



Shetland Tidal Array Monitoring Report: Vantage point surveys

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Revision history

Version	Release date	Purpose/summary of amendments
1.0	24/02/2020	To present preliminary results from analysis of nine year's land-based bird and mammal observations in Bluemull Sound
2.0	16/06/2020	Updated to incorporate feedback from MS-LOT, SIC and SNH on V1.0 and detailed species-level analysis.
3.0	08/12/2020	Updated to incorporate further feedback from MS-LOT and MSS following a meeting on 20 October 2020.
4.0	22/02/2021	Updated to incorporate further feedback from MS-LOT and MSS in writing on 05 February 2021.
5.0	09/03/2021	Confidentiality restrictions on report removed for publication.

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1. Non-technical summary

This report presents the results from analyses of Nova Innovation's nine-year programme of land-based marine wildlife observation surveys in Bluemull Sound, carried out as part of the environmental monitoring programme for the Shetland Tidal Array.

Data from a total of 5208 10-minute snapshot scans for birds and 3120 20-minute scans for mammals have been analysed in this report, spanning the nine-year survey period. A total of thirty-three bird, eight mammal and one fish species have been recorded. Fifteen of the bird species and seven of the mammal species are capable of diving to turbine rotor depth (15m below sea level) and therefore 'at risk' of near-field encounters with turbines. Only these species were taken through to detailed analysis within this report. Basking shark was also recorded so has been included. A combination of descriptive statistics and modelling techniques have been used to explore the data for these species at risk of near-field encounters with the turbines in the Shetland Tidal Array.

The approach to analysis and interpretation of the vantage point data are based on understanding site-use at different scales, to understand the likelihood or probability of near-field encounters with turbines in the Shetland Tidal Array. Near-field encounters are only possible if a bird or animal uses the site. The likelihood increases if the bird or animal uses the area immediately around the turbines. For birds, this likelihood increases again if the bird dives in the area around the turbine. Dividing the process into these scales, provides useful metrics of the likelihood of near-field encounters, namely a conservative one (large scale), an intermediate one (medium scale) and a realized one (finest scale). The last is a realized one because it is the probability of a bird or animal diving in the immediate vicinity of the turbines. The first is a conservative one, because it acknowledges that any bird or animal in the site could potentially interact with turbines if they choose. These measures provide an understanding of site-use at different scales to understand the probability of encounters between birds and animals with turbines in the Shetland Tidal Array.

Two diving bird species, black guillemot (*Cephus grylle*) and European shag (*Phalacrocorax aristotelis*) accounted for over 90% of all birds recorded in surveys. All other diving bird species were recorded only occasionally in surveys and in generally very low numbers. With the notable exception of Atlantic puffin (*Fratercula arctica*), which was only present in summer months, most diving bird species were present to some extent throughout the year. Some systematic seasonal variance in occupancy was observed in some species throughout the entire survey area, for example, corresponding with breeding seasons. Birds were generally recorded as solitary individuals or in very small groups in scans, indicating that group foraging does not occur in the site.

Black guillemot, the most frequent and abundant bird species, was recorded in the array area (Zone 1) in 11% of all scans (561 scans of 5208), with birds observed diving in the array area in fewer than 3% of scans (143 scans). The second most frequent and abundant species, European shag, was only recorded in the array area (Zone 1) in <3% of all scans (150 scans), with birds observed diving in the array area in 1% of scans (54 scans). Three of the bird species (gannet, red-throated diver and common guillemot) were each observed diving in the array area in less than 5 occasions over the entire nine-year survey period. This indicates a low level of spatial overlap between diving birds and turbines in the Shetland Tidal Array, even when taking into account the most frequently recorded and abundant species.

Marine animals (mammals and basking shark) were recorded in the surveys relatively infrequently and in low numbers. Some species such as humpback whale (*Megaptera novaeangliae*), minke whale (*Balaenoptera acutorostrata*), Risso's dolphin (*Grampus griseus*), killer whale (*Orca orcinus*) and basking shark (*Cetorhinus maximus*) were only recorded in one or two scans over the entire

nine-year survey period. Atlantic grey seal (*Halichoerus grypus*), common seal (*Phoca vitulina*) and harbour porpoise (*Phocoena phocoena*) were the most frequently recorded species, but seldom recorded in the array area. Both species of seal were normally recorded as individual animals, while harbour porpoise was generally observed in small family groups.

Harbour porpoise accounted for 45% of all mammal sightings in surveys. Despite accounting for this high proportion of overall mammal sightings, harbour porpoise was only recorded in 5% of scans overall (175 scans from a total of 3120) and within the array area (Zone 1) in only 0.71% of scans (22 scans). Common seal accounted for 35% of all mammal sightings but was recorded in just 12% of scans (381 scan). The species was recorded within the array area (Zone 1) in only 0.32% of scans (10 scans). Grey seal accounted for 11% of all mammal sightings and was recorded in 5% of scans (156 scans) and within the array area (Zone 1) in just 0.06% of scans (2 scans). This indicates a very low level of spatial overlap between marine mammals and turbines in the Shetland Tidal Array, even when taking into account the most frequently recorded and abundant species.

The results presented in this report demonstrate that site-use of diving birds, mammals and basking shark in Bluemull Sound is low. This reflects the smaller absolute number of birds and animals occurring within the array area, compared to the wider Bluemull Sound survey area which directly influences impact risk. In the case of birds, very few were observed actively diving within the array area. Encounters with turbines in the Shetland Tidal Array are only possible if a bird or animal uses the site. The likelihood increases if the bird or animal uses the area immediately around the turbines. For birds, this likelihood increases again if the bird dives in the area around the turbines.

The results presented in this report indicate that the likelihood or probability of near-field encounters between all of the diving bird and marine mammal species recorded in the site during the nine-year programme of surveys is very low. For most species, the probability is negligible, but even for the most frequently and abundantly recorded species the risk is still very low (<5%). This is supported by the findings from analyses of video footage from Nova's complementary subsea video monitoring programme¹.

¹ Nova Innovation (2020a). Shetland Tidal Array monitoring report: Subsea video monitoring. EnFAIT-0364.

2. Introduction

This report presents results from Nova Innovation's nine-year programme of land-based vantage point surveys of marine wildlife, carried out in Bluemull Sound since November 2010, as part of the environmental monitoring programme for the Shetland Tidal Array (the "Project").

Details of the survey methodology are provided, along with metadata on the number and spread of survey coverage throughout the programme. The data analysis methodologies are detailed, including a rationale for the choice of statistical techniques selected to explore the data and key factors underlying marine wildlife occupancy patterns in Bluemull Sound and the sea area occupied by the Shetland Tidal Array.

The implications of the results for understanding the likelihood of near-field encounters between marine wildlife and turbines in the Shetland Tidal Array are discussed.

The report is provided in support of discharge of conditions attached to the licences for the Shetland Tidal Array, as detailed below:

- Marine Licence 06642/18/0, issued by Marine Scotland Licensing Operations Team on behalf of the Scottish Ministers, under the Marine (Scotland) Act 2020, part 4 (condition 3.2.1.1)
- Shetland Islands Council (SIC) Works Licence 2018/021/WL, issued under the Zetland County Council Act 1974 (condition 3)

This report is structured in the following sections:

Section 1: Non-technical summary

Section 2: Introduction

Section 3: The Shetland Tidal Array

Section 4: Vantage point surveys

Section 5: Data quality and reliability

Section 6: Data analysis

Section 7: Interpreting results

Section 8: Species recorded

Section 9-15: Results for diving birds

Section 16-19: Results for mammals and basking shark

Section 20: Discussion

Annex A: Tables of inter-annual variation in species counts

Annex B: Figures for descriptive statistics (provided in a separate document)

3. The Shetland Tidal Array

3.1 Location

The Shetland Tidal Array is situated in Bluemull Sound, between the islands of Unst and Yell, just offshore from the Ness of Cullivoe, as illustrated in Figure 3-1.



Figure 3-1 Location of the Shetland Tidal Array in Bluemull Sound, Shetland.

3.2 Project details

In June 2014 Nova installed and commissioned a 30 kW turbine in Bluemull Sound. The turbine was fully decommissioned in December 2016. The Shetland Tidal Array currently consists of three Nova M100 turbines: T1, T2 (deployed in 2016) and T3 (deployed in January 2017). In 2018, Nova was awarded licences from Marine Scotland and Shetland Islands Council to extend the array to six turbines. The turbines within the extended array (T4 to T6) will be deployed in 2020/21.

The turbines within the Shetland Tidal Array are installed subsea at a depth of 30-40m. The turbines use gravity base foundations that require no piling or drilling. The Nova M100 turbine is a 2-bladed, horizontal axis device, as illustrated in Figure 3-2.

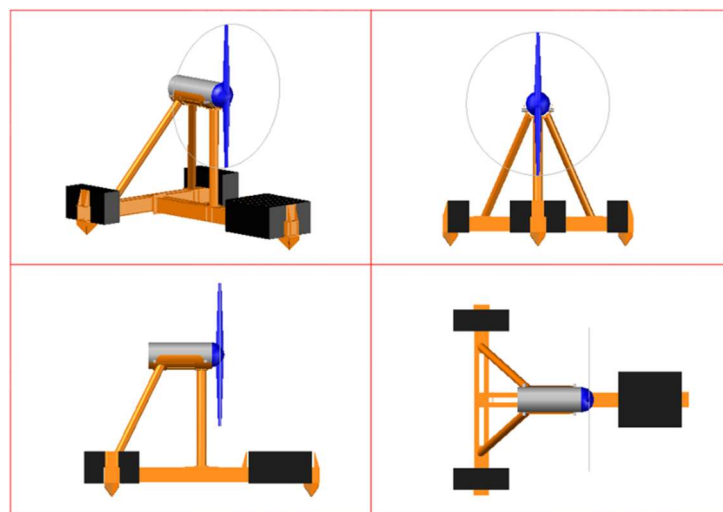


Figure 3-2 The Nova M100 turbine.

Source: Nova Innovation 2018

Figure 3-3 and Figure 3-4 show the layout of the existing three turbines and infrastructure in the Shetland Tidal Array, as well as the location of T4-T6.

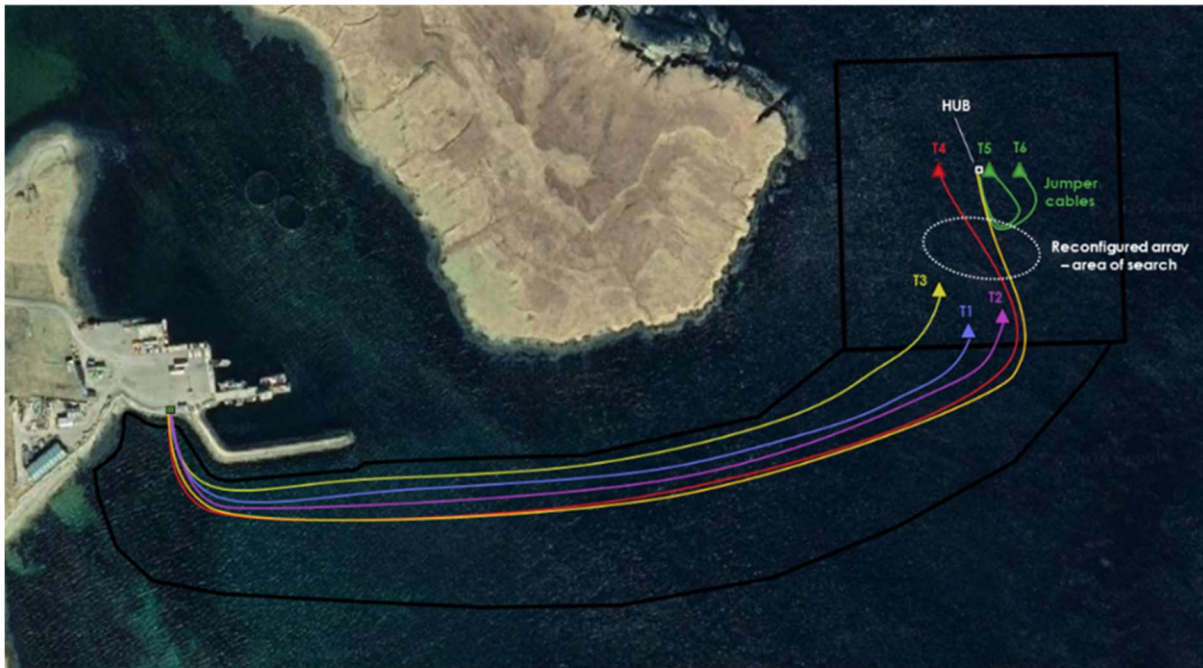


Figure 3-3 Shetland Tidal Array layout (satellite view).

Source: Nova Innovation 2020

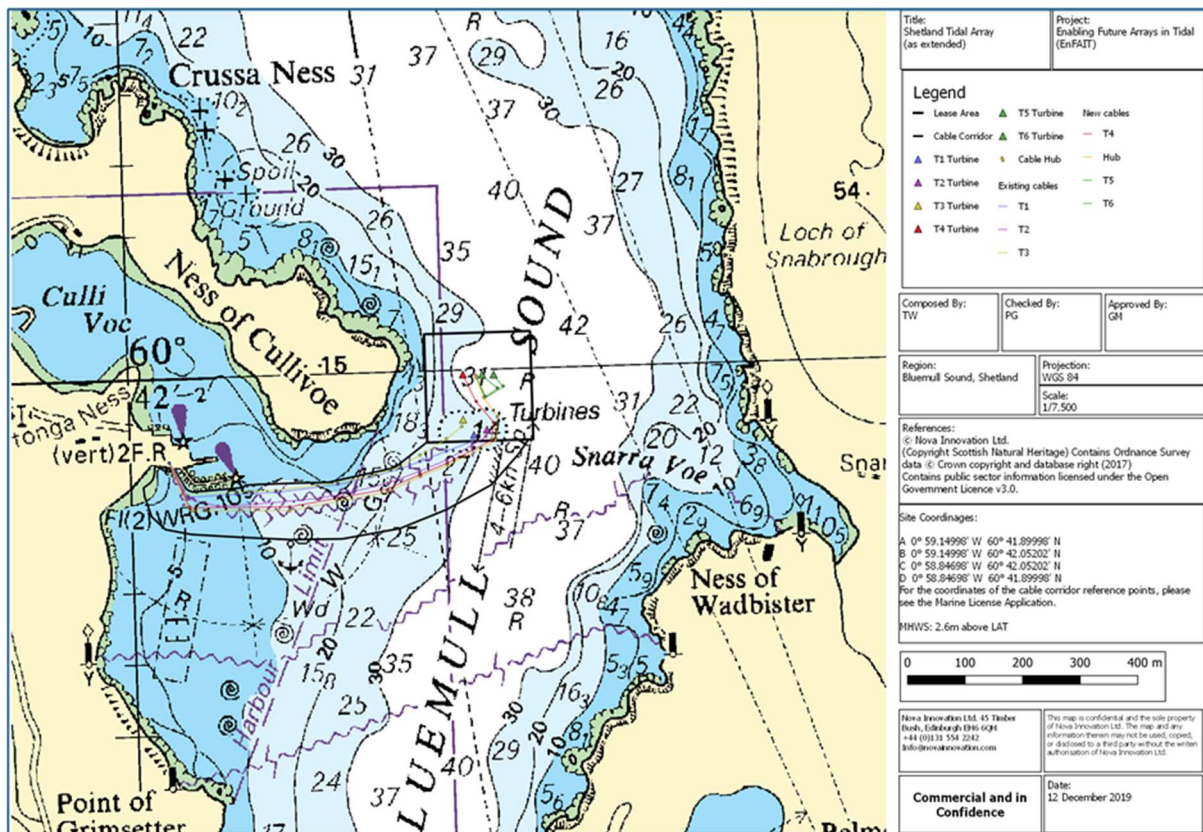


Figure 3-4 Shetland Tidal Array layout (Admiralty Chart).

Source: Nova Innovation 2020 © Crown Copyright

4. Vantage point surveys

4.1 Overview

Land-based vantage point surveys based on the methods described in this report commenced in November 2010. They continued until October 2019, at which point the methodology was amended, as set out in the Project Environmental Monitoring Plan for the extended six turbine Project². The surveys and the data presented in this report, cover pre-installation, construction and operational phases of the existing three-turbine Shetland Tidal Array. They also cover pre-installation, construction, operational and decommissioning phases of the earlier Nova 30 kW turbine deployed at the site.

The vantage point surveys were designed to gather a long-term dataset on the spatio-temporal distribution and behaviour of marine wildlife within the survey area, which includes the immediate Project site (the array area) and the wider central section of Bluemull Sound. Surveys were designed to record all marine wildlife in the survey area (birds, mammals, basking sharks).

4.2 Vantage point and survey area

The vantage point on the Ness of Cullivoe provides good coverage of the survey area and immediate Project site, while avoiding disturbance to otters on the shoreline of the Ness of Cullivoe. The position of the vantage point is 60.69949°N, -0.97091°W.

The survey area was defined to provide good coverage of the immediate Project site (the array area or Zone 1) and the wider central section of Bluemull Sound (Zone 2). Zone 2 is further subdivided into four areas A, B, C and D to enable further spatial delineation of observations. The outer boundaries of the survey area are defined by sight-lines to land-markers on Unst.

Figure 4-1 shows the survey area (delineated by green lines), with the dashed green line illustrating the trajectory of the marking point for the survey boundary. The vantage point on the Ness of Cullivoe is indicated by the blue dot. The four subdivisions (A, B, C, D) of Zone 2 are indicated by purple dashed lines. Delineation of these four subdivisions were marked out using transit sticks from the vantage point and sight-lines to a further land-marker on Unst, validated using a vessel positioned in Bluemull Sound to mark subdivision boundaries³. Figure 4-1 also indicates the array area, or Zone 1 (green circle). The pink square indicates The Crown Estate seabed lease area.

The total survey area is approximately 0.586 km². The total area of Zone 1 is approximately 0.008 km². The total area of Zone 2 is approximately 0.578 km² (A = 0.089 km², B = 0.305 km², C = 0.059 km² and D = 0.125 km²).

² Nova Innovation (2020b). EnFAIT-0362. Shetland Tidal Array Project Environmental Monitoring Plan (PEMP).

³ Note that in analyses, detailed in Section 6, data for Zone 2 (subzones A to D) have been amalgamated, removing the influence of any inconsistencies in subzone delineation between surveys. Zone 1 (the array area) was much closer to the surveyor and prominent landmarks were used to accurately delineate this zone.

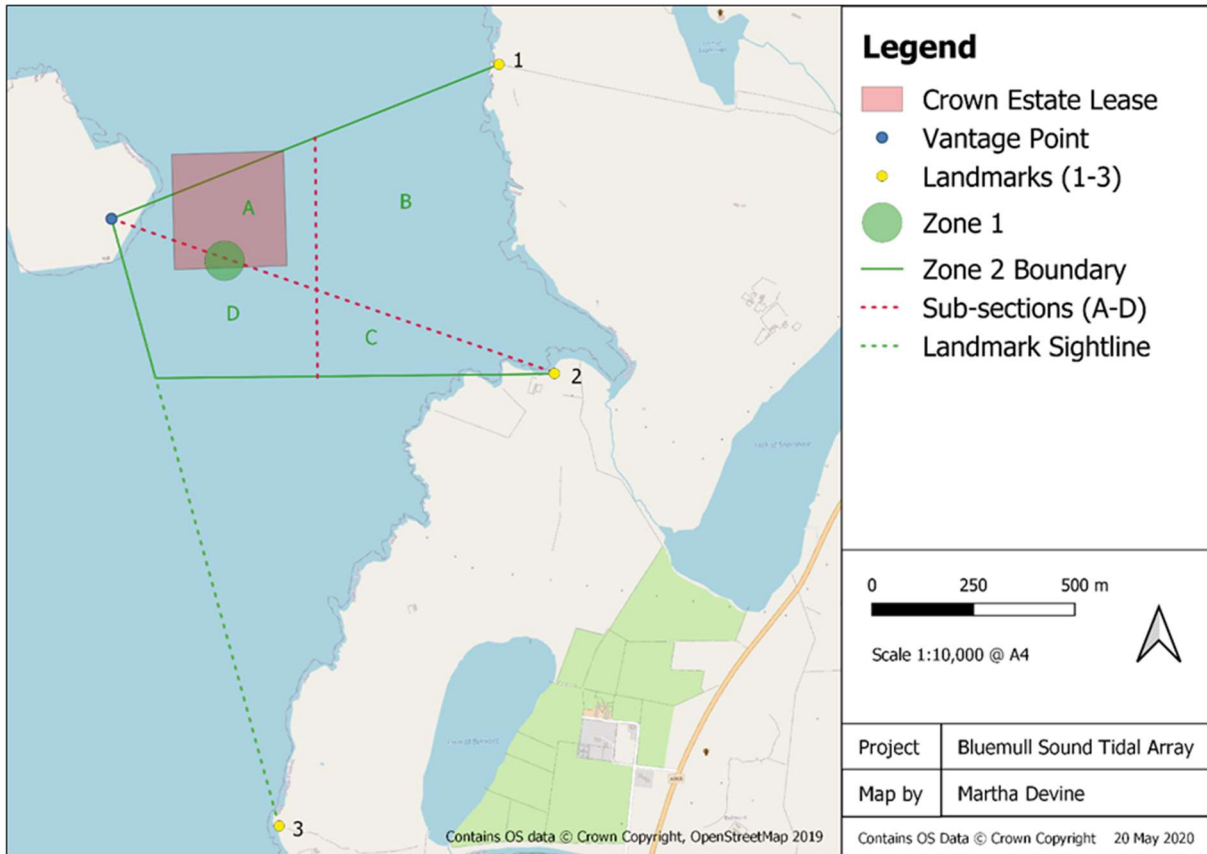


Figure 4-1 Vantage point survey area in Bluemull Sound. *Source: Nova Innovation 2020 © and Crown Copyright*

4.3 Survey design

The same survey design has been used throughout the nine-year period spanning November 2010 to October 2019. Each year was divided into 3-month periods as follows, to enable stratification throughout the year:

- February to April
- May to July
- August to October
- November to January

Nine 4-hour surveys were conducted within each 3-month period, on an annual basis. Where possible, surveys within each 3-month period were conducted across a range of times of day and states of tide (though survey design was not formally stratified to take this into account). All surveys were conducted in sea state 2 or less and in good light conditions. During winter, short daylight hours meant that surveys before 09:00 and after 15:00 were very limited.

Initial surveys were carried out by "Observer A" and "Observer B", who together run an environmental consultancy in Shetland. The initial use of two simultaneous surveyors enabled a period of methodology familiarisation, while enabling cross-validation, providing confidence in the survey design and resulting data. Between 2011 and 2016, Observer A carried out most of the surveys, with Observer B covering occasional surveys when necessary. Since 2016, all surveys have been carried out by Observer A. This high degree of surveyor consistency across the nine years of surveys helps ensure that any influence of surveyor variation in the data will be negligible.

4.4 Survey protocol

The vantage point survey methodology is based on an approach described in SNH guidance on survey and monitoring for marine renewables deployments in Scotland⁴, in which scans provide instantaneous ‘snapshot’ assessments of the marine wildlife present within the survey area.

Each 4-hour survey consisted of 24 snapshot scans for birds (one every 10 minutes) and 12 snapshot scans for mammals/basking sharks (one every 20 minutes).

Scans were completed in a single sweep to make them as analogous as possible to a snapshot in time. The rate of scanning was balanced to minimise the chance of overlooking diving individuals (birds) while minimising the chance of birds or mammals redistributing. Scans were also carried out against the tide, to minimise double-counting. This is a common method for land-based surveys in tidal environments and it functions in the same way as moving against the currents in a vessel⁵.

For the first 3 minutes of each scan all marine wildlife within the array area (Zone 1) was observed, identified to species-level and numbers of individuals counted. Birds were only counted and recorded if they were on the water, diving, or hovering directly above Zone 1. Birds transiting through Zone 1 (flying) were not counted. During each 3 minute scan in Zone 1, the following data were recorded for each bird species observed:

- a. Number of birds on the water, either making progress or stationary at the surface
- b. Number of birds diving
- c. Numbers of mammals/basking sharks

All mammals/basking sharks occurring within Zone 1 were recorded. Where possible, the following behaviours were also noted:

- a. Localised foraging: evidence of foraging within array area (e.g. repeated diving and resurfacing behaviour within array area)
- b. Transient foraging: evidence of foraging whilst transiting through the array area
- c. Transiting: no evidence of foraging (movement on a trajectory through the array area)

For the remainder of each scan birds, mammals and basking shark were identified to species level and counted in Zone 2. If the tide was running, scans were carried out against the tide, to minimise double-counting.

Only birds that were diving or loafing on the surface of the water within Zone 2 were recorded. Those transiting the area (i.e. flying) were not recorded. The number of sightings was recorded along with an estimation of the number of individuals and any general behaviour, direction of travel and other relevant observations. Any notable observations outside of scans are also recorded (for example marine mammal activity, vessel activity, bird feeding activity).

Surveys were carried out using Swarovski EL 8.5x42 binoculars. A Swarovski ATS 65 HD 25-50 zoom spotting scope was used for confirming species identification, if necessary. All marine wildlife observed during scans was recorded species level.

⁴ Jackson D. and Whitfield P. (2011). Guidance on survey and monitoring in relation to marine renewables deployments in Scotland. Volume 4. Birds. Unpublished draft report to Scottish Natural Heritage and Marine Scotland.

⁵ Waggitt JJ, Cazenave PW, Torres R, Williamson BJ and Scott BE (2016). Quantifying pursuit-diving seabirds' associations with fine-scale physical features in tidal stream environments. *J. App. Ecol.* 53: 1653-1666.

5. Data quality and reliability

5.1 Quality assurance procedures

Vantage point survey data were subject to a robust quality assurance (QA) procedure to ensure that only standardized data with high associated confidence were used in the analyses. Any errors and inconsistencies in the data were cross-checked against original data recording forms and surveyor supplementary notes. Where possible errors were corrected, but where this was not possible, data were excluded.

In general, confidence in mammal data was consistently high, even where weather and visibility was deemed to have affected confidence in some of the bird data. Black guillemot and small auk species were most affected by issues such as glare from the sun, or snow showers, with larger birds such as gannet and European shag rarely affected by such issues.

The QA process resulted in the exclusion of the following data from analyses detailed in this report:

1. Duplicate species records.
2. Counts from scans where data were missing due to poor conditions or poor visibility. Note that for some scans although bird data were deemed to be incomplete or missing, mammal data were retained. Based on discussions with the field surveyor, confidence in mammal data were always high given the larger size of targets, such that weather and glare did not affect data quality in the same way as for birds.
3. For all species, where any missing data was recorded for one or more species, the day was removed from the overall analysis to keep the number of scans used consistent between species.
4. Bird records where birds were only flying through survey area (not on surface or diving).
5. Data recorded outside scan periods.
6. Records of non-diving bird species and diving species not capable of diving to the rotor depth of the turbines (minimum 15 m below sea level), so not at risk of encounters with turbines and potential collisions with moving blades. All bird species recorded in vantage point surveys have been detailed in the full species list, but these excluded data have not been used in more detailed analyses.

This QA procedure excluded around 20% of vantage point data from the analyses detailed in this report. However, given the volume of data gathered since November 2010, significant quantities were still available for analyses. Data from a total of 5208 ten-minute bird scans from 217 survey days and 3120 twenty-minute mammal scans from 260 survey days have been analysed in this report.

5.2 Availability bias

Surface count data can be subject to availability bias since species are not visible continuously on the surface. If the data gathered were used to estimate absolute abundance, this would need to be accounted for and a correction applied to the data. However, in the analyses presented in this report we are not attempting to calculate absolute density. Instead we are using the probability of near-field encounters as the key metric for assessing risk (set out in Section 4.3).

In addition, there are no published literature on dive times in tidal energy habitats, which is likely to be quite different to that in other habitats. For instance, the behaviour and dispersal of prey in shallow and turbulent waters associated with tidal energy habitats are probably different to that in

deeper and slower waters where dive times have been recorded, encouraging the performance of alternative foraging strategies. Therefore, rather than correcting bias, use of published dive-times could introduce additional bias into the data and mis-estimate abundances. Finally, because observers were pre-occupied with providing snapshots of animal numbers rather than following birds, and because numbers of diving birds were very low, accompanying data on dive times within the site were not obtained.

Problems with correcting for availability bias in the data and the fact that birds and animals were almost always absent from scans, or present as individuals (see Section 7.3) is one of the reasons that the probability of near-field encounters represents a more appropriate metric than absolute densities for understanding encounter/collision risk for the Shetland Tidal Array, as set out in Section 6.5.

5.3 Detection decay with distance

Surface count data gathered from a land-based vantage point, as was used in the surveys in Bluemull Sound, can be subject to bias caused by reduced detectability with increasing distance from the observer (vantage point). SNH guidance on survey and monitoring for marine renewables deployments in Scotland indicates that detections using binoculars of marine birds will fall off markedly beyond about 700m which limits the use of shore-based vantage point methods to areas within approximately 1.5 km of the vantage point. All of the Bluemull Sound survey area is within 1 km of the vantage point, with most of it located much closer to the observer.

With currently available methods, accounting for detection decay with distance is only possible if distance is the major/sole influence on detectability and animals are homogeneously distributed across the survey area. Both of these are unlikely in Bluemull Sound. There is extensive evidence that animals are not homogeneously distributed in tidal sites, but use specific features and locations. There is also evidence that decay of detection of deep-diving birds with increasing distance may not apply in such sites where the furthest areas occur alongside prominent landmasses⁶. Further, fine-scale variations in surface roughness experienced at tidally influenced sites like Bluemull Sound could cause the breakdown of the conventional decay of detection with distance. Proximity to landmarks and features on Unst could mean that at certain times, detectability may be greatest in areas further from the surveyor, when surface roughness is reduced near the Unst shore.

Therefore, while there may be some detection decay with distance, in tidal sites such as Bluemull Sound, it is almost certainly confounded by other factors so cannot be accurately corrected. These other factors are likely to have greater underlying influence on patterns in the data than any detection decay.

⁶ Waggitt JJ, Bell PS and Scott BE (2014). An evaluation of the use of shore-based surveys for estimating spatial overlap between deep-diving seabirds and tidal stream turbines. *Int. J. Mar. Energy* 8: 36-49.

6. Data analysis

6.1 Approach to analysis

Data for all bird and mammal species recorded in surveys and basking shark are included in this report. A combination of descriptive statistics and modelling techniques have been used to explore the data, including any spatio-temporal occupancy patterns in species ‘at risk’ of encountering turbines within the Shetland Tidal Array. Detailed analyses have therefore focused on those species at risk of such encounters (thus excluding many of the bird species). In the case of birds, detailed analysis focused on those diving species that are features of protected sites, as identified in the environmental assessment for the extended Shetland Tidal Array⁷ have also been analysed.

Data for black guillemot (*Cepphus grylle*) were also analysed, as the most frequently observed and abundant diving bird species during the surveys. Analyses were also carried out on amalgamated data for all diving birds capable of diving to turbine depth (approximately 15m below low tide), to understand any general occupancy patterns.

For some species, sightings were limited, so for these, occurrences have been described but further analysis was not possible. Detailed analyses have been carried out on all ‘at risk’ species for which sufficient data were available. In the case of statistical modelling, data availability often prevented model convergence. Where this is the case, it has been identified in the relevant section of the report. Table 6-1 lists all the species for which detailed analyses (descriptive and statistical modelling) have been carried out in this report.

Table 6-1 Species observed in Bluemull Sound vantage point surveys for which detailed analyses have been carried out.

Diving birds	Mammals
Atlantic puffin (<i>Fratercula arctica</i>)	Common seal, <i>Phoca vitulina</i>
Common guillemot (<i>Uria aalge</i>)	Atlantic grey seal, <i>Halichoerus grypus</i>
European shag (<i>Phalacrocorax aristotelis</i>)	Harbour porpoise, <i>Phocoena phocoena</i>
Northern gannet (<i>Morus bassana</i>)	
Red-throated diver (<i>Gavia stellata</i>)	
Black guillemot (<i>Cepphus grylle</i>)	
All diving species (amalgamated)	

The approach to analysis of the vantage point data presented in this report are based on understanding site-use at different scales to understand the probability of encounters with turbines in the Shetland Tidal Array⁸. Encounters are only possible if a bird or animal uses the site. The likelihood increases if the bird or animal uses the area immediately around the turbines. For birds, this likelihood increases again if the bird dives in the area around the turbine. Dividing the process into these scales, provides useful metrics of the likelihood of near-field encounters, namely a conservative one (large scale), an intermediate one (medium scale) and a realized one (finest

⁷ Nova Innovation (2018). Shetland Tidal Array extension Environmental Assessment Report. Submitted in support of Marine Scotland Licence Application and Shetland Islands Council Works License Application.

⁸ e.g. see Waggitt JJ and Scott BE (2014). Using a spatial overlap approach to estimate the risk of collisions between deep diving seabirds and tidal stream turbines: A review of potential methods and approaches. Mar. Policy 44: 90–97.

scale). The last is a realized one because it is the probability of a bird or animal diving in the immediate vicinity of the turbines. The first is a conservative one, because it acknowledges that any bird or animal in the site could potentially interact with turbines if they choose. These measures provide an understanding of site-use at different scales to understand the probability of encounters between birds and animals with turbines in the Shetland Tidal. These 'encounter probabilities' could further be refined to understand the potential risk of collisions with rotating turbine blades by taking into account the operational status of turbines throughout the tidal cycle.

All analyses were carried out in R version 3.6.2.

6.2 Covariates for analysis

Various covariates were used in analyses to investigate potential relationships with the bird and mammal counts gathered during vantage point survey. Vantage point data were assigned to categories corresponding to each of the covariates detailed in Table 6-3.

Table 6-3 Covariates assigned to vantage point data for use in analyses.

Covariate	Details
Month	Vantage point data assigned to month
Season	Vantage point data assigned to summer (April to September) or winter (October to March)
Time period	Vantage point data assigned to one of the following time periods: <ul style="list-style-type: none"> - 06:00 to 10:00 - 10:01 to 14:00 - 14:01 to 18:00 - 18:01 to 22:00
Tidal period	Average counts per assigned to one of the following tidal periods: <ul style="list-style-type: none"> - Increasing flood (inc flood) - Maximum flood (max flood) - Decreasing flood (dec flood) - Increasing ebb (inc ebb) - Maximum ebb (max ebb) - Decreasing ebb (dec ebb)

Data for multiple years were used in the analyses set out in this report. However, year itself was not included as a covariate in analyses since this is not likely to be a key underlying driver influencing the risk of near-field encounters between the birds and animals and turbines the Shetland Tidal Array. Rather, the multiple years' data provide a large dataset to explore those covariates that are more likely to influence encounter risk (month, season, time of day and tidal period).

The tidal periods detailed in Table 6-3 were defined according to local conditions in Bluemull Sound derived from Nova’s tidal model, as set out Figure 6-1. These tidal definitions have been used previously in both tidal energy sites^{9 10} and across the wider marine environment¹¹.

Time after HW/LW	HIGH WATER						LOW WATER						HIGH WATER	
	6 th hr	1 st hr	2 nd hr	3 rd hr	4 th hr	5 th hr	6 th hr	1 st hr	2 nd hr	3 rd hr	4 th hr	5 th hr	6 th hr	1 st hr
Bluemull slacks			HW SLACK						LW SLACK					
Simplified slacks			HW SLACK						LW SLACK					
Tidal height rate of change (R.O. twelfths)	3	2	1	1	2	3	3	2	1	1	2	3	3	2
Direction	FLOODING				EBBING					FLOODING				
Tidal Periods	MF	Decreasing Flood	Increasing Ebb	Maximum Ebb	Decreasing Ebb	Increasing Flood	Maximum Flood	DF						

Figure 6-1 Details of tidal conditions in Bluemull Sound used define tidal periods for assigning to vantage point data. *Source: Nova Innovation 2020*

6.3 Count standardisation

All species counts were standardised to calculate relative densities, or individuals per scan, per km², for each 10-minute (birds) and 20-minute (mammals) scan. For each bird and animal species, counts of individuals per 10- or 20-minute scan were standardised by converting to numbers of individuals per scan, per km² using the following formula:

$$\text{Standardised count (individuals per scan, per km}^2\text{)} = \text{Scan count} \times \left[\frac{1}{\text{Zone area (km}^2\text{)}} \right]$$

For each scan, standardised counts for each species were then calculated for each of the following categories:

1. All Zones (the entire survey area, i.e. counts in Zone 1 + Zone 2)
2. Zone 1 only (the array area)
3. Birds observed diving in Zone 1 (bird species only)

The resulting standardised counts per scan for each Zone were then used to calculate mean standardised counts and standard errors, per species for the covariate categories described in Table 6-4 (over).

⁹ Zamon JE (2003). Mixed species aggregations feeding upon herring and sandlance schools in a nearshore archipelago depend on flooding tidal currents. *Mar Ecol Prog. Ser* 261: 243–255.

¹⁰ Cox SL, Scott BE and Camphuysen CJ (2013). Combined spatial and tidal processes identify links between pelagic prey species and seabirds. *Mar Ecol Prog Ser* 479: 203-221.

¹¹ Scott BE, Sharples J, Ross ON, Wang J, Pierce GJ and Camphuysen CJ (2010). Sub-surface hotspots in shallow seas: fine-scale limited locations of top predator foraging habitat indicated by tidal mixing and sub-surface chlorophyll. *Mar Ecol Prog Ser* 408: 207–226

Table 6-4 Covariate categories for which average counts of individuals per km² were calculated for use in analyses.

Covariate	Categories for count standardisation
Month	Counts by month
Season	Counts for summer and winter months
Time period	Counts for each time period
Tidal period	Counts for each tidal period

Mean standardised counts and standard errors, per species for the covariate categories above were calculated by totalling the sum of the standardised counts in a particular category and dividing by the number of scans within that category, using the following formula:

$$\text{Mean count per category} = \frac{\sum \text{standardised counts in each category}}{\text{Total scans in each category}}$$

These standardised counts, or relative densities, for each species were used in analyses to explore occupancy patterns in Zone 1 and the wider survey area, and the influence of covariates. Data for birds observed diving in Zone 1 were used for more detailed scrutiny of the risk of near-field encounters and the influence of covariates. A combination of descriptive and inferential statistical techniques using probability modelling were used. Analyses using descriptive statistics were carried out on standardised counts. For statistical modelling, counts of species per survey were presence/absence transformed.

6.4 Descriptive statistics

Descriptive statistics were used as the first step in analysing the standardised counts (number of individuals of each species per km²) from vantage point surveys, to summarize the large quantities of data and identify any patterns. Descriptive statistics were used to explore spatio-temporal patterns in species occupancy, in relation to the array area (Zone 1) and the wider survey area, as well as diving birds in Zone 1. Descriptive methods were used to explore patterns in the above by month, time of day, tidal period and to explore any inter-annual variation in overall species counts.

The outputs from descriptive statistics are presented as a series of plots in a separate Annex. Since the aim of these plots is to identify any patterns in species counts at the different spatial scales and across the different covariates explored, the axes of plots have been standardised for each species and covariate. For some of the plots this means that zooming in to relevant plots will enable the reader to examine them in more detail, if reviewing digitally. The Annex has been provided in an A3 landscape format to assist interpretation of printed copies.

An additional Annex (Annex A in this document), has been provided summarising inter-annual variation in counts for each species, to understand the degree of variability in bird and animal numbers in Bluemull Sound. Year has not been included as a covariate in analyses since this is not likely to be a key underlying driver influencing the risk of near-field encounters between the birds and animals and turbines the Shetland Tidal Array. Rather, the multiple years' data provide a large dataset to explore those covariates that are more likely to influence encounter risk (month, season, time of day and tidal period).

6.5 Statistical modelling

Modelling was used to calculate 'near-field encounter probabilities' (the likelihood of birds or animals occurring in the same space as, or interacting with a turbine) for the various species at different temporal (tides, seasons, times of day) and spatial scales (zones) in Bluemull Sound. To do so, counts of species per survey were transformed to presence (1) or absence (0) of a species per survey. A GEE-GLM (Generalised Linear Model with Generalised Estimating Equations) with a binomial distribution was used to generate the encounter probabilities. Month, season, tidal period, and time period were included as categorical explanatory variables and presence/absence transformed species' counts as the response variables. Survey day was included as a correlation structure to account for temporal autocorrelation, with counts from the same day more similar to each other than those from different days. This correlation structure also accounts for daily variations in environmental conditions likely to influence the presence of birds but not included as an explanatory variable e.g. local weather condition. Therefore, the resultant predictions of encounter probabilities should represent a typical survey in the site.

Encounter probabilities were chosen over encounter rates (numbers of animals interacting with a turbine) because high percentages of 0s and 1s in the data (see Section 7.3) are unsuitable for statistical models usually applied to count data with Poisson or Negative Binomial distribution. Moreover, the high percentage of 0s and 1s in the data would also have meant that these statistical models would have been effectively modelling encounter probabilities rather than encounter rates. Analysis was performed using the 'geepack' packages¹² in R version 3.6.2.

For each bird and mammal species analysed, encounter probabilities were calculated for each month, tidal period and time of day using the respective GEE-GLM. Spread in the encounter probabilities across surveys was estimated using the standard error. Models did not converge when one or more categories within a categorical variable contained a 100% of either presence (1) or absence (0). In these cases, probabilities were estimated by calculating the mean of the presence/absence data (i.e. 1s and 0s) and did not have a corresponding modelled range.

Where sample sizes were <15 (e.g. birds or mammals were observed in Zone 1 in less than 15 scans) a 0% probability was assumed. While it cannot be concluded that near-field encounter probability in these cases is absolute 0, it is reasonable to assume a very low encounter probability.

These approaches enabled the probability of spatial overlap, or near-field encounter probability, between birds and the Shetland Tidal Array to be calculated at three different scales, namely site (survey area), array area (Zone 1) and turbines (underwater in Zone 1) for each species, as set out below:

1. Probability of a bird occurring anywhere in the survey area (All Zones).
2. Probability of a bird occurring within Zone 1 - the array area (Zone 1).
3. Probability that a bird occurring in Zone 1 will dive (Diving Z1).

Component 3 above was calculated using the subset of positive bird sightings in Zone 1 for each species, to estimate the probability that a bird occurring in Zone 1 will dive. Finally, to calculate an overall 'proximity probability' for each bird species and the turbines in the Shetland Tidal Array, components 2 and 3 above were multiplied together to calculate a fourth component:

4. Probability of a bird diving in proximity to the turbines (Proximity probability).

¹² Højsgaard S, Halekoh U and Yan J (2006). The R Package geepack for generalized estimating equations. *Journal of Statistical Software*, 15(2): 1–11.

This value represents the conditional probability of a bird occurring within Zone 1 (the array area) **and** that it will dive, to provide an overall measure of proximity probability for diving birds and turbines in the Shetland Tidal Array.

For each of the three marine mammal species analysed, encounter probabilities were calculated for each month, tidal period and time of day as for birds at two scales, namely site (survey area) and array area (Zone 1), as set out below:

1. Probability of occurring anywhere in the survey area (All Zones).
2. Probability of occurring within Zone 1 - the array area (Zone 1).

The vantage point data do not provide information on underwater behaviour or distribution of marine mammals, so encounter probability could not be further refined. The probability of each species occurring within Zone 1 (the array area) is therefore the overall measure of proximity probability for marine mammals and turbines in the Shetland Tidal Array.

When GEE-GLMs converged and probabilities were estimated, pairwise comparisons on presence/absence data were run to identify any significant differences between categories. A Tukey test (with a Bonferroni correction) was used for all comparisons. The Bonferroni correction adjusts the p-value to produce a more conservative estimate of significance. This reduces the likelihood of falsely rejecting the null hypothesis (Type 1 error) through coming about a significant result by pure chance due to conducting multiple analyses on the same dependent variable.

7. Interpreting results

7.1 Interpreting differences in counts and probabilities

The descriptive statistics are presented as a series of plots provided in a separate Annex (Annex B). Since the aim of these plots is to identify any patterns in species counts at the different spatial scales and across the different covariates explored, the axes of plots have been standardised for each species and covariate. For some of the plots this means that zooming in to relevant plots will enable the reader to examine them in more detail, if reviewing on a computer. Annex B has been provided in an A3 landscape format to assist interpretation of printed copies.

Encounter probabilities set out in the preceding section are presented as a series of 'probability tables' in Sections 9 to 19, along with Tukey pairwise comparisons, where models converged to identify any significant differences between categories.

There are a number of important considerations for interpreting the various outputs from the analyses of data set out in this report. Overall survey effort is key, as is an understanding for the raw data, in particular the fact that the data tend to be 'zero- and one-dominated'. Most species were rarely recorded in vantage point surveys and when they were, they were almost always present as individuals or in very low numbers. Survey effort and zero and one dominance in the data are set out below.

The large number of samples (survey days = 217; individuals bird scans = 5208; individual mammal scans = 3120) used in the analysis increases the ability to detect small differences in probabilities amongst categories (tidal period, times of day and months). Small differences could result from a few surveys in relatively under-sampled categories coinciding with high numbers of encounters in good conditions, for instance. While these differences could also be the result of consistent differences between categories, interpretation of patterns should be made using absolute probabilities and differences across tidal period, times of day or months. The associated Tukey comparison p-values should only be used to confirm whether the statistical significance of any differences are of relevance in terms of refining understanding for near-field encounter risk.

While the focus of this report is on a quantitative analysis of the data gathered from vantage point surveys, Nova's field surveyor has developed a deep knowledge of the site and how it is used by marine wildlife. This comprehensive site knowledge provides contextual intelligence for interpreting the data and outputs from analyses, so is also summarised in this section.

7.2 Survey effort

7.2.1 Overview of survey effort

Overall survey effort is an important factor in interpreting the data and outputs from analyses, by providing an indication of how representative the count data are of any underlying bird and mammal occupancy patterns. A large volume of data have been gathered during vantage point surveys in Bluemull Sound since November 2010. Data from a total of 5208 ten-minute bird scans from 217 survey days and 3120 twenty-minute mammal scans from 260 survey days have been analysed in this report.

Sample sizes for each of the covariate categories used within analyses are presented below. Small sample sizes (<15 scans) are highlighted. For these categories, counts and analyses should be interpreted with caution.

7.2.2 Survey effort by month and season

The total number of scans and survey days per month are shown in Table 7-1.

Table 7-1 Total survey days and scans for birds and mammals (and basking shark) across all months for entire survey period.

Month	Birds		Mammals	
	Total survey days	Total scans	Total survey days	Total scans
January	13	312	20	240
February	18	432	22	264
March	21	504	24	288
April	22	528	26	312
May	22	528	24	288
June	21	504	21	252
July	25	600	25	300
August	21	504	22	264
September	18	432	20	240
October	15	360	21	252
November	11	264	20	240
December	10	240	15	180

7.2.3 Survey effort by time period

The total number of scans per time period category are shown in Table 7-2.

Table 7-2 Total survey effort (number of scans) across time periods for birds and mammals (and basking shark).

Time period	Birds	Mammals
06:00 to 10:00	114	77
10:01 to 14:00	2596	1626
14:01 to 18:00	2329	1316
18:01 to 22:00	169	101

The total number of scans per time period, per month are shown in Table 7-3 (over).

Table 7-3 Total survey effort (number of scans) by time period and month for a) birds and b) mammals (including basking shark). Categories for which sample size is limited (<15 scans) and for which counts and interpretation should be treated with caution are highlighted in bold italics. Analysis was not carried out on data where sample size = 0.

a) Birds

Month	06:00-10:00	10:01-14:00	14:01-18:00	18:01-22:00
January	7	265	40	0
February	2	339	91	0
March	16	253	235	0
April	5	223	291	9
May	26	186	304	12
June	4	179	253	68
July	20	167	374	39
August	2	222	263	17
September	13	137	258	24
October	10	199	151	0
November	8	199	57	0
December	1	227	12	0

b) Mammals and basking shark

Month	06:00-10:00	10:01-14:00	14:01-18:00	18:01-22:00
January	5	199	36	0
February	2	199	63	0
March	11	154	123	0
April	12	134	158	8
May	16	104	161	7
June	2	87	128	35
July	3	76	193	28
August	0	117	137	10
September	6	73	148	13
October	4	133	115	0
November	14	185	41	0
December	2	165	13	0

7.2.4 Survey effort by tidal period

The total number of scans per tidal period category are shown in Table 7-4 (over).

Table 7-4 Total survey days and scans across all months for entire survey period.

Tidal period	Birds	Mammals
Increasing Flood	727	451
Maximum Flood	716	411
Decreasing Flood	1068	647
Increasing Ebb	993	579
Maximum Ebb	866	507
Decreasing Ebb	838	525

The total number of scans per tidal period category, per month are shown in Table 7-5.

Table 7-5 Total survey effort (number of scans) by tidal period and month for a) birds and b) mammals (and basking shark). Categories for which sample size is limited (<15 scans) and for which counts and interpretation should be treated with caution are highlighted in bold italics.

a) Birds

Month	Inc Flood	Max Flood	Dec Flood	Inc Ebb	Max Ebb	Dec Ebb
January	55	94	156	69	87	48
February	45	52	79	84	99	109
March	79	48	75	95	78	92
April	28	112	139	115	81	84
May	80	73	102	109	77	91
June	94	57	62	117	82	104
July	90	42	69	94	78	77
August	71	39	75	90	21	34
September	81	39	47	46	53	12
October	32	37	39	62	62	50
November	51	61	110	44	76	56
December	21	62	115	68	72	81

b) Mammals and basking shark

Month	Inc Flood	Max Flood	Dec Flood	Inc Ebb	Max Ebb	Dec Ebb
January	45	34	45	44	36	36
February	28	35	60	50	52	39
March	51	38	64	47	39	49
April	22	53	92	67	48	30
May	41	28	47	63	53	56
June	47	25	35	59	39	47
July	45	60	76	43	38	38
August	37	36	54	50	42	45

Month	Inc Flood	Max Flood	Dec Flood	Inc Ebb	Max Ebb	Dec Ebb
September	45	27	31	24	48	65
October	28	24	54	45	48	53
November	46	26	44	37	32	55
December	16	25	45	50	32	12

7.3 Zero and one dominance in data

7.3.1 Bird species

With the exception of black guillemot and European Shag, most diving bird species were only occasionally recorded in vantage point surveys and when they were, they were almost always present as solitary individuals or in very low numbers. This zero and one dominance in the data influences the choice of analyses, as well as interpretation of the outputs. Table 7-6 details the proportion of scans in which counts were either zero (0) or one (1) for each of the bird species analysed in detail within this report.

Table 7-6 Proportion of scans (%) in which counts of the named bird species were zero (0) or one (1) for a) All Zones (the entire survey area) b) Zone 1 (array area) and c) birds observed diving in Zone 1. The actual number of scans (from the total of 5208) each proportion represents is shown in brackets.

a) All Zones (Entire survey area)

Species	% = 0	% = 1	% > 1	Total % = 0 or 1
Black guillemot	2.90 (151)	4.36 (227)	92.74 (4830)	7.26 (378)
European shag	34.12 (1777)	21.89 (1140)	43.99 (2291)	56.01 (2917)
Atlantic puffin	81.82 (4261)	7.22 (376)	10.96 (571)	89.04 (4637)
Common guillemot	88.04 (4585)	8.12 (423)	3.84 (200)	96.16 (5008)
Red-throated diver	91.95 (4789)	4.26 (222)	3.79 (197)	96.21 (5011)
Northern gannet	77.32 (4027)	11.58 (603)	11.10 (578)	88.90 (4630)

b) Zone 1 (array area)

Species	% = 0	% = 1	% > 1	Total % = 0 or 1
Black guillemot	89.23 (4647)	8.60 (448)	2.17 (113)	97.83 (5095)
European shag	97.12 (5058)	2.42 (126)	0.46 (24)	99.54 (5184)
Atlantic puffin	98.43 (5126)	1.01 (53)	0.56 (29)	99.44 (5179)
Common guillemot	99.58 (5186)	0.32 (17)	0.10 (5)	99.90 (5203)
Red-throated diver	99.90 (5203)	0.06 (3)	0.04 (2)	99.96 (5206)
Northern gannet	99.31 (5172)	0.48 (25)	0.21 (11)	99.79 (5197)

c) Birds diving in Zone 1 (array area)

Species	% = 0	% = 1	% > 1	Total % = 0 or 1
Black guillemot	97.25 (5065)	2.31 (120)	0.44 (23)	99.56 (5185)
European shag	98.96 (5154)	0.92 (48)	0.12 (6)	99.88 (5202)
Atlantic puffin	98.92 (5152)	0.77 (40)	0.31 (16)	99.69 (5192)
Common guillemot	99.92 (5204)	0.08 (4)	0.00 (0)	100 (5208)
Red-throated diver	99.98 (5207)	0.02 (1)	0.00 (0)	100 (5208)
Northern gannet	99.98 (5207)	0.02 (1)	0.00 (0)	100 (5208)

To further illustrate the low numbers of birds recorded in scans and their presence either as solitary individuals or in very small groups, Table 7-7 provides the mean count of birds in those scans where counts were greater than zero and indicates that group foraging is rare in the site.

Table 7-7 Mean counts of birds (number of individuals) in scans where counts were greater than zero, for All Zones (the entire survey area), Zone 1 (the array area) and birds observed diving in Zone 1.

Species	Entire survey area	Zone 1 (array area)	Birds diving in Zone 1
Black guillemot	9.86	1.27	1.20
European shag	6.10	1.48	1.26
Atlantic puffin	3.99	1.70	1.43
Common guillemot	1.58	1.36	1.00
Red-throated diver	1.66	1.40	1.00
Northern gannet	2.60	1.56	1.00

7.3.2 Mammal species and basking shark

Marine mammals and basking shark were recorded less frequently in vantage point surveys and in lower numbers than birds. For all species recorded at least once throughout the vantage point surveys, Table 7-8 details the proportion of scans in which counts were either zero (0) or one (1).

Table 7-8 Proportion of scans (%) in which counts of the named non-bird species were zero (0) or one (1) for a) All Zones (the entire survey area) and b) Zone 1 (array area). The actual number of scans (from the total of 3120) each proportion represents is shown in brackets.

a) All Zones (Entire survey area)

Species	% = 0	% = 1	% > 1	Total % = 0 or 1
Common seal	87.79 (2739)	9.01 (281)	3.2 (100)	96.8 (3020)
Atlantic grey seal	95.00 (2964)	4.39 (137)	0.61 (19)	99.39 (3101)
Harbour porpoise	94.39 (2945)	1.28 (40)	4.33 (135)	95.67 (2985)
Risso's dolphin	99.94 (3118)	0.00 (0)	0.06 (2)	99.94 (3118)
Humpback whale	99.97 (3119)	0.00 (0)	0.03 (1)	99.97 (3119)
Killer whale	99.97 (3119)	0.00 (0)	0.03 (1)	99.97 (3119)
Minke whale	99.90 (3117)	0.07 (2)	0.03 (1)	99.97 (3119)
Basking shark	99.94 (3118)	0.06 (2)	0.00 (0)	100 (3120)

b) Zone 1 (array area)

Species	% = 0	% = 1	% > 1	Total % = 0 or 1
Common seal	99.68 (3110)	0.32 (10)	0.00 (0)	100 (3120)
Atlantic grey seal	99.94 (3118)	0.06 (2)	0.00 (0)	100 (3120)
Harbour porpoise	99.29 (3098)	0.23 (7)	0.48 (15)	99.52 (3105)
Risso's dolphin	99.97 (3119)	0.03 (1)	0.00 (0)	0.00 (0)
Humpback whale	100.00 (3120)	0.00 (0)	0.00 (0)	100 (3120)
Killer whale	100.00 (3120)	0.00 (0)	0.00 (0)	100 (3120)
Minke whale	100.00 (3120)	0.00 (0)	0.00 (0)	100 (3120)
Basking shark	100.00 (3120)	0.00 (0)	0.00 (0)	100 (3120)

With the exception of harbour porpoise, killer whale and Risso's dolphin, when mammals and basking shark were observed in scans, they were almost always present as individuals, or in very low numbers. This is demonstrated in Table 7-9 which details the mean counts in those scans where counts were greater than zero.

Table 7-9 Mean counts of mammals and basking shark (number of individuals) in scans where counts were greater than zero, for the entire survey area and Zone 1.

Species	Entire survey area	Zone 1 (array area)
Common seal	1.51	1.00
Atlantic grey seal	1.13	1.00
Harbour porpoise	4.21	3.45
Risso's dolphin	12.50*	1.00
Humpback whale	2.00	<i>Not recorded</i>
Killer whale	10.00**	<i>Not recorded</i>
Minke whale	1.33	<i>Not recorded</i>
Basking shark	1.00	<i>Not recorded</i>

* Mean count based on one count of 5 individuals and one count of 20 individuals

** Mean count based on one count of 10 individuals

7.4 Field surveyor observations

During the nine years of vantage point surveys, Nova's field surveyor has developed a comprehensive knowledge of bird foraging behaviour in Bluemull Sound. Such observational notes are an important part of the evidence base on the occupancy patterns and behaviour of marine wildlife in Bluemull Sound, particularly in relation to surface hydrodynamic features and tidal period. Key observations are detailed as follows:

1. Diving birds are often observed to drift with surface currents through Bluemull Sound, diving and foraging as they drift. Groups and individuals periodically fly upstream, before settling on the water and drifting back ('conveyor belt' feeding). These observations are most noticeable in black guillemot and European shag, as the two species observed most frequently and consistently in vantage point surveys.

2. Diagonal rips are often observed to form off the northern and southern shores of the Ness of Cullivoe, when currents are running to the south (flood tide) or to the north (ebb tide), respectively. Birds, in particular black guillemot and European shag, are often observed foraging and feeding in these rips. During the summer, small mixed flocks of foraging Arctic tern, puffin, razorbill, common guillemot and occasionally red-throated diver sometimes also forage and feed following these rips. The rips indicate areas of high turbulence which are unsuitable for tidal energy extraction and are located several hundred metres from the turbines.
3. Aside from drifting, or foraging in the rips, diving birds sometimes remain and forage in the same spot within Bluemull Sound for extended periods of time. This is most noticeable in the still waters near to shore just off the Ness of Cullivoe, out of the main tidal flow and several hundred metres from the array turbines.
4. Large groups of European shag regularly roost in a field on the eastern side of Bluemull Sound on Unst. When they are disturbed by activity in the field (e.g. a person or farm vehicle), they fly up and settle on the water in Bluemull Sound. If this occurs during surveys, it results a large spike in counts.

8. Species recorded

All species recorded in vantage point surveys in Bluemull Sound were identified with confidence to species level. A total of thirty-three bird, eight mammal and one fish species were recorded, as detailed in Table 8-1. The final column of the table indicates whether the species recorded are capable of diving to the minimum depth of turbine rotors (15m below sea level) and therefore 'at risk' of near-field encounters with turbines (and therefore potentially collisions with moving blades). Fifteen of the bird species and seven of the mammal species are capable to diving to rotor depth. Only these species were taken through to detailed analysis within this report. Basking shark was also recorded so has been included in this report.

Table 8-1 All species recorded in Bluemull Sound vantage point surveys. Final column indicates those species capable of diving to turbine rotor depth.

Common name	Scientific name	Dives to rotor depth?
Anatidae (ducks, geese and swans)		
Greylag goose	<i>Anser anser</i>	No
Whooper swan	<i>Cygnus cygnus</i>	No
Wigeon	<i>Mareca penelope</i>	No
Mallard	<i>Anas platyrhynchos</i>	No
Greater scaup	<i>Aythya marila</i>	Yes
Common eider	<i>Somateria mollissima</i>	Yes
Long-tailed duck	<i>Clangula hyemalis</i>	Yes
Common goldeneye	<i>Bucephala clangula</i>	No
Red-breasted merganser	<i>Mergus serrator</i>	Yes
Podicipedidae (grebes)		
Slavonian grebe	<i>Podiceps auritus</i>	No
Phalaropidae (phalaropes)		
Red-necked phalarope	<i>Phalaropus lobatus</i>	No
Laridae (gull and terns)		
Black-legged kittiwake	<i>Rissa tridactyla</i>	No
Common gull	<i>Larus canus</i>	No
Iceland gull	<i>Larus glaucoides</i>	No
European herring gull	<i>Larus argentatus</i>	No

Common name	Scientific name	Dives to rotor depth?
Great black-backed gull	<i>Larus marinus</i>	No
Black headed gull	<i>Chroicocephalus ridibundus</i>	No
Arctic tern	<i>Sterna paradisaea</i>	No
Stercorariidae (skuas)		
Arctic skua	<i>Stercorarius parasiticus</i>	No
Great skua	<i>Stercorarius skua</i>	No
Alcidae (auks)		
Little auk	<i>Alle alle</i>	Yes
Common guillemot	<i>Uria aalge</i>	Yes
Razorbill	<i>Alca torda</i>	Yes
Black guillemot	<i>Cepphus grylle</i>	Yes
Atlantic puffin	<i>Fratercula articulata</i>	Yes
Gaviidae (divers)		
Red-throated diver	<i>Gavia stellata</i>	Yes
Great northern diver	<i>Gavia immer</i>	Yes
White-billed diver	<i>Gavia adamsii</i>	Yes
Procellariidae (tubenoses)		
Northern fulmar	<i>Fulmarus glacialis</i>	No
Storm petrel	<i>Hydrobates pelagicus</i>	No
Sulidae (gannets)		
Northern gannet	<i>Morus bassanus</i>	Yes
Phalacrocoracidae (cormorants and shags)		
Great cormorant	<i>Phalacrocorax carbo</i>	Yes
European shag	<i>Phalacrocorax aristotelis</i>	Yes
Phocidae (true seals)		
Grey seal	<i>Halichoerus grypus</i>	Yes
Harbour / common seal	<i>Phoca vitulina</i>	Yes

Common name	Scientific name	Dives to rotor depth?
Phocoenidae (toothed whales)		
Harbour porpoise	<i>Phocoena phocoena</i>	Yes
Delphinidae (oceanic dolphins)		
Killer whale	<i>Orca orcinus</i>	Yes
Risso's dolphin	<i>Grampus griseus</i>	Yes
Balaenopteridae (rorquals)		
Minke whale	<i>Balaenoptera acutorostrata</i>	Yes
Humpback whale	<i>Megaptera novaeangliae</i>	Yes
Lutrinae (otters)		
Eurasian otter	<i>Lutra lutra</i>	No ¹³
Cetorhinidae		
Basking shark	<i>Cetorhinus maximus</i>	Yes

¹³ As confirmed in advice from SNH to MS-LOT date 2 March 2018.

9. Black guillemot, *Cepphus grylle*

9.1 Occupancy by zone and month

The number and proportion of scans in which black guillemot was recorded, the mean standardised count per scan (per km²), and the mean count in positive scans are provided in Table 9-1.

Table 9-1 Number and proportion of scans in which counts of black guillemot were recorded, the mean standardised count per scan and the mean count in positive scans for All Zones (the entire survey area), Zone 1 (the array area) and Diving Z1 (birds observed diving in Zone 1). The actual number of scans (from the total of 5208) is shown in italics in brackets. % 0s is the proportion and number of scans in which the species was not recorded.

Survey area	% scans with positive records	% 0s	Mean standardised count per scan/km ²	Mean count per scan (positive scans only)
All Zones	97.10 (5057)	2.90 (151)	15.36	9.86
Zone 1	10.77 (561)	89.23 (4647)	2.05	1.27
Diving Z1	2.75 (143)	97.25 (5065)	0.49	1.20

Black guillemot was the most frequently recorded species in vantage point surveys. The species was observed in 97% of the 5208 scans for the entire survey area (All Zones) and in the array area (Zone 1) in 11% of scans. It was also the most abundant species, accounting for 62% of all bird sightings. In scans of the entire survey area, in which black guillemot was observed, an average of 9.86 birds per scan was recorded. Only 1 or 2 birds per scan were recorded in scans of the array area in which the species was observed.

Plots of descriptive statistics for black guillemot counts by survey area and month are provided in Annex B (separate document), Figure B1.

The highest average black guillemot count per scan across All Zones (the entire survey area) was in November (27.04 birds per km²). The corresponding counts for the species in Zone 1 (the array area) and diving in Zone were 4.18 birds per km² and 1.53 per km² respectively.

Table 9-2 (over) presents GEE-GLM (binomial) outputs for black guillemot by month, as follows:

1. Probability of a black guillemot occurring anywhere in the survey area (**All Zones**).
2. Probability of a black guillemot occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a black guillemot seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a black guillemot diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days.

Table 9-2 GEE-GLM (Binomial) estimations of 1) probabilities of a black guillemot occurring within the entire survey area (All Zones), 2) probabilities of a black guillemot occurring within the array area (Zone 1), 3) probabilities that a black guillemot seen in the array area will dive (Diving Z1) and 4) probabilities of a black guillemot diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets.

Month	All Zones		Zone 1		Diving Z1		Proximity probability	
Jan	0.981	(0.385-1)	0.099	(0-0.648)	0.194	(0-0.802)	0.019	(0-0.519)
Feb	0.993	(0.334-1)	0.097	(0-0.667)	0.381	(0-0.1)	0.037	(0-0.667)
Mar	0.996	(0.311-1)	0.067	(0-0.636)	0.206	(0-0.852)	0.014	(0-0.542)
Apr	0.989	(0.319-1)	0.110	(0-0.689)	0.379	(0-0.1)	0.042	(0-0.689)
May	0.992	(0.325-1)	0.134	(0-0.717)	0.183	(0-0.819)	0.025	(0-0.587)
Jun	0.988	(0.360-1)	0.121	(0-0.705)	0.180	(0-0.822)	0.022	(0-0.580)
Jul	0.987	(0.346-1)	0.138	(0-0.715)	0.205	(0-0.845)	0.028	(0-0.604)
Aug	0.913	(0.254-1)	0.083	(0-0.679)	0.214	(0-0.887)	0.018	(0-0.602)
Sep	0.935	(0.288-1)	0.090	(0-0.666)	0.256	(0-0.916)	0.023	(0-0.610)
Oct	0.992	(0.301-1)	0.100	(0-0.668)	0.167	(0-0.82)	0.017	(0-0.548)
Nov	0.962	(0.302-1)	0.182	(0-0.760)	0.396	(0-0.1)	0.072	(0-0.760)
Dec	0.871	(0.237-1)	0.067	(0-0.649)	0.438	(0-0.1)	0.029	(0-0.649)

Outputs from Tukey pairwise comparisons (with a Bonferroni correction) for black guillemot presence between months for All Zones and Zone 1 are shown in Table 9-3. Comparisons for Diving Z1 did not identify any significant differences so have not been provided.

Table 9-3 Black guillemot Tukey pairwise comparisons (with a Bonferroni correction) for zone and month, for a) All zones and b) Zone 1. Significant p-values are in bold.

a) All Zones

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.015
Feb	1.000		1.000	1.000	1.000	1.000	1.000	0.032	0.079	1.000	1.000	< 0.001
Mar	1.000	1.000		1.000	1.000	1.000	1.000	0.014	0.034	1.000	0.530	< 0.001
Apr	1.000	1.000	1.000		1.000	1.000	1.000	0.510	1.000	1.000	1.000	0.020
May	1.000	1.000	1.000	1.000		1.000	1.000	0.084	0.201	1.000	1.000	0.001
Jun	1.000	1.000	1.000	1.000	1.000		1.000	0.073	0.181	1.000	1.000	< 0.001
Jul	1.000	1.000	1.000	1.000	1.000	1.000		0.271	0.661	1.000	1.000	0.002
Aug	1.000	0.032	0.014	0.510	0.084	0.073	0.271		1.000	0.386	1.000	1.000
Sep	1.000	0.079	0.034	1.000	0.201	0.181	0.661	1.000		0.837	1.000	1.000
Oct	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.386	0.837		1.000	0.024
Nov	1.000	1.000	0.530	1.000	1.000	1.000	1.000	1.000	1.000	1.000		1.000
Dec	0.015	< 0.001	< 0.001	0.020	0.001	< 0.001	0.002	1.000	1.000	0.024	1.000	

b) Zone 1

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Feb	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Mar	1.000	1.000		1.000	1.000	1.000	0.659	1.000	1.000	1.000	0.028	1.000
Apr	1.000	1.000	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
May	1.000	1.000	1.000	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000
Jun	1.000	1.000	1.000	1.000	1.000		1.000	1.000	1.000	1.000	1.000	1.000
Jul	1.000	1.000	0.659	1.000	1.000	1.000		1.000	1.000	1.000	1.000	1.000
Aug	1.000	1.000	1.000	1.000	1.000	1.000	1.000		1.000	1.000	1.000	1.000
Sep	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000		1.000	1.000	1.000
Oct	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000		1.000	1.000
Nov	1.000	1.000	0.028	1.000	1.000	1.000	1.000	1.000	1.000	1.000		0.138
Dec	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	

Tables 9-2 and 9-3 do not indicate any systematic variance in overall black guillemot site occupancy (All Zones), occupancy of the array area (Zone 1) or diving (Diving Z1) amongst months. Probabilities are broadly similar in all 12 months.

9.2 Occupancy by time

Plots of descriptive statistics for black guillemot counts by time are provided in Annex B (separate document), Figures B2 and B3.

Table 9-4 (over) presents GEE-GLM (binomial) outputs for black guillemot by time as follows:

1. Probability of a black guillemot occurring anywhere in the survey area (**All Zones**).
2. Probability of a black guillemot occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a black guillemot seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a black guillemot diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 9-4 GEE-GLM (Binomial) estimations of 1) probabilities of a black guillemot occurring within the entire survey area (All Zones), 2) probabilities of a black guillemot occurring within the array area (Zone 1), 3) probabilities that a black guillemot seen in the array area will dive (Diving Z1) and 4) probabilities of a black guillemot diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	0.965 (0.288-1)	0.097 (0-0.720)	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.965 (0.278-1)	0.105 (0-0.727)	0.286 (0-1)	0.030 (0-0.727)
14:01-18:00	0.978 (0.290-1)	0.109 (0-0.735)	0.233 (0-0.959)	0.025 (0-0.705)
18:01-22:00	0.970 (0.267-1)	0.142 (0-0.790)	0.208 (0-0.974)	0.030 (0-0.769)

* Birds observed in Zone 1 in <15 scans in this time period.

b) Summer (April to September)

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	0.943 (0.272-1)	0.086 (0-0.774)	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.957 (0.262-1)	0.109 (0-0.797)	0.231 <i>No range</i>	0.025 <i>No range</i>
14:01-18:00	0.978 (0.290-1)	0.117 (0-0.807)	0.241 <i>No range</i>	0.028 <i>No range</i>
18:01-22:00	0.970 (0.272-1)	0.142 (0-0.845)	0.208 <i>No range</i>	0.030 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this time period.

c) Winter (October to March)

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	1.000 <i>No range</i>	0.114 (0-0.753)	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.971 <i>No range</i>	0.103 (0-0.733)	0.329 (0-0.965)	0.034 (0-0.707)
14:01-18:00	0.980 <i>No range</i>	0.085 (0-0.731)	0.200 (0-0.868)	0.017 (0-0.635)
18:01-22:00	<i>No data for this time period during winter months due to short daylight hours</i>			

* Birds observed in Zone 1 in <15 scans in this time period.

Table 9-4 does not indicate any systematic variance in overall black guillemot site occupancy (All Zones) with time of day, or in birds diving (Diving Z1). However, there appears to be some systematic variance in black guillemot occupancy in the array area (Zone 1), with probabilities increasing over the course of the day. Table 9-4 b) indicates that this was primarily driven by diurnal patterns in summer. Figures B2 and B3 (Annex B) also indicate a general increase in black guillemot occupancy over the course of the day, with most birds observed on the surface of the water rather than diving.

The 'All zones' (winter) model did not converge due to a high percentage of 1s (>98%), so pairwise comparisons were not possible. No significant differences were found in Tukey pairwise

comparisons (with a Bonferroni correction) between time periods for the remaining zones and seasons.

9.3 Occupancy by tidal period

Plots of descriptive statistics for black guillemot counts by tidal period are provided in Annex B (separate document), Figures B4 and B5.

Table 9-5 presents GEE-GLM (binomial) outputs for black guillemot by tidal period, as follows:

1. Probability of a black guillemot occurring anywhere in the survey area (**All Zones**).
2. Probability of a black guillemot occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a black guillemot seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a black guillemot diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days.

Table 9-5 GEE-GLM (Binomial) estimations of 1) probabilities of a black guillemot occurring within the entire survey area (All Zones), 2) probabilities of a black guillemot occurring within the array area (Zone 1), 3) probabilities that a black guillemot seen in the array area will dive (Diving Z1) and 4) probabilities of a black guillemot diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.985 (0.368-1)	0.162 (0-0.710)	0.229 (0-0.817)	0.037 (0-0.580)
Max Flood	0.946 (0.319-1)	0.119 (0-0.674)	0.282 (0-0.886)	0.034 (0-0.597)
Dec Flood	0.968 (0.331-1)	0.154 (0-0.700)	0.329 (0-0.910)	0.051 (0-0.637)
Inc Ebb	0.978 (0.343-1)	0.072 (0-0.623)	0.155 (0-0.753)	0.011 (0-0.469)
Max Ebb	0.965 (0.377-1)	0.049 (0-0.602)	0.095 (0-0.762)	0.005 (0-0.459)
Dec Ebb	0.982 (0.383-1)	0.097 (0-0.634)	0.284 (0-0.846)	0.027 (0-0.536)

b) Summer (April to September)

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.991 (0.372-1)	0.201 (0-0.760)	0.202 (0-0.825)	0.041 (0-0.627)
Max Flood	0.936 (0.278-1)	0.131 (0-0.707)	0.176 (0-0.815)	0.023 (0-0.576)
Dec Flood	0.966 (0.289-1)	0.175 (0-0.740)	0.318 (0-0.931)	0.056 (0-0.689)
Inc Ebb	0.988 (0.334-1)	0.075 (0-0.643)	0.186 (0-0.813)	0.014 (0-0.523)
Max Ebb	0.952 (0.353-1)	0.030 (0-0.611)	0.000* (0-0.602)	0.000 (0-0.368)
Dec Ebb	0.977 (0.359-1)	0.081 (0-0.635)	0.279 (0-0.872)	0.023 (0-0.554)

* Birds observed in Zone 1 in <15 scans in this tidal period.

c) Winter (October to March)

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.975 (0.337-1)	0.103 (0-0.667)	0.310 (0-0.932)	0.032 (0-0.622)
Max Flood	0.961 (0.320-1)	0.100 (0-0.676)	0.500 (0-1)	0.050 (0-0.676)
Dec Flood	0.971 (0.290-1)	0.125 (0-0.691)	0.351 (0-0.964)	0.044 (0-0.666)
Inc Ebb	0.964 (0.276-1)	0.066 (0-0.645)	0.107 (0-0.758)	0.007 (0-0.489)
Max Ebb	0.983 (0.307-1)	0.075 (0-0.642)	0.148 (0-0.834)	0.011 (0-0.535)
Dec Ebb	0.990 (0.350-1)	0.123 (0-0.670)	0.289 (0-0.869)	0.036 (0-0.582)

Where models converged, Tukey pairwise comparisons (with a Bonferroni correction) were run to compare the probabilities in the table above between tidal periods. Outputs from those pairwise comparisons that identified significant differences between tidal periods are shown in Table 9-6.

Table 9-6 Black guillemot Tukey pairwise comparisons (with a Bonferroni correction) for tidal period, for a) All months (Zone 1) b) Summer (All Zones) and c) Summer (Zone 1). Significant p-values are in bold.

a) All months (Zone 1)

	Inc Flood	Max Flood	Dec Flood	Inc Ebb	Max Ebb	Dec Ebb
Inc Flood		0.876	1.000	<0.001	<0.001	0.028
Max Flood	0.876		1.000	0.254	0.001	1.000
Dec Flood	1.000	1.000		<0.001	<0.001	0.076
Inc Ebb	<0.001	0.254	<0.001		0.717	1.000
Max Ebb	<0.001	0.001	<0.001	0.717		0.008
Dec Ebb	0.028	1.000	0.076	1.000	0.008	

b) Summer (All Zones)

	Inc Flood	Max Flood	Dec Flood	Inc Ebb	Max Ebb	Dec Ebb
Inc Flood		0.039	1.000	1.000	0.020	0.789
Max Flood	0.039		0.602	0.068	1.000	1.000
Dec Flood	1.000	0.602		1.000	1.000	1.000
Inc Ebb	1.000	0.068	1.000		0.009	1.000
Max Ebb	0.020	1.000	1.000	0.009		0.878
Dec Ebb	0.789	1.000	1.000	1.000	0.878	

c) Summer (Zone 1)

	Inc Flood	Max Flood	Dec Flood	Inc Ebb	Max Ebb	Dec Ebb
Inc Flood		0.535	1.000	0.001	<0.001	<0.001
Max Flood	0.535		1.000	0.715	<0.001	1.000
Dec Flood	1.000	1.000		<0.001	<0.001	0.013
Inc Ebb	0.001	0.715	<0.001		0.007	1.000
Max Ebb	<0.001	<0.001	<0.001	0.007		0.019
Dec Ebb	<0.001	1.000	0.013	1.000	0.019	

d) Summer (Diving Z1)

	Inc Flood	Max Flood	Dec Flood	Inc Ebb	Max Ebb	Dec Ebb
Inc Flood		1.000	1.000	1.000	<0.001	1.000
Max Flood	1.000		1.000	1.000	<0.001	1.000
Dec Flood	1.000	1.000		1.000	<0.001	1.000
Inc Ebb	1.000	1.000	1.000		<0.001	1.000
Max Ebb	<0.001	<0.001	<0.001	<0.001		<0.001
Dec Ebb	1.000	1.000	1.000	1.000	<0.001	

e) Winter (Diving Z1)

	Inc Flood	Max Flood	Dec Flood	Inc Ebb	Max Ebb	Dec Ebb
Inc Flood		0.661	1.000	0.658	1.000	1.000
Max Flood	0.661		1.000	0.017	0.325	1.000
Dec Flood	1.000	1.000		0.222	1.000	1.000
Inc Ebb	0.658	0.017	0.222		1.000	0.746
Max Ebb	1.000	0.325	1.000	1.000		1.000
Dec Ebb	1.000	1.000	1.000	0.746	1.000	

Table 9-5 does not indicate any systematic variance in overall black guillemot site occupancy (All Zones) with tidal period. However, it does indicate some systematic variance in black guillemot occupancy in the array area (Zone 1) and in birds diving in the array area between tidal periods, with probabilities mostly greater in flood than ebb tides (and around low water slack) and lower during maximum ebb. Figure B5 (Annex B) also indicates a general increase in black guillemot occupancy and diving in Zone 1 during flood tides.

9.4 Summary of key points

1. Black guillemot was the most frequently recorded species in vantage point surveys. It was observed in 97.1% of scans (5057 of 5208 scans). It was also the most abundant species, accounting for 62% of all bird sightings. The species was consistently recorded in scans throughout the year.
2. The overall average standardised black guillemot count for the entire survey area (All Zones) was 15.36 birds per scan/km², with the highest average count recorded in November (27.04 birds per scan/km²).

3. Black guillemot was recorded in the array area (Zone 1) in 11% of scans (561 of 5208 scans), while birds were recorded diving in the array area (Diving Z1) in fewer than 3% of scans (143 of 5208 scans). The overall average standardised black guillemot count for the array area was 2.05 birds per scan/km², while overall, 0.49 birds per scan/km² were observed diving in the array area.
4. The average black guillemot count in scans of the entire survey area when the species was recorded was 9.86 birds per scan. Only 1 or 2 birds per scan were observed in scans of the array area when the species was recorded. This indicates that the species is present in the site as solitary individuals rather than in groups displaying 'group foraging'.
5. Probability modelling shows that there is a 90-99% likelihood that black guillemot will be seen in the entire survey area during a scan and a 5-10% likelihood they will be seen in the array area. There is a 20-40% likelihood that a black guillemot observed in the array area will dive. Overall, there is a less than 5% likelihood of a black guillemot diving in proximity to the turbines. These values are largely independent of month.
6. The probability of seeing a black guillemot increases over the course of the day and is greatest in the evening. This appears to be primarily linked to increases over the course of the day in summer months.
7. There is no systematic variance in black guillemot occupancy across the entire survey site with tidal period. There was some systematic variation in occupancy within the array area, with the probability of seeing a bird greatest around low slack water and on flood tides and lowest around maximum ebb.
8. The overall proximity probability (probability of a black guillemot diving in proximity to the turbines) is consistently low throughout the year (generally less than 5%, even when large numbers of birds are recorded in the wider area). The overall proximity probability appears to be greater around low slack water and on flood tides.

10. European shag, *Phalacrocorax aristotelis*

10.1 Occupancy by zone and month

The number and proportion of scans in which European shag was recorded, the mean standardised count per scan (per km²), and the mean count in positive scans are provided in Table 10-1.

Table 10-1 Number and proportion of scans in which counts of European shag were recorded, the mean standardised count per scan, and the mean count in positive scans for All Zones (the entire survey area), Zone 1 (the array area) and Diving Z1 (birds observed diving in Zone 1). The actual number of scans (from the total of 5208) is shown in brackets. % 0s is the proportion and number of scans in which the species was not recorded.

Survey area	% scans with positive records	% 0s	Mean standardised count per scan/km ²	Mean count per scan (positive scans only)
All Zones	65.88 (3431)	34.12 (1777)	6.45	6.10
Zone 1	2.88 (150)	97.12 (5058)	0.64	1.48
Diving Z1	1.04 (54)	98.96 (5154)	0.19	1.26

European shag was the second most frequently recorded species (after black guillemot) in vantage point surveys. The species was observed in 65% of the 5208 scans for the entire survey area (All Zones) and in the array area (Zone 1) in 3% of scans. It was the second most abundant species (after black guillemot), accounting for 26% of all bird sightings. In scans of the entire survey area in which European shag was observed, an average of 6.10 birds per scan was recorded. Only 1 or 2 birds per scan were recorded in scans of the array area in which the species was observed.

Plots of descriptive statistics for European shag counts by survey area and month are provided in Annex B (separate document), Figure B6.

Table 10-2 (over) presents GEE-GLM (binomial) outputs for European shag by month, as follows:

1. Probability of a European shag occurring anywhere in the survey area (**All Zones**).
2. Probability of a European shag occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a European shag seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a European shag diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 10-2 GEE-GLM (Binomial) estimations of 1) probabilities of a European shag occurring within the entire survey area (All Zones), 2) probabilities of a European shag occurring within the array area (Zone 1), 3) probabilities that a European shag seen in the array area will dive (Diving Z1) and 4) probabilities of a European shag diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Month	All Zones	Zone 1	Diving Z1	Proximity probability
Jan	0.833 (0.221-1)	0.090 (0-0.665)	0.322 (0-0.912)	0.029 (0-0.607)
Feb	0.859 (0.228-1)	0.044 (0-0.641)	0.526 (0-1)	0.023 (0-0.641)
Mar	0.857 (0.227-1)	0.032 (0-0.644)	0.438 (0-1)	0.014 (0-0.644)
Apr	0.684 (0.061-1)	0.021 (0-0.650)	0.000* No range	0.000 No range
May	0.568 (0-1)	0.011 (0-0.651)	0.000* No range	0.000 No range
Jun	0.482 (0-1)	0.012 (0-0.639)	0.000* No range	0.000 No range
Jul	0.417 (0-1)	0.010 (0-0.639)	0.000* No range	0.000 No range
Aug	0.617 (0-1)	0.024 (0-0.655)	0.000* No range	0.000 No range
Sep	0.643 (0.022-1)	0.023 (0-0.644)	0.000* No range	0.000 No range
Oct	0.733 (0.113-1)	0.050 (0-0.653)	0.389 (0-1)	0.019 (0-0.653)
Nov	0.697 (0.075-1)	0.034 (0-0.656)	0.000* No range	0.000 No range
Dec	0.737 (0.110-1)	0.038 (0-0.643)	0.000* No range	0.000 No range

* Birds observed in Zone 1 in <15 scans in this month.

Outputs from Tukey pairwise comparisons (with a Bonferroni correction) for European shag presence between months for All Zones and Zone 1 are shown in Table 10-3. Comparisons for Diving Z1 did not identify any significant differences so have not been provided.

Table 10-3 European shag Tukey pairwise comparisons (with a Bonferroni correction) for zone and month, for a) All zones and b) Zone 1. Significant p-values are in bold.

a) All Zones

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan		1.000	1.000	1.000	0.534	0.043	0.004	1.000	1.000	1.000	1.000	1.000
Feb	1.000		1.000	0.191	0.001	<0.001	<0.001	0.004	0.022	1.000	0.279	1.000
Mar	1.000	1.000		0.173	0.001	<0.001	<0.001	0.003	0.018	1.000	0.254	1.000
Apr	1.000	0.191	0.173		1.000	0.136	0.002	1.000	1.000	1.000	1.000	1.000
May	0.534	0.001	0.001	1.000		1.000	1.000	1.000	1.000	0.500	1.000	1.000
Jun	0.043	<0.001	<0.001	0.136	1.000		1.000	1.000	0.749	0.001	0.040	0.024
Jul	0.004	<0.001	<0.001	0.002	1.000	1.000		0.058	0.017	<0.001	<0.001	<0.001
Aug	1.000	0.004	0.003	1.000	1.000	1.000	0.058		1.000	1.000	1.000	1.000
Sep	1.000	0.022	0.018	1.000	1.000	0.749	0.017	1.000		1.000	1.000	1.000
Oct	1.000	1.000	1.000	1.000	0.500	0.001	<0.001	1.000	1.000		1.000	1.000

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Nov	1.000	0.279	0.254	1.000	1.000	0.040	<0.001	1.000	1.000	1.000		1.000
Dec	1.000	1.000	1.000	1.000	1.000	0.024	<0.001	1.000	1.000	1.000	1.000	

b) Zone 1

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan		1.000	1.000	0.237	0.012	0.004	0.001	0.624	0.254	1.000	1.000	1.000
Feb	1.000		1.000	1.000	0.759	0.429	0.158	1.000	1.000	1.000	1.000	1.000
Mar	1.000	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Apr	0.237	1.000	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
May	0.012	0.759	1.000	1.000		1.000	1.000	1.000	1.000	0.479	1.000	1.000
Jun	0.004	0.429	1.000	1.000	1.000		1.000	1.000	1.000	0.263	1.000	1.000
Jul	0.001	0.158	1.000	1.000	1.000	1.000		1.000	1.000	0.097	1.000	0.689
Aug	0.624	1.000	1.000	1.000	1.000	1.000	1.000		1.000	1.000	1.000	1.000
Sep	0.254	1.000	1.000	1.000	1.000	1.000	1.000	1.000		1.000	1.000	1.000
Oct	1.000	1.000	1.000	1.000	0.479	0.263	0.097	1.000	1.000		1.000	1.000
Nov	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000		1.000
Dec	1.000	1.000	1.000	1.000	1.000	1.000	0.689	1.000	1.000	1.000	1.000	

Tables 10-2 and 10-3 indicate some systematic variance in overall shag site occupancy (All Zones) and array area occupancy (Zone 1), with generally higher probabilities between October and March. There was little systematic variance in diving (Diving Z1) amongst months, with any obvious differences corresponding with months when diving birds were observed.

10.2 Occupancy by time

Plots of descriptive statistics for European shag counts by time are provided in Annex B (separate document), Figures B7 and B8.

Table 10-4 (over) presents GEE-GLM (binomial) outputs for European shag by time as follows:

1. Probability of a European shag occurring anywhere in the survey area (**All Zones**).
2. Probability of a European shag occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a European shag seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a European shag diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 10-4 GEE-GLM (Binomial) estimations of 1) probabilities of a European shag occurring within the entire survey area (All Zones), 2) probabilities of a European shag occurring within the array area (Zone 1), 3) probabilities that a European shag seen in the array area will dive (Diving Z1) and 4) probabilities of a European shag diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	0.737 (0.165-1)	0.044 (0-0.644)	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.703 (0.133-1)	0.036 (0-0.636)	0.351 (0-1)	0.013 (0-0.636)
14:01-18:00	0.620 (0.045-1)	0.021 (0-0.629)	0.367 (0-1)	0.008 (0-0.629)
18:01-22:00	0.456 (0-1)	0.012 (0-0.703)	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this time period.

b) Summer (April to September)

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	0.657 (0.070-1)	0.014 (0-0.719)	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.580 (0-1)	0.022 (0-0.727)	0.240 <i>No range</i>	0.005 <i>No range</i>
14:01-18:00	0.559 (0-1)	0.013 (0-0.724)	0.261 <i>No range</i>	0.003 <i>No range</i>
18:01-22:00	0.456 (0-1)	0.012 (0-0.765)	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this time period.

c) Winter

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	0.864 (0.292-1)	0.091 (0-0.703)	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.796 (0.219-1)	0.047 (0-0.661)	0.391 (0-1)	0.018 (0-0.661)
14:01-18:00	0.804 (0.220-1)	0.044 (0-0.668)	0.462 (0-1)	0.021 (0-0.668)
18:01-22:00	<i>No data for this time period during winter months due to short daylight hours</i>			

* Birds observed in Zone 1 in <15 scans in this time period.

Where models converged, Tukey pairwise comparisons (with a Bonferroni correction) were run to compare the probabilities above between time periods. Outputs from those pairwise comparisons that identified significant differences between time periods are shown in Table 10-5 (over).

Table 10-5 European shag Tukey pairwise comparisons (with a Bonferroni correction) for time periods for a) All months (All Zones) and b) All months (Zone 1) Significant p-values are in bold.

a) All months (All Zones)

	06:00-10:00	10:01-14:00	14:01-18:00	18:01-22:00
06:00-10:00		1.000	0.456	0.008
10:01-14:00	1.000		0.005	<0.001
14:01-18:00	0.456	0.005		0.040
18:01-22:00	0.008	<0.001	0.040	

b) All months (Zone 1)

	06:00-10:00	10:01-14:00	14:01-18:00	18:01-22:00
06:00-10:00		1.000	0.497	0.574
10:01-14:00	1.000		0.017	0.642
14:01-18:00	0.497	0.017		1.000
18:01-22:00	0.574	0.642	1.000	

Table 10-4 indicates some systematic variance in overall shag site occupancy (All Zones) and array area occupancy (Zone 1) with time of day, with probabilities higher in the morning. Table 10-4 b) indicates that this was primarily linked to increased occupancy in the morning in summer. Figures B7 and B8 (Annex B) also indicate higher shag occupancy in the morning.

10.3 Occupancy by tidal period

Plots of descriptive statistics for European shag counts by tidal period are provided in Annex B (separate document), Figures B9 and B10.

Table 10-6 (over) presents GEE-GLM (binomial) outputs for European shag by tidal period, as follows:

1. Probability of a European shag occurring anywhere in the survey area (**All Zones**).
2. Probability of a European shag occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a European shag seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a European shag diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 10-6 GEE-GLM (Binomial) estimations of 1) probabilities of a European shag occurring within the entire survey area (All Zones), 2) probabilities of a European shag occurring within the array area (Zone 1), 3) probabilities that a European shag seen in the array area will dive (Diving Z1) and 4) probabilities of a European shag diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error, shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.649 (0.111-1)	0.041 (0-0.624)	0.367 (0-1)	0.015 (0-0.624)
Max Flood	0.684 (0.14-1)	0.039 (0-0.618)	0.393 (0-1)	0.015 (0-0.618)
Dec Flood	0.668 (0.122-1)	0.030 (0-0.620)	0.344 (0-0.999)	0.010 (0-0.619)
Inc Ebb	0.685 (0.143-1)	0.023 (0-0.614)	0.304 (0-0.981)	0.007 (0-0.602)
Max Ebb	0.635 (0.099-1)	0.022 (0-0.602)	0.263 (0-0.934)	0.006 (0-0.562)
Dec Ebb	0.628 (0.095-1)	0.022 (0-0.592)	0.500 (0-1)	0.011 (0-0.592)

b) Summer (April to September)

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.527 (0-1)	0.034 (0-0.662)	<i>0.200</i> No range	0.007 No range
Max Flood	0.606 (0.056-1)	0.028 (0-0.640)	<i>0.000*</i> No range	0.000 No range
Dec Flood	0.538 (0-1)	0.011 (0-0.642)	<i>0.000*</i> No range	0.000 No range
Inc Ebb	0.599 (0.051-1)	0.016 (0-0.630)	<i>0.000*</i> No range	0.000 No range
Max Ebb	0.564 (0.022-1)	0.004 (0-0.670)	<i>0.000*</i> No range	0.000 No range
Dec Ebb	0.547 (0.010-1)	0.011 (0-0.611)	<i>0.000*</i> No range	0.000 No range

* Birds observed in Zone 1 in <15 scans in this tidal period.

c) Winter (October to March)

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.841 (0.275-1)	0.053 (0-0.650)	0.533 (0-1)	0.028 (0-0.650)
Max Flood	0.807 (0.221-1)	0.057 (0-0.659)	0.438 (0-1)	0.025 (0-0.659)
Dec Flood	0.842 (0.260-1)	0.055 (0-0.667)	0.360 (0-1)	0.020 (0-0.667)
Inc Ebb	0.801 (0.224-1)	0.033 (0-0.655)	<i>0.000*</i> No range	0.000 No range
Max Ebb	0.735 (0.165-1)	0.047 (0-0.647)	0.294 (0-0.922)	0.014 (0-0.597)
Dec Ebb	0.765 (0.203-1)	0.039 (0-0.630)	<i>0.000*</i> No range	0.000 No range

* Birds observed in Zone 1 in <15 scans in this tidal period.

Table 10-6 does not indicate any systematic variance in overall shag site occupancy (All Zones) with tidal period. However, it does indicate some systematic variance in occupancy of the array area (Zone 1) amongst tidal periods, with probabilities mostly greater on flood than ebb tides and

the probability of birds diving lowest on the maximum ebb. Figure B10 (Annex B) also indicates a general increase in shag occupancy in Zone 1 during flood tides. This matches the behaviour observed for Black Guillemot in Section 9.

Where models converged, Tukey pairwise comparisons (with a Bonferroni correction) were run to compare the probabilities above between tidal periods, but no significant differences were identified.

10.4 Summary of key points

1. European shag was the second most frequently recorded species (after black guillemot) in vantage point surveys. It was observed in 65.88% of scans (3431 of 5208 scans). It was also the second most abundant species (after black guillemot), accounting for 26% of all bird sightings. The species was consistently recorded in scans throughout the year.
2. The overall average standardised European shag count for the entire survey area (All Zones) was 6.45 birds per scan/km², with the highest average count recorded in November (19.7 birds per scan/km²).
3. European shag was recorded in the array area (Zone 1) in 3% of scans (150 of 5208 scans), while birds were recorded diving in the array area (Diving Z1) in just over 1% of scans (54 of 5208 scans). The overall average standardised shag count for the array area was 0.64 birds per scan/km², while overall, 0.19 birds per scan/km² were observed diving in the array area.
4. The average shag count in scans of the entire survey area when the species was recorded was 6.10 birds per scan. Only 1 or 2 birds per scan were observed in scans of the array area when the species was recorded. This indicates that the species is present in the site as solitary individuals.
5. Probability modelling shows that there is a 50-80% likelihood that shag will be seen in the entire survey area during a scan and a 2-5% likelihood they will be seen in the array area. There is a 30-40% likelihood that a shag observed in the array area will dive. Overall, there is a less than 3% likelihood of a shag diving in proximity to the turbines.
6. There is some systematic seasonal variance in shag site occupancy across the entire survey sites and the array area, with the probability of seeing a shag generally greater between October and March.
7. The probability of seeing a shag is generally greater in the morning across the entire survey area and in the array area. This appears to be primarily linked to patterns observed in summer months. Note that this could be caused by morning disturbance to birds roosting in fields on Unst. Large numbers of shag are known to roost on farmland on Unst (see field surveyor observations in Section 7.4).
8. There is no systematic variance in shag occupancy across the entire survey site with tidal period. There was some systematic variation in occupancy within the array area, with the probability of seeing a shag greater on flood tides than ebb and the probability of birds diving lowest on the maximum ebb.
9. The overall proximity probability (probability of a European shag diving in proximity to the turbines) is consistently low throughout the year (generally <3%). The overall proximity probability appears to be greatest on flood tides and lowest on the maximum ebb.

11. Atlantic puffin, *Fratercula arctica*

11.1 Occupancy by zone and month

The number and proportion of scans in which Atlantic puffin was recorded, the mean standardised count per scan (per km²), and the mean count in positive scans are provided in Table 11-1.

Table 11-1 Number and proportion of scans in which counts of Atlantic puffin were recorded, the mean standardised count per scan, and the mean count in sportive scans for All Zones (the entire survey area), Zone 1 (the array area) and Diving Z1 (birds observed diving in Zone 1). The actual number of scans (from the total of 5208) is shown in italics in brackets. % 0s is the proportion and number of scans in which the species was not recorded.

Survey area	% scans with positive records	% 0s	Mean standardised count per scan/km ²	Mean count per scan (positive scans only)
All Zones	18.18 (947)	81.82 (4261)	1.16	3.99
Zone 1	1.57 (82)	98.43 (5126)	0.40	1.70
Diving Z1	1.08 (56)	98.92 (5152)	0.23	1.43

Atlantic puffin was recorded in 18% of scans and accounted for 4.69% of all bird sightings in vantage point surveys. The species was observed in 3% of scans in the array area (Zone 1). In scans of the entire survey area in which Atlantic puffin was observed, an average of 3.99 birds per scan was recorded. Only 1 or 2 birds per scan were recorded in scans of the array area in which the species was observed.

Plots of descriptive statistics for Atlantic puffin counts by survey area and month are provided in Annex B (separate document), Figure B11.

Table 11-2 (over) presents GEE-GLM (binomial) outputs for Atlantic puffin by month, as follows:

1. Probability of an Atlantic puffin occurring anywhere in the survey area (**All Zones**).
2. Probability of an Atlantic puffin occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that an Atlantic puffin seen in Zone 1 will dive (**Diving Z1**).
4. Probability of an Atlantic puffin diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 11-2 GEE-GLM (Binomial) estimations of 1) probabilities of an Atlantic puffin occurring within the entire survey area (All Zones), 2) probabilities of an Atlantic puffin occurring within the array area (Zone 1), 3) probabilities that an Atlantic puffin seen in the array area will dive (Diving Z1) and 4) probabilities of an Atlantic puffin diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Month	All Zones	Zone 1	Diving Z1	Proximity probability
Jan	<i>0.000</i> No range	<i>0.000</i> No range	<i>0.000*</i> No range	0.000 No range
Feb	<i>0.000</i> No range	<i>0.000</i> No range	<i>0.000*</i> No range	0.000 No range
Mar	<i>0.010</i> No range	<i>0.002</i> No range	<i>0.000*</i> No range	0.000 No range
Apr	<i>0.170</i> No range	<i>0.004</i> No range	<i>0.000*</i> No range	0.000 No range
May	<i>0.261</i> No range	<i>0.019</i> No range	<i>0.000*</i> No range	0.000 No range
Jun	<i>0.597</i> No range	<i>0.065</i> No range	<i>0.727</i> No range	0.048 No range
Jul	<i>0.572</i> No range	<i>0.052</i> No range	<i>0.742</i> No range	0.038 No range
Aug	<i>0.139</i> No range	<i>0.010</i> No range	<i>0.000*</i> No range	0.000 No range
Sep	<i>0.000</i> No range	<i>0.000</i> No range	<i>0.000*</i> No range	0.000 No range
Oct	<i>0.000</i> No range	<i>0.000</i> No range	<i>0.000*</i> No range	0.000 No range
Nov	<i>0.000</i> No range	<i>0.000</i> No range	<i>0.000*</i> No range	0.000 No range
Dec	<i>0.000</i> No range	<i>0.000</i> No range	<i>0.000*</i> No range	0.000 No range

* Birds observed in Zone 1 in <15 scans in this month.

None of the models for probabilities above converged, due to a high proportion of 0s (>98%) in winter data, so pairwise comparisons were not carried out.

The seasonal variance in overall puffin site occupancy (All Zones), occupancy of the array area (Zone 1) and in birds diving in the array area (Diving Z1 in Table 11-2 reflects a strong association with the absence of the species between September and February (inclusive) and a peak in June and July.

11.2 Occupancy by time

Plots of descriptive statistics for Atlantic puffin counts by time are provided in Annex B (separate document), Figures B12 and B13.

Table 11-3 (over) presents GEE-GLM (binomial) outputs for Atlantic puffin by time as follows:

1. Probability of an Atlantic puffin occurring anywhere in the survey area (**All Zones**).
2. Probability of an Atlantic puffin occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that an Atlantic puffin seen in Zone 1 will dive (**Diving Z1**).
4. Probability of an Atlantic puffin diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was

not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 11-3 GEE-GLM (Binomial) estimations of 1) probabilities of an Atlantic puffin occurring within the entire survey area (All Zones), 2) probabilities of an Atlantic puffin occurring within the array area (Zone 1), 3) probabilities that an Atlantic puffin seen in the array area will dive (Diving Z1) and 4) probabilities of an Atlantic puffin diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	0.211 (0-0.831)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.127 (0-0.742)	0.012 <i>No range</i>	0.750 (0.143-1))	0.009 <i>No range</i>
14:01-18:00	0.217 (0-0.842)	0.018 <i>No range</i>	0.628 (0-1)	0.012 <i>No range</i>
18:01-22:00	0.527 (0-1)	0.041 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this time period.

b) Summer (April to September)

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	0.343 (0-0.962)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.294 (0-0.910)	0.029 <i>No range</i>	0.750 (0.143-1)	0.022 <i>No range</i>
14:01-18:00	0.287 (0-0.912)	0.024 <i>No range</i>	0.619 (0-1)	0.015 <i>No range</i>
18:01-22:00	0.526 (0-1)	0.041 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this time period.

c) Winter (October to March)

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	0.000 <i>No range</i>	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.001 <i>No range</i>	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
14:01-18:00	0.007 <i>No range</i>	0.002 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
18:01-22:00	<i>No data for this time period during winter months due to short daylight hours</i>			

* Birds observed in Zone 1 in <15 scans in this time period.

Convergence in the models above was limited, due to a high proportion of 0s in the winter (>98%) for Atlantic puffin. Outputs from Tukey pairwise comparisons (with a Bonferroni correction) for those models that did converge and for which significant differences between time periods were identified are shown in Table 11-4 (over).

Table 11-4 Atlantic puffin Tukey pairwise comparisons (with a Bonferroni correction) for time period for a) All months (All Zones) and b) Summer (All Zones). Significant p-values are in bold.

a) All months (All Zones)

	06:00-10:00	10:01-14:00	14:01-18:00	18:01-22:00
06:00-10:00		1.000	1.000	1.000
10:01-14:00	1.000		0.003	<0.001
14:01-18:00	1.000	0.003		<0.001
18:01-22:00	1.000	<0.001	<0.001	

b) Summer (All Zones)

	06:00-10:00	10:01-14:00	14:01-18:00	18:01-22:00
06:00-10:00		1.000	1.000	1.000
10:01-14:00	1.000		1.000	0.034
14:01-18:00	1.000	1.000		0.007
18:01-22:00	1.000	0.034	0.007	

Tables 11-3 and 11-4 indicate some systematic variance in overall puffin site occupancy (All Zones) and array area occupancy (Zone 1) with time of day, with probabilities higher in the evening. Figures B12 and B13 (Annex B) also indicate higher puffin occupancy in the evening.

11.3 Occupancy by tidal period

Plots of descriptive statistics for Atlantic puffin counts by tidal period are provided in Annex B (separate document), Figures B14 and B15.

Table 11-5 (over) presents GEE-GLM (binomial) outputs for Atlantic puffin by tidal period, as follows:

1. Probability of an Atlantic puffin occurring anywhere in the survey area (**All Zones**).
2. Probability of an Atlantic puffin occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that an Atlantic puffin seen in Zone 1 will dive (**Diving Z1**).
4. Probability of an Atlantic puffin diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 11-5 GEE-GLM (Binomial) estimations of 1) probabilities of an Atlantic puffin occurring within the entire survey area (All Zones), 2) probabilities of an Atlantic puffin occurring within the array area (Zone 1), 3) probabilities that an Atlantic puffin seen in the array area will dive (Diving Z1) and 4) probabilities of an Atlantic puffin diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.226 (0-0.778)	0.029 (0-0.770)	0.857 <i>No range</i>	0.025 <i>No range</i>
Max Flood	0.232 (0-0.806)	0.027 (0-0.767)	0.579 <i>No range</i>	0.016 <i>No range</i>
Dec Flood	0.233 (0-0.807)	0.026 (0-0.763)	0.643 <i>No range</i>	0.017 <i>No range</i>
Inc Ebb	0.176 (0-0.746)	0.010 (0-0.750)	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Ebb	0.114 (0-0.677)	0.003 (0-0.764)	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Ebb	0.112 (0-0.669)	0.001 (0-0.731)	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this tidal period.

b) Summer (April to September)

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.365 (0-0.92)	0.047 (0-0.786)	0.857 <i>No range</i>	0.040 <i>No range</i>
Max Flood	0.378 (0-0.954)	0.044 (0-0.782)	0.579 <i>No range</i>	0.025 <i>No range</i>
Dec Flood	0.403 (0-0.978)	0.044 (0-0.781)	0.630 <i>No range</i>	0.028 <i>No range</i>
Inc Ebb	0.306 (0-0.875)	0.017 (0-0.756)	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Ebb	0.196 (0-0.758)	0.006 (0-0.765)	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Ebb	0.178 (0-0.735)	0.002 (0-0.731)	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this tidal period.

c) Winter (October to March)

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.007 <i>No range</i>	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Flood	0.004 <i>No range</i>	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Flood	0.004 <i>No range</i>	0.002 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
Inc Ebb	0.000 <i>No range</i>	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Ebb	0.000 <i>No range</i>	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Ebb	0.000 <i>No range</i>	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this tidal period.

Convergence in the winter models was limited, due to a high proportion of 0s in winter months (>98%) for Atlantic puffin. Outputs from Tukey pairwise comparisons (with a Bonferroni correction)

for those models that did converge and for which significant differences between tidal periods were identified are shown in Table 11-6.

Table 11-6 Atlantic puffin Tukey pairwise comparisons (with a Bonferroni correction) for tidal period, for a) All months (All Zones), b) All months (Zone 1), Summer (All Zones) and d) Summer (Zone 1). Significant p-values are in bold.

a) All months (All Zones)

	Inc Flood	Max Flood	Dec Flood	Inc Ebb	Max Ebb	Dec Ebb
Inc Flood		1.000	1.000	1.000	0.085	0.001
Max Flood	1.000		1.000	1.000	0.077	0.052
Dec Flood	1.000	1.000		0.966	0.021	0.050
Inc Ebb	1.000	1.000	0.966		0.029	0.918
Max Ebb	0.085	0.077	0.021	0.029		1.000
Dec Ebb	0.001	0.052	0.050	0.918	1.000	

b) All months (Zone 1)

	Inc Flood	Max Flood	Dec Flood	Inc Ebb	Max Ebb	Dec Ebb
Inc Flood		1.000	1.000	0.311	0.016	0.033
Max Flood	1.000		1.000	0.580	0.030	0.045
Dec Flood	1.000	1.000		0.212	0.006	0.037
Inc Ebb	0.311	0.580	0.212		1.000	0.615
Max Ebb	0.016	0.030	0.006	1.000		1.000
Dec Ebb	0.033	0.045	0.037	0.615	1.000	

c) Summer (All Zones)

	Inc Flood	Max Flood	Dec Flood	Inc Ebb	Max Ebb	Dec Ebb
Inc Flood		1.000	1.000	1.000	0.052	<0.001
Max Flood	1.000		1.000	1.000	0.044	0.011
Dec Flood	1.000	1.000		0.617	0.003	0.002
Inc Ebb	1.000	1.000	0.617		0.007	0.150
Max Ebb	0.052	0.044	0.003	0.007		1.000
Dec Ebb	<0.001	0.011	0.002	0.150	1.000	

d) Summer (Zone 1)

	Inc Flood	Max Flood	Dec Flood	Inc Ebb	Max Ebb	Dec Ebb
Inc Flood		1.000	1.000	0.329	0.015	0.027
Max Flood	1.000		1.000	0.638	0.030	0.035
Dec Flood	1.000	1.000		0.289	0.006	0.028
Inc Ebb	0.329	0.638	0.289		1.000	0.470
Max Ebb	0.015	0.030	0.006	1.000		1.000
Dec Ebb	0.027	0.035	0.028	0.470	1.000	

Tables 11-5 and 11-6 indicate some systematic variance in overall puffin site occupancy (All Zones) and occupancy of the array area (Zone 1) with tidal period. Probabilities are greater on flood than ebb tides. Similarly, the probabilities of puffin diving in Zone 1 are greater on flood tides and lowest on the maximum ebb. Figure B14 and B15 (Annex B) also indicates an increase in puffin occupancy in across the site and in the array area during flood tides (as observed for black guillemot and European Shag).

11.4 Summary of key points

1. Atlantic puffin was recorded in 18% of scans (947 of 5208 scan) and accounted for 4.69% of all bird sightings in vantage point surveys.
2. The overall average standardised puffin count for the entire survey area (All Zones) was 1.16 birds per scan/km², with the highest average counts recorded in June and July (4.80 and 4.47 per scan/km²). Counts were much lower in the remaining months in which the species was recorded and the species was absent from surveys between September and February.
3. Puffin was recorded in the array area (Zone 1) in 1.57% of scans (82 of 5208 scans), while birds were recorded diving in the array area (Diving Z1) in 1.08% of scans (56 of 5208 scans). The overall average standardised puffin count for the array area was 0.40 birds per scan/km², while overall, 0.23 birds per scan/km² were observed diving in the array area.
4. The average puffin count in scans of the entire survey area when the species was recorded was 3.99 birds per scan. Only 1 or 2 birds per scan were observed in scans of the array area when the species was recorded.
5. Probability modelling shows that there is a 55-60% likelihood that puffin will be seen in the entire survey area during a scan in June/July, a 0% likelihood during the autumn and winter and a less than 10-20% likelihood for the rest of the year. During months when puffin is present, there is a 2-6% likelihood they will be seen in the array area. There is a 70% likelihood that a puffin observed in the array area will dive. Overall, there is a less than 5% likelihood of a puffin diving in proximity to the turbines.
6. The probability of seeing a puffin increases over the course of the day and is greatest in the evening. This appears to be primarily linked to increases over the course of the day in summer months.
7. There is some systematic variance in puffin occupancy across the entire survey site and the array area with tidal period, with the probability of seeing a puffin greater on flood tides than ebb and lowest on the maximum ebb.
8. The overall proximity probability (probability of a puffin diving in proximity to the turbines) is consistently low throughout the year (generally less than 5%). The overall proximity probability appears to be greater on flood tides and negligible on ebb tides.

12. Common guillemot, *Uria aalge*

12.1 Occupancy by zone and month

The number and proportion of scans in which common guillemot was recorded, the mean standardised count per scan (per km²), and the mean count in positive scans are provided in Table 12-1.

Table 12-1 Number and proportion of scans in which counts of common guillemot were recorded, the mean standardised count per scan, and the mean count in positive scans for All Zones (the entire survey area), Zone 1 (the array area) and Diving Z1 (birds observed diving in Zone 1). The actual number of scans (from the total of 5208) is shown in italics in brackets. % 0s is the proportion and number of scans in which the species was not recorded.

Survey area	% scans with positive records	% 0s	Mean standardised count per scan/km ²	Mean count per scan (positive scans only)
All Zones	11.96 (623)	88.04 (4585)	0.30	1.58
Zone 1	0.42 (22)	99.58 (5186)	0.09	1.36
Diving Z1	0.08 (4)	99.92 (5204)	0.01	1.00

Common guillemot was recorded in 12% of scans and accounted for 1.22% of all bird sightings in vantage point surveys. The species was observed in <0.5% of scans in the array area (Zone 1). In scans of the entire survey area in which common guillemot was observed, an average of 1.58 birds per scan was recorded. Only 1 or 2 birds per scan were recorded in scans of the array area in which the species was observed.

Plots of descriptive statistics for common guillemot counts by survey area and month are provided in Annex B (separate document), Figure B16.

Table 12-2 (over) presents GEE-GLM (binomial) outputs for common guillemot by month, as follows:

1. Probability of a common guillemot occurring anywhere in the survey area (**All Zones**).
2. Probability of a common guillemot occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a common guillemot seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a common guillemot diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 12-2 GEE-GLM (Binomial) estimations of 1) probabilities of a common guillemot occurring within the entire survey area (All Zones), 2) probabilities of a common guillemot occurring within the array area (Zone 1), 3) probabilities that a common guillemot seen in the array area will dive (Diving Z1) and 4) probabilities of a common guillemot diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Month	All Zones	Zone 1	Diving Z1	Proximity probability
Jan	0.026 (0-0.631)	<i>0.000</i> No range	0.000* No range	0.000 No range
Feb	0.118 (0-0.759)	<i>0.007</i> No range	0.000* No range	0.000 No range
Mar	0.113 (0-0.739)	<i>0.000</i> No range	0.000* No range	0.000 No range
Apr	0.134 (0-0.755)	<i>0.004</i> No range	0.000* No range	0.000 No range
May	0.180 (0-0.796)	<i>0.013</i> No range	0.000* No range	0.000 No range
Jun	0.224 (0-0.839)	<i>0.008</i> No range	0.000* No range	0.000 No range
Jul	0.200 (0-0.818)	<i>0.007</i> No range	0.000* No range	0.000 No range
Aug	0.014 (0-0.668)	<i>0.002</i> No range	0.000* No range	0.000 No range
Sep	0.164 (0-0.820)	<i>0.002</i> No range	0.000* No range	0.000 No range
Oct	0.042 (0-0.730)	<i>0.000</i> No range	0.000* No range	0.000 No range
Nov	0.038 (0-0.703)	<i>0.000</i> No range	0.000* No range	0.000 No range
Dec	0.021 (0-0.683)	<i>0.000</i> No range	0.000* No range	0.000 No range

* Birds observed in Zone 1 in <15 scans in this month.

The models for Zone 1 and Diving Z1 did not converge due to a high percentage of 0s (>98%). Outputs for Tukey pairwise comparisons (with a Bonferroni correction) for differences between months for All Zones are shown in Table 12-3.

Table 12-3 Common guillemot Tukey pairwise comparisons (with a Bonferroni correction) for zone and tidal period, for All Zones. Significant p-values are in bold.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan		0.334	0.141	0.021	<0.001	<0.001	<0.001	1.000	0.118	1.000	1.000	1.000
Feb	0.334		1.000	1.000	1.000	1.000	1.000	0.017	1.000	1.000	1.000	0.318
Mar	0.141	1.000		1.000	1.000	1.000	1.000	0.004	1.000	1.000	1.000	0.169
Apr	0.021	1.000	1.000		1.000	1.000	1.000	<0.001	1.000	1.000	1.000	0.037
May	<0.001	1.000	1.000	1.000		1.000	1.000	<0.001	1.000	1.000	0.185	0.002
Jun	<0.001	1.000	1.000	1.000	1.000		1.000	<0.001	1.000	0.417	0.032	<0.001
Jul	<0.001	1.000	1.000	1.000	1.000	1.000		<0.001	1.000	0.850	0.101	0.001
Aug	1.000	0.017	0.004	<0.001	<0.001	<0.001	<0.001		0.006	1.000	1.000	1.000
Sep	0.118	1.000	1.000	1.000	1.000	1.000	1.000	0.006		1.000	1.000	0.113
Oct	1.000	1.000	1.000	1.000	1.000	0.417	0.850	1.000	1.000		1.000	1.000
Nov	1.000	1.000	1.000	1.000	0.185	0.032	0.101	1.000	1.000	1.000		1.000

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dec	1.000	0.318	0.169	0.037	0.002	<0.001	0.001	1.000	0.113	1.000	1.000	

While common guillemot was recorded throughout the year, Tables 12-2 and 12-3 indicate some systematic variance in overall site occupancy (All Zones) and in occupancy of the array area (Zone 1) for the species, with very low probabilities between October and January, rising to the greatest values in June and July.

12.2 Occupancy by time

Plots of descriptive statistics for common guillemot counts by time are provided in Annex B (separate document), Figures B17 and B18.

Table 12-4 presents GEE-GLM (binomial) outputs for common guillemot by time as follows:

1. Probability of a common guillemot occurring anywhere in the survey area (**All Zones**).
2. Probability of a common guillemot occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a common guillemot seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a common guillemot diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 12-4 GEE-GLM (Binomial) estimations of 1) probabilities of a common guillemot occurring within the entire survey area (All Zones), 2) probabilities of a common guillemot occurring within the array area (Zone 1), 3) probabilities that a common guillemot seen in the array area will dive (Diving Z1) and 4) probabilities of a common guillemot diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	0.105 (0-0.694)	0.009 (0-0.724)	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.102 (0-0.694)	0.003 (0-0.736)	0.000* <i>No range</i>	0.000 <i>No range</i>
14:01-18:00	0.130 (0-0.724)	0.005 (0-0.737)	0.000* <i>No range</i>	0.000 <i>No range</i>
18:01-22:00	0.248 (0-0.871)	0.000 (0-0.723)	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this time period.

b) Summer (April to September)

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	0.143 (0-0.740)	0.014 (0-0.719)	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.150 (0-0.75)	0.006 (0-0.733)	0.000* <i>No range</i>	0.000 <i>No range</i>
14:01-18:00	0.148 (0-0.752)	0.006 (0-0.732)	0.000* <i>No range</i>	0.000 <i>No range</i>
18:01-22:00	0.248 (0-0.877)	0.000 (0-0.713)	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this time period.

c) Winter (October to March)

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	0.045 (0-0.742)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.067 (0-0.733)	0.001 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
14:01-18:00	0.077 (0-0.78)	0.002 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
18:01-22:00	<i>No data for this time period during winter months due to short daylight hours</i>			

* Birds observed in Zone 1 in <15 scans in this time period.

Table 12-4 indicates little systematic variance in overall common guillemot site occupancy (All Zones) or in the array area with time of day, with some possible increase in probability in the evening. Convergence in models was limited, due to a high proportion of 0s (>98%), so Tukey pairwise comparisons to compare the probabilities above between time periods could not be run.

12.3 Occupancy by tidal period

Plots of descriptive statistics for common guillemot counts by tidal period are provided in Annex B (separate document), Figures B19 and B20.

Table 12-6 (over) presents GEE-GLM (binomial) outputs for common guillemot by tidal period, as follows:

1. Probability of a common guillemot occurring anywhere in the survey area (**All Zones**).
2. Probability of a common guillemot occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a common guillemot seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a common guillemot diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 12-6 GEE-GLM (Binomial) estimations of 1) probabilities of a common guillemot occurring within the entire survey area (All Zones), 2) probabilities of a common guillemot occurring within the array area (Zone 1), 3) probabilities that a common guillemot seen in the array area will dive (Diving Z1) and 4) probabilities of a common guillemot diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.135 (0-0.688)	0.006 (0-0.688)	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Flood	0.151 (0-0.724)	0.013 (0-0.698)	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Flood	0.127 (0-0.698)	0.004 (0-0.684)	0.000* <i>No range</i>	0.000 <i>No range</i>
Inc Ebb	0.102 (0-0.669)	0.001 (0-0.761)	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Ebb	0.095 (0-0.649)	0.001 (0-0.763)	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Ebb	0.117 (0-0.676)	0.004 (0-0.643)	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this tidal period.

b) Summer (April to September)

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.158 (0-0.721)	0.009 (0-0.715)	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Flood	0.195 (0-0.780)	0.016 (0-0.735)	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Flood	0.165 (0-0.747)	0.007 (0-0.708)	0.000* <i>No range</i>	0.000 <i>No range</i>
Inc Ebb	0.13 (0-0.703)	0.002 (0-0.775)	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Ebb	0.127 (0-0.689)	0.002 (0-0.776)	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Ebb	0.157 (0-0.725)	0.004 (0-0.673)	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this tidal period.

c) Winter (October to March)

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.099 (0-0.694)	0.000 (0-0.727)	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Flood	0.082 (0-0.689)	0.007 (0-0.809)	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Flood	0.077 (0-0.697)	0.000 (0-0.730)	0.000* <i>No range</i>	0.000 <i>No range</i>
Inc Ebb	0.064 (0-0.699)	0.000 (0-0.728)	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Ebb	0.050 (0-0.642)	0.000 (0-0.733)	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Ebb	0.048 (0-0.652)	0.003 (0-0.730)	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this tidal period.

Tukey pairwise comparisons (with a Bonferroni correction) could not be run to test for differences between the probabilities above due to very low sample sizes.

Table 12-6 indicates some systematic variance in overall common guillemot site occupancy (All Zones) with tidal period, with greater probabilities on flood tides. Similarly, occupancy of the array area (Zone 1) was greatest on the flood tide and around low water slack. Figure B19 and B20 (Annex B) indicates this increase in common guillemot occupancy across the site and in the array area during flood tides and around low water slack (as with the species reported above).

12.4 Summary of key points

1. Common guillemot was recorded in 12% of scans (623 of 5208 scans) and accounted for 1.22% of all bird sightings in vantage point surveys.
2. The overall average standardised common guillemot count for the entire survey area (All Zones) was 0.3 birds per scan/km², with the highest average counts recorded in June (0.62 per scan/km²) and very low counts between October and January.
3. Common guillemot was recorded in the array area (Zone 1) in 0.42% of scans (22 of 5208 scans), while in the nine years that vantage point surveys have been carried out four birds have been recorded diving in the array area (Diving Z1). The overall average standardised common guillemot count for the array area was 0.09 birds per scan/km², while overall, 0.01 birds per scan/km² were observed diving in the array area.
4. The average common guillemot count in scans of the entire survey area when the species was recorded was 1.58 birds per scan. Only 1 or 2 birds per scan were observed in scans of the array area when the species was recorded.
5. Probability modelling shows that there is a 20-25% likelihood that common guillemot will be seen in the entire survey area during a scan in June/July and a 10-15% likelihood for the rest of the breeding season and a <5% likelihood during winter. During months when common guillemot is present, there is a 2-6% likelihood they will be seen in the array area. There is a <1% likelihood that a common guillemot observed in the array area will dive. Overall, there is negligible likelihood of a common guillemot diving in proximity to the turbines.
6. There is little or no systematic variance in common guillemot occupancy throughout the day, though low sample sizes restricted analyses.
7. There is some systematic variance in common guillemot occupancy across the entire survey site and the array area with tidal period, with the probability of seeing a guillemot greater on flood tides and low water slack. Low sample sizes mean these observations should be treated with caution.
8. The overall proximity probability (probability of a common guillemot diving in proximity to the turbines) is consistently extremely low throughout the year (less than 1%).

13. Red-throated diver, *Gavia stellata*

13.1 Occupancy by zone and month

The number and proportion of scans in which red-throated diver was recorded, the mean standardised count per scan (per km²), and the mean count in positive scans are provided in Table 13-1.

Table 13-1 Number and proportion of scans in which counts of red-throated diver were recorded, the mean standardised count per scan, and the mean count in positive scans for All Zones (the entire survey area), Zone 1 (the array area) and Diving Z1 (birds observed diving in Zone 1). The actual number of scans (from the total of 5208) is shown in italics in brackets. % 0s is the proportion and number of scans in which the species was not recorded.

Survey area	% scans with positive records	% 0s	Mean standardised count per scan/km ²	Mean count per scan (positive scans only)
All Zones	8.05 (419)	91.95 (4789)	0.21	1.66
Zone 1	0.10 (5)	99.90 (5203)	0.02	1.40
Diving Z1	0.02 (1)	99.98 (5207)	<0.01	1.00

Red-throated diver was recorded in 8% of scans and accounted for 0.86% of all bird sightings in vantage point surveys. The species was observed in 0.1% of scans in the array area (Zone 1). In scans of the entire survey area in which red-throated diver was observed, an average of 1.66 birds per scan was recorded. Only 1 or 2 birds per scan were recorded in scans of the array area in which the species was observed.

Plots of descriptive statistics for red-throated diver counts by survey area and month are provided in Annex B (separate document), Figure B21.

Table 13-2 (over) presents GEE-GLM (binomial) outputs for red-throated diver by month, as follows:

1. Probability of a red-throated diver occurring anywhere in the survey area (**All Zones**).
2. Probability of a red-throated diver occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a red-throated diver seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a red-throated diver diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 13-2 GEE-GLM (Binomial) estimations of 1) probabilities of a red-throated diver occurring within the entire survey area (All Zones), 2) probabilities of a red-throated diver occurring within the array area (Zone 1), 3) probabilities that a red-throated diver seen in the array area will dive (Diving Z1) and 4) probabilities of a red-throated diver diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Month	All Zones	Zone 1	Diving Z1	Proximity probability
Jan	0.022 (0-0.632)	<i>0.000</i> No range	0.000* No range	0.000 No range
Feb	0.007 (0-0.673)	<i>0.000</i> No range	0.000* No range	0.000 No range
Mar	0.111 (0-0.756)	<i>0.000</i> No range	0.000* No range	0.000 No range
Apr	0.178 (0-0.803)	<i>0.006</i> No range	0.000* No range	0.000 No range
May	0.125 (0-0.759)	<i>0.000</i> No range	0.000* No range	0.000 No range
Jun	0.087 (0-0.711)	<i>0.002</i> No range	0.000* No range	0.000 No range
Jul	0.132 (0-0.762)	<i>0.000</i> No range	0.000* No range	0.000 No range
Aug	0.103 (0-0.730)	<i>0.000</i> No range	0.000* No range	0.000 No range
Sep	0.007 (0-0.673)	<i>0.000</i> No range	0.000* No range	0.000 No range
Oct	0.000 (0-0.626)	<i>0.000</i> No range	0.000* No range	0.000 No range
Nov	0.004 (0-0.746)	<i>0.000</i> No range	0.000* No range	0.000 No range
Dec	0.058 (0-0.795)	<i>0.004</i> No range	0.000* No range	0.000 No range

* Birds observed in Zone 1 in <15 scans in this month.

The models for Zone 1 and Diving Z1 did not converge due to a high percentage of 0s (>98%) and very low sample sizes. Outputs for Tukey pairwise comparisons (with a Bonferroni correction) for differences between months for All Zones are shown in Table 9-31.

Table 13-3 Red-throated diver Tukey pairwise comparisons (with a Bonferroni correction) for zone and tidal period, for All Zones. Significant p-values are in bold.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan		1.000	0.305	0.001	0.057	0.305	0.028	0.123	1.000	<0.001	1.000	1.000
Feb	1.000		0.001	<0.001	<0.001	<0.001	<0.001	<0.001	1.000	<0.001	1.000	1.000
Mar	0.305	0.001		1.000	1.000	1.000	1.000	1.000	0.001	<0.001	0.050	1.000
Apr	0.001	<0.001	1.000		1.000	1.000	1.000	1.000	<0.001	<0.001	0.003	1.000
May	0.057	<0.001	1.000	1.000		1.000	1.000	1.000	<0.001	<0.001	0.022	1.000
Jun	0.305	<0.001	1.000	1.000	1.000		1.000	1.000	<0.001	<0.001	0.071	1.000
Jul	0.028	<0.001	1.000	1.000	1.000	1.000		1.000	<0.001	<0.001	0.016	1.000
Aug	0.123	<0.001	1.000	1.000	1.000	1.000	1.000		<0.001	<0.001	0.040	1.000
Sep	1.000	1.000	0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	1.000	1.000
Oct	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001
Nov	1.000	1.000	0.050	0.003	0.022	0.071	0.016	0.040	1.000	<0.001		1.000

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dec	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	<0.001	1.000	

While red-throated diver was recorded throughout the year (except October), Tables 13-2 and 13-3 indicate some systematic variance in overall site occupancy (All Zones) for the species, with generally lower probabilities over winter months. Very few birds were observed in array area (Zone 1), so any obvious differences simply correspond with months when birds were observed.

13.2 Occupancy by time

Plots of descriptive statistics for red-throated diver counts by time are provided in Annex B (separate document), Figures B22 and B23.

Table 13-4 presents GEE-GLM (binomial) outputs for red-throated diver by time as follows:

1. Probability of a red-throated diver occurring anywhere in the survey area (**All Zones**).
2. Probability of a red-throated diver occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a red-throated diver seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a red-throated diver diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 13-4 GEE-GLM (Binomial) estimations of 1) probabilities of a red-throated diver occurring within the entire survey area (All Zones), 2) probabilities of a red-throated diver occurring within the array area (Zone 1), 3) probabilities that a red-throated diver seen in the array area will dive (Diving Z1) and 4) probabilities of a red-throated diver diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	0.070 (0-0.727)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.078 (0-0.731)	0.002 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
14:01-18:00	0.077 (0-0.739)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
18:01-22:00	0.172 (0-0.850)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this time period.

b) Summer (April to September)

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	0.114 (0-0.765)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.147 (0-0.794)	0.003 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
14:01-18:00	0.079 (0-0.734)	0.001 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
18:01-22:00	0.172 (0-0.845)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this time period.

c) Winter (October to March)

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	0.000 <i>No range</i>	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.026 <i>No range</i>	0.001 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
14:01-18:00	0.073 <i>No range</i>	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
18:01-22:00	<i>No data for this time period during winter months due to short daylight hours</i>			

* Birds observed in Zone 1 in <15 scans in this time period.

Tukey pairwise comparisons (with a Bonferroni correction) could not be run to test for differences between the probabilities above due to very low sample sizes.

Table 13-4 indicates some systematic variance in overall red-throated diver site occupancy (All Zones) with time of day, with probabilities greater in the evening. Table 9-4 b) and Figure B23 (Annex B) indicate that this was primarily linked to increases in counts and probabilities in summer. Table 13-4 does not indicate any systematic variance in occupancy of the array area (Zone 1), or in birds diving (Diving Z1) with time of day, though sample sizes were very small.

13.3 Occupancy by tidal period

Plots of descriptive statistics for red-throated diver counts by tidal period are provided in Annex B (separate document), Figures B24 and B25.

Table 13-5 (over) presents GEE-GLM (binomial) outputs for red-throated diver by tidal period, as follows:

1. Probability of a red-throated diver occurring anywhere in the survey area (**All Zones**).
2. Probability of a red-throated diver occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a red-throated diver seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a red-throated diver diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 13-5 GEE-GLM (Binomial) estimations of 1) probabilities of a red-throated diver occurring within the entire survey area (All Zones), 2) probabilities of a red-throated diver occurring within the array area (Zone 1), 3) probabilities that a red-throated diver seen in the array area will dive (Diving Z1) and 4) probabilities of a red-throated diver diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.109 (0-0.660)	0.000 (0-0.733)	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Flood	0.068 (0-0.662)	0.003 (0-0.775)	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Flood	0.079 (0-0.663)	0.001 (0-0.805)	0.000* <i>No range</i>	0.000 <i>No range</i>
Inc Ebb	0.065 (0-0.646)	0.000 (0-0.731)	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Ebb	0.077 (0-0.652)	0.001 (0-0.804)	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Ebb	0.091 (0-0.652)	0.001 (0-0.732)	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this tidal period.

b) Summer (April to September)

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.144 (0-0.703)	0.000 (0-0.735)	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Flood	0.087 (0-0.683)	0.005 (0-0.777)	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Flood	0.121 (0-0.706)	0.000 (0-0.732)	0.000* <i>No range</i>	0.000 <i>No range</i>
Inc Ebb	0.088 (0-0.668)	0.000 (0-0.731)	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Ebb	0.103 (0-0.683)	0.002 (0-0.804)	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Ebb	0.114 (0-0.673)	0.002 (0-0.732)	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this tidal period.

c) Winter (October to March)

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.053 (0-0.639)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Flood	0.039 (0-0.777)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Flood	0.022 (0-0.739)	0.002 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
Inc Ebb	0.033 (0-0.757)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Ebb	0.041 (0-0.721)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Ebb	0.052 (0-0.724)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this tidal period.

Tukey pairwise comparisons (with a Bonferroni correction) could not be run to test for differences between the probabilities above due to very low sample sizes.

Table 13-5 does not indicate any strong systematic variance in red-throated diver occupancy with tidal period across the entire site (All Zone). Table 13-5b) and Figure B25 indicate slightly greater probabilities and counts at maximum flood and ebb tides, mostly during summer months, though sample sizes were low.

13.4 Summary of key points

1. Red-throated diver was recorded in 8% of scans (419 of 5208 scans) and accounted for 0.86% of all bird sightings in vantage point surveys.
2. The overall average standardised red-throated diver count for the entire survey area (All Zones) was 0.21 birds per scan/km², with the highest average counts recorded in June (0.50 per scan/km²) and very low counts during winter months.
3. Red-throated diver was only recorded in the array area (Zone 1) in 0.10% of scans (5 of 5208 scans), while in the nine years that vantage point surveys have been carried out only a single bird has been recorded diving in the array area (Diving Z1). The overall average standardised red-throated diver count for the array area was 0.02 birds per scan/km², while overall, <0.01 birds per scan/km² were observed diving in the array area.
4. The average red-throated diver count in scans of the entire survey area when the species was recorded was 1.66 birds per scan. Only 1 or 2 birds per scan were observed in scans of the array area when the species was recorded.
5. Probability modelling shows that there is a 5-15% likelihood that red-throated diver will be seen in the entire survey area during a scan and a <1% likelihood they will be seen in the array area. There is a negligible likelihood that a red-throated diver observed in the array area will dive. Overall, there is negligible likelihood of a red-throated diver diving in proximity to the turbines.
6. The probability of seeing a red-throated diver in the entire survey area increases over the course of the day and is greatest in the evening. This appears to be primarily linked to increases over the course of the day in summer months.
7. There is little or no systematic variance in red-throated diver occupancy throughout the tidal cycle, though low sample sizes restricted analyses.
8. The overall proximity probability (probability of a red-throated diver diving in proximity to the turbines) is consistently extremely low/negligible throughout the year.

14. Northern gannet, *Morus bassanus*

14.1 Occupancy by zone and month

The number and proportion of scans in which northern gannet was recorded, the mean standardised count per scan (per km²), and the mean count in positive scans are provided in Table 14-1.

Table 14-1 Number and proportion of scans in which northern gannet were recorded, the mean standardised count per scan, and the mean count in positive scans for All Zones (the entire survey area), Zone 1 (the array area) and Diving Z1 (birds observed diving in Zone 1). The actual number of scans (from the total of 5208) is shown in italics in brackets. % 0s is the proportion and number of scans in which the species was not recorded.

Survey area	% scans with positive records	% 0s	Mean standardised count per scan/km ²	Mean count per scan (positive scans only)
All Zones	22.48 (1181)	77.52 (4027)	0.96	2.60
Zone 1	0.69 (36)	99.31 (5172)	0.16	1.56
Diving Z1	0.02 (1)	99.98 (5207)	<0.01	1.00

Northern gannet was recorded in 22% of scans and accounted for 3.85% of all bird sightings in vantage point surveys. The species was observed in 0.69% of scans in the array area (Zone 1). In scans of the entire survey area in which gannet was observed, an average of 2.60 birds per scan was recorded. Only 1 or 2 birds per scan were recorded in scans of the array area in which the species was observed.

Plots of descriptive statistics for northern gannet counts by survey area and month are provided in Annex B (separate document), Figure B26.

Table 14-2 (over) presents GEE-GLM (binomial) outputs for northern gannet by month, as follows:

1. Probability of a gannet occurring anywhere in the survey area (**All Zones**).
2. Probability of a gannet occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a gannet seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a gannet diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 14-2 GEE-GLM (Binomial) estimations of 1) probabilities of a gannet occurring within the entire survey area (All Zones), 2) probabilities of a gannet occurring within the array area (Zone 1), 3) probabilities that a gannet seen in the array area will dive (Diving Z1) and 4) probabilities of a gannet diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Month	All Zones	Zone 1	Diving Z1	Proximity probability
Jan	0.019 (0-0.679)	<i>0.000</i> No range	0.000* No range	0.000 No range
Feb	0.025 (0-0.707)	<i>0.000</i> No range	0.000* No range	0.000 No range
Mar	0.105 (0-0.781)	<i>0.000</i> No range	0.000* No range	0.000 No range
Apr	0.172 (0-0.844)	<i>0.000</i> No range	0.000* No range	0.000 No range
May	0.131 (0-0.807)	<i>0.015</i> No range	0.000* No range	0.000 No range
Jun	0.222 (0-0.895)	<i>0.016</i> No range	0.000* No range	0.000 No range
Jul	0.375 (0-1)	<i>0.003</i> No range	0.000* No range	0.000 No range
Aug	0.603 (0-1)	<i>0.018</i> No range	0.000* No range	0.000 No range
Sep	0.650 (0-1)	<i>0.019</i> No range	0.000* No range	0.000 No range
Oct	0.064 (0-0.752)	<i>0.003</i> No range	0.000* No range	0.000 No range
Nov	0.000 (0-0.674)	<i>0.000</i> No range	0.000* No range	0.000 No range
Dec	0.025 (0-0.728)	<i>0.000</i> No range	0.000* No range	0.000 No range

* Birds observed in Zone 1 in <15 scans in this month.

The models for Zone 1 and Diving Z1 did not converge due to a high percentage of 0s (>98%) and very low sample sizes. Outputs for Tukey pairwise comparisons (with a Bonferroni correction) for differences between months for All Zones are shown in Table 14-3.

Table 14-3 Northern gannet Tukey pairwise comparisons (with a Bonferroni correction) for zone and tidal period, for All Zones. Significant p-values are in bold.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan		1.000	0.994	0.065	0.375	0.014	< 0.001	< 0.001	< 0.001	1.000	< 0.001	1.000
Feb	1.000		0.156	0.001	0.026	< 0.001	< 0.001	< 0.001	< 0.001	1.000	< 0.001	1.000
Mar	0.994	0.156		1.000	1.000	1.000	0.002	< 0.001	< 0.001	1.000	< 0.001	1.000
Apr	0.065	0.001	1.000		1.000	1.000	0.170	< 0.001	< 0.001	1.000	< 0.001	0.043
May	0.375	0.026	1.000	1.000		1.000	0.025	< 0.001	< 0.001	1.000	< 0.001	0.365
Jun	0.014	< 0.001	1.000	1.000	1.000		1.000	< 0.001	< 0.001	0.400	< 0.001	0.007
Jul	< 0.001	< 0.001	0.002	0.170	0.025	1.000		0.237	0.040	0.001	< 0.001	< 0.001
Aug	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.237		1.000	< 0.001	< 0.001	< 0.001
Sep	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.040	1.000		< 0.001	< 0.001	< 0.001
Oct	1.000	1.000	1.000	1.000	1.000	0.400	0.001	< 0.001	< 0.001		< 0.001	1.000
Nov	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001		< 0.001
Dec	1.000	1.000	1.000	0.043	0.365	0.007	< 0.001	< 0.001	< 0.001	1.000	< 0.001	

Tables 14-2 and 14-3 indicate some systematic seasonal variance in overall gannet site occupancy (All Zones) with generally higher probabilities in August and September. This occupancy pattern was less pronounced in the array area (Zone 1) (see also Figure B26, Annex B). Fewer than 15 birds were observed diving in the array area across all surveys.

14.2 Occupancy by time

Plots of descriptive statistics for northern gannet counts by time are provided in Annex B (separate document), Figures B27 and B28.

Table 14-4 presents GEE-GLM (binomial) outputs for northern gannet by time as follows:

1. Probability of a gannet occurring anywhere in the survey area (**All Zones**).
2. Probability of a gannet occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a gannet seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a gannet diving in proximity to the turbines (**Proximity probability**).

Figures in brackets table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no range.

Table 14-4 GEE-GLM (Binomial) estimations of 1) probabilities of a gannet occurring within the entire survey area (All Zones), 2) probabilities of a gannet occurring within the array area (Zone 1), 3) probabilities that a gannet seen in the array area will dive (Diving Z1) and 4) probabilities of a gannet diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	0.307 (0-0.917)	0.009 (0-0.724)	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.162 (0-0.771)	0.005 (0-0.740)	0.000* <i>No range</i>	0.000 <i>No range</i>
14:01-18:00	0.293 (0-0.907)	0.009 (0-0.735)	0.000* <i>No range</i>	0.000 <i>No range</i>
18:01-22:00	0.254 (0-0.890)	0.006 (0-0.806)	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this time period.

b) Summer (April to September)

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	0.457 (0-1)	0.014 (0-0.719)	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.326 (0-0.931)	0.012 (0-0.737)	0.000* <i>No range</i>	0.000 <i>No range</i>
14:01-18:00	0.369 (0-0.982)	0.012 (0-0.729)	0.000* <i>No range</i>	0.000 <i>No range</i>
18:01-22:00	0.254 (0-0.888)	0.006 (0-0.801)	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this time period.

c) Winter (October to March)

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	0.068 (0-0.678)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
10:01-14:00	0.039 (0-0.661)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
14:01-18:00	0.065 (0-0.694)	0.002 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
18:01-22:00	<i>No data for this time period during winter months due to short daylight hours</i>			

* Birds observed in Zone 1 in <15 scans in this time period.

Convergence in the models above was limited, due to a high proportion of 0s in most time periods (>98%) for gannet. Outputs from Tukey pairwise comparisons (with a Bonferroni correction) for the All months (All Zones) model are shown in Table 14-5.

Table 14-5 Northern gannet Tukey pairwise comparisons (with a Bonferroni correction) for time period for All months (All Zones). Significant p-values are in bold.

	06:00-10:00	10:01-14:00	14:01-18:00	18:01-22:00
06:00-10:00		0.364	1.000	1.000
10:01-14:00	0.364		<0.001	0.681
14:01-18:00	1.000	<0.001		1.000
18:01-22:00	1.000	0.681	1.000	

Tables 14-4 and 14-5 indicate little systematic variance in overall gannet site occupancy (All Zones) or in occupancy of the array area (Zone 1) with time of day.

14.3 Occupancy by tidal period

Plots of descriptive statistics for northern gannet counts by tidal period are provided in Annex B (separate document), Figures B29 and B30.

Table 14-6 (over) presents GEE-GLM (binomial) outputs for northern gannet by tidal period, as follows:

1. Probability of a gannet occurring anywhere in the survey area (**All Zones**).
2. Probability of a gannet occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a gannet seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a gannet diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 14-6 GEE-GLM (Binomial) estimations of 1) probabilities of a gannet occurring within the entire survey area (All Zones), 2) probabilities of a gannet occurring within the array area (Zone 1), 3) probabilities that a gannet seen in the array area will dive (Diving Z1) and 4) probabilities of a gannet diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.227 (0-0.779)	0.006 (0-0.693)	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Flood	0.229 (0-0.789)	0.018 (0-0.689)	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Flood	0.224 (0-0.785)	0.007 (0-0.700)	0.000* <i>No range</i>	0.000 <i>No range</i>
Inc Ebb	0.190 (0-0.748)	0.002 (0-0.720)	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Ebb	0.233 (0-0.773)	0.007 (0-0.706)	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Ebb	0.265 (0-0.809)	0.005 (0-0.652)	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this tidal period.

b) Summer (April to September)

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.351 (0-0.907)	0.009 (0-0.696)	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Flood	0.342 (0-0.905)	0.028 (0-0.701)	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Flood	0.326 (0-0.892)	0.011 (0-0.703)	0.000* <i>No range</i>	0.000 <i>No range</i>
Inc Ebb	0.301 (0-0.862)	0.004 (0-0.721)	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Ebb	0.381 (0-0.925)	0.012 (0-0.711)	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Ebb	0.403 (0-0.949)	0.008 (0-0.655)	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this tidal period.

c) Winter (October to March)

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.032 (0-0.658)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Flood	0.054 (0-0.704)	0.004 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Flood	0.086 (0-0.731)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
Inc Ebb	0.040 (0-0.676)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
Max Ebb	0.028 (0-0.662)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>
Dec Ebb	0.029 (0-0.648)	0.000 <i>No range</i>	0.000* <i>No range</i>	0.000 <i>No range</i>

* Birds observed in Zone 1 in <15 scans in this tidal period.

The Zone 1 (winter) model did not converge due to a high percentage of 0s (>98%) for all tidal periods. In the Diving (Z1) category, samples sizes were low for all tidal periods and so pairwise

comparisons were not performed. For the remaining zones/seasons, Tukey pairwise comparisons (with a Bonferroni correction) identified no significant differences between tidal periods.

Table 14-6 does not indicate any strong systematic variance in gannet occupancy with tidal period across the entire site (All Zone) or in the array area (Zone 1).

14.4 Summary of key points

1. Northern gannet was recorded in 22% of scans (1181 of 5208 scans) and accounted for 3.85% of all bird sightings in vantage point surveys.
2. The overall average standardised gannet count for the entire survey area (All Zones) was 0.96 birds per scan/km², with the highest average counts recorded in August (3.70 per scan/km²).
3. Gannet was recorded in the array area (Zone 1) in 0.69% of scans (36 of 5208 scans), while in the nine years that vantage point surveys have been carried out only a single bird has been recorded diving in the array area (Diving Z1). The overall average standardised gannet count for the array area was 0.16 birds per scan/km², while overall, <0.01 birds per scan/km² were observed diving in the array area.
4. The average gannet count in scans of the entire survey area when the species was recorded was 2.60 birds per scan. Only 1 or 2 birds per scan were observed in scans of the array area when the species was recorded.
5. Probability modelling shows that the likelihood that gannet will be seen in the entire survey area during a scan varies with season and is greatest (60%) in August and September. The likelihood that gannet will be seen in the array area is <2% all year. There is a negligible likelihood that a gannet observed in the array area will dive. Overall, there is negligible likelihood of a gannet diving in proximity to the turbines.
6. There is little systematic variance in overall gannet site occupancy (All Zones) or in occupancy of the array area (Zone 1) with time of day, though low sample sizes restricted analyses.
7. There is little systematic variance in overall gannet site occupancy (All Zones) or in occupancy of the array area (Zone 1) with tidal period, though low sample sizes restricted analyses.
8. The overall proximity probability (probability of a gannet diving in proximity to the turbines) is consistently extremely low/negligible throughout the year.

15. All diving birds (amalgamated species)

15.1 Occupancy by zone and month

At least one individual of at least one of the six diving bird species examined in detail in this report was recorded in the entire survey area (All Zones) in each of the 5208 scans. Diving birds were recorded in the array area (Zone 1) in approximately 15% of scans, while birds were observed diving in the array area in less than 5% of all scans. Black guillemot and European shag were the most commonly recorded species.

Plots of descriptive statistics for all diving bird (amalgamated species) counts by survey area and month are provided in Annex B (separate document), Figure B31.

Table 15-1 presents GEE-GLM (binomial) outputs for all birds (amalgamated diving species) by month, as follows:

1. Probability of a diving bird occurring anywhere in the survey area (**All Zones**).
2. Probability of a diving bird occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a diving bird seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a bird diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days.

Table 15-1 GEE-GLM (Binomial) estimations of 1) probabilities of a diving bird occurring within the entire survey area (All Zones), 2) probabilities of a diving bird occurring within the array area (Zone 1), 3) probabilities that a diving bird seen in the array area will dive (Diving Z1) and 4) probabilities of a bird diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Month	All Zones	Zone 1	Diving Z1	Proximity probability
Jan	<i>1.000</i> No range	0.176 (0-0.724)	0.255 (0-0.839)	0.045 (0-0.607)
Feb	<i>1.000</i> No range	0.139 (0-0.701)	0.417 (0-1)	0.058 (0-0.701)
Mar	<i>1.000</i> No range	0.097 (0-0.667)	0.286 (0-0.890)	0.028 (0-0.594)
Apr	<i>0.996</i> No range	0.135 (0-0.717)	0.352 (0-0.966)	0.047 (0-0.693)
May	<i>0.998</i> No range	0.169 (0-0.750)	0.213 (0-0.835)	0.036 (0-0.626)
Jun	<i>0.998</i> No range	0.196 (0-0.768)	0.354 (0-0.973)	0.070 (0-0.747)
Jul	<i>0.998</i> No range	0.193 (0-0.758)	0.345 (0-0.955)	0.067 (0-0.724)
Aug	<i>0.990</i> No range	0.129 (0-0.709)	0.292 (0-0.933)	0.038 (0-0.661)
Sep	<i>0.995</i> No range	0.127 (0-0.708)	0.182 (0-0.822)	0.023 (0-0.582)
Oct	<i>1.000</i> No range	0.147 (0-0.718)	0.245 (0-0.875)	0.036 (0-0.628)
Nov	<i>0.989</i> No range	0.208 (0-0.788)	0.418 (0-1)	0.087 (0-0.788)
Dec	<i>0.979</i> No range	0.104 (0-0.670)	0.400 (0-1)	0.042 (0-0.670)

The 'All Zones' models did not converge due to a high percentage of 1s (>98%), so it was not possible to run monthly comparisons for this data. For the models that did converge, Tukey pairwise comparisons (with a Bonferroni correction) were run to compare the probabilities above between zones and months, but no significant differences were identified.

Tables 15-1 does not indicate any systematic variance in overall diving bird site occupancy (All Zones), occupancy of the array area (Zone 1) or diving (Diving Z1) amongst months. Probabilities are broadly similar in all 12 months, reflecting the pattern seen in black guillemot (the most commonly sighted species).

15.2 Occupancy by time

Plots of descriptive statistics for bird counts by time are provided in Annex B (separate document), Figures B32 and B33.

Table 15-2 presents GEE-GLM (binomial) outputs for all birds (amalgamated diving species) by time as follows:

1. Probability of a bird occurring anywhere in the survey area (**All Zones**).
2. Probability of a bird occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a bird seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a bird diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 15-2 GEE-GLM (Binomial) estimations of 1) probabilities of a bird occurring within the entire survey area (All Zones), 2) probabilities of a bird occurring within the array area (Zone 1), 3) probabilities that a bird seen in the array area will dive (Diving Z1) and 4) probabilities of a bird diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	<i>1.000</i> No range	0.149 (0-0.766)	0.177 (0-0.871)	0.026 (0-0.667)
10:01-14:00	<i>0.994</i> No range	0.151 (0-0.766)	0.336 (0-1)	0.051 (0-0.766)
14:01-18:00	<i>0.998</i> No range	0.150 (0-0.770)	0.289 (0-0.986)	0.043 (0-0.759)
18:01-22:00	<i>1.000</i> No range	0.189 (0-0.822)	0.344 (0-1)	0.065 (0-0.822)

b) Summer (April to September)

Time period	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	1.000 No range	0.114 (0-0.815)	0.000* No range	0.000 No range
10:01-14:00	0.992 No range	0.162 (0-0.861)	0.322 No range	0.052 No range
14:01-18:00	0.998 No range	0.158 (0-0.860)	0.287 No range	0.045 No range
18:01-22:00	1.000 No range	0.189 (0-0.897)	0.344 No range	0.065 No range

* Birds observed in Zone 1 in <15 scans in this time period.

c) Winter (October to March)

Time	All Zones	Zone 1	Diving (Z1)	Proximity probability
06:00-10:00	1.000 No range	0.205 (0-0.824)	0.000* No range	0.000 No range
10:01-14:00	0.995 No range	0.144 (0-0.756)	0.347 (0-0.995)	0.050 (0-0.752)
14:01-18:00	0.998 No range	0.128 (0-0.754)	0.293 (0-0.954)	0.038 (0-0.719)
18:01-22:00	No data for this time period during winter months due to short daylight hours			

* Birds observed in Zone 1 in <15 scans in this time period.

Many of the models above did not converge a high percentage of 1s (>98%) and so comparisons for time periods could not be run. Where models did converge, Tukey pairwise comparisons (with a Bonferroni correction) were run to compare the probabilities above between time periods, but no significant differences were identified.

Table 15-2 does not indicate any systematic variance in overall diving bird site occupancy (All Zones) with time of day but does indicate the probability of a bird occurring in the array area (Zone 1) is greatest in the evening. Table 15-2 b) indicates that this was primarily linked to occupancy patterns during the summer.

15.3 Occupancy by tidal period

Table 15-3 presents GEE-GLM (binomial) outputs for all birds (amalgamated diving species) by tidal period, as follows:

1. Probability of a bird occurring anywhere in the survey area (**All Zones**).
2. Probability of a bird occurring within Zone 1 - the array area (**Zone 1**).
3. Probability that a bird seen in Zone 1 will dive (**Diving Z1**).
4. Probability of a bird diving in proximity to the turbines (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 15-3 GEE-GLM (Binomial) estimations of 1) probabilities of a bird occurring within the entire survey area (All Zones), 2) probabilities of a bird occurring within the array area (Zone 1), 3) probabilities that a bird seen in the array area will dive (Diving Z1) and 4) probabilities of a bird diving in proximity to the turbines (Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.994 (0.232-1)	0.220 (0-0.764)	0.319 (0-0.893)	0.070 (0-0.682)
Max Flood	0.994 (0.242-1)	0.193 (0-0.741)	0.324 (0-0.909)	0.062 (0-0.674)
Dec Flood	0.995 (0.240-1)	0.201 (0-0.746)	0.391 (0-0.960)	0.079 (0-0.716)
Inc Ebb	0.997 (0.237-1)	0.105 (0-0.651)	0.231 (0-0.810)	0.024 (0-0.527)
Max Ebb	0.997 (0.235-1)	0.081 (0-0.626)	0.157 (0-0.763)	0.013 (0-0.478)
Dec Ebb	0.999 (0.268-1)	0.124 (0-0.660)	0.308 (0-0.862)	0.038 (0-0.569)

b) Summer (April to September)

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.998 (0.196-1)	0.270 (0-0.824)	0.300 (0-0.909)	0.081 (0-0.749)
Max Flood	0.995 (0.225-1)	0.218 (0-0.785)	0.263 (0-0.877)	0.057 (0-0.688)
Dec Flood	0.995 (0.219-1)	0.225 (0-0.787)	0.399 (0-1)	0.090 (0-0.787)
Inc Ebb	0.996 (0.224-1)	0.109 (0-0.670)	0.290 (0-0.896)	0.032 (0-0.600)
Max Ebb	0.994 (0.232-1)	0.052 (0-0.624)	0.077 (0-0.769)	0.004 (0-0.480)
Dec Ebb	0.998 (0.267-1)	0.102 (0-0.654)	0.222 (0-0.806)	0.023 (0-0.527)

c) Winter (October to March)

Tidal period	All Zones	Zone 1	Diving Z1	Proximity probability
Inc Flood	0.989 <i>No range</i>	0.141 (0-0.702)	0.375 (0-0.969)	0.053 (0-0.680)
Max Flood	0.993 <i>No range</i>	0.157 (0-0.723)	0.455 (0-1)	0.071 (0-0.723)
Dec Flood	0.996 <i>No range</i>	0.169 (0-0.733)	0.377 (0-0.970)	0.064 (0-0.711)
Inc Ebb	0.998 <i>No range</i>	0.100 (0-0.668)	0.143 (0-0.766)	0.014 (0-0.512)
Max Ebb	1.000 <i>No range</i>	0.122 (0-0.678)	0.205 (0-0.833)	0.025 (0-0.565)
Dec Ebb	1.000 <i>No range</i>	0.161 (0-0.708)	0.400 (0-0.970)	0.065 (0-0.687)

Where models converged, Tukey pairwise comparisons (with a Bonferroni correction) were run to compare the probabilities above between tidal periods. Outputs from those pairwise comparisons that identified significant differences between time periods are shown in Table 15-4.

Table 15-4 Tukey pairwise comparisons (with a Bonferroni correction) for zone and tidal period, for a) All months (Zone 1) and b) Summer (Zone 1). Significant p-values are in bold.

a) All months (Zone 1)

	Inc Flood	Max Flood	Dec Flood	Inc Ebb	Max Ebb	Dec Ebb
Inc Flood		1.000	1.000	<0.001	<0.001	0.001
Max Flood	1.000		1.000	0.002	<0.001	0.098
Dec Flood	1.000	1.000		<0.001	<0.001	0.021
Inc Ebb	<0.001	0.002	<0.001		1.000	1.000
Max Ebb	<0.001	<0.001	<0.001	1.000		0.128
Dec Ebb	0.001	0.098	0.021	1.000	0.128	

b) Summer (Zone 1)

	Inc Flood	Max Flood	Dec Flood	Inc Ebb	Max Ebb	Dec Ebb
Inc Flood		1.000	1.000	<0.001	<0.001	<0.001
Max Flood	1.000		1.000	0.013	<0.001	0.015
Dec Flood	1.000	1.000		<0.001	<0.001	0.003
Inc Ebb	<0.001	0.013	<0.001		0.024	1.000
Max Ebb	<0.001	<0.001	<0.001	0.024		0.161
Dec Ebb	<0.001	0.015	0.003	1.000	0.161	

Tables 15-3 and 15-4 do not indicate any systematic variance in overall site occupancy (All Zones) with tidal period. However, they do indicate some systematic variance in occupancy of the array area (Zone 1), with probabilities greater in flood than ebb tides. A similar pattern was seen in birds diving in Zone 1, with increased probabilities around low water slack and on the flood tide.

15.4 Summary of key points

1. At least one of the six diving bird species analysed in detail in this report was recorded in each of the 5208 snapshot scans. 91% of all diving birds recorded were either black guillemot or European shag.
2. Diving birds recorded in vantage point surveys were generally present as individuals or in small groups within the whole survey area (All Zones), and as individuals within the array area (Zone 1).
3. Probability modelling shows that there is a 98-100% likelihood that diving bird will be seen in the entire survey area during a scan and a 10-20% likelihood a diving bird will be seen in the array area. There is a 20-40% likelihood that a diving bird observed in the array area will dive. Overall, there is a <10% likelihood of a diving bird diving in proximity to the turbines.
4. There is no systematic seasonal variance in diving bird site occupancy in the entire survey area with a high year-round probability of seeing a diving birds within scans. This pattern is

largely driven by black guillemot and European shag, the two most frequent and abundant species recorded. Occupancy within the array area shows some seasonal variance, with greater probabilities of seeing a diving bird in November (corresponding to the times of the highest black guillemot and European shag counts) and again in June/July (corresponding to higher counts of certain species during the breeding season; presumably central-based foragers from nearby colonies).

5. There is no systematic diurnal variance in overall diving bird site occupancy, with a high probability of seeing a diving birds within the site throughout daylight hours. However, the probability of a diving bird occurring in the array area is greater in the evening (when daylight hours extended beyond 18:00).
6. There is no systematic variance in overall diving bird site occupancy with tidal period, with a high probability of seeing a diving birds within the site across all tidal periods. However, the probability of a diving bird occurring in the array area is greater during flood tide. Similarly, the probability of seeing a bird diving in the array area is greatest around low water slack and on the flood tide.
7. The overall proximity probability (probability of a bird diving in proximity to the turbines) is consistently very low (<10%), even during 'higher risk' times, such as November and flood tide (e.g. black guillemot, European shag), or summer, evening and flood tides (e.g. puffin, common guillemot).

16. Common seal, *Phoca vitulina*

16.1 Occupancy by zone and month

The number and proportion of scans in which common seal was recorded, the mean standardised count per scan (per km²), and the mean count in positive scans are provided in Table 16-1.

Table 16-1 Number and proportion of scans in which common seal was recorded, the mean standardised count per scan, and the mean count in positive scans for All Zones (the entire survey area and Zone 1 (the array area)). The actual number of scans (from the total of 3120) is shown in italics brackets. % 0s is the proportion and number of scans in which the species was not recorded.

Survey area	% scans with positive records	% 0s	Mean standardised count per scan/km ²	Mean count per scan (positive scans only)
All Zones	12.21 (381)	87.79 (2739)	0.30	1.51
Zone 1	0.32 (10)	99.68 (3110)	0.05	1.00

Common seal was the most frequently recorded marine mammal species in vantage point surveys. The species was observed in 12% of the 3120 scans. It was the second most abundant species (after harbour porpoise), accounting for 35% of all marine mammal sightings. The species was observed in 0.32% of scans in the array area (Zone 1). In scans of the entire survey area in which common seal was observed, an average of 1.51 seals per scan was recorded. Only solitary seals were recorded in scans of the array area in which the species was observed.

Plots of descriptive statistics for common seal counts by survey area and month are provided in Annex B (separate document), Figure B34.

Table 16-2 presents GEE-GLM (binomial) outputs for common seal by month, as follows:

1. Probability of a common seal occurring anywhere in the survey area (**All Zones**).
2. Probability of a common seal occurring within Zone 1 - the array area (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days.

Table 16-2 GEE-GLM (Binomial) estimations of 1) probabilities of a common seal occurring within the entire survey area (All Zones), 2) probabilities of a common seal occurring within the array area (Zone 1 - Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets.

Month	All Zones		Zone 1 (Proximity probability)	
Jan	0.238	(0-0.818)	0.000*	No range
Feb	0.159	(0-0.755)	0.000*	No range
Mar	0.139	(0-0.740)	0.000*	No range
Apr	0.106	(0-0.713)	0.000*	No range
May	0.090	(0-0.697)	0.000*	No range
Jun	0.103	(0-0.725)	0.000*	No range
Jul	0.070	(0-0.689)	0.000*	No range

Month	All Zones		Zone 1 (Proximity probability)	
Aug	0.011	(0-0.664)	0.000*	No range
Sep	0.075	(0-0.690)	0.000*	No range
Oct	0.171	(0-0.795)	0.000*	No range
Nov	0.146	(0-0.743)	0.000*	No range
Dec	0.206	(0-0.837)	0.000*	No range

* Seals observed in Zone 1 in <15 scans in this month.

The model for Zone 1 did not converge due to a high percentage of 0s (>98%). The outputs from Tukey pairwise tests (with a Bonferroni correction) comparing common seal presence within each month for All Zones are presented in Table 16-3.

Table 16-3 Common seal Tukey pairwise comparisons (with a Bonferroni correction) for zone and month, for All Zones. Significant p-values are in bold.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan		1.000	1.000	1.000	0.539	1.000	0.222	<0.001	0.270	1.000	1.000	1.000
Feb	1.000		1.000	1.000	1.000	1.000	1.000	<0.001	1.000	1.000	1.000	1.000
Mar	1.000	1.000		1.000	1.000	1.000	1.000	0.001	1.000	1.000	1.000	1.000
Apr	1.000	1.000	1.000		1.000	1.000	1.000	0.010	1.000	1.000	1.000	1.000
May	0.539	1.000	1.000	1.000		1.000	1.000	0.029	1.000	1.000	1.000	1.000
Jun	1.000	1.000	1.000	1.000	1.000		1.000	0.033	1.000	1.000	1.000	1.000
Jul	0.222	1.000	1.000	1.000	1.000	1.000		0.257	1.000	1.000	1.000	1.000
Aug	<0.001	<0.001	0.001	0.010	0.029	0.033	0.257		0.149	0.001	<0.001	<0.001
Sep	0.270	1.000	1.000	1.000	1.000	1.000	1.000	0.149		1.000	1.000	1.000
Oct	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.001	1.000		1.000	1.000
Nov	1.000	1.000	1.000	1.000	1.000	1.000	1.000	<0.001	1.000	1.000		1.000
Dec	1.000	1.000	1.000	1.000	1.000	1.000	1.000	<0.001	1.000	1.000	1.000	

While common seal was recorded throughout the year, Tables 16-2 and 16-3 indicate some systematic variance in overall site occupancy (All Zones), with generally lower probabilities in summer months. It may be more likely that any differences simply highlight positive observations in a dataset based on such a low number of sightings. With only 10 observations of seals in zone 1 in over 3000 scans, it is not possible to identify trends with any confidence.

16.2 Occupancy by time

Plots of descriptive statistics for common seal counts by survey area and time period are provided in Annex B (separate document), Figure B35 and B36.

Table 16-4 (over) presents GEE-GLM (binomial) outputs for common seal by time, as follows:

1. Probability of seeing a common seal anywhere in the survey area (**All Zones**).
2. Probability of a common seal occurring within Zone 1 - the array area (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 16-4 GEE-GLM (Binomial) estimations of 1) probabilities of a common seal occurring within the entire survey area (All Zones), 2) probabilities of a common seal occurring within the array area (Zone 1 – Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Time period	All Zones	Zone 1 (Proximity probability)
06:00-10:00	0.156 (0-0.743)	0.000* <i>No range</i>
10:01-14:00	0.154 (0-0.743)	0.000* <i>No range</i>
14:01-18:00	0.084 (0-0.677)	0.000* <i>No range</i>
18:01-22:00	0.089 (0-0.704)	0.000* <i>No range</i>

* Seals observed in Zone 1 in <15 scans in this time period.

b) Summer (April to September)

Time period	All Zones	Zone 1 (Proximity probability)
06:00-10:00	0.103 (0-0.734)	0.000* <i>No range</i>
10:01-14:00	0.103 (0-0.738)	0.000* <i>No range</i>
14:01-18:00	0.057 (0-0.696)	0.000* <i>No range</i>
18:01-22:00	0.089 (0-0.740)	0.000* <i>No range</i>

* Seals observed in Zone 1 in <15 scans in this time period.

c) Winter (October to March)

Time period	All Zones	Zone 1 (Proximity probability)
06:00-10:00	0.210 (0-0.827)	0.000* <i>No range</i>
10:01-14:00	0.183 (0-0.802)	0.000* <i>No range</i>
14:01-18:00	0.146 (0-0.770)	0.000* <i>No range</i>
18:01-22:00	<i>No data for this time period during winter months due to short daylight hours</i>	

* Seals observed in Zone 1 in <15 scans in this time period.

The models for Zone 1 did not converge due to a high percentage of 0s (>98%). Outputs from Tukey pairwise comparisons (with a Bonferroni correction) for All Zones for which significant differences between time periods were identified are shown in Table 16-5.

Table 16-5 Common seal Tukey pairwise comparisons (with a Bonferroni correction) for time period, for All months (All Zones). Significant p-values are in bold.

	06:00-10:00	10:01-14:00	14:01-18:00	18:01-22:00
06:00-10:00		1.000	0.368	1.000
10:01-14:00	1.000		<0.001	0.390
14:01-18:00	0.368	<0.001		1.000
18:01-22:00	1.000	0.390	1.000	

Tables 16-4 and 16-5 do not indicate any strong systematic diurnal variance in overall common seal site occupancy (All Zones), though probabilities are slightly greater in the first half of the day across the entire survey area. However, it may be more likely that any differences simply highlight positive observations in a dataset based on such a low number of sightings. With only 10 observations of seals in zone 1 in over 3000 scans, it is not possible to identify trends with any confidence.

16.3 Occupancy by tidal period

Plots of descriptive statistics for common seal counts by survey area and tidal period are provided in Annex B (separate document), Figure B37 and B38.

Table 16-6 presents GEE-GLM (binomial) outputs for common seal by tidal period, as follows:

1. Probability of seeing a common seal anywhere in the survey area (**All Zones**).
2. Probability of a common seal occurring within Zone 1 - the array area (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no range.

Table 16-6 GEE-GLM (Binomial) estimations of 1) probabilities of a common seal occurring within the entire survey area (All Zones), 2) probabilities of a common seal occurring within the array area (Zone 1 – Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Tidal period	All Zones		Zone 1 (Proximity probability)	
Inc Flood	0.064	(0-0.626)	0.000*	(0-0.765)
Max Flood	0.132	(0-0.707)	0.000*	(0-0.773)
Dec Flood	0.155	(0-0.724)	0.000*	(0-0.806)
Inc Ebb	0.143	(0-0.708)	0.000*	(0-0.806)
Max Ebb	0.117	(0-0.675)	0.000*	(0-0.733)
Dec Ebb	0.107	(0-0.662)	0.000*	(0-0.733)

* Seals observed in Zone 1 in <15 scans in this tidal period.

b) Summer (April to September)

Tidal period	All Zones		Zone 1 (Proximity probability)	
Inc Flood	0.030	(0-0.654)	0.000*	No range
Max Flood	0.079	(0-0.690)	0.000*	No range
Dec Flood	0.102	(0-0.695)	0.000*	No range
Inc Ebb	0.098	(0- 0.678)	0.000*	No range
Max Ebb	0.082	(0-0.671)	0.000*	No range
Dec Ebb	0.057	(0-0.628)	0.000*	No range

* Seals observed in Zone 1 in <15 scans in this tidal period.

c) Winter (October to March)

Tidal period	All Zones		Zone 1 (Proximity probability)	
Inc Flood	0.103	(0-0.673)	0.000*	No range
Max Flood	0.198	(0-0.793)	0.000*	No range
Dec Flood	0.212	(0-0.802)	0.000*	No range
Inc Ebb	0.194	(0-0.779)	0.000*	No range
Max Ebb	0.155	(0-0.729)	0.000*	No range
Dec Ebb	0.163	(0-0.736)	0.000*	No range

* Seals observed in Zone 1 in <15 scans in this tidal period.

The models for Zone 1 did not converge due to a high percentage of 0s (>98%). Outputs from Tukey pairwise comparisons (with a Bonferroni correction) for All Zones for which significant differences between tidal periods were identified are shown in Table 16-7.

Table 16-7 Common seal Tukey pairwise comparisons (with a Bonferroni correction) for tidal period, for All months (All Zones). Significant p-values are in bold.

	Inc Flood	Max Flood	Dec Flood	Inc Ebb	Max Ebb	Dec Ebb
Inc Flood		0.212	0.037	0.071	0.410	0.377
Max Flood	0.212		1.000	1.000	1.000	1.000
Dec Flood	0.037	1.000		1.000	1.000	1.000
Inc Ebb	0.071	1.000	1.000		1.000	1.000
Max Ebb	0.410	1.000	1.000	1.000		1.000
Dec Ebb	0.377	1.000	1.000	1.000	1.000	

Tables 16-6 and 16-7 indicate some possible systematic variance in common seal occupancy with tidal period across the entire site (All Zone), with a lower probability of seeing a seal around low water slack (decreasing ebb to increasing flood) and a greater probability around high water slack (decreasing flood to increasing ebb). However, it may be more likely that any differences simply highlight positive observations in a dataset based on such a low number of sightings. With only 10 observations of seals in zone 1 in over 3000 scans, it is not possible to identify trends with any confidence.

16.4 Summary of key points

1. Common seal was the most frequently recorded marine mammal species in vantage point surveys. It was observed in 12% of the 3120 scans. It was the second most abundant species (after harbour porpoise), accounting for 35% of all marine mammal sightings.
2. The overall average standardised common seal count for the entire survey area (All Zones) was 0.3 seals per scan/km².
3. Common seal was recorded in the array area (Zone 1) in 0.32% of scans, representing just 9 individuals over the nine years that vantage point surveys have been carried out. The overall average standardised common seal count for the array area was 0.05 seals per scan/km².
4. The average seal count in scans of the entire survey area when the species was recorded was 1.51 seals per scan. Only solitary seals were observed in scans of the array area in which the species was recorded.
5. Probability modelling shows that there is a 10-20% likelihood that common seal will be seen in the entire survey area (All Zones) during a scan and a negligible likelihood it will be seen in the array area (Zone 1). No strong conclusions can be drawn about common seal trends in the array area due to this paucity of data.
6. The probability of seeing a common seal in the entire survey area is generally greater in winter than summer.
7. There is little systematic diurnal variance in common seal occupancy in the entire survey site, though the probability of seeing a seal is slightly greater in the first half of the day.
8. There is some systematic variance in common seal occupancy with tidal period across the entire site, with the probability of seeing a seal lowest around low water slack (decreasing ebb to increasing flood) and a greater probability around high water slack (decreasing flood to increasing ebb).
9. The overall proximity probability for common seal (probability of a common seal occurring within Zone 1) is negligible.

17. Atlantic grey seal, *Halichoerus grypus*

17.1 Occupancy by zone and month

The number and proportion of scans in which grey seal was recorded, the mean standardised count per scan (per km²), and the mean count in positive scans are provided in Table 17-1.

Table 17-1 Number and proportion of scans in which grey seal was recorded, the mean standardised count per scan, and the mean count in positive scans for All Zones (the entire survey area and Zone 1 (the array area)). The actual number of scans (from the total of 3120) is shown in italics brackets. % 0s is the proportion and number of scans in which the species was not recorded.

Survey area	% scans with positive records	% 0s	Mean standardised count per scan/km ²	Mean count per scan (positive scans only)
All Zones	5.00 (156)	95.00 (2964)	0.09	1.13
Zone 1	0.06 (2)	99.94 (3118)	0.01	1.00

Grey seal was recorded in 5% of scans and accounted for 11% of all marine mammal sightings in vantage point surveys. The species was observed in 0.06% of scans in the array area (Zone 1). In scans of the entire survey area in which grey seal was observed, an average of 1.13 seals per scan was recorded. Only solitary seals were recorded in scans of the array area in which the species was observed.

Plots of descriptive statistics for Atlantic grey seal counts by survey area and month are provided in Annex B (separate document), Figure B39.

Table 17-2 presents GEE-GLM (binomial) outputs for Atlantic grey seal by month, as follows:

1. Probability of a grey seal occurring anywhere in the survey area (**All Zones**).
2. Probability of a grey seal occurring within Zone 1 - the array area (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 17-2 GEE-GLM (Binomial) estimations of 1) probabilities of a grey seal occurring within the entire survey area (All Zones), 2) probabilities of a grey seal occurring within the array area (Zone 1 - Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets.

Month	All Zones		Zone 1 (Proximity probability)	
Jan	0.104	(0-0.701)	0.000*	<i>No range</i>
Feb	0.080	(0-0.715)	0.000*	<i>No range</i>
Mar	0.049	(0-0.685)	0.000*	<i>No range</i>
Apr	0.045	(0-0.681)	0.000*	<i>No range</i>
May	0.017	(0-0.655)	0.000*	<i>No range</i>
Jun	0.036	(0-0.664)	0.000*	<i>No range</i>

Month	All Zones		Zone 1 (Proximity probability)	
Jul	0.027	(0-0.675)	0.000*	No range
Aug	0.034	(0-0.689)	0.000*	No range
Sep	0.058	(0-0.688)	0.000*	No range
Oct	0.024	(0-0.696)	0.000*	No range
Nov	0.112	(0-0.751)	0.000*	No range
Dec	0.022	(0-0.708)	0.000*	No range

* Seals observed in Zone 1 in <15 scans in this month.

The model for Zone 1 did not converge due to a high percentage of 0s (>98%). Outputs from Tukey pairwise tests (with a Bonferroni correction) comparing grey seal presence within each month for All Zones are presented in Table 17-3.

Table 17-3 Atlantic grey seal Tukey pairwise comparisons (with a Bonferroni correction) for zone and month, for All Zones. Significant p-values are in bold.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan		1.000	1.000	1.000	<i>0.056</i>	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Feb	1.000		1.000	1.000	0.315	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Mar	1.000	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Apr	1.000	1.000	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
May	0.056	0.315	1.000	1.000		1.000	1.000	1.000	1.000	1.000	0.041	1.000
Jun	1.000	1.000	1.000	1.000	1.000		1.000	1.000	1.000	1.000	1.000	1.000
Jul	1.000	1.000	1.000	1.000	1.000	1.000		1.000	1.000	1.000	0.934	1.000
Aug	1.000	1.000	1.000	1.000	1.000	1.000	1.000		1.000	1.000	1.000	1.000
Sep	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000		1.000	1.000	1.000
Oct	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000		1.000	1.000
Nov	1.000	1.000	1.000	1.000	0.041	1.000	0.934	1.000	1.000	1.000		1.000
Dec	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	

Tables 17-2 and 17-3 indicate little systematic seasonal variance in overall grey seal site occupancy (All Zones), though there was a slightly greater, but inconsistent (December) probability of seeing a grey seal in winter. It may be more likely that any differences simply highlight positive observations in a dataset based on such a low number of sightings. Grey seal occupancy in the array area (Zone 1) was consistently very low (virtually absent in winter), and no obvious patterns were observed.

17.2 Occupancy by time

Plots of descriptive statistics for Atlantic grey seal counts by survey area and time period are provided in Annex B (separate document), Figure B40 and B41.

Table 17-4 (over) presents GEE-GLM (binomial) outputs for Atlantic grey seal by time, as follows:

1. Probability of seeing a grey seal anywhere in the survey area (**All Zones**).

2. Probability of a grey seal occurring within Zone 1 - the array area (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 17-4 GEE-GLM (Binomial) estimations of 1) probabilities of a grey seal occurring within the entire survey area (All Zones), 2) probabilities of a grey seal occurring within the array area (Zone 1 – Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Time period	All Zones	Zone 1 (Proximity probability)
06:00-10:00	0.078 (0-0.688)	0.000* <i>No range</i>
10:01-14:00	0.058 (0-0.671)	0.000* <i>No range</i>
14:01-18:00	0.040 (0-0.659)	0.000* <i>No range</i>
18:01-22:00	0.020 (0-0.704)	0.000* <i>No range</i>

* Seals observed in Zone 1 in <15 scans in this time period.

b) Summer (April to September)

Time period	All Zones	Zone 1 (Proximity probability)
06:00-10:00	0.077 (0-0.750)	0.000* <i>No range</i>
10:01-14:00	0.034 (0-0.719)	0.000* <i>No range</i>
14:01-18:00	0.037 (0-0.717)	0.000* <i>No range</i>
18:01-22:00	0.020 (0-0.742)	0.000* <i>No range</i>

* Seals observed in Zone 1 in <15 scans in this time period.

c) Winter (October to March)

Time period	All Zones	Zone 1 (Proximity probability)
06:00-10:00	0.079 (0-0.709)	0.000* <i>No range</i>
10:01-14:00	0.073 (0-0.699)	0.000* <i>No range</i>
14:01-18:00	0.049 (0-0.698)	0.000* <i>No range</i>
18:01-22:00	<i>No data for this time period during winter months due to short daylight hours</i>	

* Seals observed in Zone 1 in <15 scans in this time period.

The models for Zone 1 did not converge due to a high percentage of 0s (>98%). Tukey pairwise tests (with a Bonferroni correction) comparing grey seal presence between time periods for All Zones identified no significant differences.

Table 17-4 does not indicate any strong systematic diurnal variance in overall grey seal site occupancy (All Zones) or occupancy in the array area (Zone 1), though probabilities for the entire survey area (All Zones) are slightly greater in the morning. However, it may be more likely that any

differences simply highlight positive observations in a dataset based on such a low number of sightings.

17.3 Occupancy by tidal period

Plots of descriptive statistics for Atlantic grey seal counts by survey area and tidal period are provided in Annex B (separate document), Figure B42 and B43.

Table 17-5 presents GEE-GLM (binomial) outputs for Atlantic grey seal by tidal period, as follows:

1. Probability of seeing a grey seal anywhere in the survey area (**All Zones**).
2. Probability of a grey seal occurring within Zone 1 - the array area (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 17-5 GEE-GLM (Binomial) estimations of 1) probabilities of a grey seal occurring within the entire survey area (All Zones), 2) probabilities of a grey seal occurring within the array area (Zone 1 – Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Tidal period	All Zones	Zone 1 (Proximity probability)
Inc Flood	0.031 (0-0.616)	0.000* <i>No range</i>
Max Flood	0.046 (0-0.653)	0.000* <i>No range</i>
Dec Flood	0.056 (0-0.651)	0.000* <i>No range</i>
Inc Ebb	0.055 (0-0.637)	0.000* <i>No range</i>
Max Ebb	0.065 (0-0.644)	0.000* <i>No range</i>
Dec Ebb	0.042 (0-0.611)	0.000* <i>No range</i>

* Seals observed in Zone 1 in <15 scans in this tidal period.

b) Summer (April to September)

Tidal period	All Zones	Zone 1 (Proximity probability)
Inc Flood	0.025 (0-0.665)	0.000* <i>No range</i>
Max Flood	0.031 (0-0.668)	0.000* <i>No range</i>
Dec Flood	0.033 (0-0.660)	0.000* <i>No range</i>
Inc Ebb	0.046 (0-0.657)	0.000* <i>No range</i>
Max Ebb	0.049 (0-0.662)	0.000* <i>No range</i>
Dec Ebb	0.029 (0-0.623)	0.000* <i>No range</i>

* Seals observed in Zone 1 in <15 scans in this tidal period.

c) Winter (October to March)

Tidal period	All Zones		Zone 1 (Proximity probability)	
Inc Flood	0.037	(0-0.641)	0.000*	No range
Max Flood	0.066	(0-0.712)	0.000*	No range
Dec Flood	0.080	(0-0.706)	0.000*	No range
Inc Ebb	0.066	(0-0.676)	0.000*	No range
Max Ebb	0.084	(0-0.689)	0.000*	No range
Dec Ebb	0.057	(0-0.651)	0.000*	No range

* Seals observed in Zone 1 in <15 scans in this tidal period.

The models for Zone 1 did not converge due to a high percentage of 0s (>98%). Tukey pairwise tests (with a Bonferroni correction) comparing grey seal presence between tidal periods for All Zones identified no significant differences.

Table 17-5 indicates little systematic variance in grey seal occupancy with tidal period across the entire site (All Zone). With only 2 observations of seals in zone 1 in over 3000 scans, it is not possible to identify trends with any confidence.

17.4 Summary of key points

1. Atlantic grey seal was recorded in 5% of scans and accounted for 11% of all marine mammal sightings in vantage point surveys.
2. The overall average standardised grey seal count for the entire survey area (All Zones) was 0.09 seals per scan/km².
3. Grey seal was recorded in the array area (Zone 1) in 0.06% of scans, representing just 2 individuals over the nine years that vantage point surveys have been carried out. The overall average standardised common seal count for the array area was 0.01 seals per scan/km².
4. The average seal count in scans of the entire survey area when the species was recorded was 1.13 seals per scan. Only solitary seals were observed in scans of the array area in which the species was recorded.
5. Probability modelling shows that there is a <10% likelihood that grey seal will be seen in the entire survey area (All Zones) during a scan and a negligible likelihood it will be seen in the array area (Zone 1). No strong conclusions can be drawn about grey seal trends in the array area due to this paucity of data.
6. The probability of seeing a grey seal in the entire survey area is generally greater in winter than summer.
7. There is little systematic diurnal variance in grey seal occupancy in the entire survey site, though the probability of seeing a seal is slightly greater in the first half of the day.
8. There is little systematic variance in grey seal occupancy with tidal period across the entire site.
9. The overall proximity probability for grey seal (probability of a grey seal occurring within Zone 1) is negligible.

18. Harbour porpoise, *Phocoena phocoena*

18.1 Occupancy by zone and month

The number and proportion of scans in which harbour porpoise was recorded, the mean standardised count per scan (per km²), and the mean count in positive scans are provided in Table 18-1.

Table 18-1 Number and proportion of scans in which harbour porpoise was recorded, the mean standardised count per scan, and the mean count in positive scans for All Zones (the entire survey area and Zone 1 (the array area)). The actual number of scans (from the total of 3120) is shown in italics brackets. % 0s is the proportion and number of scans in which the species was not recorded.

Survey area	% scans with positive records	% 0s	Mean standardised count per scan/km ²	Mean count per scan (positive scans only)
All Zones	5.61 (175)	94.39 (2945)	0.38	4.21
Zone 1	0.71 (22)	99.29 (3098)	0.36	3.45

Harbour porpoise was the second most frequently recorded marine mammal species in vantage point surveys (after common seal). The species was observed in 6% of the 3120 scans. It was the most abundant marine mammal species, accounting for 45% of all mammal sightings. In scans of the entire survey area (All Zones) in which harbour porpoise was observed, an average of 4.21 porpoise per scan was recorded. In scans of the array area (Zone 1) survey area in which harbour porpoise was observed, an average of 3.45 porpoise per scan was recorded. This indicates that the species occurs in small family groups when present.

Plots of descriptive statistics for harbour porpoise counts by survey area and month are provided in Annex B (separate document), Figure B44.

Table 18-2 presents GEE-GLM (binomial) outputs for harbour porpoise by month, as follows:

1. Probability of a harbour porpoise occurring anywhere in the survey area (**All Zones**).
2. Probability of a harbour porpoise occurring within Zone 1 - the array area (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days.

Table 18-2 GEE-GLM (Binomial) estimations of 1) probabilities of a harbour porpoise occurring within the entire survey area (All Zones), 2) probabilities of a harbour porpoise occurring within the array area (Zone 1 - Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets.

Month	All Zones		Zone 1 (Proximity probability)	
Jan	0.054	(0-0.665)	0.004	(0-0.731)
Feb	0.080	(0-0.721)	0.008	(0-0.774)
Mar	0.038	(0-0.677)	0.007	(0-0.774)
Apr	0.010	(0-0.680)	0.003	(0-0.803)
May	0.045	(0-0.674)	0.007	(0-0.774)

Month	All Zones		Zone 1 (Proximity probability)	
Jun	0.063	(0-0.689)	0.008	(0-0.775)
Jul	0.063	(0-0.698)	0.010	(0-0.764)
Aug	0.057	(0-0.690)	0.008	(0-0.774)
Sep	0.042	(0-0.711)	0.000	(0-0.732)
Oct	0.095	(0-0.728)	0.008	(0-0.775)
Nov	0.100	(0-0.730)	0.017	(0-0.763)
Dec	0.033	(0-0.681)	0.006	(0-0.804)

The outputs from Tukey pairwise tests (with a Bonferroni correction) comparing cetacean presence within each month for All Zones and Zone 1 are presented in Table 18-3.

Table 18-3 Tukey pairwise comparisons (with a Bonferroni correction) for zone and month, for a) All zones and b) Zone 1. Significant p-values are in bold.

a) All Zones

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan		1.000	1.000	0.813	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Feb	1.000		1.000	0.062	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Mar	1.000	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Apr	0.813	0.062	1.000		0.664	0.082	0.148	0.241	1.000	0.010	0.005	1.000
May	1.000	1.000	1.000	0.664		1.000	1.000	1.000	1.000	1.000	1.000	1.000
Jun	1.000	1.000	1.000	0.082	1.000		1.000	1.000	1.000	1.000	1.000	1.000
Jul	1.000	1.000	1.000	0.148	1.000	1.000		1.000	1.000	1.000	1.000	1.000
Aug	1.000	1.000	1.000	0.241	1.000	1.000	1.000		1.000	1.000	1.000	1.000
Sep	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000		1.000	1.000	1.000
Oct	1.000	1.000	1.000	0.010	1.000	1.000	1.000	1.000	1.000		1.000	1.000
Nov	1.000	1.000	1.000	0.005	1.000	1.000	1.000	1.000	1.000	1.000		1.000
Dec	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	

b) Zone 1

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan		1.000	1.000	1.000	1.000	1.000	1.000	1.000	<0.001	1.000	1.000	1.000
Feb	1.000		1.000	1.000	1.000	1.000	1.000	1.000	<0.001	1.000	1.000	1.000
Mar	1.000	1.000		1.000	1.000	1.000	1.000	1.000	<0.001	1.000	1.000	1.000
Apr	1.000	1.000	1.000		1.000	1.000	1.000	1.000	<0.001	1.000	1.000	1.000
May	1.000	1.000	1.000	1.000		1.000	1.000	1.000	<0.001	1.000	1.000	1.000
Jun	1.000	1.000	1.000	1.000	1.000		1.000	1.000	<0.001	1.000	1.000	1.000
Jul	1.000	1.000	1.000	1.000	1.000	1.000		1.000	<0.001	1.000	1.000	1.000
Aug	1.000	1.000	1.000	1.000	1.000	1.000	1.000		<0.001	1.000	1.000	1.000
Sep	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oct	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	<0.001		1.000	1.000
Nov	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	<0.001	1.000		1.000
Dec	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	<0.001	1.000	1.000	

Tables 18-2 and 18-3 do not indicate any systematic seasonal variance in overall harbour porpoise site occupancy (All Zones), or occupancy of the array area (Zone 1). Probabilities are broadly similar in all 12 months and any differences simply highlight positive observations in a dataset based on such a low number of sightings. With only 22 observations of porpoise in zone 1 in over 3000 scans, it is not possible to identify trends with any confidence.

18.2 Occupancy by time

Plots of descriptive statistics for harbour porpoise counts by survey area and time period are provided in Annex B (separate document), Figure B45 and B46.

Table 18-4 presents GEE-GLM (binomial) outputs for harbour porpoise by time, as follows:

1. Probability of seeing a harbour porpoise anywhere in the survey area (**All Zones**).
2. Probability of a harbour porpoise occurring within Zone 1 - the array area (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 18-4 GEE-GLM (Binomial) estimations of 1) probabilities of a harbour porpoise occurring within the entire survey area (All Zones), 2) probabilities of a harbour porpoise occurring within the array area (Zone 1 – Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Time period	All Zones		Zone 1 (Proximity probability)	
06:00-10:00	0.104	(0-0.721)	0.026	(0-0.688)
10:01-14:00	0.065	(0-0.685)	0.008	(0-0.682)
14:01-18:00	0.041	(0-0.665)	0.004	(0-0.695)
18:01-22:00	0.069	(0-0.720)	0.020	(0-0.746)

b) Summer (April to September)

Time period	All Zones		Zone 1 (Proximity probability)	
06:00-10:00	0.051	(0-0.711)	0.000*	No range
10:01-14:00	0.064	(0-0.732)	0.000*	No range
14:01-18:00	0.031	(0-0.699)	0.000*	No range
18:01-22:00	0.069	(0-0.753)	0.000*	No range

* Porpoise observed in Zone 1 in <15 scans in this time period.

c) Winter (October to March)

Time period	All Zones		Zone 1 (Proximity probability)	
06:00-10:00	0.158	(0-0.797)	0.053	(0-0.701)
10:01-14:00	0.066	(0-0.709)	0.007	(0-0.677)
14:01-18:00	0.064	(0-0.718)	0.008	(0-0.707)
18:01-22:00	No data for this time period during winter months due to short daylight hours			

The summer (Zone 1) model did not converge due to a high percentage of 0s within the data (>98%) so comparisons of harbour porpoise presence between time periods were not made. For remaining zones/seasons, where Tukey comparisons (with a Bonferroni correction) identified significant differences for porpoise presence with time period, outputs are detailed in Table 18-5.

Table 18-5 Harbour porpoise Tukey pairwise comparisons (with a Bonferroni correction) for zone and time, for a) Summer (All Zones) and b) All Zones (summer) and Zone 1 (winter). Significant p-values are in bold.

a) Summer (All zones)

	06:00-10:00	10:01-14:00	14:01-18:00	18:01-22:00
06:00-10:00		1.000	1.000	1.000
10:01-14:00	1.000		0.043	1.000
14:01-18:00	1.000	0.043		0.182
18:01-22:00	1.000	1.000	0.182	

a) Winter (Zone 1)

	06:00-10:00	10:01-14:00	14:01-18:00	18:01-22:00
06:00-10:00		0.009	0.058	No data
10:01-14:00	0.009		1.000	No data
14:01-18:00	0.058	1.000		No data
18:01-22:00	No data	No data	No data	

Tables 18-4 and 18-5 do not indicate any systematic diurnal variance in overall harbour porpoise site occupancy (All Zones), or occupancy of the array area (Zone 1). Probabilities are broadly similar at all times of the day and any differences simply highlight positive observations in a dataset based on such a low number of observations. With only 22 observations of porpoise in zone 1 in over 3000 scans, it is not possible to identify trends with any confidence.

18.3 Occupancy by tidal period

Plots of descriptive statistics for harbour porpoise counts by survey area and tidal period are provided in Annex B (separate document), Figure B47 and B48.

Table 18-6 presents GEE-GLM (binomial) outputs for harbour porpoise by tidal period, as follows:

1. Probability of seeing a harbour porpoise anywhere in the survey area (**All Zones**).
2. Probability of a harbour porpoise occurring within Zone 1 - the array area (**Proximity probability**).

Figures in brackets in the table show a range of estimated probabilities, reflecting the variation (standard error) in the probability of occurrence across days. Figures in italics indicate where the presence/absence data was dominated by presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range.

Table 18-6 GEE-GLM (Binomial) estimations of 1) probabilities of a harbour porpoise occurring within the entire survey area (All Zones), 2) probabilities of a harbour porpoise occurring within the array area (Zone 1 – Proximity probability). Estimations provided a range of probabilities across days (standard error), shown in brackets. Probabilities in italics could not be modelled due to a high proportion (98% threshold) of presences (1) or absences (0). Where modelling was not present, overall probabilities were manually calculated across all days, and have no corresponding range. Probabilities are shown for a) all months, b) summer months only and c) winter months only.

a) All months

Tidal period	All Zones		Zone 1 (Proximity probability)	
Inc Flood	0.053	(0-0.619)	0.007	(0-0.703)
Max Flood	0.027	(0-0.625)	0.005	(0-0.717)
Dec Flood	0.059	(0-0.633)	0.006	(0-0.687)
Inc Ebb	0.061	(0-0.632)	0.009	(0-0.681)
Max Ebb	0.059	(0-0.628)	0.010	(0-0.683)
Dec Ebb	0.070	(0-0.627)	0.006	(0-0.644)

b) Summer (April to September)

Tidal period	All Zones		Zone 1 (Proximity probability)	
Inc Flood	0.051	(0-0.637)	0.000*	<i>No range</i>
Max Flood	0.026	(0-0.665)	0.000*	<i>No range</i>
Dec Flood	0.057	(0-0.666)	0.000*	<i>No range</i>
Inc Ebb	0.056	(0-0.656)	0.000*	<i>No range</i>
Max Ebb	0.026	(0-0.658)	0.000*	<i>No range</i>
Dec Ebb	0.053	(0-0.637)	0.000*	<i>No range</i>

* Porpoise observed in Zone 1 in <15 scans in this tidal period.

c) Winter (October to March)

Tidal period	All Zones		Zone 1 (Proximity probability)	
Inc Flood	0.056	(0-0.655)	0.009	(0-0.728)
Max Flood	0.028	(0-0.658)	0.006	(0-0.765)
Dec Flood	0.061	(0-0.659)	0.003	(0-0.761)
Inc Ebb	0.066	(0-0.667)	0.011	(0-0.701)
Max Ebb	0.097	(0-0.680)	0.008	(0-0.718)
Dec Ebb	0.106	(0-0.682)	0.012	(0-0.649)

The Zone 1 (summer) model did not converge due to a high percentage of 0s (>98%) so it was not possible to run monthly comparisons for this data. Tukey comparisons (with a Bonferroni correction) for the remaining tidal periods and seasons did not result in any significant p-value so have not been provided.

Table 18-6 does not indicate any systematic variance in overall harbour porpoise site occupancy (All Zones), or occupancy of the array area (Zone 1) with tidal period. Probabilities are broadly similar on all tidal periods. With only 22 observations of porpoise in zone 1 in over 3000 scans, it is not possible to identify trends with any confidence.

18.4 Summary of key points

1. Harbour porpoise was the second most frequently recorded marine mammal species in vantage point surveys. It was observed in around 6% of the 3120 scans. It was the most abundant species, accounting for 45% of all marine mammal sightings.
2. The overall average standardised harbour porpoise count for the entire survey area (All Zones) was 0.38 porpoise per scan/km².
3. Harbour porpoise was recorded in the array area (Zone 1) in 0.71% of scans (just 22 of the 3120 scans over the nine years that vantage point surveys have been carried out). The overall average standardised count for the array area was 0.36 porpoise per scan/km².
4. The average harbour porpoise count in scans of the entire survey area when the species was recorded was 4.21 porpoise per scan was recorded. In scans of the array area (Zone 1) survey area in which harbour porpoise was observed, an average of 3.45 porpoise per scan was recorded. This indicates that the species occurs in small family groups when present.
5. Probability modelling shows that there is a <10% likelihood that harbour porpoise will be seen in the entire survey area (All Zones) during a scan and a <2% likelihood it will be seen in the array area (Zone 1). No strong conclusions can be drawn about porpoise trends in Zone 1 due to this paucity of data.
6. There is no systematic seasonal variance in harbour porpoise occurrence, with consistently low probabilities of seeing a porpoise in the entire survey area and in the array area throughout the year.
7. There is no systematic diurnal variance in harbour porpoise occurrence, with consistently low probabilities of seeing a porpoise in the entire survey area (All Zones) and in the array area (Zone 1) throughout the day.

8. There is no systematic variance in harbour porpoise occurrence with tidal period, with consistently low probabilities of seeing a porpoise in the entire survey area (All Zones) and in the array area (Zone 1) throughout all tidal periods.
9. The overall proximity probability for harbour porpoise (probability of a porpoise occurring within Zone 1) is <2%.

19. Other non-bird species

A number of other marine mammal species and basking shark were recorded in vantage point surveys. However, numbers were very low and insufficient to carry out any analyses. The records of these other species are provided in Table 20-1.

Table 20-1 Records of animal species rarely recorded in Bluemull Sound vantage point surveys. Detailed analysis on these species records was not possible.

Species	Details of records in vantage point surveys
Killer whale	<ul style="list-style-type: none"> - Species recorded in 1 of the total of 3120 scans - Species accounted for 0.61% of all mammal sightings in surveys - Single record of a pod of ten individuals on 05/01/2017, none of the animals entered the array area (Zone 1)
Risso's dolphin	<ul style="list-style-type: none"> - Species recorded in 2 of the total of 3120 scans - Species accounted for 1.52% of all mammal sightings in surveys - Pod of five individuals recorded on 30/08/2015, one of these animals entered the array area (Zone 1) - Pod of twenty individuals recorded on 17/03/2016, none of the animals entered the array area (Zone 1)
Humpback whale	<ul style="list-style-type: none"> - Species recorded in 1 of the total of 3120 scans - Species accounted for 0.21% of all mammal sightings in surveys - Single record of a mother and calf on 27/02/2016, did not enter the array area (Zone 1)
Minke whale	<ul style="list-style-type: none"> - Species recorded in 3 of the total of 3120 scans - Species accounted for 0.25% of all mammal sightings in surveys - One individual recorded on 10/11/2010, did not enter the array area (Zone 1) - One individual recorded on 20/11/2017, did not enter the array area (Zone 1) - Two individuals recorded on 21/11/2017, did not enter the array area (Zone 1)
Basking shark	<ul style="list-style-type: none"> - Single record of one individual on 23/08/2011, did not enter the array area (Zone 1)

20. Discussion

This report presents the results from analyses of Nova Innovation's nine-year programme of land-based marine wildlife observation surveys in Bluemull Sound, carried out as part of the environmental monitoring programme for the Shetland Tidal Array.

Data from a total of 5208 10-minute snapshot scans for birds and 3120 20-minute scans for mammals have been analysed in this report, spanning the nine-year survey period. A total of thirty-three bird, eight mammal and one fish species have been recorded. Fifteen of the bird species and seven of the mammal species are capable of diving to turbine rotor depth (15m below sea level) and therefore 'at risk' of near-field encounters with turbines. Only these species were taken through to detailed analysis within this report. Basking shark was also recorded so has been included. A combination of descriptive statistics and modelling techniques have been used to explore the data for these species at risk of near-field encounters with the turbines in the Shetland Tidal Array.

The approach to analysis and interpretation of the vantage point data are based on understanding site-use at different scales, to understand the likelihood or probability of near-field encounters with turbines in the Shetland Tidal Array. Near-field encounters are only possible if a bird or animal uses the site. The likelihood increases if the bird or animal uses the area immediately around the turbines. For birds, this likelihood increases again if the bird dives in the area around the turbine. Dividing the process into these scales, provides useful metrics of the likelihood of near-field encounters, namely a conservative one (large scale), an intermediate one (medium scale) and a realized one (finest scale). The last is a realized one because it is the probability of a bird or animal diving in the immediate vicinity of the turbines. The first is a conservative one, because it acknowledges that any bird or animal in the site could potentially interact with turbines if they choose. These measures provide an understanding of site-use at different scales to understand the probability of encounters between birds and animals with turbines in the Shetland Tidal.

Two diving bird species, black guillemot (*Cepphus grylle*) and European shag (*Phalacrocorax aristotelis*) accounted for over 90% of all birds recorded in surveys. All other diving bird species were recorded only occasionally in surveys and in generally very low numbers. With the notable exception of Atlantic puffin (*Fratercula arctica*), which was only present in summer months, most diving bird species were present to some extent throughout the year. Some systematic seasonal variance in occupancy was observed in some species throughout the entire survey area, for example, corresponding with breeding seasons. Birds were generally recorded as solitary individuals or in very small groups in scans, indicating that group foraging does not occur in the site.

Black guillemot, the most frequent and abundant bird species, was recorded in the array area (Zone 1) in 11% of all scans (561 scans of 5208), with birds observed diving in the array area in fewer than 3% of scans (143 scans). The second most frequent and abundant species, European shag, was only recorded in the array area (Zone 1) in <3% of all scans (150 scans), with birds observed diving in the array area in 1% of scans (54 scans). Three of the bird species (gannet, red-throated diver and common guillemot) were each observed diving in the array area in less than 5 occasions over the entire nine-year survey period. This indicates a low level of spatial overlap between diving birds and turbines in the Shetland Tidal Array, even when taking into account the most frequently recorded and abundant species.

As might be expected, given the differences in survey area, the probability of seeing a diving bird within the array area has been shown to be much lower than the probability of seeing one in the whole survey area. The array area is much smaller than the survey area, which results in an

inherently smaller likelihood of interacting with the turbine. However, for a bird to encounter a turbine, it must dive in this small area. If it does not dive, then there is no risk.

Diving bird occupancy within the array area (Zone 1) was consistently low throughout the year but showed some systematic seasonal variance. For example, the probability of seeing a diving bird in the array area was greater in November (corresponding to peak counts of black guillemot and European shag) and again in June/July (corresponding to higher counts of certain species during the breeding season; presumably central based foragers from nearby colonies).

The risk of diving birds interacting with turbines showed little diurnal variation, though there was a general increase in the probability of seeing birds in the survey area in the evening compared to other times of day. The probability of birds diving in the array area changed little with time of day.

Diving bird occupancy within the array area (Zone 1) was consistently low across all tidal periods but the probability of seeing a bird in the array area was generally greater during flood tides than ebb, for most species. The overall probabilities of birds diving in proximity to the turbines was extremely low for all species but generally greater around low water slack and on increasing flood tides in species for which systematic patterns with tidal period were identified. For a number of species (black guillemot, European shag, Atlantic puffin), probabilities of birds diving in proximity to the turbines was lowest on maximum ebb tides. This aligns with previously reported decreases in numbers of diving birds as a function of increasing in current speed in Bluemull Sound¹⁴ and suggests that species avoid foraging in the site during periods of high current velocities.

Marine animals (mammals and basking shark) were recorded in the surveys relatively infrequently and in low numbers. Some species such as humpback whale (*Megaptera novaeangliae*), minke whale (*Balaenoptera acutorostrata*), Risso's dolphin (*Grampus griseus*), killer whale (*Orca orcinus*) and basking shark (*Cetorhinus maximus*) were only recorded in one or two scans over the entire nine-year survey period.

Atlantic grey seal (*Halichoerus grypus*), common seal (*Phoca vitulina*) and harbour porpoise (*Phocoena phocoena*) were the most frequently recorded species, but seldom recorded in the array area. Both species of seal were normally recorded as individual animals, while harbour porpoise was generally observed in small family groups.

Harbour porpoise accounted for 45% of all mammal sightings in surveys. Despite accounting for this high proportion of overall mammal sightings, harbour porpoise was only recorded in 5% of scans overall (175 scans from a total of 3120) and within the array area (Zone 1) in only 0.71% of scans (22 scans). Common seal accounted for 35% of all mammal sightings but was recorded in just 12% of scans (381 scan). The species was recorded within the array area (Zone 1) in only 0.32% of scans (10 scans). Grey seal accounted for 11% of all mammal sightings and was recorded in 5% of scans (156 scans) and within the array area (Zone 1) in just 0.06% of scans (2 scans). This indicates a very low level of spatial overlap between marine mammals and turbines in the Shetland Tidal Array, even when taking into account the most frequently recorded and abundant species.

As might be expected, given the differences in survey area, the probability of seeing a mammal within the array area is much lower than the probability of seeing one in the whole survey area. The array area is substantially smaller than the survey area, which (as stated) results in an inherently smaller likelihood of interacting with the turbine. However, for a mammal to encounter

¹⁴ Robbins AMC (2017). Seabird ecology in high-energy environments: approaches to assessing impacts of marine renewables. PhD thesis. University of Glasgow. <http://theses.gla.ac.uk/8300/>

and potentially collide with a turbine, it must interact with this small area. If it does not interact with this small area, then there is no risk.

There were few systematic seasonal, diurnal or tidal occupancy patterns in mammals within the array area (Zone 1), with very low recorded relative densities. Common and grey seal occupancy throughout the wider survey area showed some systematic seasonal variance, with the probability of seeing a seal generally greater in winter than summer. For both species, the probability of seeing a seal was slightly greater in the morning than later in day. The probability of seeing a common seal was slightly lower around low slack water, when seals might be expected to be hauled out.

The results presented in this report demonstrate that site-use of diving birds, mammals and basking shark in Bluemull Sound is low. This reflects the smaller absolute number of birds and animals occurring within the array area, compared to the wider Bluemull Sound survey area which directly influences impact risk. In the case of birds, very few were observed actively diving within the array area. Encounters with turbines in the Shetland Tidal Array are only possible if a bird or animal uses the site. The likelihood increases if the bird or animal uses the area immediately around the turbines. For birds, this likelihood increases again if the bird dives in the area around the turbines.

The results presented in this report indicate that the likelihood or probability of near-field encounters between all of the diving bird and marine mammal species recorded in the site during the nine-year programme of surveys is very low. For most species, the probability is negligible, but even for the most frequently and abundantly recorded species the risk is still very low (<5%). This is supported by the findings from analyses of video footage from Nova's complementary subsea video monitoring programme¹⁵.

Encounter Risk Modelling (ERM) was carried out for species features of protected sites to inform the environmental assessment for the extended Shetland Tidal Array¹⁶, to provide predictions of encounters with turbines. While the probabilities and descriptive statistics presented in this report are not directly comparable with the ERM predictions, for qualitative comparison, they are provided alongside each other in Table 20-1 (over).

In Table 20-1, 'ERM prediction' is the predicted number of annual encounters (encounters/year) for each species, calculated using the Encounter Risk Model detailed in SNH guidance on assessing collision risk between underwater turbines and marine wildlife¹⁷. 'Number of positive scans in Zone 1' is the total number of scans (from the total of 3120 for common seal and 5208 for birds) in which each species was recorded in the array area (Zone 1). 'Mean count in Zone 1' is the mean number of individuals/scan recorded in positive scans in Zone 1. 'Mean number of individuals/year in Zone 1' is the average number of individuals/year in Zone 1 (calculated by multiplying the preceding two rows). 'Mean count birds diving in Zone 1' is the total number of scans in which each bird species was recorded diving in the array area. 'Mean count birds diving in Zone 1' is the mean number of individuals/scan recorded diving in positive scans in Zone 1. 'Mean number individuals/year birds diving Zone 1' is the average number of individuals/year diving in Zone 1 (calculated by multiplying the preceding two rows). 'Probability (Zone 1) is the probability of a diving bird/seal occurring within Zone 1. Proximity probability is the probability of a bird or mammal diving in proximity to the turbines.

¹⁵ Nova Innovation (2020a). Shetland Tidal Array monitoring report: Subsea video monitoring. EnFAIT-0364.

¹⁶ Nova Innovation (2018). Shetland Tidal Array Environmental Assessment Report.

¹⁷ SNH (2016). Guidance note on assessing collision risk between underwater turbines and marine wildlife. 96pp.

Table 20-1 Encounter Risk Modelling (ERM) predictions and measures of potential near-field encounters detailed in this report.

	Common seal	Puffin	Red-throated diver	Northern gannet	Common guillemot	European shag
ERM prediction (number encounters/year)	3.96	1.36	0.15	0.00	0.36	11.25
Number of positive scans in Zone 1*	10	82	5	36	22	150
Mean count in Zone 1 (individuals/scan)**	1.0	1.70	1.40	1.56	1.36	1.48
Mean number of individuals/year in Zone 1	1.11	15.49	0.78	6.24	3.32	24.67
Number of scans where species diving in Zone 1*	-	56	1	1	4	54
Mean count birds diving in Zone 1 (individuals/scan)**	-	1.40	1	1	1.00	1.26
Mean number of individuals/year birds diving Zone 1	-	8.90	0.11	0.11	0.44	7.56
Probability (Zone1)	<0.001	≤0.06	<0.01	<0.02	≤0.06	≤0.05
Proximity probability	<0.001	<0.05	<0.001	<0.001	<0.001	<0.03

* Number of positive scans from a total of 3120 for common seal and 5108 for bird species.

** Mean counts in scans in which the species was recorded.

Table 20-1 indicates that European shag and puffin are the protected species most likely to interact with turbines in the Shetland Tidal Array. Even for these species, the overall probability of an individual diving in proximity to the turbines is < 5%. Table 20-1 indicate that the ERM prediction may be over-estimating the likely magnitude of near-field encounters between common seal and the turbines in the Shetland Tidal Array.

Improving understanding for fine-scale occupancy patterns of these three species will be important in refining knowledge about the likelihood of near-field encounters with turbines in the extended array. Ongoing vantage point surveys that are more spatially focused on the array area will gather information to improve knowledge on the fine-scale movements and use of the sea area around the turbines by these and other species. Combined with the ongoing subsea video monitoring, this should enable further refinement of understanding for the nature and likelihood of near-field encounters between the turbines and diving birds and marine mammals.

The probabilities of near-field encounters between diving birds and marine mammals presented and discussed in this report could further be refined to understand the risk of encounters with rotating turbine blades and in relation to blade tip speed. However, this report has shown that observations of marine wildlife within the array area are limited, even for the most frequently recorded species.

Annex A Tables of annual variation in species counts

This Annex provides tabulated summaries of inter-annual variation in counts for each of the main species analysed in detail in this report, to understand the degree of variability in bird and animal numbers in Bluemull Sound. Year was not included as a covariate in analyses detailed in this report, since this is not likely to be a key underlying driver influencing the risk of near-field encounters between the birds and animals and turbines the Shetland Tidal Array. Rather, the multiple years' data provide a large dataset to explore those covariates that are more likely to influence encounter risk (month, season, time of day and tidal period).

Table A1 Annual variation in black guillemot relative densities, showing densities (individuals per scan per km²) for each year and corresponding absolute change and % change from the previous year. Only years for which a complete 12 month dataset is available have been included in the table.

Year	All Zones			Zone 1		
	Average (km ²)	Absolute change (km ²)	% Change	Average (km ²)	Absolute Change (km ²)	% Change
2010	<i>Surveys commenced November 2010</i>					
2011	20.33	-	-	4.54	-	-
2012	10.97	9.36	-46.04	1.58	2.96	-65.28
2013	13.70	2.73	24.86	2.25	0.67	42.48
2014	12.49	1.21	-8.82	2.01	0.24	-10.64
2015	19.29	6.80	54.48	1.46	0.55	-27.28
2016	18.50	0.79	-4.08	0.78	0.68	-46.36
2017	12.62	5.88	-31.79	0.62	0.16	-20.59
2018	14.79	2.17	17.20	1.46	0.84	135.29
2019	<i>Trial of new vantage point methods commenced October 2019</i>					

Table A2 Annual variation in European shag relative densities, showing densities (individuals per scan per km²) for each year and corresponding absolute change and % change from the previous year. Only years for which a complete 12 month dataset is available have been included in the table.

Year	All Zones			Zone 1		
	Average (km ²)	Absolute change (km ²)	% Change	Average (km ²)	Absolute Change (km ²)	% Change
2010	<i>Surveys commenced November 2010</i>					
2011	8.38	-	-	1.28	-	-
2012	5.28	3.10	-36.98	1.33	0.05	3.99
2013	6.46	1.18	22.25	0.62	0.71	-53.33
2014	8.40	1.94	30.02	0.34	0.28	-45.71
2015	7.89	0.51	-6.06	0.16	0.18	-51.95
2016	5.70	2.19	-27.72	0.51	0.34	212.35
2017	2.43	3.27	-57.38	0.15	0.36	-70.78
2018	4.09	1.66	68.38	0.22	0.07	48.24
2019	<i>Trial of new vantage point methods commenced October 2019</i>					

Table A3 Annual variation in Atlantic puffin relative densities, showing densities (individuals per scan per km²) for each year and corresponding absolute change and % change from the previous year. Only years for which a complete 12 month dataset is available have been included in the table.

Year	All Zones			Zone 1		
	Average (km ²)	Absolute change (km ²)	% Change	Average (km ²)	Absolute Change (km ²)	% Change
2010	<i>Surveys commenced November 2010</i>					
2011	0.57	-	-	0.45	-	-
2012	2.00	1.43	250.65	0.40	0.05	-11.61
2013	0.45	1.55	-77.39	0.14	0.26	-64.87
2014	0.77	0.32	70.39	0.48	0.34	241.63
2015	2.25	1.48	191.54	0.89	0.41	85.99
2016	1.33	0.93	-41.12	0.25	0.64	-71.60
2017	1.50	0.17	13.19	0.30	0.04	16.88
2018	1.02	0.48	-32.07	0.33	0.03	11.18
2019	<i>Trial of new vantage point methods commenced October 2019</i>					

Table A4 Annual variation in common guillemot relative densities, showing densities (individuals per scan per km²) for each year and corresponding absolute change and % change from the previous year. Only years for which a complete 12 month dataset is available have been included in the table.

Year	All Zones			Zone 1		
	Average (km ²)	Absolute change (km ²)	% Change	Average (km ²)	Absolute Change (km ²)	% Change
2010	<i>Surveys commenced November 2010</i>					
2011	0.21	-	-	0.34	-	-
2012	0.59	0.38	178.78	0.07	0.27	-80.36
2013	0.20	0.38	-65.49	0.02	0.05	-69.89
2014	0.26	0.06	28.15	0.04	0.02	77.14
2015	0.29	0.03	13.01	0.03	0.01	-23.91
2016	0.35	0.06	20.61	0.02	0.00	-14.81
2017	0.12	0.23	-65.83	0.00	0.02	-100.00
2018	0.48	0.36	299.85	0.15	0.15	100.00
2019	<i>Trial of new vantage point methods commenced October 2019</i>					

Table A5 Annual variation in red-throated diver relative densities, showing densities (individuals per scan per km²) for each year and corresponding absolute change and % change from the previous year. Only years for which a complete 12 month dataset is available have been included in the table.

Year	All Zones			Zone 1		
	Average (km ²)	Absolute change (km ²)	% Change	Average (km ²)	Absolute Change (km ²)	% Change
2010	<i>Surveys commenced November 2010</i>					
2011	0.06	-	-	0.16	-	-
2012	0.00	0.06	-100.00	0.23	0.07	46.20
2013	0.06	0.06	100.00	0.43	0.19	81.57
2014	0.00	0.06	-100.00	0.14	0.29	-67.18
2015	0.00	0.00	0.00	0.30	0.16	116.80
2016	0.00	0.00	0.00	0.07	0.23	-77.07
2017	0.00	0.00	0.00	0.24	0.17	244.39
2018	0.04	0.04	100.00	0.16	0.08	-32.47
2019	<i>Trial of new vantage point methods commenced October 2019</i>					

Table A6 Annual variation in northern gannet relative densities, showing densities (individuals per scan per km²) for each year and corresponding absolute change and % change from the previous year. Only years for which a complete 12 month dataset is available have been included in the table.

Year	All Zones			Zone 1		
	Average (km ²)	Absolute change (km ²)	% Change	Average (km ²)	Absolute Change (km ²)	% Change
2010	<i>Surveys commenced November 2010</i>					
2011	0.79	-	-	1.16	-	-
2012	0.16	0.64	-80.36	2.32	1.16	99.93
2013	0.00	0.16	-100.00	0.27	2.05	-88.20
2014	0.12	0.12	100.00	1.11	0.83	304.50
2015	0.00	0.12	-100.00	0.74	0.37	-33.62
2016	0.00	0.00	0.00	0.83	0.10	13.13
2017	0.00	0.00	0.00	0.69	0.14	-17.35
2018	0.00	0.00	0.00	0.18	0.51	-74.26
2019	<i>Trial of new vantage point methods commenced October 2019</i>					

Table A7 Annual variation in common seal relative densities, showing densities (individuals per scan per km²) for each year and corresponding absolute change and % change from the previous year. Only years for which a complete 12 month dataset is available have been included in the table.

Year	All Zones			Zone 1		
	Average (km ²)	Absolute change (km ²)	% Change	Average (km ²)	Absolute Change (km ²)	% Change
2010	<i>Surveys commenced November 2010</i>					
2011	0.11	-	-	0.00	-	-
2012	0.19	0.08	77.29	0.12	0.12	100.00
2013	0.16	0.03	-15.68	0.11	0.00	-3.03
2014	0.07	0.09	-56.58	0.00	0.11	-100.00
2015	0.11	0.03	49.70	0.11	0.11	100.00
2016	0.80	0.70	661.54	0.04	0.08	-68.57
2017	0.43	0.37	-45.83	0.00	0.04	-100.00
2018	0.74	0.30	70.04	0.00	0.00	0.00
2019	<i>Trial of new vantage point methods commenced October 2019</i>					

Table A8 Annual variation in grey seal relative densities, showing densities (individuals per scan per km²) for each year and corresponding absolute change and % change from the previous year. Only years for which a complete 12 month dataset is available have been included in the table.

Year	All Zones			Zone 1		
	Average (km ²)	Absolute change (km ²)	% Change	Average (km ²)	Absolute Change (km ²)	% Change
2010	<i>Surveys commenced November 2010</i>					
2011	0.22	-	-	0.07	-	-
2012	0.06	0.16	-73.02	0.00	0.07	-100.00
2013	0.03	0.03	-44.59	0.00	0.00	0.00
2014	0.01	0.02	-67.43	0.00	0.00	0.00
2015	0.08	0.07	629.29	0.00	0.00	0.00
2016	0.03	0.05	-60.30	0.00	0.00	0.00
2017	0.05	0.02	71.88	0.00	0.00	0.00
2018	0.18	0.12	234.93	0.00	0.00	0.00
2019	<i>Trial of new vantage point methods commenced October 2019</i>					

Table A9 Annual variation in harbour porpoise relative densities, showing densities (individuals per scan per km²) for each year and corresponding absolute change and % change from the previous year. Only years for which a complete 12 month dataset is available have been included in the table.

Year	All Zones			Zone 1		
	Average (km ²)	Absolute change (km ²)	% Change	Average (km ²)	Absolute Change (km ²)	% Change
2010	<i>Surveys commenced November 2010</i>					
2011	0.14	-	-	0.00	-	-
2012	0.55	0.41	298.60	1.28	1.28	100.00
2013	0.28	0.27	-49.66	0.57	0.72	-55.92
2014	0.24	0.04	-14.43	0.10	0.47	-82.63
2015	0.54	0.30	128.58	0.23	0.13	130.30
2016	0.48	0.06	-11.39	0.28	0.06	25.71
2017	0.37	0.11	-22.00	0.22	0.06	-21.88
2018	0.46	0.09	24.70	0.07	0.16	-70.53
2019	<i>Trial of new vantage point methods commenced October 2019</i>					

Annex B Figures for descriptive statistics (separate document)

Provided in separate document:

Nova Innovation (2021). Shetland Tidal Array Monitoring Report: Vantage point surveys Annex B: Descriptive statistics plots. EnFAIT-0347.