Environmental Impact Assessment Report

NISA

North Irish Sea Array

Volume 9: Appendices (Offshore)

Appendix 15.2

MRSea Modelling for Offshore Ornithology

Statkraft CIP Copenhagen Infrastructure Partners GoBe APEM Group ARUP

North Irish Sea Array Windfarm Ltd

MRSea Modelling for Offshore Ornithology

North Irish Sea Array Offshore Wind Farm

Confidentiality

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Revision	Date	Status	Author:	Checked by:	Approved by:
1.0	May 2024	Final	GoBe	JM	CC

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Acronyms

Term	Definition
ACF	Autocorrelation function
ANOVA	Analysis of Variance
CI	Confidence interval
CREEM	Centre for Research into Ecological and Environmental Modelling
CReSS	Complex Region Spatial Smoother
DAS	Digital aerial survey
EIAR	Environmental Impact Assessment Report
GAM	Generalised Additive Model
GVIF	Generalised variance inflation factors
MAC	Maritime Area Consent
MRSea	Marine Renewables Strategic Environmental Assessment
NISA	The North Irish Sea Array
OWF	Offshore wind farm
QA	Quality assurance
SALSA	Spatially Adaptive Local Smoothing Algorithm

1 Introduction

1.1 Project Background

1.1.1 This document has been prepared by GoBe Consultants Limited (GoBe) on behalf of North Irish Sea Array Windfarm Limited (NISA Ltd) to accompany Volume 3, Chapter 15: Offshore and Intertidal Ornithology.

1.1.2 The North Irish Sea Array (NISA) Offshore Wind Farm (OWF) (hereafter the 'proposed development') is proposed for construction 11.3 km off the east coast of Ireland (at their nearest points to the mainland). The proposed development will consist of offshore wind turbine generators (WTGs), an offshore substation platform (OSP), inter-array cables and export cables. The area considered in the context of offshore ornithological receptors includes the entire proposed development array area, covering 89 km^2, an asymmetric 4 km buffer surrounding the array area, and the offshore Export Cable Corridor (ECC) covering a further 67.9 km^2.

1.1.3 During the breeding season, the Irish Sea region provides foraging, loafing and preening habitat for a range of seabirds, including (but not limited to) northern gannet, *Morus bassanus*, various gull species, and several species of auks and terns. An overview of key species present within and in close proximity to the proposed development is presented in Volume 9, Appendix 15.1: Offshore Ornithology Technical Baseline (hereafter referred to as the 'Technical Baseline').

1.2 MRSea modelling

1.2.1 This report summarises analysis of pre-construction Digital Aerial Surveys (DAS) undertaken at the proposed development site. One survey per month was conducted between May 2020 and October 2022 inclusive, although no surveys were completed in January 2021. This survey programme consisted of 29 surveys in total across more than two years.

1.2.2 GoBe were tasked with providing model-based abundance and density estimates for guillemots and razorbills using the Marine Renewables Strategic Environmental Assessment (MRSea) modelling framework, created specifically for offshore wind development (Scott-Hayward et al., 2013). A single model run was completed to determine receptor distribution across all surveys.

1.2.3 The aim of this analysis was to support the impact assessment of the proposed development and to verify the design-based results (abundance estimates used within displacement modelling) within the Environmental Impact Assessment Report (EIAR). The distribution of auks within the array estimated from models can be compared with the distributions predicted from raw observations to get a better understanding of area usage in relation to environmental variables. Where necessary, information about 'hotspots' (i.e. areas that regularly support high densities of birds) can be used to help inform the EIA process in terms of understanding area usage relative to the location of the proposed development. This analysis is additional to the standard assessment guidance and was undertaken in acknowledgement that the proposed development now sits within the North-West Irish Sea candidate Special Protection Area (cSPA), which was not the case when the proposed development was awarded its Maritime Area Consent (MAC). Therefore, a robust assessment with) and verification of outcomes on impacts to qualifying interests is of greater importance.

1.2.4 Common guillemot (*Uria aalge*, referred to as guillemot for the remainder of this report) and razorbill (*Alca torda*) were prioritised for model-based abundance and distribution within the survey area because they were the most frequently sighted species, and observed in varying densities throughout all months of the year, which lends themselves to MRSea modelling. They are also qualifying interests of the cSPA and potentially sensitive to displacement.

2 Survey Methods

2.1 Data Collection and Survey Design – Digital Aerial Surveys

2.1.1 The DAS data was collected via monthly transect surveys across the Maritime Area Consent (MAC) boundary, with a 4 km buffer (644 km^2), of the proposed development site, shown in Figure 2-1.

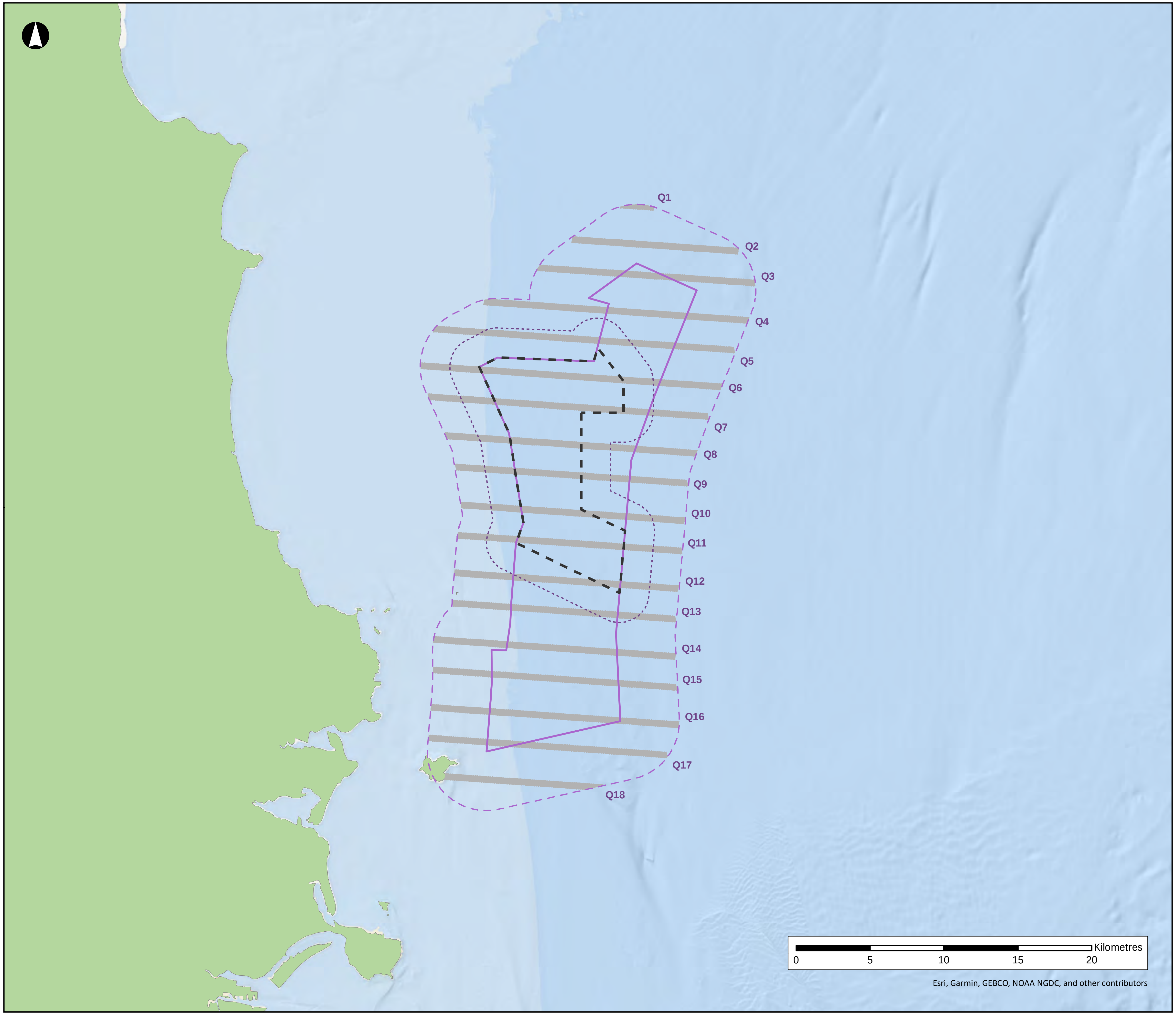
2.1.2 The data collected were 1.5 cm ground survey distance digital still images, by a twin-engine aircraft flying at an altitude of 1,300 feet at a speed of approximately 120 knots. Images were collected along 18 transects across the MAC plus 4 km buffer (referred to herein as the 'Survey Area'), with a minimum of 15% of the sea surface covered, during each survey, for analysis. Surveys were also conducted under the following environmental conditions:

- Cloud base: >1,700 feet;
- Visibility: >5 km;
- Windspeed: <30 knots;
- Sea state: 4 or less (Beaufort 5 or 6); and
- No icing conditions.

2.1.3 Seabirds were identified to species level during image analysis, where identification to species level was not possible, individuals were classified to the lowest taxonomic level. To ensure the accuracy of the species identification, the survey contractor (APEM Ltd) conducted internal quality assurance, this also guaranteed any missed individuals were included in the data. The data collected during the DAS provided the following information:

- Date and time of each seabird and recorded during a survey;
- Corresponding coordinates for each seabird recorded;
- Age, sex and moult status of seabirds, where possible;
- Additional behavioural information whether a bird is sitting, flying, or diving; and
- Estimated flight heights, where possible.

2.1.4 Further details regarding data collection and survey design are available in Appendix 15.1: Offshore and Intertidal Ornithology Technical Baseline.



Array Area
2km Buffer from Array Area
MAC Boundary (Array Area Only)
4km Buffer from MAC Boundary (Array Area Only)
Survey Transect

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Figure Title
Ornithological Digital Survey Area (Array MAC and 4km Buffer) and Transects. The Area of Interest (Array Area and 2km Buffer) is also presented

Job No: 281240	Datum: WGS84 Projection: UTM30N
Date: May 2024	Figure No: 2.1
Scale: 1:250,000 @A3	
Status: Issue	

2.2 Quality Assurance Procedure

2.2.1 A standard internal Quality Assurance (QA) procedure was carried out for each survey. Images were assessed in batches with a different staff member responsible for each batch. Each bird image was reviewed and checked by APEM's own dedicated QA manager, ensuring that 100% of birds found in the images were subject to internal QA. The QA manager, an experienced ornithologist, is responsible for maintaining and updating the image library and provides advice and guidance to the image processing staff. Images containing no birds were removed and kept separately for further QA. Of these 'blank' images, 20% were randomly selected for the QA process.

2.3 Data Analysis: Model-based Abundance Estimates

2.3.1 To provide more detail for guillemot and razorbill within the array area, model-based approaches were used to determine statistically robust, spatially distributed population estimates. Using model-based techniques means that environmental variables can be included within the analysis to help predict abundance and density distributions within the Survey Area or any subset of this area. MRSea based analysis was used to generate estimates of distribution and abundance, underpinned by observations of guillemot and razorbill recorded in the DAS imagery (Scott-Hayward et al., 2014).

2.3.2 MRSea is a statistical analysis software package specifically designed by the Centre for Research into Ecological and Environmental Modelling (CREEM) for both baseline analysis (site characterisation) and, where data are available, pre- and post-construction analysis (Scott-Hayward et al., 2013). The latter can be used for investigating potential changes in distributions of birds following an OWF's development. The model uses a "Complex Region Spatial Smoother" spatial modelling technique with a "Spatially Adaptive Local Smoothing Algorithm" (CReSS-SALSA) to estimate bird distributions in a Generalised Additive Model (GAM) framework. This modelling method was developed to analyse spatial abundance data following an environmental change, such as the construction of a wind farm, and allows spatially auto-correlated and zero-inflated data to be modelled in a robust way (Onoufriou et al., 2021).

Modelling Approach Details

2.3.3 The steps used to fit the models are described below in general terms. Actual model fit and the environmental variables included in the models may vary with each species.

2.3.4 The model was based on a spatially adaptive GAM to permit nonlinear relationships on the link scale for each candidate covariate (depth, distance to SPA). This model was used to test for collinearity between variables using generalised variance inflation factors (GVIF) using the 'Car' package (Fox & Weisberg, 2015). Variables were assessed using both the GVIF value and by inspecting correlation plots to determine whether the variables correlate with each other. Excessive levels of collinearity (above five) can cause issues with model fit.

2.3.5 The X and Y coordinates were included as a two-dimensional spatial smoother. Survey was included as a factor variable within the model which also included an interaction term between the survey variable and the smoothed spatial term (X and Y coordinates). This allowed for the knot coefficients (but not the position of the knots) to vary between surveys, if appropriate.

Model Specifications

2.3.6 Due to the nature of seabird count data, such data generally displays properties of an over-dispersed Poisson distribution. Models were assessed visually to determine the most appropriate error terms. Data collected along transects and repeated surveys may lead to temporal correlation. This was assessed as part of the model process with runs tests and autocorrelation function plots.

2.3.7 A CreSS basis was used to fit the spatial density surface. Model flexibility is determined by both the number of 'knots' used (i.e. anchor points) for the model and the effective range (r) of the basis associated with each knot. SALSA2D was used to determine the number/location of knots and the r parameters with quantile regression BIC (QBIC) as the selection criterion.

Spatially Explicit Inference

2.3.8 The data used within the modelling process were collected from a DAS programme, across the Survey Area, conducted from May 2020 to October 2022 (Table 2-1). One survey per month was conducted between May 2020 and October 2022 inclusive, although no surveys were completed in January 2021 due to weather. For the months November 2020 and February 2021 no guillemots or razorbills were identified to species level within the surveys conducted.

2.3.9 Similar geo-referenced locations are deemed more likely to return similar counts, with points close together often showing greater similarity than points distant in time and space. If the environmental variables that describe patterns of high and low numbers in a specific geographic location were missing from the model specification, a pattern in the model residuals often remains. This pattern in the model residuals violates the critical assumption for most statistical analysis (such as GAMs) which requires independence of errors. This can invalidate all model-based estimates of precision and may mean estimates are poor. If residual correlation was detected, then robust standard errors were used as these allow for the autocorrelation present to provide realistic model-based estimates of uncertainty. As part of this process, a blocking structure must be chosen such that the residuals are permitted to be correlated within blocks but are deemed independent between blocks. Survey ID (month as a numeric variable), concatenated with Transect ID, was specified as the blocking structure to ensure that the model should treat data from within each transect of each survey as correlated, but independent between different transects and surveys. These independence assumptions were validated by visual assessment of autocorrelation function (ACF) plots (See Appendix A1).

Table 2-1 Surveys included within the model for guillemot and razorbill. Months with no observations (orange) and no surveys undertaken (grey) are highlighted.

Guillemot & Razorbill					
Survey No.	Survey Month 2020	Survey No.	Survey Month 2021	Survey No.	Survey Month 2022
	January		January	20	January
	February	09	February	21	February
	March	10	March	22	March
	April	11	April	23	April
01	May	12	May	24	May
02	June	13	June	25	June
03	July	14	July	26	July
04	August	15	August	27	August
05	September	16	September	28	September
06	October	17	October	29	October
07	November	18	November		November
08	December	19	December		December

Model Selection

2.3.10 In the initial one-dimensional SALSA model, a knot is placed at the median of the variables. During the optimisation process, additional knots can be chosen based on areas within the covariate range in greatest need of extra flexibility. For the two-dimensional SALSA model, initial knot locations on the spatial surface were chosen to maximise the coverage across the spatial area, with these permitted to move according to the SALSA model selection. QBIC was be used to determine the flexibility for the spatial models or to have knots added or removed depending on the areas in need of flexibility across the spatial term.

2.3.11 Model fits were assessed via review of levels of residual autocorrelation using autocorrelation functions and run tests. Additionally, model selection was completed using an Analysis of Variance (ANOVA), enabling p-values for each term to be scrutinised. The two-dimensional relationship was plotted and checked for sensibility and an F-test was used for cumulative residual plots to check if covariates were modelled appropriately.

2.3.12 The final model used for each analysis are summarised in Table 2-2. The model selection process for the complete dataset determined the best model to include.

Table 2-2 Final model used in all guillemot and razorbill analysis.

Model	Model Covariates
Final Model	Survey + LRF.g(radiusIndices, dists, radii, aR) + Survey:LRF.g(radiusIndices, dists, radii, aR) + offset(log(area))

Prediction Grid

2.3.13 A Prediction grid was constructed by clipping a grid of 1 km² grid cells to the shapefile of the Survey Area. Each grid cell was then associated with depth (bathymetry) and distance to SPA, which were derived from the location information derived from the survey observations.

2.3.14 This prediction grid was clipped to the array area (with 2km buffer) to provide unapportioned guillemot and razorbill population and density estimates for this region. A 2km buffer was used because this is the standard area over which displacement of auks is assessed as stated in the Irish Phase One Method Statement (Appendix 15.7). These additional outputs are displayed, alongside the overall Survey Area results, within sections 3 & 4.

2.3.15 Array area (with 2 km buffer) estimates were adjusted to account for birds not identified to a species level by adding an apportionment factor taken from the design-based estimates over the same region. This provided total apportioned population and density estimates for the array area (with 2 km buffer) that is displayed, alongside the overall Survey Area results, within sections 3 & 4.

2.3.16 This analysis was used to model the abundance and distribution of guillemots and razorbills. Bootstrapping (n=1,000) was used to estimate the uncertainty of parameter estimation and the resulting parametric confidence intervals were plotted for each month.

Modelling Distribution

2.3.17 To model the distribution of birds, the output of the model-based abundances for each species were clipped to the array area and 2km buffer. For each zone, the density per km^2, and lower and upper confidence intervals (CIs) were calculated. The 95% CIs were generated from the 1,000 replicates of a parametric bootstrap created during the modelling process. These outputs were used to visually estimate the density of guillemots and razorbills in the array area + 2km buffer.

3 Guillemot Results

3.1 Guillemot Population Estimates and Distribution

Overall Analysis

3.1.1 Guillemots were recorded in all but two surveys (November 2020 and February 2021). The peak raw count for guillemots (Survey Area) was recorded in August 2021 (17,653 individuals). Raw counts for each month are presented in Table 3-1.

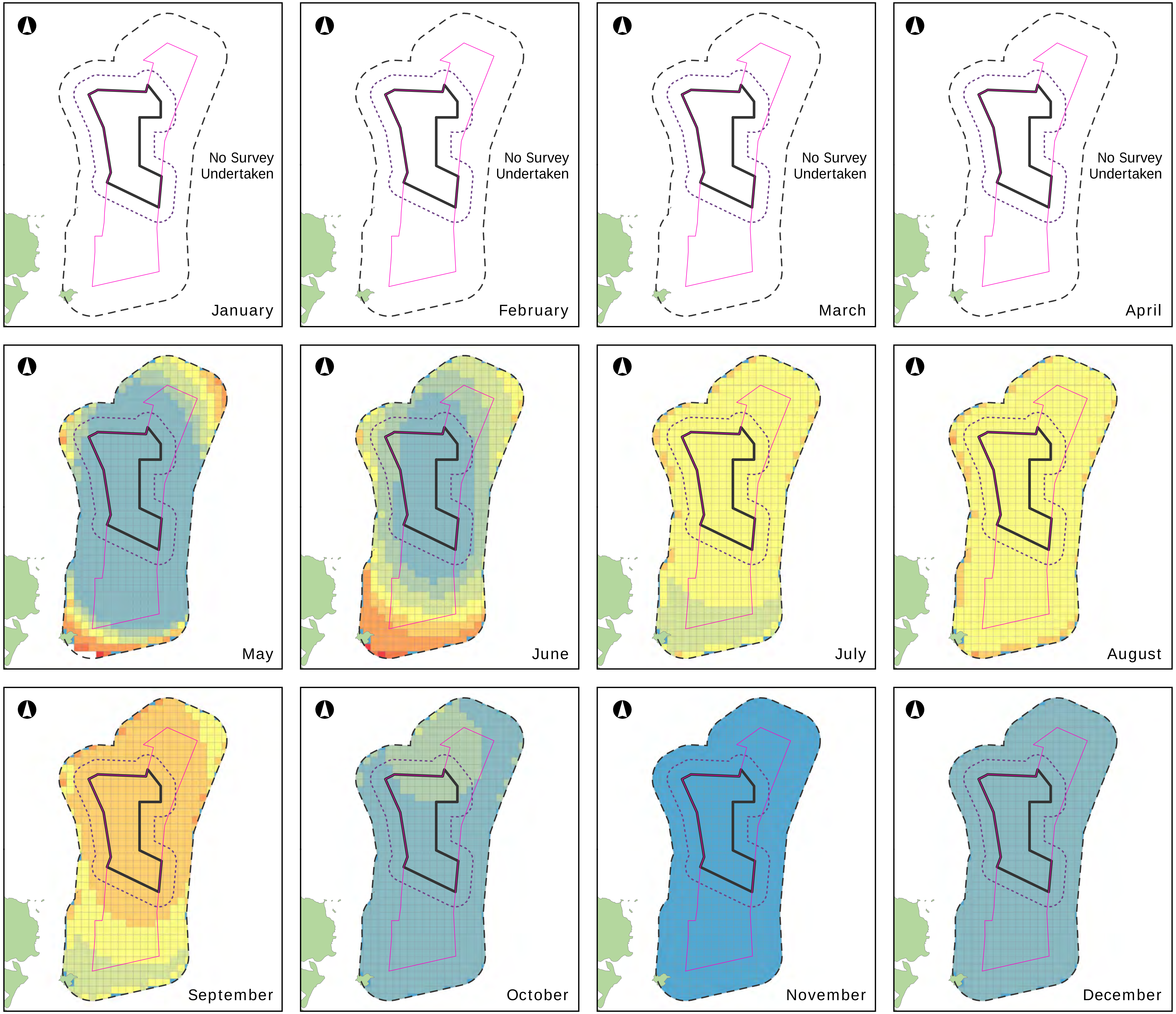
3.1.2 Model-based population estimates are also presented in Table 3-1. Unapportioned peak abundance in the array area (with 2 km buffer), was estimated in August 2021, with 22,627 guillemots - equating to a density of 112 birds/km^2. Peak abundance in the overall Survey Area was estimated in August 2021, with 86,927 guillemots – equating to a density of 135 birds/km^2. Apportioned abundance estimates are presented in Table 3-1.

3.1.3 Results from the model-based density distributions are presented in Figure 3-1Figure 3-2Figure 3-3 for the years 2020, 2021 and 2022 respectively. These indicate that the highest density of guillemots is predicted in the south-western section of the Survey Area and generally outside of the array area +2km buffer. The months of August and September (across all years) are estimated to have the highest densities of guillemots.

3.1.4 The highest densities of guillemots were to the south-west of the survey area, with relatively low overlap with the array area. Therefore, there are lower densities recorded within the array area and 2km buffer.

Table 3-1 Overall numbers of individual guillemots recorded within each survey and model-based abundance and density estimates, with lower and upper confidence limits, within the NISA array boundary (with a 2 km buffer) and the Survey Area. Surveys with no data availability are highlighted in orange. No surveys were undertaken in January 2021.

Survey No.	Survey Month	Raw Count (Survey Area)	Array area plus 2 km buffer - Unapportioned				Array area plus 2 km buffer - Apportioned				Survey Area - Unapportioned			
			Model Based Population Estimate	Lower CI	Upper CI	Density Estimate (birds/km^2)	Model Based Population Estimate	Lower CI	Upper CI	Density Estimate (birds/km^2)	Model Based Population Estimate	Lower CI	Upper CI	Density (birds/km^2)
01	May, 2020	3,585	119	56	1,998	1	198	93	3,324	1	15,535	3,360	111,081	24
02	June, 2020	6,326	778	476	1,467	4	992	607	1,871	5	19,734	12,247	33,229	31
03	July, 2020	3,898	7,426	6,095	9,167	37	8,430	6,919	10,406	42	20,688	16,546	26,176	32
04	August, 2020	4,339	7,057	4,746	10,536	35	7,214	4,852	10,770	36	22,496	14,193	36,313	35
05	September, 2020	7,268	16,107	12,600	20,520	80	18,583	14,537	23,675	92	36,743	28,624	47,093	57
06	October, 2020	336	683	388	1,246	3	5,416	3,077	9,880	27	1,683	1,024	2,947	3
07	November, 2020													
08	December, 2020	79	124	79	193	1	1,121	714	1,745	6	389	227	689	1
-	January, 2021													
09	February, 2021													
10	March, 2021	3,089	6,097	4,711	7,835	30	6,915	5,343	8,886	34	15,254	11,303	20,534	24
11	April, 2021	861	1,300	1,068	1,601	6	1,630	1,339	2,007	8	3,987	3,098	5,186	6
12	May, 2021	3,815	368	149	2,064	2	469	190	2,633	2	18,163	8,872	43,991	28
13	June, 2021	1,932	356	122	1,206	2	448	154	1,519	2	8,666	4,461	18,211	13
14	July, 2021	3,427	587	201	2,099	3	605	207	2,164	3	11,600	4,115	40,296	18
15	August, 2021	17,653	22,627	18,129	28,520	112	23,998	19,227	30,248	119	86,927	68,575	111,583	135
16	September, 2021	12,337	19,837	15,219	26,489	98	21,683	16,635	28,954	108	64,984	46,997	91,388	101
17	October, 2021	1,699	2,571	1,941	3,429	13	3,477	2,625	4,637	17	8,441	6,279	11,400	13
18	November, 2021	1,764	2,862	2,269	3,592	14	4,928	3,907	6,185	24	9,295	7,098	12,319	14
19	December, 2021	647	1,117	837	1,528	6	1,817	1,361	2,485	9	3,351	2,209	5,903	5
20	January, 2022	3,998	1,102	616	2,054	5	1,771	990	3,301	9	21,830	14,167	34,064	34
21	February, 2022	2,413	2,406	1,680	3,498	12	3,494	2,440	5,080	17	12,137	8,373	17,833	19
22	March, 2022	1,244	827	470	1,437	4	1,114	633	1,935	6	6,132	3,704	10,132	10
23	April, 2022	925	1,694	1,110	2,581	8	1,869	1,225	2,848	9	4,514	2,786	7,213	7
24	May, 2022	2,814	344	118	2,474	2	396	136	2,849	2	16,407	6,376	53,622	25
25	June, 2022	2,769	239	84	1,225	1	249	88	1,276	1	15,503	7,672	36,545	24
26	July, 2022	6,423	10,390	7,371	14,727	52	10,581	7,507	14,998	52	29,019	20,105	41,787	45
27	August, 2022	10,964	19,725	16,947	23,099	98	19,793	17,006	23,179	98	52,150	42,963	63,505	81
28	September, 2022	10,847	18,485	14,755	23,233	92	19,265	15,377	24,213	96	53,238	42,165	67,770	83
29	October, 2022	4,727	8,173	6,787	9,857	41	11,166	9,272	13,466	55	23,302	18,571	29,502	36



Array Area
2km Buffer from Array Area
MAC Boundary (Array Area Only)
4km Buffer from MAC Boundary (Array Area Only)

Density (per km^2)
- 0
- 0 - 5
- 5 - 10
- 10 - 25
- 25 - 50
- 50 - 100
- 100 - 500
- 500 - 1000
- >1000

Kilometres
0 2 4 6 8 10

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Figure Title
Model-based Density Distribution for Guillemots, within the MAC Boundary (Array Area only) with a 4km Buffer applied, in 2020

Job No: 281240	Datum: WGS84 Projection: UTM30N
Date: May 2024	Figure No: 3.1
Scale: 1:500,000 @A3	
Status: Issue	

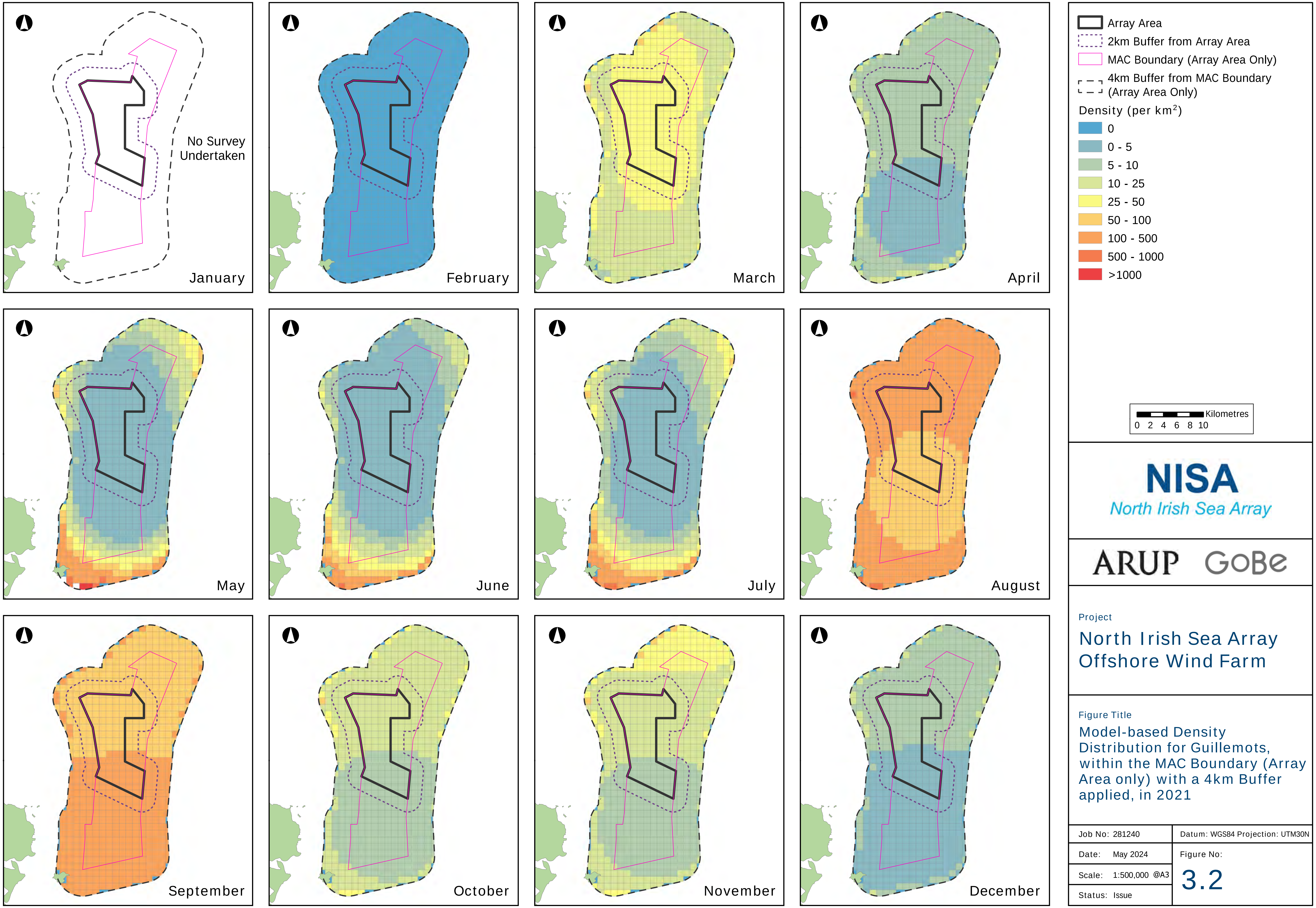

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Figure Title
Model-based Density Distribution for Guillemots, within the MAC Boundary (Array Area only) with a 4km Buffer applied, in 2021

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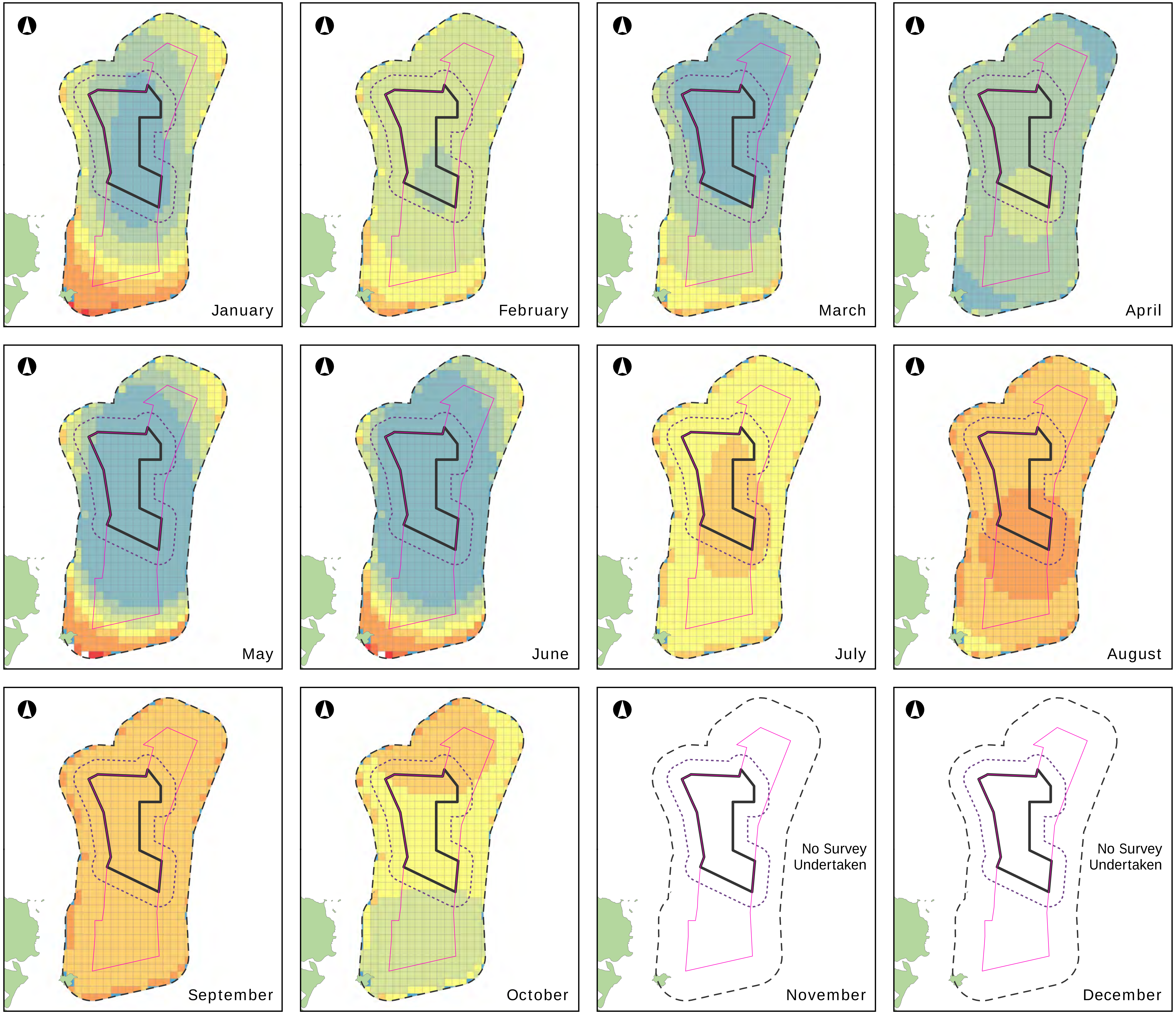
Date: May 2024	Figure No: 3.2
Scale: 1:500,000 @A3	
Status: Issue	



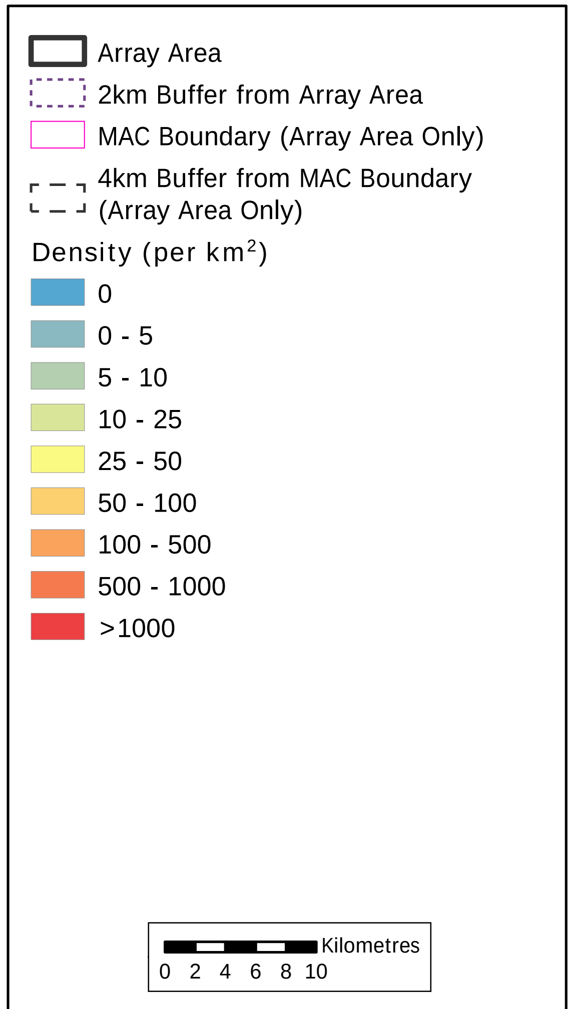


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Figure Title
Model-based Density Distribution for Guillemots, within the MAC Boundary (Array Area only) with a 4km Buffer applied, in 2022

Job No: 281240	Datum: WGS84 Projection: UTM30N
Date: May 2024	Figure No: 3.3
Scale: 1:500,000 @A3	
Status: Issue	

4 Razorbill Results

4.1 Razorbill Population Estimates and Distribution

Overall Analysis

4.1.1 Razorbills were recorded in all but two surveys (November 2020 and February 2021). The peak raw count for razorbills (Survey Area) was recorded in August 2021 (3,495 individuals). Raw counts for each month are presented in Table 4-1.

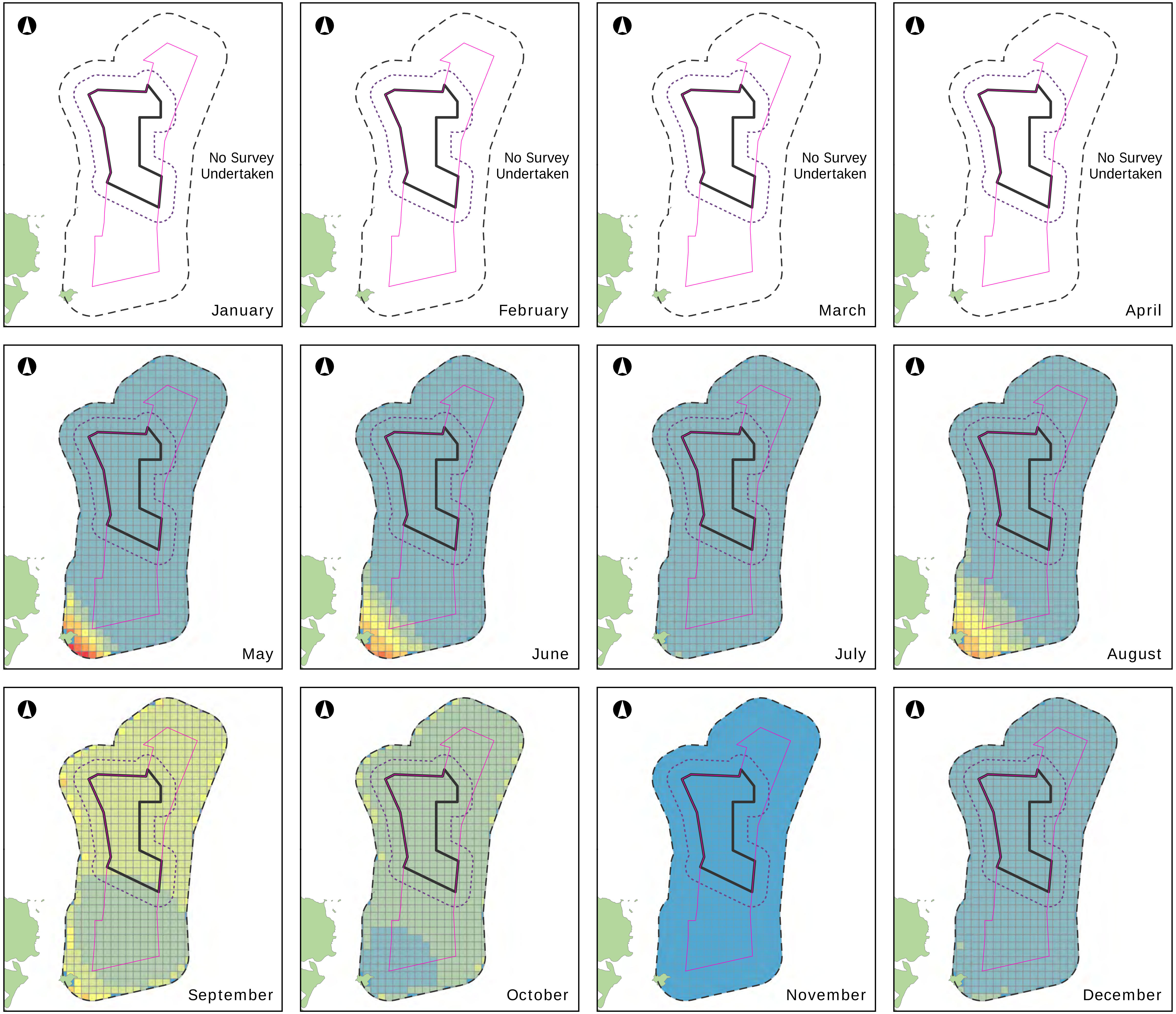
4.1.2 Model-based population estimates are also presented in Table 4-1. Peak abundance within the array area (with 2 km buffer) was estimated in December 2021, with 2,614 razorbills - equating to a density of 13 birds/km^2. Peak abundance for the overall Survey Area was estimated in August 2021, with 17,527 razorbills – equating to a density of 27 birds/km^2.

4.1.3 Results from the model-based density distributions are presented in Figure 4-1Figure 4-2Figure 4-3 for the years 2020, 2021 and 2022 respectively. These indicate that the highest density of razorbills is predicted in the south-western section of the Survey Area. The months of August (in 2020 and 2021) and September (in 2022) are estimated to have the highest densities of razorbills in this area.

4.1.4 The highest densities of razorbills were to the south-west of the survey area, with relatively low overlap with the array area). Therefore, there are lower densities recorded within the array area and 2km buffer.

Table 4-1 Overall numbers of individual razorbills recorded within each survey and model-based abundance and density estimates, with lower and upper confidence limits, within the NISA array boundary (with a 2 km buffer) and the Survey Area. Surveys with no data availability are highlighted in orange.

Survey No.	Survey Month and Year	Raw Count (Survey Area)	Array area plus 2 km buffer - Unapportioned				Array area plus 2 km buffer - Apportioned				Survey Area - Unapportioned			
			Model Based Population Estimate	Lower CI	Upper CI	Density Estimate (birds/km^2)	Model Based Population Estimate	Lower CI	Upper CI	Density Estimate (birds/km^2)	Model Based Population Estimate	Lower CI	Upper CI	Density (birds/km^2)
01	May, 2020	551	70	46	112	-	79	52	126	-	1,917	1,061	3,596	3
02	June, 2020	410	64	44	95	-	74	51	109	-	1,058	625	1,882	2
03	July, 2020	66	115	78	163	1	130	88	185	1	356	227	561	1
04	August, 2020	278	107	36	309	1	108	36	312	1	1,184	332	4,207	2
05	September, 2020	790	1,467	574	3,777	7	1,644	643	4,232	8	4,124	1,662	10,531	6
06	October, 2020	361	616	417	943	3	2,300	1,557	3,521	11	1,753	1,086	3,054	3
07	November, 2020													
08	December, 2020	69	86	47	164	-	926	506	1,767	5	338	159	779	1
-	January, 2021													
09	February, 2021													
10	March, 2021	162	267	207	342	1	299	232	383	1	795	576	1,111	1
11	April, 2021	29	45	27	76	-	52	31	88	-	131	70	282	-
12	May, 2021	222	16	5	42	-	18	6	48	-	1,034	549	2,088	2
13	June, 2021	52	11	2	46	-	11	2	46	-	242	82	731	-
14	July, 2021	65	18	10	36	-	18	10	36	-	107	44	352	-
15	August, 2021	3,495	1,111	771	1,645	6	1,168	810	1,729	6	17,527	11,080	29,266	27
16	September, 2021	923	553	384	788	3	581	403	827	3	5,727	3,113	11,568	9
17	October, 2021	295	556	371	828	3	697	465	1,038	3	1,473	939	2,356	2
18	November, 2021	1,238	2,490	1,517	4,208	12	3,320	2,023	5,611	16	6,210	3,700	11,182	10
19	December, 2021	1,309	2,614	1,547	4,492	13	3,572	2,114	6,139	18	6,740	3,714	13,018	10
20	January, 2022	78	44	25	74	-	63	36	105	-	394	202	800	1
21	February, 2022	254	344	235	503	2	479	327	700	2	1,321	829	2,176	2
22	March, 2022	51	57	29	125	-	65	33	143	-	234	96	695	-
23	April, 2022	95	148	91	232	1	163	100	255	1	469	253	905	1
24	May, 2022	188	52	30	92	-	55	32	97	-	1,166	566	2,569	2
25	June, 2022	349	10	2	47	-	10	2	47	-	3,340	1,536	7,924	5
26	July, 2022	325	156	98	241	1	159	100	246	1	966	623	1,493	2
27	August, 2022	174	6	2	22	-	6	2	22	-	861	511	1,541	1
28	September, 2022	1,469	272	116	719	1	289	123	763	1	7,517	4,840	11,903	12
29	October, 2022	1,363	2,245	1,459	3,503	11	3,555	2,310	5,547	18	6,817	4,160	11,484	11



Array Area
2km Buffer from Array Area
MAC Boundary (Array Area Only)
4km Buffer from MAC Boundary (Array Area Only)

Density (per km^2)

- 0
- 0 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- >200

Kilometres
0 2 4 6 8 10

NISA
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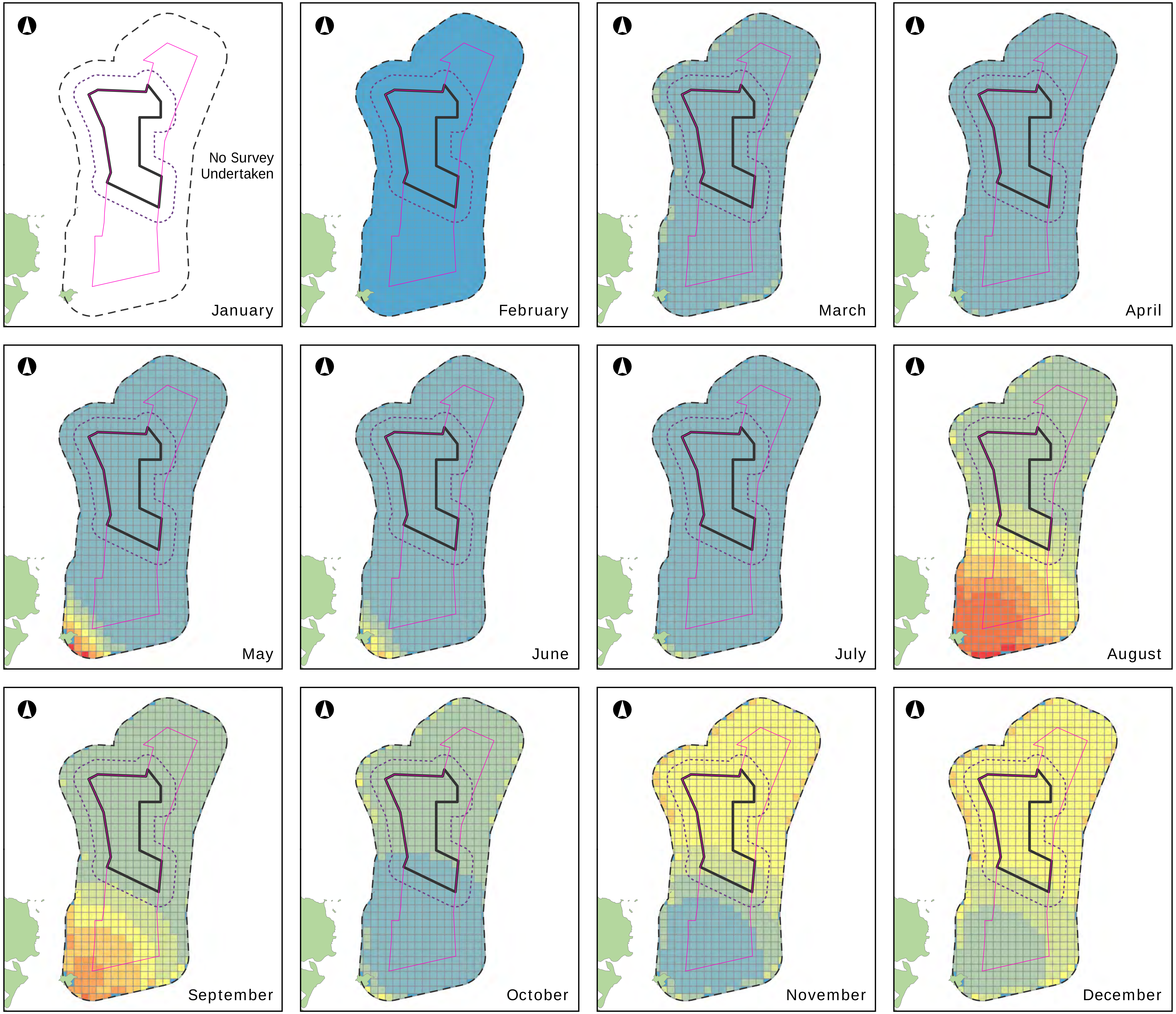
Figure Title
Model-based Density Distribution for Razorbills, within the MAC Boundary (Array Area only) with a 4km Buffer applied, in 2020

Job No: 281240	Datum: WGS84 Projection: UTM30N
Date: May 2024	Figure No:
Scale: 1:500,000 @A3	4.1
Status: Issue	



Array Area
2km Buffer from Array Area
MAC Boundary (Array Area Only)
4km Buffer from MAC Boundary (Array Area Only)

Density (per km^2)
- 0
- 0 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- >200

Kilometres
0 2 4 6 8 10

NISA
North Irish Sea Array

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Figure Title
Model-based Density Distribution for Razorbills, within the MAC Boundary (Array Area only) with a 4km Buffer applied, in 2021

Job No: 281240	Datum: WGS84 Projection: UTM30N
Date: May 2024	Figure No:
Scale: 1:500,000 @A3	4.2
Status: Issue	

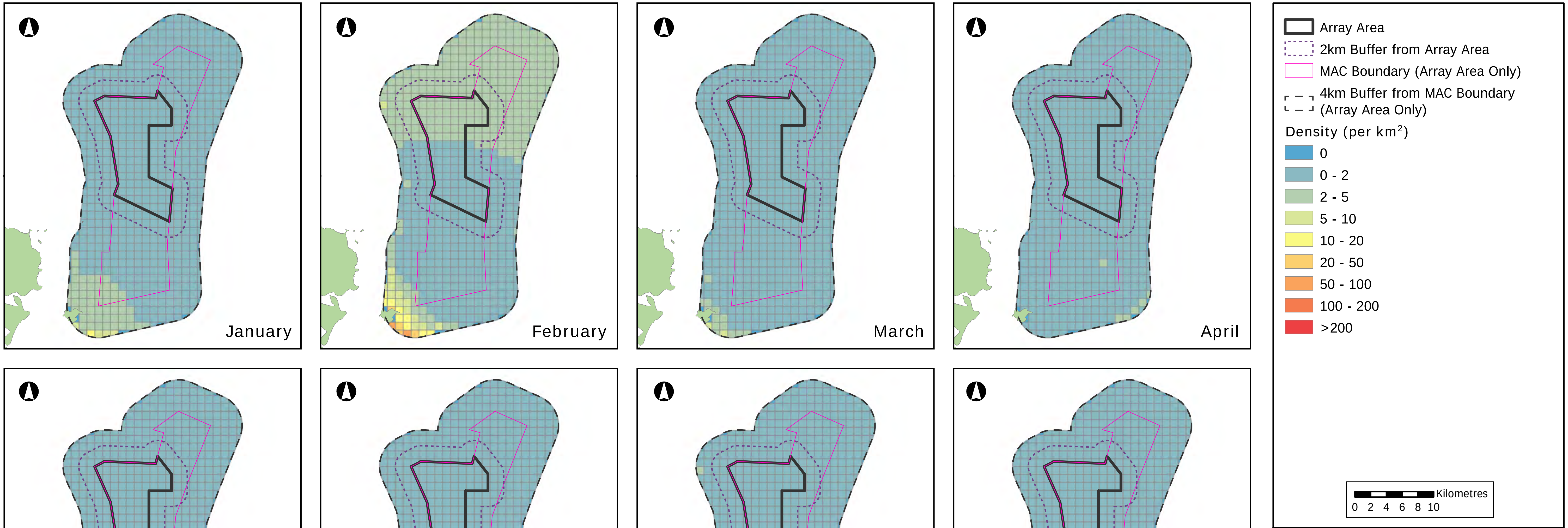

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Figure Title
Model-based Density Distribution for Razorbills, within the MAC Boundary (Array Area only) with a 4km Buffer applied, in 2022

Job No: 281240	Datum: WGS84 Projection: UTM30N
Date: May 2024	Figure No:
Scale: 1:500,000 @A3	4.3
Status: Issue	

5 References

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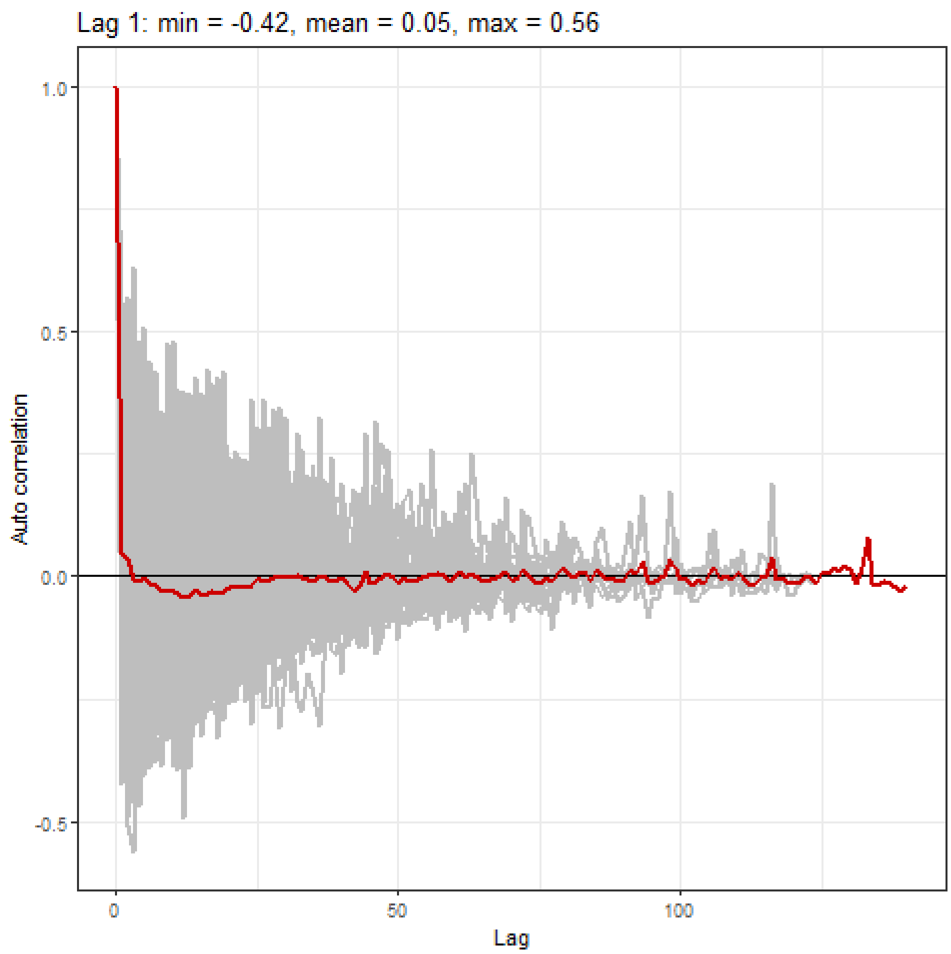
Scott-Hayward, L., Oedekoven, C., Mackenzie, M., & Rexstad, E. (2013). *Statistical Modelling of bird and cetacean distributions in offshore renewables development areas*.

Appendices

A.1 Autocorrelation plots



A-1 1 Autocorrelation plot for the final MRSea model used for guillemot analysis.

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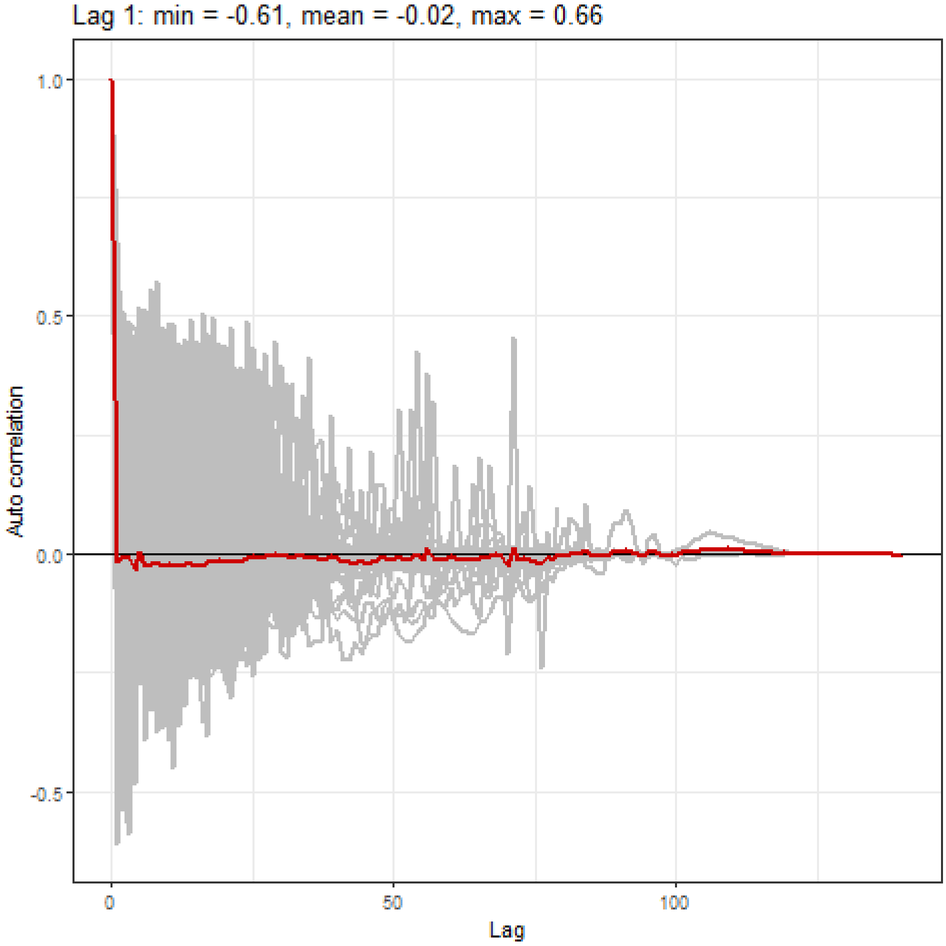

A-1 2 Autocorrelation plot for the final MRSea model used for razorbill analysis.

Further diagnostic plots and materials can be provided upon request.

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