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# Appendix 10.2, Annex A: Marine Mammal Digital Aerial Survey Data Report

## Array EIA Report

2024

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# 1. INTRODUCTION

1. This Annex to the Marine Mammal Technical Report provides an analysis of spatial and temporal distribution of marine mammals observed during the Digital Aerial Survey (DAS) campaign for the Ossian Array (hereafter referred to as the 'site boundary'). The DAS campaign commenced in March 2021, with a total of 24 months of data collected up to and including February 2023.

2. The extent of the DAS area provides an indication of marine mammal activity over the site boundary and an 8 km buffer, which constitutes the Array marine mammal study area (Figure 2.1), and therefore will be useful to determine where Zones of Influence (ZoIs) for some impacts associated with the Array extend further than the site boundary (although may not cover the full extent of the ZoI for all impacts e.g. piling noise).

3. Marine mammal data collected during these DAS complement the historic site-specific survey data that were collected for various offshore wind projects between December 2009 and April 2021 as well as other published data sources for the region. A detailed overview of these data sources is provided volume 3, appendix 10.2.

# 2. METHODOLOGY

## 2.1. STUDY AREA

4. The study area for the DAS campaign was delineated as the site boundary plus an 8 km buffer. This whole area, including the buffer corresponds with the 'Array marine mammal study area' and will inform the baseline for those impacts which may potentially extend beyond the boundaries of the site boundary. The aerial survey area covers a total area of approximately 2,264 km$^2$ (Figure 2.1).

## 2.2. SURVEY APPROACH

5. Aerial surveys of seabirds and marine mammals commenced in March 2021 and continued monthly up to and including February 2023 to allow 24 months of data collection, including any additional surveys to account for delayed survey flights (refer to section 2.5.2).

6. The surveys were conducted by HiDef Aerial Surveying Limited (hereafter 'HiDef') from an aircraft flying at an operational speed of 220 km/h (equivalent to 120 kn) at a survey height of approximately 550 m Above Sea Level (ASL). The aircraft was equipped with four HiDef 'GEN 2.5' cameras with a set resolution of 2 cm ground sample distance. Each camera surveyed a strip width of 125 m and cameras were set such that a gap of approximately 20 m between the strips was maintained, thereby ensuring there would be no overlap between the strips. For four cameras there was therefore a combined survey width of 500 m.

7. A total of 31 transects were spaced 2.5 km apart across the Array marine mammal study area, aligned in a broadly north-east to south-west orientation, perpendicular to the depth contours along the coast. The transects followed the routes shown in Figure 2.1. Position data for the aircraft was recorded at 1 s intervals from a Garmin GPSMap 296 differential Global Positioning System (GPS) device with 2 m positional accuracy, and allowed recording updates to match to seabird and marine mammal observations.

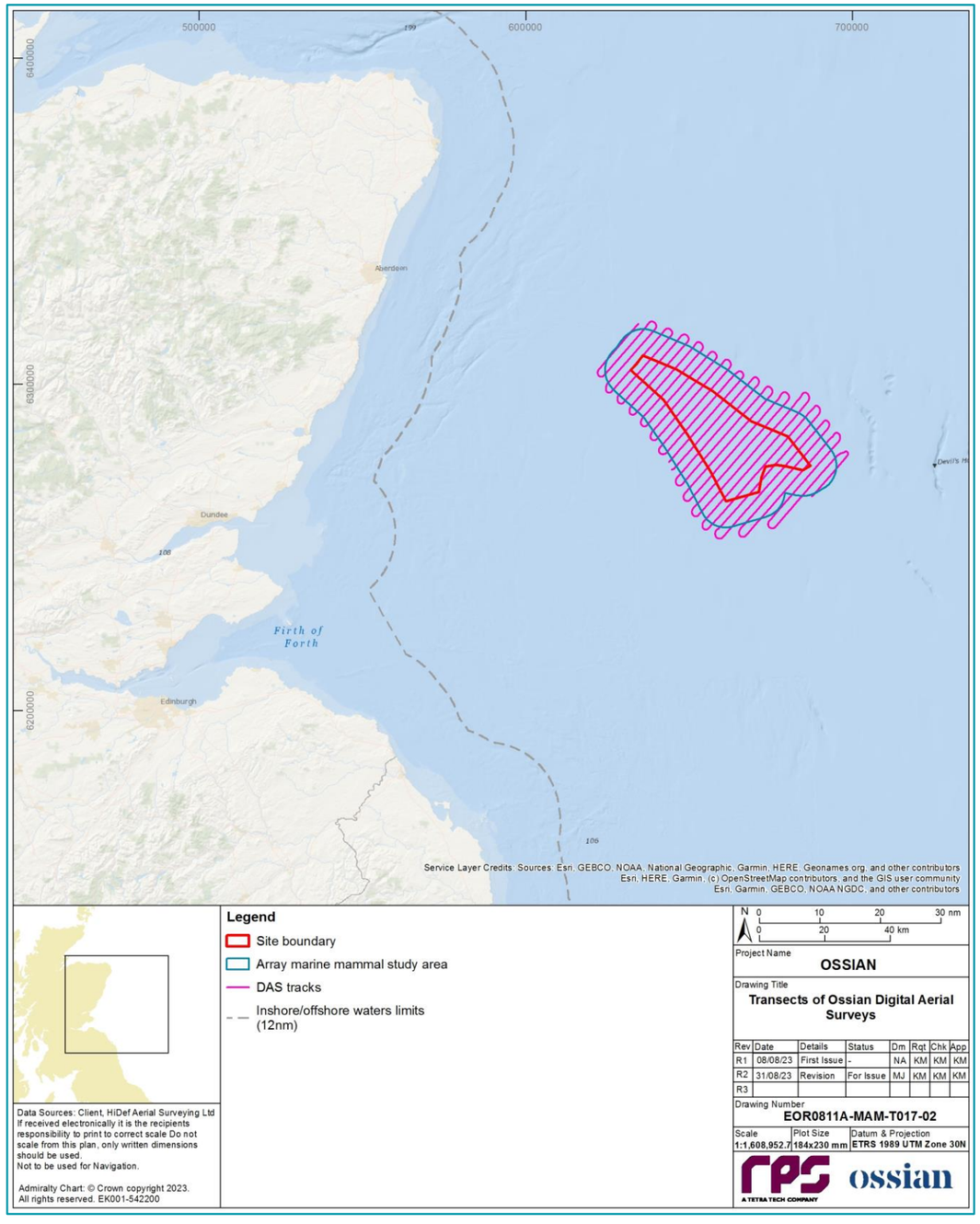


**Figure 2.1: Geographical Location of Array Marine Mammal Study Area and DAS Flight Tracks**

8. The total transect length covered by the DAS was 23,150.13 km, with a monthly mean of 964.59 km. Data from two cameras (approximately 0.25 km combined width, although camera coverage at the end of transects was reduced by clipping of data to the boundary of the Array marine mammal study area) were subsampled to provide a monthly mean sampled area of 226.66 $km^2$, which exceeded the minimum target of 10% coverage of the total aerial survey area (which was 226.41 $km^2$).

9. Imaging and GPS equipment continued to collect data between transects (i.e. as the aircraft turned at the end of one transect to begin the next), as to avoid including additional survey effort outside of the aerial survey area, all DAS data were clipped to the aerial survey area before analysis began.

## 2.3. PROCESSING OF AERIAL DATA

10. Digital aerial imagery, collected via the GEN 2.5 cameras, was reviewed by a team of trained and experienced professionals within HiDef, using high resolution viewing screens. Objects were marked, and their location recorded, before being passed to the second stage of species identification. Here, experienced marine surveyors used high definition digital imagery to identify each marked object to species level where possible. Other features including fixed structures, fishing vessels, dredgers, construction vessels, ferries, yachts and recreational vessels were also recorded.

11. An object was only recorded where it reached a reference line (known as 'the red line') which defines the true transect width for each camera. By excluding objects that do not cross the red line, biases in abundance estimates caused by flux (movement of objects in the video footage relative to the aircraft, such as 'wing wobble') could be eliminated.

12. For marine mammals, image analysts assigned the following classifications to each image:

- 'surfacing at red line': the dorsal fin (cetaceans) or head (pinnipeds) was above the water surface in the middle frame of the video sequence;
- 'surfacing': part of the animal appeared above the water surface in any of the frames, but not the dorsal fin or head in the middle frame of the sequence;
- 'submerged': no part of the animal appeared above the surface in any of the frames; or
- 'unknown': it was not fully clear from the footage whether an animal was surfacing or just submerged.

13. A qualitative measurement of the confidence in the identification was also provided as follows:

- 'definite': as certain as is reasonably possible;
- 'probable': very likely to be this species or species group; or
- 'possible': more likely to be this species or species group than anything else.

14. An additional 'blind' review was undertaken on a subset (20%) of the data as part of HiDef's Quality Assurance (QA) process. The reviewed data were compared to the original and if there was less than 90% agreement then all the data were re-reviewed.

15. All data were geo-referenced and compiled into a single output, taking into account the offset from the transect line of the cameras, which gave a higher degree of positional accuracy to each geo-referenced object. Geographical Information System (GIS) files for the 'Observation' and 'Track' data were provided by HiDef in ArcGIS shapefile format, using UTM30N projection, WGS84 datum.

16. On receipt of the geo-referenced aerial survey data, an additional QA on the data was carried out by RPS. Track lines for each camera reel were plotted in GIS and the total effort was subsequently calculated for each transect flown and compared with the minimum target of 10.0% coverage of the aerial survey area. Where the minimum coverage was not met, further detail was sought from HiDef to understand why this was the case. In addition, the marine mammal sightings data were reviewed, and any anomalies were highlighted and discussed with HiDef to validate the data. Further detail is provided in section 3.1.1 (Table 3.1).

## 2.4. DATA ANALYSES

17. Summary statistics were produced to describe the data for each of the key species or species groups within the DAS dataset. Data were presented to show the survey effort achieved in each month of survey against the minimum target of 10.0% coverage of the aerial survey area, and a description of any remedial action taken to address data gaps from delayed surveys was given.

18. Raw count data for each of the species or species groups was presented for each month of survey to highlight the frequency of sightings in each identification category. These raw count data were also spatially mapped in GIS to illustrate the distribution of sightings across the aerial survey area.

19. Further summary data were also produced to describe the number of sightings that fell into the different surfacing classifications (paragraph 12) and the different confidence classifications (paragraph 13).

20. Sightings data were corrected for effort in each month of the survey to produce counts per unit effort (i.e. number of individuals per km of track line flown) and are referred to as 'encounter rate'. These effort-corrected data allowed comparisons across months where effort varied; for example, for months which included weather downtime.

### 2.4.1. DENSITY ESTIMATES WITH BOOTSTRAPPING

21. For those species where there were sightings in a sufficient number of surveys to allow for temporal trends in observations to be estimated, seasonal relative densities were calculated from the DAS count data. Although there is no definitive minimum threshold, common dolphin *Delphinus delphis* was identified in one survey, harbour seal *Phoca vitulina* was identified in two surveys and minke whale *Balaenoptera acutorostrata* was identified in four surveys, so it was not possible to ascertain temporal trends for these species across the 24-month DAS campaign. For harbour porpoise *Phocoena phocoena*, white-beaked dolphin *Lagenorhynchus albirostris* and grey seal *Halichoerus grypus*, it was possible for temporal trends to be estimated.

22. Research into temporal patterns of harbour porpoise density identified two broad divisions in distribution, termed by Heinänen and Skov (2015) as 'summer' (April to September) and 'winter' (October to March). Similarly for grey seal, broad-scale seasonal patterns of density have been determined based upon potential changes in distribution between the breeding season (defined as September to December for this region (Marine Scotland, 2020; Special Committee on Seals (SCOS), 2020)) and the non-breeding season (January to August). This is because most females would be expected to be hauled out with pups during the breeding season, rather than being at sea.

23. Pooling data further into two bio-seasons allows the robustness of analyses to be improved where sample sizes in seasonal or monthly divisions may be small, while retaining greater resolution than pooling data by year.

24. To provide estimates of relative density and associated variance, the data were analysed using a non-parametric bootstrap approach, with replacement (Buckland *et al.*, 2001). Bootstrapping is a commonly applied method to produce an approximate distribution of the empirical data, particularly where the sample size is insufficient for straightforward statistical inference. The resampling generates a probability distribution which is subsequently used to produce estimates of accuracy (e.g. standard errors, confidence intervals (CI)). Non-parametric bootstrapping makes no assumptions about the data, in contrast to parametric bootstrapping which assumes that data follow a specific distribution.

25. Density estimates with bootstrapping were undertaken for harbour porpoise, white-beaked dolphin and grey seal. Monthly densities were resampled with replacement (1,000 times) to generate an estimated value for overall uncorrected density and 95% CIs for the aerial survey area.

## 2.4.2. MODEL BASED DENSITY ESTIMATES

26. Data were imported into R v4.2.0 (R Core Team, 2022) and the MRSea package (Scott-Hayward *et al.*, 2013a) was used in the analysis to best predict the density of marine mammals within the Array marine mammal study area. To account for the missing data appropriately, a Spatially Adaptive Local Smoothing Algorithm (SALSA); (Walker *et al.*, 2010) was used within MRSea (Scott-Hayward *et al.*, 2013a; 2013b). This approach allowed adjustment for the presence of missing data by (a) exploiting empirical relationships between abundance and other variables (water depth, terrain ruggedness and distance to coast) and (b) exploiting commonalities between distributions in different months.

27. Before any analyses could take place, the data required pre-processing to ensure no transect start or end times/locations differed (start and end times/locations were within both 10 s and 600 m of each other). In two cases across the 24 month DAS campaign this deviation occurred and the corresponding data were removed from further analysis.

28. In total, 793 transects were used in the analysis, covering a total aerial survey area of 5,439.85 km$^2$ and a mean monthly coverage of 226.66 km$^2$ (Figure 2.2). Note that surveys for May 2021 and February 2022 were flown in June 2021 and March 2022, respectively (refer to section 2.5.2 and Table 3.1).The spatial coverage of the monthly surveys used in the analyses, also indicating removed transects, is shown in Figure 2.3. Note that survey effort was greater in the February 2022 survey, and that all variation has been accounted for in subsequent analyses.

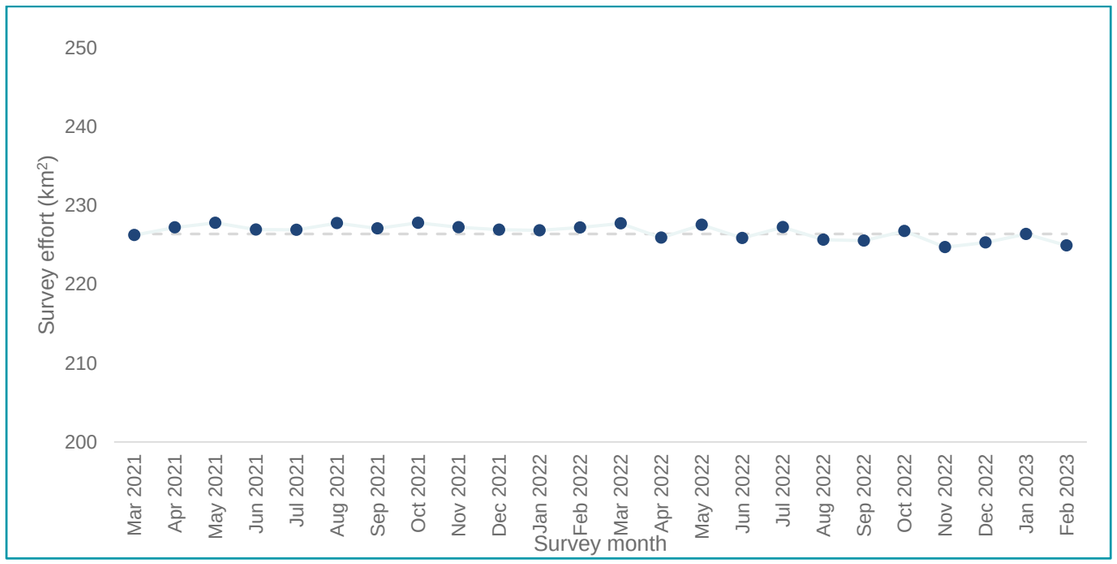


**Figure 2.2: Survey Effort Across 24 Month DAS Campaign within Array Marine Mammal Study Area**

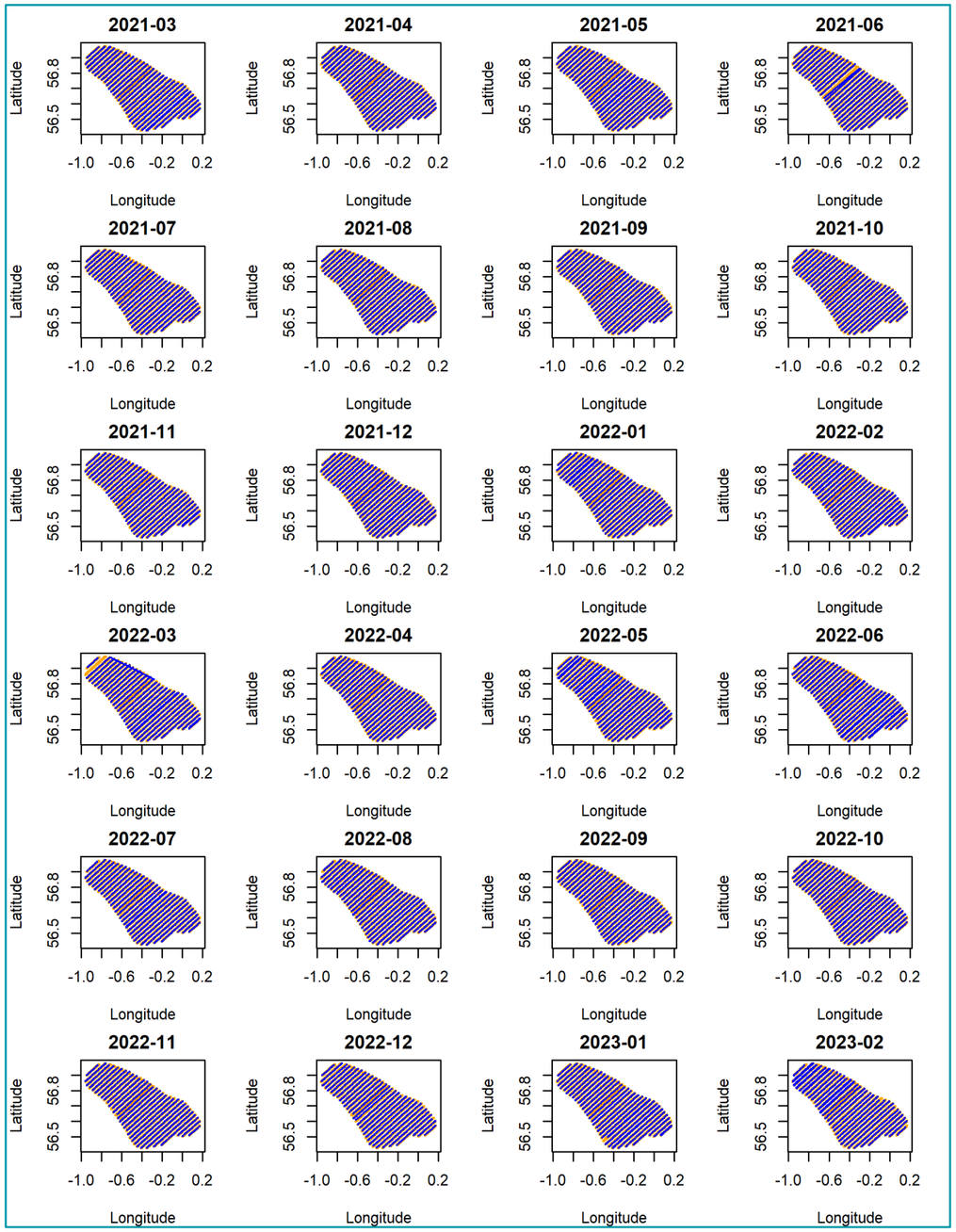


**Figure 2.3: Monthly Survey Coverage (Blue Lines) Across 24 Month DAS Campaign within Array Marine Mammal Study Area (Orange)**

29. It was originally intended that months would be modelled separately, however this approach was not possible due to monthly data being too sparse to fit MRSea models. Data were instead pooled across months within seasons (winter: December, January and February; spring: March, April and May; summer: June, July, August; and autumn: September, October and November) to overcome this issue, incorporating the biological assumption that species behave similarly within each season.

30. To improve the predictive power of MRSea analyses, data were therefore also pooled into bio-seasons where relevant.

31. The following covariates were used within modelling to predict species distribution:

- water depth (m);
- terrain ruggedness index (TRI);
- distance to coast (km);
- X and Y coordinates;
- season; and
- bio-season (where species-appropriate).

32. The degree of smoothing for each season/bio-season was determined within the MRSea package using tenfold cross validation, and the best model was used to predict species distribution. Within each of the models, separate maps for mean and associated upper and lower 95% Confidence Limits (CLs) were also produced for each season/bio-season.

33. For the purposes of MRSea modelling, the transects were split into 1 km sections (with a final section of less than 1 km on each transect, to ensure no data were omitted). The number of records for each species (across cameras) was then summed within each of these sections. To perform this aggregation, each record was mapped on to the nearest point of the transect line (i.e. the straight line between the transect start and transect end locations). Records did not always lie directly on this line and the distribution of distances between records, and the nearest point on the transect line is shown in Figure 2.4.

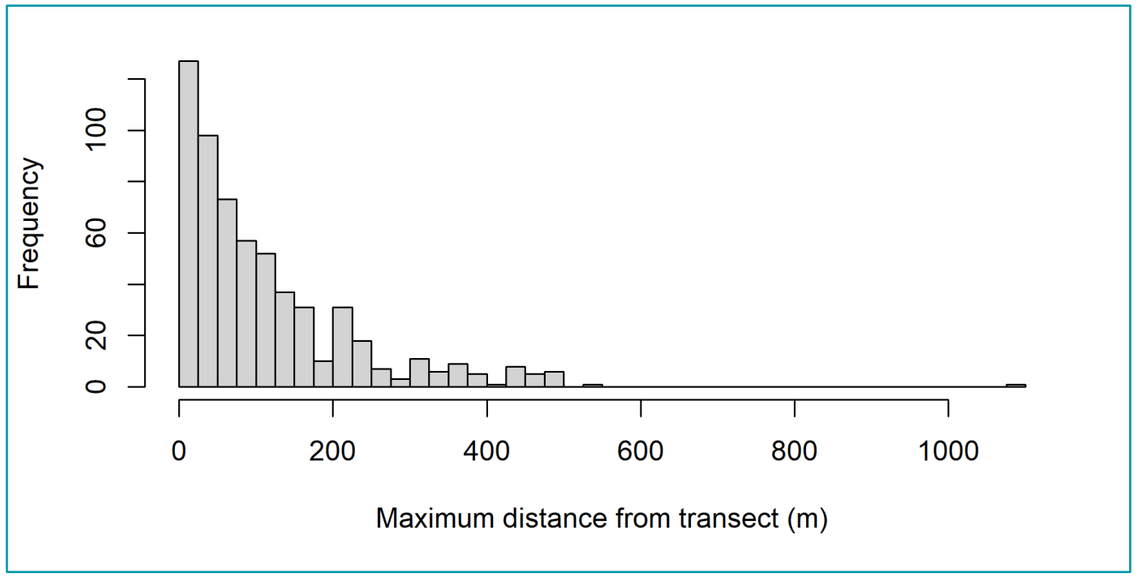


**Figure 2.4: Frequency Distribution of Distances from Marine Mammal Records to the Nearest Point on the Straight Line Between Camera-Specific Transect Start- and End-Point**

34. After removing the two transects as described in paragraph 27, a total of 825 records of harbour porpoise were used to predict densities within the aerial survey area.

35. Mean seasonal abundance estimates were calculated using the summed density estimates within square kilometre grid cells and scaled back up to estimate abundance across the aerial survey area.

### 2.4.3. CORRECTION FACTORS

36. Noting that the density estimates are relative and do not account for availability bias during the aerial surveys (refer to section 2.5.3) a literature review was undertaken to determine appropriate correction factors for the key species. Further detail on the correction factors is provided in section 3.5 on a species-by-species basis.

## 2.5. DATA LIMITATIONS

### 2.5.1. SNAPSHOT DATA

37. Aerial survey data represent a snapshot of marine mammal distribution and densities within a given survey period and may not fully capture the natural variability of marine mammal distribution or densities over time. Changes in sightings rates may be influenced by environmental conditions; however, due to the short time frames (single day) of data collection, this has not been possible to analyse. Therefore, whilst differences in sightings rates between months may be due to seasonal changes, environmental conditions also have the potential to influence these results. However, for the Marine Mammal Technical Report the aerial survey data were interpreted in the context of historic survey data collected for other offshore wind farms in the region, and in the context of historic published information available for this region, therefore providing a robust baseline (refer to volume 3, appendix 10.2).

### 2.5.2. DELAYED SURVEYS

38. Logistical issues and/or downtime due to unsuitable weather conditions prevented surveys from being flown in two months: May 2021 and February 2022. Potential data gaps were avoided by flying additional surveys as close in time as possible to those missed. Subsequently, the May 2021 survey was replaced by a supplementary flight on 09 June 2021, and the survey for February 2022 was conducted on 06 March 2022.

### 2.5.3. BIAS

39. Availability bias, i.e., an estimator of the probability that an animal is available for detection (i.e. visible) at any randomly chosen time, is used as multiplier to account for the period of time that each species may be available for detection. In the case of DAS, the time when an animal is available for detection is during the period that an animal is on the sea surface or just below the surface.

40. Availability bias is likely to be influenced by extrinsic factors that combine to produce a situation that is unique to each survey: factors such as light conditions, water clarity (turbidity) and animal behaviour can influence whether an animal will be detected, particularly those beneath the water surface. In most cases, animals under the sea surface were noted and identified from digital images (refer to section 3.1.3). The depth at which reliable interpretation of images is assured will therefore rely considerably on the factors mentioned and for this reason availability bias may differ from month to month.

41. Estimates of availability bias during aerial surveys are often based on studies looking at diving behaviour of a species because diving animals are inherently less likely to be visible. The results of these studies provide a correction factor for the proportion of time that animals are under the sea surface and therefore not available for detection. For the purpose of this assessment, correction factors were derived from studies in both the North Sea and other regions (e.g. harbour porpoise diving behaviour in the Baltic and

North Seas (Teilmann *et al.*, 2013); white-beaked dolphin diving behaviour in Iceland (Rasmussen *et al.*, 2013) and grey seal diving behaviour in the North Sea (Thompson *et al.*, 1991; Ørsted, 2018)) (refer to sections 3.5.1, 3.5.2 and 3.5.3, respectively). The caveat here is that species correction factors are unlikely to be a true representation of availability bias from one region to another, or from one month to the next, due to the potential spatial and temporal differences in environmental conditions. However, a precautionary approach was taken by reviewing the literature to compare correction factors from different studies and different months and then applying a conservative estimate (refer to species accounts in section 3.5).

42. Perception bias, i.e. where an animal is available for detection, but the detection is missed, is less of a limiting factor during DAS compared to visual boat based surveys since the high definition video utilised during DAS captures all animals on the sea surface, or just under the sea surface, and the detection is not influenced by the ability of an observer to detect an animal. In addition, during data processing, a 20% subsample of the data were quality assured by HiDef to ensure that images were not overlooked, and therefore the potential for perception bias is negligible (refer to section 2.3).

43. Similarly, a response bias, i.e. where an animal may respond to the presence of the surveying platform by either moving towards or away from the platform, is considered to be less of a limiting factor for aerial surveys compared to boat based surveys, due to the height of observation (in this case being approximately 550 m ASL). Therefore, the potential for response bias associated with the DAS is considered negligible.

#### 2.5.4. SPECIES IDENTIFICATION

44. Animals were identified first to a species group (e.g. seals) and then to species level where possible (for example grey seal or harbour seal). For seals, the identification to species level is more difficult as it is not always possible to distinguish between species in cases where an individual is submerged. A subsample of data was subject to an external QA process by a third-party marine mammal expert to ensure agreement in identification.

45. Where a full species identification could not be made, rather than discarding data it is sometimes possible for animals identified to higher taxonomic groups (e.g. seals) to be assigned to a species based on the proportion of the key species identified within the aerial survey area. However, it was considered that this approach may introduce unquantifiable bias (NatureScot, 2023), and as such individuals which were not identifiable to species level were not included in the design based analyses. Instead, only animals for which it was possible to assign species-level identification were included for analysis, while animals not identified to species level were included only in a high-level summary (refer to sections 3.1, 3.2 and 3.3).

# 3. RESULTS

## 3.1. SUMMARY DATA

### 3.1.1. SURVEY EFFORT

46. A summary of monthly survey effort, as calculated from the clipped data set described in section 2.2, is presented in Table 3.1, which also provides information for surveys in which minimum target coverage of the aerial survey area was not met.

47. For the design-based analysis, the 10% target coverage was met or exceeded in 16 out of 24 surveys. The minimum coverage obtained in any survey was 9.93% on 08 November 2022. For the model-based analysis, one transect was removed in two surveys: 18 March 2022 and 03 May 2022 (see paragraph 27), meaning that although the minimum 10% coverage was achieved during these surveys, the corresponding subset of data used in the analysis was below the 10% target by 0.47% and 0.58%, respectively. For model-based analyses, the 10% target was therefore met or exceeded in 14 out of 24 surveys. Critically, there was no reduction in the number of individuals included in the model-based analyses, since the two removed transects contained no observations of marine mammals.

48. Since the size of deviations from the 10% target were minimal, and the overall coverage across the 24-month DAS campaign exceeded the 10% target, the small shortfall in some surveys was not considered to affect the outcome of the analyses. Moreover, 95% CLs for marine mammal densities have been reported in all cases (refer to section 3.5) to account for inherent uncertainty in the calculation of summarised density estimates. The use of 95% CLs also reduces the sensitivity of calculated density estimates to the small deviations from the 10% target coverage which occurred in some surveys. Given the small size of these deviations, if slightly greater survey coverage had been achieved in these surveys (bringing survey coverage to the 10% target), then subsequent density estimates would still be expected to fall within the reported 95% confidence intervals.

### 3.1.2. SPECIES COUNTS

49. Harbour porpoise accounted for the highest number of sightings identified to species level (based on raw count data) across the aerial survey area and was recorded in all but three survey months: January 2022, October 2022 and January 2023 (Table 3.2). White-beaked dolphin accounted for the second highest number of sightings and was recorded in seven months over the 24 month survey period. For other sightings identified to species level – grey seal, minke whale, common dolphin and harbour seal – both the number and frequency of sightings was small (Table 3.2). No bottlenose dolphin *Tursiops truncatus* were observed during any survey months across the DAS campaign.

50. There were also four cetaceans observed that could not be assigned to species level, and sightings classified as ‘seal species’ (due to the difficulty of identifying phocids to species level from aerial survey data) occurred in 16 of the 24 months surveyed.

**Table 3.1: Monthly Survey Effort Across the Array Marine Mammal Study Area. Raw Survey Data Refer to those Data Used in the Design-Based Analysis and Processed Survey Data Refer to those Data Used in the Model-Based Analysis**

| Date | Raw Survey Data | | | Processed Survey Data | | | Notes on Survey |
|---|---|---|---|---|---|---|---|
| | Total Transect Length (km) | Survey Coverage ($km^2$) | Survey Coverage (%) | Total Transect length (km) | Survey Coverage ($km^2$) | Survey Coverage (%) | |
| 25 March 2021 | 905.04 | 226.26 | 9.99 | 905.04 | 226.26 | 9.99 | Target coverage not achieved: 0.007% (0.15 $km^2$) below target. |
| 17 April 2021 | 908.92 | 227.23 | 10.04 | 908.92 | 227.23 | 10.04 | Target coverage achieved. |
| 09 June 2021 | 911.24 | 227.81 | 10.06 | 911.24 | 227.81 | 10.06 | Target coverage achieved.<br><br>For the purposes of analyses the 09 June 2021 dataset will serve as the dataset for May 2021. |
| 19 June 2021 | 907.80 | 226.95 | 10.02 | 907.80 | 226.95 | 10.02 | Target coverage achieved. |
| 17 July 2021 | 907.68 | 226.92 | 10.02 | 907.68 | 226.92 | 10.02 | Target coverage achieved. |
| 05 August 2021 | 911.12 | 227.78 | 10.06 | 911.12 | 227.78 | 10.06 | Target coverage achieved. |
| 05 September 2021 | 908.40 | 227.10 | 10.03 | 908.40 | 227.10 | 10.03 | Target coverage achieved. |
| 04 October 2021 | 911.24 | 227.81 | 10.06 | 911.24 | 227.81 | 10.06 | Target coverage achieved. |
| 14 November 2021 | 909.04 | 227.26 | 10.04 | 909.04 | 227.26 | 10.04 | Target coverage achieved. |
| 09 December 2021 | 907.76 | 226.94 | 10.02 | 907.76 | 226.94 | 10.02 | Target coverage achieved. |
| 13 January 2022 | 907.44 | 226.86 | 10.02 | 907.44 | 226.86 | 10.02 | Target coverage achieved. |
| 06 March 2022 | 984.91 | 227.22 | 10.04 | 989.84 | 227.22 | 10.04 | Target coverage achieved.<br><br>For the purposes of analyses the 06 March 2022 dataset will serve as the dataset for February 2022. |
| 18 March 2022 | 910.96 | 227.74 | 10.06 | 862.84 | 215.71 | 9.53 | Target coverage achieved, but one transect removed as start/end times or locations deviated by more than 10 s or 600 m respectively. Target coverage therefore not achieved for model-based analysis: 0.47% (10.64 $km^2$) below target. |
| 14 April 2022 | 903.68 | 225.92 | 9.98 | 903.68 | 225.92 | 9.98 | Minimum target coverage not achieved during survey: 0.021% (0.49 $km^2$) below target |
| 03 May 2022 | 910.24 | 227.56 | 10.05 | 853.42 | 213.36 | 9.42 | Target coverage achieved but one transect removed as start/end times or locations deviated by more than 10 s or 600 m respectively. Target coverage therefore not achieved for model-based analysis: 0.58% (13.13 $km^2$) below target. |
| 04 June 2022 | 903.52 | 225.88 | 9.98 | 903.52 | 225.88 | 9.98 | Minimum target coverage not achieved during survey: 0.023% (0.53 $km^2$) below target |
| 10 July 2022 | 909.04 | 227.26 | 10.04 | 909.04 | 227.26 | 10.04 | Target coverage achieved. |
| 08 August 2022 | 902.68 | 225.67 | 9.97 | 902.68 | 225.67 | 9.97 | Minimum target coverage not achieved during survey: 0.033% (0.74 $km^2$) below target |
| 13 September 2022 | 902.20 | 225.55 | 9.96 | 902.20 | 225.55 | 9.96 | Minimum target coverage not achieved during survey: 0.038% (0.86 $km^2$) below target |
| 01 October 2022 | 907.04 | 226.76 | 10.02 | 907.04 | 226.76 | 10.02 | Target coverage achieved. |
| 08 November 2022 | 898.92 | 224.73 | 9.93 | 898.92 | 224.73 | 9.93 | Minimum target coverage not achieved during survey: 0.074% (1.68 $km^2$) below target |
| 23 December 2022 | 901.24 | 225.31 | 9.95 | 901.24 | 225.31 | 9.95 | Minimum target coverage not achieved during survey: 0.048% (1.10 $km^2$) below target |
| 27 January 2023 | 905.56 | 226.39 | 10.00 | 905.56 | 226.39 | 10.00 | Target coverage achieved. |

| Date | Raw Survey Data | | | Processed Survey Data | | | Notes on Survey |
|---|---|---|---|---|---|---|---|
| | Total Transect Length (km) | Survey Coverage ($km^2$) | Survey Coverage (%) | Total Transect length (km) | Survey Coverage ($km^2$) | Survey Coverage (%) | |
| 12 February 2023 | 899.72 | 224.93 | 9.93 | 899.72 | 224.93 | 9.93 | Minimum target coverage not achieved during survey: 0.065% (1.48 $km^2$) below target |
| **Overall** | **21,840.32** | **5,429.85** | **10.01** | **21,735.38** | **5,413.61** | **10.00** | **Target coverage achieved for DAS campaign.** |

**Table 3.2: Monthly Raw Sightings Data (Number of Animals) (Uncorrected for Effort) Across the Aerial Survey Area. To Improve Clarity and Aid Readability, Zero Counts are Indicated as Dashes**

| Survey | Harbour Porpoise | Minke Whale | Common Dolphin | White-beaked Dolphin | Grey Seal | Harbour Seal | Cetacean Species | Dolphin Species | Seal/Small Cetacean Species | Seal Species | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| March 2021 | 3 | - | - | - | - | - | - | - | - | 1 | 4 |
| April 2021 | 34 | - | - | 2 | 1 | 1 | - | - | - | 6 | 44 |
| May 2021* | 73 | - | - | 4 | 1 | - | - | - | - | 1 | 79 |
| June 2021 | 70 | - | - | - | 4 | - | - | - | 1 | 1 | 76 |
| July 2021 | 140 | 3 | 3 | 12 | - | - | 1 | - | - | 3 | 162 |
| August 2021 | 5 | - | - | - | - | - | - | - | - | 1 | 6 |
| September 2021 | 4 | - | - | 3 | - | - | - | - | - | - | 7 |
| October 2021 | 2 | - | - | - | - | - | - | - | - | - | 2 |
| November 2021 | 1 | - | - | - | 1 | - | - | - | - | - | 2 |
| December 2021 | 2 | - | - | - | - | - | - | 1 | - | 2 | 5 |
| January 2022 | - | - | - | - | 2 | - | - | - | - | - | 2 |
| March 2022* | 42 | - | - | 6 | 4 | - | - | - | 1 | 9 | 62 |
| March 2022 | 5 | - | - | - | - | - | - | - | - | 2 | 7 |
| April 2022 | 109 | 1 | - | - | 2 | - | - | - | - | 9 | 121 |
| May 2022 | 11 | - | - | - | 2 | 1 | - | - | - | 3 | 17 |
| June 2022 | 127 | 3 | - | - | - | - | - | - | - | 1 | 131 |
| July 2022 | 122 | 5 | - | - | - | - | - | - | 1 | 4 | 132 |
| August 2022 | 56 | - | - | 2 | - | - | - | - | - | 2 | 60 |
| September 2022 | 2 | - | - | 1 | - | - | - | - | - | - | 3 |
| October 2022 | - | - | - | - | - | - | - | 1 | - | 1 | 2 |
| November 2022 | 8 | - | - | - | - | - | 1 | - | - | - | 9 |
| December 2022 | 6 | - | - | - | - | - | - | - | - | 1 | 7 |
| January 2023 | - | - | - | - | - | - | - | - | - | - | - |

| Survey | Harbour Porpoise | Minke Whale | Common Dolphin | White-beaked Dolphin | Grey Seal | Harbour Seal | Cetacean Species | Dolphin Species | Seal/Small Cetacean Species | Seal Species | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| February 2023 | 3 | - | - | - | 1 | - | - | - | - | - | 4 |
| **Total** | 825 | **12** | **3** | **30** | **18** | **2** | **2** | **2** | **3** | **47** | 944 |

**Table 3.3: Seasonal Raw Sightings Data (Number of Animals, Uncorrected for Effort) Across the Aerial Survey Area. To Improve Clarity and Aid Readability, Zero Counts are Indicated as Dashes**

| Species | Winter | Spring | Summer | Autumn | Total |
|---|---|---|---|---|---|
| Harbour porpoise | 53 | 235 | 520 | 17 | 825 |
| Minke whale | - | 1 | 11 | - | **12** |
| Common dolphin | - | - | 3 | - | **3** |
| White-beaked dolphin | 6 | 6 | 14 | 4 | **30** |
| Grey seal | 7 | 6 | 4 | 1 | **18** |
| Harbour seal | - | 2 | - | - | **2** |
| Cetacean species | - | - | 1 | 1 | **2** |
| Dolphin species | 1 | - | - | 1 | **2** |
| Seal/small cetacean species | 1 | - | 2 | - | **3** |
| Seal species | 12 | 22 | 12 | 1 | **47** |
| **Total** | 80 | 272 | 567 | 25 | 94 |

51. Seasonal marine mammal sightings across the aerial survey area are summarised in Figure 3.1.

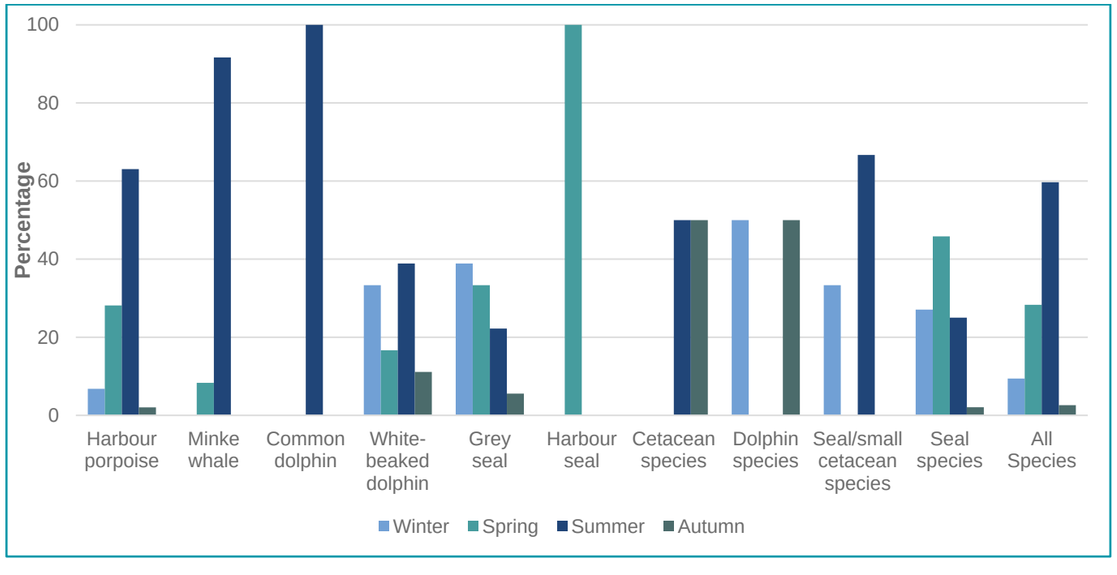


**Figure 3.1: Seasonal Percentage of Marine Mammal Sightings in the Aerial Survey Area**

### 3.1.3. SURFACING CATEGORIES

52. There were no clear temporal patterns in surfacing behaviour across the 24 month survey period. In four survey months all sighted marine mammals were observed to be surfacing, and during eight of the months surveyed a clear majority of observations were of submerged individuals. For seven surveys there was a broadly equal split between individuals submerged or surfacing, and in three months this was split between surfacing animals and those for which a behavioural category could not be assigned (Figure 3.2). No surfacing categories were assigned to any individuals in the January 2023 survey.

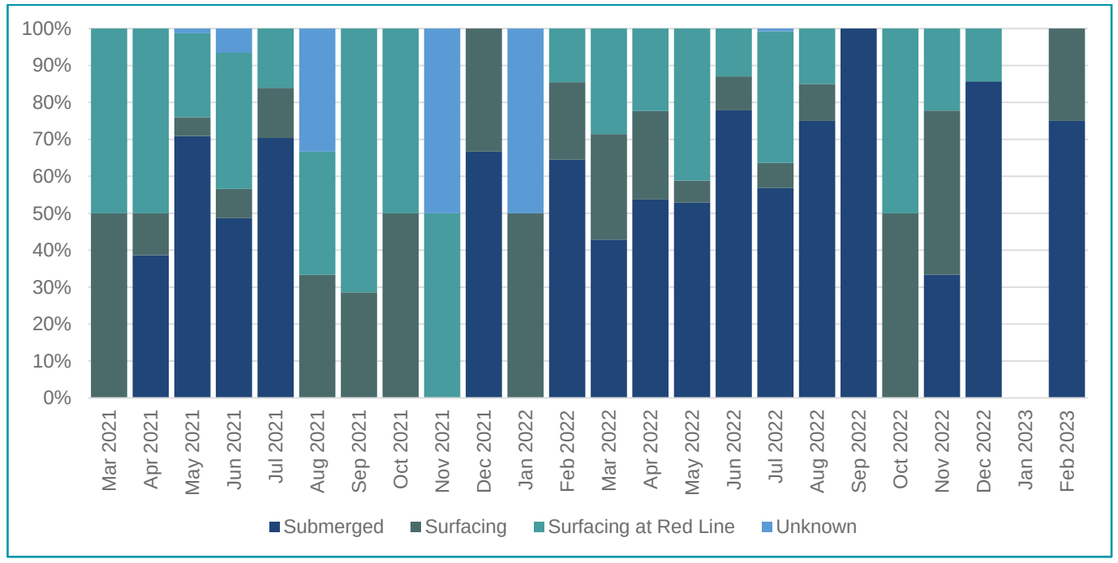


**Figure 3.2: Summary of Surfacing Categories by Month, Combined Across Species**

53. There were also inter-species differences noted in the surfacing categories for the more abundant species. Harbour porpoise, minke whale and white-beaked dolphin were recorded as 'submerged' in at least 65% of observations, whilst grey seal and 'seal species' were most often recorded as they surfaced ('surfacing' plus 'surfacing at red line') (Figure 3.3). This highlights the potential differences in availability bias between species.

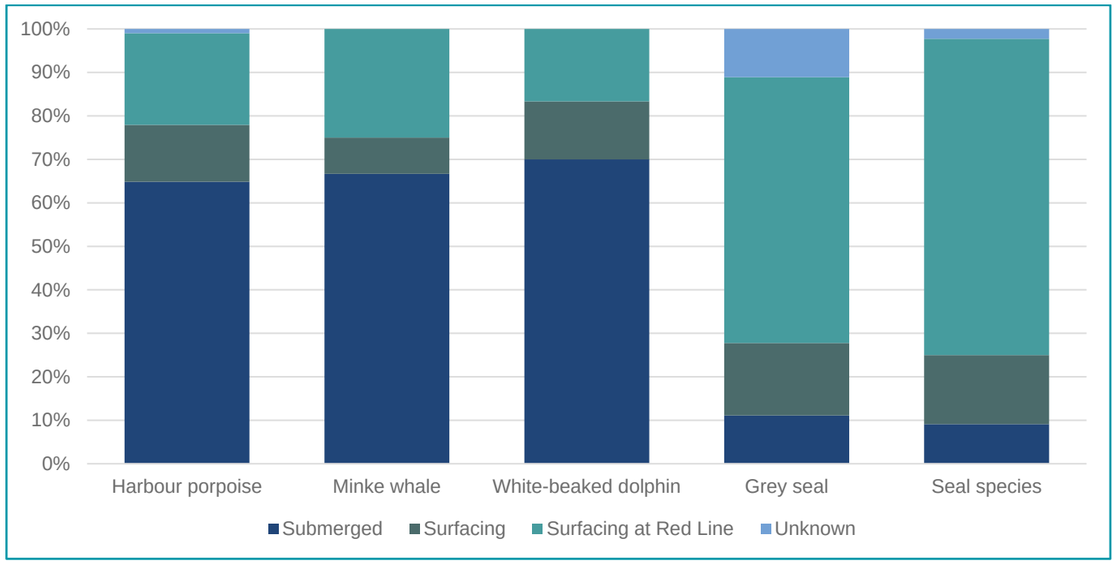


**Figure 3.3: Summary of Surfacing Categories by Species, Combined Across Months**

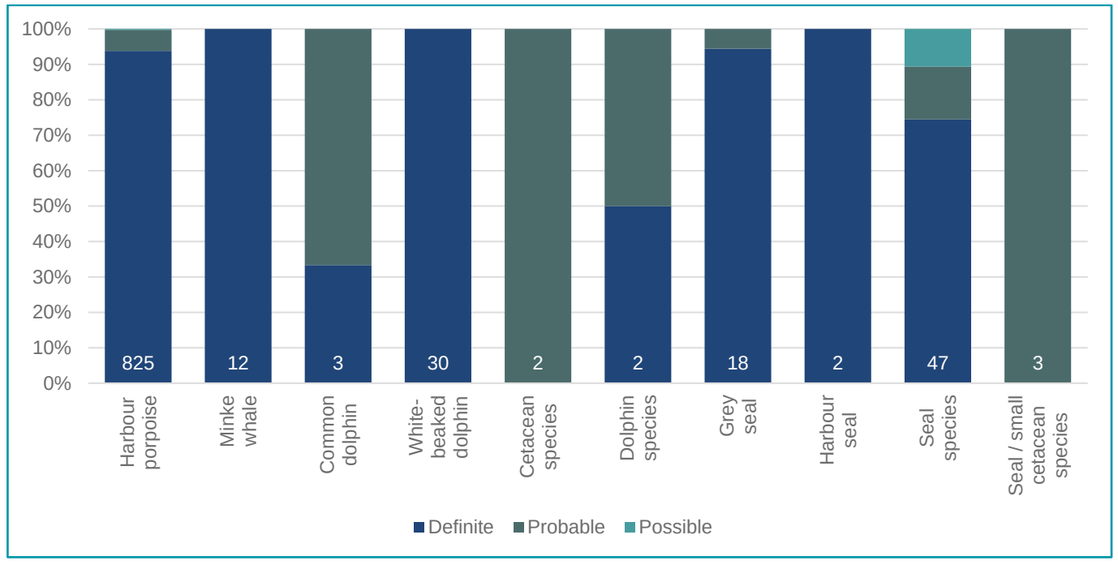


**Figure 3.4: Proportion of Marine Mammal Sightings Classified as 'Definite', 'Probable' or 'Possible'. Numbers within Bars Indicate Numbers of Sightings**

### 3.1.4. CONFIDENCE ASSESSMENT

54. Confidence in identification varied by species/species group (Figure 3.4). Where an animal was identified to species level there was typically a high level of confidence in the identification and subsequently most identifications were classified as 'definite', with one species (common dolphin) split 1:2 between 'Definite' and 'Probable'.

55. Seals appear to have been the hardest group to identify to a high level of confidence, given that 40% of identified grey seal (n = 18) and 50% of identified harbour seal (n=2) were classified as 'definite' identifications. A total of seven individuals were identified as 'Definite' grey seals whilst a total of 48 animals were identified as 'seal species' (i.e. could not be assigned to either grey seal or harbour seal). Of the seal species, 36 animals were 'Definite' identifications, seven were 'Probable' identifications and five were 'Possible' identifications. Three sightings could be identified only as 'seal/small cetacean species', all of which were classified as 'Probable'.

## 3.2. DISTRIBUTION OF SIGHTINGS

56. Sightings of marine mammals were spatially distributed throughout the aerial survey area. Figure 3.5 indicates the distribution of harbour porpoise sightings, Figure 3.6 indicates the distribution of all cetacean sightings, excluding harbour porpoise for clarity, and Figure 3.7 indicates the distribution of seal species, within the aerial survey area.

57. No clear spatial patterns were observed in the distribution of any species.

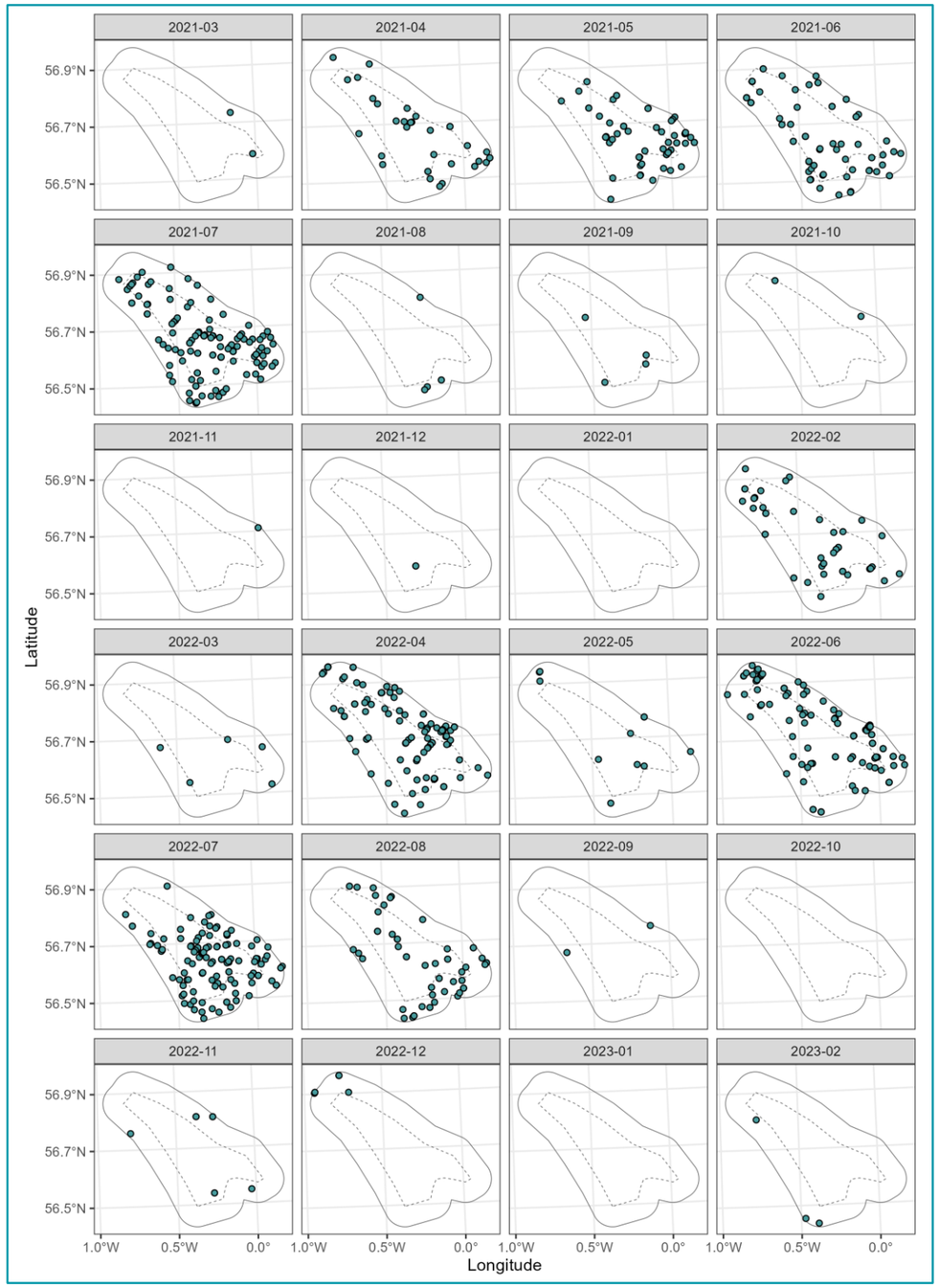


**Figure 3.5: Distribution of Harbour Porpoise Sightings within the Array Marine Mammal Study Area (Solid Line), with Site Boundary Illustrated by Dashed Line**

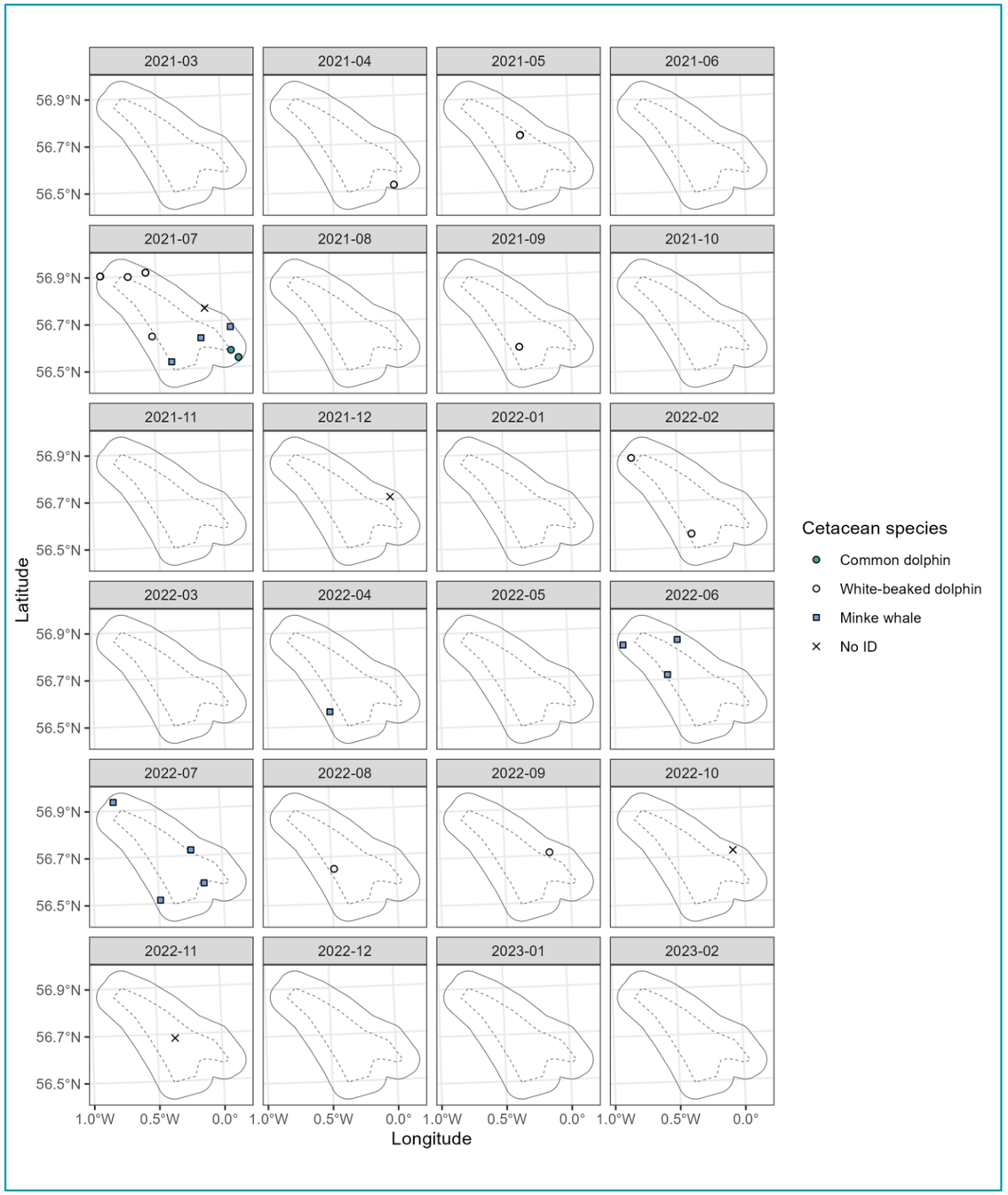


**Figure 3.6: Distribution of Cetacean Sightings within the Array Marine Mammal Study Area (Solid Line), with Site Boundary Illustrated by Dashed Line. Harbour Porpoise Sightings have been Removed for Clarity**

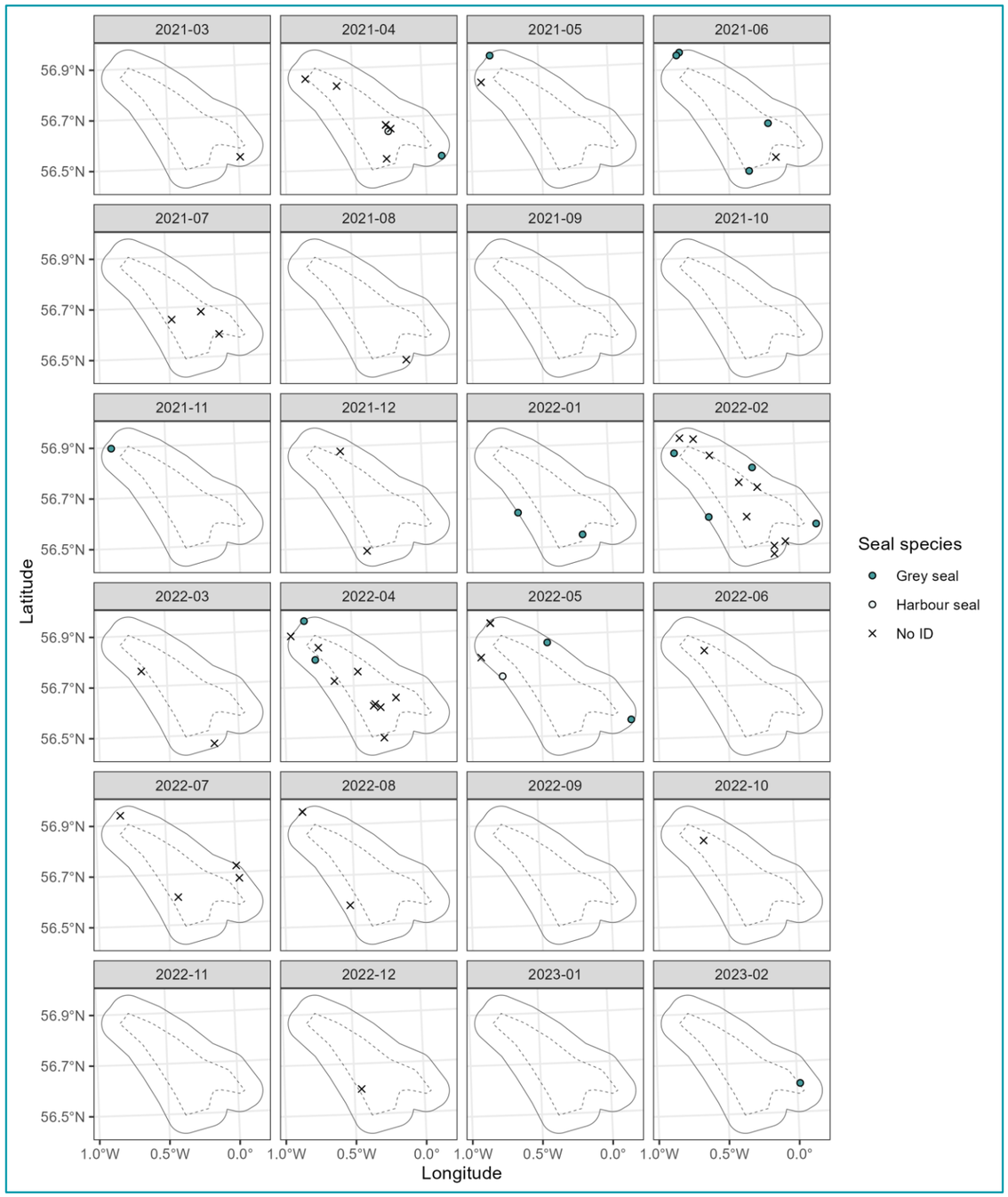


**Figure 3.7: Distribution of Seal Observations within the Array Marine Mammal Study Area (Solid Line), with Site Boundary Illustrated by Dashed Line**

## 3.3. ENCOUNTER RATE

58. Encounter rate varied across and within species throughout the 24 month DAS period. The highest encounter rate for a given species or species group was for harbour porpoise, which was encountered in every survey except three and for which a mean of 0.041 animals per km (95% CI = 0.018, 0.064) was estimated. Monthly harbour porpoise encounter rate varied across months with the encounter rate for July 2021, April 2022, June 2022 and July 2022 estimated to be considerably higher compared to all other months of the year (Figure 3.8).

59. White-beaked dolphin were found to have the second highest mean encounter rate (0.005 animals per km, 95% CI = 0.002, 0.008) and were encountered in consecutive surveys between April 2021 and May 2021, and between June 2022 and July 2022, with numbers peaking in July 2021 and February 2022. However, subsequent encounters were much less frequent, and this species was only encountered during one other survey: September 2021 (seven surveys in total) (Figure 3.9).

60. Minke whale were mostly encountered during the spring and summer months (with the encounter rate peaking in July 2022 at 0.006 animals/km. Although observations in this case are sparse, this seasonality corroborates observations from previous surveys undertaken in waters off the north-east coast of Scotland with minke whales showing seasonal peaks during summer months (e.g. MacLeod *et al.*, 2007; Weir *et al.*, 2007).

61. Grey seal were encountered in nine surveys and had a mean encounter rate of 0.002 animals per km (95% CI = 0.001, 0.003) in June 2021 and February 2022. 'Seal species' (0.003 animals per km, 95% CI = 0.002, 0.004) and common dolphin (0.003 animals per km, no 95% CI available as n = 1) were the third highest. A total of two harbour seal were sighted across two surveys (0.001 animals per km (no robust 95% CI available as n = 2)) and no bottlenose dolphin were observed in the study area during the 24 month DAS period.

**Table 3.4: Monthly Encounter Rate (Number of Animals per km of Track Line) for Marine Mammals within the Aerial Survey Area**

| Survey | Track Line Length (km) | Harbour Porpoise | Minke Whale | Common Dolphin | White-beaked Dolphin | Grey Seal | Harbour Seal | Cetacean Species | Seal Species | Seal/Small Cetacean |
|---|---|---|---|---|---|---|---|---|---|---|
| March 2021 | 905.04 | 0.003 | - | - | - | - | - | - | 0.001 | - |
| April 2021 | 908.92 | 0.037 | - | - | 0.002 | 0.001 | 0.001 | - | 0.007 | - |
| May 2021* | 911.24 | 0.080 | - | - | 0.004 | 0.001 | - | - | 0.001 | - |
| June 2021 | 907.8 | 0.077 | - | - | - | 0.004 | - | - | 0.001 | 0.001 |
| July 2021 | 907.68 | 0.154 | 0.003 | 0.003 | 0.013 | - | - | 0.001 | 0.003 | - |
| August 2021 | 911.12 | 0.005 | - | - | - | - | - | - | 0.001 | - |
| September 2021 | 908.4 | 0.004 | - | - | 0.003 | - | - | - | - | - |
| October 2021 | 911.24 | 0.002 | - | - | - | - | - | - | - | - |
| November 2021 | 909.04 | 0.001 | - | - | - | 0.001 | - | - | - | - |
| December 2021 | 907.76 | 0.002 | - | - | - | - | - | - | 0.002 | - |
| January 2022 | 907.44 | - | - | - | - | 0.002 | - | - | - | - |
| February 2022* | 984.91 | 0.043 | - | - | 0.006 | 0.004 | - | - | 0.009 | 0.001 |
| March 2022 | 910.96 | 0.005 | - | - | - | - | - | - | 0.002 | - |
| April 2022 | 903.68 | 0.121 | 0.001 | - | - | 0.002 | - | - | 0.010 | - |
| May 2022 | 910.24 | 0.012 | - | - | - | 0.002 | 0.001 | - | 0.003 | - |
| June 2022 | 903.52 | 0.141 | 0.003 | - | - | - | - | - | 0.001 | - |
| July 2022 | 909.04 | 0.134 | 0.006 | - | - | - | - | - | 0.004 | 0.001 |
| August 2022 | 902.68 | 0.062 | - | - | 0.002 | - | - | - | 0.002 | - |
| September 2022 | 902.2 | 0.002 | - | - | 0.001 | - | - | - | - | - |
| October 2022 | 907.04 | - | - | - | - | - | - | - | 0.001 | - |
| November 2022 | 898.92 | 0.009 | - | - | - | - | - | 0.001 | - | - |
| December 2022 | 901.24 | 0.007 | - | - | - | - | - | - | 0.001 | - |
| January 2023 | 905.56 | - | - | - | - | 0.001 | - | - | - | - |
| February 2023 | 899.72 | 0.003 | - | - | - | 0.001 | - | - | - | - |
| Mean | 909.81 | 0.041 | 0.003 | 0.003 | 0.005 | 0.002 | 0.001 | 0.001 | 0.003 | 0.001 |
| 95% CI [±] | 6.57 | 0.023 | 0.002 | n/a | 0.003 | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 |
| Minimum (>0) | 6.57 | 0.022 | 0.002 | 0.003 | 0.003 | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 |
| Maximum | 898.92 | 0.000 | 0.001 | 0.003 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

* Surveys for May 2021 and February 2022 were undertaken in June 2021 and March 2022, respectively (see section 2.5.2)

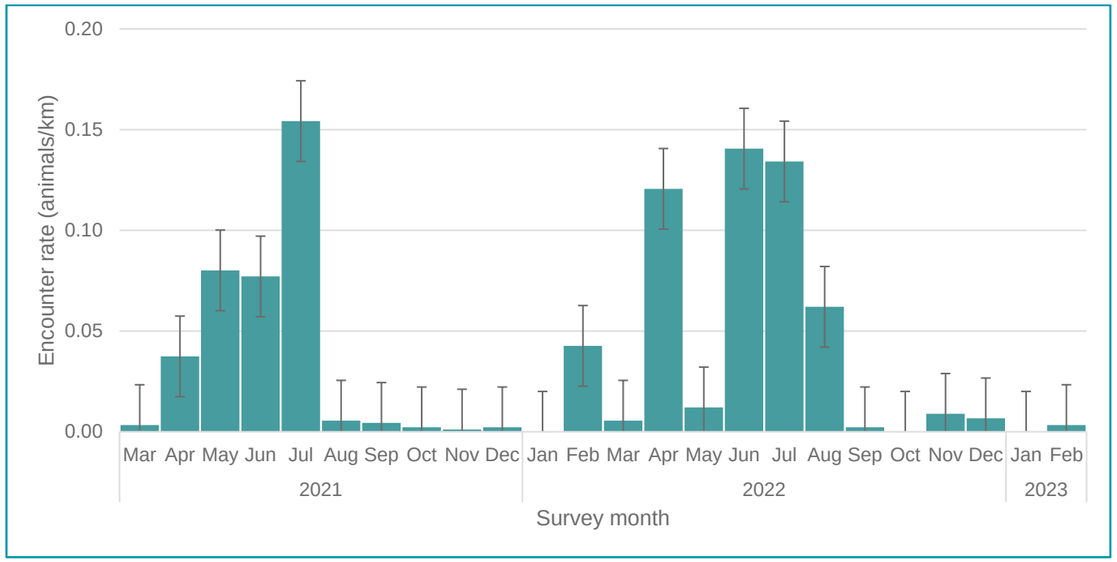


**Figure 3.8: Monthly Encounter Rate of Harbour Porpoise Across the Aerial Survey Area. Error Bars Indicate 95% CIs**

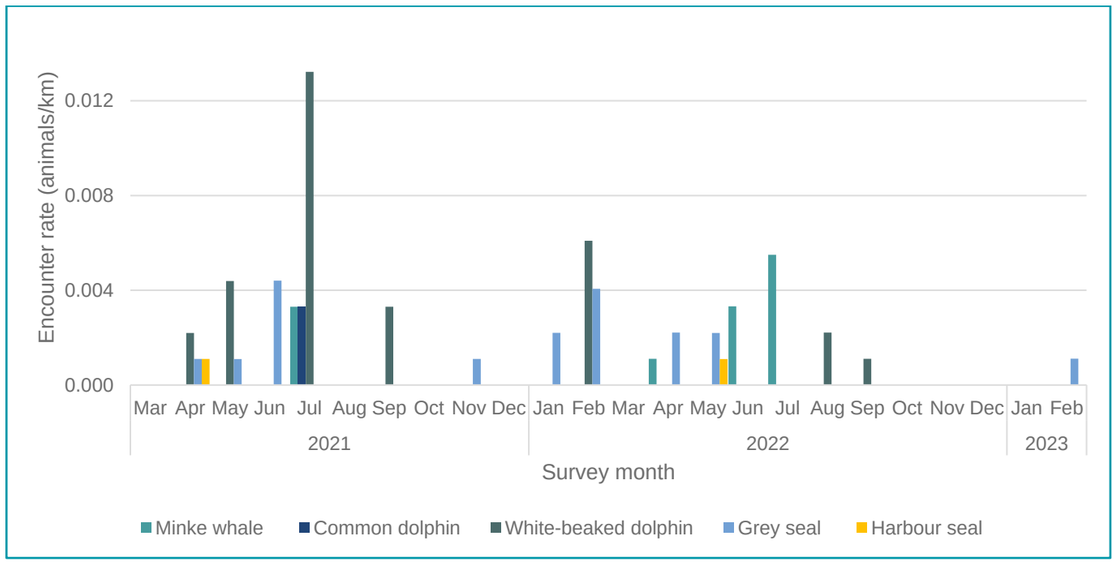


**Figure 3.9: Monthly Encounter Rate for Marine Mammals Identified to Species Level (Excluding Harbour Porpoise). Error Bars for 95% CIs have been Omitted to Retain Clarity**

## 3.4. GROUP SIZE

62. Marine mammals were considered to occur as a group on any occasion when more than one individual of a species was identified within the same survey image. Group size varied by species and across the months. The largest group sizes of four individuals were recorded for harbour porpoise and white-beaked dolphin, with an average group size of 2.15 animals (95% CI ±0.08) and 2.56 animals (95% CI ±0.58) respectively, across all sightings over the 24 months of survey (Table 3.5). Figure 3.10 shows the monthly variation in the mean and maximum group size for harbour porpoise and Figure 3.11 presents the monthly variation in mean and maximum group size for white-beaked dolphin. The higher count of harbour porpoise in spring and summer months (Table 3.2) coincided with larger groups of animals sighted within the aerial survey area. For example, in June a maximum group size of four animals was recorded whilst the overall mean for this month was 2.29 animals.

63. In the 24 months of survey, most sightings of common dolphin were of single animals, with only a single instance in which two animals were recorded for either species, both in the month of July (Table 3.5). For minke whale and grey seal, all sightings were of single animals, so it was not possible to calculate group size for these species.

**Table 3.5: Monthly Mean and Maximum Group Sizes for Species Sightings Across the Aerial Survey Area**

| | Harbour Porpoise | | White-beaked Dolphin | | Common Dolphin | |
|---|---|---|---|---|---|---|
| | **Mean** | **Max** | **Mean** | **Max** | **Mean** | **Max** |
| January | - | - | - | - | - | - |
| February | 2.00 | 2 | 3.00 | 4 | - | - |
| March | 2.00 | 2 | - | - | - | - |
| April | 2.08 | 3 | 2.00 | 2 | - | - |
| May | 2.11 | 3 | 2.00 | 2 | - | - |
| June | 2.29 | 4 | - | - | - | - |
| July | 2.09 | 3 | 2.00 | 2 | 2.00 | 2 |
| August | 2.13 | 3 | 2.00 | 2 | - | - |
| September | - | - | 3.00 | 3 | - | - |
| October | - | - | - | - | - | - |
| November | 2.00 | 2 | - | - | - | - |
| December | 2.00 | 2 | - | - | - | - |
| **Overall mean** | **2.15** | **2.67** | **2.56** | **2.50** | **2.00** | **2.00** |
| **95% CI [±]** | **0.08** | **0.46** | **0.58** | **0.67** | **N/A** | **N/A** |

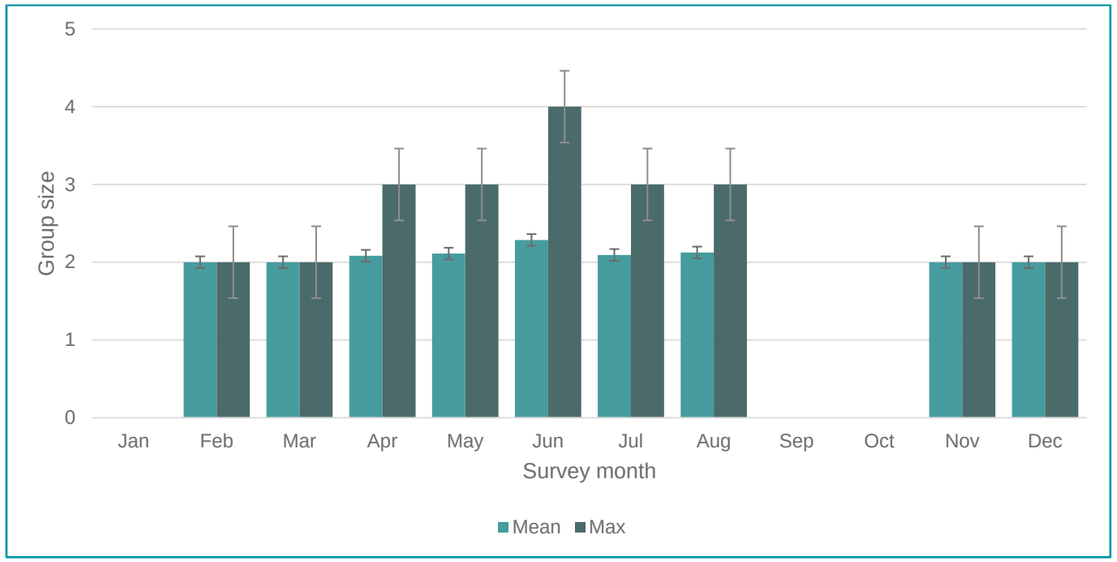


**Figure 3.10: Monthly Mean and Maximum Group Sizes (i.e. ≥2 Individuals Sighted in the Same Survey Image) for Harbour Porpoise. Error Bars Indicate 95% CIs**

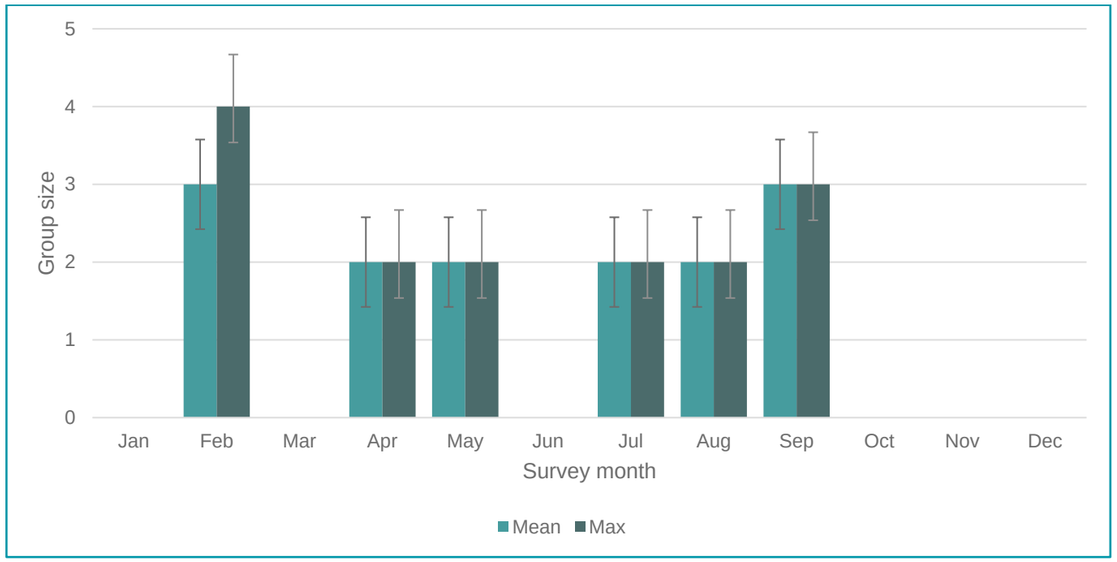


**Figure 3.11: Monthly Mean and Maximum Group Sizes (i.e. ≥2 Individuals Sighted in the Same Survey Image) for White-Beaked Dolphin. Error Bars Indicate 95% CIs**

## 3.5. DENSITY ESTIMATES

64. Mean densities of marine mammals were produced from the DAS count data, averaged at the monthly, seasonal and (where relevant) bio-season scale, and an overall mean was also estimated across the survey period. Coefficient of variation (CV) has also been calculated to present the variability in the raw data. Density estimates were calculated only for species that occurred at sufficient frequency to allow patterns of occurrence to be inferred: harbour porpoise, white-beaked dolphin and grey seal.

### 3.5.1. HARBOUR PORPOISE

Design-based approach: relative densities

65. Mean estimates of relative density for harbour porpoise were estimated across monthly, seasonal, bio-season and annual scales (Table 3.6), with 95% CLs obtained via bootstrapping (1,000 simulations) (Wessa, 2019). Figure 3.12 illustrates the simulated mean relative densities resulting from the bootstrapping process.

**Table 3.6: Summary of Mean Relative Density of Harbour Porpoise, Aggregated Across Monthly, Seasonal, Bio-Season and Annual Scales**

| Temporal Division | Mean Relative Abundance | Mean Relative Density (Animals/km$^2$) | Lower 95% CL | Upper 95% CL | CV |
|---|---|---|---|---|---|
| **Monthly** | | | | | |
| January | - | - | - | - | - |
| February | 225 | 0.099 | 0.055 | 0.147 | 1.224 |
| March | 40 | 0.018 | 0.010 | 0.026 | 0.349 |
| April | 716 | 0.316 | 0.175 | 0.468 | 0.745 |
| May | 418 | 0.184 | 0.102 | 0.273 | 1.043 |
| June | 986 | 0.435 | 0.241 | 0.644 | 0.412 |
| July | 1,307 | 0.577 | 0.320 | 0.854 | 0.098 |
| August | 306 | 0.135 | 0.075 | 0.200 | 1.184 |
| September | 30 | 0.013 | 0.007 | 0.020 | 0.467 |
| October | 10 | 0.004 | 0.002 | 0.006 | 1.414 |
| November | 46 | 0.020 | 0.011 | 0.030 | 1.103 |
| December | 41 | 0.018 | 0.010 | 0.026 | 0.711 |
| **Meteorological Season** | | | | | |
| Winter | 89 | 0.039 | 0.022 | 0.058 | 1.853 |
| Spring | 391 | 0.173 | 0.096 | 0.256 | 1.105 |
| Summer | 866 | 0.382 | 0.212 | 0.566 | 0.602 |

| Temporal Division | Mean Relative Abundance | Mean Relative Density (Animals/km²) | Lower 95% CL | Upper 95% CL | CV |
|---|---|---|---|---|---|
| Autumn | 29 | 0.013 | 0.007 | 0.019 | 1.014 |
| **Bio-season** | | | | | |
| 'Winter' | 60 | 0.026 | 0.015 | 0.039 | 2.819 |
| 'Summer' | 627 | 0.277 | 0.154 | 0.410 | 0.848 |
| **Yearly** | | | | | |
| Annual | 344 | 0.152 | 0.084 | 0.224 | 1.367 |

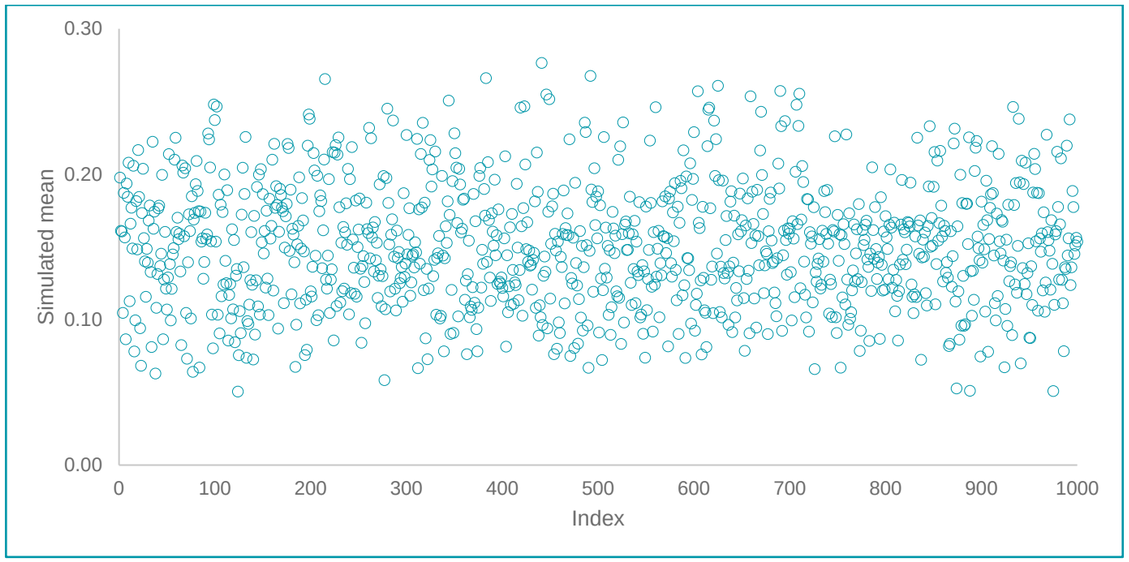


**Figure 3.12: Bootstrapped (n = 1,000) Simulation of Mean Relative Density Estimates of Harbour Porpoise**

66. Peaks in density were estimated for the months of July 2021, June 2022 and July 2022, with a maximal relative density of 0.617 (95% CLs = 0.348, 0.898) animals per km² in July 2021. Due to the large variability in relative density across surveys, with very low densities in some months and higher densities in others (range = 0.000, 0.617; CV = 1.367), monthly trends in density are not easy to interpret visually on a linear scale (Figure 3.13). Data were therefore also plotted on a $\log_{10}$ scale (Figure 3.14), where seasonality is more apparent and suggests that densities are broadly higher in spring and summer months (March to August) with lower values in late autumn and winter (September to February).

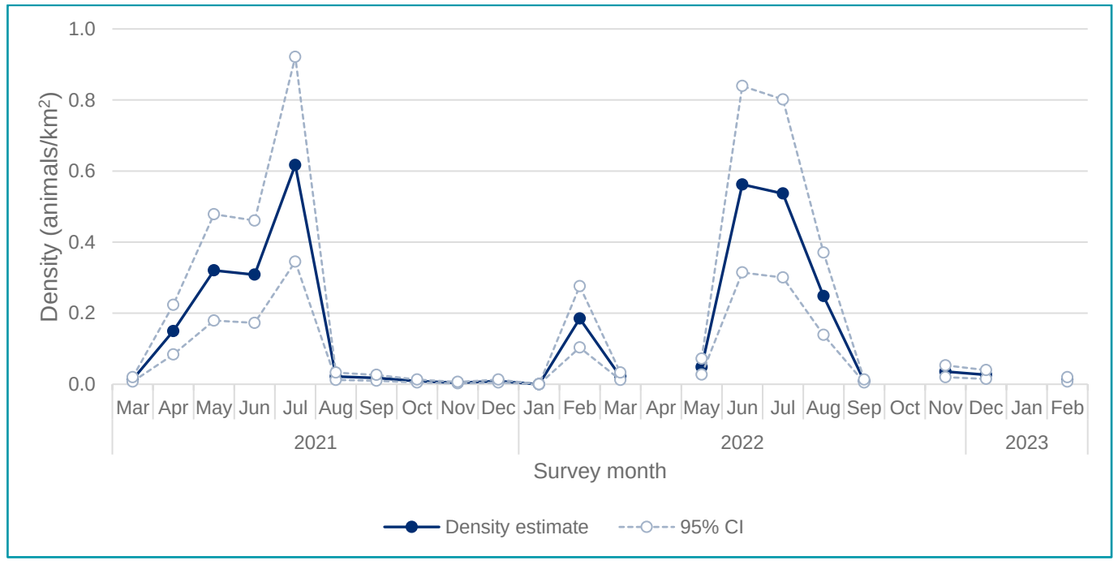


**Figure 3.13: Estimated Relative Density of Harbour Porpoise Over the Aerial Survey Area (Solid Line) for Each Survey Month, with Bootstrapped 95% CLs (Dotted Lines)**

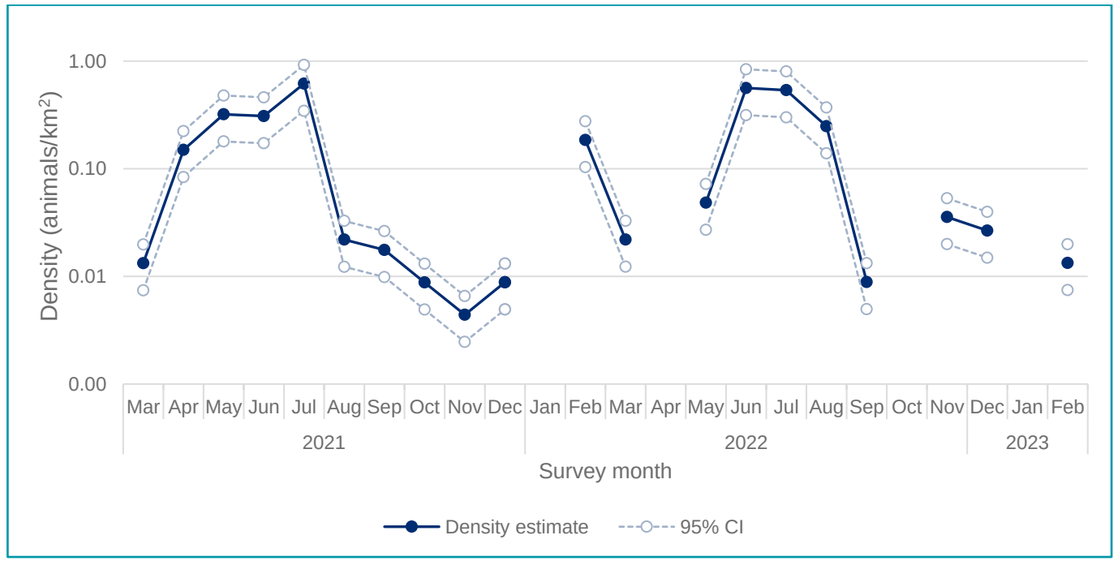


**Figure 3.14: Estimated Relative Density of Harbour Porpoise ($\log_{10}$ scale) in the Aerial Survey Area (Solid Line) for Each Survey Month, with Bootstrapped 95% CLs (Dotted Lines)**

67. The overall mean relative density of harbour porpoise, estimated from data pooled across all transects and all months for the 24 month survey period, with bootstrapping, was 0.152 animals per km$^2$ (95% CLs = 0.084, 0.224; CV = 1.367). The maximal mean relative density estimates for respective temporal divisions were:

- monthly: 0.577 animals/km$^2$ (95% CLs = 0.320, 0.854; CV = 0.098) (July);
- seasonal: 0.382 animals/km$^2$ (95% CLs = 0.212, 0.566; CV = 0.602) (summer); and
- bio-season: 0.277 animals/km$^2$ (95% CLs = 0.154, 0.410; CV = 0.848) ('summer').

### Design based approach: absolute densities

68. Relative density estimates of harbour porpoise can be corrected for availability bias using published correction factors based on the proportion of time individuals are likely to be at or near the surface and available for detection. For example, availability bias was estimated based on a tagging study in the Baltic/North Sea which looked at the proportion of time that harbour porpoise spent surfacing or in the top 0 m to 2 m (Teilmann *et al.*, 2013). Notably, in this study Teilmann *et al.* (2013) found no significant difference in diving behaviour between geographic areas or in relation to the size of the animals, although there was a significant seasonal difference in diving behaviour. The correction factor which gave the lowest estimate of availability (i.e. most conservative) was 42.5%, based on winter months, when surfacing time was found to be lower than in other seasons (Teilmann *et al.*, 2013).

69. Similarly, fine scale movements of harbour porpoise in the Danish North Sea were investigated by van Beest *et al.* (2018). GPS and dive recorders (V-tags) were used to record the diving behaviour of tagged individuals and the study estimated a mean dive duration of 53 s (min = 10.1 s, max = 250.0 s) and a mean surfacing time of 39 s (min = 2 s, max = 309 s). Using the mean values, the availability bias was calculated as 42.4% (mean surfacing time as a proportion of the mean surfacing time plus mean dive time) which is almost identical to the value estimated by Teilmann *et al.* (2013).

70. Using the most conservative correction factor (0.425), the mean absolute density estimate across all transects and all monthly surveys for the 24 month survey period, with bootstrapping, was estimated as 0.357 animals per km$^2$ (95% CLs = 0.200, 0.510; CV = 1.367). The maximal absolute density estimate in respective temporal divisions was:

- monthly: 1.357 animals/km$^2$ (95% CLs = 0.761, 1.939; CV = 0.098) (July);
- seasonal: 0.900 animals/km$^2$ (95% CLs = 0.505, 1.286; CV = 0.602) (summer); and
- bio-season: 0.651 animals/km$^2$ (95% CLs = 0.365, 0.931; CV = 0.848) ('summer').

71. Temporal patterns in monthly harbour porpoise density are identical to those presented in paragraphs 65 to 67 for relative densities, so to avoid duplication these have not been plotted here. Mean estimates of absolute density for harbour porpoise across monthly, seasonal, bio-season and annual scales are summarised in Table 3.7.

**Table 3.7: Summary of Mean Absolute Density of Harbour Porpoise, Aggregated Across Monthly, Seasonal, Bio-Season and Annual Scales**

| Temporal Division | Mean Absolute Abundance | Mean Absolute Density (Animals/km$^2$) | Lower 95% CL | Upper 95% CL | CV |
|---|---|---|---|---|---|
| **Monthly** | | | | | |
| January | - | - | - | - | - |
| February | 528 | 0.233 | 0.131 | 0.333 | 1.224 |
| March | 94 | 0.041 | 0.023 | 0.059 | 0.349 |
| April | 1,684 | 0.744 | 0.417 | 1.062 | 0.745 |
| May | 983 | 0.434 | 0.243 | 0.620 | 1.043 |
| June | 2,320 | 1.024 | 0.574 | 1.463 | 0.412 |
| July | 3,074 | 1.357 | 0.761 | 1.939 | 0.098 |
| August | 720 | 0.318 | 0.178 | 0.454 | 1.184 |
| September | 71 | 0.031 | 0.017 | 0.045 | 0.467 |
| October | 24 | 0.010 | 0.006 | 0.015 | 1.414 |
| November | 107 | 0.047 | 0.026 | 0.067 | 1.103 |
| December | 95 | 0.042 | 0.023 | 0.060 | 0.711 |
| **Meteorological season** | | | | | |
| Winter | 208 | 0.092 | 0.051 | 0.131 | 1.853 |
| Spring | 920 | 0.406 | 0.228 | 0.581 | 1.105 |
| Summer | 2,038 | 0.900 | 0.505 | 1.286 | 0.602 |
| Autumn | 67 | 0.030 | 0.017 | 0.042 | 1.014 |
| **Bio-season** | | | | | |
| 'Winter' | 141 | 0.062 | 0.035 | 0.089 | 2.819 |
| 'Summer' | 1,475 | 0.651 | 0.365 | 0.931 | 0.848 |
| **Yearly** | | | | | |
| Annual | 808 | 0.357 | 0.200 | 0.510 | 1.367 |

### Model based approach

72. Harbour porpoise were only present in sufficient numbers for robust modelling when divided by bio-season, and when considered across the whole year. Abundance varied across bio-seasons, with higher densities in the aerial survey area observed during the 'summer' bio-season (April to September, inclusive). Estimates of relative density (plus 95% CLs) are presented in Table 3.8, and estimates of absolute density are presented in Table 3.9.

**Table 3.8: Modelled Relative Density of Harbour Porpoise, with 95% CLs and CV. Relative Abundance is Calculated as Mean Density Scaled up to the Total Aerial Survey Area**

| | Mean modelled relative abundance | Mean modelled relative density (animals/km$^2$) | Lower 95% CL | Upper 95% CL | CV |
|---|---|---|---|---|---|
| 'Winter' | 62 | 0.027 | 0.013 | 0.052 | 0.540 |
| 'Summer' | 624 | 0.275 | 0.043 | 0.389 | 0.422 |
| Annual | 342 | 0.151 | 0.107 | 0.205 | 0.362 |

**Table 3.9: Modelled Absolute Density of Harbour Porpoise, Corrected for Availability Bias, with 95% CLs and CV. Abundance is Calculated as Density Scaled up to the Total Aerial Survey Area**

| | Mean modelled absolute abundance | Mean modelled absolute density (animals/km$^2$) | Lower 95% CL | Upper 95% CL | CV |
|---|---|---|---|---|---|
| 'Winter' | 146 | 0.064 | 0.030 | 0.121 | 0.540 |
| 'Summer' | 1,468 | 0.648 | 0.102 | 0.916 | 0.422 |
| Annual | 804 | 0.355 | 0.252 | 0.482 | 0.362 |

73. Seasonal relative density maps for harbour porpoise distribution are shown in Figure 3.15, illustrating estimates of mean predicted densities for each bio-season alongside estimates of the lower and upper 95% CLs. The mean modelled relative density across the 24-month survey period was 0.151 (95% CLs = 0.107, 0.205; CV = 0.362) and the corrected (absolute) density for this same period was 0.355 (95% CLs = 0.252, 0.482; CV = 0.362).

74. Spatial distribution during the 'Winter' bio-season appears to be concentrated in two locations in the south and west of the Array marine mammal study area, and density is broadly lower than during the 'summer' bio-season. Spatial distribution is also less concentrated during the 'summer' bio-season, and spread more evenly across the Array marine mammal study area. When considered across the whole 24 month DAS campaign, spatial distribution is greater at the east and north of the Array marine mammal study area.

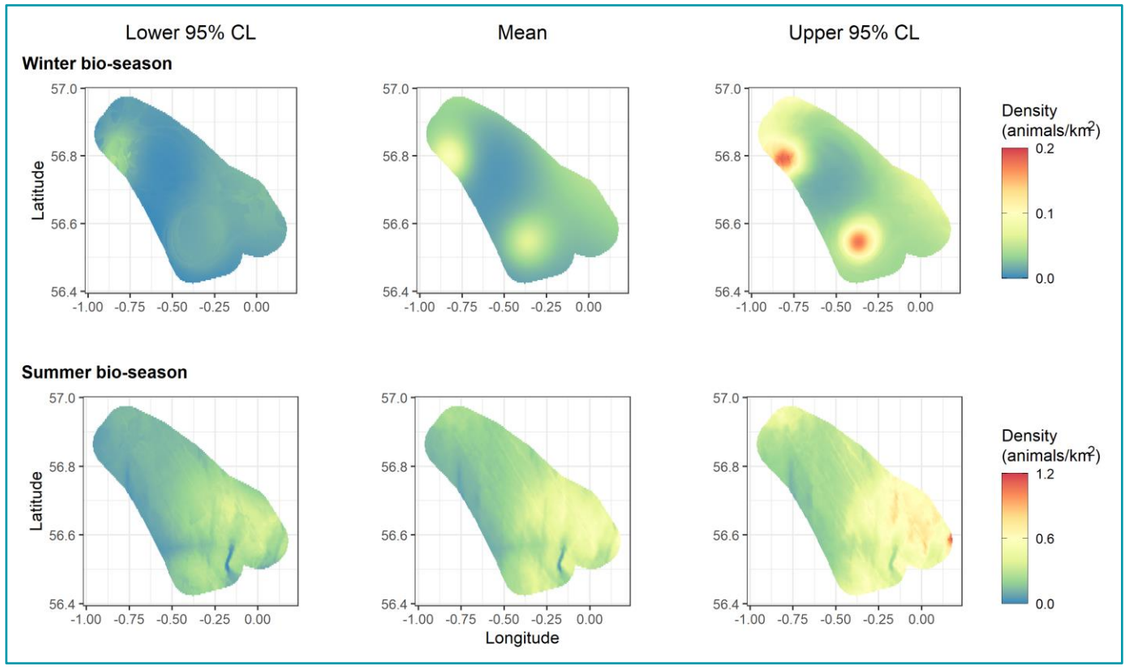


**Figure 3.15: Predicted Mean Relative Density of Harbour Porpoise, with 95% CLs for the 'Winter' (Top) and 'Summer' (Bottom) Bio-Seasons. Note that Colour Scales for the Two Bio-Seasons are Different to Accommodate the Differences in Seasonal Abundance**

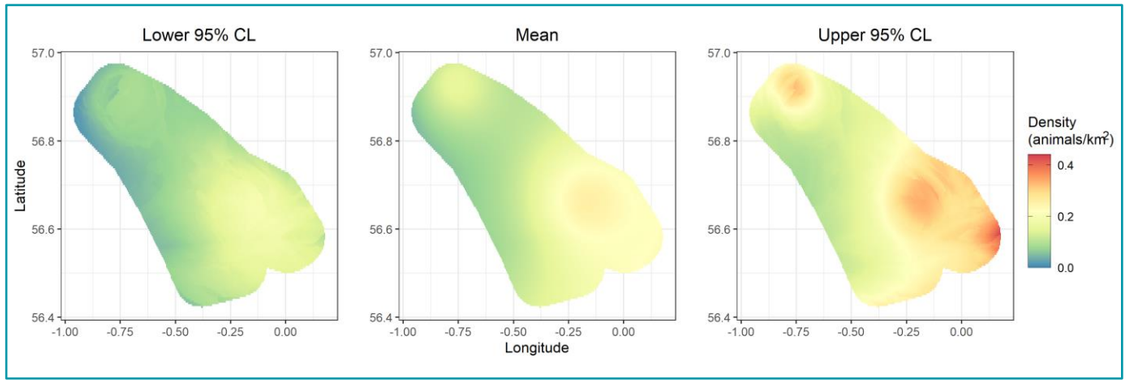


**Figure 3.16: Overall Predicted Mean Relative Density of Harbour Porpoise, with 95% CLs, Across the Aerial Survey Area for the Full 24-Month Survey Period**

### 3.5.2. WHITE-BEAKED DOLPHIN

Design based approach: relative densities

75. Alongside estimates of monthly, seasonal and annual means calculated directly from observations, bootstrapped estimates of mean relative density for white-beaked dolphin were obtained and used to calculate 95% CLs across these temporal scales. Table 3.10 presents a summary of the aggregated mean relative densities and Figure 3.17 illustrates the simulated mean relative densities resulting from the bootstrapping process.

**Table 3.10: Summary of Mean Relative Density of White-Beaked Dolphin, Aggregated Across Monthly, Seasonal and Annual Scales. Note that Missing Monthly Values are a Result of 'Zero Counts' in Respective Months, Across the 24-Month Survey Period**

| Temporal division | Mean relative abundance | Mean relative density (animals/km²) | Lower 95% CL | Upper 95% CL | CV |
|---|---|---|---|---|---|
| **Monthly** | | | | | |
| January | - | - | - | - | - |
| February | 30 | 0.013 | 0.004 | 0.024 | 1.414 |
| March | - | - | - | - | - |
| April | 10 | 0.004 | 0.001 | 0.008 | 1.414 |
| May | 20 | 0.009 | 0.003 | 0.016 | 1.414 |
| June | - | - | - | - | - |
| July | 60 | 0.026 | 0.008 | 0.047 | 1.414 |
| August | 11 | 0.004 | 0.001 | 0.008 | 1.414 |
| September | 20 | 0.009 | 0.003 | 0.016 | 0.703 |
| October | - | - | - | - | - |
| November | - | - | - | - | - |
| December | - | - | - | - | - |
| **Meteorological season** | | | | | |
| Winter | 10 | 0.004 | 0.001 | 0.008 | 2.449 |
| Spring | 10 | 0.004 | 0.001 | 0.008 | 1.672 |
| Summer | 24 | 0.010 | 0.003 | 0.018 | 2.057 |
| Autumn | 7 | 0.003 | 0.001 | 0.005 | 1.814 |
| **Yearly** | | | | | |
| Annual | 13 | 0.006 | 0.002 | 0.010 | 2.216 |

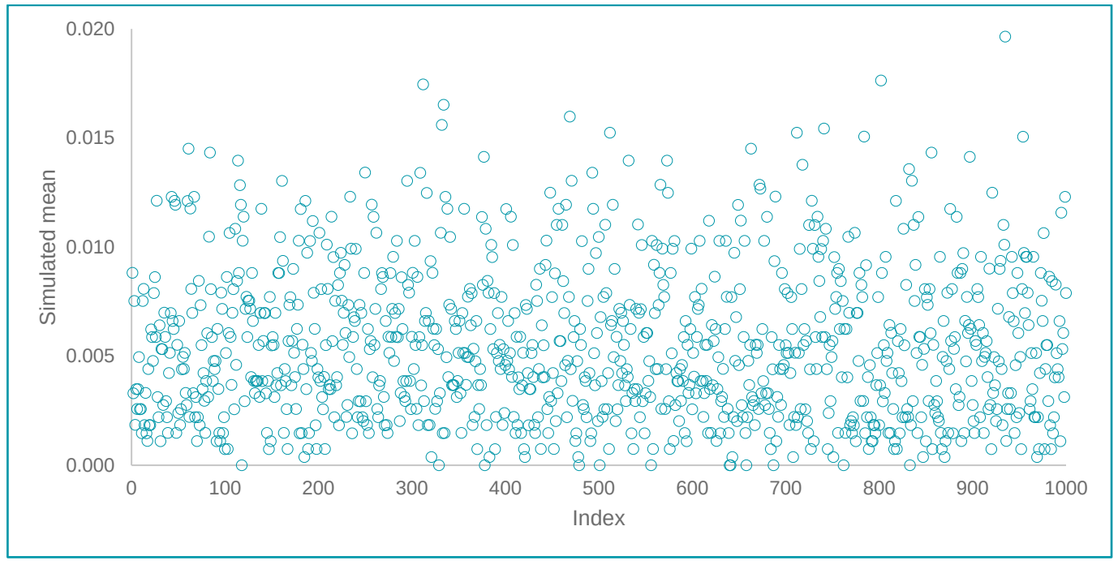


**Figure 3.17: Bootstrapped (n = 1,000) Simulation of Mean Relative Density Estimates of White-Beaked Dolphin**

76. White-beaked dolphin were sighted during seven of the 24 surveys, which included just two surveys in the second year. An overall mean of 0.006 animals per km² (95% CLs = 0.002, 0.010; CV = 2.216) was estimated. Peak densities were recorded during July 2021 when 12 animals were sighted (in groups of two to six), equivalent to a relative density of 0.053 (95% CLs = 0.016, 0.095) animals per km² (Figure 3.18).

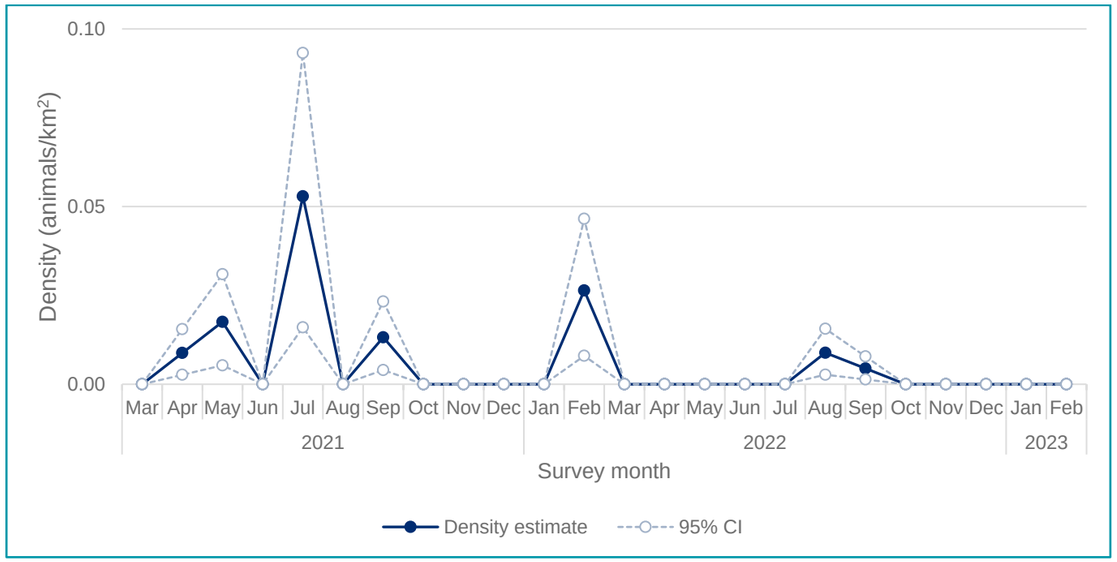


**Figure 3.18: Estimated Relative Density of White-Beaked Dolphin Over the Aerial Survey Area (Solid Line) for Each Survey Month with Bootstrapped 95% CLs (Dotted Lines)**

77. The maximal relative density estimates for respective temporal divisions were:

- monthly: 0.026 animals/km$^2$ (95% CLs = 0.008, 0.047; CV = 1.414) (July); and
- seasonal: 0.010 animals/km$^2$ (95% CLs = 0.003, 0.018; CV = 2.057) (summer).

78. Given the inconsistent temporal distribution of white-beaked dolphin within the aerial survey area, and the occurrence of the species in only two surveys during the second year of the 24 month survey period, the relative densities presented above should be interpreted with caution.

### Design based approach: absolute densities

79. There is limited information on diving and surfacing times of white-beaked dolphin and consequently many studies report relative density estimates only (refer to Paxton *et al.*, 2016). A bio-logging study of two individual free-ranging white-beaked dolphins in Iceland found that, on average, animals spent 18% of time close to the surface (0 m to 2 m depth) and 82% of the time diving (Rasmussen *et al.*, 2013). Therefore, based on these data, the correction factor to account for availability bias would be 0.18.

80. The mean absolute density estimate across all transects and all monthly surveys for the 24 month survey period, with bootstrapping, was estimated as 0.036 animals per km$^2$ (95% CLs = 0.011, 0.064; CV = 2.251). The maximal absolute density estimate in respective temporal divisions was:

- monthly: 0.147 animals/km$^2$ (95% CLs = 0.054, 0.260; CV = 1.414) (July); and
- seasonal: 0.057 animals/km$^2$ (95% CLs = 0.021, 0.101; CV = 2.057) (summer).

81. Temporal patterns in monthly white-beaked dolphin absolute density are identical to those presented in paragraphs 75 to 78 for relative densities, and to avoid duplication these have not been plotted here. Mean estimates of absolute density for white-beaked dolphin across monthly, seasonal and annual scales are summarised in Table 3.11.

**Table 3.11: Summary of Mean Absolute Density of White-Beaked Dolphin, Aggregated Across Monthly, Seasonal and Annual Scales, and Corrected for Availability Bias. Note that Missing Values are a Result of 'Zero Counts' in Respective Months, Across the 24-Month Survey Period**

| Temporal division | Mean absolute abundance | Mean absolute density (animals/km$^2$) | Lower 95% CL | Upper 95% CL | CV |
|---|---|---|---|---|---|
| **Monthly** | | | | | |
| January | - | - | - | - | - |
| February | 167 | 0.073 | 0.027 | 0.130 | 1.414 |
| March | - | - | - | - | - |
| April | 56 | 0.024 | 0.009 | 0.043 | 1.414 |
| May | 111 | 0.049 | 0.018 | 0.086 | 1.414 |
| June | - | - | - | - | - |
| July | 333 | 0.147 | 0.054 | 0.260 | 1.414 |
| August | 56 | 0.025 | 0.009 | 0.044 | 1.414 |
| September | 111 | 0.049 | 0.018 | 0.087 | 0.703 |
| October | - | - | - | - | - |
| November | - | - | - | - | - |
| December | - | - | - | - | - |
| **Meteorological season** | | | | | |
| Winter | 56 | 0.024 | 0.009 | 0.043 | 2.449 |
| Spring | 56 | 0.024 | 0.009 | 0.043 | 1.672 |
| Summer | 130 | 0.057 | 0.021 | 0.101 | 2.057 |
| Autumn | 37 | 0.016 | 0.006 | 0.029 | 1.814 |
| **Yearly** | | | | | |
| Annual | 70 | 0.031 | 0.011 | 0.054 | 2.216 |

### Model based approach

82. White-beaked dolphin were not observed in sufficient numbers for robust modelling, and as such their density in the aerial survey area can only be estimated via design based methods.

### 3.5.3. GREY SEAL

Design-based approach: relative densities

83. Mean estimates of relative density for grey seal were estimated across monthly, seasonal, bio-season and annual scales (Table 3.12), with 95% CLs obtained via bootstrapping (1,000 simulations) (Wessa, 2019). Figure 3.19 illustrates the bootstrapped mean relative densities.

**Table 3.12: Summary of Mean Relative Density of Grey Seal, Aggregated Across Monthly, Seasonal, Bio-Season and Annual Scales. Note that Missing Monthly Values are a Result of 'Zero Counts' in Respective Months, Across the 24-Month Survey Period**

| Temporal division | Mean relative abundance | Mean relative density (animals/km²) | Lower 95% CL | Upper 95% CL | CV |
|---|---|---|---|---|---|
| **Monthly** | | | | | |
| January | 10 | 0.004 | 0.002 | 0.007 | 1.414 |
| February | 25 | 0.011 | 0.005 | 0.018 | 0.844 |
| March | - | - | - | - | - |
| April | 16 | 0.007 | 0.003 | 0.011 | 0.475 |
| May | 15 | 0.007 | 0.003 | 0.011 | 0.472 |
| June | 20 | 0.009 | 0.004 | 0.014 | 1.414 |
| July | - | - | - | - | - |
| August | - | - | - | - | - |
| September | - | - | - | - | - |
| October | - | - | - | - | - |
| November | 5 | 0.002 | 0.001 | 0.004 | 1.414 |
| December | - | - | - | - | - |
| **Meteorological season** | | | | | |
| Winter | 12 | 0.005 | 0.003 | 0.008 | 1.371 |
| Spring | 10 | 0.004 | 0.002 | 0.007 | 0.895 |
| Summer | 7 | 0.003 | 0.001 | 0.005 | 2.449 |
| Autumn | 2 | 0.001 | 0.000 | 0.001 | 2.449 |
| **Bio-season** | | | | | |
| 'Breeding' | 1 | 0.000 | 0.000 | 0.001 | 3.162 |
| 'Non-breeding' | 13 | 0.005 | 0.003 | 0.009 | 1.172 |
| **Yearly** | | | | | |
| Annual | 8 | 0.003 | 0.002 | 0.005 | 1.632 |

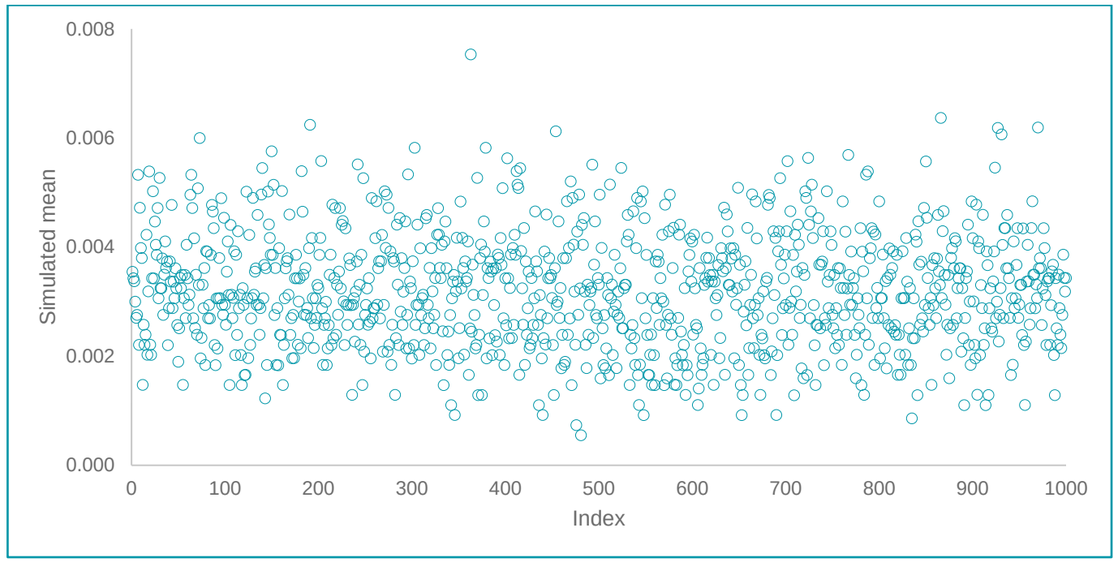


**Figure 3.19: Bootstrapped (n = 1,000) Simulation of Mean Relative Density Estimates of Grey Seal**

84. Grey seal were sighted within the aerial survey area during nine months of the 24 month survey period, and of these, three months (February, April and May) contained sightings in both survey years. Peaks in presence occurred in June 2021 and February 2022 (relative density = 0.018; 95% CLs = 0.009, 0.029) when four individuals were sighted, with an equivalent abundance across the Array marine mammal study area of approximately 40 animals when corrected for survey effort.

85. The overall mean relative density of grey seal, estimated from data pooled across all transects and all months for the 24 month survey period, with bootstrapping, was 0.003 animals per km² (95% CLs = 0.002, 0.005; CV = 1.632). The maximal relative density estimates for respective temporal divisions were:

- monthly: 0.011 animals/km² (95% CLs = 0.005, 0.018; CV = 0.844) (February);
- seasonal: 0.005 animals/km² (95% CLs = 0.003, 0.008; CV = 1.371) (winter); and
- bio-season: 0.005 animals/km² (95% CLs = 0.003, 0.009; CV = 1.172) ('non-breeding').

86. Temporal variability in grey seal observations in the aerial survey area is illustrated in Figure 3.20, although given the scarcity of sightings, plotting these data on a $\log_{10}$ scale did not provide further clarity, and this has not been presented here.

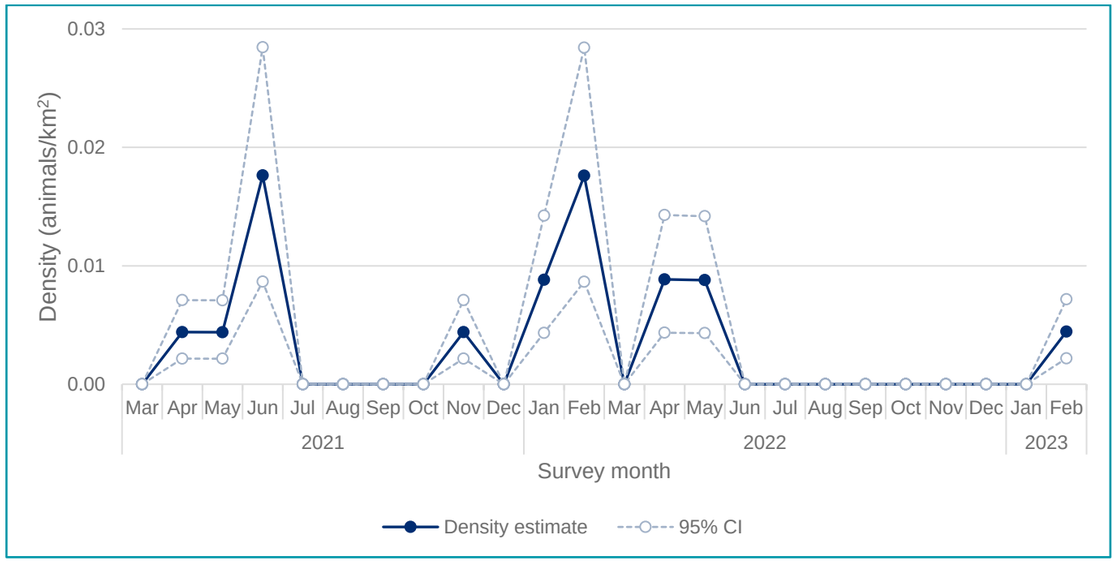


**Figure 3.20:** **Estimated Relative Density of Grey Seal Across the Aerial Survey Area (Solid Line) for Each Survey Month, with Bootstrapped 95% CLs (Dotted Lines)**

Design based approach: absolute densities

87. The densities shown in Figure 3.20 are relative values and do not account for availability bias during aerial surveys. A tracking study of three male grey seals in the Farne Islands (north-east England) found that the average proportion of time animals were submerged as they travelled was 84.3%, which was slightly lower during short duration trips (83.4%) (Thompson *et al.*, 1991). It therefore follows that the average proportion of time a travelling grey seal would be available for detection ranges between 15.7% and 16.6%.

88. Similarly, telemetry data from tags deployed by the Sea Mammal Research Unit (SMRU) on grey seals in the North Sea recorded 1,551 grey seal dives. These data were analysed for the Hornsea Three Offshore Wind Farm (to estimate detection probability) and showed that 60% of surfacing periods were between 15 s and 45 s, with an average of 40 s (Ørsted, 2018). Recorded grey seal dive durations varied between 20 s and 496 s with an average of 216 s (Ørsted, 2018). The average values reported from the telemetry data were used to estimate the proportion of time that grey seals were surfacing compared to diving to give an indication of the availability bias for the site-specific aerial surveys. The estimated availability was calculated as 15.6% (Ørsted, 2018) and was therefore similar to the figures cited by Thompson *et al.* (1991).

89. As with harbour porpoise, it was assumed that all animals on (or near) the surface were available for detection during the aerial surveys (i.e. no perception bias) (section 2.5.3). The correction factor for availability bias, based on the telemetry studies described in paragraph 88, was 15.6% as the most conservative estimate. Thus, estimates for absolute density for grey seal across the aerial survey area (Table 3.13) ranged between 0.028 and 0.113 animals per km$^2$ and mean corrected density across all transects and all seasons was 0.021 animals per km$^2$ (95% CLs = 0.009, 0.034; CV = 1.632).

90. The maximal absolute density estimate in respective temporal divisions was:

- monthly: 0.071 animals/km2 (95% CLs = 0.031, 0.115; CV = 0.844) (February);
- seasonal: 0.033 animals/km2 (95% CLs = 0.014, 0.054; CV = 1.371) (winter); and
- bio-season: 0.034 animals/km$^2$ (95% CLs = 0.015, 0.056; CV = 1.172) (‘non-breeding’).

**Table 3.13:** **Summary of Mean Absolute Density of Grey Seal, Aggregated Across Monthly, Seasonal, Bio-Season and Annual Scales, and Corrected for Availability Bias. Note that Missing Values Result from ‘Zero Counts’ in Respective Months, Across the 24-Month Survey Period**

| Temporal division | Mean absolute abundance | Mean absolute density (animals/km$^2$) | Lower 95% CL | Upper 95% CL | CV |
|---|---|---|---|---|---|
| **Monthly** | | | | | |
| January | 64 | 0.028 | 0.012 | 0.046 | 1.414 |
| February | 161 | 0.071 | 0.031 | 0.115 | 0.844 |
| March | - | - | - | - | - |
| April | 97 | 0.042 | 0.019 | 0.069 | 0.475 |
| May | 96 | 0.042 | 0.018 | 0.069 | 0.472 |
| June | 128 | 0.056 | 0.025 | 0.092 | 1.414 |
| July | - | - | - | - | - |
| August | - | - | - | - | - |
| September | - | - | - | - | - |
| October | - | - | - | - | - |
| November | 32 | 0.014 | 0.006 | 0.023 | 1.414 |
| December | - | - | - | - | - |
| **Meteorological season** | | | | | |
| Winter | 75 | 0.033 | 0.014 | 0.054 | 1.371 |
| Spring | 64 | 0.028 | 0.012 | 0.046 | 0.895 |
| Summer | 43 | 0.019 | 0.008 | 0.031 | 2.449 |
| Autumn | 11 | 0.005 | 0.002 | 0.008 | 2.449 |
| **Bio-season** | | | | | |
| ‘Breeding’ | 7 | 0.003 | 0.001 | 0.005 | 3.162 |
| ‘Non-breeding’ | 78 | 0.034 | 0.015 | 0.056 | 1.172 |
| **Yearly** | | | | | |
| Annual | 48 | 0.021 | 0.009 | 0.034 | 1.632 |

Model based approach

91. Grey seal were not observed in sufficient numbers for robust modelling to be undertaken, and as such their density in the aerial survey area can only be estimated via design based methods.

# 4. SUMMARY

92. This annex provides a summary of estimated marine mammal distribution recorded during the 24-month DAS campaign across the Array marine mammal study area, encompassing the site boundary plus 8 km buffer.

93. A mean coverage of 10% of the aerial survey area was processed by HiDef across the DAS campaign, and this target was met in 16 out of 24 surveys (Table 3.1). The mean area processed for design based analyses was 10.01% (SE: ± 0.04%), and the mean area included in model-based analysis (after removal of erroneous transects) was 10.00% (SE: ± 0.01%). The removed transects contained no observations of marine mammals, there was no reduction in the number of individuals included in the model-based analyses. The small shortfalls in survey coverage (maximum 0.074% deviation) were not considered to reduce the accuracy of the analyses, and in the event that all surveys had achieved the 10% target, the subsequent estimates would be expected to fall within the inherent range of uncertainty accounted for in the reported 95% CLs.

94. The division of the year into two bio-seasons for harbour porpoise, based upon bimodal patterns of spatial distribution ("winter" and "summer") is an approach intended to address the difficulties in implementing criteria for designating Special Areas of Conservation (Heinänen and Skov, 2015). Similarly for grey seal, broad-scale seasonal patterns of density have been determined based upon potential changes in distribution between the breeding season (defined as September to December for this region (Marine Scotland, 2020; SCOS, 2020)) and the non-breeding season (January to August). For white-beaked dolphin, meteorological season was used as a means to determine broader-scale temporal patterns in density. This approach has also been taken forward to the EIA.

95. Harbour porpoise accounted for the highest number of individuals identified to species level (n = 825, based on raw count data) across the aerial survey area, and were recorded in all survey months except for January 2022, October 2022 and January 2023.

96. White-beaked dolphin was the second most abundant species (n = 30) and were sighted in only seven months across the 24 month survey period. Eighteen grey seal were identified across nine months, and 47 unidentified seal species were observed across 12 survey months.

97. Twelve minke whale, three common dolphin and two harbour seal were also identified, and no bottlenose dolphin were sighted across all 24 surveys.

98. For harbour porpoise, white-beaked dolphin and grey seal, relative density estimates were corrected for availability bias to give absolute densities, calculated with correction factors derived from studies of these species' diving behaviour. These correction factors give an indication of the average proportion of time that individuals of a species may be on, or near, the surface and available for detection.

99. The limitations of using availability bias estimates from published studies are recognised (e.g. potentially subject to geographic, seasonal, diurnal, and individual animal variation) and therefore absolute densities are considered to be approximations only but have been employed in an effort to obtain more precautionary estimates of marine mammal abundance.

100. Peaks in harbour porpoise abundance were estimated to occur in the Summer (n = 2,038) and the 'summer' bio-season (n = 1,475). In the latter, for which modelling was possible to undertake, an estimated density of 0.651 animals/km$^2$ from the design-based approach, and a predicted density of 0.648 animals/km$^2$ from the model-based approach (Table 4.1).

**Table 4.1: Summary Table of Mean Estimated Absolute Abundance and Density (Corrected for Availability Bias) for Annual and Seasonal Divisions for Design-Based Estimates. For Harbour Porpoise, Model-Based Estimates are Shown in Parentheses**

| Temporal division | Mean absolute abundance | Mean absolute density (animals/km$^2$) | Lower 95% CL | Upper 95% CL | CV |
|---|---|---|---|---|---|
| **Harbour porpoise** | | | | | |
| 'Winter' bio-season | 141 (146) | 0.062 (0.064) | 0.035 (0.030) | 0.089 (0.121) | 2.819 (0.540) |
| 'Summer' bio-season | 1,475 (1,468) | 0.651 (0.648) | 0.365 (0.102) | 0.931 (0.916) | 0.848 (0.422) |
| Annual estimate | 808 (804) | 0.357 (0.355) | 0.200 (0.252) | 0.510 (0.482) | 1.367 (0.362) |
| **White-beaked dolphin** | | | | | |
| Winter meteorological season | 56 | 0.024 | 0.009 | 0.043 | 2.449 |
| Spring meteorological season | 56 | 0.024 | 0.009 | 0.043 | 1.672 |
| Summer meteorological season | 130 | 0.057 | 0.021 | 0.101 | 2.057 |
| Autumn meteorological season | 37 | 0.016 | 0.006 | 0.029 | 1.814 |
| Annual estimate | 70 | 0.031 | 0.011 | 0.054 | 2.216 |
| **Grey seal** | | | | | |
| 'Breeding' bio-season | 7 | 0.003 | 0.001 | 0.005 | 3.162 |
| 'Non-breeding' bio-season | 78 | 0.034 | 0.015 | 0.056 | 1.172 |
| Annual estimate | 48 | 0.021 | 0.009 | 0.034 | 1.632 |

101. There was no clear spatial pattern in distribution for any of the species, although seasonal concentrations of harbour porpoise were predicted by the MRSea analysis in the western portion of the aerial survey area (Figure 3.15).

102. These data suggest seasonality in the occurrence of marine mammals within the aerial survey area. However, interpretation of seasonal differences should be treated with caution due to potential confounding effects of environmental variables during the aerial surveys and the limitations of the 'snap-shot' nature of aerial data.

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