Appendix 11.4: Offshore Ornithology MRSea Technical Report

Array EIA Report

2024

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1. INTRODUCTION

1. RPS was commissioned by Ossian Offshore Wind Farm Limited (Ossian OWFL) (hereafter referred to as the Applicant) to model the spatial distribution and numbers of bird species within the Array and a 8 km buffer zone (Figure 3.1). The modelled data presented within this report will provide the baseline spatial distribution and abundance and density estimates of the most abundant seabird species observed.

2. NatureScot published online guidance documents in early 2023 (NatureScot, 2023a; NatureScot, 2023b). Detailing the appropriate methodology to follow when carrying out ornithological impact assessments for offshore wind farms.

3. Within Guidance Note 2: Guidance to Support Offshore Wind Applications: Advice for Marine Ornithology Baseline Characterisation Surveys and Reporting (NatureScot, 2023b), it is stated that baseline site characterisation should include detailed spatial data for all species present. NatureScot advise that the spatial modelling package MRSea (Marine Renewables Strategic Environmental Assessment; originally developed by Scott-Hayward *et al.,* 2013) should be used to derive density estimates for species observed in sufficient numbers during site specific Digital Aerial Surveys (DAS). MRSea is a statistical package that has been developed by the Centre for Research into Ecological and Environmental Modelling (CREEM) to model spatial distribution and abundances of animal populations and the potential impact of human infrastructural developments on these populations (Scott-Hayward *et al.*, 2013).

4. The guidance note states that it is unlikely that MRSea will run successfully when the number of data points (the number of each species observed) is less than ten across a surface area over multiple months. Based on RPS' experience using MRSea, models typically ran into issues, with outputs being unrealistic, when species with less than 30 observations per month were included in the analysis when modelling across large spatial scales. For example, when conducting previous MRSea modelling work for an offshore wind farm across a similar spatial scale only 13 gannets were recorded in December, with design-based abundances estimating that 102 birds were present. MRSea models however estimated that over 1 million birds were present. Additionally, when carrying out modelling for puffin, only 21 puffin were recorded in February with design-based estimates predicting that 190 puffin were in the area. MRSea estimates however predicted that 790 birds were in the area). Furness (2015) states that these species are typically absent during winter months (due to migrating to wintering grounds overseas with most gannet not returning to the UK until mid-January to February, and puffin in March), therefore making these estimates unrealistic.

5. Within temporal or spatial Species Distribution Models (SDMs), model uncertainty is inevitable, with prediction error occurring when species have scattered distributions (Hanspach *et al.,* 2010) and hence can result in poor predictive power (Hernandes *et al.,* 2006). The results found in previous analysis conducted by RPS resulted from low sample size, meaning that the MRSea model (a form of SDM) ran into performance issues due to the large spatial area containing too few records, with data being sufficiently sparse relative to the complexity of the model. It is typically recommended that when SDM performance is low, that these models are removed from the analysis (Tessarolo *et al.,* 2021). It was therefore concluded that for this analysis, only species that had more than 30 data points across multiple months were modelled as this produced biologically realistic results and increased model accuracy due to the larger sample size (Hernandes *et al.,* 2006).

6. The statistical modelling was executed in the R package MRSea using the 24 months of high resolution digital aerial video survey data collected by HiDef (refer to volume 3, appendix 11.1, annex D).

7. The results from MRSea are summarised for each month and compared to design-based estimates, with confidence intervals, to validate the numbers produced. The outputs for the selected species are also presented in density surface distribution maps for each of the 24 survey months (section 4).

2. STUDY AREA

8. The Array is located approximately 80 km off the north-east coast of Scotland, covering an area of approximately 858 km^2, with Ossian DAS carried out over the Array plus a surrounding 8 km buffer amounting to an overall survey area of 2,264 km^2 (Figure 3.1). The MRSea analysis is carried out on this Array plus 8km buffer (hereafter referred to as the MRSea study area).

3. BASELINE

3.1. DIGITAL AERIAL SURVEY DATA

9. DAS were flown by HiDef between March 2021 and February 2023 inclusive using a transect survey design of 24 tracks spaced 2 km apart and oriented approximately perpendicular to the coastline (to gather information across the environmental gradient) (Figure 3.2). The survey area comprised of the Array plus an 8 km buffer. This survey design has been agreed upon with Marine Directorate - Licensing Operations Team (MD-LOT). Surveys were undertaken using aircraft flying at approximately 550 m above sea level. The aircraft was equipped with four HiDef Gen 2.5 cameras, with each camera sampling a 125 m wide transect, capturing video at a resolution of 2 cm Ground Sampling Distance (GSD). Generally, image analysis of two out of four cameras was sufficient (achieving 250 m coverage along each transect) to reach the desired coverage of 10% (Figure 3.3), in line with studies suggesting baseline surveys require collection of a minimum of 10% coverage (German Federal Maritime and Hydrographic Agency (BSH), 2013). Raw data from the two additional cameras were retained for future image analysis if considered necessary. Full detail of DAS methodology is provided in volume 3, appendix 11.1, annex D.

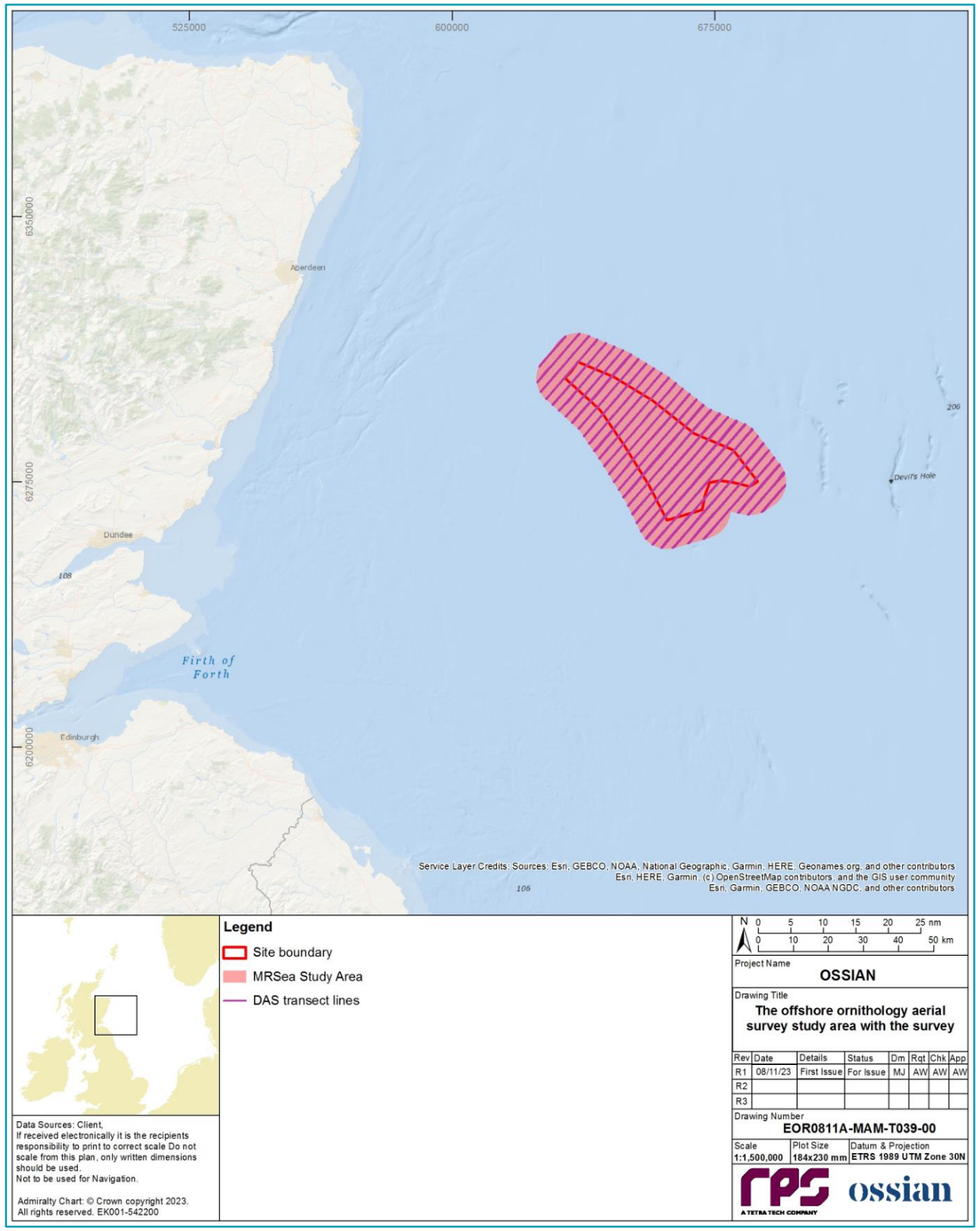

Figure 3.1: MRSea Study Area (Array plus 8 km Buffer)

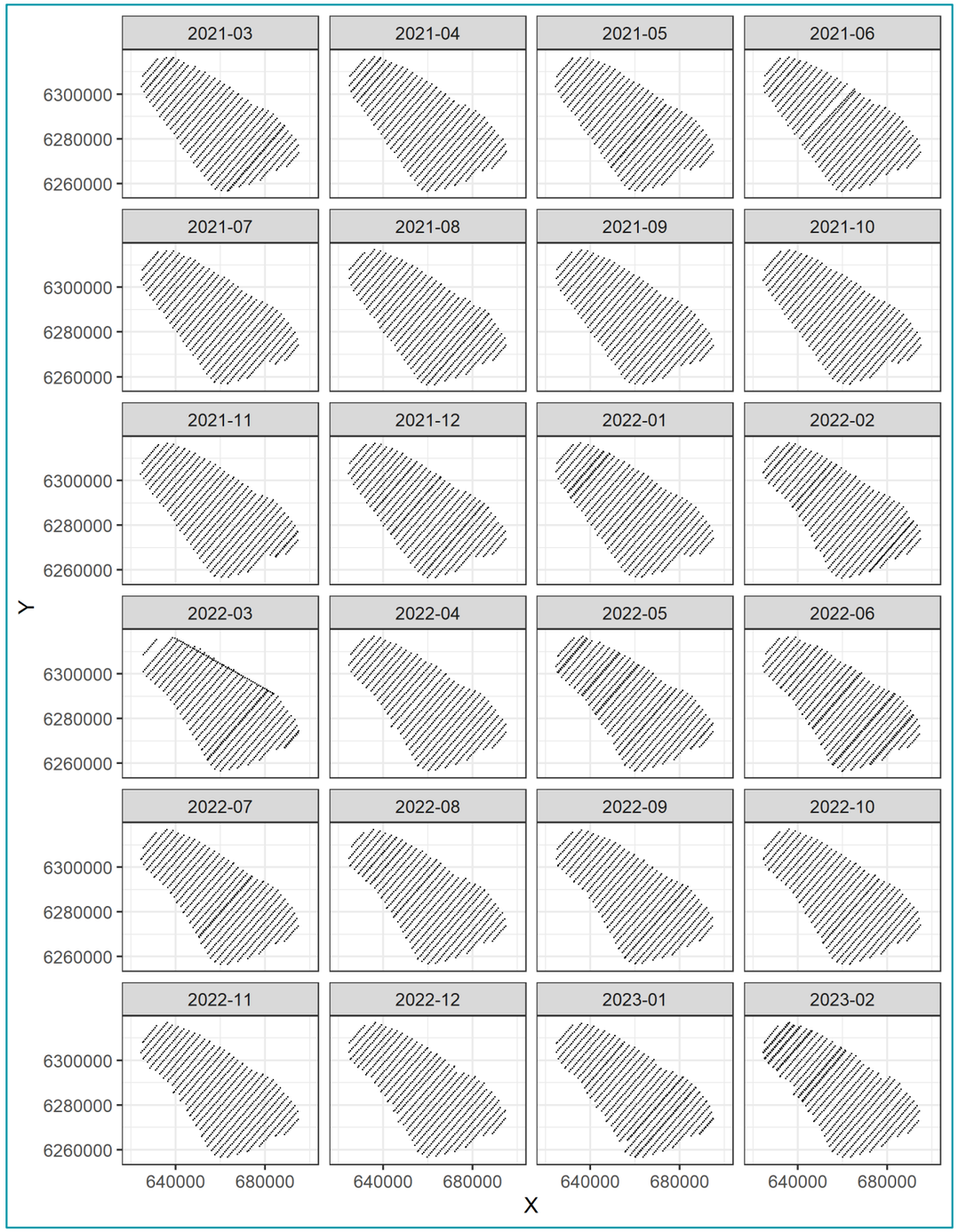

Figure 3.2: Transects Coverage in Each Survey Month

10. Due to poor weather conditions, surveys were not flown in May 2021 and February 2022. These months were compensated by an additional aerial survey in early June 2021 (for May 2021 missed survey) and early March 2022 (for February missed survey) to represent the missed previous month of the same year.

11. With a desired coverage of 10% and a total area of approximately 2,264 km^2 (Array plus 8 km buffer), the area covered per month should approximate to 226 km^2. This coverage was achieved (Figure 3.3), with an average area surveyed of 227.54 km (10.05%; Figure 3.2). Coverage was slightly higher for the February 2022 survey due to three transects having been reflown at the end of the survey. Since both effort and the count were repeated, this did not affect the abundance estimates.

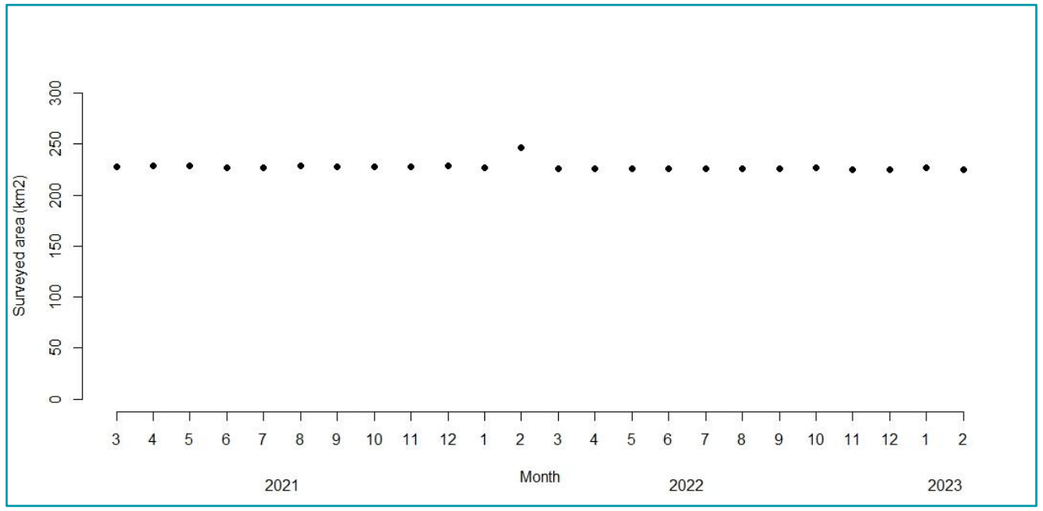

Figure 3.3: Area (km^2) Surveyed by Month (DAS)

Table 3.1: Percentage Covered by Month (DAS)

Month	Area Covered (km^2)	Percentage Coverage
March 2021	227.68	10.06%
April 2021	228.43	10.09%
May 2021 (June 2021 survey 1)	228.18	10.08%
June 2021 (June 2021 survey 2)	226.52	10.01%
July 2021	226.62	10.01%
August 2021	228.09	10.07%
September 2021	227.68	10.06%
October 2021	228.13	10.08%
November 2021	227.52	10.05%
December 2021	228.43	10.09%
January 2022	226.38	10.00%
February 2022 (March 2022 survey 1)	246.93	10.91%
March 2022 (March 2022 survey 2)	225.49	9.96%
April 2022	225.93	9.98%
May 2022	225.92	9.98%
June 2022	225.97	9.98%
July 2022	226.29	9.99%
August 2022	225.75	9.97%
September 2022	225.86	9.98%
October 2022	226.99	10.03%
November 2022	225.61	9.96%
December 2022	225.15	9.94%
January 2023	226.39	10.00%
February 2023	225.05	9.94%

3.2. DATA PRE-PROCESSING

3.2.1. PRE-PROCESSING BY HIDEF

12. Raw bird observations were extracted by expert ornithologists at HiDef using a strict Quality Assurance protocol, where 20% of the footage collected was subject to internal review by other members of the team within HiDef. To avoid double counting across cameras, each camera had a line drawn across the middle of the video image to signify the transect width of 125 m. Any bird that had crossed this line was not counted, as it might appear in the footage of another one of the four cameras. Bird observations were identified to the lowest possible taxonomic level. Each bird observation was georeferenced and had a behaviour assigned to it where possible (e.g. flying, sitting). Some birds were unidentifiable to species level, and these were assigned the next lowest taxonomic level (e.g. large auk, shearwater species). Note that these unidentified individuals could not be apportioned to any species before the MRSea analysis, as this would require arbitrary assignments of species labels to unknown individuals in georeferenced locations. This would dilute the distribution maps of known species, especially if different species forage in different locations. To control for unknown birds, apportioning correction factors were calculated first, to then allow for the monthly MRSea estimates to be corrected to account for unidentified birds recorded during surveys. This is explained in more detail in section 3.2.2.

3.2.2. PRE-PROCESSING BY RPS

13. RPS quality checked the data to make sure that the analysis was run on the best possible data. The data was subject to the following checks:

- data were imported into R Studio using the function “st_read” from the “sf” package (R Core Team, 2023) and 7,180 rows of entirely missing data were excluded.
- latitude and longitude values were checked to ensure no incorrect coordinates were included in the analysis.
- no incorrect coordinates were identified; and
- visual checks were carried out to ensure that the end times/locations differed between cameras. If this was not the case these were excluded from the analysis on the grounds that they appeared to have partial data for some of the cameras and duplication may therefore have been present. However, no duplication occurred.

14. An identifier field “Transect ID”, required for MRSea, was created by using a combination of the variables “year”, “month” and the first part of the “Reel_Ref” (the contents of “Reel_Ref” before the “.” Separator) as provided within the monthly Ossian DAS files. Bird records from individual cameras within transects were identified by using the combination of Transect ID and the camera number. Based on these definitions the raw data contain a total of 815 transects.

15. After the full quality check, 73,715 records were taken forward for analysis.

Observed data

16. Ossian DAS data contained 69,262 records of birds, 1,153 of non-avian animals, 36 of man-made objects and 11 boats. 3,253 records related to start and end times of transects. RPS focussed only on birds for the purposes of this report (Table 3.2). During the quality check, 572 birds were recorded as deceased and were removed from further analysis (Table 3.3). Bird records taken forward to MRSea modelling are outlined in Figure 3.2.

Table 3.2: Bird Records Used Within MRSea Modelling Following Pre-Processing

Species	Number of Individuals	Percentage of Total (%)
Identified birds	**65,852**	**95.87**
Guillemot *Uria aalge*	49,364	74.96
Kittiwake *Rissa tridactyla*	4,788	7.27
Gannet *Morus bassanus*	2,995	4.55
Fulmar *Fulmarus glacialis*	2,741	4.16
Razorbill *Alca torda*	2,719	4.13
Puffin *Fratercula arctica*	2,649	4.02
Arctic tern *Sterna paradisaea*	245	0.37
Great black-backed gull *Larus marinus*	136	0.21
Common tern *Sterna hirundo*	91	0.14
Herring gull *Larus argentatus*	48	0.07
Common gull *Larus canus*	28	0.04
Manx shearwater *Puffinus puffinus*	19	0.03
Little auk *Alle alle*	8	0.012
Great skua *Stercorarius skua*	6	<0.01%
Whimbrel *Numenius phaeopus*	5	<0.01%
Red-throated diver *Gavia stellata*	3	<0.01%
Little gull *Hydrocoloeus minutus*	2	<0.01%
Lesser black-backed gull *Larus fuscus*	2	<0.01%
Sandwich tern *Thalasseus sandvicensis*	1	<0.01%
Wigeon *Mareca penelope*	1	<0.01%
Unidentified birds	**2,838**	**4.13**
Large auk	1,286	45.31
Auk species	1,190	41.93
Arctic/common tern	181	6.38
Fulmar/gull species	88	3.10
Auk/small gull	47	1.66
Small gull species	14	0.49
Auk/shearwater species	9	0.317
Gull species	9	0.317
Tern/small gull	6	0.211
Large gull species	4	0.141
Small bird	2	0.070
Large auk/diver species	1	0.035
Tern species	1	0.035

Table 3.3: Recorded Deceased Birds During Each Survey Month (Number of Individuals)

Month	Gannet	Kittiwake	Guillemot	Razorbill	Auk/small gull	Auk species	Fulmar/gull species	Large auk	Large gull	Small bird	Small gull	Tern/ Small Gull
March 2021	0	0	0	0	0	0	0	0	0	0	0	0
April 2021	0	0	0	0	0	0	0	0	0	0	0	0
May 2021	0	0	0	0	1	0	0	0	0	0	0	0
June 2021	0	0	0	0	0	0	0	0	0	0	0	0
July 2021	1	0	0	0	0	0	0	0	0	0	0	0
August 2021	0	0	0	0	0	0	0	0	0	1	0	0
September 2021	1	0	0	0	0	0	0	0	0	0	0	0
October 2021	0	0	0	0	0	0	0	0	0	0	0	0
November 2021	0	0	0	0	0	0	0	0	0	0	0	0
December 2021	0	0	0	0	0	0	0	0	0	0	0	0
January 2022	0	0	0	0	0	0	0	0	0	0	0	0
February 2022	0	0	0	0	0	0	0	0	0	0	0	0
March 2022	0	0	0	0	0	0	0	0	0	0	0	0
April 2022	2	0	0	0	0	0	0	0	0	0	0	0
May 2022	0	1	0	0	0	0	1	0	0	0	0	0
June 2022	15	0	0	1	1	0	1	0	1	0	0	0
July 2022	238	2	13	0	5	0	1	239	0	0	0	0
August 2022	6	2	5	0	2	1	0	26	0	0	1	1
September 2022	0	0	0	0	0	0	0	0	0	0	0	0
October 2022	3	0	0	0	0	0	0	0	0	0	0	0
November 2022	0	0	0	0	0	0	0	0	0	0	0	0
December 2022	0	0	0	0	0	0	0	0	0	0	0	0
January 2023	0	0	0	0	0	0	0	0	0	0	0	0
February 2023	0	0	0	0	0	0	0	0	0	0	0	0

17. In order to run a spatial model in MRSea, it requires observations to be aggregated in segments of a certain size. Based on previous analyses (Butler, 2019) it was determined that 1 km segments gave compromise between maintaining an appropriately high spatial resolution and generating a smooth surface that did not overfit to small-scale variations in the data (Figure 3.4).

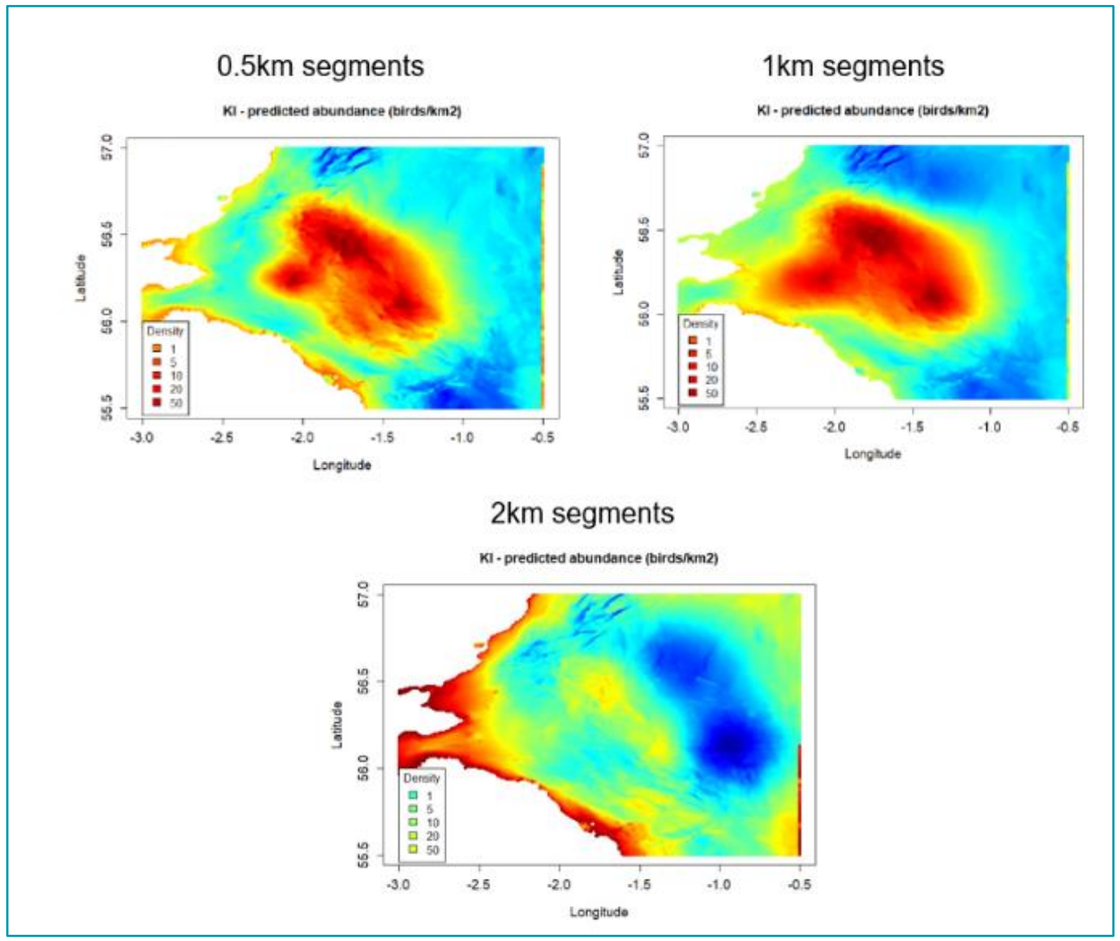

Figure 3.4: Comparison of the Effect of Different Choices of Segment Length (Butler, 2019)

18. Because HiDef used continuous transects, it was assumed that the entire area between the start and the end of the transect was covered by the survey. The area covered could thus be defined as the length of a straight line drawn from the start to the end of the transect multiplied by the width of the area covered for each camera (125 m). The geodesic distance in kilometres between the start and the end of the transect was calculated using "distGeo" function in the R package geosphere (Hijmans, 2021). Transects were then split up into segments of equal length. To get segments of equal length, the number of segments on a transect was defined by rounding up the geodesic distance of the transect to next available integer. For example, if a transect spanned 27.2 km, the number of segments was defined as 28. Segment length would in this case be defined as 27.2km / 28 segments = 0.9714 km. With each camera covering an area of 125 m, segment area covered in square kilometres was then defined as:

$$number\ of\ cameras\ \times transect\ width\ \times segment\ length = \ total\ area\ for\ each\ segment$$

$$2 \times 0.125\ \times 1 = 0.25$$

Environmental parameters

19. Choosing which variables to include within the model was an important part of the modelling process. Typically, including too few variables makes for poor predictions whereas including too many variables make predictions highly uncertain. Environmental parameters within the analysis were chosen based on RPS experience running similar MRSea models across similar spatial scales. The initial environmental parameters chosen were;

- Water depth - Bathymetry data downloaded from the GEBCO 2023 Grid at a 30 arc second resolution (GEBCO, 2023)
- Latitude and Longitude – taken from HiDef Aerial Survey data
- Segment area – taken from HiDef Aerial Survey data
- Month – taken from HiDef Aerial Survey data
- Distance to coast – calculated in R (R Core Team, 2023).

20. After doing a collinearity check among the chosen predictor variables, "distance to coast" were excluded from further analysis based on having Variance Inflation Factor (VIF) in the hundreds, where the desirable value is for VIFs to be <2.5 (Johnston *et al.*, 2018). All other environmental variables remained in the final model.

Seasonality

21. Separate MRSea models for month and species were initially considered, however this was time and computer intensive and so two models were fitted based on species biological seasons. Seasonal definitions were based on Furness (2015). These seasonal definitions were for modelling purposes only, with the model producing outputs at the monthly, not seasonal level. This was achieved by using month as an interaction term. These seasonal definitions were used as each season used for pooling needs to contain at least two months of data.

3.3. MODELLED ABUNDANCE ESTIMATES

22. MRSea is a modelling package executable in the R environment (R Core Team, 2023) based on the Generalised Additive Model (GAM), fitting spatially adaptive regression splines with Spatially Adaptive Local Smoothing Algorithm (SALSA; Walker *et al.*, 2010) through 1- and 2-dimensional data. MRSea was specifically developed to provide a robust tool for estimating the impact of infrastructure developments on animal populations. MRSea/SALSA are statistical spatial models which, in common with kernel density estimation, make an assumption that the density of birds varies smoothly over space. MRSea models also allow for additional variables to be accounted for when estimating the spatial distribution. An alternative approach is using design-based estimates, however the advantage of using MRSea over design-based approaches is threefold:

- MRSea can produce continuous spatially varying density estimates;
- MRSea can handle missing segments and transects better than design-based approaches by using a 2-dimensional SALSA (SALSA2D); and
- Other environmental covariates (e.g. bathymetric data) can be flexibly and non-linearly implemented in the model to further enhance the precision of the abundance and density estimates.

23. MRSea builds a set of models by adding and removing combinations of covariates, and selects the best fitting model to explain species abundance. To do so, MRSea goes through a two-step process that first

adds different combinations of environmental covariates and keeps those that significantly explain species abundance. For each survey, firstly a generalised linear model (GLM) was produced, modelling the bird count as a function of spatial coordinates 'x.pos' and 'y.pos', with an offset of log(area), a quasi-Poisson error distribution and a log link. This model is referred to as the "basic GLM".

24. Then, the function SALSA2D was used to fit two Complex Region Spatial Smoother (CreSS) models (based on season), again using 'bird count' as the response, 'x.pos' and 'y.pos' as the spatial coordinates, with an offset of log(area), a quasi-Poisson error distribution and a log link and the depth variable. 'Transect ID' was used as a panel identifier. The SALSA2D function trials various models and compares them using a user-specified criterion; Cross Validation (CV) was used in this instance, as this method is considered the gold standard compared to using information criteria like the Quasi-Akaike information criterion (QAIC) and Quasi-Bayesian information criterion (QBIC).

25. All bird behaviours (flying and sitting) were included in this analysis. Other behaviours (e.g. diving, feeding or landing) were excluded from analysis as it was unclear if feeding or landing behaviours could be linked to the specific categories of flying or sitting. Including these birds would lead to a misrepresentation of behaviour and potentially lead to overestimates of the number of birds flying or sitting. With regards to diving behaviours, these birds were excluded on the grounds that no bird below water was included in the analysis. This ensured that no overestimation occurred when sitting birds were corrected for availability bias. As all behaviours were modelled, an assumption is made that flying and sitting birds do not differ in their distributions within the MR Sea study area.

26. The final model for each species was used to predict the numbers and densities of birds across an environmental grid that spanned the MR Sea study area. A bootstrapping procedure present in the MR Sea package was used to estimate confidence intervals around the predictions. A parametric bootstrap resamples model coefficients, assuming a multivariate normal distribution of parameters from the best fitting 2D model. In all cases, 1,000 bootstraps were carried out. The bootstrapped predictions were used to estimate the upper and lower 95% confidence limits, and also the standard deviation and coefficient of variation of the extracted total abundance for the Area of Interest. Each grid cell in the environmental grid contained an area of 0.47 km^2, which was the smallest resolution available from the bathymetric data. Results are presented in the form of predicted density maps and monthly tables of abundance estimates for four areas:

- the Array;
- the Array plus 2 km buffer;
- the Array plus 4 km buffer; and
- the Array plus 8 km buffer.

27. To aid with model validation, example MRSea diagnostic plots for the most abundant species common guillemot in the breeding season have been provided in volume 3, appendix 11.4, annex A. These have also been provided as requested in NatureScot (2023) guidance.

28. To further validate the MRSea models, abundance estimates derived for the Array from the MRSea model outputs were compared against design-based estimates (volume 3, appendix 11.4, annex B).

3.4. APPORTIONING AND AVAILABILITY BIAS

29. The abundance estimates derived from MRSea (and the design based approach) are described as relative as they are only based on the number of visible and identified birds. However, there are sources of bias that lead to an underestimate of these numbers.

30. Firstly, some birds were not identified to species level, but to broader groups (e.g. large auk, auk species). These birds must be apportioned to relevant species to get the best estimate of the absolute number. Second, some seabird species spend considerable time underwater whilst foraging, and these birds are often not captured during DAS due to the 'snap-shot' nature of DAS. This is referred to as availability bias.

31. In summary, to obtain absolute population estimates from the DAS, the relative estimates need to be adjusted for:

- unidentified birds (apportioning analysis); and
- submerged birds (availability bias).

3.4.1. APPORTIONING UNKNOWN SPECIES TO KNOWN SPECIES

32. There was a total of 10 unidentified groups of birds that needed to be apportioned to known species (Table 3.4). Note only species relevant to MRSea have been included within this table). The known (relative) species estimates for each survey month are increased by proportionally assigning the numbers of the unknown groups of birds to each of the relevant known species. In formula form, for each unknown groups "h" that belongs to known species "i" and month "j", this additional ratio is presented as:

$$\frac{Unknown_{hj}}{\sum(Known_{ij})} = Ratio_{hj}$$

33. This approach allows each species to have a single proportional increase assigned to it for each survey month across all unapportioned groups that it belongs to. These ratios can simply be summed to calculate the total proportional increase. For example, both guillemot and razorbill numbers are increased by apportioning "auk species" and "large auk" unknown groups to them. Because guillemot and razorbill belong to the same unknown groups, their proportional increase from the apportioning analysis will be the same.

34. For example, a month with 1,200 large auks (guillemot or razorbill), 200 of which are unknown, 900 identified guillemots, and 100 identified razorbills. Applying the formula leads to a ratio of:

$$\frac{200}{900 + 100} = 0.20$$

35. Thus, both razorbill and guillemot will be increased by 0.20 (or multiplied by 1.20), which leads to an absolute estimate of 1,080 guillemots (900 × 1.20) and 120 razorbill (100 × 1.2). The 200 unknown birds have thus been apportioned to razorbill and guillemot, 80 to guillemot and 20 to razorbill.

36. If the same month had a total of 1,700 auk species. Apart from the previously mentioned 1,200 birds, it also had 300 unknown auk species (guillemot, razorbill, or puffin) and 200 puffins. Applying the formula again this leads to a ratio of:

$$\frac{300}{900 + 100 + 200} = 0.25$$

37. Following the original formula, the ratios from "large auk" and "auk species" can now be summed, leading to a proportional increase of 0.45 (0.20 × 0.25) (or multiply by 1.45) for guillemot and razorbill, and 0 + 0.25 for puffin (as puffin is not a "large auk"). This results in 900 × 1.45 = 1305 guillemots, 100 × 1.45 = 145 razorbills, and 200 × 1.25 = 250 puffins. Both "large auk" and "auk species" have now been apportioned, as 1,305 + 145 + 250 = 1,700.

Table 3.4: Unknown Species Groups Apportioning to Known Species for MRSea Analysis

Unknown species group	Apportioned to known species
Large auk	Guillemot, razorbill
Auk species	Guillemot, razorbill, puffin
Fulmar/gull species	fulmar, kittiwake, great-black backed gull, herring gull, common gull, little gull, lesser black-backed gull
Auk/small gull	Guillemot, razorbill, puffin, kittiwake, great-black backed gull, herring gull, common gull, little gull, lesser black-backed gull
Small gull species	Kittiwake, common gull, little gull
Auk/shearwater species	Guillemot, razorbill, puffin, Manx shearwater
Gull species	Kittiwake, great-black backed gull, herring gull, common gull, little gull, lesser black-backed gull
Tern/small gull	Sandwich tern, Arctic tern, kittiwake, common gull, little gull
Large gull species	Great-black backed gull, herring gull, lesser black-backed gull
Large auk/diver species	Guillemot, razorbill, red-throated diver

38. Apportioning values used to adjust MRSea outputs for each species analysed are shown in Table 3.5.

Table 3.5: Apportioning Analysis Multiplication Factors by Species

Survey	Guillemot	Razorbill	Puffin	Kittiwake	Gannet	Fulmar
March 2021	1.12	1.12	1.08	1.01	1.00	1.01
April 2021	1.05	1.05	1.02	1.00	1.00	1.00
May 2021	1.03	1.03	1.01	1.01	1.00	1.00
June 2021	1.03	1.03	1.01	1.02	1.00	1.02
July 2021	1.07	1.07	1.03	1.01	1.00	1.01
August 2021	1.05	1.05	1.02	1.03	1.00	1.03
September 2021	1.04	1.04	1.02	1.01	1.00	1.01
October 2021	1.11	1.11	1.07	1.04	1.00	1.04
November 2021	1.06	1.06	1.03	1.02	1.00	1.00
December 2021	1.09	1.09	1.04	1.07	1.00	1.04
January 2022	1.09	1.09	1.03	1.06	1.00	1.05
February 2022	1.07	1.07	1.04	1.07	1.00	1.07
March 2022	1.10	1.10	1.06	1.00	1.00	1.00
April 2022	1.03	1.03	1.02	1.00	1.00	1.00
May 2022	1.03	1.03	1.01	1.00	1.00	1.00
June 2022	1.02	1.02	1.01	1.00	1.00	1.00
July 2022	1.03	1.03	1.01	1.03	1.00	1.01
August 2022	1.03	1.03	1.01	1.02	1.00	1.00
September 22	1.07	1.07	1.07	1.03	1.00	1.03
October 2022	1.10	1.10	1.04	1.03	1.00	1.03
November 2022	1.07	1.07	1.03	1.03	1.00	1.02
December 2022	1.07	1.07	1.06	1.00	1.00	1.00
January 2023	1.11	1.11	1.08	1.00	1.00	1.00
February 2023	1.23	1.23	1.21	1.01	1.00	1.01

3.4.2. AVAILABILITY BIAS

39. There is an assumption that all seabirds, above the water, are detected during the aerial survey. However, some seabirds (e.g. auks) are not always visible as they spend time foraging beneath the water surface. To account for this, the proportion of time spent on the sea surface needs to be measured and estimates corrected accordingly (Thaxter *et al.*, 2010). This is known as availability bias, which can be accounted for by applying a correction factor based on known times spent under water. To calculate the absolute estimate from the relative estimates, the numbers of seabirds observed in the DAS are divided by the proportion of time that a bird is expected to be visible at the surface.

40. Availability bias is not known for every species, but is negligible for gulls and terns, as these species spend little time under water. For gannet, although there is no availability bias recommendation, there is good information on their foraging patterns. From the available literature (Garthe *et al.*, 2000, 2003, 2007, 2014; Grémillet *et al.*, 2006), gannet dive on average 2.71 to 4.63 times per hour spent flying, with a mean time spent under water per dive ranging from 6.0 to 10.9 seconds among studies. Therefore, gannets are likely to spend <1% of their foraging time submerged, meaning availability bias is very limited for this species. As such, it was not considered necessary to adjust the relative numbers of gannet for availability bias in this report.

41. The correction factors applied to sitting common guillemot and razorbill, were based on the proportion of time spent underwater from Thaxter *et al.* (2010) and were refined following the method recommended by Joint Nature Conservation Committee (JNCC) which excludes the percentage of birds in flight from the calculations. Proportion of time spent underwater were 23.75% and 17.4%, respectively for common

guillemot and razorbill. For puffin, a proportion of time spent underwater of 14.16% was used (Spencer, 2012).

42. Availability bias correction multiplication factors were calculated using the following formula: (Correction factor) = (1 / (1-proportion(time spent underwater)), leading to correction factors of 1.311 for guillemot, 1.211 for razorbill, and 1.165 for puffin.

43. Availability bias correction factors were only applied to estimates of abundance of birds sitting on the sea surface and were not applied to seabirds in flight. Availability bias is corrected for by applying the above correction factors to sitting auks (excluding other behaviours) using the following formula:

$$(Absolute\ birds) = (Relative\ birds \times \frac{pr(sitting)}{pr(visible)}) + (Relative\ birds * (1 - pr(sitting))).$$

44. For example, if it was estimated from the visible data (relative number) that there were 1,000 guillemots in an area, 900 of which were sitting, it would result in an adjusted absolute number of 1,280:

$$(1{,}000 \times 0.90 \times 1.311) + \left(1{,}000 \times (1 - 0.90)\right) = 1{,}180 + 100 = 1{,}280$$

3.4.1. DESIGN-BASED AND MODEL-BASED ESTIMATES OF FLYING AND SITTING BIRDS

45. For MRSea estimates, the monthly mean densities of flying and sitting birds have been generated from the bird behaviour observed during the monthly Ossian DAS of the MRSea study area. This has been done by apportioning the MRSea estimates for all behaviour to birds flying and sitting based on the ratios recorded of birds sitting and birds in flight.

4. RESULTS

46. In this section, results of the MRSea modelling are presented in abundance estimates and spatial distribution maps generated by MRSea.

47. The MRSea maps depict relative densities and are therefore not corrected for apportioning and availability bias. In contrast, the numbers in the tables have been corrected according to the methods described in section 3.4.1 and 3.4.2, and therefore provide the best estimates of the absolute numbers and densities of birds.

48. These are compared to design based estimates for the Array plus 8 km buffer for comparative purposes and to aid in validating the MRSea outputs. For each species, data are presented in four tables with each table presenting data covering four scenarios:

- Array;
- Array plus 2 km buffer;
- Array plus 4 km buffer; and
- Array plus 8 km buffer.

4.1. GUILLEMOT

4.1.1. DIGITAL AERIAL SURVEY DATA RESULTS

49. Guillemot was the most abundant bird species recorded as part of the DAS covering the Array, with a total raw count of 49,364 across all surveys in the whole survey area consisting of the Array plus a 8 km buffer. A total of 11,196 of the guillemot observations were within the Array. Guillemots are one of the less-airborne species, with an average percentage of flying birds of 3.78% (Table 4.1).

Table 4.1: Guillemot: Behaviours in Birds Observed During DAS

Survey	Diving	Feeding	Flying	Landing	Sitting	Taking Off	Total	% Flying
March 2021	0	0	78	0	619	0	697	11.19
April 2021	1	0	206	0	3,590	1	3,798	5.43
May 2021	0	0	30	0	5,618	1	5,649	0.53
June 2021	0	0	0	0	2,453	0	2,453	0.00
July 2021	8	0	35	0	4,382	0	4,425	0.79
August 2021	3	0	10	0	1,091	0	1,104	0.91
September 2021	0	0	2	0	2,403	0	2,405	0.08
October 2021	0	0	3	0	399	0	402	0.75
November 2021	0	0	1	0	730	0	731	0.14
December 2021	0	0	14	0	671	0	685	2.04
January 2022	0	0	3	0	648	0	651	0.46
February 2022	0	0	8	0	986	0	994	0.80
March 2022	0	0	116	0	583	0	699	16.60
April 2022	1	0	43	0	1,627	0	1,671	2.57
May 2022	0	0	52	0	950	0	1,002	5.19
June 2022	0	0	0	0	663	0	663	0.00
July 2022	10	0	5	0	6,858	0	6873	0.07
August 2022	44	0	0	0	11,844	1	11,889	0.00
September 2022	1	0	3	0	140	0	144	2.08
October 2022	0	0	23	0	467	0	490	4.69

Survey	Diving	Feeding	Flying	Landing	Sitting	Taking Off	Total	% Flying
November 2022	0	0	48	4	1,243	0	1,295	3.71
December 2022	0	0	19	0	274	0	293	6.48
January 2023	0	0	7	0	151	0	158	4.43
February 2023	0	0	42	0	151	0	193	21.76

4.1.2. MRSEA ABUNDANCE AND DENSITY ESTIMATES: GUILLEMOT

50. Guillemot distribution was heterogeneous depending on year and month. Whilst birds were widespread across the MRSea study area during breeding months, the birds were predominantly observed outside the Array during non-breeding months (Figure 4.1).

51. Within the Array plus 2 km buffer, the highest density estimates of guillemot in the first year of surveys were recorded in April 2021, with 13,494 individuals (95% range; 7,554 to 22,012) estimated to be within the Array plus 2 km. During the second year of surveys, the highest estimated numbers of birds were recorded in August 2022 with 85,380 individuals (95% range: 61,649 to 116,940; Figure 4.3). This time of the year coincides with the beginning and end of the guillemot breeding season, with peak abundances observed likely relating to pre- and post-breeding migration. Thereafter, abundance declined into the non-breeding season in both years suggesting that the area was of lower importance for common guillemot during the non-breeding season.

52. MRSea estimates for each behaviour (sitting, flying, and all behaviour) are given for each of the four boundary scenarios as outlined in paragraph 48 in Figure 4.2 to Figure 4.5). Estimates are provided with range given in brackets.

Table 4.2: Guillemot in Array Area: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**Standard Deviation (SD)**	**Coefficient of Variance (CV)**
March 2021	1,320 (1,032-1,765)	116 (91-155)	1,204 (941-1610)	1.54 (1.2-2.06)	0.13 (0.11-0.18)	1.4 (1.1-1.88)	187	14.17
April 2021	8,995 (5,208-14,391)	375 (217-600)	8,620 (4,991-13,791)	10.48 (6.07-16.77)	0.44 (0.25-0.7)	10.04 (5.81-16.07)	2343	26.04
May 2021	7,488 (5,492-10,148)	29 (21-39)	7,460 (5,471-10,109)	8.72 (6.4-11.82)	0.03 (0.02-0.05)	8.69 (6.37-11.78)	1188	15.86
June 2021	1,556 (10,46-2,230)	0 (0-0)	1,556 (1,046-2,230)	1.81 (1.22-2.6)	0 (0-0)	1.81 (1.22-2.6)	302	19.41
July 2021	6,972 (5,506-8,433)	43 (34-52)	6,930 (5,472-8,381)	8.12 (6.41-9.82)	0.05 (0.04-0.06)	8.07 (6.37-9.76)	747	10.71
August 2021	1,884 (1,400-2,435)	13 (10-17)	1,871 (1,390-2,418)	2.19 (1.63-2.84)	0.02 (0.01-0.02)	2.18 (1.62-2.82)	264	14.02
September 2021	8,717 (4,439-16,921)	7 (3-13)	8,711 (4,436-16,908)	10.16 (5.17-19.71)	0.01 (0-0.02)	10.15 (5.17-19.7)	3184	36.53
October 2021	1,344 (1,149-1,578)	7 (6-8)	1,337 (1,143-1,570)	1.57 (1.34-1.84)	0.01 (0.01-0.01)	1.56 (1.33-1.83)	109	8.14
November 2021	2,393 (1,914-2,898)	2 (1-2)	2,391 (1,913-2,896)	2.79 (2.23-3.38)	0 (0-0)	2.79 (2.23-3.37)	251	10.49
December 2021	1,819 (1,494-2,182)	28 (23-33)	1,791 (1,471-2,149)	2.12 (1.74-2.54)	0.03 (0.03-0.04)	2.09 (1.71-2.5)	176	9.65
January 2022	1,400 (1,150-1,721)	5 (4-7)	1,395 (1,146-1,715)	1.63 (1.34-2.01)	0.01 (0.01-0.01)	1.62 (1.33-2)	146	10.41
February 2022	5,355 (4,731-6,170)	33 (29-38)	5,322 (4,702-6,132)	6.24 (5.51-7.19)	0.04 (0.03-0.04)	6.2 (5.48-7.14)	367	6.85
March 2022	2,859 (2,154-3,568)	377 (284-470)	2,482 (1,870-3,098)	3.33 (2.51-4.16)	0.44 (0.33-0.55)	2.89 (2.18-3.61)	361	12.62
April 2022	5,610 (4,448-7,030)	112 (89-140)	5,498 (4,360-6,890)	6.54 (5.18-8.19)	0.13 (0.1-0.16)	6.41 (5.08-8.03)	659	11.74
May 2022	3,784 (2,872-5,089)	152 (115-204)	3,632 (2,757-4,885)	4.41 (3.35-5.93)	0.18 (0.13-0.24)	4.23 (3.21-5.69)	566	14.95
June 2022	2,179 (1,786-2,670)	0 (0-0)	2,179 (1,786-2,670)	2.54 (2.08-3.11)	0 (0-0)	2.54 (2.08-3.11)	226	10.36
July 2022	27,959 (24,567-31,832)	21 (19-24)	27,937 (24,549-31,808)	32.57 (28.62-37.08)	0.02 (0.02-0.03)	32.55 (28.6-37.06)	1853	6.63
August 2022	61,775 (45,200-83,170)	0 (0-0)	61,775 (45,200-83,170)	71.97 (52.66-96.89)	0 (0-0)	71.97 (52.66-96.89)	9,686	15.68
September 2022	774 (618-957)	12 (10-15)	762 (608-941)	0.9 (0.72-1.11)	0.01 (0.01-0.02)	0.89 (0.71-1.1)	86	11.15
October 2022	2,324 (1,899-2,887)	84 (69-105)	2,240 (1,830-2,782)	2.71 (2.21-3.36)	0.1 (0.08-0.12)	2.61 (2.13-3.24)	252	10.84

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**Standard Deviation (SD)**	**Coefficient of Variance (CV)**
November 2022	7,525 (6,504-8,484)	214 (185-242)	7,311 (6,319-8,243)	8.77 (7.58-9.88)	0.25 (0.22-0.28)	8.52 (7.36-9.6)	505	6.71
December 2022	1,570 (1,260-1,894)	79 (63-95)	1,491 (1,197-1,799)	1.83 (1.47-2.21)	0.09 (0.07-0.11)	1.74 (1.39-2.1)	162	10.29
January 2023	829 (689-982)	28 (23-33)	801 (666-949)	0.97 (0.8-1.14)	0.03 (0.03-0.04)	0.93 (0.78-1.1)	75	9.00
February 2023	996 (840-1,182)	175 (147-207)	821 (693-975)	1.16 (0.98-1.38)	0.2 (0.17-0.24)	0.96 (0.81-1.14)	87	8.76

Table 4.3: Guillemot in Array Area plus 2 km: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	1,818 (1,385-2,519)	160 (122-221)	1,659 (1,264-2,298)	1.55 (1.18-2.15)	0.14 (0.1-0.19)	1.41 (1.08-1.96)	289	15.9
April 2021	13,494 (7,554-22,012)	563 (315-918)	12,931 (7,238-21,094)	11.5 (6.44-18.76)	0.48 (0.27-0.78)	11.02 (6.17-17.98)	3,688	27.33
May 2021	11,270 (8,271-15,131)	43 (32-58)	11,227 (8,240-15,073)	9.61 (7.05-12.9)	0.04 (0.03-0.05)	9.57 (7.02-12.85)	1,750	15.53
June 2021	2,471 (1,670-35,44)	0 (0-0)	2,471 (1,670-3,544)	2.11 (1.42-3.02)	0 (0-0)	2.11 (1.42-3.02)	478	19.34
July 2021	9,711 (7,649-11,787)	59 (47-72)	9,651 (7,602-11,715)	8.28 (6.52-10.05)	0.05 (0.04-0.06)	8.23 (6.48-9.99)	1,056	10.87
August 2021	2,649 (1,951-3,462)	18 (13-24)	2,631 (1,937-3,438)	2.26 (1.66-2.95)	0.02 (0.01-0.02)	2.24 (1.65-2.93)	385	14.55
September 2021	11,301 (5,913-21,218)	9 (5-16)	11,292 (5,909-21201)	9.63 (5.04-18.09)	0.01 (0-0.01)	9.63 (5.04-18.07)	3,904	34.55
October 2021	1,835 (1,568-2,157)	10 (8-12)	1,826 (1,559-2,145)	1.56 (1.34-1.84)	0.01 (0.01-0.01)	1.56 (1.33-1.83)	150	8.19
November 2021	3,232 (2,574-3,934)	2 (2-3)	3,229 (2,572-3,931)	2.75 (2.19-3.35)	0 (0-0)	2.75 (2.19-3.35)	347	10.73
December 2021	2,488 (2,032-3,000)	38 (31-46)	2,450 (2,000-2,954)	2.12 (1.73-2.56)	0.03 (0.03-0.04)	2.09 (1.71-2.52)	247	9.93
January 2022	1,995 (1,654-2,430)	8 (6-9)	1,988 (1,648-2,420)	1.7 (1.41-2.07)	0.01 (0.01-0.01)	1.69 (1.4-2.06)	198	9.92
February 2022	7,245 (6,361-8,376)	44 (39-51)	7,201 (6,322-8,325)	6.18 (5.42-7.14)	0.04 (0.03-0.04)	6.14 (5.39-7.1)	514	7.1
March 2022	4,184 (3,170-5,220)	552 (418-688)	3,633 (2,752-4,532)	3.57 (2.7-4.45)	0.47 (0.36-0.59)	3.1 (2.35-3.86)	523	12.5

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
April 2022	8,466 (6,692-10,687)	169 (134-213)	8,297 (6,558-10,474)	7.22 (5.7-9.11)	0.14 (0.11-0.18)	7.07 (5.59-8.93)	1,019	12.04
May 2022	6,051 (4,576-8,084)	243 (184-325)	5,808 (4,392-7,760)	5.16 (3.9-6.89)	0.21 (0.16-0.28)	4.95 (3.74-6.61)	895	14.79
June 2022	3,349 (2,758-4,098)	0 (0-0)	3,349 (2,758-4,098)	2.85 (2.35-3.49)	0 (0-0)	2.85 (2.35-3.49)	342	10.2
July 2022	40,999 (35,828-46,874)	31 (27-36)	40,968 (35,801-46,838)	34.95 (30.54-39.95)	0.03 (0.02-0.03)	34.92 (30.52-39.92)	2,818	6.87
August 2022	85,380 (61,649-11,6940)	0 (0-0)	85,380 (61,649-116,940)	72.78 (52.55-99.68)	0 (0-0)	72.78 (52.55-99.68)	14,105	16.52
September 2022	1,057 (843-1,307)	17 (14-21)	1,040 (829-1,286)	0.9 (0.72-1.11)	0.01 (0.01-0.02)	0.89 (0.71-1.1)	118	11.19
October 2022	3,276 (2,666-4,075)	119 (97-148)	3,157 (2,569-3,927)	2.79 (2.27-3.47)	0.1 (0.08-0.13)	2.69 (2.19-3.35)	359	10.97
November 2022	10,079 (8,648-11,441)	287 (246-326)	9,792 (8,402-11,115)	8.59 (7.37-9.75)	0.24 (0.21-0.28)	8.35 (7.16-9.47)	712	7.07
December 2022	2,144 (1,718-2,590)	108 (87-130)	2,036 (1,631-2,459)	1.83 (1.46-2.21)	0.09 (0.07-0.11)	1.74 (1.39-2.1)	222	10.37
January 2023	1,132 (938-1,340)	38 (32-45)	1,094 (906-1,294)	0.97 (0.8-1.14)	0.03 (0.03-0.04)	0.93 (0.77-1.1)	103	9.06
February 2023	1,818 (1,385-2,519)	160 (122-221)	1,659 (1,264-2,298)	1.55 (1.18-2.15)	0.14 (0.1-0.19)	1.41 (1.08-1.96)	289	15.9

Table 4.4: Guillemot in Array Area plus 4 km: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	2,453 (1,804-3,535)	215 (158-310)	2,237 (1646-3225)	1.62 (1.19-2.34)	0.14 (0.1-0.21)	1.48 (1.09-2.13)	442	18
April 2021	18,207 (10,009-30,016)	760 (418-1252)	17,448 (9592-28764)	12.04 (6.62-19.84)	0.5 (0.28-0.83)	11.53 (6.34-19.02)	5,104	28.03
May 2021	16,195 (11,879-21,580)	62 (45-82)	16,133 (11,833-21,497)	10.71 (7.85-14.27)	0.04 (0.03-0.05)	10.67 (7.82-14.21)	2,475	15.28
June 2021	3,784 (2,528-5,438)	0 (0-0)	3,784 (2,528-54,38)	2.5 (1.67-3.59)	0 (0-0)	2.5 (1.67-3.59)	742	19.62
July 2021	12,788 (10,033-15,584)	78 (61-95)	12,710 (9,971-15,489)	8.45 (6.63-10.3)	0.05 (0.04-0.06)	8.4 (6.59-10.24)	1,416	11.07
August 2021	3,631 (2,614-4,919)	25 (18-34)	3,606 (2,596-4,885)	2.4 (1.73-3.25)	0.02 (0.01-0.02)	2.38 (1.72-3.23)	588	16.2
September 2021	13,888 (7,424-25,450)	11 (6-19)	13,878 (7,418-25,431)	9.18 (4.91-16.82)	0.01 (0-0.01)	9.17 (4.9-16.81)	4,599	33.11

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
October 2021	2,370 (2,014-2,812)	13 (11-15)	2,357 (2,003-2,797)	1.57 (1.33-1.86)	0.01 (0.01-0.01)	1.56 (1.32-1.85)	204	8.59
November 2021	4,142 (3,275-5,113)	3 (2-4)	4,139 (3,272-5,109)	2.74 (2.16-3.38)	0 (0-0)	2.74 (2.16-3.38)	469	11.32
December 2021	3,199 (2,587-3,940)	49 (40-60)	3,150 (2,547-3,880)	2.12 (1.71-2.6)	0.03 (0.03-0.04)	2.08 (1.68-2.56)	345	10.79
January 2022	2,670 (2,215-3,257)	10 (8-12)	2,660 (2,207-3,245)	1.77 (1.46-2.15)	0.01 (0.01-0.01)	1.76 (1.46-2.15)	266	9.96
February 2022	9,254 (8,067-10,796)	57 (49-66)	9,197 (8,018-10,730)	6.12 (5.33-7.14)	0.04 (0.03-0.04)	6.08 (5.3-7.09)	696	7.52
March 2022	5,744 (4,358-7,183)	757 (574-947)	4,987 (3,784-6,236)	3.8 (2.88-4.75)	0.5 (0.38-0.63)	3.3 (2.5-4.12)	721	12.54
April 2022	12,282 (9,649-15,583)	245 (193-311)	12,037 (9,456-15,272)	8.12 (6.38-10.3)	0.16 (0.13-0.21)	7.96 (6.25-10.1)	1,514	12.33
May 2022	8,624 (6,407-11,647)	346 (257-468)	8,277 (6,150-11,179)	5.7 (4.24-7.7)	0.23 (0.17-0.31)	5.47 (4.07-7.39)	1,337	15.5
June 2022	4,830 (3,982-5,910)	0 (0-0)	4,830 (3,982-5,910)	3.19 (2.63-3.91)	0 (0-0)	3.19 (2.63-3.91)	492	10.18
July 2022	56,864 (49,338-65,411)	43 (38-50)	56,821 (49,301-65,361)	37.59 (32.62-43.24)	0.03 (0.02-0.03)	37.56 (32.59-43.21)	4,100	7.21
August 2022	111,736 (79,490-155,596)	0 (0-0)	111,736 (79,490-155,596)	73.87 (52.55-102.86)	0 (0-0)	73.87 (52.55-102.86)	19,415	17.38
September 2022	1,365 (1,084-1,704)	22 (17-27)	1,343 (1,066-1,677)	0.9 (0.72-1.13)	0.01 (0.01-0.02)	0.89 (0.7-1.11)	158	11.59
October 2022	4,372 (3,526-5,522)	158 (128-200)	4,213 (3,398-5,322)	2.89 (2.33-3.65)	0.1 (0.08-0.13)	2.79 (2.25-3.52)	509	11.65
November 2022	12,775 (10,855-14,754)	364 (309-420)	12,411 (10,546-14,334)	8.45 (7.18-9.75)	0.24 (0.2-0.28)	8.21 (6.97-9.48)	995	7.79
December 2022	2,768 (2,208-3,374)	139 (111-170)	2,629 (2,097-3,204)	1.83 (1.46-2.23)	0.09 (0.07-0.11)	1.74 (1.39-2.12)	297	10.74
January 2023	1,462 (1,204-1,746)	50 (41-59)	1,412 (1,163-1,687)	0.97 (0.8-1.15)	0.03 (0.03-0.04)	0.93 (0.77-1.12)	138	9.47
February 2023	2,453 (1,804-3,535)	215 (158-310)	2237 (1646-3225)	1.62 (1.19-2.34)	0.14 (0.1-0.21)	1.48 (1.09-2.13)	442	18

Table 4.5: Guillemot in Array Area plus 8 km: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	4,607 (3,171-7,160)	404 (278-628)	4,203 (2,893-6,532)	2.03 (1.4-3.16)	0.18 (0.12-0.28)	1.86 (1.28-2.88)	1,018	22.09
April 2021	26,510 (14,504-43,788)	1,106 (605-1,827)	25,404 (13,899-41,961)	11.71 (6.41-19.34)	0.49 (0.27-0.81)	11.22 (6.14-18.53)	7,470	28.18
May 2021	30,135 (21,912-40,149)	115 (84-153)	30,020 (21,828-39,996)	13.31 (9.68-17.73)	0.05 (0.04-0.07)	13.26 (9.64-17.67)	4,652	15.44
June 2021	8,085 (5,146-11,757)	0 (0-0)	8,085 (5,146-11,757)	3.57 (2.27-5.19)	0 (0-0)	3.57 (2.27-5.19)	1,686	20.86
July 2021	19,973 (15,558-24,472)	122 (95-150)	19,851 (15,463-24,322)	8.82 (6.87-10.81)	0.05 (0.04-0.07)	8.77 (6.83-10.74)	2,274	11.38
August 2021	7,046 (4,480-11,987)	48 (31-82)	6,997 (4,449-11,905)	3.11 (1.98-5.29)	0.02 (0.01-0.04)	3.09 (1.97-5.26)	1,915	27.18
September 2021	19,163 (10,562-33,811)	15 (8-26)	19,148 (10,554-33,785)	8.46 (4.67-14.93)	0.01 (0-0.01)	8.46 (4.66-14.92)	5,931	30.95
October 2021	3,548 (3,011-4,203)	19 (16-22)	3,529 (2,995-4,180)	1.57 (1.33-1.86)	0.01 (0.01-0.01)	1.56 (1.32-1.85)	304	8.57
November 2021	6,153 (4,848-7,606)	5 (4-6)	6,148 (4,845-7,600)	2.72 (2.14-3.36)	0 (0-0)	2.72 (2.14-3.36)	703	11.43
December 2021	4,671 (3,761-5,755)	72 (58-88)	4,599 (3,704-5,667)	2.06 (1.66-2.54)	0.03 (0.03-0.04)	2.03 (1.64-2.5)	509	10.89
January 2022	4,241 (3,536-5,112)	16 (14-20)	4,225 (3,523-5,092)	1.87 (1.56-2.26)	0.01 (0.01-0.01)	1.87 (1.56-2.25)	402	9.48
February 2022	13,520 (11,697-15,832)	83 (72-97)	13,438 (11,625-15,735)	5.97 (5.17-6.99)	0.04 (0.03-0.04)	5.94 (5.13-6.95)	1,055	7.8
March 2022	9,602 (7,299-1,2031)	1,266 (962-1,586)	8,336 (6,337-10,445)	4.24 (3.22-5.31)	0.56 (0.42-0.7)	3.68 (2.8-4.61)	1,207	12.57
April 2022	23,676 (18,304-30,341)	472 (365-605)	23,204 (17,939-29,736)	10.46 (8.08-13.4)	0.21 (0.16-0.27)	10.25 (7.92-13.13)	3,071	12.97
May 2022	13,866 (9,766-19,611)	557 (392-788)	13,309 (9,374-18,823)	6.12 (4.31-8.66)	0.25 (0.17-0.35)	5.88 (4.14-8.31)	2,511	18.11
June 2022	8,853 (7,267-10,880)	0 (0-0)	8,853 (7,267-10,880)	3.91 (3.21-4.81)	0 (0-0)	3.91 (3.21-4.81)	922	10.41
July 2022	97,952 (83,951-11,3582)	75 (64-87)	97,877 (83,886-113,495)	43.26 (37.08-50.17)	0.03 (0.03-0.04)	43.23 (37.05-50.13)	7,559	7.72
August 2022	172,708 (119,534-246,682)	0 (0-0)	172,708 (119,534-246,682)	76.28 (52.8-108.96)	0 (0-0)	76.28 (52.8-108.96)	32,436	18.78
September 2022	2,044 (1,620-2,548)	33 (26-41)	2,011 (1,594-2,507)	0.9 (0.72-1.13)	0.01 (0.01-0.02)	0.89 (0.7-1.11)	237	11.58
October 2022	6,995 (5,642-8,760)	254 (205-318)	6,741 (5,437-8,442)	3.09 (2.49-3.87)	0.11 (0.09-0.14)	2.98 (2.4-3.73)	795	11.37

November 2022	18,434 (15,530-21,455)	525 (442-611)	17,909 (15,088-20,844)	8.14 (6.86-9.48)	0.23 (0.2-0.27)	7.91 (6.66-9.21)	1512	8.2
December 2022	4,145 (3,303-5,048)	209 (166-254)	3,936 (3,137-4,794)	1.83 (1.46-2.23)	0.09 (0.07-0.11)	1.74 (1.39-2.12)	445	10.74
January 2023	2,189 (1,797-2,612)	74 (61-89)	2,115 (1736-2523)	0.97 (0.79-1.15)	0.03 (0.03-0.04)	0.93 (0.77-1.11)	208	9.49
February 2023	4,607 (3,171-7,160)	404 (278-628)	4,203 (2893-6532)	2.03 (1.4-3.16)	0.18 (0.12-0.28)	1.86 (1.28-2.88)	1018	22.09

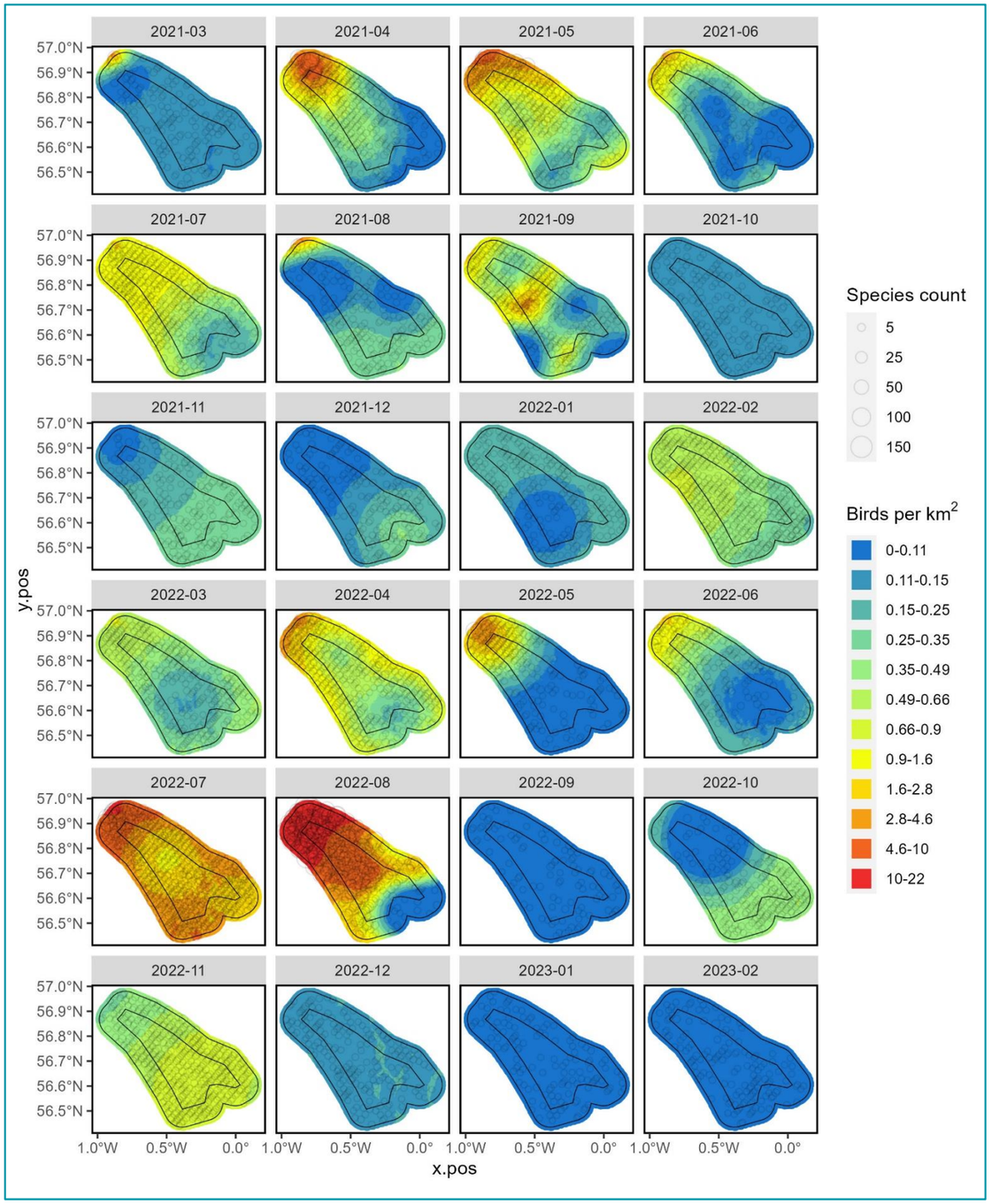

Figure 4.1: MRSea Modelled Guillemot Relative Densities (Birds per km^2) and Raw Counts in Survey Area

4.2. KITTIWAKE

4.2.1. DIGITAL AERIAL SURVEY DATA RESULTS

53. Kittiwake was the second most abundant species recorded with a total raw count of 4,788 across all surveys in the whole survey area consisting of the Array plus an 8 km buffer zone. On average 62.38% of kittiwake were observed in flight (Figure 4.6).

Table 4.6: Kittiwake Behaviours in Birds Observed During the Surveys

Survey	Diving	Feeding	Flying	Landing	Sitting	Taking off	Total	% Flying
2021-03	0	0	115	0	115	1	231	50.00
2021-04	0	0	78	0	93	0	171	45.61
2021-05	0	0	729	2	739	3	1473	49.59
2021-06	0	0	319	0	231	0	550	58.00
2021-07	0	0	162	0	483	2	647	25.12
2021-08	0	0	14	0	16	0	30	46.67
2021-09	0	0	8	0	8	0	16	50.00
2021-10	0	0	26	0	6	0	32	81.25
2021-11	0	0	47	0	12	0	59	79.66
2021-12	0	0	31	0	3	0	34	91.18
2022-01	0	0	22	0	5	0	27	81.48
2022-02	0	0	13	0	14	0	27	48.15
2022-03	0	0	38	0	15	0	53	71.70
2022-04	0	0	5	0	3	0	8	62.50
2022-05	0	0	74	0	7	0	81	91.36
2022-06	0	0	41	0	54	0	95	43.16
2022-07	0	0	135	0	393	0	528	25.57
2022-08	0	0	19	0	398	0	417	4.56
2022-09	0	0	3	0	0	0	3	100.00
2022-10	0	0	18	0	0	0	18	100.00
2022-11	0	0	159	0	80	0	239	66.53

Survey	Diving	Feeding	Flying	Landing	Sitting	Taking off	Total	% Flying
2022-12	0	0	6	0	3	0	9	66.67
2023-01	0	0	3	0	1	0	4	75.00
2023-02	0	0	30	0	6	0	36	83.33

4.2.2. MRSEA ABUNDANCE AND DENSITY ESTIMATES: KITTIWAKE

54. Kittiwake were more abundant at the start of the breeding season (April to August), with the predicted abundance variable with high inter-month variability recorded (Figure 4.2). Kittiwake appeared less abundant within the non-breeding period, likely suggesting that the Array were not important foraging grounds during non-breeding periods (Figure 4.2).

55. Within the Array, a highest peak estimate of 2,803 individuals (95% range: 2,204 to 3,736) was estimate in May 2021.

56. Within the Array plus 2 km, the highest estimates in the first year of surveys were recorded in May 2020, with 3,866 individuals (95% range: 2,909 to 5,160) estimated to be within the site. During the second year of surveys, the highest estimated numbers of birds were recorded In July 2022 with 2,561 individuals (95% range: 1,746 to 3,859 (Table 4.8).

57. MRSea estimates for each behaviour (sitting, flying, and all behaviour) are given for each of the four boundaries (Array, Array plus 2 km, Array plus 4 km and the Array plus 8 km) in Table 4.7 to Table 4.10. Months with N/A values occurred when MRSea was unable to run for that month due to less than 30 birds being recorded across the full MRSea study area.

Table 4.7: Kittiwake in Array Area: Abundance and Density Estimates

Abundance (Number of Animals)				Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	654 (143-1,649)	327 (72-825)	327 (72-825)	0.76 (0.17-1.92)	0.38 (0.08-0.96)	0.38 (0.08-0.96)	384	58.77
April 2021	123 (65-231)	56 (29-106)	67 (35-126)	0.14 (0.08-0.27)	0.07 (0.03-0.12)	0.08 (0.04-0.15)	43	34.46
May 2021	2,803 (2,104-3,736)	1,390 (1,044-1,853)	1,413 (1,061-1,883)	3.27 (2.45-4.35)	1.62 (1.22-2.16)	1.65 (1.24-2.19)	416	14.85
June 2021	835 (611-1,074)	484 (355-623)	351 (257-451)	0.97 (0.71-1.25)	0.56 (0.41-0.73)	0.41 (0.3-0.53)	118	14.15
July 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
August 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
September 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
March 2022	196 (146-261)	141 (104-187)	56 (41-74)	0.23 (0.17-0.3)	0.16 (0.12-0.22)	0.06 (0.05-0.09)	29	14.99
April 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
May 2022	294 (223-403)	269 (203-368)	25 (19-35)	0.34 (0.26-0.47)	0.31 (0.24-0.43)	0.03 (0.02-0.04)	46	15.67
June 2022	343 (184-573)	148 (79-248)	195 (104-325)	0.4 (0.21-0.67)	0.17 (0.09-0.29)	0.23 (0.12-0.38)	99	28.95
July 2022	1,856 (1,267-2,790)	475 (324-714)	1381 (943-2,076)	2.16 (1.48-3.25)	0.55 (0.38-0.83)	1.61 (1.1-2.42)	388	20.92
August 2022	332 (136-737)	15 (6-34)	317 (130-703)	0.39 (0.16-0.86)	0.02 (0.01-0.04)	0.37 (0.15-0.82)	153	46.16
September 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2022	556 (262-1,083)	370 (174-720)	186 (88-363)	0.65 (0.31-1.26)	0.43 (0.2-0.84)	0.22 (0.1-0.42)	209	37.67
December 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2023	134 (88-187)	112 (73-156)	22 (15-31)	0.16 (0.1-0.22)	0.13 (0.09-0.18)	0.03 (0.02-0.04)	25	18.92

Table 4.8: Kittiwake in Array Area plus 2 km: Abundance and Density Estimates

Abundance (Number of Animals)				Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	902 (195-2,286)	451 (97-1,143)	451 (97-1143)	0.77 (0.17-1.95)	0.38 (0.08-0.97)	0.38 (0.08-0.97)	533	59.16
April 2021	222 (116-417)	101 (53-190)	121 (63-227)	0.19 (0.1-0.36)	0.09 (0.04-0.16)	0.1 (0.05-0.19)	77	34.68
May 2021	3,866 (2,909-5,160)	1,918 (1,443-2,559)	1,949 (1,466-2,601)	3.3 (2.48-4.4)	1.63 (1.23-2.18)	1.66 (1.25-2.22)	574	14.85
June 2021	1,151 (845-1,488)	668 (490-863)	484 (355-625)	0.98 (0.72-1.27)	0.57 (0.42-0.74)	0.41 (0.3-0.53)	164	14.26
July 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
August 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
September 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
March 2022	271 (201-360)	194 (144-258)	77 (57-102)	0.23 (0.17-0.31)	0.17 (0.12-0.22)	0.07 (0.05-0.09)	41	14.97
April 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
May 2022	405 (307-557)	371 (281-509)	35 (26-48)	0.35 (0.26-0.47)	0.32 (0.24-0.43)	0.03 (0.02-0.04)	64	15.7
June 2022	473 (254-793)	204 (110-342)	269 (144-450)	0.4 (0.22-0.68)	0.17 (0.09-0.29)	0.23 (0.12-0.38)	137	29.06
July 2022	2,561 (1,746-3,859)	656 (447-988)	1,905 (1,299-2,871)	2.18 (1.49-3.29)	0.56 (0.38-0.84)	1.62 (1.11-2.45)	539	21.05
August 2022	764 (326-1,518)	35 (15-70)	729 (311-1,448)	0.65 (0.28-1.29)	0.03 (0.01-0.06)	0.62 (0.27-1.23)	304	39.81
September 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2022	967 (463-1,841)	643 (308-1,225)	324 (155-617)	0.82 (0.39-1.57)	0.55 (0.26-1.04)	0.28 (0.13-0.53)	352	36.37
December 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2023	183 (119-256)	152 (99-213)	30 (20-43)	0.16 (0.1-0.22)	0.13 (0.08-0.18)	0.03 (0.02-0.04)	35	19.11

Table 4.9: Kittiwake in Array Area plus 4 km: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	1,162 (250-2,957)	581 (125-1,478)	581 (125-1,478)	0.77 (0.16-1.95)	0.38 (0.08-0.98)	0.38 (0.08-0.98)	691	59.46
April 2021	369 (185-712)	168 (84-325)	201 (101-388)	0.24 (0.12-0.47)	0.11 (0.06-0.21)	0.13 (0.07-0.26)	134	36.42
May 2021	4,980 (3,735-6,683)	2,470 (1,852-3,315)	2,510 (1,882-3,368)	3.29 (2.47-4.42)	1.63 (1.22-2.19)	1.66 (1.24-2.23)	752	15.1
June 2021	1,483 (1,085-1,930)	860 (629-1,119)	623 (456-811)	0.98 (0.72-1.28)	0.57 (0.42-0.74)	0.41 (0.3-0.54)	216	14.54
July 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
August 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
September 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
March 2022	349 (258-466)	250 (185-334)	99 (73-132)	0.23 (0.17-0.31)	0.17 (0.12-0.22)	0.07 (0.05-0.09)	53	15.18
April 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
May 2022	522 (394-720)	477 (360-659)	45 (34-62)	0.35 (0.26-0.48)	0.32 (0.24-0.44)	0.03 (0.02-0.04)	83	15.93
June 2022	609 (326-1025)	263 (141-443)	346 (185-582)	0.4 (0.22-0.68)	0.17 (0.09-0.29)	0.23 (0.12-0.38)	178	29.24
July 2022	3,299 (2,240-4,994)	844 (573-1,279)	2,454 (1,666-3,716)	2.18 (1.48-3.3)	0.56 (0.38-0.85)	1.62 (1.1-2.46)	703	21.3
August 2022	1,491 (649-2,810)	69 (30-129)	1,422 (620-2,681)	0.99 (0.43-1.86)	0.05 (0.02-0.09)	0.94 (0.41-1.77)	551	36.98
September 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2022	1,456 (712-2,688)	968 (474-1,787)	488 (239-900)	0.96 (0.47-1.78)	0.64 (0.31-1.18)	0.32 (0.16-0.6)	504	34.62
December 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2023	236 (153-332)	196 (128-277)	39 (26-56)	0.16 (0.1-0.22)	0.13 (0.08-0.18)	0.03 (0.02-0.04)	46	19.41

Table 4.10: Kittiwake in Array Area plus 8 km: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km²)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	1,752 (375-4,500)	876 (187-2,250)	876 (187-2250)	0.77 (0.77-1.99)	0.39 (0.08-0.99)	0.39 (0.08-0.99)	1,052	60.06
April 2021	879 (395-1,825)	401 (180-832)	478 (215-993)	0.39 (0.39-0.81)	0.18 (0.08-0.37)	0.21 (0.09-0.44)	365	41.49
May 2021	7,513 (5,591-10,169)	3,727 (2,773-5,044)	3,787 (2818-5,125)	3.32 (3.32-4.49)	1.65 (1.22-2.23)	1.67 (1.24-2.26)	1,168	15.54
June 2021	2,237 (1,624-2,941)	1,298 (942-1,706)	940 (682-1,235)	0.99 (0.99-1.3)	0.57 (0.42-0.75)	0.42 (0.3-0.55)	336	15.01
July 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
August 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
September 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
March 2022	527 (387-708)	378 (277-508)	149 (109-200)	0.23 (0.23-0.31)	0.17 (0.12-0.22)	0.07 (0.05-0.09)	82	15.57
April 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
May 2022	788 (590-1,094)	720 (539-1,000)	68 (51-94)	0.35 (0.35-0.48)	0.32 (0.24-0.44)	0.03 (0.02-0.04)	129	16.31
June 2022	919 (490-1,554)	397 (212-671)	522 (278-882)	0.41 (0.41-0.69)	0.18 (0.09-0.3)	0.23 (0.12-0.39)	271	29.51
July 2022	4,977 (3,344-7,585)	1,274 (856-1,942)	3,703 (2488-5643)	2.2 (2.2-3.35)	0.56 (0.38-0.86)	1.64 (1.1-2.49)	1,082	21.74
August 2022	4,061 (1,777-8,069)	187 (82-371)	3,874 (1695-7698)	1.79 (1.79-3.56)	0.08 (0.04-0.16)	1.71 (0.75-3.4)	1,605	39.53
September 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2022	2,404 (1,186-4,340)	1,599 (789-2,886)	806 (397-1454)	1.06 (1.06-1.92)	0.71 (0.35-1.27)	0.36 (0.18-0.64)	805	33.47
December 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2023	355 (229-5,07)	296 (191-422)	59 (38-85)	0.16 (0.16-0.22)	0.13 (0.08-0.19)	0.03 (0.02-0.04)	71	19.99

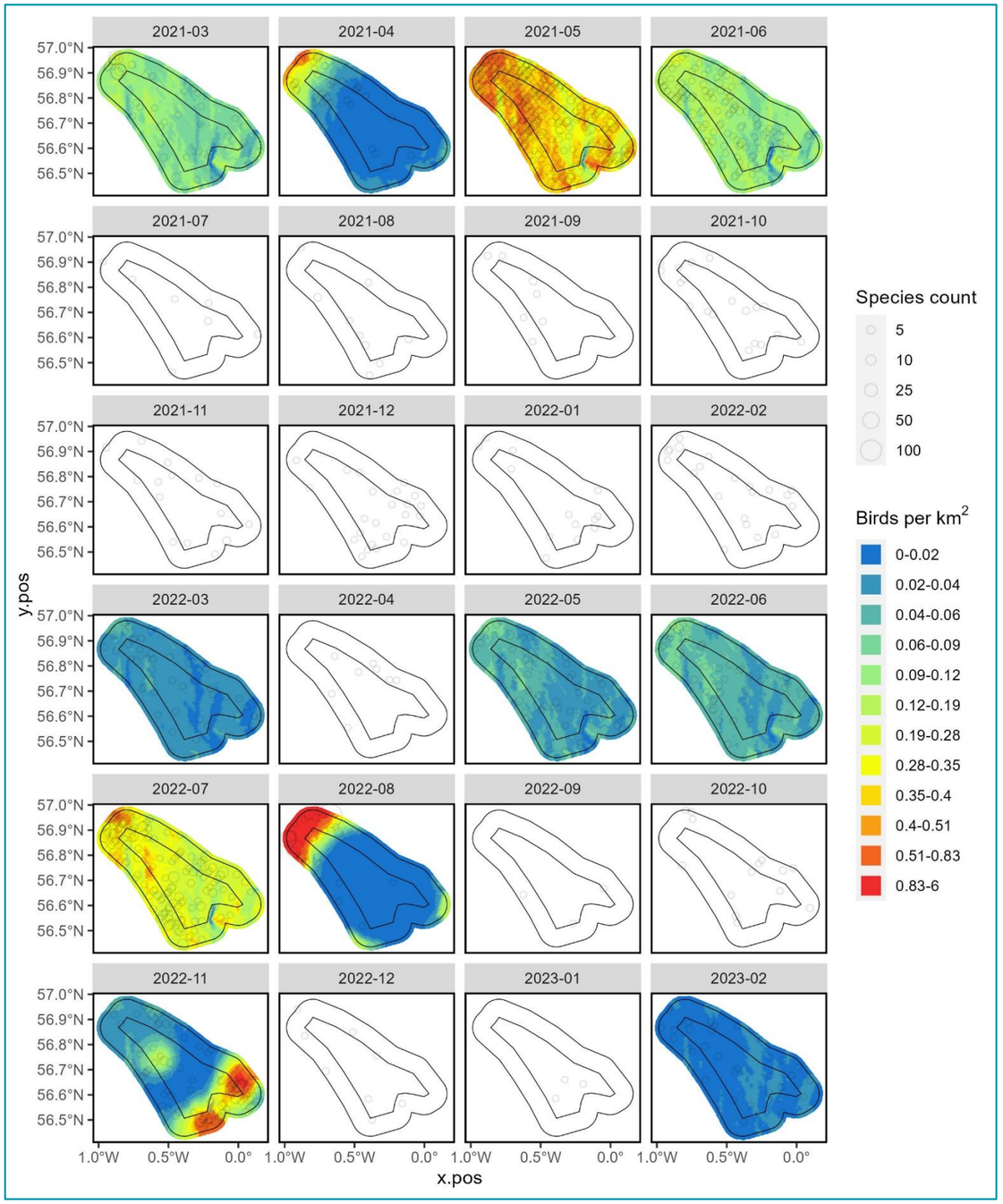

Figure 4.2: **MRSea Modelled Kittiwake Relative Densities (Birds per km^2) and Raw Counts in Survey Area**

4.3. GANNET

4.3.1. DIGITAL AERIAL SURVEY DATA RESULTS

58. Gannet were the third most abundant species, with a total raw count of 2,995 birds across all surveys in the whole survey area consisting of the Array plus a 8 km buffer zone. On average 56.39% of gannets were observed in flight (Table 4.11).

Table 4.11: **Gannet Behaviours in Birds Observed During the Surveys**

Survey	Diving	Feeding	Flying	Landing	Sitting	Taking off	Total	% Flying
2021-03	0	0	25	0	8	0	33	75.76
2021-04	0	0	145	0	17	0	162	89.51
2021-05	1	0	172	0	137	1	311	55.48
2021-06	0	0	153	0	103	0	256	59.77
2021-07	0	0	339	0	341	2	682	49.85
2021-08	0	0	76	0	85	1	162	47.20
2021-09	1	0	202	0	133	4	340	60.12
2021-10	0	0	186	0	291	1	478	38.99
2021-11	0	0	17	0	6	0	23	73.91
2021-12	0	0	2	0	0	0	2	100.00
2022-01	0	0	0	0	0	0	0	0.00
2022-02	0	0	5	0	4	0	9	55.56
2022-03	0	0	13	0	29	0	42	30.95
2022-04	0	0	18	0	28	0	46	39.13
2022-05	0	0	124	0	48	0	172	72.09
2022-06	0	0	45	0	30	0	75	60.00
2022-07	0	0	20	0	31	0	51	39.22
2022-08	0	0	26	0	46	1	73	36.11
2022-09	0	0	9	0	6	0	15	60.00
2022-10	0	0	27	0	7	0	34	79.41
2022-11	0	0	14	0	8	0	22	63.64

Survey	Diving	Feeding	Flying	Landing	Sitting	Taking off	Total	% Flying
2022-12	0	0	4	0	2	0	6	66.67
2023-01	0	0	0	0	0	0	0	0.00
2023-02	0	0	1	0	0	0	1	100.00

4.3.2. MRSEA ABUNDANCE AND DENSITY ESTIMATES: GANNET

59. In the first year of DAS, the highest abundance in the Array was recorded in the middle of the breeding season (July), with 1,434 individuals (95% range 1,119 to 1,793; Table 4.12) suggesting that the Array are key foraging grounds for gannet during the breeding season.

60. As expected, abundance was low during the non-breeding season with the birds' departure to wintering grounds off West Africa. During post-breeding migration, hotpots were observed in the north region of the Array (Figure 4.3), with majority of birds observed in flight likely due to birds migrating out from surrounding colonies (e.g. Bass Rock).

61. Within the Array plus 2 km, the highest estimates in the first year of surveys were recorded in July 2021, with 1,962 individuals (95% range: 1,521 to 2,467) estimated to be within the Array plus 2 km. During the second year of surveys, the highest estimated numbers of birds were recorded in May 2022 with 824 individuals (95% range: 599 to 1,077; Table 4.13).

62. MRSea Estimates for each behaviour (sitting, flying, and all behaviour) are given for each of the four boundaries (Array, Array plus 2 km, Array plus 4 km and the Array plus 8 km) in Table 4.12 to Table 4.15. Months with N/A values occurred when MRSea was unable to run for that month due to less than 30 birds being recorded across the full MRSea study area.

Table 4.12: Gannet in Array Area: Abundance and Density Estimates

Abundance (Number of Animals)				Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
April 2021	402 (169-1,022)	360 (151-915)	42 (18-107)	0.47 (0.2-1.19)	0.42 (0.18-1.07)	0.05 (0.02-0.13)	218	54.17
May 2021	551 (380-762)	306 (211-423)	245 (169-339)	0.64 (0.44-0.89)	0.36 (0.25-0.49)	0.29 (0.2-0.39)	97	17.67
June 2021	384 (258-537)	229 (154-321)	154 (104-216)	0.45 (0.3-0.63)	0.27 (0.18-0.37)	0.18 (0.12-0.25)	71	18.56
July 2021	1,434 (1,793-1,119)	716 (895-558)	719 (898-560)	1.67 (2.09-1.3)	0.83 (1.04-0.65)	0.84 (1.05-0.65)	172	12.00
August 2021	98 (46-203)	46 (22-96)	52 (24-107)	0.11 (0.05-0.24)	0.05 (0.03-0.11)	0.06 (0.03-0.13)	40	40.92
September 2021	386 (247-627)	232 (148-377)	154 (98-250)	0.45 (0.29-0.73)	0.27 (0.17-0.44)	0.18 (0.11-0.29)	97	25.12
October 2021	1,038 (643-1,625)	405 (251-634)	633 (392-991)	1.21 (0.75-1.89)	0.47 (0.29-0.74)	0.74 (0.46-1.15)	250	24.12
November 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
March 2022	28 (9-87)	9 (3-27)	20 (6-60)	0.03 (0.01-0.1)	0.01 (0-0.03)	0.02 (0.01-0.07)	20	69.82
April 2022	131 (80-194)	51 (31-76)	80 (49-118)	0.15 (0.09-0.23)	0.06 (0.04-0.09)	0.09 (0.06-0.14)	29	22.25
May 2022	589 (434-767)	425 (313-553)	164 (121-214)	0.69 (0.51-0.89)	0.5 (0.36-0.64)	0.19 (0.14-0.25)	85	14.38
June 2022	252 (185-324)	151 (111-194)	101 (74-130)	0.29 (0.22-0.38)	0.18 (0.13-0.23)	0.12 (0.09-0.15)	35	14.03
July 2022	182 (129-248)	71 (51-97)	111 (79-151)	0.21 (0.15-0.29)	0.08 (0.06-0.11)	0.13 (0.09-0.18)	30	16.69
August 2022	326 (224-441)	118 (81-159)	208 (143-282)	0.38 (0.26-0.51)	0.14 (0.09-0.19)	0.24 (0.17-0.33)	55	17.02
September 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2022	121 (72-186)	96 (57-148)	25 (15-38)	0.14 (0.08-0.22)	0.11 (0.07-0.17)	0.03 (0.02-0.04)	29	24.17
November 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 4.13: Gannet in Array Area plus 2 km: Abundances and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
April 2021	529 (224-1,343)	473 (1,202-1,202)	56 (141-141)	0.45 (0.19-1.15)	0.4 (1.02-1.02)	0.05 (0.12-0.12)	285	54.01
May 2021	826 (573-1,132)	458 (318-628)	368 (255-504)	0.7 (0.49-0.97)	0.39 (0.27-0.54)	0.31 (0.22-0.43)	143	17.26
June 2021	516 (345-726)	308 (206-434)	207 (139-292)	0.44 (0.29-0.62)	0.26 (0.18-0.37)	0.18 (0.12-0.25)	97	18.83
July 2021	1962 (1,521-2,467)	979 (759-1,231)	983 (762-1,236)	1.67 (1.3-2.1)	0.83 (0.65-1.05)	0.84 (0.65-1.05)	241	12.30
August 2021	177 (84-345)	84 (40-163)	94 (44-182)	0.15 (0.07-0.29)	0.07 (0.03-0.14)	0.08 (0.04-0.16)	67	37.67
September 2021	556 (342-917)	334 (206-551)	222 (137-366)	0.47 (0.29-0.78)	0.28 (0.18-0.47)	0.19 (0.12-0.31)	146	26.36
October 2021	1382 (863-2,973)	539 (337-1,159)	843 (527-1,814)	1.18 (0.74-2.53)	0.46 (0.29-0.99)	0.72 (0.45-1.55)	538	38.95
November 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
March 2022	54 (18-150)	17 (6-47)	37 (13-104)	0.05 (0.02-0.13)	0.01 (0-0.04)	0.03 (0.01-0.09)	34	62.73
April 2022	188 (116-278)	73 (45-109)	114 (70-169)	0.16 (0.1-0.24)	0.06 (0.04-0.09)	0.1 (0.06-0.14)	41	22.08
May 2022	824 (1077-599)	594 (777-432)	230 (301-167)	0.7 (0.92-0.51)	0.51 (0.66-0.37)	0.2 (0.26-0.14)	122	14.81
June 2022	353 (261-454)	212 (156-272)	141 (104-182)	0.3 (0.22-0.39)	0.18 (0.13-0.23)	0.12 (0.09-0.15)	49	13.98
July 2022	247 (175-339)	97 (69-133)	150 (107-206)	0.21 (0.15-0.29)	0.08 (0.06-0.11)	0.13 (0.09-0.18)	42	16.87
August 2022	423 (287-584)	153 (104-211)	270 (183-373)	0.36 (0.24-0.5)	0.13 (0.09-0.18)	0.23 (0.16-0.32)	76	17.93
September 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2022	169 (99-527)	134 (78-419)	35 (20-109)	0.14 (0.08-0.45)	0.11 (0.07-0.36)	0.03 (0.02-0.09)	109	64.73
November 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 4.14: Gannet in Array Area plus 4 km: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
April 2021	644 (274-1,618)	576 (246-1,448)	68 (29-170)	0.43 (0.18-1.07)	0.38 (0.16-0.96)	0.04 (0.02-0.11)	343	53.21
May 2021	1173 (803-1,735)	651 (446-963)	522 (357-772)	0.78 (0.53-1.15)	0.43 (0.29-0.64)	0.35 (0.24-0.51)	238	20.27
June 2021	654 (435-952)	391 (260-570)	263 (175-383)	0.43 (0.29-0.63)	0.26 (0.17-0.38)	0.17 (0.12-0.25)	132	20.16
July 2021	2585 (1,975-3,530)	1290 (985-1,762)	1295 (989-1,769)	1.71 (1.31-2.33)	0.85 (0.65-1.16)	0.86 (0.65-1.17)	397	15.35
August 2021	299 (140-587)	141 (66-277)	158 (74-310)	0.2 (0.09-0.39)	0.09 (0.04-0.18)	0.1 (0.05-0.2)	114	38.12
September 2021	798 (460-1,383)	480 (277-831)	318 (184-552)	0.53 (0.3-0.91)	0.32 (0.18-0.55)	0.21 (0.12-0.36)	235	29.48
October 2021	1702 (1,075-4,048)	664 (419-1,579)	1038 (656-2,469)	1.13 (0.71-2.68)	0.44 (0.28-1.04)	0.69 (0.43-1.63)	758	44.56
November 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
March 2022	106 (38-288)	33 (12-89)	73 (26-198)	0.07 (0.02-0.19)	0.02 (0.01-0.06)	0.05 (0.02-0.13)	64	59.97
April 2022	255 (157-384)	100 (61-150)	155 (96-234)	0.17 (0.1-0.25)	0.07 (0.04-0.1)	0.1 (0.06-0.15)	58	22.66
May 2022	1,095 (785-1,494)	789 (566-1,077)	305 (219-417)	0.72 (0.52-0.99)	0.52 (0.37-0.71)	0.2 (0.14-0.28)	181	16.51
June 2022	468 (345-610)	281 (207-366)	187 (138-244)	0.31 (0.23-0.4)	0.19 (0.14-0.24)	0.12 (0.09-0.16)	68	14.47
July 2022	322 (225-467)	126 (88-183)	196 (137-284)	0.21 (0.15-0.31)	0.08 (0.06-0.12)	0.13 (0.09-0.19)	62	19.19
August 2022	524 (349-758)	189 (126-274)	335 (223-484)	0.35 (0.23-0.5)	0.13 (0.08-0.18)	0.22 (0.15-0.32)	104	19.91
September 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2022	219 (125-1,344)	174 (100-1,067)	45 (26-277)	0.14 (0.08-0.89)	0.11 (0.07-0.71)	0.03 (0.02-0.18)	311	141.94
November 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 4.15: Gannet in Array Area plus 8 km: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
April 2021	851 (371-2,067)	762 (332-1,850)	89 (39-217)	0.38 (0.16-0.91)	0.34 (0.15-0.82)	0.04 (0.02-0.1)	433	50.82
May 2021	2,011 (1,383-2,883)	1,116 (768-1,600)	895 (615-1283)	0.89 (0.61-1.27)	0.49 (0.34-0.71)	0.4 (0.27-0.57)	383	19.02
June 2021	932 (631-1,330)	557 (377-795)	375 (254-535)	0.41 (0.28-0.59)	0.25 (0.17-0.35)	0.17 (0.11-0.24)	178	19.14
July 2021	4008 (3,057-5,336)	2,000 (1,525-2,663)	2,008 (1531-2,673)	1.77 (1.35-2.36)	0.88 (0.67-1.18)	0.89 (0.68-1.18)	581	14.51
August 2021	714 (323-1,409)	337 (153-665)	377 (171-744)	0.32 (0.14-0.62)	0.15 (0.07-0.29)	0.17 (0.08-0.33)	277	38.81
September 2021	1,637 (817-3,131)	984 (491-1,882)	653 (326-1,249)	0.72 (0.36-1.38)	0.43 (0.22-0.83)	0.29 (0.14-0.55)	590	36.06
October 2021	2,324 (1,495-5,344)	906 (583-2,084)	1418 (912-3,260)	1.03 (0.66-2.36)	0.4 (0.26-0.92)	0.63 (0.4-1.44)	982	42.25
November 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
March 2022	404 (115-1,135)	125 (36-352)	279 (80-783)	0.18 (0.05-0.5)	0.06 (0.02-0.16)	0.12 (0.04-0.35)	260	64.44
April 2022	422 (263-628)	165 (103-245)	257 (160-382)	0.19 (0.12-0.28)	0.07 (0.05-0.11)	0.11 (0.07-0.17)	93	22.04
May 2022	1,722 (1,220-2341)	1,242 (879-1,688)	480 (340-653)	0.76 (0.54-1.03)	0.55 (0.39-0.75)	0.21 (0.15-0.29)	286	16.62
June 2022	742 (546-969)	445 (328-581)	297 (218-388)	0.33 (0.24-0.43)	0.2 (0.14-0.26)	0.13 (0.1-0.17)	108	14.52
July 2022	483 (338-692)	189 (132-271)	294 (205-420)	0.21 (0.15-0.31)	0.08 (0.06-0.12)	0.13 (0.09-0.19)	90	18.68
August 2022	721 (467-1,066)	260 (169-385)	461 (299-681)	0.32 (0.21-0.47)	0.11 (0.07-0.17)	0.2 (0.13-0.3)	153	21.19
September 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2022	328 (182-1,585)	260 (145-1,258)	67 (38-326)	0.14 (0.08-0.7)	0.11 (0.06-0.56)	0.03 (0.02-0.14)	358	109.21
November 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

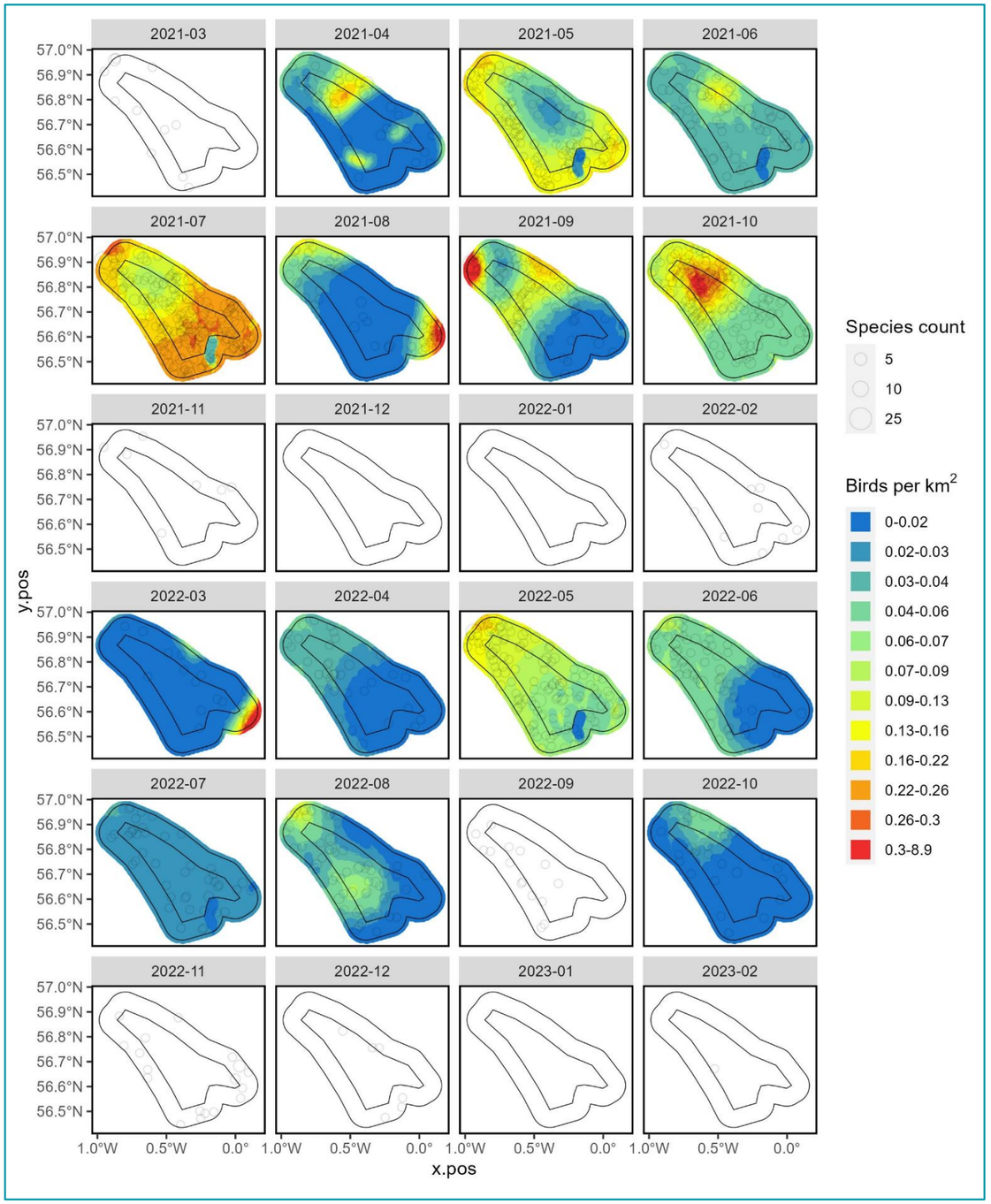

Figure 4.3: MRSea Modelled Gannet Relative Densities (Birds per km^2) and Raw Counts in Survey Area

4.4. FULMAR

4.4.1. DIGITAL AERIAL SURVEY DATA RESULTS

63. Fulmar were recorded in similar numbers to gannet, with a total raw count of 2,741 across all surveys in the whole survey area consisting of the Array plus a 8 km buffer zone. Of those recorded, 42.72% were observed flying (Table 4.16).

Table 4.16: Fulmar Behaviours in Birds Observed During the Surveys

Survey	Diving	Feeding	Flying	Landing	Sitting	Taking off	Total	% Flying
2021-03	0	0	9	0	4	0	13	69.23
2021-04	0	0	13	0	69	0	82	15.85
2021-05	0	0	43	0	108	1	152	28.48
2021-06	0	0	112	0	254	2	368	30.60
2021-07	0	0	41	0	65	0	106	38.68
2021-08	0	0	40	0	63	0	103	38.83
2021-09	0	0	51	0	157	0	208	24.52
2021-10	0	0	7	0	15	0	22	31.82
2021-11	0	0	110	0	104	1	215	51.40
2021-12	0	0	118	0	55	0	173	68.21
2022-01	0	0	35	0	12	0	47	74.47
2022-02	0	0	18	0	40	0	58	31.03
2022-03	0	0	7	0	10	0	17	41.18
2022-04	0	0	13	0	35	0	48	27.08
2022-05	0	0	23	0	8	1	32	74.19
2022-06	0	0	68	0	99	0	167	40.72
2022-07	0	0	68	0	408	0	476	14.29
2022-08	0	0	10	0	21	0	31	32.26
2022-09	0	1	14	0	57	0	72	19.72
2022-10	0	0	1	0	11	0	12	8.33
2022-11	0	0	22	0	39	2	63	36.07

Survey	Diving	Feeding	Flying	Landing	Sitting	Taking off	Total	% Flying
2022-12	0	0	157	0	25	0	182	86.26
2023-01	0	0	44	0	13	0	57	77.19
2023-02	0	0	24	0	13	0	37	64.86

4.4.2. MRSEA ABUNDANCE AND DENSITY ESTIMATES: FULMAR

64. In the first year of DAS, the highest abundance in the Array was recorded near the end of the breeding season (June 2021), with 825 individuals (95% range 543 to 1,196; Table 4.17), with over half of those birds sitting (Table 4.16) suggesting that the Array area is a key foraging ground for fulmar during the chick rearing period. In the second year of surveys, peak abundances were recorded in July with 1,863 individuals estimated to be within the site (95% range: 669 to 5,062; Table 4.17). Again a low percentage of those birds were observed in flight, confirming that this area is likely a key area for breeding adults and fledged young.

65. During the non-breeding months, peak estimates were predominantly estimated outside of the Array (Figure 4.4).

66. MRSea estimates for each behaviour (sitting, flying, and all behaviour) are given for each of the four areas (Array, Array plus 2 km, Array plus 4 km and the Array plus 8 km) in Table 4.17 to Table 4.20

67. Months with N/A values occurred when MRSea was unable to run for that month due to less than 30 birds being recorded across the full MRSea study area.

Table 4.17: Fulmar in Array Area: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
April 2021	140 (83-220)	22 (13-35)	117 (70-185)	0.16 (0.1-0.26)	0.03 (0.02-0.04)	0.14 (0.08-0.22)	35	24.92
May 2021	147 (62-291)	42 (18-83)	105 (44-208)	0.17 (0.07-0.34)	0.05 (0.02-0.1)	0.12 (0.05-0.24)	59	39.85
June 2021	825 (543-1,196)	253 (166-366)	573 (377-830)	0.96 (0.63-1.39)	0.29 (0.19-0.43)	0.67 (0.44-0.97)	166	20.17
July 2021	272 (173-387)	105 (67-150)	167 (106-237)	0.32 (0.2-0.45)	0.12 (0.08-0.17)	0.19 (0.12-0.28)	54	20.01
August 2021	283 (133-546)	110 (52-212)	173 (82-334)	0.33 (0.16-0.64)	0.13 (0.06-0.25)	0.2 (0.1-0.39)	105	37.26
September 2021	577 (266-1,087)	141 (65-266)	436 (201-821)	0.67 (0.31-1.27)	0.16 (0.08-0.31)	0.51 (0.23-0.96)	209	36.3
October 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2021	433 (352-517)	223 (181-266)	210 (171-251)	0.5 (0.41-0.6)	0.26 (0.21-0.31)	0.25 (0.2-0.29)	42	9.73
December 2021	293 (190-466)	200 (130-318)	93 (61-148)	0.34 (0.22-0.54)	0.23 (0.15-0.37)	0.11 (0.07-0.17)	70	23.95
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	198 (126-303)	147 (94-226)	50 (32-77)	0.23 (0.15-0.35)	0.17 (0.11-0.26)	0.06 (0.04-0.09)	45	22.74
March 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
April 2022	189 (95-315)	41 (21-68)	148 (74-247)	0.22 (0.11-0.37)	0.05 (0.02-0.08)	0.17 (0.09-0.29)	56	29.69
May 2022	70 (28-141)	52 (21-105)	18 (7-36)	0.08 (0.03-0.16)	0.06 (0.02-0.12)	0.02 (0.01-0.04)	29	41.55
June 2022	657 (446-932)	267 (182-379)	389 (265-552)	0.76 (0.52-1.09)	0.31 (0.21-0.44)	0.45 (0.31-0.64)	124	18.87
July 2022	1863 (669-5,062)	266 (96-724)	1,596 (574-4,338)	2.17 (0.78-5.9)	0.31 (0.11-0.84)	1.86 (0.67-5.05)	1121	60.16
August 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
September 2022	272 (199-347)	54 (39-68)	218 (159-279)	0.32 (0.23-0.4)	0.06 (0.05-0.08)	0.25 (0.19-0.32)	38	13.92
October 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2022	203 (105-357)	73 (38-129)	130 (67-228)	0.24 (0.12-0.42)	0.09 (0.04-0.15)	0.15 (0.08-0.27)	64	31.76
December 2022	684 (579-819)	590 (499-707)	94 (79-112)	0.8 (0.67-0.95)	0.69 (0.58-0.82)	0.11 (0.09-0.13)	61	8.97
January 2023	210 (143-297)	162 (110-230)	48 (33-68)	0.24 (0.17-0.35)	0.19 (0.13-0.27)	0.06 (0.04-0.08)	39	18.76
February 2023	134 (77-219)	87 (50-142)	47 (27-77)	0.16 (0.09-0.25)	0.1 (0.06-0.17)	0.05 (0.03-0.09)	36	27.02

Table 4.18: Fulmar in Array Area plus 2 km: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
April 2021	189 (113-300)	30 (18-48)	159 (95-252)	0.16 (0.1-0.26)	0.03 (0.02-0.04)	0.14 (0.08-0.21)	48	25.12
May 2021	268 (110-535)	76 (31-153)	191 (79-383)	0.23 (0.09-0.46)	0.07 (0.03-0.13)	0.16 (0.07-0.33)	108	40.54
June 2021	1,040 (691-1,494)	318 (211-457)	721 (479-1,037)	0.89 (0.59-1.27)	0.27 (0.18-0.39)	0.61 (0.41-0.88)	205	19.72
July 2021	378 (239-542)	146 (92-210)	232 (146-332)	0.32 (0.2-0.46)	0.12 (0.08-0.18)	0.2 (0.12-0.28)	77	20.45
August 2021	378 (179-724)	147 (69-281)	231 (109-443)	0.32 (0.15-0.62)	0.12 (0.06-0.24)	0.2 (0.09-0.38)	139	36.83
September 2021	857 (386-1,632)	210 (95-400)	647 (292-1,232)	0.73 (0.33-1.39)	0.18 (0.08-0.34)	0.55 (0.25-1.05)	318	37.09
October 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2021	591 (481-706)	304 (247-363)	287 (234-343)	0.5 (0.41-0.6)	0.26 (0.21-0.31)	0.25 (0.2-0.29)	58	9.73
December 2021	418 (273-653)	285 (187-445)	133 (87-208)	0.36 (0.23-0.56)	0.24 (0.16-0.38)	0.11 (0.07-0.18)	97	23.16
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	268 (170-412)	83 (53-128)	185 (118-284)	0.23 (0.15-0.35)	0.07 (0.05-0.11)	0.16 (0.1-0.24)	62	22.94
March 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
April 2022	261 (130-438)	57 (28-95)	204 (101-343)	0.22 (0.11-0.37)	0.05 (0.02-0.08)	0.17 (0.09-0.29)	79	30.21
May 2022	105 (43-210)	78 (32-156)	27 (11-54)	0.09 (0.04-0.18)	0.07 (0.03-0.13)	0.02 (0.01-0.05)	43	40.73
June 2022	894 (603-1,277)	364 (245-520)	530 (358-757)	0.76 (0.51-1.09)	0.31 (0.21-0.44)	0.45 (0.3-0.65)	172	19.25
July 2022	2,856 (1,134-7,149)	408 (162-1022)	2448 (972-6,127)	2.43 (0.97-6.09)	0.35 (0.14-0.87)	2.09 (0.83-5.22)	1534	53.73
August 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
September 2022	371 (271-474)	73 (53-93)	298 (218-381)	0.32 (0.23-0.4)	0.06 (0.05-0.08)	0.25 (0.19-0.32)	52	13.92
October 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2022	299 (153-531)	108 (55-192)	191 (98-339)	0.26 (0.13-0.45)	0.09 (0.05-0.16)	0.16 (0.08-0.29)	96	32.22
December 2022	934 (790-1,119)	806 (682-965)	128 (108-153)	0.8 (0.67-0.95)	0.69 (0.58-0.82)	0.11 (0.09-0.13)	84	8.97
January 2023	285 (193-405)	220 (149-313)	65 (44-92)	0.24 (0.16-0.35)	0.19 (0.13-0.27)	0.06 (0.04-0.08)	54	19.03
February 2023	182 (103-297)	118 (67-193)	64 (36-104)	0.15 (0.09-0.25)	0.1 (0.06-0.16)	0.05 (0.03-0.09)	50	27.27

Table 4.19: Fulmar in Array Area plus 4 km: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
April 2021	243 (145-392)	39 (23-62)	204 (122-330)	0.16 (0.1-0.26)	0.03 (0.02-0.04)	0.14 (0.08-0.22)	63	25.98
May 2021	464 (177-995)	132 (51-284)	331 (127-712)	0.31 (0.12-0.66)	0.09 (0.03-0.19)	0.22 (0.08-0.47)	209	45.02
June 2021	1,256 (838-1,818)	384 (256-556)	872 (582-1,262)	0.83 (0.55-1.2)	0.25 (0.17-0.37)	0.58 (0.38-0.83)	250	19.89
July 2021	501 (312-743)	194 (121-288)	307 (191-456)	0.33 (0.21-0.49)	0.13 (0.08-0.19)	0.2 (0.13-0.3)	110	21.96
August 2021	470 (227-895)	182 (88-347)	288 (139-548)	0.31 (0.15-0.59)	0.12 (0.06-0.23)	0.19 (0.09-0.36)	170	36.27
September 2021	1,116 (490-2,159)	273 (120-529)	843 (370-1630)	0.74 (0.32-1.43)	0.18 (0.08-0.35)	0.56 (0.24-1.08)	426	38.13
October 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2021	763 (620-911)	392 (319-468)	371 (301-443)	0.5 (0.41-0.6)	0.26 (0.21-0.31)	0.25 (0.2-0.29)	74	9.73
December 2021	560 (861-370)	382 (587-252)	178 (274-118)	0.37 (0.57-0.24)	0.25 (0.39-0.17)	0.12 (0.18-0.08)	-125	-22.37
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	344 (217-538)	257 (162-401)	88 (55-137)	0.23 (0.14-0.36)	0.17 (0.11-0.26)	0.06 (0.04-0.09)	82	23.76
March 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
April 2022	330 (163-561)	72 (35-122)	258 (128-439)	0.22 (0.11-0.37)	0.05 (0.02-0.08)	0.17 (0.08-0.29)	101	30.78
May 2022	154 (63-313)	114 (47-232)	40 (16-81)	0.1 (0.04-0.21)	0.08 (0.03-0.15)	0.03 (0.01-0.05)	64	41.41
June 2022	1,136 (759-1673)	463 (309-681)	674 (450-992)	0.75 (0.5-1.11)	0.31 (0.2-0.45)	0.45 (0.3-0.66)	233	20.51
July 2022	3,623 (1,505-8,675)	518 (215-1241)	3105 (1,290-7,435)	2.39 (0.99-5.74)	0.34 (0.14-0.82)	2.05 (0.85-4.92)	1829	50.49
August 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
September 2022	479 (350-611)	94 (69-120)	385 (281-491)	0.32 (0.23-0.4)	0.06 (0.05-0.08)	0.25 (0.19-0.32)	67	13.92
October 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2022	407 (206-723)	147 (75-261)	260 (132-462)	0.27 (0.14-0.48)	0.1 (0.05-0.17)	0.17 (0.09-0.31)	132	32.37
December 2022	1,205 (1,019-1,443)	1,040 (880-1,245)	165 (140-198)	0.8 (0.67-0.95)	0.69 (0.58-0.82)	0.11 (0.09-0.13)	108	8.97
January 2023	365 (246-532)	282 (190-411)	83 (56-121)	0.24 (0.16-0.35)	0.19 (0.13-0.27)	0.06 (0.04-0.08)	73	19.97
February 2023	233 (131-388)	151 (85-252)	82 (46-136)	0.15 (0.09-0.26)	0.1 (0.06-0.17)	0.05 (0.03-0.09)	65	28.07

Table 4.20: Fulmar in Array Area plus 8 km: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
April 2021	368 (218-594)	59 (35-95)	309 (183-500)	0.16 (0.1-0.26)	0.03 (0.02-0.04)	0.14 (0.08-0.22)	96	26.1
May 2021	1,169 (389-2,609)	333 (111-744)	836 (278-1,866)	0.52 (0.17-1.15)	0.15 (0.05-0.33)	0.37 (0.12-0.82)	566	48.43
June 2021	1,730 (1163-2,486)	529 (356-761)	1201 (807-1,726)	0.76 (0.51-1.1)	0.23 (0.16-0.34)	0.53 (0.36-0.76)	338	19.51
July 2021	803 (494-1,188)	311 (191-460)	492 (303-728)	0.35 (0.22-0.52)	0.14 (0.08-0.2)	0.22 (0.13-0.32)	177	22.04
August 2021	656 (335-1,192)	255 (130-462)	402 (205-729)	0.29 (0.15-0.53)	0.11 (0.06-0.2)	0.18 (0.09-0.32)	219	33.32
September 2021	1,524 (626-3,068)	373 (153-752)	1150 (473-2,317)	0.67 (0.28-1.36)	0.16 (0.07-0.33)	0.51 (0.21-1.02)	623	40.89
October 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2021	1,142 (928-1,364)	587 (477-701)	555 (451-663)	0.5 (0.41-0.6)	0.26 (0.21-0.31)	0.25 (0.2-0.29)	111	9.73
December 2021	902 (604-1,343)	615 (412-916)	287 (192-427)	0.4 (0.27-0.59)	0.27 (0.18-0.4)	0.13 (0.08-0.19)	188	20.9
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	522 (326-819)	389 (243-610)	133 (83-209)	0.23 (0.14-0.36)	0.17 (0.11-0.27)	0.06 (0.04-0.09)	126	24.1
March 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
April 2022	471 (235-798)	102 (51-173)	369 (184-625)	0.21 (0.1-0.35)	0.05 (0.02-0.08)	0.16 (0.08-0.28)	144	30.5
May 2022	313 (129-631)	232 (96-468)	81 (33-163)	0.14 (0.06-0.28)	0.1 (0.04-0.21)	0.04 (0.01-0.07)	128	40.85
June 2022	1,653 (1,098-2,432)	673 (447-990)	980 (651-1,442)	0.73 (0.48-1.07)	0.3 (0.2-0.44)	0.43 (0.29-0.64)	340	20.59
July 2022	4,513 (1,809-10,896)	645 (259-1,558)	3867 (1551-9,338)	1.99 (0.8-4.81)	0.29 (0.11-0.69)	1.71 (0.68-4.12)	2318	51.36
August 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
September 2022	717 (524-915)	141 (103-180)	576 (421-735)	0.32 (0.23-0.4)	0.06 (0.05-0.08)	0.25 (0.19-0.32)	100	13.92
October 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2022	636 (325-1,120)	230 (117-404)	406 (208-716)	0.28 (0.14-0.49)	0.1 (0.05-0.18)	0.18 (0.09-0.32)	203	31.89
December 2022	1,805 (1,526-2,160)	1,557 (1,317-1,864)	247 (209-296)	0.8 (0.67-0.95)	0.69 (0.58-0.82)	0.11 (0.09-0.13)	162	8.97
January 2023	553 (369-808)	427 (285-624)	126 (84-184)	0.24 (0.16-0.36)	0.19 (0.13-0.28)	0.06 (0.04-0.08)	112	20.21
February 2023	353 (199-588)	229 (129-382)	124 (70-206)	0.16 (0.09-0.26)	0.1 (0.06-0.17)	0.05 (0.03-0.09)	99	28.1

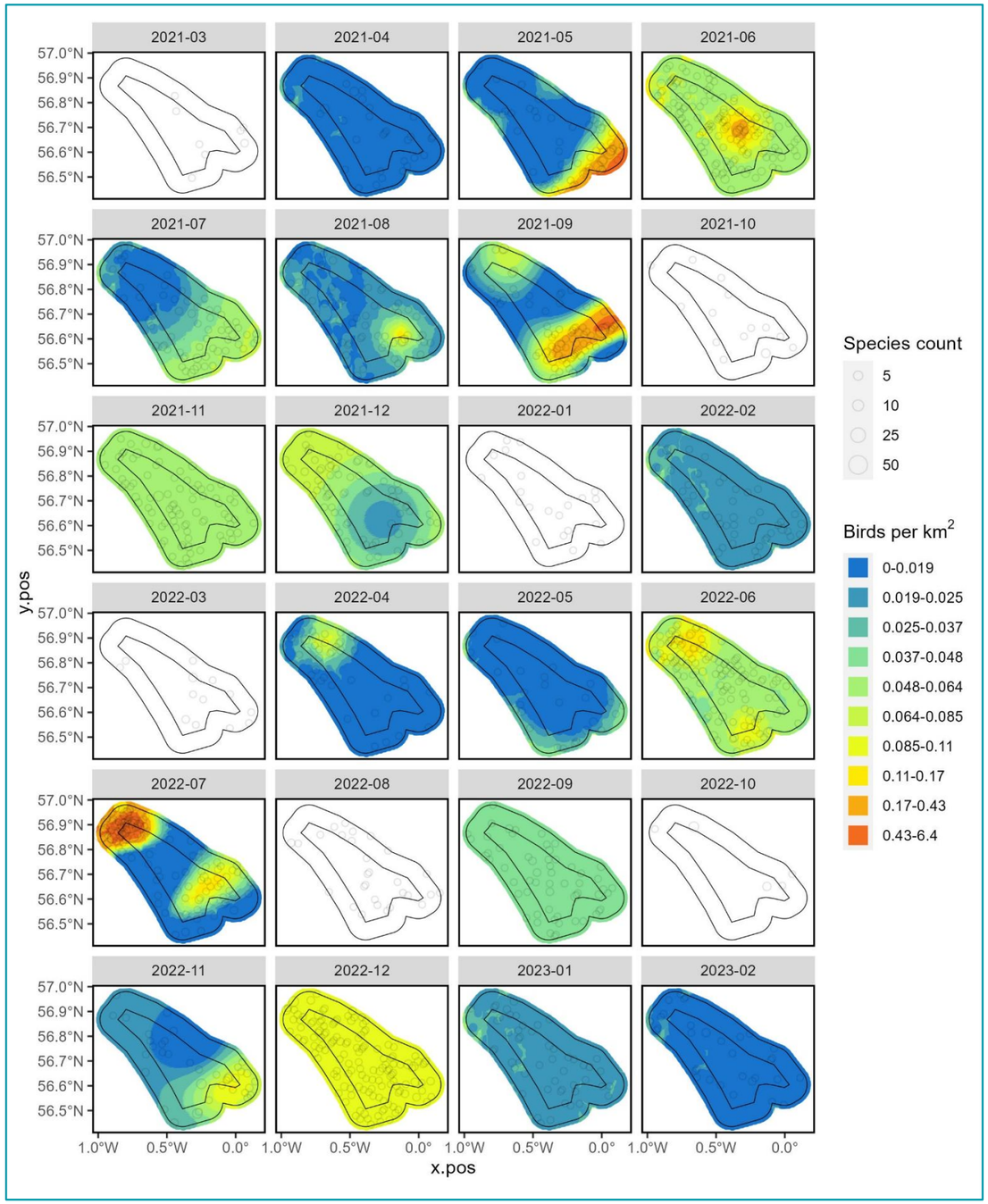

Figure 4.4: MRSea Modelled Fulmar Relative Densities (Birds per km^2) And Raw Counts In Survey Area

4.5. RAZORBILL

4.5.1. DIGITAL AERIAL SURVEY DATA RESULTS

68. Razorbill were recorded in similar numbers to fulmar with a total raw count of 2,719 across all surveys in the whole survey area consisting of the Array plus a 8 km buffer zone. On average 6.30% of razorbill were observed in flight Table 4.21.

Table 4.21: Razorbill Behaviours in Birds Observed During the Surveys

Survey	Diving	Feeding	Flying	Landing	Sitting	Taking off	Total	% Flying
2021-03	0	0	3	0	94	0	97	3.09
2021-04	0	0	25	0	269	0	294	8.50
2021-05	0	0	0	0	120	0	120	0.00
2021-06	0	0	0	0	194	0	194	0.00
2021-07	2	0	18	0	661	0	681	2.64
2021-08	0	0	0	0	73	0	73	0.00
2021-09	0	0	0	0	0	0	0	0.00
2021-10	0	0	0	0	9	0	9	0.00
2021-11	0	0	0	0	1	0	1	0.00
2021-12	0	0	0	0	17	0	17	0.00
2022-01	0	0	1	0	19	0	20	5.00
2022-02	0	0	0	0	3	0	3	0.00
2022-03	0	0	2	0	16	0	18	11.11
2022-04	0	0	2	0	48	0	50	4.00
2022-05	0	0	2	0	30	0	32	6.25
2022-06	0	0	1	0	30	0	31	3.23
2022-07	1	0	0	0	583	0	584	0.00
2022-08	1	0	0	0	406	0	407	0.00
2022-09	0	0	0	0	1	0	1	0.00
2022-10	0	0	24	0	12	0	36	66.67
2022-11	0	0	0	0	24	0	24	0.00

Survey	Diving	Feeding	Flying	Landing	Sitting	Taking off	Total	% Flying
2022-12	0	0	0	0	0	0	0	0.00
2023-01	0	0	0	0	0	0	0	0.00
2023-02	0	0	11	0	16	0	27	40.74

4.5.2. MRSEA ABUNDANCE AND DENSITY ESTIMATES: RAZORBILL

69. Abundances varied considerably between years, with 2022 having double the average density of 2021, with peaks occurring in July 2021 and July 2022. Razorbill were near absent during the non-breeding months. Estimates for monthly razorbill numbers in the Array plus 2 km varied from 307 (95% range:185 to 473) to 1,231 (95% range: 657 to 2,000) in the breeding season in 2021, while abundances ranged from 146 individuals (95% range: 97 to 217) to 3,984 individuals (95% range: 3,098 to 5,089; Table 4.23).

70. Razorbills were generally widespread across the MRSea study area, although there was some heterogeneity. In some months like April, May, and October, their distributions were more localized in the North, but in most months they were widespread (Figure 4.5). Months with N/A values occurred when MRSea was unable to run for that month due to less than 30 birds being recorded across the full MRSea study area.

Table 4.22: Razorbill in Array Area: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	228 (115-415)	6 (3-11)	223 (112-404)	0.27 (0.13-0.48)	0.01 (0-0.01)	0.26 (0.13-0.47)	77	33.54
April 2021	407 (210-771)	29 (15-55)	378 (195-716)	0.47 (0.25-0.9)	0.03 (0.02-0.06)	0.44 (0.23-0.83)	143	35.12
May 2021	225 (136-346)	0 (0-0)	225 (136-346)	0.26 (0.16-0.4)	0 (0-0)	0.26 (0.16-0.4)	54	23.93
June 2021	443 (347-567)	0 (0-0)	443 (347-567)	0.52 (0.4-0.66)	0 (0-0)	0.52 (0.4-0.66)	56	12.64
July 2021	901 (481-1,464)	19 (10-32)	882 (471-1433)	1.05 (0.56-1.71)	0.02 (0.01-0.04)	1.03 (0.55-1.67)	251	27.82
August 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
September 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
March 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
April 2022	252 (166-353)	8 (6-12)	243 (161-341)	0.29 (0.19-0.41)	0.01 (0.01-0.01)	0.28 (0.19-0.4)	48	18.94
May 2022	89 (58-134)	5 (3-7)	84 (55-127)	0.1 (0.07-0.16)	0.01 (0-0.01)	0.1 (0.06-0.15)	20	21.97
June 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
July 2022	2,917 (2,268-3,726)	0 (0-0)	2,917 (2268-3726)	3.4 (2.64-4.34)	0 (0-0)	3.4 (2.64-4.34)	372	12.75
August 2022	2,138 (1,263-3,491)	0 (0-0)	2,138 (1263-3491)	2.49 (1.47-4.07)	0 (0-0)	2.49 (1.47-4.07)	568	26.59
September 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2022	181 (47-591)	113 (29-368)	68 (18-223)	0.21 (0.05-0.69)	0.13 (0.03-0.43)	0.08 (0.02-0.26)	139	76.59
November 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 4.23: Razorbill in Array Area plus 2 km: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	313 (157-572)	8 (4-15)	305 (153-557)	0.27 (0.13-0.49)	0.01 (0-0.01)	0.26 (0.13-0.47)	106	33.8
April 2021	713 (364-1,359)	51 (26-97)	662 (338-1262)	0.61 (0.31-1.16)	0.04 (0.02-0.08)	0.56 (0.29-1.08)	254	35.6
May 2021	307 (185-473)	0 (0-0)	307 (185-473)	0.26 (0.16-0.4)	0 (0-0)	0.26 (0.16-0.4)	73	23.93
June 2021	605 (474-774)	0 (0-0)	605 (474-774)	0.52 (0.4-0.66)	0 (0-0)	0.52 (0.4-0.66)	77	12.64
July 2021	1,231 (657-2,000)	27 (14-43)	1204 (643-1957)	1.05 (0.56-1.7)	0.02 (0.01-0.04)	1.03 (0.55-1.67)	343	27.82
August 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
September 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
March 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
April 2022	344 (227-482)	11 (8-16)	332 (220-466)	0.29 (0.19-0.41)	0.01 (0.01-0.01)	0.28 (0.19-0.4)	65	18.94
May 2022	146 (97-217)	8 (5-11)	139 (91-206)	0.12 (0.08-0.19)	0.01 (0-0.01)	0.12 (0.08-0.18)	31	21.07
June 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
July 2022	3,984 (3,098-5,089)	0 (0-0)	3,984 (3,098-5,089)	3.4 (2.64-4.34)	0 (0-0)	3.4 (2.64-4.34)	508	12.75
August 2022	2,953 (1,681-5,003)	0 (0-0)	2,953 (1,681-5,003)	2.52 (1.43-4.26)	0 (0-0)	2.52 (1.43-4.26)	848	28.7
September 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2022	260 (66-864)	162 (41-538)	98 (25-325)	0.22 (0.06-0.74)	0.14 (0.04-0.46)	0.08 (0.02-0.28)	203	78.28
November 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 4.24: Razorbill in Array Area plus 4 km: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	403 (201-742)	10 (5-19)	393 (196-723)	0.27 (0.13-0.49)	0.01 (0-0.01)	0.26 (0.13-0.48)	138	34.22
April 2021	1,113 (560-2141)	79 (40-153)	1,034 (520-1,988)	0.74 (0.37-1.42)	0.05 (0.03-0.1)	0.68 (0.34-1.31)	403	36.23
May 2021	396 (239-610)	0 (0-0)	396 (239-610)	0.26 (0.16-0.4)	0 (0-0)	0.26 (0.16-0.4)	95	23.93
June 2021	781 (612-999)	0 (0-0)	781 (612-999)	0.52 (0.4-0.66)	0 (0-0)	0.52 (0.4-0.66)	99	12.64
July 2021	1,588 (848-2,580)	34 (18-56)	1,554 (830-2,525)	1.05 (0.56-1.71)	0.02 (0.01-0.04)	1.03 (0.55-1.67)	442	27.82
August 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
September 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
March 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
April 2022	443 (293-622)	15 (10-21)	429 (283-602)	0.29 (0.19-0.41)	0.01 (0.01-0.01)	0.28 (0.19-0.4)	84	18.94
May 2022	219 (146-322)	12 (8-17)	207 (138-305)	0.14 (0.1-0.21)	0.01 (0.01-0.01)	0.14 (0.09-0.2)	45	20.52
June 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
July 2022	5,140 (3,997-6,565)	0 (0-0)	5,140 (3,997-6,565)	3.4 (2.64-4.34)	0 (0-0)	3.4 (2.64-4.34)	655	12.75
August 2022	3,799 (2,094-6,624)	0 (0-0)	3,799 (2,094-6,624)	2.51 (1.38-4.38)	0 (0-0)	2.51 (1.38-4.38)	1155	30.42
September 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2022	330 (85-1,086)	206 (53-677)	124 (32-409)	0.22 (0.06-0.72)	0.14 (0.03-0.45)	0.08 (0.02-0.27)	255	77.36
November 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 4.25: Razorbill in Array Area plus 8 km: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	605 (300-1,116)	16 (8-29)	589 (293-1,088)	0.27 (0.13-0.49)	0.01 (0-0.01)	0.26 (0.13-0.48)	208	34.41
April 2021	2,227 (1,088-4,351)	159 (77-310)	2,068 (1,010-4,041)	0.98 (0.48-1.92)	0.07 (0.03-0.14)	0.91 (0.45-1.78)	833	37.39
May 2021	593 (358-914)	0 (0-0)	593 (358-914)	0.26 (0.16-0.4)	0 (0-0)	0.26 (0.16-0.4)	142	23.93
June 2021	1,169 (916-1,495)	0 (0-0)	1,169 (916-1,495)	0.52 (0.4-0.66)	0 (0-0)	0.52 (0.4-0.66)	148	12.64
July 2021	2,378 (1,270-3,863)	51 (27-83)	2,326 (1,243-3,780)	1.05 (0.56-1.71)	0.02 (0.01-0.04)	1.03 (0.55-1.67)	662	27.82
August 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
September 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
March 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
April 2022	664 (439-932)	22 (15-31)	642 (424-901)	0.29 (0.19-0.41)	0.01 (0.01-0.01)	0.28 (0.19-0.4)	126	18.94
May 2022	416 (280-603)	22 (15-32)	394 (265-571)	0.18 (0.12-0.27)	0.01 (0.01-0.01)	0.17 (0.12-0.25)	82	19.82
June 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
July 2022	7,696 (5,984-9,830)	0 (0-0)	7,696 (5,984-9,830)	3.4 (2.64-4.34)	0 (0-0)	3.4 (2.64-4.34)	981	12.75
August 2022	5,450 (2,882-9,910)	0 (0-0)	5,450 (2,882-9,910)	2.41 (1.27-4.38)	0 (0-0)	2.41 (1.27-4.38)	1793	32.9
September 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
October 2022	433 (117-1,347)	270 (73-840)	163 (44-508)	0.19 (0.05-0.6)	0.12 (0.03-0.37)	0.07 (0.02-0.22)	314	72.46
November 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

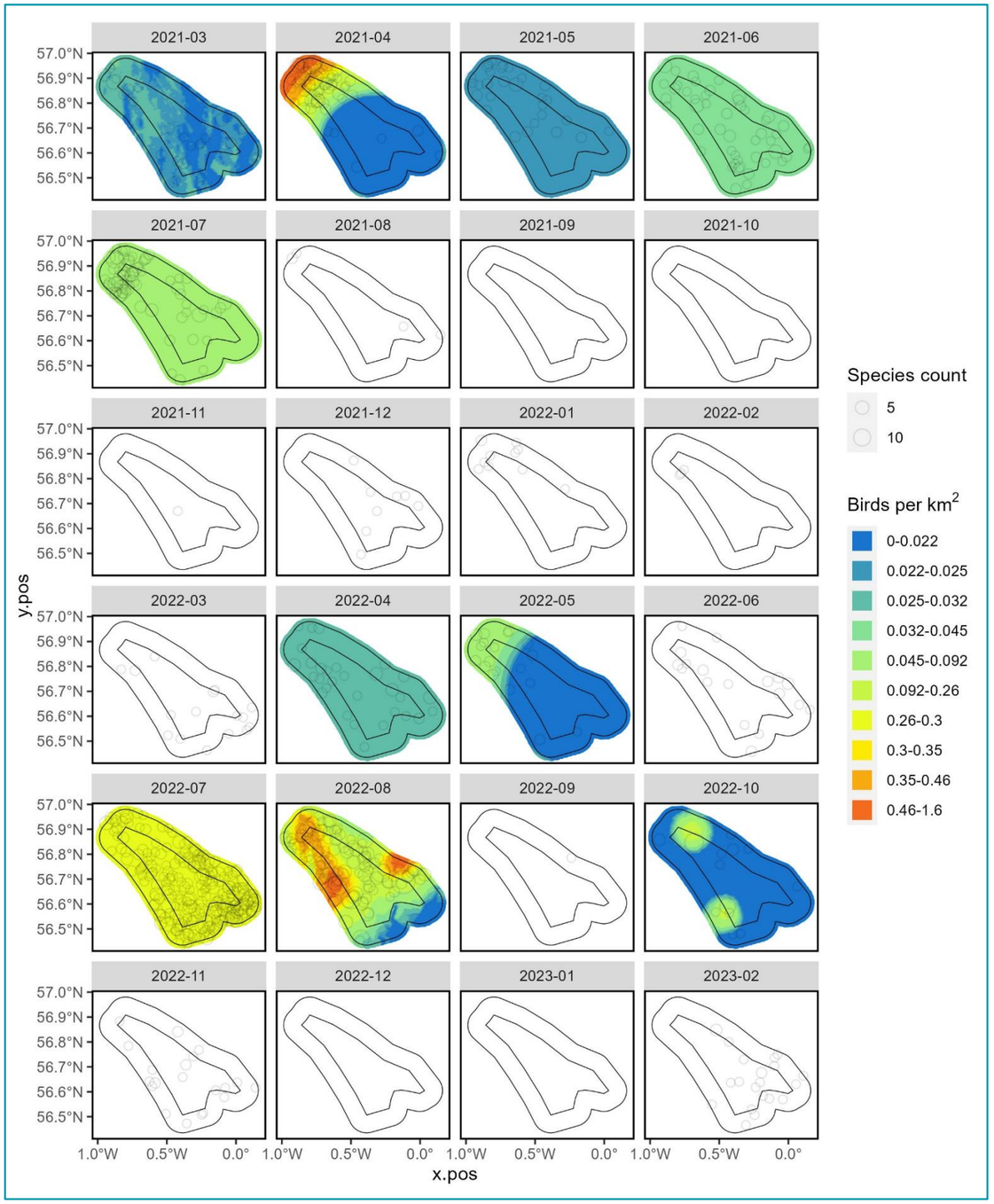

Figure 4.5: MRSea Modelled Razorbill Relative Densities (Birds per km^2) and Raw Counts in Survey Area

4.6. PUFFIN

4.6.1. DIGITAL AERIAL SURVEY DATA RESULTS

71. Puffin was the least abundant auk species recorded during DAS with a total raw count of 2,649 across all surveys in the whole survey area consisting of the Array plus an 8 km buffer zone. Out of those observed during surveys, on average only 1.29% were observed in flight (Table 4.26).

Table 4.26: Puffin Behaviour in Birds Observed During the Surveys

Survey	Diving	Feeding	Flying	Landing	Sitting	Taking off	Total	% Flying
2021-03	0	0	0	0	307	0	307	0.00
2021-04	0	0	4	0	138	0	142	2.82
2021-05	0	0	0	0	450	0	450	0.00
2021-06	0	0	1	0	303	0	304	0.33
2021-07	1	0	1	0	135	1	138	0.73
2021-08	0	0	0	0	79	0	79	0.00
2021-09	0	0	0	0	107	0	107	0.00
2021-10	0	0	4	0	69	0	73	5.48
2021-11	0	0	0	0	0	0	0	0.00
2021-12	0	0	0	0	5	0	5	0.00
2022-01	0	0	0	0	8	0	8	0.00
2022-02	0	0	0	0	68	0	68	0.00
2022-03	0	0	2	0	64	0	66	3.03
2022-04	0	0	1	0	127	0	128	0.78
2022-05	0	0	1	0	96	0	97	1.03
2022-06	0	0	0	0	30	0	30	0.00
2022-07	0	0	1	0	84	0	85	1.18
2022-08	0	0	0	0	369	0	369	0.00
2022-09	0	0	0	0	118	0	118	0.00
2022-10	0	0	6	0	32	0	38	15.79
2022-11	0	0	0	0	3	0	3	0.00

Survey	Diving	Feeding	Flying	Landing	Sitting	Taking off	Total	% Flying
2022-12	0	0	0	0	6	0	6	0.00
2023-01	0	0	0	0	0	0	0	0.00
2023-02	0	0	0	0	28	0	28	0.00

4.6.2. MRSEA ABUNDANCE AND DENSITY ESTIMATES: PUFFIN

72. The lowest numbers were observed between November and February (Table 4.26). Estimates for monthly puffin numbers in the Array plus 2 km varied from 257 (95% range: 136 to 423) to 1,833 (95% range: 1,101 to 2,709) during the first breeding season, while abundances ranged from 280 individuals (95% range: 165 to 458) to 2,023 individuals (95% range: 1,298 to 2,791) during the second year breeding season (Table 4.28).

73. In months where they were present, puffins were generally widespread across the MRSea study area, especially during the breeding months (Figure 4.6). In some months like March, July and August, their distributions were more localized in the north). Months with N/A values occurred when MRSea was unable to run for that month due to less than 30 birds being recorded across the full MRSea study area.

Table 4.27: Puffin in Array Area: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	709 (520-980)	0 (0-0)	709 (520-980)	0.83 (0.61-1.14)	0 (0-0)	0.83 (0.61-1.14)	117	16.57
April 2021	378 (277-509)	95 (69-127)	283 (208-382)	0.44 (0.32-0.59)	0.11 (0.08-0.15)	0.33 (0.24-0.44)	59	15.63
May 2021	1,339 (783-2,007)	0 (0-0)	1,339 (783-2,007)	1.56 (0.91-2.34)	0 (0-0)	1.56 (0.91-2.34)	312	23.32
June 2021	863 (556-1320)	2 (1-3)	861 (554-1316)	1.01 (0.65-1.54)	0 (0-0)	1 (0.65-1.53)	195	22.58
July 2021	173 (93-284)	1 (1-2)	172 (92-283)	0.2 (0.11-0.33)	0 (0-0)	0.2 (0.11-0.33)	49	28.28
August 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
September 2021	184 (116-270)	0 (0-0)	184 (116-270)	0.21 (0.13-0.31)	0 (0-0)	0.21 (0.13-0.31)	39	21.38
October 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	228 (169-301)	0 (0-0)	228 (169-301)	0.27 (0.2-0.35)	0 (0-0)	0.27 (0.2-0.35)	34	14.78
March 2022	185 (107-308)	5 (3-8)	180 (104-300)	0.22 (0.12-0.36)	0.01 (0-0.01)	0.21 (0.12-0.35)	51	27.79
April 2022	535 (363-750)	4 (2-5)	532 (360-744)	0.62 (0.42-0.87)	0 (0-0.01)	0.62 (0.42-0.87)	99	18.42
May 2022	480 (312-702)	4 (3-6)	476 (309-696)	0.56 (0.36-0.82)	0 (0-0.01)	0.55 (0.36-0.81)	100	20.77
June 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
July 2022	431 (274-700)	4 (3-7)	427 (272-692)	0.5 (0.32-0.81)	0.01 (0-0.01)	0.5 (0.32-0.81)	108	25.15
August 2022	1313 (824-1,861)	0 (0-0)	1313 (824-1,861)	1.53 (0.96-2.17)	0 (0-0)	1.53 (0.96-2.17)	265	20.15
September 2022	474 (337-698)	0 (0-0)	474 (337-698)	0.55 (0.39-0.81)	0 (0-0)	0.55 (0.39-0.81)	92	19.44
October 2022	144 (86-262)	20 (12-36)	124 (74-226)	0.17 (0.1-0.31)	0.02 (0.01-0.04)	0.14 (0.09-0.26)	45	31.23
November 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 4.28: Puffin in Array Area plus 2 km: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	993 (720-1,384)	0 (0-0)	993 (720-1,384)	0.85 (0.61-1.18)	0 (0-0)	0.85 (0.61-1.18)	169	17.05
April 2021	516 (377-699)	129 (94-175)	387 (283-524)	0.44 (0.32-0.6)	0.11 (0.08-0.15)	0.33 (0.24-0.45)	82	15.91
May 2021	1,833 (1,101-2,709)	0 (0-0)	1,833 (1,101-2,709)	1.56 (0.94-2.31)	0 (0-0)	1.56 (0.94-2.31)	410	22.38
June 2021	1,150 (737-1,782)	3 (2-5)	1,147 (735-1,777)	0.98 (0.63-1.52)	0 (0-0)	0.98 (0.63-1.51)	267	23.17
July 2021	257 (136-423)	2 (1-3)	256 (136-420)	0.22 (0.12-0.36)	0 (0-0)	0.22 (0.12-0.36)	73	28.4
August 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
September 2021	266 (168-387)	0 (0-0)	266 (168-387)	0.23 (0.14-0.33)	0 (0-0)	0.23 (0.14-0.33)	56	21.01
October 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	334 (246-443)	0 (0-0)	334 (246-443)	0.28 (0.21-0.38)	0 (0-0)	0.28 (0.21-0.38)	50	15.04
March 2022	280 (165-458)	7 (4-12)	273 (161-447)	0.24 (0.14-0.39)	0.01 (0-0.01)	0.23 (0.14-0.38)	75	26.72
April 2022	753 (511-1055)	5 (4-7)	748 (507-1,047)	0.64 (0.44-0.9)	0 (0-0.01)	0.64 (0.43-0.89)	139	18.42
May 2022	649 (415-968)	6 (4-8)	644 (411-960)	0.55 (0.35-0.83)	0 (0-0.01)	0.55 (0.35-0.82)	141	21.75
June 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
July 2022	590 (358-1,007)	6 (4-10)	583 (354-997)	0.5 (0.3-0.86)	0.01 (0-0.01)	0.5 (0.3-0.85)	166	28.1
August 2022	2,023 (1,298-2791)	0 (0-0)	2023 (1,298-2,791)	1.72 (1.11-2.38)	0 (0-0)	1.72 (1.11-2.38)	381	18.83
September 2022	641 (446-957)	0 (0-0)	641 (446-957)	0.55 (0.38-0.82)	0 (0-0)	0.55 (0.38-0.82)	130	20.32
October 2022	206 (125-369)	29 (17-51)	177 (108-318)	0.18 (0.11-0.31)	0.02 (0.01-0.04)	0.15 (0.09-0.27)	62	30.21
November 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 4.29: Puffin in Array Area plus 4 km: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	1,332 (956-1,869)	0 (0-0)	1,332 (956-1,869)	0.88 (0.63-1.24)	0 (0-0)	0.88 (0.63-1.24)	233	17.49
April 2021	666 (484-922)	167 (121-231)	499 (363-691)	0.44 (0.32-0.61)	0.11 (0.08-0.15)	0.33 (0.24-0.46)	112	16.77
May 2021	2,370 (1,452-3,489)	0 (0-0)	2,370 (1,452-3,489)	1.57 (0.96-2.31)	0 (0-0)	1.57 (0.96-2.31)	520	21.92
June 2021	1,435 (913-2,271)	4 (2-6)	1,432 (911-2,265)	0.95 (0.6-1.5)	0 (0-0)	0.95 (0.6-1.5)	346	24.13
July 2021	356 (188-588)	2 (1-4)	354 (187-584)	0.24 (0.12-0.39)	0 (0-0)	0.23 (0.12-0.39)	102	28.63
August 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
September 2021	357 (227-517)	0 (0-0)	357 (227-517)	0.24 (0.15-0.34)	0 (0-0)	0.24 (0.15-0.34)	74	20.74
October 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	460 (337-614)	0 (0-0)	460 (337-614)	0.3 (0.22-0.41)	0 (0-0)	0.3 (0.22-0.41)	71	15.36
March 2022	406 (241-661)	11 (6-17)	396 (235-644)	0.27 (0.16-0.44)	0.01 (0-0.01)	0.26 (0.16-0.43)	107	26.38
April 2022	1004 (680-1,423)	7 (5-10)	997 (675-1413)	0.66 (0.45-0.94)	0 (0-0.01)	0.66 (0.45-0.93)	190	18.88
May 2022	830 (524-1,266)	7 (5-11)	823 (520-1255)	0.55 (0.35-0.84)	0 (0-0.01)	0.54 (0.34-0.83)	189	22.79
June 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
July 2022	750 (435-1,350)	8 (4-14)	742 (430-1,336)	0.5 (0.29-0.89)	0.01 (0-0.01)	0.49 (0.28-0.88)	233	31.12
August 2022	2824 (1,844-3,836)	0 (0-0)	2,824 (1,844-3,836)	1.87 (1.22-2.54)	0 (0-0)	1.87 (1.22-2.54)	508	18
September 2022	845 (580-1,270)	0 (0-0)	845 (580-1,270)	0.56 (0.38-0.84)	0 (0-0)	0.56 (0.38-0.84)	176	20.83
October 2022	278 (170-489)	39 (24-68)	239 (147-421)	0.18 (0.11-0.32)	0.03 (0.02-0.04)	0.16 (0.1-0.28)	81	29.28
November 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 4.30: Puffin in Array Area plus 8 km: Abundance and Density Estimates

	Abundance (Number of Animals)			Density (Number of Animals/km^2)				
Survey	**All Behaviour**	**Flying**	**Sitting**	**All Behaviour**	**Flying**	**Sitting**	**SD**	**CV**
March 2021	2,219 (1,551-3,176)	0 (0-0)	2,219 (1,551-3,176)	0.98 (0.69-1.4)	0 (0-0)	0.98 (0.69-1.4)	415	18.69
April 2021	1,001 (726-1,377)	250 (182-345)	750 (545-1,032)	0.44 (0.32-0.61)	0.11 (0.08-0.15)	0.33 (0.24-0.46)	166	16.58
May 2021	3,574 (2,264-5,122)	0 (0-0)	3,574 (2,264-5,122)	1.58 (1-2.26)	0 (0-0)	1.58 (1-2.26)	729	20.4
June 2021	1,978 (1,243-3,151)	5 (3-8)	1,973 (1,240-3,143)	0.87 (0.55-1.39)	0 (0-0)	0.87 (0.55-1.39)	487	24.6
July 2021	606 (315-1,000)	4 (2-6)	602 (314-994)	0.27 (0.14-0.44)	0 (0-0)	0.27 (0.14-0.44)	175	28.84
August 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
September 2021	568 (365-818)	0 (0-0)	568 (365-818)	0.25 (0.16-0.36)	0 (0-0)	0.25 (0.16-0.36)	116	20.33
October 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
November 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2021	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2022	777 (564-1,055)	0 (0-0)	777 (564-1,055)	0.34 (0.25-0.47)	0 (0-0)	0.34 (0.25-0.47)	125	16.12
March 2022	789 (453-1,316)	20 (12-34)	768 (441-1,282)	0.35 (0.2-0.58)	0.01 (0.01-0.02)	0.34 (0.19-0.57)	220	27.93
April 2022	1,609 (1,094-2,239)	11 (8-15)	1,598 (1,087-2,224)	0.71 (0.48-0.99)	0 (0-0.01)	0.71 (0.48-0.98)	292	18.15
May 2022	1217 (770-1,831)	10 (7-16)	1,207 (763-1,815)	0.54 (0.34-0.81)	0 (0-0.01)	0.53 (0.34-0.8)	271	22.24
June 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
July 2022	1,038 (567-1,949)	11 (6-20)	1,027 (561-1,929)	0.46 (0.25-0.86)	0 (0-0.01)	0.45 (0.25-0.85)	353	33.99
August 2022	4,533 (3,025-6,136)	0 (0-0)	4,533 (3,025-6,136)	2 (1.34-2.71)	0 (0-0)	2 (1.34-2.71)	794	17.51
September 2022	1,428 (957-2,148)	0 (0-0)	1,428 (957-2,148)	0.63 (0.42-0.95)	0 (0-0)	0.63 (0.42-0.95)	304	21.28
October 2022	451 (281-771)	63 (39-107)	389 (242-664)	0.2 (0.12-0.34)	0.03 (0.02-0.05)	0.17 (0.11-0.29)	125	27.71
November 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
December 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
January 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
February 2023	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

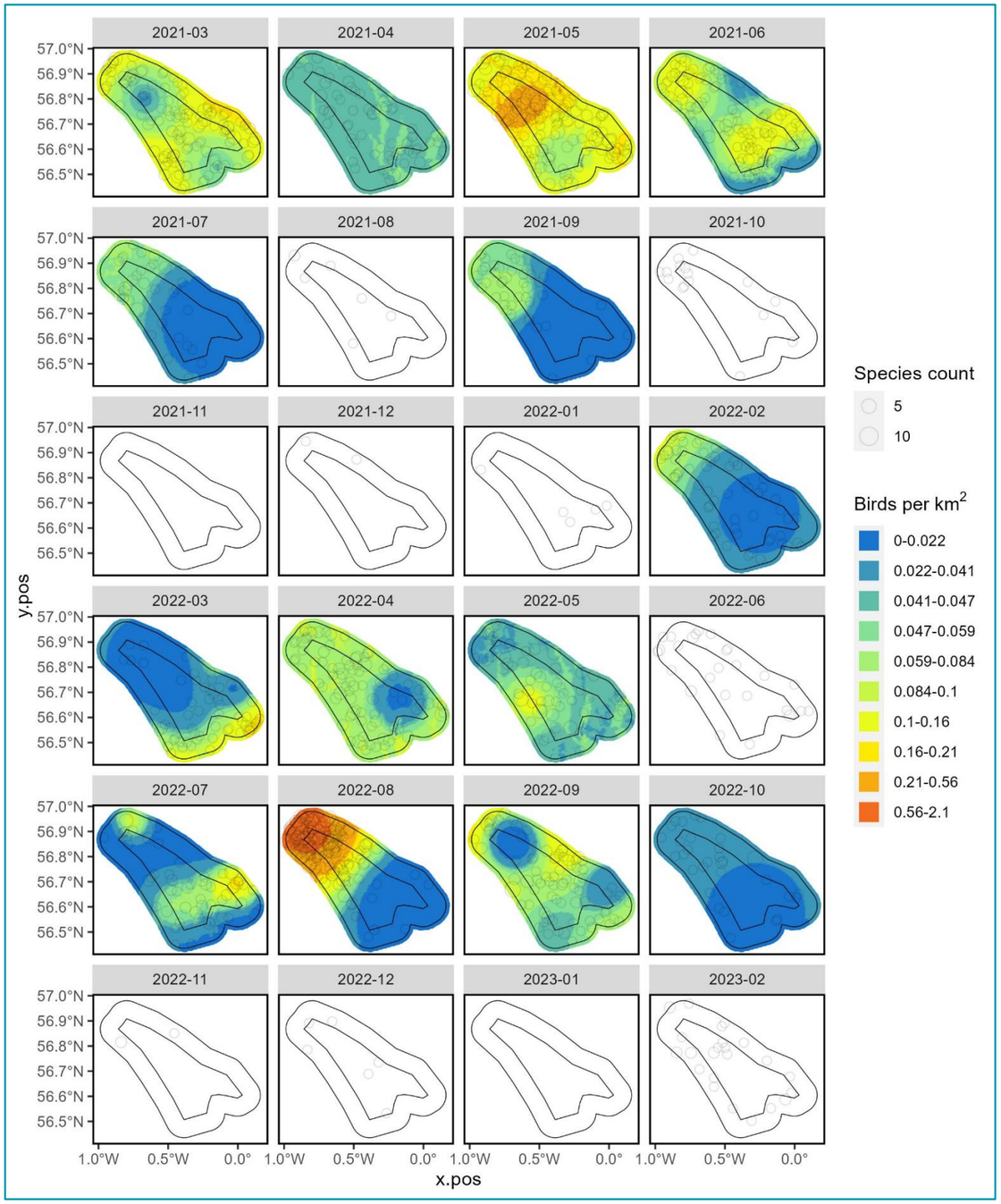

Figure 4.6: MRSea Modelled Puffin Relative Densities (Birds per km^2) and Raw Counts in Survey Area

5. DISCUSSION AND CONCLUSIONS

74. Species densities and distributions were modelled using the MRSea package in R and compared to design-based estimates to verify the outputs. For the majority of months and species there was good agreement between the MRSea estimates and design-based estimates (<1,000 bird difference; volume 3, appendix 11.4, annex B). Differences did occur with regard to common guillemot when more data points were observed nearer the edge of the site (e.g. as seen in Months April 2021 and May 2021 and 2022). For other months, large differences did not appear to be due to edge effects (i.e. the presence data which are concentrated near the boundary or edge of the study area. These effects can have significant implications for the accuracy and interpretation of the model results) indicating that the environmental variables are influencing the model predictions. Due to the large MRSea study area with depths ranging from -57m to -145 m, it is considered likely that environmental covariates have a significant impact on species abundance within this surveyed area.

75. This report has identified the following key points:

- Guillemot was the most abundant auk species in the MRSea study area. They were heterogeneously distributed across the MRSea study area, with peaks occurring in the breeding season in 2021 and directly after the breeding season in 2022.
- Kittiwake varied in their abundance across the MRSea study area, with peaks observed in June 2021 and July 2021. The peak densities of kittiwake were typically observed in the far north and south of the MRSea study area.
- Gannet were observed in high densities in the MRSea study area in July 2021 and October 2022
- Like guillemot, fulmar were present within the MRSea study area in all months (Table 4.16), with hotspots typically occurring within the Array (Figure 4.4).
- Abundances were highest in the summer months.
- Razorbills were relatively abundant in the MRSea study area, and similar to guillemots, the peak timings were typically in July (Table 4.21).
- Puffins were the third most abundant auk species in the MRSea study area, with peak numbers varying between years. In 2021, the highest abundances were observed in June, whereas in 2022 the highest abundances were in August.

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ANNEX A: MRSEA VALIDATION METHODOLOGY

76. Please find Annex A attached to this document separately.

ANNEX B: MRSEA AND DESIGN BASED COMPARISONS

77. Please find Annex B attached to this document separately.

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