as much as possible, the surveys were undertaken when weather forecasts suggested that surveying in a sea state of 3 or below could be achieved. This proved to be the case for nearly the full duration of all surveys, except for just 2% of the time when sea state 4 was experienced. For 90% of the time, conditions were of a sea state 2 or less (Table 3.18).

The duration of sea states encountered on each of the different transects over the course of the 24 surveys was visually inspected to see whether any transects experienced consistently rougher sea states due to strong tidal currents. This was not apparent from the data (Table 3.19 and Figure 3.28), although the southern-most transects show the highest proportions of both smooth sea state (sea state 0) and rough sea state (sea state 4) compared to the transects further north. This is likely a result of these transects having both a sheltered nature at their eastern end and the most offshore part of the survey area being at the western end of these transects.

Table 3.18: The duration of sea states recorded during each survey (November 2016 to October 2018).

	Duration of sea state (hrs:mins)					
	Sea state					
Survey	**0**	**0.5**	**1**	**2**	**3**	**4**
November 2016			0:31	4:42	0:6	
December			1:50	3:25	0:7	
January 2017		0:48	1:31	3:8		
March	0:24		2:21	2:39	0:8	
April			1:8	3:9	1:2	
May 1	0:7	0:55	2:39	1:41		
May 2			1:5	1:43	2:6	0:28
July	1:3		3:8	1:14		
August				4:42	0:30	
September			1:30	3:36		
November			0:29	3:40	1:2	
December				5:20		
January 2018			0:58	4:14		
February 1			3:7	2:36		
February 2	1:30		3:0	0:49		
March			0:8	3:24	1:37	0:3
April			2:25	2:36		
May 1			1:42	3:23		
May 2	4:40		0:24			
June	1:24	0:7	3:24	0:5		
July	1:12		3:51			
August	0:58		1:35	2:16		
October 1			0:11	1:47	1:59	1:27
October 2			1:2	2:12	1:35	
Total duration of sea state (hrs:mins)	**11:18**	**1:50**	**37:59**	**62:21**	**10:12**	**1:58**
Total duration of sea state, %	**9%**	**1%**	**30%**	**50%**	**8%**	**2%**

Table 3.19: The duration of sea states recorded on each transect line across all 24 surveys (November 2016 to October 2018).

	Duration of sea state, mins (% of total)*					
	Sea state					
Transect	**0**	**0.5**	**1**	**2**	**3**	**4**
1	21 (3)	35 (43)	154 (7)	256 (7)	18 (3)	
2	13 (2)		258 (11)	292 (8)	18 (3)	
3	21 (3)		252 (11)	220 (6)	107 (17)	
4	11 (2)	27 (25)	229 (10)	310 (8)	29 (5)	3 (3)

Transect	Duration of sea state, mins (% of total)*					
	Sea state					
	0	0.5	1	2	3	4
5	18 (3)	10 (9)	95 (4)	223 (6)	112 (17)	1 (1)
6	24 (3)	14 (13)	112 (5)	198 (5)	83 (14)	
7	40 (6)	11 (10)	160 (7)	283 (8)	52 (8)	
8	53 (8)		135 (6)	267 (7)	31 (5)	19 (16)
9	70 (10)		127 (6)	353 (9)	31 (5)	21 (18)
10	66 (10)		232 (10)	324 (9)	48 (8)	10 (8)
11	135 (20)		165 (7)	409 (11)	17 (3)	26 (22)
12	131 (20)		145 (6)	347 (9)	43 (7)	12 (10)
13	75 (11)	13 (12)	205 (9)	259 (7)	23 (4)	26 (22)
Total duration of sea state, mins	**678 (100)**	**110 (100)**	**2279 (100)**	**3741 (100)**	**612 (100)**	**118 (100)**

*Percentages are rounded to nearest whole number, thus summed totals may not equal 100%

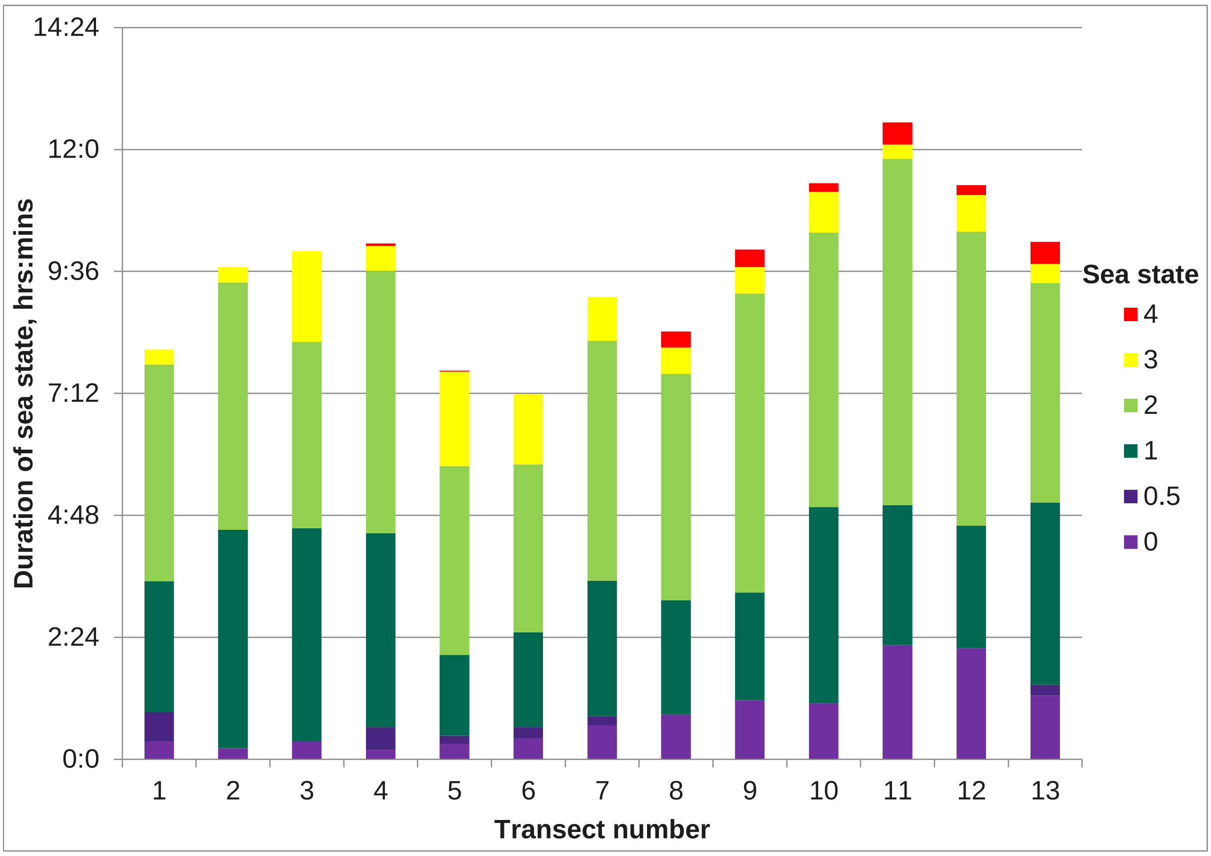

Figure 3.29: Duration of sea states recorded by transect (November 2016 to October 2018).

4. Discussion

4.1. Birds and Energy Generating Tidal Devices

At present, although there is limited information regarding the actual impacts that tidal turbines and wave energy devices may have on seabird populations, there is strong consensus that 'wet' renewable technologies are unlikely to represent as great a risk to seabirds as posed by offshore wind farms (Grecian *et al*., 2010; Langton *et al*., 2011; Furness *et al*., 2012).

Furness *et al.* (2012) produced a relative index of species vulnerability to wave and tidal developments. No species were regarded as being in the 'very high vulnerability' category, but there were five species that fell into the 'high vulnerability' category. These were black guillemot (*Cepphus grille*), razorbill, shag, guillemot and cormorant. Of these five highly vulnerable species, black guillemot was not recorded in the survey area and cormorant was only recorded in very small numbers and not on the sea within the survey area. Therefore, guillemot, razorbill and shag are considered to be key species at this site.

A further five species were regarded by Furness *et al.* (2012) as being of 'moderate' risk from tidal turbine developments; of these red-throated diver and puffin were recorded within the Site. The remaining 28 species reviewed by Furness *et al.* (2012) fell into categories of 'low' or 'very low' vulnerability, indicating that their populations are unlikely to be affected by tidal turbine development. These low vulnerability species include those such as herring gull ('very low vulnerability') and Manx shearwater ('low vulnerability') which were recorded in relative abundance in the survey area.

The three tern species (Sandwich, common and Arctic) recorded in the survey area are all considered to have 'low vulnerability' to tidal turbine impacts. However, the recently established Anglesey Terns SPA, of which these three species are named features, suggests that any potential impacts on these species should be fully assessed.

The discussion of this technical report focusses on the species recorded during the MDZ baseline and which have been identified as being potentially vulnerable to tidal turbine developments by Furness *et al.* (2012).

4.2. Discussion of Seabird Survey Results

Bird records from within the MDZ were split into approximately 52% which were recorded on the sea surface and 48% which were transiting over the Site. Fifteen species were recorded on the sea surface, with guillemot being the most frequently recorded of these species (n=1585) followed by herring gull (n=286), razorbill (n=258) and Manx shearwater (n=186). All other species on the sea within the Site were present in relatively small numbers (n=155). In the remaining survey area (2 km buffer), guillemots were again the most frequently recorded species on the sea surface (n=1,805), followed by Manx shearwater (n=469).

Across all 24 surveys, 12 key species were recorded within the Site; eight of these species were recorded on the sea. In total, 2,348 individuals comprising red-throated diver, Manx shearwater, gannet, shag, Arctic tern, guillemot, razorbill and puffin were recorded on the sea surface within the Site. Five of these eight species are considered to have high or moderate vulnerability to tidal devices, but the proportion of these species recorded as actively foraging within the Site was generally low: guillemot (16% foraging), razorbill (26% foraging) and red-throated diver, shag and puffin (all 0% foraging).

The prevalence of guillemots and razorbill in the boat-based survey data is to be expected as large numbers of these species breed on the cliffs at South Stack, <1 km east from the Site. The source of birds within the survey area may be this local colony, in the breeding season at least, but even at this time of year, birds may have originated from further afield; the mean maximum foraging range of breeding guillemots being 84.2 ± 50.1 km (Thaxter *et al.,* 2012).

Relatively low numbers of guillemot (12%) and razorbill (3%) were recorded diving or feeding within the Site, suggesting the survey area is used as a resting area for locally nesting birds rather than as a destination for foraging birds.

Guillemots forage using both shallow dives (≤ 30 m) and long, deep dives (30-70 m) (Thaxter *et al*., 2010). Razorbill dives are typically less than 32 m in depth, although they are capable of diving much deeper (120 m dives have been recorded; Piatt and Nettleship, 1985). Guillemots have 'U' shaped dives and spend a relatively long time in the deepest part of the dive profile in comparison to razorbills. Razorbills undertake more frequent 'V' shaped dives. Overall, guillemots make fewer dives but these are of longer duration and cover greater distances underwater. Several studies suggest that both species may preferentially use the edges of high flow areas at particular times (Slater, 1976; Coyle *et al*. 1992; Wanless *et al*., 1990; Holm & Burger 2002). It is therefore possible that guillemots and razorbills may forage within the Site during the periods at which tidal devices would be operating.

This is also the case for shags which were recorded on the sea within the Site, and which are known to forage at depths which may bring them into contact with tidal devices. Wanless *et al*. (1991) found shags to forage most frequently in water of 21-40 m depth. Shags may be particularly vulnerable since they are benthic foragers unlike auk species which tend to forage within the water column (Watanuki *et al.,* 2008; Thaxter *et al*., 2010). However, this species was present in relatively low numbers (five individuals) within the Site.

Puffins, like razorbills, undertake relatively shallow 'V' shaped dives; these have a mean depth of 12 m (Shoji *et al.*, 2015). Puffins were only recorded in the breeding season and there were only small numbers within the survey area. Within the Site there were six records of birds on the sea and none of these were seen to be foraging. Within the 2 km buffer three puffins were recorded deep-diving.

Red-throated diver is a non-breeding species present in Anglesey waters, with small numbers recorded during baseline surveys. Most individuals were recorded in flight, however it should be noted that red-throated divers are particularly sensitive to disturbance by boats and some of the birds seen in flight may have been flushed by the survey vessel (or other boats) prior to detection. Only one bird was recorded on the sea within the Site

4.3. Discussion of Marine Mammal Survey Results

Visual surveys were carried out in good conditions (conditions were optimal i.e. sea state 2 or less) 90% of the time. Animals were sighted on all but one of the surveys and it is considered that the boat-based surveys have characterised the baseline conditions of the survey area for marine mammals.

Harbour porpoise was the most frequently recorded marine mammal species. Records were made throughout the survey area, however this species was most abundant on the northern-most transects. The total number of observations of harbour porpoise from the 24 months of surveys was 233 individuals (range 0-76 per survey). Distance analysis was undertaken for harbour porpoise, with a maximum abundance estimate of 35 individuals within the Site in January 2017.

Two dolphin species (Risso's and bottlenose) were recorded occasionally during baseline surveys but only one animal (a single Risso's dolphin) was recorded within the Site.

Grey seal was the only seal species identified during baseline surveys. Grey seals were recorded in very low numbers but were recorded in most months of the year. Only two individuals were recorded within the Site.

5. Conclusion

Two years of boat-based seabird and marine mammal surveys have been successfully undertaken for the Morlais Development Zone and a surrounding 2 km buffer. These surveys were able to characterise the baseline conditions for this area. The ornithological and marine mammal communities present are considered to be typical of a near-shore environment in north-west Wales. The species and number of ecological features within the Site is comparable with those in the surrounding buffer area. The close proximity of seabird breeding cliffs is evident in the number of some seabird species present, particularly those of guillemot. Guillemot is considered likely to be a key species for the MDZ, along with razorbill, Manx shearwater and shag. However, overall the number of most seabird species recorded within the survey area was low, especially in the non-breeding season. Harbour porpoise was the most regularly recorded marine mammal and the numbers encountered indicate that this is a key species for the MDZ year-round, whilst other species of marine mammal were present in the Site infrequently.

6. References

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. & Thomas, L. (2001) *Introduction to distance sampling: estimating abundance of biological populations.* Oxford University Press, UK.

Buckland, S.T., Anderson, D.R., Burnham K.P., Laake, J.L., Borchers, D.L. & Thomas L (eds) (2004) *Advanced Distance Sampling*. Oxford University Press, Oxford

Camphuysen, C. J., Fox, T., Leopold, M. F. & Petersen, I. K. (2004) *Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the UK*. Report to COWRIE.

Coyle, K., Hunt, G.L., Decker, M.B., & Weingartner, T.J. (1992) Murre foraging, epibenthic sound scattering and tidal advection over a shoal near St. George Island, Bering Sea. *Marine Ecology Progress Series*, 83: 1-14.

Furness, R. W., Wade, H. M., Robbins, A. M. C. & Masden E. A. (2012) Assessing the sensitivity of seabird populations to adverse effects from tidal stream turbines and wave energy devices. *ICES Journal of Marine Science*. 1466-1479.

Furness, R.W., Wade, H.M. & Masden, E.A. (2013) Assessing vulnerability of marine bird populations to offshore wind farms. *Journal of Environmental Management,* 119, 56-66.

Grecian, W.J., Inger, R., Attrill, M.J., Bearhop, S., Godley, B.J., Witt, M.J. & Votier, S.C. (2010) Potential impacts of wave-powered marine renewable energy installations on marine birds. Ibis, 152, 683-697.

Hammond, P.S., MacLeod, K., Berggren, P., Borchers, D.L., Burt, L., Canadas, A., Desportes, G., Donovan, G.P., Gilles, A., Gillespie, D., Gordon, J., Hiby, L., Kuklik, I., Leaper, R., Lehnert, K., Leopold, M., Lovell, P., Oien, N., Paxton, C.G.M., Ridoux, V., Rogen, E., Samarra, F., Scheidat, M., Sequiera, M., Siebert, U., Skov, H., Swift, R., Tasker, M.L., Teilmann, J., Van Canneyt, O. & Vazquez, J.A. (2013) Cetacean abundance and distribution in European Atlantic shelf waters to inform conservation and management. *Biological Conservation,* 164: 107-122.

Holm, K.J. & Burger, A.E. (2002) Foraging behaviour and resource partitioning by diving birds during winter in areas of strong tidal currents. *Waterbirds*, 25, 312-325.

Langton, R., Davies, I.M. & Scott, B.E. (2011) Seabird conservation and tidal stream and wave power generation: information needs for predicting and managing potential impacts. *Marine Policy*, 35, 623-630.

Maclean, I.M.D., Wright, L.J., Showler, D.A. & Rehfisch, M.M. (2009) *A review of assessment methodologies for offshore wind farms*. British Trust for Ornithology (BTO) report commissioned by COWRIE.

Palka, D. (1995) *Effects of Beaufort sea state on the sightability of harbour porpoises in the Gulf of Maine.* Report to the International Whaling Commission; 46. SC/47/SM26

Piatt, J. F. and Nettleship, D. N, (1985) Diving depths of four alcids. *The Auk*. 102: 293-297.

Shoji, A., Elliott, K., Fayet, A., Boyle, D., Perrins, C. & Guilford, D. 2015. Foraging behaviour of sympatric razorbills and puffins. *Marine Ecology Progress Series*, 520: 257-267.

Slater, P.J.B. (1976) Tidal rhythm in a seabird. *Nature*, 264: 636-638.

Thaxter, C.B., Wanless, S., Daunt, F., Harris, M.P., Benvenuti, S., Watanuki, Y., Grémillet, D. & Hamer, K.C. (2010) Influence of wing-loading on the trade-off between pursuit-diving and flight in common guillemots and razorbills. *Journal of Experimental Biology*, 213, 1018-1025.

Thaxter, C.B., Lascelles, B., Sugar, K., Cook, A.S.C.P., Roos, S., Bolton, M., Langston, R.H.W. & Burton, N.H.K. (2012) Seabird foraging ranges as a preliminary tool for identifying candidate Marine Protected Areas. *Biological Conservation*. doi:10.1016/j.biocon.2011.12.009.

Thomas, L., Buckland, S.T., Rexstad, E.A., Laake, J.L., Strindberg, S., Hedley, S.L., Bishop, J.R.B., Marques, T.A. & Burnham, K.P. (2010) Distance software: design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology*, 47: 5-14.

Wanless, S., Harris, M.P. & Morris, J.A. (1990) A comparison of feeding areas used by individual common murres (Uria aalge), razorbills (Alca torda) and an Atlantic puffin (Fratercula arctica) during the breeding season. *Colonial Waterbirds*, 13: 16-24.

Wanless, S., Harris, M.P. & Morris, J.A. (1991) Foraging range and feeding locations of shags Phalacrocorax aristotelis during chick rearing. *Ibis*: 133, 30-36.

Watanuki, Y., Daunt, F., Takahashi, A., Newell, M., Wanless, S., Sato, K. & Miyazaki, N. (2008) Microhabitat use and prey capture of a bottom-feeding top predator, the European Shag, shown by camera loggers. *Marine Ecology Progress Series*, 356: 283-293.

Webb, A. & Durinck, J. 1992. Counting birds from ships. In J. Komdeur; J. Berelsen & G. Cracknell *Manual for aeroplane and ship surveys of waterfowl and seabirds*. International Wildfowl Research Bureau, Slimbridge, 24-37.

Appendices

A. Boat-based Survey: Detailed Conditions

Table A.1: Date, time and tidal details for each survey, November 2016 to October 2018.

Date	Start time	End time	Survey duration, hours	Tide (South Stack, Anglesey)
29th November 2016	08:20	14:46	6hr 26mins	Low tide (1.29 m) 03:48, high tide (5.11 m) 09:46, low tide (1.34 m) 16:04
05th December 2016	08:26	14:34	6hrs 8mins	Low tide (1.76 m) 07:21, high tide (4.80 m) 13:23, low tide (1.66 m) 19:53
19th January 2017	08:31	14:58	6hrs 27mins	Low tide (1.85 m) 08:44, high tide (4.51 m) 14:51, low tide (1.80 m) 17:27
25th March 2017	07:51	14:10	6hrs 19mins	Low tide (1.62 m) 02:08, high tide (4.62 m) 08:12, low tide (1.28 m) 14:30
02nd April 2017	09:44	15:52	6hrs 8mins	Low tide (0.95 m) 08:43, high tide (4.91 m) 14:47, low tide (1.24 m) 21:09
10th May 2017	07:36	14:14	6hrs 38mins	Low tide (1.10 m) 04:44, high tide (4.91 m) 10:42, low tide (0.99 m) 17:03
24th May 2017	08:22	15:38	7hrs 16mins	Low tide (0.99 m) 03:26, high tide (5.17 m) 09:29, low tide (0.67 m) 15:48
18th July 2017	11:33	18:08	6hrs 35mins	High tide (4.53 m) 05:31, low tide (1.49 m) 11:57, high tide (4.33 m) 18:23
31st August 2017	11:48	17:46	6hrs 2mins	High tide (3.85 m) 06:07, low tide (2.28 m) 12:31, high tide (3.98 m) 18:50
26th September 2017	09:01	14:50	5hrs 49mins	Low tide (1.67 m) 08:35, high tide (4.51 m) 14:30, low tide (1.83 m) 20:54
02nd November 2017	09:10	14:59	5hrs 49mins	High tide (4.97 m) 08:29, low tide (1.27 m) 14:37, high tide (5.27 m) 20:38
22nd December 2017	09:06	15:30	6hrs 24mins	Low tide (1.52 m) 06:13, high tide (5.02 m) 12:07, low tide (1.46 m) 18:39
10th January 2018	09:31	15:32	6hrs 1min	High tide (4.21 m) 04:47, low tide (2.05 m) 10:53, high tide (4.37 m) 17:11
05th February 2018	09:15	15:30	6hrs 15mins	Low tide (1.06 m) 07:18, high tide (5.20 m) 13:22, low tide (1.05 m) 19:54
21st February 2018	09:47	15:54	6hrs 7mins	Low tide (1.23 m) 07:22, high tide (4.98 m) 13:22, low tide (1.21 m) 19:47
24th March 2018	08:40	14:42	6hrs 2mins	Low tide (1.47 m) 08:49, high tide (4.45 m) 14:56
08th April 2018	09:58	15:40	5hrs 42mins	High tide (4.06 m) 03:55, low tide (2.05 m) 10:30, high tide (3.78 m) 16:44
18th May 2018	07:25	13:08	5hrs 43mins	Low tide (0.60 m) 06:49, high tide (5.25 m) 12:45, low tide (0.79 m) 19:07
31st May 2018	07:46	13:28	5hrs 42mins	Low tide (1.05 m) 06:00, high tide (4.81 m) 11:57, low tide (1.14 m) 18:16
24th June 2018	11:09	16:46	5hrs 37mins	High tide (4.51 m) 08:23, low tide (1.40 m) 14:41, high tide (4.53 m) 20:53
19th July 2018	08:20	14:01	5hrs 41mins	High tide (4.97 m) 03:25, low tide (1.12 m) 10:00, high tide (4.49 m) 16:06
30th August 2018	08:23	13:56	5hrs 33mins	Low tide (1.03 m) 07:11, high tide (4.86 m) 13:05, low tide (1.2 m) 19:24
15th October 2018	08:46	16:01	7hrs 15mins	Low tide (1.85 m) 08:50, high tide (4.49 m) 14:47, low tide (1.93 m) 21:17
30th October 2018	08:30	13:57	5hrs 27mins	Low tide (1.54 m) 07:31, high tide (4.79 m) 13:35, low tide (1.56 m) 20:10

Table A.2: Weather details[1] for each survey, November 2016 to October 2018.

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
29/11/2016	08:20		1	SW	2	2	2	0.5	5	1	0
29/11/2016	08:35		1	SW	2	2	2	0.5	5	1	0
29/11/2016	08:46		2	SW	2	2	2	0.5	5	1	0
29/11/2016	09:00		2	SW	2	2	2	0.5	5	1	0
29/11/2016	09:05		2	SW	2	2	2	0.5	5	1	0
29/11/2016	09:20		3	SW	2	2	2	0.5	5	1	0
29/11/2016	09:25		3	SW	2	2	4	1	5	1	0
29/11/2016	09:27		3	SW	2	2	4	1	5	1	0
29/11/2016	09:29		3	SW	2	2	1	0.75	5	1	0
29/11/2016	09:30		3	SW	2	2	2	0.75	5	1	0
29/11/2016	09:31		3	SW	2	2	2	0.75	5	1	0
29/11/2016	09:33		3	SW	2	2	2	0.5	5	1	0
29/11/2016	09:51		4	SW	2	2	2	0.5	5	1	0
29/11/2016	10:06		4	SW	2	2	2	0.5	5	1	0
29/11/2016	10:08		4	SW	2	2	4	0.5	5	1	0
29/11/2016	10:13		4	SW	2	2	2	0.5	5	1	0
29/11/2016	10:28		5	SW	2	2	2	0.25	5	1	0
29/11/2016	10:43		5	SW	2	2	2	0.5	5	1	0
29/11/2016	10:52		6	SW	2	2	2	0.5	5	1	0
29/11/2016	11:05		6	SW	2	2	3	0.25	5	1	0
29/11/2016	11:15		7	SW	2	2	2	0.75	5	1	0
29/11/2016	11:21		7	SW	2	2	3	0.75	5	1	0
29/11/2016	11:30		7	SW	2	2	2	0.75	5	1	0
29/11/2016	11:43		8	SW	2	2	2	0.5	5	1	0
29/11/2016	11:56		8	SW	2	2	4	0.5	5	1	0
29/11/2016	12:02		8	SW	2	2	2	0.5	5	1	0
29/11/2016	12:12		9	SW	2	2	2	0.5	5	1	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
29/11/2016	12:22		9	SW	2	2	3	0.75	5	1	0
29/11/2016	12:27		9	SW	2	2	3	0.75	5	1	0
29/11/2016	12:44		10	SW	2	2	2	0.5	5	2	0
29/11/2016	12:59		10	SW	2	3	3	0.75	5	2	0
29/11/2016	13:05		10	SW	2	2	2	0.25	5	2	0
29/11/2016	13:16		11	SW	2	1	1	0.25	5	0	0
29/11/2016	13:24		11	SW	2	2	2	0.25	5	1	0
29/11/2016	13:49		12	SW	2	2	2	0.25	5	1	0
29/11/2016	14:11		12	SW	2	1	1	0.25	5	0	0
29/11/2016	14:21		13	SW	2	1	1	0.25	5	0	0
29/11/2016	14:38		13	SW	2	2	2	0.5	5	0	0
05/12/2016	08:26		1	SE	2	2	2	0.5	5	6	0
05/12/2016	08:39		1	SE	2	2	2	0.5	5	7	0
05/12/2016	08:51		2	E	2	1	1	0.25	5	7	0
05/12/2016	09:08		2	SSE	2	2	2	0.5	5	7	0
05/12/2016	09:23		3	SE	2	2	2	0.5	5	8	0
05/12/2016	09:34		3	ESE	2	1	1	0.5	5	7	0
05/12/2016	09:49		4	SE	2	1	1	0.5	5	8	0
05/12/2016	09:56		4	SE	2	3	3	0.5	5	7	0
05/12/2016	10:03		4	ESE	2	2	2	0.5	5	7	0
05/12/2016	10:21		5	SE	1	2	2	0.5	5	4	0
05/12/2016	10:38		5	SE	1	2	4	2	5	6	0
05/12/2016	10:40		5	SE	1	2	2	0.5	5	6	0
05/12/2016	10:45		6	SE	1	2	2	0.5	5	6	0
05/12/2016	11:07		7	SE	2	2	2	0.5	5	7	0
05/12/2016	11:33		8	SE	1	2	2	0.5	5	8	0
05/12/2016	11:47		8	SSE	1	1	1	0.5	5	7	0
05/12/2016	12:00		9	S	1	1	1	0.25	5	7	0
05/12/2016	12:18		9	N	1	1	3	0.25	5	7	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
05/12/2016	12:33		10	W	1	1	1	0.25	5	7	0
05/12/2016	12:49		10	S	2	2	2	0.5	5	7	0
05/12/2016	13:06		11	S	2	2	2	0.25	5	7	0
05/12/2016	13:24		11	S	2	2	2	0.25	5	7	0
05/12/2016	13:40		12	S	2	2	2	0.25	5	7	0
05/12/2016	13:55		12	S	2	2	2	0.5	5	7	0
05/12/2016	14:10		13	S	2	2	2	0.5	5	6	0
05/12/2016	14:15		13	S	1	1	1	0.5	5	6	0
19/01/2017	08:31		13	S	1	2	2	0.25	5	8	1
19/01/2017	09:02		12	S	1	2	2	0.25	5	8	1
19/01/2017	09:37		11	S	1	2	2	0.25	5	8	1
19/01/2017	10:13		10	S	1	2	2	0.25	5	8	1
19/01/2017	10:48		9	S	1	2	2	0.25	5	8	1
19/01/2017	11:12		9	S	1	2	3	0.25	5	8	1
19/01/2017	11:18		8	S	1	2	2	0.25	5	8	1
19/01/2017	11:45		7	S	1	1	1	0.25	5	8	0
19/01/2017	11:58		7	S	1	0.5	0.5	0.25	5	8	0
19/01/2017	12:15		6	SSW	1	1	1	0.25	5	8	0
19/01/2017	12:20		6	SSW	1	0.5	0.5	0.25	5	8	0
19/01/2017	12:37		5	SSW	1	2	2	0.25	5	8	0
19/01/2017	12:48		5	SSW	1	1	1	0.25	5	8	0
19/01/2017	12:54		5	SSW	1	1	2	0.25	5	8	0
19/01/2017	12:55		5	SSW	1	1	1	0.25	5	8	0
19/01/2017	13:07		4	SSW	1	0.5	0.5	0.25	5	8	0
19/01/2017	13:10		4	SSW	1	1	3	0.25	5	8	0
19/01/2017	13:12		4	SSW	1	1	1	0.25	5	8	0
19/01/2017	13:22		4	SSW	1	2	2	0.25	5	8	1
19/01/2017	13:37		3	SSW	1	1	1	0.25	5	8	1
19/01/2017	14:07		2	SSW	1	1	1	0.25	5	8	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
19/01/2017	14:38		1	SSW	1	0.5	0.5	<0.25	5	8	0
25/03/2017	07:51		1	E	1	2	2	0.25	5	1	0
25/03/2017	08:18		2	E	1	2	2	0.25	5	1	0
25/03/2017	08:49		3	E	1	2	2	0.25	5	1	0
25/03/2017	09:07		3	E	1	1	1	0.25	5	1	0
25/03/2017	09:19		4	E	1	1	1	0.25	5	1	0
25/03/2017	09:22		4	E	1	1	2	0.25	5	1	0
25/03/2017	09:25		4	E	1	1	1	0.25	5	1	0
25/03/2017	09:50		5	E	1	2	2	0.5	5	1	0
25/03/2017	10:18		6	E	1	2	2	0.25	5	1	0
25/03/2017	10:41		7	E	1	1	1	0.25	5	1	0
25/03/2017	11:08		8	E	1	1	1	0.25	5	1	0
25/03/2017	11:33		9	E	1	2	2	0.25	5	1	0
25/03/2017	12:06		10	E	1	1	1	0.25	5	1	0
25/03/2017	12:40		11	E	1	0	0	0.25	5	1	0
25/03/2017	13:04		11	E	1	2	2	0.25	5	1	0
25/03/2017	13:13		12	E	1	1	1	0.25	5	1	0
25/03/2017	13:45		13	E	3	2	2	0.25	5	1	0
25/03/2017	14:02		13	E	3	3	3	0.25	5	1	0
02/04/2017		09:44	13	NW	2	1	1	0.5	5	0	0
02/04/2017		09:59	13	NW	2	2	2	0.75	5	0	0
02/04/2017		10:13	12	WNW	2	2	2	0.75	5	1	0
02/04/2017		10:27	12	WNW	2	2	2	0.5	5	1	0
02/04/2017		10:40	12	WNW	2	1	1	0.5	5	1	0
02/04/2017		10:46	11	WNW	2	2	2	0.5	5	1	0
02/04/2017		10:56	11	WNW	2	2	2	0.75	5	0	0
02/04/2017		11:16	10	WNW	1	1	1	0.75	5	1	0
02/04/2017		11:33	10	W	2	2	2	0.5	5	1	0
02/04/2017		12:00	9	W	2	1	1	0.5	5	1	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
02/04/2017		12:26	8	W	2	2	2	0.5	5	1	0
02/04/2017		12:52	7	W	2	1	3	0.5	5	0	0
02/04/2017		13:03	7	W	2	2	2	0.5	5	0	0
02/04/2017		13:19	6	W	2	2	2	0.5	5	0	0
02/04/2017		13:27	6	W	2	3	3	0.5	5	0	0
02/04/2017		13:44	5	W	2	3	3	0.5	5	0	0
02/04/2017		14:02	5	W	2	2	2	0.5	5	0	0
02/04/2017		14:06	4	W	2	2	2	0.5	5	0	0
02/04/2017		14:35	3	W	2	3	3	0.5	5	0	0
02/04/2017		14:54	3	W	2	3	3	0.5	5	0	0
02/04/2017		15:03	2	WSW	2	2	3	0.5	5	1	0
02/04/2017		15:32	1	WSW	2	2	3	0.5	5	1	0
02/04/2017		15:45	1	WSW	2	3	3	0.5	5	1	0
10/05/2017		07:36	1	N	1	0.5	0.5	0.25	5	0	0
10/05/2017		08:02	2	NE	1	1	1	0.25	5	0	0
10/05/2017		08:28	3	NE	1	1	1	0.25	5	0	0
10/05/2017		09:01	4	NE	1	0.5	0.5	0.25	4	0	0
10/05/2017		09:18	4	NE	1	1	2	0.5	4	0	0
10/05/2017		09:21	4	NE	1	1	1	0.25	4	0	0
10/05/2017		09:22	4	NE	1	1	2	0.25	4	0	0
10/05/2017		09:24	4	NE	1	1	1	0.25	4	0	0
10/05/2017		09:37	5	SW	2	2	2	0.25	5	1	0
10/05/2017		09:42	5	SW	2	1	1	0.25	5	1	0
10/05/2017		09:48	5	SW	1	0.5	0.5	0.25	4	1	0
10/05/2017		10:03	6	SW	1	0	0	0	4	0	0
10/05/2017		10:10	6	SW	1	1	1	0.25	5	0	0
10/05/2017		10:28	7	SW	2	2	2	0.5	5	0	0
10/05/2017		11:02	8	SW	1	1	1	0.25	5	0	0
10/05/2017		11:12	8	SW	2	2	2	0.25	5	0	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
10/05/2017		11:33	9	SW	2	2	2	0.25	5	0	0
10/05/2017		11:38	9	SW	2	2	3	0.5	5	0	0
10/05/2017		11:42	9	SW	2	2	2	0.25	5	0	0
10/05/2017		12:06	10	SW	2	2	2	0.25	5	0	0
10/05/2017		12:22	10	SW	1	1	1	0.25	5	0	0
10/05/2017		12:30	10	SW	1	1	3	0.5	5	0	0
10/05/2017		12:31	10	SW	1	1	1	0.25	5	0	0
10/05/2017		12:40	11	SW	1	1	1	0.25	5	0	0
10/05/2017		12:55	11	SW	1	2	2	0.25	5	0	0
10/05/2017		13:14	12	SW	1	1	1	0.25	5	0	0
10/05/2017		13:47	13	SW	1	0.5	0.5	0.25	5	0	0
10/05/2017		14:00	13	SW	1	1	1	0.25	5	0	0
24/05/2017		08:22	1	SW	2	2	2	0.25	3	8	0
24/05/2017		08:30	1	SW	2	1	1	0.25	3	8	0
24/05/2017		08:37	1	SW	2	1	1	0.25	3	8	0
24/05/2017		08:49	2	S	2	2	2	0.25	2	8	0
24/05/2017		09:03	2	S	2	1	2	0.25	2	8	0
24/05/2017		09:06	2	SW	2	2	2	0.5	3	8	0
24/05/2017		09:08	2	SW	2	2	2	0.25	3	8	0
24/05/2017		09:15	3	SW	2	2	3	0.25	4	8	0
24/05/2017		09:19	3	SW	2	2	3	0.25	2	8	0
24/05/2017		09:24	3	S	2	1	1	0.25	2	8	0
24/05/2017		09:30	3	SW	2	1	1	0.25	2	8	0
24/05/2017		09:43	4	SW	2	1	1	0.25	2	8	0
24/05/2017		09:52	4	SW	2	1	3	0.25	2	8	0
24/05/2017		09:57	4	SW	2	1	3	0.25	2	8	0
24/05/2017		10:02	4	SW	2	1	4	0.5	2	8	0
24/05/2017		10:08	4	SW	2	1	1	0.25	2	8	0
24/05/2017		11:23	13	S	2	2	2	0.25	2	8	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
24/05/2017		11:37	13	S	2	3	3	0.25	2	8	0
24/05/2017		11:50	13	S	2	3	3	0.5	2	8	0
24/05/2017		11:55	12	SSW	3	3	3	0.25	2	8	0
24/05/2017		12:10	12	SSW	3	3	3	0.25	2	8	0
24/05/2017		12:23	12	S	2	2	2	0.25	2	8	0
24/05/2017		12:28	11	S	3	2	2	0.25	2	8	0
24/05/2017		12:41	11	S	3	2	3	0.25	2	8	0
24/05/2017		12:43	11	S	3	2	3	0.25	2	8	0
24/05/2017		12:47	11	S	3	3	3	0.25	2	8	0
24/05/2017		12:59	11	S	3	4	4	0.5	2	8	0
24/05/2017		13:04	10	SW	3	3	3	0.5	3	8	0
24/05/2017		13:12	10	SW	3	3	3	0.5	4	8	0
24/05/2017		13:22	10	S	3	2	3	0.25	4	8	0
24/05/2017		13:26	10	S	3	2	2	0.25	4	8	0
24/05/2017		13:40	9	S	3	2	2	0.25	4	8	0
24/05/2017		13:43	9	S	3	3	4	0.5	4	8	0
24/05/2017		13:44	9	S	3	3	3	0.25	4	8	0
24/05/2017		13:56	9	S	3	4	4	0.5	4	8	0
24/05/2017		14:08	8	S	3	4	4	0.5	4	8	0
24/05/2017		14:22	8	S	3	4	4	0.5	4	8	0
24/05/2017		14:23	8	S	3	4	4	0.5	4	8	0
24/05/2017		14:27	8	S	3	2	2	0.25	4	8	0
24/05/2017		14:33	7	SW	3	2	2	0.25	4	7	0
24/05/2017		14:49	7	SW	3	3	3	0.5	4	8	0
24/05/2017		14:58	6	SW	3	3	3	0.5	4	8	0
24/05/2017		15:13	6	SW	3	3	3	0.5	4	8	0
24/05/2017		15:20	5	SW	3	3	3	0.25	4	8	0
24/05/2017		15:35	5	SW	3	3	3	0.25	4	8	0
24/05/2017		15:37	5	SW	3	4	4	0.5	4	8	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
18/07/2017		11:33	13	SE	1	0	0	<0.25	5	6	0
18/07/2017		11:48	13	SE	1	1	1	<0.25	5	6	0
18/07/2017		12:03	12	None	0	0	0	<0.25	5	6	0
18/07/2017		12:25	12	SE	1	1	1	<0.25	5	6	0
18/07/2017		12:37	11	E	1	1	1	<0.25	5	5	0
18/07/2017		12:54	11	E	1	1	1	<0.25	5	5	0
18/07/2017		13:12	10	SE	1	1	1	<0.25	5	5	0
18/07/2017		13:27	10	SE	1	1	1	<0.25	5	5	0
18/07/2017		13:40	10	NE	1	1	1	<0.25	5	5	0
18/07/2017		13:46	9	NE	1	1	1	<0.25	5	5	0
18/07/2017		13:59	9	SE	1	1	1	<0.25	5	5	0
18/07/2017		14:11	9	NE	1	1	2	<0.25	5	5	0
18/07/2017		14:13	9	NE	1	1	1	<0.25	5	5	0
18/07/2017		14:26	8	E	1	1	1	<0.25	5	4	0
18/07/2017		14:38	8	None	0	0	0	<0.25	5	4	0
18/07/2017		14:45	8	None	0	0	0	<0.25	5	4	0
18/07/2017		14:52	7	N	1	1	1	<0.25	5	4	0
18/07/2017		15:00	7	None	0	0	0	<0.25	5	4	0
18/07/2017		15:06	7	None	0	0	0	<0.25	5	4	0
18/07/2017		15:10	7	None	0	0	1	<0.25	5	4	0
18/07/2017		15:24	6	NE	2	1	1	<0.25	5	3	0
18/07/2017		15:39	6	N	2	1	1	<0.25	5	3	0
18/07/2017		15:45	5	N	2	2	2	0.5	5	3	0
18/07/2017		16:02	5	N	3	1	2	<0.25	5	3	0
18/07/2017		16:03	5	N	2	1	1	<0.25	5	3	0
18/07/2017		16:17	4	N	2	1	2	0.5	5	3	0
18/07/2017		16:21	4	E	2	1	2	<0.25	5	3	0
18/07/2017		16:24	4	E	1	1	1	<0.25	5	3	0
18/07/2017		16:27	4	NE	2	2	2	<0.25	5	3	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
18/07/2017		16:41	4	NE	2	2	2	0.5	5	3	0
18/07/2017		16:47	3	N	3	2	2	0.5	5	4	0
18/07/2017		16:57	3	N	2	1	1	<0.25	5	5	0
18/07/2017		17:02	3	N	2	1	1	<0.25	5	5	0
18/07/2017		17:10	3	SE	3	2	2	<0.25	5	6	0
18/07/2017		17:21	2	ESE	3	2	2	<0.25	5	7	0
18/07/2017		17:36	2	E	1	1	1	<0.25	5	7	0
18/07/2017		17:44	2	NE	2	2	2	0.5	5	7	0
18/07/2017		17:50	1	NE	2	2	2	0.5	5	7	0
18/07/2017		17:59	1	NE	2	1	1	0.5	5	7	0
18/07/2017		18:04	1	E	3	2	2	0.5	5	7	0
31/08/2017		11:48	13	NW	2	2	2	0.3	5	2	0
31/08/2017		12:18	12	NW	2	2	2	0.5	5	4	0
31/08/2017		12:48	11	NW	2	2	2	0.5	5	4	0
31/08/2017		13:21	10	NW	2	2	2	0.5	5	3	0
31/08/2017		14:02	9	NW	2	2	2	0.5	5	1	0
31/08/2017		14:27	8	NW	2	2	2	0.5	5	2	0
31/08/2017		14:51	7	NW	2	2	2	0.5	5	2	0
31/08/2017		15:13	6	NW	2	2	2	0.5	5	2	0
31/08/2017		15:21	6	NW	3	3	2	0.5	5	2	0
31/08/2017		15:35	5	NW	3	3	4	0.5	5	2	0
31/08/2017		15:40	5	NW	3	3	3	0.5	5	2	0
31/08/2017		15:58	4	NW	2	2	2	0.5	5	4	0
31/08/2017		16:13	4	NW	2	2	3	0.5	5	4	0
31/08/2017		16:18	4	NW	2	2	2	0.3	5	3	0
31/08/2017		16:25	3	NW	2	2	3	0.3	5	3	0
31/08/2017		16:55	2	NW	2	2	2	0.3	5	2	0
31/08/2017		17:23	1	NW	2	2	2	0.4	5	1	0
26/09/2017		09:01	13	SSE	3	2	2	0.25	5	8	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
26/09/2017		09:16	13	SSE	2	2	2	0.25	5	8	0
26/09/2017		09:31	12	S	2	2	2	0.25	5	8	0
26/09/2017		09:49	12	S	2	2	2	0.5	5	8	0
26/09/2017		10:04	11	S	2	2	2	0.5	5	8	0
26/09/2017		10:22	11	S	2	2	2	0.25	5	8	0
26/09/2017		10:34	11	S	2	1	1	0.25	5	8	0
26/09/2017		10:38	10	SSW	2	1	1	0.25	5	8	0
26/09/2017		10:42	10	SSW	2	2	2	0.25	5	8	0
26/09/2017		10:52	10	SW	2	2	2	0.5	5	8	0
26/09/2017		11:07	9	S	2	2	2	0.5	5	8	0
26/09/2017		11:24	9	S	2	2	2	0.5	5	8	0
26/09/2017		11:29	9	S	2	2	3	0.5	5	8	0
26/09/2017		11:33	8	SW	2	2	3	0.5	5	8	0
26/09/2017		11:39	8	SW	2	2	2	0.25	5	8	0
26/09/2017		11:56	7	S	2	2	2	0.5	5	8	0
26/09/2017		12:08	7	SW	2	2	3	0.25	5	7	0
26/09/2017		12:15	7	SW	2	2	1	0.25	5	7	0
26/09/2017		12:17	7	SW	2	2	2	0.25	5	7	0
26/09/2017		12:23	6	SW	2	2	2	0.5	5	7	0
26/09/2017		12:34	6	SW	2	1	1	0.25	5	7	0
26/09/2017		12:45	5	SE	2	2	2	0.25	5	6	0
26/09/2017		12:54	5	S	2	2	2	0.25	5	6	0
26/09/2017		13:12	4	S	2	1	1	0.25	5	7	0
26/09/2017		13:14	4	S	2	2	3	0.25	5	7	0
26/09/2017		13:17	4	S	2	1	1	0.25	5	7	0
26/09/2017		13:27	4	S	2	2	2	0.25	5	7	0
26/09/2017		13:32	4	S	2	1	1	0.25	5	7	0
26/09/2017		13:39	3	SE	2	1	1	0.25	5	7	0
26/09/2017		13:51	3	SE	2	1	1	0.25	5	7	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
26/09/2017		13:55	3	SE	2	1	2	0.25	5	7	0
26/09/2017		13:56	3	SE	2	1	1	0.25	5	7	0
26/09/2017		14:05	2	SE	2	1	1	0.25	5	7	0
26/09/2017		14:19	2	SE	2	1	1	0.25	5	7	0
26/09/2017		14:31	1	SE	2	1	1	0.25	5	7	0
26/09/2017		14:43	1	SE	2	1	1	0.25	5	7	0
26/09/2017		14:47	1	SE	2	2	2	0.25	5	7	0
02/11/2017	09:10		1	NNW	3	2	2	0.4	5	8	0
02/11/2017	09:30		1	NNW	3	2	2	0.4	5	8	0
02/11/2017	09:34		2	NNW	3	2	2	0.4	5	8	0
02/11/2017	09:40		2	NNW	3	3	3	0.4	5	8	0
02/11/2017	09:46		2	NNW	3	2	2	0.4	5	8	0
02/11/2017	10:02		2	NNW	3	2	2	0.4	5	8	0
02/11/2017	10:06		3	NW	3	3	3	0.4	5	8	0
02/11/2017	10:22		3	NW	2	2	2	0.4	5	8	0
02/11/2017	10:29		3	NW	2	2	2	0.4	5	8	0
02/11/2017	10:31		4	NW	2	2	2	0.4	5	8	0
02/11/2017	10:53		4	NW	2	2	2	0.4	5	8	0
02/11/2017	10:56		5	NW	2	3	3	0.5	5	8	0
02/11/2017	11:12		5	NW	2	3	3	0.5	5	8	0
02/11/2017	11:15		6	NW	2	2	2	0.5	5	8	0
02/11/2017	11:31		6	NW	2	3	3	0.4	5	8	0
02/11/2017	11:33		6	NW	2	3	3	0.4	5	8	0
02/11/2017	11:37		7	NW	2	3	3	0.4	5	8	0
02/11/2017	11:59		7	NW	2	3	3	0.4	5	8	0
02/11/2017	12:01		8	NW	2	2	2	0.3	5	7	0
02/11/2017	12:23		8	NW	2	2	2	0.3	5	7	0
02/11/2017	12:27		9	NW	2	2	2	0.3	5	7	0
02/11/2017	12:51		9	NW	2	2	2	0.3	5	7	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
02/11/2017	12:53		10	NW	2	2	2	0.3	5	7	0
02/11/2017	13:23		10	NW	2	2	2	0.3	5	7	0
02/11/2017	13:26		11	NW	2	2	2	0.3	5	6	0
02/11/2017	13:56		11	NW	2	2	2	0.3	5	6	0
02/11/2017	13:59		12	NW	2	2	2	0.3	5	7	0
02/11/2017	14:26		12	NW	2	2	2	0.3	5	7	0
02/11/2017	14:31		13	WNW	2	1	1	0.25	5	8	0
02/11/2017	15:00		13	WNW	2	1	1	0.25	5	8	0
22/12/2017	09:06		13	W	2	2	2	0.25	1	8	0
22/12/2017	09:34		13	W	2	2	2	0.25	1	8	0
22/12/2017	09:40		12	W	2	2	2	0.25	1	8	0
22/12/2017	09:55		12	W	2	2	2	0.25	2	8	0
22/12/2017	10:10		12	W	2	2	2	0.25	2	8	0
22/12/2017	10:13		11	W	2	2	2	0.25	2	8	0
22/12/2017	10:21		11	W	2	2	2	0.25	1	8	0
22/12/2017	10:33		11	W	2	2	2	0.25	2	8	0
22/12/2017	10:46		11	W	2	2	2	0.25	2	8	0
22/12/2017	10:49		10	W	2	2	2	0.4	3	8	0
22/12/2017	11:10		10	W	2	2	2	0.5	2	8	0
22/12/2017	11:19		10	W	2	2	2	0.5	2	8	0
22/12/2017	11:22		9	W	2	2	2	0.4	3	8	0
22/12/2017	11:45		9	W	2	2	2	0.4	3	8	0
22/12/2017	11:48		8	W	2	2	2	0.7	4	8	0
22/12/2017	12:00		8	W	2	2	2	0.7	4	8	0
22/12/2017	12:13		7	E	2	2	2	0.5	4	8	0
22/12/2017	12:37		7	E	2	2	2	0.5	4	8	0
22/12/2017	12:44		6	W	2	2	2	0.7	3	8	0
22/12/2017	13:02		6	W	2	2	2	0.7	3	8	0
22/12/2017	13:05		5	W	2	2	2	0.5	3	7	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
22/12/2017	13:26		5	W	2	2	2	0.5	3	7	0
22/12/2017	13:37		4	W	2	2	2	0.5	3	7	0
22/12/2017	14:04		4	W	2	2	2	0.5	3	7	0
22/12/2017	14:08		3	W	2	2	2	0.3	4	8	0
22/12/2017	14:36		3	W	2	2	2	0.3	4	8	0
22/12/2017	14:40		2	W	2	2	2	0.5	4	8	0
22/12/2017	15:03		2	W	2	2	2	0.5	4	8	0
22/12/2017	15:07		1	WSW	2	2	2	0.5	4	8	0
22/12/2017	15:30		1	WSW	2	2	2	0.5	4	8	0
10/01/2018	09:31		13	SW	1	2	2	0.75	5	1	0
10/01/2018	10:00		12	SW	1	2	2	0.75	5	1	0
10/01/2018	10:35		11	SW	1	2	2	0.5	5	1	0
10/01/2018	11:08		10	S	1	2	2	0.5	5	0	0
10/01/2018	11:12		10	S	1	2	3	0.5	5	0	0
10/01/2018	11:14		10	S	2	2	2	0.5	5	0	0
10/01/2018	11:42		9	S	2	2	2	0.5	5	1	0
10/01/2018	12:01		9	S	2	2	3	0.5	5	1	0
10/01/2018	12:04		9	S	2	2	4	0.75	5	1	0
10/01/2018	12:09		8	S	2	2	2	0.5	5	1	0
10/01/2018	12:34		7	SW	2	2	2	0.75	5	1	0
10/01/2018	12:59		6	SW	2	2	3	0.75	5	0	0
10/01/2018	13:01		6	SW	2	2	2	0.5	5	0	0
10/01/2018	13:22		5	SW	2	2	2	0.5	5	1	0
10/01/2018	13:39		5	SW	2	2	4	0.5	5	0	0
10/01/2018	13:45		4	SW	2	2	3	0.5	5	0	0
10/01/2018	13:48		4	SW	1	2	2	0.5	5	0	0
10/01/2018	14:12		3	SW	1	2	2	0.5	5	1	0
10/01/2018	14:25		3	SW	1	1	1	0.5	5	3	0
10/01/2018	14:40		2	SW	1	1	1	0.25	5	2	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
10/01/2018	15:12		1	S	1	1	1	0.25	5	2	0
05/02/2018	09:13		1	ESE	2	1	1	0.25	5	7	0
05/02/2018	09:38		2	ESE	1	1	1	0.25	5	7	0
05/02/2018	10:09		3	SE	2	2	2	0.25	5	7	0
05/02/2018	10:14		3	SE	1	1	1	0.25	5	7	0
05/02/2018	10:36		4	SE	1	1	1	0.25	5	7	0
05/02/2018	11:09		5	SE	1	1	1	0.25	5	7	0
05/02/2018	11:33		6	SE	1	1	1	0.25	5	8	0
05/02/2018	11:51		6	SE	1	2	2	0.25	5	8	0
05/02/2018	11:58		7	SE	1	2	2	0.25	5	8	0
05/02/2018	12:10		7	SE	1	1	1	0.25	5	8	0
05/02/2018	12:26		8	SE	1	1	1	0.25	5	8	0
05/02/2018	12:52		9	SE	2	2	2	0.25	5	8	0
05/02/2018	13:25		10	SE	2	2	2	0.25	5	8	0
05/02/2018	13:58		11	SE	2	2	2	0.25	5	8	0
05/02/2018	14:08		11	SE	1	1	1	0.25	5	8	0
05/02/2018	14:31		12	SE	2	2	2	0.25	5	8	0
05/02/2018	15:02		13	SE	2	2	2	0.25	5	8	0
21/02/2018	09:47		1	E	2	2	2	0.25	5	1	0
21/02/2018	10:04		1	E	2	2	2	0.25	5	1	0
21/02/2018	10:11		2	E	2	2	2	0.25	5	1	0
21/02/2018	10:22		2	E	2	1	1	0.25	5	1	0
21/02/2018	10:38		3	E	2	2	2	0.25	5	1	0
21/02/2018	10:55		3	E	2	1	1	0.25	5	1	0
21/02/2018	11:07		4	E	2	1	1	0.25	5	2	0
21/02/2018	11:16		4	E	2	1	2	0.25	5	3	0
21/02/2018	11:26		4	E	2	1	1	0.25	5	3	0
21/02/2018	11:43		5	E	2	1	2	0.25	5	7	0
21/02/2018	11:46		5	E	2	1	1	0.25	5	7	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
21/02/2018	11:55		5	E	1	1	1	0.25	5	7	0
21/02/2018	12:07		6	E	1	1	1	0.25	5	7	0
21/02/2018	12:19		6	E	1	1	1	0.25	5	7	0
21/02/2018	12:29		7	E	1	1	1	0.25	5	7	0
21/02/2018	12:41		7	E	1	1	1	0.25	5	7	0
21/02/2018	12:57		8	E	1	0	0	0.25	5	7	0
21/02/2018	13:09		8	E	1	0	0	0.25	5	7	0
21/02/2018	13:23		9	NE	1	0	0	0.25	5	7	0
21/02/2018	13:37		9	NE	1	0	0	0.25	5	7	0
21/02/2018	13:50		10	None	0	0	0	0.25	5	7	0
21/02/2018	14:06		10	None	0	0	0	0.25	5	7	0
21/02/2018	14:11		10	E	1	1	1	0.25	5	7	0
21/02/2018	14:23		11	E	1	1	1	0.25	5	7	0
21/02/2018	14:37		11	None	0	0	0	0.25	5	7	0
21/02/2018	14:55		12	None	0	0	0	0.25	5	7	0
21/02/2018	15:04		12	ESE	1	1	1	0.25	5	7	0
21/02/2018	15:13		12	ESE	1	1	1	0.25	5	7	0
21/02/2018	15:28		13	ESE	1	1	1	0.25	5	7	0
21/02/2018	15:40		13	ESE	1	1	1	0.25	5	7	0
24/03/2018	08:40		13	NE	2	2	2	0.3	4	8	0
24/03/2018	09:01		13	NE	2	2	2	0.3	4	8	1
24/03/2018	09:10		12	NE	2	2	2	0.3	5	8	0
24/03/2018	09:20		12	NE	2	2	2	0.3	5	8	0
24/03/2018	09:43		11	NE	2	1	1	0.2	5	8	0
24/03/2018	09:49		11	NE	2	2	2	0.3	5	8	0
24/03/2018	10:02		11	NE	2	2	2	0.3	5	8	0
24/03/2018	10:10		11	NE	2	2	2	0.2	3	7	0
24/03/2018	10:17		10	N	2	2	2	0.3	5	8	0
24/03/2018	10:21		10	N	2	3	3	0.5	5	8	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
24/03/2018	10:35		10	N	2	2	2	0.3	5	4	0
24/03/2018	10:48		9	NNW	2	2	2	0.3	5	2	0
24/03/2018	11:15		8	NNW	2	2	2	0.3	5	3	0
24/03/2018	11:38		7	NNW	2	2	2	0.3	5	2	0
24/03/2018	11:57		7	NNW	2	3	3	0.5	5	2	0
24/03/2018	11:59		7	NNW	2	1	1	0.3	5	2	0
24/03/2018	12:06		6	NNW	2	3	3	0.5	5	2	0
24/03/2018	12:17		6	NNW	2	2	2	0.3	5	1	0
24/03/2018	12:28		5	NNW	2	2	2	0.3	5	1	0
24/03/2018	12:41		5	NNW	2	3	3	0.5	5	1	0
24/03/2018	12:46		5	NNW	2	2	2	0.3	5	1	0
24/03/2018	12:58		4	NNW	2	3	3	0.3	5	1	0
24/03/2018	13:00		4	NNW	2	4	4	0.5	5	1	0
24/03/2018	13:03		4	NNW	2	3	3	0.3	5	1	0
24/03/2018	13:13		4	NNW	3	3	3	0.3	5	1	0
24/03/2018	13:25		3	NNW	2	3	3	0.3	5	1	0
24/03/2018	13:45		3	NW	2	2	2	0.2	5	2	0
24/03/2018	13:54		2	NW	2	2	2	0.2	5	0	0
24/03/2018	14:07		2	NW	3	3	3	0.5	5	0	0
24/03/2018	14:22		1	NW	3	3	3	0.5	5	1	0
24/03/2018	14:33		1	NW	2	2	2	0.3	5	1	0
08/04/2018		10:58	13	S	2	2	2	0.75	5	8	0
08/04/2018		11:21	13	S	2	2	2	0.5	5	8	0
08/04/2018		11:23	13	S	2	2	2	0.5	5	8	0
08/04/2018		11:27	12	S	2	2	2	0.75	5	8	0
08/04/2018		11:43	12	SSE	2	2	2	0.75	5	7	0
08/04/2018		11:58	12	SSE	2	2	2	0.75	5	7	0
08/04/2018		11:57	11	SSE	2	2	2	0.75	5	4	0
08/04/2018		12:12	11	SSE	2	2	2	0.5	5	2	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
08/04/2018		12:28	11	SSE	2	2	2	0.5	5	2	0
08/04/2018		12:31	10	SSE	1	1	1	0.5	5	1	0
08/04/2018		12:55	10	SSE	1	1	1	0.5	5	1	0
08/04/2018		12:59	10	SSE	1	1	1	0.5	5	1	0
08/04/2018		13:01	9	SSE	1	2	2	0.5	5	2	0
08/04/2018		13:14	9	SE	1	1	1	0.5	5	2	0
08/04/2018		13:24	9	SE	1	1	1	0.5	5	2	0
08/04/2018		13:28	8	SE	1	1	1	0.5	5	2	0
08/04/2018		13:44	8	SE	1	1	1	0.5	5	2	0
08/04/2018		13:48	8	SE	1	1	1	0.5	5	2	0
08/04/2018		13:51	7	SE	1	1	1	0.5	5	1	0
08/04/2018		14:03	7	SE	1	1	1	0.25	5	1	0
08/04/2018		14:08	7	SE	1	1	2	0.25	5	1	0
08/04/2018		14:13	7	SE	1	1	2	0.25	5	1	0
08/04/2018		14:19	6	SE	2	2	2	0.25	5	1	0
08/04/2018		14:33	6	SE	2	2	2	0.25	5	1	0
08/04/2018		14:35	6	SE	2	2	2	0.25	5	1	0
08/04/2018		14:38	5	SE	2	2	2	0.25	5	1	0
08/04/2018		14:46	5	SE	2	2	2	0.25	5	1	0
08/04/2018		14:56	5	SE	2	2	2	0.25	5	1	0
08/04/2018		15:04	4	SE	2	2	2	0.25	5	1	0
08/04/2018		15:26	4	SE	2	2	2	0.25	5	1	0
08/04/2018		15:29	3	SE	1	1	1	0.25	5	0	0
08/04/2018		15:52	3	SE	1	1	1	0.25	5	0	0
08/04/2018		15:55	2	SE	1	1	1	0.25	5	0	0
08/04/2018		16:08	2	SE	1	1	1	0.25	5	0	0
08/04/2018		16:18	2	SE	1	1	1	0.25	5	0	0
08/04/2018		16:21	1	SE	1	1	1	0.25	5	0	0
08/04/2018		16:30	1	SE	1	1	1	0.25	5	0	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
08/04/2018		16:40	1	SE	1	1	1	0.25	5	0	0
18/05/2018		07:25	13	SE	1	1	1	0.2	4	1	0
18/05/2018		07:52	12	SE	1	1	1	0.2	4	1	0
18/05/2018		08:21	11	SE	1	1	1	0.2	4	1	0
18/05/2018		08:48	11	S	1	1	1	0	4	1	0
18/05/2018		08:55	10	SW	1	1	1	0	4	3	0
18/05/2018		09:16	10	SW	2	2	2	0.2	4	3	0
18/05/2018		09:23	9	SW	2	2	2	0.2	4	4	0
18/05/2018		09:50	8	SW	2	2	2	0.2	4	4	0
18/05/2018		10:15	7	SW	2	2	2	0.2	4	2	0
18/05/2018		10:40	6	SW	2	2	2	0.2	4	2	0
18/05/2018		11:00	5	SW	2	2	2	0.2	4	2	0
18/05/2018		11:27	4	SW	2	2	2	0.2	4	5	0
18/05/2018		11:53	3	SW	2	2	2	0.2	4	5	0
18/05/2018		12:21	2	SW	2	2	2	0.3	4	7	0
18/05/2018		12:48	1	SW	2	2	2	0.2	4	7	0
31/05/2018		07:46	13	E	1	0	0	0.1	3	8	0
31/05/2018		08:15	12	E	1	0	0	0.1	3	8	0
31/05/2018		08:45	11	NE	1	0	0	0.1	4	8	0
31/05/2018		09:18	10	NE	1	0	0	0.1	4	8	0
31/05/2018		09:46	9	E	1	0	0	0.1	4	7	0
31/05/2018		10:09	9	E	1	0	2	0.1	4	7	0
31/05/2018		10:14	8	E	1	0	2	0.1	4	8	0
31/05/2018		10:17	8	E	1	0	0	0.1	4	8	0
31/05/2018		10:36	7	E	1	0	0	0.1	4	7	0
31/05/2018		10:48	7	E	1	0	0	0.1	3	7	0
31/05/2018		10:53	7	E	1	0	1	0.3	2	7	0
31/05/2018		11:03	6	E	1	0	1	0.3	3	8	0
31/05/2018		11:08	6	E	1	0	0	0.1	3	8	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
31/05/2018		11:16	6	E	1	0	0	0.1	4	8	0
31/05/2018		11:22	5	E	1	0	0	0.1	4	8	0
31/05/2018		11:30	5	E	1	0	0	0.2	3	8	0
31/05/2018		11:34	5	E	1	0	1	0.2	3	8	0
31/05/2018		11:49	4	NE	1	1	1	0.2	4	7	0
31/05/2018		11:50	4	NE	1	1	2	0.3	4	7	0
31/05/2018		11:55	4	NE	1	1	1	0.3	4	7	0
31/05/2018		12:01	4	NE	1	0	0	0.3	3	7	0
31/05/2018		12:15	3	NE	1	0	0	0.2	3	7	0
31/05/2018		12:31	3	NE	1	0	2	0.2	4	7	0
31/05/2018		12:36	3	NE	1	1	0	0.2	4	7	0
31/05/2018		12:44	2	N	1	1	1	0.1	3	7	0
31/05/2018		12:51	2	N	1	0	0	0.1	4	7	0
31/05/2018		13:07	1	NE	1	0	0	0.1	4	7	0
24/06/2018		11:09	1	SSW	1	1	1	0	4	1	0
24/06/2018		11:34	2	SW	1	1	1	0	4	1	0
24/06/2018		11:56	3	SW	1	1	1	0	4	1	0
24/06/2018		12:26	4	SW	2	2	2	0	4	0	0
24/06/2018		12:31	4	SW	1	1	1	0	4	0	0
24/06/2018		12:42	4	SW	1	0.5	0.5	0	4	0	0
24/06/2018		12:51	5	SW	1	1	1	0	4	0	0
24/06/2018		13:10	5	SW	1	1	1	0	4	0	0
24/06/2018		13:14	6	SW	1	1	1	0	4	0	0
24/06/2018		13:29	6	SW	1	1	1	0	4	0	0
24/06/2018		13:32	7	SW	1	1	1	0	4	0	0
24/06/2018		13:53	7	SW	1	1	1	0	4	0	0
24/06/2018		13:56	8	SW	1	1	1	0	4	0	0
24/06/2018		14:16	8	SW	1	1	1	0	4	0	0
24/06/2018		14:18	9	SW	1	1	1	0	4	0	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
24/06/2018		14:41	9	SW	1	1	1	0	4	0	0
24/06/2018		14:47	10	SW	1	1	1	0	4	0	0
24/06/2018		15:12	10	SW	1	1	1	0	4	0	0
24/06/2018		15:15	11	SW	1	0	0	0	4	0	0
24/06/2018		15:50	12	S	1	0	0	0	4	0	0
24/06/2018		16:20	13	S	1	0	0	0	4	0	0
19/07/2018		08:20	13	SW	1	1	1	0.25	5	4	0
19/07/2018		08:47	12	SW	1	0	0	0.25	5	4	0
19/07/2018		09:14	11	SW	1	1	1	0.25	5	4	0
19/07/2018		09:22	11	SW	1	0	0	0.25	5	6	0
19/07/2018		09:50	10	SW	1	1	1	0.25	5	4	0
19/07/2018		10:18	9	None	0	0	0	0.25	5	6	0
19/07/2018		10:37	9	None	0	0	1	0.25	5	5	0
19/07/2018		10:41	8	SW	1	1	1	0.25	5	4	0
19/07/2018		11:03	7	SW	2	1	1	0.25	5	2	0
19/07/2018		11:18	7	SW	2	1	1	0.25	3	3	0
19/07/2018		11:30	6	SW	1	1	1	0.25	5	0	0
19/07/2018		11:51	5	SW	1	1	1	0.25	5	1	0
19/07/2018		12:06	5	W	1	1	3	0.75	5	0	0
19/07/2018		12:17	4	W	2	1	1	0.25	5	0	0
19/07/2018		12:47	3	W	2	1	1	0.25	5	0	0
19/07/2018		13:13	2	W	1	1	1	0.25	5	0	0
19/07/2018		13:43	1	SW	1	1	1	0.25	5	1	0
30/08/2018		08:23	13	SE	1	1	1	0.25	5	7	0
30/08/2018		08:38	13	SE	1	0	0	0.25	5	7	0
30/08/2018		08:51	12	SSE	1	0	0	0.25	5	7	0
30/08/2018		09:11	12	SE	1	1	1	0.25	5	6	0
30/08/2018		09:19	11	SSE	1	1	1	0.25	5	7	0
30/08/2018		09:40	11	S	1	0	0	0.25	5	7	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
30/08/2018		09:52	10	S	1	0	0	0.25	5	7	0
30/08/2018		10:11	10	SE	1	1	1	0.25	5	8	0
30/08/2018		10:19	9	SE	2	2	2	0.25	5	8	0
30/08/2018		10:33	9	SE	1	1	1	0.25	5	7	0
30/08/2018		10:45	8	SE	1	2	2	0.25	5	8	0
30/08/2018		11:06	7	SE	1	2	2	0.25	5	8	0
30/08/2018		11:34	6	SE	1	2	2	0.25	5	8	0
30/08/2018		11:54	5	SE	1	2	2	0.25	5	8	0
30/08/2018		12:21	4	NW	2	2	2	0.25	5	8	0
30/08/2018		12:47	3	NW	2	1	1	0.25	5	8	0
30/08/2018		12:54	3	NW	2	2	2	0.25	5	8	0
30/08/2018		13:13	2	NW	2	2	2	0.25	5	8	0
30/08/2018		13:20	2	WNW	1	1	1	0.25	5	8	0
30/08/2018		13:37	1	NW	1	1	1	0.25	5	8	0
15/10/2018		08:46	1	E	3	2	2	0.5	5	4	0
15/10/2018		09:18	2	ENE	3	2	2	0.5	5	4	0
15/10/2018		09:46	3	ENE	3	3	3	0.5	5	4	0
15/10/2018		10:12	4	NE	3	1	1	0.25	5	4	0
15/10/2018		10:14	4	NE	3	1	1	0.25	5	4	0
15/10/2018		10:23	4	NE	3	2	2	0.5	5	4	0
15/10/2018		10:40	5	NE	3	3	3	0.5	5	4	0
15/10/2018		10:53	5	NE	3	3	3	0.25	5	4	0
15/10/2018		10:58	5	NE	3	3	4	0.25	5	4	0
15/10/2018		11:15	6	NE	3	3	3	0.5	5	4	0
15/10/2018		11:31	6	NE	3	3	3	0.5	5	4	0
15/10/2018		12:02	7	NE	4	3	3	0.5	5	1	0
15/10/2018		12:14	7	NE	4	2	2	0.25	5	1	0
15/10/2018		12:39	8	NE	4	2	2	0.5	5	1	0
15/10/2018		12:44	8	NE	4	3	3	0.5	5	1	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
15/10/2018		13:08	9	NE	4	4	4	0.5	5	1	0
15/10/2018		13:22	9	NE	4	2	2	0.5	5	1	0
15/10/2018		13:51	10	NE	4	2	2	0.5	5	1	0
15/10/2018		14:05	10	NE	4	3	3	0.5	5	1	0
15/10/2018		14:11	10	NE	4	4	4	0.5	5	1	0
15/10/2018		14:25	11	NE	4	4	4	0.5	5	1	0
15/10/2018		14:50	11	NE	4	3	3	0.5	5	1	0
15/10/2018		14:58	12	NE	4	3	3	0.5	5	1	0
15/10/2018		15:13	12	NE	4	4	4	0.5	5	1	0
15/10/2018		15:35	13	NE	4	4	4	0.75	5	1	0
30/10/2018	08:30		13	NE	1	1	1	0.2	5	1	0
30/10/2018	08:56		12	NE	1	1	1	0.2	5	1	0
30/10/2018	09:17		12	NNE	2	2	2	0.2	5	1	0
30/10/2018	09:25		11	NNE	2	2	2	0.2	5	1	0
30/10/2018	09:44		11	N	1	1	1	0.2	5	1	0
30/10/2018	09:56		10	N	1	1	1	0.2	5	1	0
30/10/2018	10:05		10	N	2	2	2	0.2	5	1	0
30/10/2018	10:17		10	N	2	3	3	0.2	5	1	0
30/10/2018	10:23		9	N	3	3	3	0.2	5	1	0
30/10/2018	10:41		9	N	2	2	2	0.2	5	2	0
30/10/2018	10:48		8	NW	2	2	2	0.2	5	1	0
30/10/2018	10:57		8	NW	3	3	3	0.3	5	1	0
30/10/2018	11:10		7	NW	3	3	3	0.3	5	2	0
30/10/2018	11:21		7	NW	2	2	2	0.2	5	3	0
30/10/2018	11:38		6	NW	2	2	2	0.2	5	1	0
30/10/2018	11:44		6	NW	3	3	3	0.4	5	1	0
30/10/2018	11:57		5	NW	3	3	3	0.4	5	1	0
30/10/2018	12:23		4	NW	3	2	2	0.2	5	1	0
30/10/2018	12:48		3	NW	3	3	3	0.3	5	2	0

Date	Time GMT	Time BST	Transect	Wind Direction	Wind Force[2]	Sea State	Sightability[3]	Swell (m)	Visibility[4]	Cloud Cover[5]	Rain[6]
30/10/2018	13:14		2	NW	2	2	2	0.3	5	1	0
30/10/2018	13:38		1	NW	2	2	2	0.3	5	1	0

[1] Weather data recorded at the start of each transect or when there was a change in any variable

[2] Wind force using Beaufort Scale: 1=calm, 2=light breeze, 3=moderate breeze, 4=strong breeze, 5=moderate wind, 6=strong wind

[3] Sightability: sea state usually correlates with wind speed. However in areas of strong tidal currents, the mixing of tidal fronts can produce localised areas of choppy water with white caps irrespective of wind strength. This can result in patches of choppy water with white caps in an otherwise calm sea. This column refers to sea state within a 500 m radius of the vessel

[4] Visibility 1=fog (<300 m visibility), 2=poor (visibility 300-500 m), 3=moderate (visibility 500 m-2 km), 4=good (horizon hazy but otherwise good), 5=excellent (horizon clearly visible)

[5] Cloud cover: recorded in oktas

[6] Rain 0=none, 1=drizzle, 2=light shower, 3=heavy shower, 4=persistent rain

B. Herring gull: Density and Abundance Estimates

Table B.1: Herring gull abundance and density (birds/km^2) estimates, together with lower 95% confidence limits (LCL) and upper 95% confidence limits (UCL) derived from Distance sampling.

		Abundance			Density			
Survey	Region	Estimate	LCl	UCL	Estimate	LCL	UCL	%CV
November 2016	Buffer	13	2	79	0.19	0.03	1.22	102.93
	Site	34	11	105	0.97	0.31	3.00	53.35
December	Buffer	38	9	161	0.58	0.14	2.47	75.49
	Site	0	0	0	0.00	0.00	0.00	
January 2017	Buffer	75	13	439	1.16	0.20	6.75	96.94
	Site	45	11	191	1.29	0.31	5.46	70.23
March	Buffer	63	22	179	0.96	0.34	2.74	51.96
	Site	68	16	285	1.94	0.46	8.14	69.83
April	Buffer	63	17	225	0.96	0.27	3.46	65.00
	Site	11	2	79	0.32	0.05	2.26	102.75
May (1)	Buffer	50	11	238	0.77	0.16	3.65	82.30
	Site	11	2	79	0.32	0.05	2.26	102.75
May (2)	Buffer	0	0	0	0.00	0.00	0.00	
	Site	0	0	0	0.00	0.00	0.00	
July	Buffer	213	79	574	3.27	1.22	8.81	48.90
	Site	204	41	1014	5.83	1.17	28.95	79.94
August	Buffer	13	2	82	0.19	0.03	1.26	105.73
	Site	0	0	0	0.00	0.00	0.00	
September	Buffer	0	0	0	0.00	0.00	0.00	
	Site	0	0	0	0.00	0.00	0.00	
November	Buffer	25	6	101	0.38	0.10	1.56	72.03
	Site	11	2	76	0.32	0.05	2.16	99.57
December	Buffer	25	6	103	0.38	0.09	1.58	72.83
	Site	0	0	0	0.00	0.00	0.00	
January 2018	Buffer	13	2	73	0.19	0.03	1.12	96.94
	Site	11	2	80	0.32	0.05	2.28	103.31
February (1)	Buffer	25	4	157	0.38	0.06	2.42	102.34
	Site	0	0	0	0.00	0.00	0.00	
February (2)	Buffer	13	2	71	0.19	0.03	1.09	94.67
	Site	0	0	0	0.00	0.00	0.00	
March 2018	Buffer	13	2	71	0.19	0.03	1.09	94.67
	Site	11	2	75	0.32	0.05	2.13	98.54
April 2018	Buffer	63	18	212	0.96	0.28	3.26	61.53
	Site	91	25	326	2.59	0.72	9.30	61.28
May (1)	Buffer	0	0	0	0.00	0.00	0.00	
	Site	0	0	0	0.00	0.00	0.00	
May (2)	Buffer	25	6	103	0.38	0.09	1.57	72.78
	Site	11	2	80	0.32	0.05	2.28	103.31
June	Buffer	38	9	165	0.58	0.13	2.53	77.12
	Site	57	16	205	1.62	0.45	5.84	61.57
July	Buffer	25	6	102	0.38	0.09	1.57	72.40
	Site	0	0	0	0.00	0.00	0.00	
August	Buffer	0	0	0	0.00	0.00	0.00	
	Site	0	0	0	0.00	0.00	0.00	

Survey	Region	Abundance			Density			%CV
		Estimate	LCI	UCL	Estimate	LCL	UCL	
October (1)	Buffer	0	0	0	0.00	0.00	0.00	
	Site	0	0	0	0.00	0.00	0.00	
October (2)	Buffer	0	0	0	0.00	0.00	0.00	
	Site	11	2	76	0.32	0.05	2.16	99.57

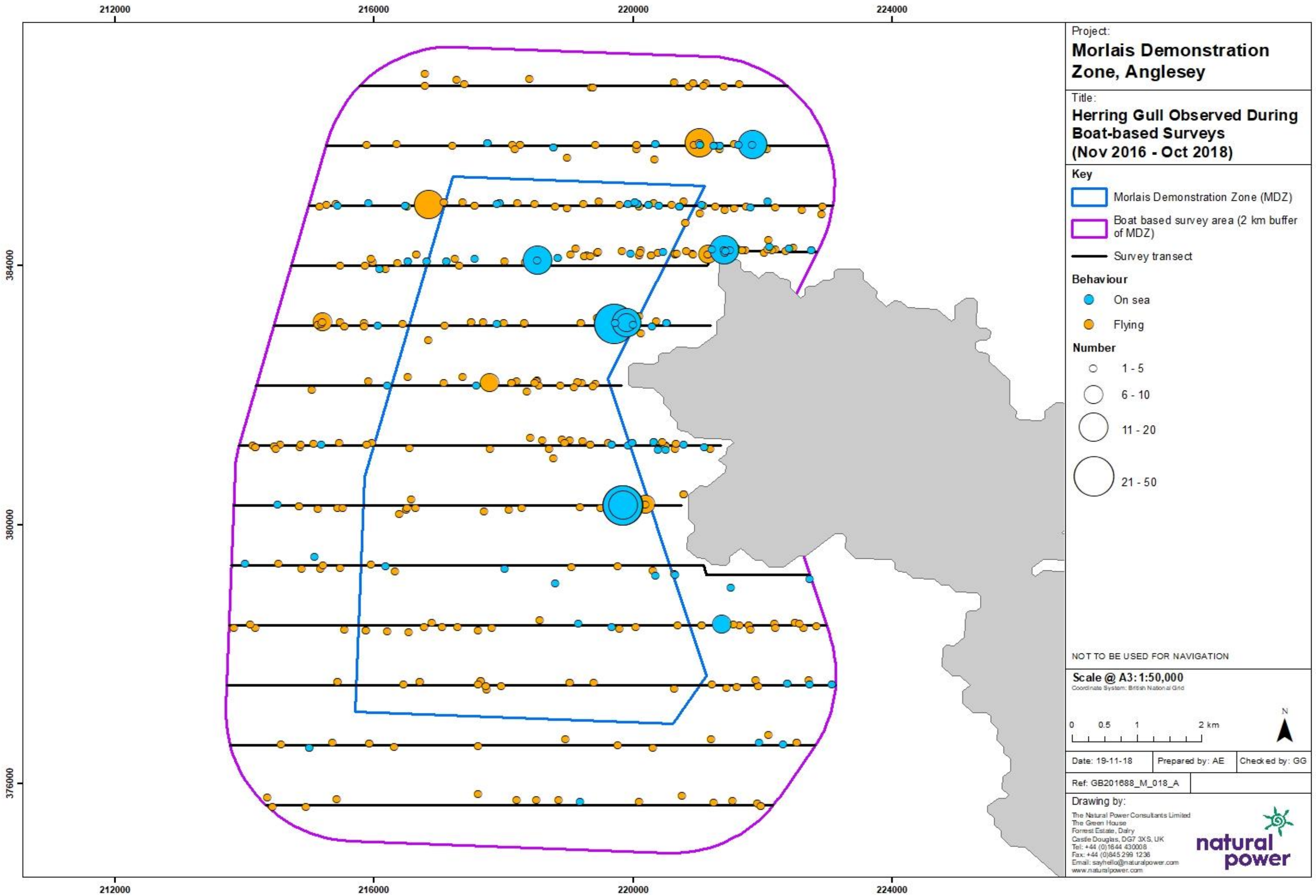

Figure B.1: Distribution of herring gull recorded in flight and on the sea during boat-based surveys (November 2016 to October 2018).

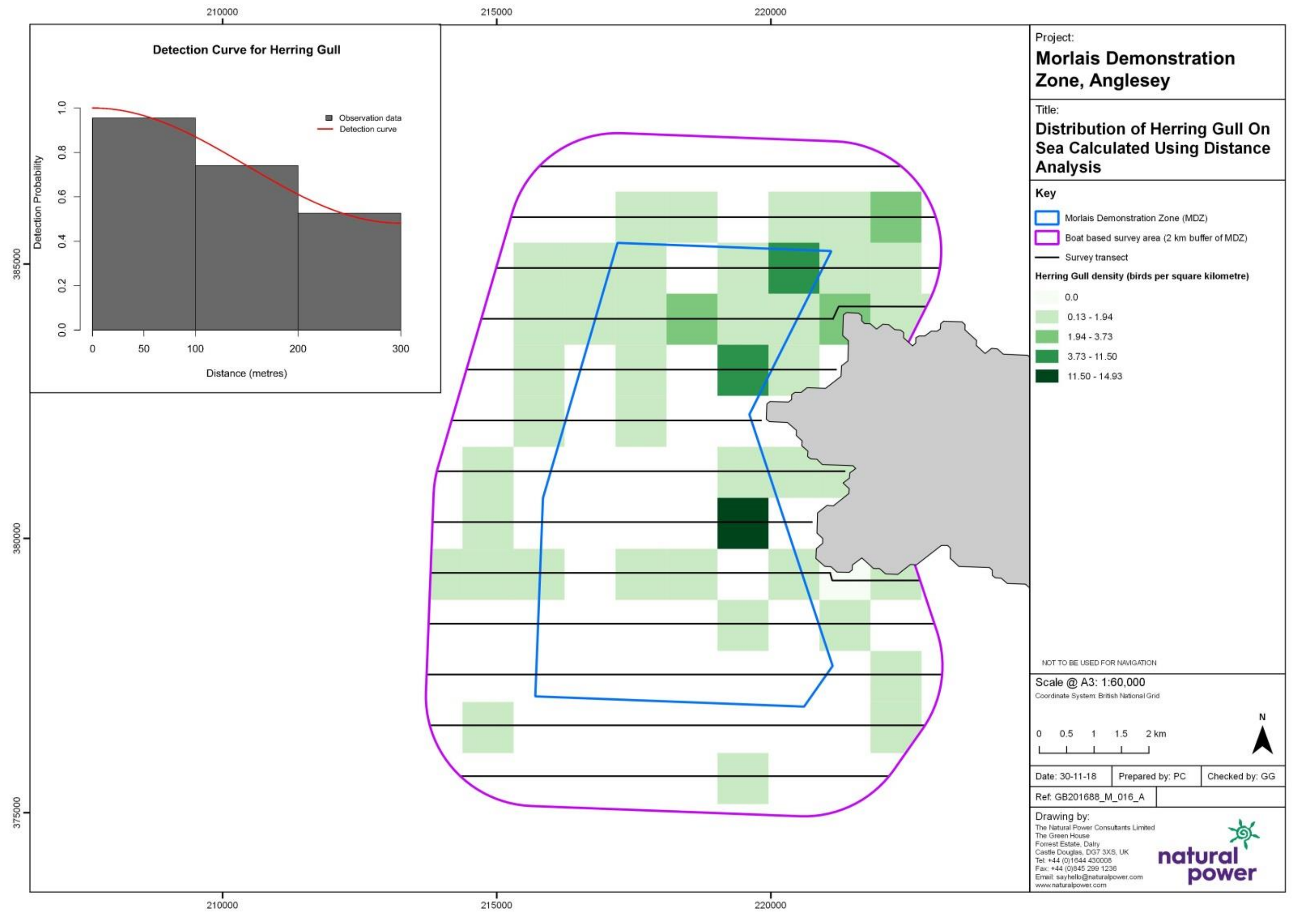

Figure B.2: Density of herring gull calculated using Distance analysis (and associated detection curve)

C. Density and Abundance Estimates

Diving birds on the sea

Number of eiders observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
November 2016	0	0	0	0	0	0
December	0	0	0	0	0	0
January 2017	0	0	0	0	0	0
March	0	0	0	0	0	0
April	0	0	0	0	0	0
May 1	0	0	0	0	0	0
May 2	0	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0	0	0	0	0
September	0	0	0	0	0	0
November	0	0	0	0	0	0
December	0	0	0	0	0	0
January 2018	0	0	0	0	0	0
February 1	0	0	0	0	0	0
February 2	0	0	0	0	0	0
March	0	0	0	0	0	0
April	0	0	0	0	0	0
May 1	0	0	0	0	0	0
May 2	0	0	0	0	0	0
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0	0	0	0	0
October 1	0.03	0.00	0.05	3.27	0.00	3.39
October 2	0	0	0	0	0	0

Number of red-throated diver observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
November 2016	0.00	0.00	0.00	0.00	0.00	0.00
December	0.03	0.00	0.05	3.27	0.00	3.39
January 2017	0.03	0.00	0.05	3.27	0.00	3.39
March	0.10	0.00	0.16	9.82	0.00	10.18
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.03	0.00	0.05	3.27	0.00	3.39
July	0.16	0.09	0.21	16.37	3.07	13.58
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
November	0.03	0.00	0.05	3.27	0.00	3.39
December	0.00	0.00	0.00	0.00	0.00	0.00

Survey	Density of observed individuals Full survey area	Site	Buffer	Indicator of likely abundance Full survey area	Site	Buffer
January 2018	0.00	0.00	0.00	0.00	0.00	0.00
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.00	0.00	0.00	0.00	0.00	0.00
June	0.13	0.35	0.00	13.10	12.29	0.00
July	0.03	0.00	0.05	3.27	0.00	3.39
August	0.00	0.00	0.00	0.00	0.00	0.00
October 1	0.00	0.00	0.00	0.00	0.00	0.00
October 2	0.00	0.00	0.00	0.00	0.00	0.00

Number of Manx shearwater observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals Full survey area	Site	Buffer	Indicator of likely abundance Full survey area	Site	Buffer
November 2016	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2017	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	2.45	1.75	2.87	245.56	61.43	186.71
July	0.23	0.53	0.05	22.92	18.43	3.39
August	0.07	0.00	0.10	6.55	0.00	6.79
September	0.00	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2018	0.00	0.00	0.00	0.00	0.00	0.00
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	1.99	0.61	2.82	199.72	21.50	183.31
June	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00
August	16.68	13.42	18.61	1669.81	469.92	1211.91
October 1	0.00	0.00	0.00	0.00	0.00	0.00
October 2	0.00	0.00	0.00	0.00	0.00	0.00

Number of gannet observed per km^2 per survey, together with extrapolated abundance indicators.

	Density of observed individuals			Indicator of likely abundance		
Survey	Full survey area	Site	Buffer	Full survey area	Site	Buffer
November 2016	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2017	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.03	0.09	0.00	3.27	3.07	0.00
May 2	0.00	0.00	0.00	0.00	0.00	0.00
July	0.20	0.00	0.31	19.64	0.00	20.37
August	0.10	0.18	0.05	9.82	6.14	3.39
September	0.00	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2018	0.00	0.00	0.00	0.00	0.00	0.00
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.07	0.00	0.10	6.55	0.00	6.79
June	0.00	0.00	0.00	0.00	0.00	0.00
July	0.03	0.00	0.05	3.27	0.00	3.39
August	0.10	0.00	0.16	9.82	0.00	10.18
October 1	0.00	0.00	0.00	0.00	0.00	0.00
October 2	0.00	0.00	0.00	0.00	0.00	0.00

Number of shag observed per km^2 per survey, together with extrapolated abundance indicators.

	Density of observed individuals			Indicator of likely abundance		
Survey	Full survey area	Site	Buffer	Full survey area	Site	Buffer
November 2016	0.00	0.00	0.00	0.00	0.00	0.00
December	0.03	0.00	0.05	3.27	0.00	3.39
January 2017	0.03	0.00	0.05	3.27	0.00	3.39
March	0.10	0.00	0.16	9.82	0.00	10.18
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.03	0.00	0.05	3.27	0.00	3.39
July	0.16	0.09	0.21	16.37	3.07	13.58
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
November	0.03	0.00	0.05	3.27	0.00	3.39
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2018	0.00	0.00	0.00	0.00	0.00	0.00

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.00	0.00	0.00	0.00	0.00	0.00
June	0.13	0.35	0.00	13.10	12.29	0.00
July	0.03	0.00	0.05	3.27	0.00	3.39
August	0.00	0.00	0.00	0.00	0.00	0.00
October 1	0.00	0.00	0.00	0.00	0.00	0.00
October 2	0.00	0.00	0.00	0.00	0.00	0.00

Number of common tern observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
November 2016	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2017	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2018	0.00	0.00	0.00	0.00	0.00	0.00
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.10	0.00	0.16	9.82	0.00	10.18
June	0.03	0.00	0.05	3.27	0.00	3.39
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
October 1	0.00	0.00	0.00	0.00	0.00	0.00
October 2	0.00	0.00	0.00	0.00	0.00	0.00

Number of Arctic tern observed per km^2 per survey, together with extrapolated abundance indicators.

	Density of observed individuals			Indicator of likely abundance		
Survey	Full survey area	Site	Buffer	Full survey area	Site	Buffer
November 2016	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2017	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.95	1.40	0.68	94.95	49.14	44.13
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2018	0.00	0.00	0.00	0.00	0.00	0.00
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.00	0.00	0.00	0.00	0.00	0.00
June	0.03	0.00	0.05	3.27	0.00	3.39
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.03	0.09	0.00	3.27	3.07	0.00
October 1	0.00	0.00	0.00	0.00	0.00	0.00
October 2	0.00	0.00	0.00	0.00	0.00	0.00

Number of common/ Arctic tern observed per km^2 per survey, together with extrapolated abundance indicators.

	Density of observed individuals			Indicator of likely abundance		
Survey	Full survey area	Site	Buffer	Full survey area	Site	Buffer
November 2016	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2017	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.03	0.09	0.00	3.27	3.07	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2018	0.00	0.00	0.00	0.00	0.00	0.00
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.03	0.00	0.05	3.27	0.00	3.39
June	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
October 1	0.00	0.00	0.00	0.00	0.00	0.00
October 2	0.00	0.00	0.00	0.00	0.00	0.00

Number of guillemot observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
November 2016	0.95	0.70	1.09	94.95	24.57	71.29
December	0.82	0.70	0.89	81.85	24.57	57.71
January 2017	1.80	1.84	1.77	180.08	64.50	115.42
March	2.13	2.89	1.67	212.82	101.36	108.63
April	3.37	5.61	2.03	337.24	196.57	132.39
May 1	4.35	2.72	5.32	435.46	95.21	346.26
May 2	4.97	5.79	4.48	497.67	202.71	291.94
July	10.17	8.42	11.21	1018.26	294.85	729.86
August	3.66	2.81	4.17	366.70	98.28	271.58
September	0.82	0.96	0.73	81.85	33.79	47.53
November	0.56	0.44	0.63	55.66	15.36	40.74
December	0.78	1.32	0.47	78.58	46.07	30.55
January 2018	0.52	0.61	0.47	52.39	21.50	30.55
February 1	3.56	5.00	2.71	356.88	175.07	176.52
February 2	0.39	0.26	0.47	39.29	9.21	30.55
March	0.26	0.18	0.31	26.19	6.14	20.37
April	9.45	14.12	6.67	946.23	494.49	434.52
May 1	3.11	5.00	1.98	311.04	175.07	129.00
May 2	29.56	40.16	23.26	2959.83	1406.70	1514.04
June	7.29	13.59	3.55	730.13	476.07	230.84
July	7.13	7.28	7.04	713.76	254.93	458.29
August	11.77	14.91	9.91	1178.69	522.14	644.99
October 1	2.19	1.93	2.35	219.37	67.57	152.76
October 2	0.85	0.53	1.04	85.13	18.43	67.89

Number of razorbill observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
November 2016	0.85	0.44	1.09	85.13	15.36	71.29
December	0.36	0.79	0.10	36.02	27.64	6.79
January 2017	0.07	0.00	0.10	6.55	0.00	6.79

Survey	Density of observed individuals Full survey area	Site	Buffer	Indicator of likely abundance Full survey area	Site	Buffer
March	0.20	0.26	0.16	19.64	9.21	10.18
April	0.36	0.70	0.16	36.02	24.57	10.18
May 1	0.16	0.26	0.10	16.37	9.21	6.79
May 2	0.36	0.53	0.26	36.02	18.43	16.97
July	0.20	0.26	0.16	19.64	9.21	10.18
August	2.88	3.33	2.61	288.12	116.71	169.74
September	0.03	0.00	0.05	3.27	0.00	3.39
November	0.13	0.26	0.05	13.10	9.21	3.39
December	0.49	0.44	0.52	49.11	15.36	33.95
January 2018	0.62	1.05	0.36	62.21	36.86	23.76
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.29	0.70	0.05	29.47	24.57	3.39
March	0.03	0.00	0.05	3.27	0.00	3.39
April	0.72	0.79	0.68	72.03	27.64	44.13
May 1	0.36	0.61	0.21	36.02	21.50	13.58
May 2	1.31	1.84	0.99	130.97	64.50	64.50
June	1.70	2.10	1.46	170.26	73.71	95.05
July	0.29	0.18	0.36	29.47	6.14	23.76
August	5.07	7.10	3.86	507.49	248.78	251.21
October 1	0.69	0.70	0.68	68.76	24.57	44.13
October 2	0.03	0.00	0.05	3.27	0.00	3.39

Number of ‘guillemot/ razorbill’ observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals Full survey area	Site	Buffer	Indicator of likely abundance Full survey area	Site	Buffer
November 2016	0.29	0.18	0.36	29.47	6.14	23.76
December	0.26	0.53	0.10	26.19	18.43	6.79
January 2017	0.00	0.00	0.00	0.00	0.00	0.00
March	0.23	0.44	0.10	22.92	15.36	6.79
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.03	0.00	0.05	3.27	0.00	3.39
May 2	0.00	0.00	0.00	0.00	0.00	0.00
July	0.13	0.00	0.21	13.10	0.00	13.58
August	0.65	0.70	0.63	65.48	24.57	40.74
September	0.03	0.09	0.00	3.27	3.07	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00
December	0.26	0.35	0.21	26.19	12.29	13.58
January 2018	0.36	0.70	0.16	36.02	24.57	10.18
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.10	0.00	0.16	9.82	0.00	10.18
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.36	0.79	0.10	36.02	27.64	6.79
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	1.05	2.63	0.10	104.77	92.14	6.79
June	6.54	17.54	0.00	654.83	614.28	0.00

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
July	0.39	0.00	0.63	39.29	0.00	40.74
August	2.81	0.09	4.43	281.58	3.07	288.55
October 1	0.36	0.26	0.42	36.02	9.21	27.16
October 2	0.07	0.00	0.10	6.55	0.00	6.79

Number of puffin observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
November 2016	0.00	0.00	0.00	0.00	0.00	0.00
December	0.03	0.00	0.05	3.27	0.00	3.39
January 2017	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.13	0.18	0.10	13.10	6.14	6.79
July	0.13	0.18	0.10	13.10	6.14	6.79
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2018	0.00	0.00	0.00	0.00	0.00	0.00
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.03	0.00	0.05	3.27	0.00	3.39
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.07	0.00	0.10	6.55	0.00	6.79
June	0.16	0.00	0.26	16.37	0.00	16.97
July	0.20	0.18	0.21	19.64	6.14	13.58
August	0.00	0.00	0.00	0.00	0.00	0.00
October 1	0.00	0.00	0.00	0.00	0.00	0.00
October 2	0.00	0.00	0.00	0.00	0.00	0.00

Diving birds in flight

Number of eiders observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
November 2016	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2017	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00

Survey	Density of observed individuals Full survey area	Site	Buffer	Indicator of likely abundance Full survey area	Site	Buffer
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2018	0.00	0.00	0.00	0.00	0.00	0.00
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.00	0.00	0.00	0.00	0.00	0.00
June	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
October 1	0.46	1.14	0.05	45.84	39.93	3.39
October 2	0.00	0.00	0.00	0.00	0.00	0.00

Number of common scoter observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals Full survey area	Site	Buffer	Indicator of likely abundance Full survey area	Site	Buffer
November 2016	0.00	0.00	0.00	0.00	0.00	0.00
December	0.07	0.18	0.00	6.55	6.14	0.00
January 2017	0.13	0.09	0.16	13.10	3.07	10.18
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.03	0.00	0.05	3.27	0.00	3.39
September	0.10	0.00	0.16	9.82	0.00	10.18
November	0.69	1.05	0.47	68.76	36.86	30.55
December	0.03	0.09	0.00	3.27	3.07	0.00
January 2018	0.26	0.00	0.42	26.19	0.00	27.16
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.23	0.61	0.00	22.92	21.50	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.07	0.18	0.00	6.55	6.14	0.00
May 2	0.00	0.00	0.00	0.00	0.00	0.00
June	0.00	0.00	0.00	0.00	0.00	0.00
July	1.31	0.00	2.09	130.97	0.00	135.79
August	0.46	1.23	0.00	45.84	43.00	0.00

Survey	Density of observed individuals Full survey area	Site	Buffer	Indicator of likely abundance Full survey area	Site	Buffer
October 1	0.00	0.00	0.00	0.00	0.00	0.00
October 2	0.29	0.09	0.42	29.47	3.07	27.16

Number of red-throated diver observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals Full survey area	Site	Buffer	Indicator of likely abundance Full survey area	Site	Buffer
November 2016	0.16	0.35	0.05	16.37	12.29	3.39
December	0.03	0.09	0.00	3.27	3.07	0.00
January 2017	0.00	0.00	0.00	0.00	0.00	0.00
March	0.07	0.00	0.10	6.55	0.00	6.79
April	0.03	0.09	0.00	3.27	3.07	0.00
May 1	0.03	0.00	0.05	3.27	0.00	3.39
May 2	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2018	0.03	0.00	0.05	3.27	0.00	3.39
February 1	0.07	0.09	0.05	6.55	3.07	3.39
February 2	0.00	0.00	0.00	0.00	0.00	0.00
March	0.07	0.00	0.10	6.55	0.00	6.79
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.00	0.00	0.00	0.00	0.00	0.00
June	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
October 1	0.07	0.00	0.10	6.55	0.00	6.79
October 2	0.00	0.00	0.00	0.00	0.00	0.00

Number of Manx shearwater observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals Full survey area	Site	Buffer	Indicator of likely abundance Full survey area	Site	Buffer
November 2016	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2017	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.07	0.09	0.05	6.55	3.07	3.39
May 1	0.49	0.61	0.42	49.11	21.50	27.16
May 2	1.44	0.88	1.77	144.06	30.71	115.42
July	12.69	11.49	13.40	1270.37	402.35	872.44

Survey	Density of observed individuals Full survey area	Site	Buffer	Indicator of likely abundance Full survey area	Site	Buffer
August	0.56	0.79	0.42	55.66	27.64	27.16
September	0.03	0.00	0.05	3.27	0.00	3.39
November	0.03	0.09	0.00	3.27	3.07	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2018	0.00	0.00	0.00	0.00	0.00	0.00
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.00	0.00	0.00	0.00	0.00	0.00
March	0.10	0.00	0.16	9.82	0.00	10.18
April	0.39	0.53	0.31	39.29	18.43	20.37
May 1	0.65	0.96	0.47	65.48	33.79	30.55
May 2	0.62	1.14	0.31	62.21	39.93	20.37
June	1.01	0.26	1.46	101.50	9.21	95.05
July	2.19	2.72	1.88	219.37	95.21	122.21
August	3.37	4.74	2.55	337.24	165.86	166.34
October 1	0.00	0.00	0.00	0.00	0.00	0.00
October 2	0.00	0.00	0.00	0.00	0.00	0.00

Number of gannet observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals Full survey area	Site	Buffer	Indicator of likely abundance Full survey area	Site	Buffer
November 2016	0.03	0.00	0.05	3.27	0.00	3.39
December	0.07	0.00	0.10	6.55	0.00	6.79
January 2017	0.00	0.00	0.00	0.00	0.00	0.00
March	0.20	0.18	0.21	19.64	6.14	13.58
April	0.23	0.18	0.26	22.92	6.14	16.97
May 1	0.29	0.53	0.16	29.47	18.43	10.18
May 2	0.16	0.18	0.16	16.37	6.14	10.18
July	0.56	0.44	0.63	55.66	15.36	40.74
August	0.36	0.35	0.36	36.02	12.29	23.76
September	0.23	0.18	0.26	22.92	6.14	16.97
November	0.20	0.00	0.31	19.64	0.00	20.37
December	0.03	0.09	0.00	3.27	3.07	0.00
January 2018	0.00	0.00	0.00	0.00	0.00	0.00
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.03	0.09	0.00	3.27	3.07	0.00
March	0.16	0.35	0.05	16.37	12.29	3.39
April	0.23	0.44	0.10	22.92	15.36	6.79
May 1	0.07	0.09	0.05	6.55	3.07	3.39
May 2	0.07	0.00	0.10	6.55	0.00	6.79
June	0.10	0.00	0.16	9.82	0.00	10.18
July	0.36	0.18	0.47	36.02	6.14	30.55
August	0.16	0.18	0.16	16.37	6.14	10.18
October 1	0.23	0.53	0.05	22.92	18.43	3.39
October 2	0.03	0.00	0.05	3.27	0.00	3.39

Number of cormorant observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
November 2016	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2017	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2018	0.00	0.00	0.00	0.00	0.00	0.00
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.03	0.00	0.05	3.27	0.00	3.39
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.00	0.00	0.00	0.00	0.00	0.00
June	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.03	0.00	0.05	3.27	0.00	3.39
October 1	0.00	0.00	0.00	0.00	0.00	0.00
October 2	0.00	0.00	0.00	0.00	0.00	0.00

Number of shag observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
November 2016	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2017	0.07	0.00	0.10	6.55	0.00	6.79
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.13	0.00	0.21	13.10	0.00	13.58
May 2	0.03	0.00	0.05	3.27	0.00	3.39
July	0.10	0.09	0.10	9.82	3.07	6.79
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2018	0.00	0.00	0.00	0.00	0.00	0.00
February 1	0.00	0.00	0.00	0.00	0.00	0.00

Survey	Density of observed individuals Full survey area	Site	Buffer	Indicator of likely abundance Full survey area	Site	Buffer
February 2	0.00	0.00	0.00	0.00	0.00	0.00
March	0.07	0.00	0.10	6.55	0.00	6.79
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.00	0.00	0.00	0.00	0.00	0.00
June	0.03	0.00	0.05	3.27	0.00	3.39
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.03	0.00	0.05	3.27	0.00	3.39
October 1	0.00	0.00	0.00	0.00	0.00	0.00
October 2	0.00	0.00	0.00	0.00	0.00	0.00

Number of Sandwich tern observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals Full survey area	Site	Buffer	Indicator of likely abundance Full survey area	Site	Buffer
November 2016	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2017	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2018	0.00	0.00	0.00	0.00	0.00	0.00
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.07	0.18	0.00	6.55	6.14	0.00
June	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.20	0.09	0.26	19.64	3.07	16.97
October 1	0.00	0.00	0.00	0.00	0.00	0.00
October 2	0.00	0.00	0.00	0.00	0.00	0.00

Number of common tern observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals Full survey area	Site	Buffer	Indicator of likely abundance Full survey area	Site	Buffer
November 2016	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
January 2017	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2018	0.00	0.00	0.00	0.00	0.00	0.00
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.03	0.09	0.00	3.27	3.07	0.00
May 2	0.16	0.09	0.21	16.37	3.07	13.58
June	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.23	0.53	0.05	22.92	18.43	3.39
October 1	0.00	0.00	0.00	0.00	0.00	0.00
October 2	0.00	0.00	0.00	0.00	0.00	0.00

Number of Arctic tern observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
November 2016	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2017	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	1.18	0.88	1.36	117.87	30.71	88.26
July	0.10	0.00	0.16	9.82	0.00	10.18
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2018	0.00	0.00	0.00	0.00	0.00	0.00
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.03	0.00	0.05	3.27	0.00	3.39
May 2	0.03	0.00	0.05	3.27	0.00	3.39
June	0.16	0.18	0.16	16.37	6.14	10.18

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
July	0.33	0.00	0.52	32.74	0.00	33.95
August	0.03	0.00	0.05	3.27	0.00	3.39
October 1	0.00	0.00	0.00	0.00	0.00	0.00
October 2	0.00	0.00	0.00	0.00	0.00	0.00

Number of common/ Arctic tern observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
November 2016	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2017	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.29	0.35	0.26	29.47	12.29	16.97
July	0.03	0.00	0.05	3.27	0.00	3.39
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2018	0.00	0.00	0.00	0.00	0.00	0.00
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.36	0.26	0.42	36.02	9.21	27.16
June	0.07	0.00	0.10	6.55	0.00	6.79
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
October 1	0.00	0.00	0.00	0.00	0.00	0.00
October 2	0.00	0.00	0.00	0.00	0.00	0.00

Number of guillemot observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
November 2016	1.05	0.35	1.46	104.77	12.29	95.05
December	1.11	0.61	1.41	111.32	21.50	91.66
January 2017	6.47	7.45	5.89	648.28	261.07	383.60
March	7.03	10.61	4.90	703.94	371.64	319.10
April	3.92	6.40	2.45	392.90	224.21	159.55
May 1	6.96	8.15	6.26	697.39	285.64	407.36
May 2	5.75	5.00	6.20	576.25	175.07	403.97
July	3.30	3.42	3.23	330.69	119.78	210.47

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.29	0.26	0.31	29.47	9.21	20.37
November	1.11	1.49	0.89	111.32	52.21	57.71
December	1.96	3.16	1.25	196.45	110.57	81.47
January 2018	0.82	1.14	0.63	81.85	39.93	40.74
February 1	8.34	6.31	9.54	834.91	221.14	621.23
February 2	0.59	1.05	0.31	58.93	36.86	20.37
March	1.37	1.32	1.41	137.51	46.07	91.66
April	3.37	6.14	1.72	337.24	215.00	112.03
May 1	9.84	11.75	8.71	985.52	411.57	566.92
May 2	4.68	3.07	5.63	468.20	107.50	366.63
June	11.31	16.05	8.50	1132.85	562.06	553.34
July	9.06	14.47	5.84	906.94	506.78	380.21
August	0.20	0.26	0.16	19.64	9.21	10.18
October 1	0.43	0.70	0.26	42.56	24.57	16.97
October 2	0.56	0.44	0.63	55.66	15.36	40.74

Number of razorbill observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
November 2016	0.23	0.44	0.10	22.92	15.36	6.79
December	0.33	0.53	0.21	32.74	18.43	13.58
January 2017	0.03	0.00	0.05	3.27	0.00	3.39
March	0.95	1.14	0.83	94.95	39.93	54.32
April	0.75	1.32	0.42	75.31	46.07	27.16
May 1	1.05	1.14	0.99	104.77	39.93	64.50
May 2	1.21	1.75	0.89	121.14	61.43	57.71
July	0.07	0.09	0.05	6.55	3.07	3.39
August	0.07	0.09	0.05	6.55	3.07	3.39
September	0.23	0.35	0.16	22.92	12.29	10.18
November	0.95	1.40	0.68	94.95	49.14	44.13
December	0.03	0.00	0.05	3.27	0.00	3.39
January 2018	0.13	0.18	0.10	13.10	6.14	6.79
February 1	0.07	0.18	0.00	6.55	6.14	0.00
February 2	0.16	0.18	0.16	16.37	6.14	10.18
March	0.98	0.79	1.09	98.22	27.64	71.29
April	0.88	0.88	0.89	88.40	30.71	57.71
May 1	1.37	1.75	1.15	137.51	61.43	74.68
May 2	0.75	0.61	0.83	75.31	21.50	54.32
June	3.07	5.96	1.36	307.77	208.85	88.26
July	0.78	0.70	0.83	78.58	24.57	54.32
August	0.00	0.00	0.00	0.00	0.00	0.00
October 1	0.20	0.35	0.10	19.64	12.29	6.79
October 2	0.33	0.70	0.10	32.74	24.57	6.79

Number of ‘guillemot/ razorbill’ observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals Full survey area	Site	Buffer	Indicator of likely abundance Full survey area	Site	Buffer
November 2016	0.43	0.79	0.21	42.56	27.64	13.58
December	0.49	0.88	0.26	49.11	30.71	16.97
January 2017	0.16	0.18	0.16	16.37	6.14	10.18
March	2.06	3.77	1.04	206.27	132.07	67.89
April	0.65	1.58	0.10	65.48	55.29	6.79
May 1	1.31	2.28	0.73	130.97	79.86	47.53
May 2	0.56	1.14	0.21	55.66	39.93	13.58
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.69	1.40	0.26	68.76	49.14	16.97
November	1.05	1.40	0.83	104.77	49.14	54.32
December	0.16	0.35	0.05	16.37	12.29	3.39
January 2018	0.29	0.61	0.10	29.47	21.50	6.79
February 1	0.23	0.44	0.10	22.92	15.36	6.79
February 2	0.52	0.61	0.47	52.39	21.50	30.55
March	0.10	0.26	0.00	9.82	9.21	0.00
April	1.47	1.75	1.30	147.34	61.43	84.87
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.00	0.00	0.00	0.00	0.00	0.00
June	0.16	0.35	0.05	16.37	12.29	3.39
July	0.33	0.18	0.42	32.74	6.14	27.16
August	0.00	0.00	0.00	0.00	0.00	0.00
October 1	0.29	0.18	0.36	29.47	6.14	23.76
October 2	0.39	0.00	0.63	39.29	0.00	40.74

Number of puffin observed per km^2 per survey, together with extrapolated abundance indicators.

Survey	Density of observed individuals Full survey area	Site	Buffer	Indicator of likely abundance Full survey area	Site	Buffer
November 2016	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2017	0.00	0.00	0.00	0.00	0.00	0.00
March	0.03	0.09	0.00	3.27	3.07	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.00	0.00	0.00	0.00	0.00	0.00
May 2	0.33	0.18	0.42	32.74	6.14	27.16
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
January 2018	0.00	0.00	0.00	0.00	0.00	0.00

Survey	Density of observed individuals			Indicator of likely abundance		
	Full survey area	Site	Buffer	Full survey area	Site	Buffer
February 1	0.00	0.00	0.00	0.00	0.00	0.00
February 2	0.00	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00
April	0.00	0.00	0.00	0.00	0.00	0.00
May 1	0.23	0.61	0.00	22.92	21.50	0.00
May 2	0.07	0.09	0.05	6.55	3.07	3.39
June	0.10	0.26	0.00	9.82	9.21	0.00
July	0.20	0.26	0.16	19.64	9.21	10.18
August	0.00	0.00	0.00	0.00	0.00	0.00
October 1	0.00	0.00	0.00	0.00	0.00	0.00
October 2	0.00	0.00	0.00	0.00	0.00	0.00

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Morlais Project
Environmental Statement

Appendix 11.2: Seabird Densities Derived from Boat-Based Surveys

Volume III

Applicant: Menter Môn Morlais Limited

Document Reference: PB5034-ES-0112

Appendix 11.2: Seabird Densities Derived from Boat-Based Surveys

Author: Royal HaskoningDHV

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GLOSSARY OF ABBREVIATIONS

Acronym	**Term**
BPKM	Birds per kilometre
MDZ	Morlais Demonstration Zone

GLOSSARY OF TERMINOLOGY

Bird per kilometre	Unit of measurement for offshore boat-based bird surveys
Morlais Demonstration Zone	An offshore area of 35 km^2 within which the Project will deploy arrays of tidal devices and associated infrastructure. Defined by The Crown Estate Lease boundary, the area within which the tidal devices/arrays will be deployed along with associated infrastructure such as inter-array cables, export cables, marker buoys, site monitoring equipment and electrical connections to the export cables.

1. INTRODUCTION

1. This appendix to **Chapter 11, Marine Ornithology**, presents the densities of marine ornithology receptors recorded both in flight and on the sea during a two year programme of boat-based surveys, along with the methods used to calculate them.

2. Details of the survey programme itself and the survey method employed are available in **Appendix 11.1** (**Volume III**), along with an account of the Distance sampling method used to derive distance-corrected densities for those species that were seen sufficiently frequently to enable this (guillemot, herring gull and razorbill).

2. METHODOLOGY

3. Densities and abundances were calculated for each survey undertaken. Mean densities, abundances and 90 % confidence intervals have been calculated for the breeding and non-breeding seasons for most species. The exceptions are common scoter, eider and red-throated diver, which have not been allocated a breeding season density due to the absence of a breeding population in Wales.

4. All densities presented in this appendix use the units birds per kilometre. Abundances are reported in number of birds. The reporting regions used are the Morlais Demonstration Zone (MDZ), 2 km buffer, and for most species, the study area, which is the MDZ and 2 km buffer combined. Due to the manner in which they were calculated, density estimates for the study area are not available for guillemot, herring gull and razorbill.

5. The breeding and non-breeding seasons used are presented in **Table 2-1**.

Table 2-1 Breeding and Non-Breeding Seasons Used for Density Calculation

Species	Breeding Season	Non-breeding Season	Source
Arctic tern	May-early Aug	Sept-Apr	(Furness, 2015)
Black-headed gull	Apr-Aug	Sept-Mar	(Cramp and Simmons, 1983)
Common gull	Apr-Aug	Sept-Mar	(Cramp and Simmons, 1983)
Common scoter	Year round		-
Common tern	May-Aug	Sept-Apr	(Furness, 2015)
Cormorant	Apr-Aug	Sept-Mar	(Furness, 2015)
Eider	Year round		-
Fulmar	Jan-Aug	Sept-Dec	(Furness, 2015)
Gannet	Mar-Sept	Oct-Feb	(Furness, 2015)
Great black-backed gull	Late Mar-Aug	Sept-Mar	(Furness, 2015)
Guillemot	Mar-Jul	Aug-Feb	(Furness, 2015)
Herring gull	Mar-Aug	Sept-Feb	(Furness, 2015)
Kittiwake	Mar-Aug	Sept-Feb	(Furness, 2015)
Lesser black-backed gull	Apr-Aug	Sept-Mar	(Furness, 2015)
Manx shearwater	Apr-Aug	Sept-Mar	(Furness, 2015)

Species	Breeding Season	Non-breeding Season	Source
Mediterranean gull	Apr-Aug	Sept-Mar	Assumed as per black-headed gull
Puffin	Apr-early Aug	Mid Aug-Mar	(Furness, 2015)
Razorbill	Apr-Jul	Aug-Mar	(Furness, 2015)
Red-throated diver	Year round		-
Sandwich tern	Apr-Aug	Sept-Mar	(Furness, 2015)
Shag	Feb-Aug	Sept-Jan	(Furness, 2015)

6. Three species (guillemot, herring gull and razorbill) were recorded sufficiently frequently on the sea to enable Distance analysis to occur. Details are provided in **Appendix 11.1** (**Volume III**).

7. For all other species, numbers of records on the sea were not sufficient to enable the use of this method. Instead, generic correction factors were applied to account for birds on the sea that could have been missed during surveys (Stone et al., 1995).

8. Where records of non-speciated birds existed (e.g. auk species not identified as either guillemot or razorbill, "commic" terns not identified as either Arctic or common tern), these were proportionally allocated to species level based on the ratio of each possible species they could be, that was recorded on that particular survey.

9. It is assumed that all birds present and in flight are recorded during boat-based surveys (i.e. none are missed). As a result, no corrections are applied.

3. DENSITES BY SPECIES

3.1. ARCTIC TERN

Table 3-1 Arctic Tern Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	1.615	2.380	1.156	161.415	83.538	75.021
18/07/2017	0	0	0	0	0	0
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0.051	0	0.085	5.559	0	5.763
19/07/2018	0	0	0	0	0	0
30/08/2018	0.051	0.153	0	5.559	5.219	0
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-2 Arctic Tern Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: May to August						
Mean	0.191	0.281	0.138	19.170	9.862	8.976
90 % CI	0.293	0.432	0.210	29.276	15.178	13.619
Non-breeding Season: September to April						
Mean	0	0	0	0	0	0
90 % CI	-	-	-	-	-	-

Table 3-3 Arctic Tern Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	1.470	1.230	1.620	147.340	43.000	105.230
18/07/2017	0.130	0	0.210	13.090	0	13.570
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0.030	0	0.050	3.270	0	3.390
31/05/2018	0.087	0	0.131	9.267	0	8.816

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
24/06/2018	0.230	0.180	0.260	22.920	6.140	16.970
19/07/2018	0.330	0	0.520	32.740	0	33.950
30/08/2018	0.030	0	0.050	3.270	0	3.390
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-4 Arctic Tern Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: May to August						
Mean	0.256	0.157	0.316	25.766	5.460	20.591
90 % CI	0.257	0.223	0.283	25.724	7.798	18.373
Non-breeding Season: September to April						
Mean	0	0	0	0	0	0
90 % CI	-	-	-	-	-	-

3.2. BLACK-HEADED GULL

Table 3-5 Black-Headed Gull Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	3.113	0	4.964	311.698	0	323.176
05/12/2016	0.275	0.614	0.073	27.503	21.500	4.753
19/01/2017	0.137	0	0.219	13.751	0	14.258
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0.092	0	0.146	9.168	0	9.505
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0.046	0.123	0	4.584	4.300	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0	0	0	0	0	0
19/07/2018	0	0	0	0	0	0

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
30/08/2018	0	0	0	0	0	0
15/10/2018	0.092	0.246	0	9.168	8.600	0
30/10/2018	0.137	0.123	0.146	13.751	4.300	9.505

Table 3-6 Black-Headed Gull Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: April to August						
Mean	0.012	0.011	0.013	1.250	0.391	0.864
90 % CI	0.015	0.018	0.022	1.470	0.643	1.421
Non-breeding Season: September to March						
Mean	0.289	0.076	0.416	28.913	2.646	27.053
90 % CI	0.389	0.081	0.624	38.957	2.836	40.643

Table 3-7 Black-Headed Gull Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0.163	0.175	0.156	16.371	6.143	10.184
05/12/2016	2.616	0.263	4.015	261.931	9.214	261.392
19/01/2017	0.033	0	0.052	3.274	0	3.395
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0.196	0	0.313	19.645	0	20.368
31/08/2017	0.033	0	0.052	3.274	0	3.395
26/09/2017	0.556	1.052	0.261	55.660	36.857	16.974
02/11/2017	0.065	0	0.104	6.548	0	6.789
22/12/2017	0	0	0	0	0	0
10/01/2018	0.033	0	0.052	3.274	0	3.395
05/02/2018	0.033	0	0.052	3.274	0	3.395
21/02/2018	0.065	0	0.104	6.548	0	6.789
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0	0	0	0	0	0
19/07/2018	0	0	0	0	0	0
30/08/2018	0	0	0	0	0	0
15/10/2018	0.425	0.088	0.626	42.564	3.071	40.736
30/10/2018	0.458	0.263	0.574	45.838	9.214	37.342

Table 3-8 Black-Headed Gull Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: April to August						
Mean	0.021	0	0.033	2.084	0	2.160
90 % CI	0.029	-	0.047	2.929	-	3.037
Non-breeding Season: September to March						
Mean	0.342	0.142	0.461	34.253	4.961	30.030
90 % CI	0.324	0.133	0.496	32.460	4.666	32.305

3.3. COMMON GULL

Table 3-9 Common Gull Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	2.014	0.123	3.139	201.687	4.300	204.361
05/12/2016	0.092	0.246	0	9.168	8.600	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0.137	0	0.219	13.751	0	14.258
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0	0	0	0	0	0
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0.092	0	0.146	9.168	0	9.505
22/12/2017	0.137	0.123	0.146	13.751	4.300	9.505
10/01/2018	0.046	0	0.073	4.584	0	4.753
05/02/2018	0.046	0	0.073	4.584	0	4.753
21/02/2018	0.092	0	0.146	9.168	0	9.505
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0.046	0	0.073	4.584	0	4.753
19/07/2018	0	0	0	0	0	0
30/08/2018	0	0	0	0	0	0
15/10/2018	0.183	0.246	0.146	18.335	8.600	9.505
30/10/2018	0.137	0.123	0.146	13.751	4.300	9.505

Table 3-10 Common Gull Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: April to August						

Mean	0.004	0	0.007	0.417	0	0.432
90 % CI	0.007	-	0.011	0.685	-	0.711
Non-breeding Season: September to March						
Mean	0.229	0.066	0.326	22.919	2.315	21.204
90 % CI	0.246	0.043	0.387	24.654	1.523	25.201

Table 3-11 Common Gull Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0.163	0.175	0.156	16.371	6.143	10.184
05/12/2016	0.360	0.263	0.417	36.016	9.214	27.158
19/01/2017	0.033	0	0.052	3.274	0	3.395
25/03/2017	0.065	0	0.104	6.548	0	6.789
02/04/2017	0.033	0	0.052	3.274	0	3.395
10/05/2017	0	0	0	0	0	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0	0	0	0	0	0
31/08/2017	0	0	0	0	0	0
26/09/2017	0.033	0	0.052	3.274	0	3.395
02/11/2017	0.229	0.351	0.156	22.919	12.286	10.184
22/12/2017	0.262	0.526	0.104	26.193	18.428	6.789
10/01/2018	0.098	0.088	0.104	9.822	3.071	6.789
05/02/2018	0.229	0.175	0.261	22.919	6.143	16.974
21/02/2018	0.458	0.438	0.469	45.838	15.357	30.552
24/03/2018	0.131	0.175	0.104	13.097	6.143	6.789
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0	0	0	0	0	0
19/07/2018	0	0	0	0	0	0
30/08/2018	0	0	0	0	0	0
15/10/2018	0.098	0.088	0.104	9.822	3.071	6.789
30/10/2018	0.163	0.351	0.052	16.371	12.286	3.395

Table 3-12 Common Gull Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: April to August						
Mean	0.003	0	0.005	0.298	0	0.309
90 % CI	0.005	-	0.008	0.490	-	0.508
Non-breeding Season: September to March						
Mean	0.179	0.202	0.164	17.882	7.088	10.706
90 % CI	0.058	0.079	0.062	5.805	2.766	4.041

3.4. COMMON SCOTER

Table 3-13 Common Scoter Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0	0	0	0	0	0
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0	0	0	0	0	0
19/07/2018	0	0	0	0	0	0
30/08/2018	0	0	0	0	0	0
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-14 Common Scoter Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Year round						
Mean	0	0	0	0	0	0
90 % CI	-	-	-	-	-	-

Table 3-15 Common Scoter Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0.070	0.180	0	6.550	6.140	0
19/01/2017	0.130	0.090	0.160	13.100	3.070	10.180
25/03/2017	0	0	0	0	0	0

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0	0	0	0	0	0
31/08/2017	0.030	0	0.050	3.270	0	3.390
26/09/2017	0.100	0	0.160	9.820	0	10.180
02/11/2017	0.690	1.050	0.470	68.760	36.860	30.550
22/12/2017	0.030	0.090	0	3.270	3.070	0
10/01/2018	0.260	0	0.420	26.190	0	27.160
05/02/2018	0	0	0	0	0	0
21/02/2018	0.230	0.610	0	22.920	21.500	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0.070	0.180	0	6.550	6.140	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0	0	0	0	0	0
19/07/2018	1.310	0	2.090	130.970	0	135.790
30/08/2018	0.460	1.230	0	45.840	43.000	0
15/10/2018	0	0	0	0	0	0
30/10/2018	0.290	0.090	0.420	29.470	3.070	27.160

Table 3-16 Common Scoter Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Year round						
Mean	0.153	0.147	0.157	15.280	5.119	10.184
90 % CI	0.101	0.112	0.147	10.105	3.926	9.542

3.5. COMMON TERN

Table 3-17 Common Tern Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0	0	0	0	0	0

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0.170	0	0.272	16.694	0	17.306
24/06/2018	0.051	0	0.085	5.559	0	5.763
19/07/2018	0	0	0	0	0	0
30/08/2018	0	0	0	0	0	0
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-18 Common Tern Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: May to August						
Mean	0.025	0	0.040	2.473	0	2.563
90 % CI	0.031	-	0.050	3.093	-	3.206
Non-breeding Season: September to April						
Mean	0	0	0	0	0	0
90 % CI	-	-	-	-	-	-

Table 3-19 Common Tern Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0	0	0	0	0	0
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0.030	0.090	0	3.270	3.070	0
31/05/2018	0.463	0.350	0.549	46.393	12.280	35.314
24/06/2018	0	0	0	0	0	0
19/07/2018	0	0	0	0	0	0
30/08/2018	0.230	0.530	0.050	22.920	18.430	3.390
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-20 Common Tern Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: May to August						
Mean	0.080	0.108	0.067	8.065	3.753	4.300
90 % CI	0.089	0.107	0.100	8.889	3.744	6.406
Non-breeding Season: September to April						
Mean	0	0	0	0	0	0
90 % CI	-	-	-	-	-	-

3.6. CORMORANT

Table 3-21 Cormorant Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0	0	0	0	0	0
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0	0	0	0	0	0
19/07/2018	0	0	0	0	0	0
30/08/2018	0	0	0	0	0	0
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-22 Cormorant Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: April to August						
Mean	0	0	0	0	0	0
90 % CI	-	-	-	-	-	-
Non-breeding Season: September to March						
Mean	0	0	0	0	0	0
90 % CI	-	-	-	-	-	-

Table 3-23 Cormorant Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0	0	0	0	0	0
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0.030	0	0.050	3.270	0	3.390
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
31/05/2018	0	0	0	0	0	0
24/06/2018	0	0	0	0	0	0
19/07/2018	0	0	0	0	0	0
30/08/2018	0.030	0	0.050	3.270	0	3.390
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-24 Cormorant Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: May to August						
Mean	0.003	0	0.005	0.297	0	0.308
90 % CI	0.004	-	0.007	0.489	-	0.507
Non-breeding Season: September to April						
Mean	0.002	0	0.004	0.252	0	0.261
90 % CI	0.004	-	0.006	0.414	-	0.429

3.7. EIDER

Table 3-25 Eider Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0	0	0	0	0	0
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0	0	0	0	0	0

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
19/07/2018	0	0	0	0	0	0
30/08/2018	0	0	0	0	0	0
15/10/2018	0.030	0	0.050	3.270	0	3.390
30/10/2018	0	0	0	0	0	0

Table 3-26 Eider Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Year round						
Mean	0.001	0	0.002	0.136	0	0.141
90 % CI	0.002	-	0.003	0.224	-	0.232

Table 3-27 Eider Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0	0	0	0	0	0
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0	0	0	0	0	0
19/07/2018	0	0	0	0	0	0
30/08/2018	0	0	0	0	0	0
15/10/2018	0.460	1.140	0.050	45.840	39.930	3.390
30/10/2018	0	0	0	0	0	0

Table 3-28 Eider Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Year round						
Mean	0.019	0.048	0.002	1.910	1.664	0.141
90 % CI	0.032	0.078	0.003	3.142	2.737	0.232

3.8. FULMAR

Table 3-29 Fulmar Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0.036	0.096	0	3.602	3.379	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0	0	0	0	0	0
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0.108	0.193	0.057	10.805	6.757	3.734
18/05/2018	0	0	0	0	0	0
31/05/2018	0.036	0	0.057	3.602	0	3.734
24/06/2018	0	0	0	0	0	0
19/07/2018	0	0	0	0	0	0
30/08/2018	0.036	0.096	0	3.602	3.379	0
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-30 Fulmar Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: January to August						
Mean	0.020	0.035	0.010	1.964	1.229	0.679
90 % CI	0.011	0.022	0.008	1.129	0.758	0.495

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Non-breeding Season: September to December						
Mean	0	0	0	0	0	0
90 % CI	-	-	-	-	-	-

Table 3-31 Fulmar Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0.065	0.088	0.052	6.548	3.071	3.395
25/03/2017	0	0	0	0	0	0
02/04/2017	0.098	0.088	0.104	9.822	3.071	6.789
10/05/2017	0.196	0.175	0.209	19.645	6.143	13.579
24/05/2017	0	0	0	0	0	0
18/07/2017	0.033	0	0.052	3.274	0	3.395
31/08/2017	0.033	0.088	0	3.274	3.071	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0.098	0.088	0.104	9.822	3.071	6.789
10/01/2018	0	0	0	0	0	0
05/02/2018	0.033	0	0.052	3.274	0	3.395
21/02/2018	0.033	0	0.052	3.274	0	3.395
24/03/2018	0.196	0.263	0.156	19.645	9.214	10.184
08/04/2018	0.065	0	0.104	6.548	0	6.789
18/05/2018	0.098	0.175	0.052	9.822	6.143	3.395
31/05/2018	0.065	0.175	0	6.548	6.143	0
24/06/2018	0.033	0	0.052	3.274	0	3.395
19/07/2018	0	0	0	0	0	0
30/08/2018	0.163	0	0.261	16.371	0	16.974
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-32 Fulmar Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: January to August						
Mean	0.071	0.064	0.076	7.144	2.234	4.938
90 % CI	0.026	0.034	0.031	2.612	1.207	2.018
Non-breeding Season: September to December						
Mean	0.033	0.034	0.032	3.274	1.181	2.089
90 % CI	0.023	0.021	0.025	2.308	0.722	1.595

3.9. GANNET

Table 3-33 Gannet Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0.030	0.090	0	3.270	3.070	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0.200	0	0.310	19.640	0	20.370
31/08/2017	0.100	0.180	0.050	9.820	6.140	3.390
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0.070	0	0.100	6.550	0	6.790
24/06/2018	0	0	0	0	0	0
19/07/2018	0.030	0	0.050	3.270	0	3.390
30/08/2018	0.100	0	0.160	9.820	0	10.180
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-34 Gannet Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: March to September						
Mean	0.038	0.019	0.048	3.741	0.658	3.151
90 % CI	0.026	0.023	0.039	2.578	0.781	2.582
Non-breeding Season: October to February						
Mean	0	0	0	0	0	0
90 % CI	-	-	-	-	-	-

Table 3-35 Gannet Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0.030	0	0.050	3.270	0	3.390

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
05/12/2016	0.070	0	0.100	6.550	0	6.790
19/01/2017	0	0	0	0	0	0
25/03/2017	0.200	0.180	0.210	19.640	6.140	13.580
02/04/2017	0.230	0.180	0.260	22.920	6.140	16.970
10/05/2017	0.290	0.530	0.160	29.470	18.430	10.180
24/05/2017	0.160	0.180	0.160	16.370	6.140	10.180
18/07/2017	0.560	0.440	0.630	55.660	15.360	40.740
31/08/2017	0.360	0.350	0.360	36.020	12.290	23.760
26/09/2017	0.230	0.180	0.260	22.920	6.140	16.970
02/11/2017	0.200	0	0.310	19.640	0	20.370
22/12/2017	0.030	0.090	0	3.270	3.070	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0.030	0.090	0	3.270	3.070	0
24/03/2018	0.160	0.350	0.050	16.370	12.290	3.390
08/04/2018	0.230	0.440	0.100	22.920	15.360	6.790
18/05/2018	0.070	0.090	0.050	6.550	3.070	3.390
31/05/2018	0.070	0	0.100	6.550	0	6.790
24/06/2018	0.100	0	0.160	9.820	0	10.180
19/07/2018	0.360	0.180	0.470	36.020	6.140	30.550
30/08/2018	0.160	0.180	0.160	16.370	6.140	10.180
15/10/2018	0.230	0.530	0.050	22.920	18.430	3.390
30/10/2018	0.030	0	0.050	3.270	0	3.390

Table 3-36 Gannet Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: March to September						
Mean	0.227	0.234	0.224	22.686	8.117	14.546
90 % CI	0.058	0.072	0.073	5.853	2.519	4.699
Non-breeding Season: October to February						
Mean	0.062	0.071	0.056	6.219	2.457	3.733
90 % CI	0.044	0.086	0.050	4.282	2.994	3.272

3.10. GREAT BLACK-BACKED GULL

Table 3-37 Great Black-Backed Gull Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0.183	0.246	0.146	18.335	8.600	9.505
05/12/2016	0.046	0	0.073	4.584	0	4.753
19/01/2017	0.046	0.123	0	4.584	4.300	0

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0.046	0.123	0	4.584	4.300	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0	0	0	0	0	0
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0.046	0.123	0	4.584	4.300	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0.046	0.123	0	4.584	4.300	0
19/07/2018	0	0	0	0	0	0
30/08/2018	0	0	0	0	0	0
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-38 Great Black-Backed Gull Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: Late March to August						
Mean	0.011	0.028	0	1.058	0.992	0
90 % CI	0.009	0.025	-	0.917	0.860	-
Non-breeding Season: September to mid-March						
Mean	0.025	0.033	0.020	2.500	1.173	1.296
90 % CI	0.028	0.039	0.023	2.759	1.379	1.524

Table 3-39 Great Black-Backed Gull Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0.163	0.088	0.209	16.371	3.071	13.579
19/01/2017	0.065	0.175	0	6.548	6.143	0
25/03/2017	0.033	0	0.052	3.274	0	3.395
02/04/2017	0	0	0	0	0	0
10/05/2017	0.033	0	0.052	3.274	0	3.395
24/05/2017	0	0	0	0	0	0

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
18/07/2017	0.033	0	0.052	3.274	0	3.395
31/08/2017	0.033	0	0.052	3.274	0	3.395
26/09/2017	0.196	0.351	0.104	19.645	12.286	6.789
02/11/2017	0.098	0	0.156	9.822	0	10.184
22/12/2017	0.098	0.088	0.104	9.822	3.071	6.789
10/01/2018	0.131	0	0.209	13.097	0	13.579
05/02/2018	0.033	0	0.052	3.274	0	3.395
21/02/2018	0.098	0.175	0.052	9.822	6.143	3.395
24/03/2018	0.033	0.088	0	3.274	3.071	0
08/04/2018	0.065	0	0.104	6.548	0	6.789
18/05/2018	0.033	0	0.052	3.274	0	3.395
31/05/2018	0.033	0	0.052	3.274	0	3.395
24/06/2018	0.131	0.175	0.104	13.097	6.143	6.789
19/07/2018	0.065	0.088	0.052	6.548	3.071	3.395
30/08/2018	0.065	0.088	0.052	6.548	3.071	3.395
15/10/2018	0.033	0	0.052	3.274	0	3.395
30/10/2018	0.033	0	0.052	3.274	0	3.395

Table 3-40 Great Black-Backed Gull Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: Late March to August						
Mean	0.043	0.034	0.048	4.282	1.181	3.134
90 % CI	0.015	0.026	0.015	1.541	0.911	0.992
Non-breeding Season: September to mid-March						
Mean	0.086	0.080	0.090	8.632	2.792	5.864
90 % CI	0.030	0.057	0.037	3.018	1.981	2.392

3.11. GUILLEMOT

Table 3-41 Guillemot Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	-	2.093	3.544	-	73.478	231.226
05/12/2016	-	2.293	2.100	-	80.576	136.809
19/01/2017	-	3.865	4.268	-	135.000	278.000
25/03/2017	-	6.934	2.430	-	242.417	159.002
02/04/2017	-	9.386	4.268	-	329.000	278.000
10/05/2017	-	6.901	6.145	-	242.000	399.821
24/05/2017	-	4.693	7.551	-	164.000	492.000
18/07/2017	-	13.802	11.954	-	483.000	778.420
31/08/2017	-	6.261	10.082	-	219.286	656.352

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
26/09/2017	-	2.891	2.298	-	101.452	150
02/11/2017	-	1.104	1.477	-	39.000	96.000
22/12/2017	-	2.313	1.458	-	81.365	94.327
10/01/2018	-	2.029	1.116	-	71.125	72.303
05/02/2018	-	5.245	4.596	-	184.000	299.000
21/02/2018	-	0.828	1.687	-	29.000	109.287
24/03/2018	-	0.552	0.985	-	19.000	64.000
08/04/2018	-	16.820	8.175	-	588.956	532.938
18/05/2018	-	7.729	3.940	-	271.000	256.000
31/05/2018	-	50.574	31.163	-	1771.746	2029.443
24/06/2018	-	37.211	7.879	-	1303.287	513.000
19/07/2018	-	14.630	12.688	-	512.000	825.161
30/08/2018	-	8.922	13.159	-	312.015	857.118
15/10/2018	-	6.074	6.053	-	212.793	393.555
30/10/2018	-	1.656	2.601	-	58.000	169.377

Table 3-42 Guillemot Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: March to July						
Mean	-	15.385	8.834	-	538.764	575.253
90 % CI	-	7.508	4.092	-	263.049	266.460
Non-breeding Season: August to February						
Mean	-	3.506	4.188	-	122.853	272.566
90 % CI	-	1.106	1.667	-	38.661	108.588

Table 3-43 Guillemot Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	1.403	0.700	1.657	139.691	24.576	107.725
05/12/2016	1.488	1.081	1.636	149.269	38.036	106.440
19/01/2017	6.629	7.630	6.049	664.568	267.210	393.691
25/03/2017	8.845	14.014	5.789	885.694	490.897	377.114
02/04/2017	4.466	7.710	2.535	447.848	270.076	165.352
10/05/2017	8.098	10.150	6.890	811.254	355.705	448.393
24/05/2017	6.213	5.844	6.384	622.242	204.628	415.853
18/07/2017	3.300	3.420	3.230	330.690	119.780	210.470
31/08/2017	0	0	0	0	0	0
26/09/2017	0.675	0.857	0.481	68.148	30.260	31.685
02/11/2017	1.676	2.212	1.361	167.862	77.524	88.492
22/12/2017	2.118	3.510	1.298	212.552	122.860	84.725
10/01/2018	1.070	1.667	0.716	107.254	58.565	46.560

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
05/02/2018	8.568	6.738	9.640	857.652	236.085	628.020
21/02/2018	0.999	1.571	0.620	99.931	55.290	40.740
24/03/2018	1.428	1.483	1.410	143.238	51.826	91.660
08/04/2018	4.536	7.671	2.577	453.979	268.752	168.045
18/05/2018	9.840	11.750	8.710	985.520	411.570	566.920
31/05/2018	4.680	3.070	5.630	468.200	107.500	366.630
24/06/2018	11.436	16.305	8.543	1145.723	571.020	556.264
19/07/2018	9.364	14.642	6.208	937.069	512.636	403.975
30/08/2018	0.200	0.260	0.160	19.640	9.210	10.180
15/10/2018	0.628	0.820	0.520	62.725	28.663	33.940
30/10/2018	0.805	0.440	1.174	80.398	15.360	75.660

Table 3-44 Guillemot Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: March to July						
Mean	6.564	8.733	5.264	657.405	305.854	342.789
90 % CI	1.561	2.503	1.230	156.324	87.653	80.027
Non-breeding Season: August to February						
Mean	2.020	2.114	1.947	202.284	74.126	126.758
90 % CI	1.174	1.112	1.263	117.595	38.935	82.272

3.12. HERRING GULL

Table 3-45 Herring Gull Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	-	0.971	0.192	-	34.000	13.000
05/12/2016	-	0	0.577	-	0	38.000
19/01/2017	-	1.295	1.155	-	45.000	75.000
25/03/2017	-	1.942	0.962	-	68.000	63.000
02/04/2017	-	0.324	0.962	-	11.000	63.000
10/05/2017	-	0.324	0.770	-	11.000	50
24/05/2017	-	0	0	-	0	0
18/07/2017	-	5.827	3.272	-	204.000	213.000
31/08/2017	-	0	0.192	-	0	13.000
26/09/2017	-	0	0	-	0	0
02/11/2017	-	0.324	0.385	-	11.000	25.000
22/12/2017	-	0	0.385	-	0	25.000
10/01/2018	-	0.324	0.192	-	11.000	13.000
05/02/2018	-	0	0.385	-	0	25.000
21/02/2018	-	0	0.192	-	0	13.000

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
24/03/2018	-	0.324	0.192	-	11.000	13.000
08/04/2018	-	2.590	0.962	-	91.000	63.000
18/05/2018	-	0	0	-	0	0
31/05/2018	-	0.324	0.385	-	11.000	25.000
24/06/2018	-	1.619	0.577	-	57.000	38.000
19/07/2018	-	0	0.385	-	0	25.000
30/08/2018	-	0	0	-	0	0
15/10/2018	-	0	0	-	0	0
30/10/2018	-	0.324	0	-	11.000	0

Table 3-46 Herring Gull Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: March to August						
Mean	-	1.021	0.666	-	35.692	43.538
90 % CI	-	0.767	0.395	-	26.890	25.728
Non-breeding Season: September to February						
Mean	-	0.294	0.315	-	10.182	20.636
90 % CI	-	0.221	0.167	-	7.689	10.828

Table 3-47 Herring Gull Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0.294	0.263	0.313	29.467	9.214	20.368
05/12/2016	0.948	0.438	1.251	94.950	15.357	81.473
19/01/2017	0.817	0.789	0.834	81.854	27.643	54.315
25/03/2017	0.425	0.701	0.261	42.564	24.571	16.974
02/04/2017	0.425	0.701	0.261	42.564	24.571	16.974
10/05/2017	0.523	0.526	0.521	52.386	18.428	33.947
24/05/2017	0.229	0.526	0.052	22.919	18.428	3.395
18/07/2017	0.785	0.263	1.095	78.579	9.214	71.289
31/08/2017	0.163	0.088	0.209	16.371	3.071	13.579
26/09/2017	0	0	0	0	0	0
02/11/2017	0.752	0.701	0.782	75.305	24.571	50.921
22/12/2017	0.425	0.701	0.261	42.564	24.571	16.974
10/01/2018	1.177	0.526	1.564	117.869	18.428	101.841
05/02/2018	0.327	0.263	0.365	32.741	9.214	23.763
21/02/2018	1.308	0.965	1.512	130.966	33.785	98.447
24/03/2018	0.916	0.965	0.886	91.676	33.785	57.710
08/04/2018	1.144	1.315	1.043	114.595	46.071	67.894
18/05/2018	0.163	0.263	0.104	16.371	9.214	6.789
31/05/2018	0.360	0.351	0.365	36.016	12.286	23.763

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
24/06/2018	2.289	3.420	1.616	229.190	119.784	105.236
19/07/2018	0.589	0.438	0.678	58.935	15.357	44.131
30/08/2018	0.131	0.175	0.104	13.097	6.143	6.789
15/10/2018	0.229	0.088	0.313	22.919	3.071	20.368
30/10/2018	0.262	0.438	0.156	26.193	15.357	10.184

Table 3-48 Herring Gull Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: March to August						
Mean	0.63	0.75	0.55	62.71	26.22	36.04
90 % CI	0.27	0.40	0.22	26.82	13.91	14.27
Non-breeding Season: September to February						
Mean	0.59	0.47	0.67	59.53	16.47	43.51
90 % CI	0.21	0.15	0.28	21.28	5.24	18.02

3.13. KITTIWAKE

Table 3-49 Kittiwake Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0.275	0.737	0	27.503	25.800	0
25/03/2017	0.046	0	0.073	4.584	0	4.753
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	1.144	0	1.825	114.595	0	118.815
18/07/2017	0	0	0	0	0	0
31/08/2017	0.366	0.246	0.438	36.670	8.600	28.516
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0.137	0	0.219	13.751	0	14.258
18/05/2018	0.366	0	0.584	36.670	0	38.021
31/05/2018	0	0	0	0	0	0
24/06/2018	0.229	0.246	0.219	22.919	8.600	14.258
19/07/2018	0	0	0	0	0	0

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
30/08/2018	4.257	6.138	3.139	426.293	214.997	204.361
15/10/2018	0	0	0	0	0	0
30/10/2018	0.046	0	0.073	4.584	0	4.753

Table 3-50 Kittiwake Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: March to August						
Mean	0.504	0.510	0.500	50.422	17.861	32.537
90 % CI	0.535	0.773	0.428	53.532	27.061	27.876
Non-breeding Season: September to February						
Mean	0.029	0.067	0.007	2.917	2.345	0.432
90 % CI	0.041	0.110	0.011	4.101	3.858	0.711

Table 3-51 Kittiwake Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0.033	0	0.052	3.274	0	3.395
05/12/2016	0.065	0.175	0	6.548	6.143	0
19/01/2017	0.131	0.175	0.104	13.097	6.143	6.789
25/03/2017	0.131	0	0.209	13.097	0	13.579
02/04/2017	0.098	0.175	0.052	9.822	6.143	3.395
10/05/2017	0.589	1.315	0.156	58.935	46.071	10.184
24/05/2017	0.262	0.438	0.156	26.193	15.357	10.184
18/07/2017	0.131	0.088	0.156	13.097	3.071	10.184
31/08/2017	0.556	0.877	0.365	55.660	30.714	23.763
26/09/2017	0.131	0.263	0.052	13.097	9.214	3.395
02/11/2017	2.943	2.806	3.024	294.673	98.285	196.893
22/12/2017	0.065	0.088	0.052	6.548	3.071	3.395
10/01/2018	0.262	0.438	0.156	26.193	15.357	10.184
05/02/2018	0	0	0	0	0	0
21/02/2018	0.033	0.088	0	3.274	3.071	0
24/03/2018	0.065	0.088	0.052	6.548	3.071	3.395
08/04/2018	0.327	0.263	0.365	32.741	9.214	23.763
18/05/2018	0.523	1.052	0.209	52.386	36.857	13.579
31/05/2018	0.098	0.263	0	9.822	9.214	0
24/06/2018	0.229	0.175	0.261	22.919	6.143	16.974
19/07/2018	0.131	0.175	0.104	13.097	6.143	6.789
30/08/2018	1.177	0.701	1.460	117.869	24.571	95.052
15/10/2018	0.131	0	0.209	13.097	0	13.579
30/10/2018	0.458	1.228	0	45.838	42.999	0

Table 3-52 Kittiwake Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: March to August						
Mean	0.332	0.432	0.273	33.245	15.121	17.757
90 % CI	0.143	0.191	0.170	14.351	6.707	11.099
Non-breeding Season: September to February						
Mean	0.386	0.478	0.332	38.694	16.753	21.603
90 % CI	0.425	0.421	0.444	42.597	14.743	28.919

3.14. LESSER BLACK-BACKED GULL

Table 3-53 Lesser Black-Backed Gull Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0.046	0.123	0	4.584	4.300	0
18/07/2017	0.870	1.228	0.657	87.092	42.999	42.773
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0.046	0.123	0	4.584	4.300	0
18/05/2018	0.046	0	0.073	4.584	0	4.753
31/05/2018	0.092	0.246	0	9.168	8.600	0
24/06/2018	0	0	0	0	0	0
19/07/2018	0	0	0	0	0	0
30/08/2018	0	0	0	0	0	0
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-54 Lesser Black-Backed Gull Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: April to August						

Mean	0.100	0.156	0.066	10.001	5.473	4.321
90 % CI	0.128	0.181	0.098	12.772	6.333	6.364
Non-breeding Season: September to March						
Mean	0	0	0	0	0	0
90 % CI	-	-	-	-	-	-

Table 3-55 Lesser Black-Backed Gull Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0.033	0.088	0	3.274	3.071	0
18/07/2017	0.196	0.263	0.156	19.645	9.214	10.184
31/08/2017	0.033	0	0.052	3.274	0	3.395
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0.033	0.088	0	3.274	3.071	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0.065	0.175	0	6.548	6.143	0
18/05/2018	0.033	0	0.052	3.274	0	3.395
31/05/2018	0	0	0	0	0	0
24/06/2018	0.458	0.614	0.365	45.838	21.500	23.763
19/07/2018	0.098	0.175	0.052	9.822	6.143	3.395
30/08/2018	0	0	0	0	0	0
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-56 Lesser Black-Backed Gull Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: April to August						
Mean	0.083	0.120	0.062	8.334	4.188	4.012
90 % CI	0.068	0.094	0.055	6.826	3.286	3.597
Non-breeding Season: September to March						
Mean	0.003	0.007	0	0.252	0.236	0
90 % CI	0.004	0.011	-	0.414	0.389	-

3.15. MANX SHEARWATER

Table 3-57 Manx Shearwater Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	3.185	2.275	3.731	319.228	79.859	242.723
18/07/2017	0.299	0.689	0.065	29.796	23.959	4.407
31/08/2017	0.091	0	0.130	8.515	0	8.827
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	2.587	0.793	3.666	259.636	27.950	238.303
24/06/2018	0	0	0	0	0	0
19/07/2018	0	0	0	0	0	0
30/08/2018	21.684	17.446	24.193	2170.753	610.896	1575.483
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-58 Manx Shearwater Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: April to August						
Mean	2.531	1.928	2.890	253.448	67.515	188.158
90 % CI	3.201	2.576	3.579	320.482	90.200	233.067
Non-breeding Season: September to March						
Mean	0	0	0	0	0	0
90 % CI	-	-	-	-	-	-

Table 3-59 Manx Shearwater Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0.070	0.090	0.050	6.550	3.070	3.390
10/05/2017	0.490	0.610	0.420	49.110	21.500	27.160
24/05/2017	1.440	0.880	1.770	144.060	30.710	115.420
18/07/2017	12.690	11.490	13.400	1270.370	402.350	872.440
31/08/2017	0.560	0.790	0.420	55.660	27.640	27.160
26/09/2017	0.030	0	0.050	3.270	0	3.390
02/11/2017	0.030	0.090	0	3.270	3.070	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0.100	0	0.160	9.820	0	10.180
08/04/2018	0.390	0.530	0.310	39.290	18.430	20.370
18/05/2018	0.650	0.960	0.470	65.480	33.790	30.550
31/05/2018	0.620	1.140	0.310	62.210	39.930	20.370
24/06/2018	1.010	0.260	1.460	101.500	9.210	95.050
19/07/2018	2.190	2.720	1.880	219.370	95.210	122.210
30/08/2018	3.370	4.740	2.550	337.240	165.860	166.340
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-60 Manx Shearwater Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: April to August						
Mean	2.135	2.201	2.095	213.713	77.064	136.405
90 % CI	1.800	1.667	1.904	180.157	58.360	123.955
Non-breeding Season: September to March						
Mean	0.012	0.007	0.016	1.258	0.236	1.044
90 % CI	0.013	0.011	0.021	1.299	0.388	1.323

3.16. MEDITERRANEAN GULL

Table 3-61 Mediterranean Gull Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0	0	0	0	0	0
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0	0	0	0	0	0
19/07/2018	0	0	0	0	0	0
30/08/2018	0	0	0	0	0	0
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-62 Mediterranean Gull Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: April to August						
Mean	0	0	0	0	0	0
90 % CI	-	-	-	-	-	-
Non-breeding Season: September to March						
Mean	0	0	0	0	0	0
90 % CI	-	-	-	-	-	-

Table 3-63 Mediterranean Gull Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0.030	0.045	0	3.270	3.051	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0	0	0	0	0	0

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
18/07/2017	0	0	0	0	0	0
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0.030	0.045	0	3.270	3.051	0
19/07/2018	0.030	0	0.050	3.270	0	3.390
30/08/2018	0	0	0	0	0	0
15/10/2018	0.030	0	0.050	3.270	0	3.390
30/10/2018	0	0	0	0	0	0

Table 3-64 Mediterranean Gull Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: April to August						
Mean	0.005	0.004	0.005	0.595	0.277	0.308
90 % CI	0.006	0.007	0.007	0.656	0.456	0.507
Non-breeding Season: September to March						
Mean	0.005	0.003	0.004	0.503	0.235	0.261
90 % CI	0.005	0.006	0.006	0.560	0.386	0.429

3.17. PUFFIN

Table 3-65 Puffin Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0.045	0	0.075	4.905	0	5.085
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0.195	0.270	0.150	19.650	9.210	10.185
18/07/2017	0.195	0.270	0.150	19.650	9.210	10.185
31/08/2017	0	0	0	0	0	0

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0.045	0	0.075	4.905	0	5.085
18/05/2018	0	0	0	0	0	0
31/05/2018	0.105	0	0.150	9.825	0	10.185
24/06/2018	0.240	0	0.390	24.555	0	25.455
19/07/2018	0.300	0.270	0.315	29.460	9.210	20.370
30/08/2018	0	0	0	0	0	0
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-66 Puffin Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: April to August						
Mean	0.098	0.074	0.112	9.822	2.512	7.406
90 % CI	0.057	0.063	0.068	5.660	2.134	4.426
Non-breeding Season: September to March						
Mean	0.003	0	0.006	0.377	0	0.391
90 % CI	0.006	-	0.009	0.621	-	0.643

Table 3-67 Puffin Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0.030	0.090	0	3.270	3.070	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0.330	0.180	0.420	32.740	6.140	27.160
18/07/2017	0	0	0	0	0	0
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0.230	0.610	0	22.920	21.500	0
31/05/2018	0.070	0.090	0.050	6.550	3.070	3.390
24/06/2018	0.100	0.260	0	9.820	9.210	0
19/07/2018	0.200	0.260	0.160	19.640	9.210	10.180
30/08/2018	0	0	0	0	0	0
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-68. Puffin Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: April to August						
Mean	0.085	0.127	0.057	8.334	4.466	3.703
90 % CI	0.058	0.095	0.064	5.780	3.362	4.155
Non-breeding Season: September to March						
Mean	0.002	0.007	0	0.252	0.236	0
90 % CI	0.004	0.011	-	0.414	0.388	-

3.18. RAZORBILL

Table 3-69 Razorbill Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	-	0.407	2.082	-	14.425	136.226
05/12/2016	-	1.938	0.197	-	68.147	13.036
19/01/2017	-	0	0.182	-	0	12.000
25/03/2017	-	0.971	0.195	-	33.855	12.844
02/04/2017	-	1.225	0.364	-	43.000	24.000
10/05/2017	-	0.918	0.183	-	32.000	12.095
24/05/2017	-	0.918	0.546	-	32.000	36.000
18/07/2017	-	0.918	0.550	-	32.000	36.271
31/08/2017	-	5.143	3.811	-	180.340	247.721
26/09/2017	-	0	0.182	-	0	12.000
02/11/2017	-	0.612	0.182	-	21.000	12.000
22/12/2017	-	0.739	0.888	-	25.456	57.364
10/01/2018	-	2.173	1.011	-	76.502	65.458
05/02/2018	-	0	0	-	0	0
21/02/2018	-	0.918	0.204	-	32.000	13.474

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
24/03/2018	-	0	0.182	-	0	12.000
08/04/2018	-	1.591	1.288	-	56.122	83.908
18/05/2018	-	1.531	0.728	-	54.000	47.000
31/05/2018	-	5.066	2.373	-	177.857	154.402
24/06/2018	-	6.159	3.095	-	216.419	201.000
19/07/2018	-	0.612	0.773	-	21.000	49.912
30/08/2018	-	8.921	8.901	-	312.437	579.279
15/10/2018	-	1.937	1.593	-	67.561	103.827
30/10/2018	-	0	0.189	-	0	12.468

Table 3-70 Razorbill Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: April to July						
Mean	-	2.104	1.100	-	73.822	71.621
90 % CI	-	1.114	0.544	-	39.180	35.294
Non-breeding Season: August to March						
Mean	-	1.584	1.320	-	55.448	85.980
90 % CI	-	1.037	0.993	-	36.348	64.629

Table 3-71 Razorbill Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0.307	0.880	0.113	30.559	30.714	7.695
05/12/2016	0.442	0.939	0.244	43.901	32.604	15.770
19/01/2017	0.031	0	0.051	3.352	0	3.479
25/03/2017	1.195	1.506	0.981	119.466	52.743	64.196
02/04/2017	0.854	1.590	0.435	85.842	55.494	28.148
10/05/2017	1.222	1.420	1.090	121.876	49.725	70.997
24/05/2017	1.307	2.046	0.916	130.808	71.802	59.408
18/07/2017	0.070	0.090	0.050	6.550	3.070	3.390
31/08/2017	0.070	0.090	0.050	6.550	3.070	3.390
26/09/2017	0.535	1.153	0.249	53.002	40.380	15.835
02/11/2017	1.434	2.078	1.039	143.178	72.966	67.668
22/12/2017	0.032	0	0.052	3.538	0	3.525
10/01/2018	0.170	0.263	0.114	17.166	9.005	7.760
05/02/2018	0.072	0.192	0	6.728	6.555	0
21/02/2018	0.271	0.269	0.320	27.759	9.210	20.360
24/03/2018	1.022	0.887	1.090	102.312	31.094	71.290
08/04/2018	1.184	1.099	1.333	119.001	38.388	86.565
18/05/2018	1.370	1.750	1.150	137.510	61.430	74.680
31/05/2018	0.750	0.610	0.830	75.310	21.500	54.320

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
24/06/2018	3.104	6.055	1.367	311.267	212.180	88.726
19/07/2018	0.806	0.708	0.882	81.191	24.854	57.715
30/08/2018	0	0	0	0	0	0
15/10/2018	0.292	0.410	0.200	28.945	14.337	13.580
30/10/2018	0.475	0.700	0.186	47.292	24.570	12.610

Table 3-72 Razorbill Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: April to July						
Mean	1.185	1.708	0.895	118.817	59.827	58.217
90 % CI	0.451	0.956	0.233	45.271	33.492	15.135
Non-breeding Season: August to March						
Mean	0.423	0.625	0.313	42.250	21.817	20.477
90 % CI	0.191	0.263	0.164	19.123	9.220	10.711

3.19. RED-THROATED DIVER

Table 3-73 Red-Throated Diver Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0.039	0	0.065	4.251	0	4.407
19/01/2017	0.039	0	0.065	4.251	0	4.407
25/03/2017	0.130	0	0.208	12.766	0	13.234
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0.039	0	0.065	4.251	0	4.407
18/07/2017	0.208	0.117	0.273	21.281	3.991	17.654
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0.039	0	0.065	4.251	0	4.407
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0.169	0.455	0	17.030	15.977	0
19/07/2018	0.039	0	0.065	4.251	0	4.407

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
30/08/2018	0	0	0	0	0	0
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-74 Red-Throated Diver Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Year round						
Mean	0.029	0.024	0.034	3.014	0.832	2.205
90 % CI	0.019	0.032	0.023	1.953	1.117	1.513

Table 3-75 Red-Throated Diver Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0.160	0.350	0.050	16.370	12.290	3.390
05/12/2016	0.030	0.090	0	3.270	3.070	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0.070	0	0.100	6.550	0	6.790
02/04/2017	0.030	0.090	0	3.270	3.070	0
10/05/2017	0.030	0	0.050	3.270	0	3.390
24/05/2017	0	0	0	0	0	0
18/07/2017	0	0	0	0	0	0
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0.030	0	0.050	3.270	0	3.390
05/02/2018	0.070	0.090	0.050	6.550	3.070	3.390
21/02/2018	0	0	0	0	0	0
24/03/2018	0.070	0	0.100	6.550	0	6.790
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0	0	0	0	0	0
19/07/2018	0	0	0	0	0	0
30/08/2018	0	0	0	0	0	0
15/10/2018	0.070	0	0.100	6.550	0	6.790
30/10/2018	0	0	0	0	0	0

Table 3-76 Red-Throated Diver Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Year round						
Mean	0.023	0.026	0.021	2.319	0.896	1.414
90 % CI	0.013	0.025	0.012	1.316	0.886	0.817

3.20. SANDWICH TERN

Table 3-77 Sandwich Tern Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0	0	0	0	0	0
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0	0	0	0	0	0
19/07/2018	0	0	0	0	0	0
30/08/2018	0	0	0	0	0	0
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-78 Sandwich Tern Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: April to August						
Mean	0	0	0	0	0	0
90 % CI	-	-	-	-	-	-
Non-breeding Season: September to March						

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Mean	0	0	0	0	0	0
90 % CI	-	-	-	-	-	-

Table 3-79 Sandwich Tern Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0	0	0	0	0	0
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0	0	0	0	0	0
18/07/2017	0	0	0	0	0	0
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0.070	0.180	0	6.550	6.140	0
24/06/2018	0	0	0	0	0	0
19/07/2018	0	0	0	0	0	0
30/08/2018	0.200	0.090	0.260	19.640	3.070	16.970
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-80 Sandwich Tern Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: April to August						
Mean	0.025	0.025	0.024	2.381	0.837	1.543
90 % CI	0.031	0.029	0.039	3.001	0.985	2.538
Non-breeding Season: September to March						
Mean	0	0	0	0	0	0
90 % CI	-	-	-	-	-	-

3.21. SHAG

Table 3-81 Shag Density and Abundance on Sea by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0.033	0	0.055	3.597	0	3.729
19/01/2017	0.033	0	0.055	3.597	0	3.729
25/03/2017	0.110	0	0.176	10.802	0	11.198
02/04/2017	0	0	0	0	0	0
10/05/2017	0	0	0	0	0	0
24/05/2017	0.033	0	0.055	3.597	0	3.729
18/07/2017	0.176	0.099	0.231	18.007	3.377	14.938
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0.033	0	0.055	3.597	0	3.729
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0	0	0	0	0	0
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0.143	0.385	0	14.410	13.519	0
19/07/2018	0.033	0	0.055	3.597	0	3.729
30/08/2018	0	0	0	0	0	0
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-82 Shag Density and Abundance on Sea by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: February to August						
Mean	0.033	0.032	0.034	3.361	1.126	2.240
90 % CI	0.025	0.043	0.031	2.551	1.502	1.970
Non-breeding Season: September to January						
Mean	0.011	0	0.018	1.199	0	1.243
90 % CI	0.001	-	0.001	0.075	-	0.078

Table 3-83 Shag Density and Abundance in Flight by Survey

Survey Date	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
29/11/2016	0	0	0	0	0	0
05/12/2016	0	0	0	0	0	0
19/01/2017	0.070	0	0.100	6.550	0	6.790
25/03/2017	0	0	0	0	0	0
02/04/2017	0	0	0	0	0	0
10/05/2017	0.130	0	0.210	13.100	0	13.580
24/05/2017	0.030	0	0.050	3.270	0	3.390
18/07/2017	0.100	0.090	0.100	9.820	3.070	6.790
31/08/2017	0	0	0	0	0	0
26/09/2017	0	0	0	0	0	0
02/11/2017	0	0	0	0	0	0
22/12/2017	0	0	0	0	0	0
10/01/2018	0	0	0	0	0	0
05/02/2018	0	0	0	0	0	0
21/02/2018	0	0	0	0	0	0
24/03/2018	0.070	0	0.100	6.550	0	6.790
08/04/2018	0	0	0	0	0	0
18/05/2018	0	0	0	0	0	0
31/05/2018	0	0	0	0	0	0
24/06/2018	0.030	0	0.050	3.270	0	3.390
19/07/2018	0	0	0	0	0	0
30/08/2018	0.030	0	0.050	3.270	0	3.390
15/10/2018	0	0	0	0	0	0
30/10/2018	0	0	0	0	0	0

Table 3-84 Shag Density and Abundance in Flight by Season with 90 % Confidence Interval

Parameter	Study Area Density	MDZ Density	Buffer Density	Study Area Abundance	MDZ Abundance	Buffer Abundance
Breeding Season: February to August						
Mean	0.026	0.006	0.037	2.619	0.205	2.489
90 % CI	0.018	0.010	0.026	1.759	0.337	1.677
Non-breeding Season: September to January						
Mean	0.008	0	0.011	0.728	0	0.754
90 % CI	0.001	-	0.001	0.091	-	0.095

4. REFERENCES

Cramp, S., Simmons, K.E.L. (Eds.), 1983. Handbook of the Birds of Europe, the Middle East and North Africa: The Birds of the Western Palearctic. Volume 3: Waders to Gulls. Oxford University Press.

Furness, R., 2015. Non-breeding season populations of seabirds in UK waters: Population sizes for Biologically Defined Minimum Population Scales (BDMPS). Natural England Commissioned Report 164.

Stone, C.J., Webb, A., Barton, C., Ratcliffe, N., Reed, T.C., Tasker, M.L., Camphuysen, C.J., Pienkowski, M.W., 1995. An atlas of seabird distribution in north-west European waters. JNCC, Peterborough.

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Morlais Project
Environmental Statement

Appendix 11.3: Encounter Rate Modelling, Collision Risk Modelling and Population Viability Analysis Technical Report

Volume III

Applicant: Menter Môn Morlais Limited

Document Reference: PB5034-ES-0113

Appendix 11.3: ERM, CRM and PVA Technical Report

Author: Royal HaskoningDHV

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GLOSSARY OF ABBREVIATIONS

Acronym	Term
CRM	Collision Risk Modelling
EIA	Environmental Impact Assessment
EMEC	European Marine Energy Centre
ERM	Encounter Rate Modelling
MDZ	Morlais Development Zone
MW	Megawatts
PVA	Population Viability Analysis
RSPB	Royal Society for the Protection of Birds
SMP	Seabird Monitoring Programme
SNH	Scottish Natural Heritage
TWG	Technical Working Group

GLOSSARY OF TERMINOLOGY

Density dependent	Where population growth rates are regulated by the density of a population.
Density independent	Where the growth of a population does not depend on the population density.
Deterministic	Where the values for the dependent variables of the system are completely determined by the parameters of the model.
Stochastic	Having a random probability distribution or pattern that may be analysed statistically but may not be predicted precisely.

1. INTRODUCTION

1. This appendix to **Chapter 11, Marine Ornithology** considers in detail the potential for the operational tidal devices to be deployed during the operational phase of the project to kill or injure diving marine ornithology receptors through collision. It presents the results of collision risk modelling studies carried out using two different methods that aim to predict the theoretical impact of collisions on annual mortality rates for each species investigated.

2. For two species, guillemot and razorbill, the outputs of these models are then used as inputs into a deterministic Population Viability Analysis (PVA) assessment to provide further context of theoretical collision risk on the breeding populations of the South Stack and Penlas Seabird Monitoring Programme (SMP) master site, which consists of the South Stack, Abraham's Bosom and Gogarth sub-colonies.

3. Tidal stream devices possess the potential to pose a theoretical risk to diving bird species (Furness et al., 2012; McCluskie et al., 2012; SNH, 2016). The risk is theoretical because any effect has yet to be empirically demonstrated, due largely to the fact that the tidal stream industry is still in its infancy. There are very few studies that have empirically examined collision risk of operational tidal devices.

4. Collision risk has been estimated for seven seabird species, which where appropriate have been assessed on a seasonal basis (Furness, 2015). These are breeding gannet, breeding and non-breeding guillemot, breeding Manx shearwater, breeding puffin, breeding and non-breeding razorbill, non-breeding red-throated diver, and breeding shag. These species have been selected because the baseline ornithological surveys (**Appendix 11.1, Volume III**) and the densities calculated from these (**Appendix 11.2, Volume III**) show that these are the only species regularly using the Morlais Development Zone (MDZ) which may habitually dive to the depth where there is a risk of collision with operational tidal devices.

5. The two methods used to estimate collision risk are Encounter Rate Modelling (ERM) and Collision Risk Modelling (CRM). Both methods have been issued as industry standard guidance by Scottish Natural Heritage (SNH) (SNH, 2016). ERM and CRM have been selected for use on this project following discussions with the Ornithology Technical Working Group (TWG).

6. For both methods of collision risk modelling, the number of collisions is estimated by undertaking predictive modelling of the number of encounters between operational tidal devices and diving birds, and then adjusting this number by an avoidance rate. This is a catch-all term which describes a range of factors, which has a very large effect on the predicted number of collisions. Due to uncertainties surrounding avoidance rates of diving birds, a range of avoidance rates are presented as per SNH (2016) and discussions with the Ornithology TWG.

7. Two different deployment scenarios have been considered. The first presents the estimated number of collisions due to the deployment of a 40 MW array of one of nine different device envelopes. The second considers the estimated number of collisions due to the deployment of a 240 MW array consisting of a selection of these device envelopes. PVAs for the breeding guillemot and razorbill populations have been undertaken for two scenarios; the 40 MW array that produced the highest collision risk for each species, and the 240 MW deployment.

8. Although the modelling outputs are quantitative they should be regarded as indicative. While actual rates of behavioural avoidance, evasion and mortality/injury of diving birds are unknown, model outputs are considered useful in terms of giving a first order and, most likely, precautionary, estimate of the absolute magnitude of the potential collision risk. Model outputs are also a useful tool for comparing different device deployment scenarios.

2. CALCULATING AND INTERPRETING POSSIBLE COLLISION RISK

2.1. INTRODUCTION

9. This section provides an overview of the ERM and CRM methods used to estimate underwater collision risk to diving birds during the operation of the project. It describes the input parameters used for each of the marine ornithology receptors along with the sources of this information, and the device envelopes included in the modelling (the physical parameters of device envelopes and array sizes). Finally, information on how the outputs of the models should be interpreted is provided.

2.2. MODEL INFORMATION

2.2.1. Overview and Comparison of ERM and CRM

10. The details of how both the ERM and CRM processes are carried out are provided in SNH (2016) and are not reproduced here. A brief overview of both methods is provided below.

11. The ERM is based on a predator-prey model initially developed for modelling jellyfish preying on plankton (Gerritsen and Strickler, 1977). More recently, an adapted version of the model was developed to predict the potential for fish and marine mammals to be harmed by open rotor tidal device types (Wilson et al., 2007). The model estimates the number of encounter events per unit time per device based on the relative velocities (i.e. closing velocity) of the ‘predator’ (a rotating turbine) and the ‘prey’ (a swimming animal), and their sizes.

12. The CRM is based on the ‘Band model’. This model was developed to estimate the risk of collision of flying birds with wind turbines (Band et al., 2007). It is used widely in Environmental Impact Assessment (EIA) of onshore and offshore wind farms in the UK and Europe. The model has two stages. The first stage estimates the likelihood that a flying bird travelling through the rotor swept area (i.e. the airspace through which turbine blades are moving) will collide with a rotor. The second stage estimates the number of passes by a species through the rotor swept area per unit time. There are a number of differences between the flying birds that this model was originally developed for, and diving birds that are modelled here, that need to be taken into account.

13. ERM produces an “Encounter Rate” and CRM a “Collision Rate”, which can be considered comparable.

2.2.2. Avoidance Rates

14. Neither the Encounter Rate produced by ERM or the Collision Rate produced by CRM take into account the avoidance behaviour of birds, which is incorporated into the outputs of both models

as a correction factor. This approach has and continues to be widely used for estimating collision risk at wind farms both onshore and offshore.

15. It is considered that for diving birds, the avoidance rate should take account of the following factors:

- Avoidance of use of the site;
- Evasive action near a tidal device, or in the vicinity of the rotors;
- Burst speed of diving birds relative to tidal turbine blades, which is substantially higher than equivalent situation for flying birds and wind turbine blades;
- Being swept clear of the blades by hydrodynamic forces; and
- Collisions not resulting in injury/fatality.

16. The current body of evidence relating to diving bird behaviour, and likely avoidance, is limited. For this reason, a wide range of avoidance rates from 0 % to 99.9 % are considered

2.3. BIRD INPUT PARAMETERS

2.3.1. Seasons

17. Both ERM and CRM calculate an approximate number of encounters for each species in a single second. This can be scaled up to a more user-friendly and biologically relevant time period. To enable biologically relevant conclusions to be drawn from the outputs of the modelling, breeding and non-breeding seasons have been used rather than monthly estimates, which are somewhat arbitrary.

18. For all species except red-throated diver, ERM and CRM were carried out separately for the breeding and non-breeding seasons; the latter only being run if birds were present in the MDZ during the surveys at this time of year (**Appendix 11.2, Volume III**). All seasonal information was derived from Furness (2015) and is presented in **Chapter 11, Marine Ornithology** and **Appendix 11.2** (**Volume III**). In the case of red-throated diver, the models have been run without seasonal partitioning. Small numbers of birds were recorded in the MDZ during the breeding season for this species but as this species does not breed in Wales (Stroud et al., 2016), it is assumed that these individuals were non-breeding birds.

2.3.2. Seabird Densities

19. Mean densities of birds on the sea within the MDZ, derived from two years of boat-based surveys (**Appendix 11.2, Volume III**) were used as model inputs, with the exception of gannet, which was the only plunge diving species included in the modelling. For this species, flying densities were used.

20. On-sea densities were calculated using Distance correction (Buckland et al., 2001) where the numbers of observations made this possible; this applied to guillemot and razorbill. Details of this process are provided in **Appendix 11.1** (**Volume III**). For species where this was not possible, generic published corrections to account for missed birds were applied (Stone et al., 1995). Densities of birds in flight are uncorrected as it was assumed that all birds present were recorded.

21. Any observations made to group rather than species level (e.g. "auk species" for guillemot and razorbill) were proportionally allocated to a species by survey (**Appendix 11.2, Volume III**). No filtering of the data on the basis of observations such as feeding behaviour was carried out. In this way, all available data that was considered relevant was used in as a model input.

22. The densities of marine ornithology receptors using the subtidal habitats within the MDZ that have been used as model inputs are presented in **Table 2-1**.

Table 2-1 Marine Ornithology Receptor Densities Used in ERM/CRM

Species	Season (B = breeding, NB = non-breeding)	Density (birds/km on sea unless otherwise stated)	90 % Confidence Interval
Gannet	B	0.234 (flying density)	0.072 (flying density)
Guillemot	B	15.385	7.508
	NB	3.506	1.106
Manx shearwater	B	1.928	2.576
Puffin	B	0.074	0.063
Razorbill	B	2.104	1.114
	NB	1.584	1.037
Red-throated diver	Year round	0.024	0.032
Shag	B	0.032	0.043

2.3.3. Calculation of Diving Bird Densities at Different Depths

23. On-sea or flying densities of marine ornithology receptors need to be converted to densities at collision risk depth to enable ERM and CRM to be carried out. This requires a species-specific 'dive frequency' to be calculated. Two possible methods are accepted by both models (SNH, 2016). The parameters used here are presented in **Section 2.3.5**.

24. The proportion of birds visible at surface calculations for ERM and CRM incorporate a watch period calculation, which feeds into a revised density estimate to correct for birds under the water during the observation of a particular area of the sea or airspace, and therefore not recorded by the surveyor. For boat-based surveys, assuming a constant survey vessel speed of 10 knots, the watch period is 58.34 seconds, which is the parameter that has been used in the model.

25. The final step in this part of the model is to use dive definitions along with vertical swim speed to calculate the proportion of time spent by each species at risk depth, and therefore derive an estimated density at collision risk depth. These values are then used by ERM and CRM. Depth distribution data was not available at the time of assessment, so as suggested by SNH (2016), three diving categories were used to estimate bird densities in 'at-risk' depth range from surface densities:

- Deep diving: assumes foraging below collision risk depth; the 'at risk' times of each dive occur whilst the bird is passing through the risk depth range during descent and ascent;

- Shallow diving: assumes foraging at collision risk depth; the bird is considered not to be at risk of collision only during the time during which it is descending to and ascending from the level of the upper limit of the collision risk depth; and
- Plunge diving: as per the shallow diving category, but with a plunge speed during descent.

26. It should be noted that the vast majority of dive parameter information available in the literature was collected during the breeding season. Where required (in the cases of guillemot and razorbill) the same parameters have been applied to non-breeding season collision estimates.

2.3.4. Nocturnal Activity

27. The CRM and ERM use known sunrise and sunset times (plus an hour before sunrise and an hour after sunset each day to account for the twilight period) to determine the daytime activity period. Where appropriate, both ERM and CRM apply corrections to account for levels of nocturnal activity that differ from daytime activity; this is presented in **Section 2.3.5**. A justification of how these values have been set is provided for each species in the following paragraphs.

28. Gannet nocturnal flight activity during the breeding season has been empirically estimated from activity data from tagged birds to be 8 % of daytime activity (Furness et al., 2018). Whilst not presented as a percentage, it was noted that nocturnal diving activity was found to be even less frequent than nocturnal flight activity. As data from a large number of studies was drawn upon in the assessment, a high degree of confidence is assigned to this estimate. A precautionary nocturnal diving activity value of 8 % of daytime activity is therefore used in ERM and CRM for gannet.

29. A study on guillemots at a Newfoundland breeding colony (at a similar latitude at UK seabird colonies) reported a peak in guillemot diving activity in the twilight period, with birds continuing to dive through the night at comparable levels to the day. Dive depths during the night were considerably reduced compared to the daytime, which was thought to be in response to vertical movement of the primary prey species (capelin) towards the sea surface (Regular et al., 2010). Further analysis of breeding guillemots in the same study area showed that nocturnal diving occurred much more frequently under moonlit and starlit conditions, and less so when light levels were less than this (implying cloudy conditions) (Regular et al., 2011). Low light conditions also resulted in reductions in diving rates during daylight and twilight periods. Similar observations with respect to differences in dive depth in response to light levels have been recorded elsewhere in thick-billed murres *Uria lomvia* (Elliott and Gaston, 2015) and both thick-billed murres and guillemots (Kokubun et al., 2016). A study from the Isle of May (Thaxter et al., 2009) indicated substantial differences between male and female guillemot foraging behaviour during the breeding season, with males travelling approximately twice as far as females to forage, though no segregation in foraging areas between sexes was noted, and dive frequency between sexes was comparable. Half of foraging trips by males occurred overnight, as opposed to 14 % of female foraging trips; and overnight trips were significantly longer in duration than daytime foraging trips. This resulted in males being approximately twice as likely to be away from the nest during the night than females. Temporal sex-based segregation of diving activity has been reported elsewhere in similar species (Elliott and Gaston, 2015).

30. With regard to razorbill, whilst Shoji et al. (2015) noted a pattern of inactivity during the night during the breeding season, another study noted similar diving activity patterns to guillemot, though unlike guillemot, nocturnal behaviour was comparable between male and female birds (Benvenuti et al., 2001). A trend towards shallower diving depths during nocturnal conditions has been observed, as with guillemot (Benvenuti et al., 2001; Falk et al., 2000; Paredes et al., 2006).

31. On the basis that studies have been identified for both guillemot and razorbill that suggest that nocturnal and daytime activity appear to be quite similar, but may be constrained by overcast conditions, which are prevalent in the UK, a precautionary nocturnal diving activity value of 90 % is used in ERM and CRM for breeding guillemot and razorbill. No attempt has been made to include observed differences in foraging behaviour between male and female guillemots in the model, or potential differences in dive depths during nocturnal conditions.

32. During the non-breeding season, the formation of large single or mixed-species aggregations of guillemots (along with razorbill and kittiwake) just before sunset at common sleeping areas was frequently observed over an extended period in the central North Sea (Camphuysen, 1998). These large, dense aggregations of birds occurred in areas of known low prey species density, with no feeding activity observed when birds were within them. Whilst not confirmed, it is hypothesised that the purpose of these nocturnal concentrations at night may be to provide information on the location of suitable food supplies, safety against predators and/or giving the birds the opportunity to socialise. As this study was based on a long term, reliable dataset, and there is no reason to believe that birds in the western UK wintering population behave differently, a nocturnal diving activity value of 30 % (based on expert judgement, incorporating a precautionary element) is used in ERM and CRM for non-breeding guillemot and razorbill.

33. Manx shearwaters tracked from Skomer Island over three breeding seasons did not exhibit any diving activity at night. Diving activity was heavily constrained to daylight and twilight hours (Dean, 2012; Dean et al., 2012; Shoji et al., 2016). On the basis that the number of study subjects, observations and the multiyear nature of the study provides a high degree of confidence, a nocturnal diving activity of 0 % during the breeding season has been set for Manx shearwater for use in ERM and CRM.

34. A tracking study involving seven puffins in Wales, in a single season revealed very strong evidence of no diving occurring at night (Shoji et al., 2015). Due to the limited sample size and temporal coverage of this study, it is proposed that a precautionary nocturnal correction factor is applied. Therefore, a nocturnal diving activity of 10 % during the breeding season has been set for puffin for use in ERM and CRM.

35. The nocturnal activity of non-breeding red-throated diver is completely unknown, though it is known that it is a visual feeder (Polak and Ciach, 2007), suggesting nocturnal activity is unlikely to be as high as during the day, or that shallower areas of sea may be favoured at night, though both of these possibilities are conjecture. On a precautionary basis it is assumed that this species is as active during the night as it is during the day by the models presented.

36. A study that tracked 21 shags at the Isle of May during the breeding season for a period of 24-53 hours revealed that this species is an exclusively daytime feeding bird, with no diving activity recorded at night (Wanless et al., 1999). Due to the limited sample size and temporal coverage

of this study, it is proposed that a precautionary nocturnal correction factor is applied. Therefore, a nocturnal diving activity of 10 % during the breeding season has been set for shag for use in ERM and CRM.

2.3.5. Diving Seabird Parameters

37. A literature search was carried out to identify parameters considered by expert judgement to be appropriate for ERM and CRM. **Table 2-2, Table 2-3, Table 2-4, Table 2-5, Table 2-6, Table 2-7** and **Table 2-8** summarise the input data used for CRM and ERM for each species considered, along with the sources of this information.

Table 2-2 CRM/ERM Input Parameters for Gannet

Parameter and Unit	Value	Source
Dive type	Plunge	(SNH, 2016)
Length (metres)	0.94	(Robinson, 2019; SNH, 2016)
Wingspan (metres)	1.72	(Robinson, 2019; SNH, 2016)
Mean number of dives per hour	0.90	(Cox et al., 2016)
Mean underwater dive duration (seconds)	7.30	(Robbins, 2017)
Vertical swim speed (metres per second)	1.20	(Garthe et al., 2000)
Plunge speed (metres per second)	5.70	(Robbins, 2017)
Breeding season nocturnal activity (% of daytime activity)	8	(Furness et al., 2018)

Table 2-3 CRM/ERM Input Parameters for Guillemot

Parameter and Unit	Value	Source
Dive type	Deep	Expert judgement based on data in (Robbins, 2017)
Length (metres)	0.40	(Robinson, 2019; SNH, 2016)
Wingspan (metres)	0.67	(Robinson, 2019; SNH, 2016)
Foraging trips per day	3.2	(Robbins, 2017)
Dives per foraging trip	55.3	(Robbins, 2017)
Mean underwater dive duration (seconds)	73.10	(Robbins, 2017)
Vertical swim speed (metres per second)	1.10	(Robbins, 2017)
Breeding season nocturnal activity (% of daytime activity)	90	Expert judgement based on data in (Regular et al., 2010, 2011; Thaxter et al., 2009)
Non-breeding season nocturnal activity (% of daytime activity)	30	Expert judgement based on data in (Camphuysen, 1998)

Table 2-4 CRM/ERM Input Parameters for Manx Shearwater

Parameter and Unit	Value	Source
Dive type	Shallow	Expert judgement based on data in (Dean, 2012; Robbins, 2017; Shoji et al., 2016)
Length (metres)	0.34	(Robinson, 2019; SNH, 2016)
Wingspan (metres)	0.82	(Robinson, 2019; SNH, 2016)
Average number of dives in one hour	4.10	(Dean, 2012)

Parameter and Unit	Value	Source
Mean underwater dive duration (seconds)	13.49	(Shoji et al., 2016)
Vertical swim speed (metres per second)	0.976	(Dean, 2012)
Breeding season nocturnal activity (% of daytime activity)	0	Expert judgement based on data in (Dean, 2012; Dean et al., 2012; Shoji et al., 2016)

Table 2-5 CRM/ERM Input Parameters for Puffin

Parameter and Unit	Value	Source
Dive type	Shallow	Expert judgement based on data in (Robbins, 2017)
Length (metres)	0.28	(Robinson, 2019; SNH, 2016)
Wingspan (metres)	0.55	(Robinson, 2019; SNH, 2016)
Average number of dives in one day	332.9	(Robbins, 2017)
Mean underwater dive duration (seconds)	35.50	(Robbins, 2017)
Vertical swim speed (metres per second)	0.85	No data; razorbill value used as surrogate
Breeding season nocturnal activity (% of daytime activity)	10	Expert judgement based on data in (Shoji et al., 2015)

Table 2-6 CRM/ERM Input Parameters for Razorbill

Parameter and Unit	Value	Source
Dive type	Shallow	(SNH, 2016)
Length (metres)	0.38	(Robinson, 2019; SNH, 2016)
Wingspan (metres)	0.66	(Robinson, 2019; SNH, 2016)
Foraging trips per day	2.40	(Robbins, 2017)
Dives per foraging trip	268.3	(Robbins, 2017)
Mean underwater dive duration (seconds)	36.00	(Robbins, 2017)
Vertical swim speed (metres per second)	0.85	(Robbins, 2017)
Breeding season nocturnal activity (% of daytime activity)	90	Expert judgement based on data in (Regular et al., 2010, 2011; Thaxter et al., 2009)
Non-breeding season nocturnal activity (% of daytime activity)	30	Expert judgement based on data in (Camphuysen, 1998)

Table 2-7 CRM/ERM Input Parameters for Red-Throated Diver

Parameter and Unit	Value	Source
Dive type	Shallow	(SNH, 2016)
Length (metres)	0.61	(Robinson, 2019; SNH, 2016)
Wingspan (metres)	1.11	(Robinson, 2019; SNH, 2016)
Proportion of time foraging when at sea (%)	60.7	(Polak and Ciach, 2007)
Dive frequency when foraging (dives per second)	0.0309	(SNH, 2016)
Mean underwater dive duration (seconds)	27.20	(Robbins, 2017)
Vertical swim speed (metres per second)	1.50	No data; shag value used as surrogate

Table 2-8 CRM/ERM Input Parameters for Shag

Parameter and Unit	Value	Source
Dive type	Deep	SNH (2016)
Length (metres)	0.72	(Robinson, 2019; SNH, 2016)
Wingspan (metres)	0.98	(Robinson, 2019; SNH, 2016)
Foraging trips per day	2.70	(Robbins, 2017)
Dives per foraging trip	27.30	(Robbins, 2017)
Mean underwater dive duration (seconds)	41.10	(Robbins, 2017)
Vertical swim speed (metres per second)	1.50	(Robbins, 2017)

2.4. TURBINE ENVELOPE PARAMETERS

2.4.1. 40 MW Scenario

38. The parameters for the nine device envelopes considered for deployment in a single, 40 MW array, are presented in **Table 2-9**. These parameters have been developed following extensive consultation with a number of tidal device developers. As the parameters shared during the consultation process are commercially sensitive, the device envelopes are identified by alphanumeric codes rather than names.

39. With regard to rotor minimum depth, for floating devices this was set at the minimum water depth in which the device can be operated as per information provided by tidal device developers. Actual deployment depths may be deeper, meaning that for floating tidal devices, theoretical collision risk will be overestimated for birds with the "shallow dive" profile selected. For seabed mounted devices, minimum rotor depth was calculated using the average MDZ depth of 40 m (**Chapter 4, Project Description**), minus a single rotor diameter, minus an assumed 5 m clearance between the seabed and the lower reach of the rotor swept area.

Table 2-9 Tidal Device Parameter Envelopes

	1F	2F	3F	4F	5S	6S	7S	8S	9F
Position in water column (F = floating, S = seabed)	F	F	F	F	S	S	S	S	F
Blade length (metres)	10	2.5	5	13.5	7.5	13	5	5	2.5
Rotor minimum depth (metres)	3.2	5	5	6	20	9	25	25	1.3
Number of blades per rotor	2	3	2	2	6	3	2	3	3
Number of rotors per device	2	20	5	1	1	1	1	3	2
Blade "depth" (front to back when device viewed from side)	0.84	0.09	0.25	0.4	0.3	0.4	0.25	0.25	0.064
Blade "width" (edge to edge when device viewed from front)	2	0.2	1.1	0.2	0.2	0.2	0.8	0.8	-
Blade pitch at tip	2.4	0	5	5	5	5	5	0	-
Rotation speed (RPM)	8.71	26.7	18	10.1	7.5	7.5	22	22	13.6

	1F	2F	3F	4F	5S	6S	7S	8S	9F
Indicative power output of one device (MW)	2	1	1.5	1	1	1	0.3	1.2	0.1
Indicative number of devices for 40 MW array	20	40	27	40	40	40	134	34	400

2.4.1. 240 MW Scenario

40. The 240 MW scenario comprises of a combination of the device envelopes detailed in **Table 2-9**, which is described in **Table 2-10**. Whilst device envelopes 2 and 5 are not included in this indicative array, they remain under consideration for deployment, as evidenced by their inclusion in 40 MW scenario modelling. In total, the 240 MW array scenario consists of 259 devices.

Table 2-10 240 MW Array Composition

	1F	1F	4F	9F	3F	8S	3F	7S	6S	3F	Total
Array size (number of devices)	15	15	30	50	20	25	10	50	30	14	259
Array output (MW)	30	30	30	10	30	30	15	15	30	20	240

2.5. INTERPRETING THE OUTPUTS OF ERM AND CRM

2.5.1. Introduction

41. The risk posed to diving seabirds by collision risk with tidal stream devices is theoretical. This is because any effect has yet to be empirically demonstrated (i.e. there are no known records of bird collisions with tidal turbines). This may be due in part to the fact that the tidal stream industry is still in its infancy and there are very few studies in existence that empirically examine collision risk.

42. This section examines the modelling process and identifies a range of considerations that are of high importance when interpreting the outputs of ERM and CRM.

2.5.2. Comparison of ERM and CRM

43. A comparison of ERM and CRM outputs using the same input parameters was undertaken during collision risk assessment for the Fall of Warness tidal energy test site at the European Marine Energy Centre (EMEC). For the range of scenarios tested, the two models gave broadly similar output values but with a relatively consistent difference. The average number of encounter events predicted by CRM exceeded the number of collisions predicted by the Band model by a factor of approximately 1.4 for foot-propelled diving birds (which include red-throated diver and shag in this study) and was between 0.83-1.03 for wing-propelled diving birds (gannet, guillemot, puffin Manx shearwater (which may use both feet and wings for propulsion), and razorbill in this study).

44. The CRM to ERM ratios for this study are presented in **Table 2-11**. There is substantial variation between devices. ERM and CRM using device 1F, which of the device envelopes used in this

study bears the most similarity to the device used in the comparison described above, produced a CRM to ERM ratio of 1.51 to 1.60 for foot-propelled birds, and 0.88 to 1.09 for wing-propelled birds. These values are comparable to the ratios reported in the study described above.

Table 2-11 CRM/ERM Ratios for All Species

Species	1F	2F	3F	4F	5S	6S	7S	8S	9F
Gannet	1.08	0.31	0.75	1.45	-	-	-	-	-
Guillemot	0.99	0.47	0.85	1.30	0.58	1.13	0.71	0.47	-
Manx shearwater	1.09	0.46	0.88	1.39	-	-	-	-	-
Puffin	0.88	0.45	0.79	1.19	-	1.04	-	-	0.88
Razorbill	0.98	0.47	0.85	1.29	-	1.13	-	-	0.98
Red-throated diver	1.60	0.78	1.39	2.10	0.92	1.82	1.60	0.78	1.39
Shag	1.51	0.81	1.38	2.02	0.90	1.76	1.16	0.77	1.51

2.5.3. Model Assumptions Regarding Dive Profiles

45. Diving birds typically possess dive profiles which can be broadly classified as v-shaped or u-shaped, which start and end at the water surface, although they are almost certain to be more complex in reality and dependent on a wide range of factors. Trajectories relative to a tidal device could therefore be orientated at any angle between horizontal and vertical. For diving birds, the CRM assumes that birds approach devices from one direction only (travelling downstream at current speed, in a level swimming pattern front on into the device). In ERM, birds are assumed to be swimming in random directions and orientations with respect to the device. Neither model realistically represents the typical dive profile of many diving seabirds. However, the ERMs assumption of random swim direction and orientation is more akin to the real-life situation than the CRM assumption of perpendicular approach.

2.5.4. Precaution and Uncertainty

46. It is considered that the enforced simplification of assigning dive depth distribution (**Section 2.3.3)** may result in overestimation of the time spent at collision risk depth. Rather than always diving to collision risk depth, shallow diving birds such as razorbill undertake a substantial proportion of their dives in the first few metres of the water column (Benvenuti et al., 2001; MBIEG, 2019), and the same may also be true of deeper diving guillemots (MBIEG, 2019; Thaxter et al., 2010), although this species is adapted to both pelagic and benthic foraging, and therefore spends a relatively large proportion of its diving time at the bottom of u-shaped dives (Chimienti et al., 2017), which could occur at or beyond collision risk depth.

47. Whilst adjustment for diving activity at night has been made where appropriate by reducing by % of activity (**Section 2.3.4**), it is possible that dive profiles at night result in foraging activity occurring at substantially shallower depths in response to lower light levels, and potentially to prey occurring closer to the surface than during the day. This effect has been observed in guillemots (Kokubun et al., 2016; Regular et al., 2011) and razorbills (Benvenuti et al., 2001; Falk et al., 2000; Paredes et al., 2006). As this factor is not accounted for in the models, as it was considered there was no way of empirically accounting for this in a justifiable manner, substantial overestimation of collision risk at night is likely to have occurred for both guillemot and razorbill.

48. For birds, it should also be noted that ERM is likely to overestimate encounter rate, as it does not take account of the geometry of the blade and underestimates the likelihood that a small animal moving downstream may pass between blades.

2.5.5. Selecting Appropriate Avoidance Rates

49. There is considerable uncertainty regarding avoidance rates for several reasons. Firstly, it is expected that animals of relatively small size such as diving seabirds might be swept past moving tidal device blades while entrained within the tidal stream (Wilson et al., 2007). Secondly, given that the rotation speed of tidal stream turbines is generally much lower than wind turbines (where collisions are assumed to result in 100 % collision mortality) (Fraenkel, 2006), and dive and swim speeds of seabirds are much lower than their flight speeds (Alerstam et al., 2007; Bruderer and Boldt, 2001; Robbins, 2017), it is considered highly unlikely that the strike force of a collision would result in a trauma sufficient to cause injury or death in all collision events (Wilson et al., 2007). This may be particularly applicable to collisions occurring near the centre of rotor, downward strikes occurring on dive descents, and upward strikes occurring on dive ascent. Finally, no information exists on the ability of seabirds to avoid collisions with tidal turbines at any range. It should be noted that the burst speed of some species of diving birds relative to the speed of tidal device turbine blades is thought to be much higher when compared to the equivalent relationships between flying birds and wind turbines (Fraenkel, 2006; Wilson et al., 2007). This suggests that such close-range avoidance behaviour will be more successful in diving seabirds than may be the case for flying birds at wind farms.

50. For balance, it should also be noted that some information suggests that narrow fields of view and/or inability to see great distances underwater may increase the potential vulnerability of diving birds to collision with objects underwater (Martin and Wanless, 2015; White et al., 2007). Furthermore, in general, the eyes of birds occur on the sides of the head, meaning that high resolution occurs in the lateral fields of view, and frontal vision may be therefore be tuned for the detection of movement rather than detail (Martin, 2011), although it is possible that underwater adaptations to diving birds eyesight grants them greater sensitivity than is currently understood. The length, width and position of the bill may result in blind spots. That being said, no extensive reports of underwater collisions between seabirds and underwater objects have been reported. Whilst seabird bycatch due to entanglement of seabirds in fishing nets is a widely reported issue (Žydelis et al., 2013, 2009), this is considered a separate phenomenon to the theoretical risk of underwater collision presented here.

51. It is recognised that the models used here, and the comparability of their outputs to potential real-world impacts, will be shaped enormously by the selection of avoidance rates. As discussed during Ornithology Technical Working Group (TWG) meetings for this project, and in compliance with SNH (2016), a range of avoidance rates from 0 % to 99.9 % have been presented.

3. RESULTS OF CRM AND ERM

3.1. 40 MW SCENARIOS

52. For each species, three tables are presented. These present the predicted number of collisions in a single season for each device envelope for ERM and CRM, and a mean of the two models.

The size of the biologically relevant population of birds, based on information in **Chapter 11, Marine Ornithology**, is also provided.

53. As outputs have been presented as whole numbers, any small discrepancies in the mean of ERM and CRM tables are due to rounding up or down of values.

3.1.1. Breeding Gannet

Table 3-1 ERM Outputs for Breeding Gannet, 40 MW Scenarios

Reference population		**138,474 individuals**							
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	2	20	2	0	0	0	0	0	34
50 %	1	10	1	0	0	0	0	0	17
90 %	0	2	0	0	0	0	0	0	3
95 %	0	1	0	0	0	0	0	0	2
98 %	0	0	0	0	0	0	0	0	1
99 %	0	0	0	0	0	0	0	0	0
99.5 %	0	0	0	0	0	0	0	0	0
99.9 %	0	0	0	0	0	0	0	0	0

Table 3-2 CRM Outputs for Breeding Gannet, 40 MW Scenarios

Reference population		**138,474 individuals**							
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	2	6	2	1	0	0	0	0	-
50 %	1	3	1	0	0	0	0	0	-
90 %	0	1	0	0	0	0	0	0	-
95 %	0	0	0	0	0	0	0	0	-
98 %	0	0	0	0	0	0	0	0	-
99 %	0	0	0	0	0	0	0	0	-
99.5 %	0	0	0	0	0	0	0	0	-
99.9 %	0	0	0	0	0	0	0	0	-

Table 3-3 Mean ERM/CRM Outputs for Breeding Gannet, 40 MW Scenarios

Reference population		**138,474 individuals**							
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	2	13	2	1	0	0	0	0	-
50 %	1	6	1	0	0	0	0	0	-
90 %	0	1	0	0	0	0	0	0	-
95 %	0	1	0	0	0	0	0	0	-
98 %	0	0	0	0	0	0	0	0	-
99 %	0	0	0	0	0	0	0	0	-
99.5 %	0	0	0	0	0	0	0	0	-
99.9 %	0	0	0	0	0	0	0	0	-

3.1.2. Breeding Guillemot

Table 3-4 ERM Outputs for Breeding Guillemot, 40 MW Scenarios

Reference population		8,308 individuals							
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	3144	9263	3160	4311	3045	4578	3783	4255	5101
50 %	1572	4631	1580	2156	1523	2289	1891	2128	2550
90 %	314	926	316	431	305	458	378	426	510
95 %	157	463	158	216	152	229	189	213	255
98 %	63	185	63	86	61	92	76	85	102
99 %	31	93	32	43	30	46	38	43	51
99.5 %	16	46	16	22	15	23	19	21	26
99.9 %	3	9	3	4	3	5	4	4	5

Table 3-5 CRM Outputs for Breeding Guillemot, 40 MW Scenarios

Reference population		8,308 individuals							
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	3101	4345	2686	5593	1767	5193	2686	2015	-
50 %	1550	2173	1343	2797	883	2596	1343	1007	-
90 %	310	435	269	559	177	519	269	201	-
95 %	155	217	134	280	88	260	134	101	-
98 %	62	87	54	112	35	104	54	40	-
99 %	31	43	27	56	18	52	27	20	-
99.5 %	16	22	13	28	9	26	13	10	-
99.9 %	3	4	3	6	2	5	3	2	-

Table 3-6 Mean ERM/CRM Outputs for Breeding Guillemot, 40 MW Scenarios

Reference population		8,308 individuals							
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	3122	6804	2923	4952	2406	4885	3234	3135	-
50 %	1561	3402	1462	2476	1203	2443	1617	1568	-
90 %	312	680	292	495	241	489	323	314	-
95 %	156	340	146	248	120	244	162	157	-
98 %	62	136	58	99	48	98	65	63	-
99 %	31	68	29	50	24	49	32	31	-
99.5 %	16	34	15	25	12	24	16	16	-
99.9 %	3	7	3	5	2	5	3	3	-

3.1.3. Non-Breeding Guillemot

Table 3-7 ERM Outputs for Non-Breeding Guillemot, 40 MW Scenarios

Reference population		1,139,220 individuals							
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	674	1987	678	925	653	982	812	913	1094
50 %	337	994	339	463	327	491	406	457	547

Reference population	1,139,220 individuals								
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
90 %	67	199	68	93	65	98	81	91	109
95 %	34	99	34	46	33	49	41	46	55
98 %	13	40	14	19	13	20	16	18	22
99 %	7	20	7	9	7	10	8	9	11
99.5 %	3	10	3	5	3	5	4	5	5
99.9 %	1	2	1	1	1	1	1	1	1

Table 3-8 CRM Outputs for Non-Breeding Guillemot, 40 MW Scenarios

Reference population	1,139,220 individuals								
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	665	932	576	1200	379	1114	576	432	-
50 %	333	466	288	600	190	557	288	216	-
90 %	67	93	58	120	38	111	58	43	-
95 %	33	47	29	60	19	56	29	22	-
98 %	13	19	12	24	8	22	12	9	-
99 %	7	9	6	12	4	11	6	4	-
99.5 %	3	5	3	6	2	6	3	2	-
99.9 %	1	1	1	1	0	1	1	0	-

Table 3-9 Mean ERM/CRM Outputs for Non-Breeding Guillemot, 40 MW Scenarios

Reference population	1,139,220 individuals								
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	670	1460	627	1063	516	1048	694	673	-
50 %	335	730	314	531	258	524	347	336	-
90 %	67	146	63	106	52	105	69	67	-
95 %	33	73	31	53	26	52	35	34	-
98 %	13	29	13	21	10	21	14	13	-
99 %	7	15	6	11	5	10	7	7	-
99.5 %	3	7	3	5	3	5	3	3	-
99.9 %	1	1	1	1	1	1	1	1	-

3.1.4. Breeding Manx Shearwater

Table 3-10 ERM Outputs for Breeding Manx Shearwater, 40 MW Scenarios

Reference population	673,350 individuals								
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	33	204	33	6	0	0	0	0	326
50 %	17	102	17	3	0	0	0	0	163
90 %	3	20	3	1	0	0	0	0	33
95 %	2	10	2	0	0	0	0	0	16
98 %	1	4	1	0	0	0	0	0	7
99 %	0	2	0	0	0	0	0	0	3

Reference population	673,350 individuals								
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
99.5 %	0	1	0	0	0	0	0	0	2
99.9 %	0	0	0	0	0	0	0	0	0

Table 3-11 CRM Outputs for Breeding Manx Shearwater, 40 MW Scenarios

Reference population	673,350 individuals								
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	36	94	29	8	0	0	0	0	-
50 %	18	47	15	4	0	0	0	0	-
90 %	4	9	3	1	0	0	0	0	-
95 %	2	5	1	0	0	0	0	0	-
98 %	1	2	1	0	0	0	0	0	-
99 %	0	1	0	0	0	0	0	0	-
99.5 %	0	0	0	0	0	0	0	0	-
99.9 %	0	0	0	0	0	0	0	0	-

Table 3-12 Mean ERM/CRM Outputs for Breeding Manx Shearwater, 40 MW Scenarios

Reference population	673,350 individuals								
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	35	149	31	7	0	0	0	0	-
50 %	17	74	16	4	0	0	0	0	-
90 %	3	15	3	1	0	0	0	0	-
95 %	2	7	2	0	0	0	0	0	-
98 %	1	3	1	0	0	0	0	0	-
99 %	0	1	0	0	0	0	0	0	-
99.5 %	0	1	0	0	0	0	0	0	-
99.9 %	0	0	0	0	0	0	0	0	-

3.1.5. Breeding Puffin

Table 3-13 ERM Outputs for Breeding Puffin

Reference population	120 individuals								
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	15	137	24	11	0	8	0	0	96
50 %	8	68	12	6	0	4	0	0	48
90 %	2	14	2	1	0	1	0	0	10
95 %	1	7	1	1	0	0	0	0	5
98 %	0	3	0	0	0	0	0	0	2
99 %	0	1	0	0	0	0	0	0	1
99.5 %	0	1	0	0	0	0	0	0	0
99.9 %	0	0	0	0	0	0	0	0	0

Table 3-14 CRM Outputs for Breeding Puffin, 40 MW Scenarios

Reference population		120 individuals							
Avoidance Rate	1F	2F	3F	4F	5S	6S	7S	8S	9F
0 %	13	61	19	14	0	9	0	0	-
50 %	7	31	10	7	0	4	0	0	-
90 %	1	6	2	1	0	1	0	0	-
95 %	1	3	1	1	0	0	0	0	-
98 %	0	1	0	0	0	0	0	0	-
99 %	0	1	0	0	0	0	0	0	-
99.5 %	0	0	0	0	0	0	0	0	-
99.9 %	0	0	0	0	0	0	0	0	-

Table 3-15 Mean ERM/CRM Outputs for Breeding Puffin, 40 MW Scenarios

Reference population		120 individuals							
Avoidance Rate	1F	2F	3F	4F	5S	6S	7S	8S	9F
0 %	14	99	22	13	0	9	0	0	-
50 %	7	50	11	6	0	4	0	0	-
90 %	1	10	2	1	0	1	0	0	-
95 %	1	5	1	1	0	0	0	0	-
98 %	0	2	0	0	0	0	0	0	-
99 %	0	1	0	0	0	0	0	0	-
99.5 %	0	0	0	0	0	0	0	0	-
99.9 %	0	0	0	0	0	0	0	0	-

3.1.6. Breeding Razorbill

Table 3-16 ERM Outputs for Breeding Razorbill, 40 MW Scenarios

Reference population		1,458 individuals							
Avoidance Rate	1F	2F	3F	4F	5S	6S	7S	8S	9F
0 %	963	9544	1641	753	0	561	0	0	6723
50 %	481	4772	820	376	0	280	0	0	3362
90 %	96	954	164	75	0	56	0	0	672
95 %	48	477	82	38	0	28	0	0	336
98 %	19	191	33	15	0	11	0	0	134
99 %	10	95	16	8	0	6	0	0	67
99.5 %	5	48	8	4	0	3	0	0	34
99.9 %	1	10	2	1	0	1	0	0	7

Table 3-17 CRM Outputs for Breeding Razorbill, 40 MW Scenarios

Reference population		1,458 individuals							
Avoidance Rate	1F	2F	3F	4F	5S	6S	7S	8S	9F
0 %	946	4490	1393	972	0	635	0	0	-
50 %	473	2245	696	486	0	317	0	0	-
90 %	95	449	139	97	0	63	0	0	-

Reference population	1,458 individuals								
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
95 %	47	225	70	49	0	32	0	0	-
98 %	19	90	28	19	0	13	0	0	-
99 %	9	45	14	10	0	6	0	0	-
99.5 %	5	22	7	5	0	3	0	0	-
99.9 %	1	4	1	1	0	1	0	0	-

Table 3-18 Mean ERM/CRM Outputs for Breeding Razorbill, 40 MW Scenarios

Reference population	1,458 individuals								
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	954	7017	1517	862	0	598	0	0	-
50 %	477	3508	758	431	0	299	0	0	-
90 %	95	702	152	86	0	60	0	0	-
95 %	48	351	76	43	0	30	0	0	-
98 %	19	140	30	17	0	12	0	0	-
99 %	10	70	15	9	0	6	0	0	-
99.5 %	5	35	8	4	0	3	0	0	-
99.9 %	1	7	2	1	0	1	0	0	-

3.1.7. Non-Breeding Razorbill

Table 3-19 ERM Outputs for Non-Breeding Razorbill, 40 MW Scenarios

Reference population	341,422 (minimum) individuals								
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	961	9523	1637	751	0	560	0	0	6708
50 %	480	4762	818	376	0	280	0	0	3354
90 %	96	952	164	75	0	56	0	0	671
95 %	48	476	82	38	0	28	0	0	335
98 %	19	190	33	15	0	11	0	0	134
99 %	10	95	16	8	0	6	0	0	67
99.5 %	5	48	8	4	0	3	0	0	34
99.9 %	1	10	2	1	0	1	0	0	7

Table 3-20 CRM Outputs for Non-Breeding Razorbill, 40 MW Scenarios

Reference population	341,422 (minimum) individuals								
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	944	4480	1390	970	0	634	0	0	-
50 %	472	2240	695	485	0	317	0	0	-
90 %	94	448	139	97	0	63	0	0	-
95 %	47	224	69	49	0	32	0	0	-
98 %	19	90	28	19	0	13	0	0	-
99 %	9	45	14	10	0	6	0	0	-
99.5 %	5	22	7	5	0	3	0	0	-

Reference population		341,422 (minimum) individuals							
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
99.9 %	1	4	1	1	0	1	0	0	-

Table 3-21 Mean ERM/CRM Outputs for Non-Breeding Razorbill, 40 MW Scenarios

Reference population		341,422 (minimum) individuals							
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	952	7002	1513	861	0	597	0	0	-
50 %	476	3501	757	430	0	298	0	0	-
90 %	95	700	151	86	0	60	0	0	-
95 %	48	350	76	43	0	30	0	0	-
98 %	19	140	30	17	0	12	0	0	-
99 %	10	70	15	9	0	6	0	0	-
99.5 %	5	35	8	4	0	3	0	0	-
99.9 %	1	7	2	1	0	1	0	0	-

3.1.8. Non-Breeding (Year Round) Red-Throated Diver

Table 3-22 ERM Outputs for Non-Breeding Red-Throated Diver (Year Round), 40 MW Scenarios

Reference population		1,676 individuals							
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	69	753	126	59	2	52	0	0	506
50 %	35	377	63	29	1	26	0	0	253
90 %	7	75	13	6	0	5	0	0	51
95 %	3	38	6	3	0	3	0	0	25
98 %	1	15	3	1	0	1	0	0	10
99 %	1	8	1	1	0	1	0	0	5
99.5 %	0	4	1	0	0	0	0	0	3
99.9 %	0	1	0	0	0	0	0	0	1

Table 3-23 CRM Outputs for Non-Breeding Red-Throated Diver (Year Round), 40 MW Scenarios

Reference population		1,676 individuals							
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	111	589	176	124	2	94	0	0	-
50 %	56	295	88	62	1	47	0	0	-
90 %	11	59	18	12	0	9	0	0	-
95 %	6	29	9	6	0	5	0	0	-
98 %	2	12	4	2	0	2	0	0	-
99 %	1	6	2	1	0	1	0	0	-
99.5 %	1	3	1	1	0	0	0	0	-
99.9 %	0	1	0	0	0	0	0	0	-

Table 3-24 Mean ERM/CRM Outputs for Non-Breeding Red-Throated Diver (Year Round), 40 MW Scenarios

Reference population		**1,676 individuals**							
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	90	671	151	91	2	73	0	0	-
50 %	45	336	76	46	1	37	0	0	-
90 %	9	67	15	9	0	7	0	0	-
95 %	5	34	8	5	0	4	0	0	-
98 %	2	13	3	2	0	1	0	0	-
99 %	1	7	2	1	0	1	0	0	-
99.5 %	0	3	1	0	0	0	0	0	-
99.9 %	0	1	0	0	0	0	0	0	-

3.1.9. Breeding Shag

Table 3-25 ERM Outputs for Breeding Shag, 40 MW Scenarios

Reference population		**26 individuals**							
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	2	5	2	3	2	3	2	3	3
50 %	1	3	1	1	1	1	1	1	2
90 %	0	1	0	0	0	0	0	0	0
95 %	0	0	0	0	0	0	0	0	0
98 %	0	0	0	0	0	0	0	0	0
99 %	0	0	0	0	0	0	0	0	0
99.5 %	0	0	0	0	0	0	0	0	0
99.9 %	0	0	0	0	0	0	0	0	0

Table 3-26 CRM Outputs for Breeding Shag, 40 MW Scenarios

Reference population		**26 individuals**							
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	3	4	3	5	2	5	3	2	-
50 %	1	2	1	3	1	2	1	1	-
90 %	0	0	0	1	0	0	0	0	-
95 %	0	0	0	0	0	0	0	0	-
98 %	0	0	0	0	0	0	0	0	-
99 %	0	0	0	0	0	0	0	0	-
99.5 %	0	0	0	0	0	0	0	0	-
99.9 %	0	0	0	0	0	0	0	0	-

Table 3-27 Mean ERM/CRM Outputs for Breeding Shag, 40 MW Scenarios

Reference population		**26 individuals**							
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
0 %	2	5	2	4	2	4	2	2	-
50 %	1	2	1	2	1	2	1	1	-
90 %	0	0	0	0	0	0	0	0	-

Reference population		26 individuals						
Avoidance Rate	**1F**	**2F**	**3F**	**4F**	**5S**	**6S**	**7S**	**8S**	**9F**
95 %	0	0	0	0	0	0	0	0	-
98 %	0	0	0	0	0	0	0	0	-
99 %	0	0	0	0	0	0	0	0	-
99.5 %	0	0	0	0	0	0	0	0	-
99.9 %	0	0	0	0	0	0	0	0	-

3.2. 240 MW SCENARIO

54. For each species, three tables are presented. These present the predicted number of collisions in a single season for each device envelope for ERM and CRM, and a mean of the two models. The size of the biologically relevant population of birds, based on information in **Chapter 11, Marine Ornithology**, is also provided.

55. As outputs have been presented as whole numbers, any small discrepancies in the totals columns of all tables, and mean of ERM and CRM tables are due to rounding up or down of values.

3.2.1. Breeding Gannet

Table 3-28 ERM Outputs for Breeding Gannet, 240 MW Scenario

Reference population			**138,474 individuals**								
Avoidance Rate	**1F**	**1F**	**4F**	**9F**	**3F**	**8S**	**3F**	**7S**	**6S**	**3F**	**Total**
0 %	1	1	0	8	2	0	1	0	0	1	15
50 %	1	1	0	4	1	0	0	0	0	1	8
90 %	0	0	0	1	0	0	0	0	0	1	2
95 %	0	0	0	0	0	0	0	0	0	1	2
98 %	0	0	0	0	0	0	0	0	0	1	1
99 %	0	0	0	0	0	0	0	0	0	1	1
99.5 %	0	0	0	0	0	0	0	0	0	1	1
99.9 %	0	0	0	0	0	0	0	0	0	1	1

Table 3-29 CRM Outputs for Breeding Gannet, 240 MW Scenario

Reference population			**138,474 individuals**								
Avoidance Rate	**1F**	**1F**	**4F**	**9F**	**3F**	**8S**	**3F**	**7S**	**6S**	**3F**	**Total**
0 %	1	1	1	8	1	0	1	0	0	1	14
50 %	1	1	0	4	1	0	0	0	0	0	7
90 %	0	0	0	1	0	0	0	0	0	0	1
95 %	0	0	0	0	0	0	0	0	0	0	1
98 %	0	0	0	0	0	0	0	0	0	0	0
99 %	0	0	0	0	0	0	0	0	0	0	0
99.5 %	0	0	0	0	0	0	0	0	0	0	0

Reference population		138,474 individuals								
99.9 %	0	0	0	0	0	0	0	0	0	0

Table 3-30 Mean ERM/CRM Outputs for Breeding Gannet, 240 MW Scenario

Reference population		138,474 individuals								
Avoidance Rate	**1F**	**1F**	**4F**	**9F**	**3F**	**8S**	**3F**	**7S**	**6S**	**3F**	**Total**
0 %	1	1	0	8	2	0	1	0	0	1	14
50 %	1	1	0	4	1	0	0	0	0	1	7
90 %	0	0	0	1	0	0	0	0	0	0	2
95 %	0	0	0	0	0	0	0	0	0	0	1
98 %	0	0	0	0	0	0	0	0	0	0	1
99 %	0	0	0	0	0	0	0	0	0	0	1
99.5 %	0	0	0	0	0	0	0	0	0	0	1
99.9 %	0	0	0	0	0	0	0	0	0	0	0

3.2.2. Breeding Guillemot

Table 3-31 ERM Outputs for Breeding Guillemot, 240 MW Scenario

Reference population		8,308 individuals									
Avoidance Rate	**1F**	**1F**	**4F**	**9F**	**3F**	**8S**	**3F**	**7S**	**6S**	**3F**	**Total**
0 %	2358	2358	3234	1275	2370	3192	1185	1418	3433	1185	22008
50 %	1179	1179	1617	638	1185	1596	593	709	1717	593	11004
90 %	236	236	323	128	237	319	119	142	343	119	2201
95 %	118	118	162	64	119	160	59	71	172	59	1100
98 %	47	47	65	26	47	64	24	28	69	24	440
99 %	24	24	32	13	24	32	12	14	34	12	220
99.5 %	12	12	16	6	12	16	6	7	17	6	110
99.9 %	2	2	3	1	2	3	1	1	3	1	22

Table 3-32 CRM Outputs for Breeding Guillemot, 240 MW Scenario

Reference population		8,308 individuals									
Avoidance Rate	**1F**	**1F**	**4F**	**9F**	**3F**	**8S**	**3F**	**7S**	**6S**	**3F**	**Total**
0 %	2325	2325	4195	1275	2015	1511	1007	504	3894	1007	20059
50 %	1163	1163	2098	638	1007	755	504	252	1947	504	10030
90 %	233	233	420	128	201	151	101	50	389	101	2006
95 %	116	116	210	64	101	76	50	25	195	50	1003
98 %	47	47	84	26	40	30	20	10	78	20	401
99 %	23	23	42	13	20	15	10	5	39	10	201
99.5 %	12	12	21	6	10	8	5	3	19	5	100
99.9 %	2	2	4	1	2	2	1	1	4	1	20

Table 3-33 Mean ERM/CRM Outputs for Breeding Guillemot, 240 MW Scenario

Reference population			8,308 individuals							
Avoidance Rate	1F	1F	4F	9F	3F	8S	3F	7S	6S	3F	Total
0 %	2342	2342	3714	1275	2192	2351	1096	961	3664	1096	21034
50 %	1171	1171	1857	638	1096	1176	548	481	1832	548	10517
90 %	234	234	371	128	219	235	110	96	366	110	2103
95 %	117	117	186	64	110	118	55	48	183	55	1052
98 %	47	47	74	26	44	47	22	19	73	22	421
99 %	23	23	37	13	22	24	11	10	37	11	210
99.5 %	12	12	19	6	11	12	5	5	18	5	105
99.9 %	2	2	4	1	2	2	1	1	4	1	21

3.2.3. Non-Breeding Guillemot

Table 3-34 ERM Outputs for Non-Breeding Guillemot, 240 MW Scenario

Reference population			1,139,220 individuals								
Avoidance Rate	1F	1F	4F	9F	3F	8S	3F	7S	6S	3F	Total
0 %	506	506	694	274	508	685	763	304	737	763	5739
50 %	253	253	347	137	254	342	381	152	368	381	2869
90 %	51	51	69	27	51	68	76	30	74	76	574
95 %	25	25	35	14	25	34	38	15	37	38	287
98 %	10	10	14	5	10	14	15	6	15	15	115
99 %	5	5	7	3	5	7	8	3	7	8	57
99.5 %	3	3	3	1	3	3	4	2	4	4	29
99.9 %	1	1	1	0	1	1	1	0	1	1	6

Table 3-35 CRM Outputs for Non-Breeding Guillemot, 240 MW Scenario

Reference population			1,139,220 individuals								
Avoidance Rate	1F	1F	4F	9F	3F	8S	3F	7S	6S	3F	Total
0 %	499	499	900	274	432	324	216	108	836	216	4304
50 %	249	249	450	137	216	162	108	54	418	108	2152
90 %	50	50	90	27	43	32	22	11	84	22	430
95 %	25	25	45	14	22	16	11	5	42	11	215
98 %	10	10	18	5	9	6	4	2	17	4	86
99 %	5	5	9	3	4	3	2	1	8	2	43
99.5 %	2	2	5	1	2	2	1	1	4	1	22
99.9 %	0	0	1	0	0	0	0	0	1	0	4

Table 3-36 Mean ERM/CRM Outputs for Non-Breeding Guillemot, 240 MW Scenario

Reference population			1,139,220 individuals								
Avoidance Rate	1F	1F	4F	9F	3F	8S	3F	7S	6S	3F	Total

Reference population		1,139,220 individuals								
0 %	502	502	797	274	470	504	489	206	786	489	5021
50 %	251	251	398	137	235	252	245	103	393	245	2511
90 %	50	50	80	27	47	50	49	21	79	49	502
95 %	25	25	40	14	24	25	24	10	39	24	251
98 %	10	10	16	5	9	10	10	4	16	10	100
99 %	5	5	8	3	5	5	5	2	8	5	50
99.5 %	3	3	4	1	2	3	2	1	4	2	25
99.9 %	1	1	1	0	0	1	0	0	1	0	5

3.2.4. Breeding Manx Shearwater

Table 3-37 ERM Outputs for Breeding Manx Shearwater, 240 MW Scenario

Reference population			673,350 individuals								
Avoidance Rate	**1F**	**1F**	**4F**	**9F**	**3F**	**8S**	**3F**	**7S**	**6S**	**3F**	**Total**
0 %	25	25	5	82	25	0	13	0	0	13	186
50 %	12	12	2	41	13	0	6	0	0	6	93
90 %	2	2	0	8	3	0	1	0	0	1	19
95 %	1	1	0	4	1	0	1	0	0	1	9
98 %	0	0	0	2	1	0	0	0	0	0	4
99 %	0	0	0	1	0	0	0	0	0	0	2
99.5 %	0	0	0	0	0	0	0	0	0	0	1
99.9 %	0	0	0	0	0	0	0	0	0	0	0

Table 3-38 CRM Outputs for Breeding Manx Shearwater, 240 MW Scenario

Reference population			673,350 individuals								
Avoidance Rate	**1F**	**1F**	**4F**	**9F**	**3F**	**8S**	**3F**	**7S**	**6S**	**3F**	**Total**
0 %	27	27	6	82	22	0	11	0	0	11	186
50 %	14	14	3	41	11	0	5	0	0	5	93
90 %	3	3	1	8	2	0	1	0	0	1	19
95 %	1	1	0	4	1	0	1	0	0	1	9
98 %	1	1	0	2	0	0	0	0	0	0	4
99 %	0	0	0	1	0	0	0	0	0	0	2
99.5 %	0	0	0	0	0	0	0	0	0	0	1
99.9 %	0	0	0	0	0	0	0	0	0	0	0

Table 3-39 Mean ERM/CRM Outputs for Breeding Manx Shearwater, 240 MW Scenario

Reference population			673,350 individuals								
Avoidance Rate	**1F**	**1F**	**4F**	**9F**	**3F**	**8S**	**3F**	**7S**	**6S**	**3F**	**Total**
0 %	26	26	5	82	24	0	12	0	0	12	186
50 %	13	13	3	41	12	0	6	0	0	6	93
90 %	3	3	1	8	2	0	1	0	0	1	19

Reference population			673,350 individuals							
95 %	1	1	0	4	1	0	1	0	0	1	9
98 %	1	1	0	2	0	0	0	0	0	0	4
99 %	0	0	0	1	0	0	0	0	0	0	2
99.5 %	0	0	0	0	0	0	0	0	0	0	1
99.9 %	0	0	0	0	0	0	0	0	0	0	0

3.2.5. Breeding Puffin

Table 3-40 ERM Outputs for Breeding Puffin, 240 MW Scenario

Reference population			120 individuals								
Avoidance Rate	**1F**	**1F**	**4F**	**9F**	**3F**	**8S**	**3F**	**7S**	**6S**	**3F**	**Total**
0 %	11	11	9	24	18	0	9	0	6	9	99
50 %	6	6	4	12	9	0	5	0	3	5	49
90 %	1	1	1	2	2	0	1	0	1	1	10
95 %	1	1	0	1	1	0	0	0	0	0	5
98 %	0	0	0	0	0	0	0	0	0	0	2
99 %	0	0	0	0	0	0	0	0	0	0	1
99.5 %	0	0	0	0	0	0	0	0	0	0	0
99.9 %	0	0	0	0	0	0	0	0	0	0	0

Table 3-41 CRM Outputs for Breeding Puffin, 240 MW Scenario

Reference population			120 individuals								
Avoidance Rate	**1F**	**1F**	**4F**	**9F**	**3F**	**8S**	**3F**	**7S**	**6S**	**3F**	**Total**
0 %	10	10	10	24	15	0	7	0	7	7	90
50 %	5	5	5	12	7	0	4	0	3	4	45
90 %	1	1	1	2	1	0	1	0	1	1	9
95 %	1	1	1	1	1	0	0	0	0	0	5
98 %	0	0	0	0	0	0	0	0	0	0	2
99 %	0	0	0	0	0	0	0	0	0	0	1
99.5 %	0	0	0	0	0	0	0	0	0	0	0
99.9 %	0	0	0	0	0	0	0	0	0	0	0

Table 3-42 Mean ERM/CRM Outputs for Breeding Puffin, 240 MW Scenario

Reference population			120 individuals								
Avoidance Rate	**1F**	**1F**	**4F**	**9F**	**3F**	**8S**	**3F**	**7S**	**6S**	**3F**	**Total**
0 %	11	11	9	24	16	0	8	0	6	8	94
50 %	5	5	5	12	8	0	4	0	3	4	47
90 %	1	1	1	2	2	0	1	0	1	1	9
95 %	1	1	0	1	1	0	0	0	0	0	5
98 %	0	0	0	0	0	0	0	0	0	0	2
99 %	0	0	0	0	0	0	0	0	0	0	1

Reference population		120 individuals								
99.5 %	0	0	0	0	0	0	0	0	0	0
99.9 %	0	0	0	0	0	0	0	0	0	0

3.2.6. Breeding Razorbill

Table 3-43 ERM Outputs for Breeding Razorbill, 240 MW Scenario

Reference population		1,458 individuals								
Avoidance Rate	**1F**	**1F**	**4F**	**9F**	**3F**	**8S**	**3F**	**7S**	**6S**	**3F**	**Total**
0 %	722	722	565	1681	1230	0	615	0	421	615	6571
50 %	361	361	282	840	615	0	308	0	210	308	3285
90 %	72	72	56	168	123	0	62	0	42	62	657
95 %	36	36	28	84	62	0	31	0	21	31	329
98 %	14	14	11	34	25	0	12	0	8	12	131
99 %	7	7	6	17	12	0	6	0	4	6	66
99.5 %	4	4	3	8	6	0	3	0	2	3	33
99.9 %	1	1	1	2	1	0	1	0	0	1	7

Table 3-44 CRM Outputs for Breeding Razorbill, 240 MW Scenario

Reference population		1,458 individuals									
Avoidance Rate	**1F**	**1F**	**4F**	**9F**	**3F**	**8S**	**3F**	**7S**	**6S**	**3F**	**Total**
0 %	710	710	729	1681	1045	0	522	0	476	522	6395
50 %	355	355	365	840	522	0	261	0	238	261	3197
90 %	71	71	73	168	104	0	52	0	48	52	639
95 %	35	35	36	84	52	0	26	0	24	26	320
98 %	14	14	15	34	21	0	10	0	10	10	128
99 %	7	7	7	17	10	0	5	0	5	5	64
99.5 %	4	4	4	8	5	0	3	0	2	3	32
99.9 %	1	1	1	2	1	0	1	0	0	1	6

Table 3-45 Mean ERM/CRM Outputs for Breeding Razorbill, 240 MW Scenario

Reference population		1,458 individuals									
Avoidance Rate	**1F**	**1F**	**4F**	**9F**	**3F**	**8S**	**3F**	**7S**	**6S**	**3F**	**Total**
0 %	716	716	647	1681	1138	0	569	0	448	569	6483
50 %	358	358	323	840	569	0	284	0	224	284	3241
90 %	72	72	65	168	114	0	57	0	45	57	648
95 %	36	36	32	84	57	0	28	0	22	28	324
98 %	14	14	13	34	23	0	11	0	9	11	130
99 %	7	7	6	17	11	0	6	0	4	6	65
99.5 %	4	4	3	8	6	0	3	0	2	3	32
99.9 %	1	1	1	2	1	0	1	0	0	1	6

3.2.7. Non-Breeding Razorbill

Table 3-46 ERM Outputs for Non-Breeding Razorbill, 240 MW Scenario

Reference population			341,422 (minimum) individuals							
Avoidance Rate	1F	1F	4F	9F	3F	8S	3F	7S	6S	3F	Total
0 %	721	721	563	1677	1228	0	614	0	420	614	6557
50 %	360	360	282	839	614	0	307	0	210	307	3278
90 %	72	72	56	168	123	0	61	0	42	61	656
95 %	36	36	28	84	61	0	31	0	21	31	328
98 %	14	14	11	34	25	0	12	0	8	12	131
99 %	7	7	6	17	12	0	6	0	4	6	66
99.5 %	4	4	3	8	6	0	3	0	2	3	33
99.9 %	1	1	1	2	1	0	1	0	0	1	7

Table 3-47 CRM Outputs for Non-Breeding Razorbill, 240 MW Scenario

Reference population			341,422 (minimum) individuals								
Avoidance Rate	1F	1F	4F	9F	3F	8S	3F	7S	6S	3F	Total
0 %	708	708	728	1677	1042	0	521	0	475	521	6381
50 %	354	354	364	839	521	0	261	0	238	261	3190
90 %	71	71	73	168	104	0	52	0	48	52	638
95 %	35	35	36	84	52	0	26	0	24	26	319
98 %	14	14	15	34	21	0	10	0	10	10	128
99 %	7	7	7	17	10	0	5	0	5	5	64
99.5 %	4	4	4	8	5	0	3	0	2	3	32
99.9 %	1	1	1	2	1	0	1	0	0	1	6

Table 3-48 Mean ERM/CRM Outputs for Non-Breeding Razorbill, 240 MW Scenario

Reference population			341,422 (minimum) individuals								
Avoidance Rate	1F	1F	4F	9F	3F	8S	3F	7S	6S	3F	Total
0 %	714	714	645	1677	1135	0	568	0	447	568	6469
50 %	357	357	323	839	568	0	284	0	224	284	3234
90 %	71	71	65	168	114	0	57	0	45	57	647
95 %	36	36	32	84	57	0	28	0	22	28	323
98 %	14	14	13	34	23	0	11	0	9	11	129
99 %	7	7	6	17	11	0	6	0	4	6	65
99.5 %	4	4	3	8	6	0	3	0	2	3	32
99.9 %	1	1	1	2	1	0	1	0	0	1	6

3.2.8. Non-Breeding (Year Round) Red-Throated Diver

Table 3-49 ERM Outputs for Non-Breeding Red-Throated Diver (Year Round), 240 MW Scenario

Reference population		1,676 individuals								
Avoidance Rate	1F	1F	4F	9F	3F	8S	3F	7S	6S	3F	Total
0 %	52	52	44	126	95	0	47	0	39	47	503
50 %	26	26	22	63	47	0	24	0	19	24	252
90 %	5	5	4	13	9	0	5	0	4	5	50
95 %	3	3	2	6	5	0	2	0	2	2	25
98 %	1	1	1	3	2	0	1	0	1	1	10
99 %	1	1	0	1	1	0	0	0	0	0	5
99.5 %	0	0	0	1	0	0	0	0	0	0	3
99.9 %	0	0	0	0	0	0	0	0	0	0	1

Table 3-50 CRM Outputs for Non-Breeding Red-Throated Diver (Year Round), 240 MW Scenario

Reference population		1,676 individuals									
Avoidance Rate	1F	1F	4F	9F	3F	8S	3F	7S	6S	3F	Total
0 %	83	83	93	126	132	0	66	0	71	66	720
50 %	42	42	46	63	66	0	33	0	35	33	360
90 %	8	8	9	13	13	0	7	0	7	7	72
95 %	4	4	5	6	7	0	3	0	4	3	36
98 %	2	2	2	3	3	0	1	0	1	1	14
99 %	1	1	1	1	1	0	1	0	1	1	7
99.5 %	0	0	0	1	1	0	0	0	0	0	4
99.9 %	0	0	0	0	0	0	0	0	0	0	1

Table 3-51 Mean ERM/CRM Outputs Non-Breeding Red-Throated Diver (Year Round), 240 MW Scenario

Reference population		1,676 individuals									
Avoidance Rate	1F	1F	4F	9F	3F	8S	3F	7S	6S	3F	Total
0 %	68	68	68	126	113	0	57	0	55	57	612
50 %	34	34	34	63	57	0	28	0	27	28	306
90 %	7	7	7	13	11	0	6	0	5	6	61
95 %	3	3	3	6	6	0	3	0	3	3	31
98 %	1	1	1	3	2	0	1	0	1	1	12
99 %	1	1	1	1	1	0	1	0	1	1	6
99.5 %	0	0	0	1	1	0	0	0	0	0	3
99.9 %	0	0	0	0	0	0	0	0	0	0	1

3.2.9. Breeding Shag

Table 3-52 ERM Outputs for Breeding Shag, 240 MW Scenario

Reference population			26 individuals							
Avoidance Rate	**1F**	**1F**	**4F**	**9F**	**3F**	**8S**	**3F**	**7S**	**6S**	**3F**	**Total**
0 %	1	1	2	1	1	2	1	1	2	1	13
50 %	1	1	1	0	1	1	0	0	1	0	7
90 %	0	0	0	0	0	0	0	0	0	0	1
95 %	0	0	0	0	0	0	0	0	0	0	1
98 %	0	0	0	0	0	0	0	0	0	0	0
99 %	0	0	0	0	0	0	0	0	0	0	0
99.5 %	0	0	0	0	0	0	0	0	0	0	0
99.9 %	0	0	0	0	0	0	0	0	0	0	0

Table 3-53 CRM Outputs for Breeding Shag, 240 MW Scenario

Reference population			26 individuals								
Avoidance Rate	**1F**	**1F**	**4F**	**9F**	**3F**	**8S**	**3F**	**7S**	**6S**	**3F**	**Total**
0 %	2	2	4	1	2	1	1	0	4	1	18
50 %	1	1	2	0	1	1	0	0	2	0	9
90 %	0	0	0	0	0	0	0	0	0	0	2
95 %	0	0	0	0	0	0	0	0	0	0	1
98 %	0	0	0	0	0	0	0	0	0	0	0
99 %	0	0	0	0	0	0	0	0	0	0	0
99.5 %	0	0	0	0	0	0	0	0	0	0	0
99.9 %	0	0	0	0	0	0	0	0	0	0	0

Table 3-54 Mean ERM/CRM Outputs for Breeding Shag, 240 MW Scenario

Reference population			26 individuals								
Avoidance Rate	**1F**	**1F**	**4F**	**9F**	**3F**	**8S**	**3F**	**7S**	**6S**	**3F**	**Total**
0 %	2	2	3	1	2	1	2	1	3	1	16
50 %	1	1	1	0	1	0	1	0	1	0	8
90 %	0	0	0	0	0	0	0	0	0	0	2
95 %	0	0	0	0	0	0	0	0	0	0	1
98 %	0	0	0	0	0	0	0	0	0	0	0
99 %	0	0	0	0	0	0	0	0	0	0	0
99.5 %	0	0	0	0	0	0	0	0	0	0	0
99.9 %	0	0	0	0	0	0	0	0	0	0	0

4. PVA

4.1. INTRODUCTION

56. PVAs were undertaken to assess the potential population-level impacts of the predicted collision and displacement mortalities as a result of the project on the South Stack and Penlas SMP master site breeding guillemot and breeding razorbill populations. The outputs of the estimation of collision mortalities is provided in **Section 3**, and for PVA, the means of ERM and CRM outputs are used as inputs. Also included in the PVA are any mortalities due to airborne noise and visual disturbance, details of which are provided in **Chapter 11, Marine Ornithology**.

4.2. METHODS

57. PVAs were based on density independent, deterministic, Leslie-matrix population models (Green et al., 2016) run over a 25-year projection period. The growth of each population over the projection period was simulated using a matrix-based age-structured model, generally termed a transition matrix, as commonly used in population modelling (Caswell, 2000). Age-structured models attempt to account for the fact that organisms of different ages have different characteristics, with these reflected in their vital rates (e.g. annual survival rates).

58. Population growth for each species under baseline conditions (i.e. with no additional mortality as a result of the project) was modelled using the starting population sizes for the breeding adult age class, which consisted of the total number of breeding adults at the South Stack, Gogarth and Abraham's Bosom sub-colonies at the last available count. This was calculated by multiplying the total number of individuals on land counted by an appropriate k-value correction factor to give an estimate of the breeding adult population (in this case 1.34 (Harris et al., 2015)), together with the estimates of age-specific annual survival rates and breeding productivity (i.e. the demographic rates) presented in **Table 4-1** for guillemot and **Table 4-3** for razorbill.

59. The number of individuals in the non-adult age classes at the start of the projection was calculated from the population stable age distribution, as estimated on the basis of the breeding adult population size and the demographic rates. The population models were based on a post-breeding census (i.e. immediately after annual reproduction) and assumed an even sex ratio.

60. The starting populations used for both species was that according to the latest SMP count multiplied by an appropriate k-value (1.34) (Harris et al., 2015). Had more recent RSPB count been available when the model had been run, the starting population would have been 12,984 for guillemot, and 1,790 for razorbill. These population estimates are approximately 75 % and 34 % larger than the starting populations used by the PVA. Larger starting populations would result in a population which may possess greater resilience with respect to additional mortality. As a result, the model outputs present a further layer of precaution.

61. Annual collision and displacement mortality (estimated using a matrix-based approach detailed in **Chapter 11, Marine Ornithology**) was assumed to be additive and was applied to the breeding adult age class only, resulting in a highly precautionary set of outputs. This additional mortality was applied in such a way that it was proportional to the population size throughout the projection period.

62. Population models were undertaken using the Rramas package, available in the R statistical software, and were run in R (R Core Team, 2016). The population stable age distribution was first estimated in Rramas, to provide the population sizes of each age class, prior to modelling the population projection and impact of the additional mortality.

63. Outputs from the PVAs were expressed in terms of the counterfactuals of the end-point population size (i.e. the ratio of the size of the impacted to predicted baseline population size after 25 years) and of the annual growth rate (i.e. the ratio of the growth rate of the impacted to predicted baseline population). These metrics have been demonstrated to have low sensitivity to the mis-specification of input parameters (e.g. demographic rates) and to the underlying assumptions of the population models from which the PVAs are derived (Cook and Robinson, 2016; Jitlal et al., 2017).

64. Although PVAs produced from deterministic population models may give less precautionary outputs than those based on stochastic population models (Cook and Robinson, 2016), recent work indicates that their overall performance is similar (Searle, 2018). Input Parameters

65. The input parameters used for the PVAs for guillemot and razorbill are presented in **Table 4-1, Table 4-2, Table 4-3** and **Table 4-4.**

Table 4-1 PVA Input Parameters for Guillemot

Parameter	Value	Source
Starting population size (in terms of no. of breeding adults)	7,457	(JNCC, 2018)
Age of first breeding	6	(Horswill and Robinson, 2015)
Annual survival rate of breeding adults (and immatures beyond 3 years)	0.939	(Horswill and Robinson, 2015)
Juvenile annual survival rate	0.56	(Horswill and Robinson, 2015)
Immature (1-2) annual survival rate	0.792	(Horswill and Robinson, 2015)
Immature (2-3) annual survival rate	0.917	(Horswill and Robinson, 2015)
Annual breeding success per active site	0.72	(Stubbings et al., 2017)

Table 4-2 PVA Annual Harvest Figures for Guillemot

Avoidance Rate	Annual Harvest (Collision, 40 MW Worst Case)	Annual Harvest (Collision, 240 MW)	Annual Harvest (Displacement)	Total Annual Harvest (40 MW Worst Case)	Total Annual Harvest (240 MW)
95 %	248	1052	12	254	1064
98 %	99	421	12	105	433
99 %	50	210	12	56	222
99.5 %	25	105	12	31	117
99.9 %	5	21	12	11	33

Table 4-3 PVA Input Parameters for Razorbill

Parameter	Value	Source
Starting population size (in terms of no. of breeding adults)	1,467	(JNCC, 2018)
Age of first breeding	5	(Horswill and Robinson, 2015)

Parameter	Value	Source
Annual survival rate of breeding adults (and immatures beyond 3 years)	0.895	(Horswill and Robinson, 2015)
Average survival rate, juvenile to recruitment	0.63	(Horswill and Robinson, 2015)
Annual breeding success per active site	0.53	(Stubbings et al., 2017)

Table 4-4 PVA Annual Harvest Figures for Razorbill

Avoidance Rate	Annual Harvest (Collision, 40 MW Worst Case)	Annual Harvest (Collision, 240 MW)	Annual Harvest (Displacement)	Total Annual Harvest (40 MW Worst Case)	Total Annual Harvest (240 MW)
95 %	76	324	0	76	324
98 %	30	130	0	30	130
99 %	15	65	0	15	65
99.5 %	8	32	0	8	32
99.9 %	2	6	0	2	6

4.3. RESULTS

4.3.1. Guillemot

Table 4-5 PVA Outputs for Guillemot at 40 MW Worst Case Device Deployment

Avoidance Rate	Growth Rate	Population After 25 Years (total individual breeding adults)	Counterfactual of Growth Rate	Counterfactual of 25 Year Population	25 Year Population Relative to Current Population
Baseline	1.037	18,353	N/A	N/A	2.461
95 %	1.018	11,686	0.982	0.637	1.566
98 %	1.030	15,615	0.994	0.851	2.092
99 %	1.033	16,485	0.997	0.918	2.209
99.5 %	1.035	17,445	0.998	0.951	2.337
99.9 %	1.036	17,909	0.999	0.976	2.399

Table 4-6 PVA Outputs for Guillemot at 240 MW Deployment

Avoidance Rate	Growth Rate	Population After 25 Years (total individual breeding adults)	Counterfactual of Growth Rate	Counterfactual of 25 Year Population	25 Year Population Relative to Current Population
Baseline	1.037	18,353	N/A	N/A	2.461
95 %	0.911	438	0.893	0.024	0.059
98 %	1.004	7,437	1.000	0.405	0.996
99 %	1.023	12,691	1.021	0.692	1.700
99.5 %	1.031	15,461	1.030	0.842	2.071
99.9 %	1.035	17,539	1.035	0.956	2.350

4.3.1. Razorbill

Table 4-7 PVA Outputs for Razorbill at 40 MW Worst Case Device Deployment

Avoidance Rate	Growth Rate	Population After 25 Years (total individual breeding adults)	Counterfactual of Growth Rate	Counterfactual of 25 Year Population	25 Year Population Relative to Current Population
Baseline	1.035	3,430	N/A	N/A	2.338
95 %	0.977	827	0.945	0.241	0.564
98 %	1.021	2,446	0.987	0.713	1.667
99 %	1.028	2,953	0.994	0.861	2.013
99.5 %	1.031	3,140	0.996	0.915	2.140
99.9 %	1.033	3,266	0.998	0.952	2.226

Table 4-8 PVA Outputs for Razorbill at 240 MW Deployment

Avoidance Rate	Growth Rate	Population After 25 Years (total individual breeding adults)	Counterfactual of Growth Rate	Counterfactual of 25 Year Population	25 Year Population Relative to Current Population
Baseline	1.035	3,430	N/A	N/A	2.338
95 %	0.233	0	0.226	0.000	0.000
98 %	0.889	77	0.859	0.022	0.052
99 %	0.990	1,152	0.957	0.336	0.785
99.5 %	1.019	2,371	0.985	0.691	1.616
99.9 %	1.032	3,186	0.997	0.929	2.172

5. REFERENCES

Alerstam, T., Rosén, M., Bäckman, J., Ericson, P.G.P., Hellgren, O., 2007. Flight Speeds among Bird Species: Allometric and Phylogenetic Effects. PLOS Biology 5, e197. https://doi.org/10.1371/journal.pbio.0050197

Band, W., Madders, M., Whitfield, P., 2007. Developing field and analytical methods to assess avian collision risk at windfarms, in: De Lucas, M., Janss, G., Ferrer, M. (Eds.), Birds and Wind Power.

Benvenuti, S., Dall'Antonia, L., Lyngs, P., 2001. Foraging behaviour and time allocation of chick-rearing Razorbills Alca torda at Græsholmen, central Baltic Sea. Ibis 143, 402–412. https://doi.org/10.1111/j.1474-919X.2001.tb04941.x

Bruderer, B., Boldt, A., 2001. Flight characteristics of birds: I. radar measurements of speeds. Ibis 143, 178–204. https://doi.org/10.1111/j.1474-919X.2001.tb04475.x

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L., Thomas, L., 2001. Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press, Oxford.

Camphuysen, C., 1998. Diurnal Activity Patterns and Nocturnal Group Formation of Wintering Common Murres in the Central North Sea. Colonial Waterbirds 21, 406. https://doi.org/10.2307/1521652

Caswell, H., 2000. Matrix Population Models: Construction, Analysis and Interpretation, 2nd Edition. ed. Sinauer Associates Inc, United States.

Chimienti, M., Cornulier, T., Owen, E., Bolton, M., Davies, I.M., Travis, J.M.J., Scott, B.E., 2017. Taking movement data to new depths: Inferring prey availability and patch profitability from seabird foraging behavior. Ecology and Evolution 7, 10252–10265. https://doi.org/10.1002/ece3.3551

Cook, A.S.C.P., Robinson, R.A., 2016. Testing sensitivity of metrics of seabird population response to offshore wind farm effects (JNCC Report No. 553). JNCC.

Cox, S.L., Miller, P.I., Embling, C.B., Scales, K.L., Bicknell, A.W.J., Hosegood, P.J., Morgan, G., Ingram, S.N., Votier, S.C., 2016. Seabird diving behaviour reveals the functional significance of shelf-sea fronts as foraging hotspots. Royal Society Open Science 3. https://doi.org/10.1098/rsos.160317

Dean, B., 2012. The at-sea behaviour of the Manx shearwater (Thesis submitted for the degree of Doctor of Philosophy). University of Oxford, Oxford.

Dean, B., Freeman, R., Kirk, H., Leonard, K., Phillips, R., M Perrins, C., Guilford, T., 2012. Behavioural mapping of a pelagic seabird: Combining multiple sensors and a hidden Markov model reveals the distribution of at-sea behaviour. Journal of the Royal Society Interface 10. https://doi.org/10.1098/rsif.2012.0570

Elliott, K.H., Gaston, A.J., 2015. Diel vertical migration of prey and light availability constrain foraging in an Arctic seabird. Marine Biology 162, 1739–1748. https://doi.org/10.1007/s00227-015-2701-1

Falk, K., Benvenuti, S., Dall'Antonia, L., Kampp, K., Ribolini, A., 2000. Time allocation and foraging behaviour of chick-rearing Brünnich's Guillemots Uria lomvia in high-arctic Greenland. Ibis 142, 82–92. https://doi.org/10.1111/j.1474-919X.2000.tb07687.x

Fraenkel, P.L., 2006. Tidal Current Energy Technologies. Ibis 148, 145–151. https://doi.org/10.1111/j.1474-919X.2006.00518.x

Furness, R., 2015. Non-breeding season populations of seabirds in UK waters: Population sizes for Biologically Defined Minimum Population Scales (BDMPS). Natural England Commissioned Report 164.

Furness, R.W., Garthe, S., Trinder, M., Matthiopoulos, J., Wanless, S., Jeglinski, J., 2018. Nocturnal flight activity of northern gannets Morus bassanus and implications for modelling collision risk at offshore wind farms. Environmental Impact Assessment Review 73, 1–6. https://doi.org/10.1016/j.eiar.2018.06.006

Furness, R.W., Wade, H.M., Robbins, A.M.C., Masden, E.A., 2012. Assessing the sensitivity of seabird populations to adverse effects from tidal stream turbines and wave energy devices. ICES Journal of Marine Science 69, 1466–1479. https://doi.org/10.1093/icesjms/fss131

Garthe, S., Benvenuti, S., Montevecchi, W.A., 2000. Pursuit plunging by northern gannets (Sula bassana) feeding on capelin (Mallotus villosus). Proc Biol Sci 267, 1717. https://doi.org/10.1098/rspb.2000.1200

Gerritsen, J., Strickler, J.R., 1977. Encounter Probabilities and Community Structure in Zooplankton: a Mathematical Model. J. Fish. Res. Bd. Can. 34, 73–82. https://doi.org/10.1139/f77-008

Green, R.E., Langston, R.H.W., McCluskie, A., Sutherland, R., Wilson, J.D., 2016. Lack of sound science in assessing wind farm impacts on seabirds. Journal of Applied Ecology 53, 1635–1641. https://doi.org/10.1111/1365-2664.12731

Harris, M.P., Heubeck, M., Newell, M.A., Wanless, S., 2015. The need for year-specific correction factors (k values) when converting counts of individual Common Guillemots Uria aalge to breeding pairs. Bird Study 62, 276–279. https://doi.org/10.1080/00063657.2015.1017444

Horswill, C., Robinson, R.A., 2015. Review of seabird demographic rates and density dependence (JNCC Report No. 552). JNCC, Peterborough.

Jitlal, M., Burthe, S., Freeman, S., Daunt, F., 2017. Testing and Validating Metrics of Change Produced by Population Viability Analysis (PVA) (Vol. 8 No. 23), Scottish Marine and Freshwater Science.

JNCC, 2018. Seabird Monitoring Programme Online Database (Online Database). JNCC.

Kokubun, N., Yamamoto, T., Sato, N., Watanuki, Y., Will, A., Kitaysky, A.S., Takahashi, A., 2016. Foraging segregation of two congeneric diving seabird species breeding on St. George Island, Bering Sea. Biogeosciences 13, 2579–2591. https://doi.org/10.5194/bg-13-2579-2016

Martin, G.R., 2011. Understanding bird collisions with man-made objects: a sensory ecology approach. Ibis 153, 239–254. https://doi.org/10.1111/j.1474-919X.2011.01117.x

Martin, G.R., Wanless, S., 2015. The visual fields of Common Guillemots Uria aalge and Atlantic Puffins Fratercula arctica: foraging, vigilance and collision vulnerability. Ibis 157, 798–807. https://doi.org/10.1111/ibi.12297

MBIEG, 2019. Improved understanding of underwater collision risks of marine renewable energy devices for birds while diving. A report produced by British Trust for Ornithology for the Marine Management Organisation on behalf of the Marine Biodiversity Impacts Evidence Group (No. MMO Project No: 1139).

McCluskie, A.E., Langston, R.H.W., Wilkinson, N.I., 2012. Birds and wave & tidal stream energy: an ecological review (RSPB Research Report No. 42). RSPB.

Paredes, R., L. Jones, I., Boness, D., 2006. Parental roles of male and female thick-billed murres and razorbills at the Gannet Islands, Labrador. Behaviour 143, 451–481. https://doi.org/10.1163/156853906776240641

Polak, M., Ciach, M., 2007. Behaviour of black-throated diver Gavia arctica and red-throated diver Gavia stellata during autumn migration stopover. Ornis Svecica 17, 90–94.

R Core Team, 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna.

Regular, P., Davoren, G., Hedd, A., Montevecchi, W., 2010. Crepuscular foraging by a pursuit-diving seabird: Tactics of common murres in response to the diel vertical migration of capelin. Marine Ecology Progress Series 415, 295–304. https://doi.org/10.3354/meps08752

Regular, P.M., Hedd, A., Montevecchi, W.A., 2011. Fishing in the dark: a pursuit-diving seabird modifies foraging behaviour in response to nocturnal light levels. PloS one 6, e26763–e26763. https://doi.org/10.1371/journal.pone.0026763

Robbins, A.M.C., 2017. Seabird ecology in high-energy environments: approaches to assessing impacts of marine renewables. University of Glasgow, Glasgow.

Robinson, R.A., 2019. BirdFacts: profiles of birds occurring in Britain & Ireland (BTO Research Report No. 407). British Trust for Ornithology, Thetford.

Searle, K., 2018. Regional Population Viability Analysis for Key Bird Species: a review of different modelling approaches.

Shoji, A., Dean, B., Kirk, H., Freeman, R., Perrins, C.M., Guilford, T., 2016. The diving behaviour of the Manx Shearwater Puffinus puffinus. Ibis 158, 598–606. https://doi.org/10.1111/ibi.12381

Shoji, A., Elliot, K., Fayet, A., Boyle, D., Perrins, C., Guilford, T., 2015. Foraging behaviour of sympatric razorbills and puffins. Mar Ecol Prog Ser 520, 257–267.

SNH, 2016. Assessing collision risk between underwater turbines and marine wildlife (Guidance note). Scottish Natural Heritage.

Stone, C.J., Webb, A., Barton, C., Ratcliffe, N., Reed, T.C., Tasker, M.L., Camphuysen, C.J., Pienkowski, M.W., 1995. An atlas of seabird distribution in north-west European waters. JNCC, Peterborough.

Stroud, D.A., Bainbridge, I.P., Maddock, A., Anthony, S., Baker, H., Buxton, N., Chambers, D., Enlander, I., Hearn, R.D., Jennings, K.R., Mavor, R., Whitehead, S., Wilson, J.D., 2016. The status of UK SPAs in the 2000s: the Third Network Review. JNCC, Peterborough.

Stubbings, E., Büche, B., Riordan, J., Moss, J., Wood, M., 2017. Seabird monitoring on Skomer Island in 2017 (JNCC Report).

Thaxter, C.B., Daunt, F., Hamer, K.C., Watanuki, Y., Harris, M.P., Grémillet, D., Peters, G., Wanless, S., 2009. Sex-specific food provisioning in a monomorphic seabird, the common guillemot Uria aalge: nest defence, foraging efficiency or parental effort? Journal of Avian Biology 40, 75–84. https://doi.org/10.1111/j.1600-048X.2008.04507.x

Thaxter, C.B., Wanless, S., Daunt, F., Harris, M.P., Benvenuti, S., Watanuki, Y., Grémillet, D., Hamer, K.C., 2010. Influence of wing loading on the trade-off between pursuit-diving and flight in common guillemots and razorbills. J. Exp. Biol. 213, 1018. https://doi.org/10.1242/jeb.037390

Wanless, S., Finney, S.K., Harris, M., McCafferty, D., 1999. Effect of the diel light cycle on the diving behaviour of two bottom feeding marine birds: the Blue-eyed Shag Phalacrocorax atriceps and the European Shag P. aristotelis. Marine Ecology Progress Series 188, 219–224. https://doi.org/10.3354/meps188219

White, C.R., Day, N., Butler, P.J., Martin, G.R., 2007. Vision and Foraging in Cormorants: More like Herons than Hawks? PLOS ONE 2, e639. https://doi.org/10.1371/journal.pone.0000639

Wilson, B., Batty, R.S., Daunt, F., Carter, C., 2007. Collision risks between marine renewable energy devices and mammals, fish and diving birds (Report to the Scottish Executive). Scottish Association for Marine Science.

Žydelis, R., Bellebaum, J., Osterblom, H., Vetemaa, M., Schirmeister, B., Stipniece, A., Dagys, M., van Eerden, M., Garthe, S., 2009. Bycatch in gillnet fisheries - An overlooked threat to waterbird populations. Biological Conservation 142, 1269–1281.

Žydelis, R., Small, C., French, G., 2013. The incidental catch of seabirds in gillnet fisheries: A global review. Biological Conservation 162, 76–88. https://doi.org/10.1016/j.biocon.2013.04.002