Bellrock Offshore Wind Farm

Wind Farm Development Area

Environmental Impact Assessment Report - Volume IV

Appendix 10.3: Offshore Ornithology Displacement Assessment Report

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Glossary of Terminology

Term	Definition
Applicant	Bellrock Offshore Wind Farm Limited, the legal entity submitting Section 36 Consent and Marine Licence applications for the Bellrock Wind Farm Development Area.
Bellrock Offshore Wind Farm (or the Bellrock Project)	An offshore wind farm capable of exporting up to 1.8 GW of renewable energy to the National Electricity Transmission System. The Wind Farm Development Area is located 120 km east of Stonehaven, and will connect to the National Electricity Transmission System at the proposed SSEN Transmission Hurlie substation, west of Stonehaven in Aberdeenshire. The Bellrock Offshore Wind Farm comprises of the following Development Areas: ▪ Wind Farm Development Area; ▪ Offshore Transmission Development Area; and ▪ Onshore Transmission Development Area.

Glossary of Abbreviations

Term	Definition
AOB	Apparently Occupied Burrows
AON	Apparently Occupied Nests
DD	Decimal Degrees
EIA	Environmental impact assessment
HRA	Habitats Regulation Appraisal
OASA	Offshore Aerial Survey Area
OWF	Offshore wind farm
RIAA	Report to Inform Appropriate Assessment
SD	Standard Deviation
SNCBs	Statutory Nature Conservation Bodies
SPA	Special Protection Area
WFDA	Wind Farm Development Area
WTG	Wind turbine generator

1 Introduction

1. This offshore ornithology displacement assessment report is an Appendix to **Chapter 10: Offshore Ornithology (Volume II)** of the Bellrock Wind Farm Development Area (WFDA) Environmental Impact Assessment (EIA) Report and also supports the **Bellrock WFDA Report to Inform Appropriate Assessment (RIAA) (Volume VI).** This report presents the methods and results of the displacement analysis undertaken to assess the potential effects of displacement of seabirds due to the Wind Farm Infrastructure and associated activities in the Bellrock WFDA during the operations and maintenance (O&M) phase.

2. In relation to assessments for offshore wind farms (OWFs), displacement can be defined as the reduction in the number of birds occurring within or immediately adjacent to an OWF (Furness et al. 2013) and for the purposes of the current assessment, this is assumed to apply to birds present in the air and on the water (Statutory Nature Conservation Bodies (SNCBs, 2022)). Distinguishing effects of displacement from those of barrier effects (where flight trajectories are altered to avoid entering, or approaching close to, wind turbine generators (WTGs) – (Masden et al. 2010) is usually not possible within the context of an OWF assessment. Therefore, for much of this report, the displacement effect estimates are assumed to also encompass barrier effects. The analyses undertaken using the SeabORD modelling approach (which are presented for context only) are an exception in this regard (see **Section 3.2** and **Section 4.2** below).

3. Displacement and barrier effects may occur due to the presence of operating WTGs within a wind farm array and/or from the presence of other sources of disturbance associated with the development, such as vessel and helicopter traffic. These effects are considered to have the potential to result in reductions in the annual survival rates and/or breeding productivity of seabird species due to a loss of habitat (e.g. for foraging or roosting), increases in intra-specific competition (via increased densities in the waters outside the wind farm array) and/or increased energetic costs (due to increased flight distances) (Searle et al. 2018).

4. In this report, estimates of the mortality of seabird species that could potentially arise from displacement and barrier effects are considered using two different approaches, namely the matrix approach (SNCBs, 2022) and the SeabORD modelling tool (Searle et al. 2018). This is in accordance with the NatureScot Guidance Note 8 (NatureScot, 2023a). Following advice subsequently received from NatureScot[1], it is the estimates derived from the matrix approach which are the focus of this report, and which are taken forward for use in the offshore ornithology assessment for the Bellrock WFDA (with the SeabORD outputs presented for context only).

[1] Email from NatureScot to the Applicant on 31 March 2025. Please see Section 10.3 in **Chapter 10: Offshore Ornithology (Volume II).**

2 Species Considered

5. The selection of seabird species for analysis of displacement effects was based upon:

- Outcome and conclusions of the work already undertaken in the **Bellrock WFDA Scoping Report (Appendix 1.1 (Volume IV))** and the **Bellrock WFDA Habitats Regulations Appraisal (HRA) Screening Report** (**RIAA Part 1: Annex A (Volume VI)**) on species occurrence and abundance within the Offshore Aerial Survey Area[2,3] (OASA), the potential impacts and the effect pathways relevant to each seabird species, together with the subsequent **Bellrock WFDA Scoping Opinion (Appendix 1.2 (Volume IV))** and NatureScot scoping advice for the Bellrock WFDA (NatureScot, 2024);
- Consideration of existing assessments on species' vulnerability and sensitivity to displacement, including the interpretation and associated context on these as set out in relevant NatureScot and SNCB guidance (Bradbury et al. 2014), (Wade et al. 2016), (SNCBs, 2022), (NatureScot, 2023a); and
- The occurrence and abundance of seabird species as determined from the two years of baseline aerial survey data (**Appendix 10.1: Offshore Ornithology Digital Aerial Survey Baseline Report (Volume IV)**).

6. Based upon the above, the following species are included for analysis:

- Black-legged Kittiwake, hereafter referred to as 'kittiwake';
- Guillemot;
- Razorbill;
- Atlantic Puffin, hereafter referred to as 'puffin'; and
- Northern Gannet, hereafter referred to as 'gannet'.

7. A total of 11 other species were detected in the OASA, but were either not deemed sensitive to displacement/barrier effects (as per the joint SNCBs advice note (see Table 1 in SNCBs, 2022) and/or justifications set out in **Bellrock WFDA Scoping Report (Appendix 1.1 (Volume IV))** and **Bellrock WFDA HRA Screening Report,** or were recorded in such low abundance that the area is not deemed important to them (see Table 3.1 in **Appendix 10.1: Offshore Ornithology Digital Aerial Survey Baseline Report (Volume IV)**).

[2] Defined as the Bellrock WFDA plus a 4 km buffer (See \ 10.1.1 presented **in Appendix 10.1, Annex A (Volume IV)).**

[3] Although based on the first year of aerial surveys only, these outcomes and conclusions have been reviewed (and where necessary amended) on the basis of the full two years of baseline aerial survey data for the purpose of the assessment.

3 Methods

3.1 Matrix Approach

8. The matrix approach to estimating displacement effects on a species requires that the population size (for a defined seasonal period) within the relevant area is first estimated, with assumed species-specific rates of displacement and of mortality amongst the displaced birds then applied to produce an estimate of potential mortality (SNCBs, 2022). The resulting mortality estimates are summed across the different seasonal periods to estimate the potential annual mortality resulting from displacement.

9. For each species on which displacement effects are assessed, the seasonal periods used are as detailed in **Table 3.1 to Table 3.6** (see also **Appendix 10.1: Offshore Ornithology Digital Aerial Survey Baseline Report (Volume IV)**)[4], whilst the area over which the displacement effects are assumed to manifest is the Bellrock WFDA plus a 2 km buffer (SNCBs, 2022). The abundance estimates for the Bellrock WFDA plus 2 km buffer are derived from the baseline aerial survey data, using the mean of the peak estimate of the total number of birds (i.e. in flight and on the water) for the defined seasonal period in each survey year (noting that estimates for months which are split between two seasonal periods can contribute to both periods).

10. As detailed in the **Appendix 10.1: Offshore Ornithology Digital Aerial Survey Baseline Report (Volume IV)**, the monthly abundance estimates were derived by design-based methods for all species, with a model-based method also used for guillemot. However, for guillemot, the model-based methods produced similar estimates to those derived by design-based methods, providing no clear advantages. Hence, the displacement analyses for guillemot also rely on the design-based abundance estimates. The design-based estimates were calculated using a block bootstrap routine with replacement across the survey transects occurring within the Bellrock WFDA plus 2 km buffer. The resultant density estimates were then extrapolated by the area of Bellrock WFDA plus 2 km buffer to give the estimated abundance for each monthly survey[5] (**Appendix 10.1: Offshore Ornithology Digital Aerial Survey Baseline Report (Volume IV)**). The bootstrap estimates for the peak month in each seasonal period for the first and second survey year were combined, and the mean peak derived by taking the mean of the resultant 2,000 bootstrap estimates (**Table 3.1** to **Table 3.6**).

11. The species-specific rates of displacement and mortality which are used to derive the potential displacement mortality follow the NatureScot guidance (2023a) and are detailed in **Table 3.3**.

[4] Except in the case of guillemot, these follow NatureScot (2020), with the resultant non-breeding period then sub-divided to align as closely as possible with Furness (2015), aligning with NatureScot (2023b, 2024). For guillemot, NatureScot advised inclusion of a post-breeding dispersal period (July – September) based on the temporal distribution of the abundance estimates from the baseline aerial surveys (email from NatureScot to the Applicant on 8 October 2024, see **Section 10.3** in **Chapter 10: Offshore Ornithology (Volume II)**). This is additional to the two seasonal periods defined for guillemot in NatureScot (2020).

[5] Corrections for availability bias were applied to these estimates for guillemot, razorbill and puffin (**Appendix 10.1: Offshore Ornithology Digital Aerial Survey Baseline Report (Volume IV)**).

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Table 3.1: Monthly Population Estimates for Each Assessed Species in Each Survey Month for the Bellrock Wind Farm Development Area Plus 2 km Buffer (All Observations) Based Upon Records as Apportioned to Each Species (Accounting for Availability Bias)

Species	Survey Year	Mar [1]	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Kittiwake	*Year 1*	**129.29**	97.30	137.08	**590.81**	19.09	0.00	18.95	28.31	28.36	**111.52**	0.00	9.36
	Year 2	**39.52**	29.48	9.27	**38.00**	0.00	0.00	0.00	**76.36**	10.16	0.00	9.69	0.00
Guillemot[2]	*Year 1*	2,273.79	**1,576.29**	483.26	131.95	**16,393.41**	828.47	1,661.74	1,883.33	**2,594.13**	686.65	728.06	535.94
	Year 2	**465.05**	260.45	**1,002.62**	134.00	133.01	**165.08**	141.13	105.70	199.78	12.60	246.93	295.22
Razorbill	*Year 1*	**140.29**	0.00	0.00	63.40	**2,600.44**	0.00	0.00	0.00	0.00	0.00	0.00	59.18
	Year 2	**23.85**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**11.97**	0.00	12.70	0.00
Puffin	*Year 1*	**611.92**	110.99	373.90	22.24	**628.99**	41.39	196.53	147.43	45.66	16.18	0.00	0.00
	Year 2	59.75	10.88	**90.50**	67.60	0.00	11.20	0.00	0.00	11.33	0.00	14.96	**76.22**
Gannet[3]	*Year 1*	**163.04**	**361.18**	185.08	87.79	134.50	39.20	19.08	**48.01**	0.00	19.02	9.84	9.71
	Year 2	**155.71**	66.89	57.38	0.00	67.57	10.05	0.00	**399.35**	0.00	0.00	0.00	0.00

Notes:
[1] Estimates are derived using design-based methods. The seasonal peaks for each survey year are shown in **bold** and cell colours indicate seasons. Dark blue = Breeding season; Mid blue = Autumn passage/Post-breeding dispersal; Light blue = Winter/Non-breeding season; Lightest blue = Spring passage.

[2] The seasonal periods used for guillemot follow WFDA-specific advice provided by NatureScot (see **footnote 4**) but differ from that advised in NatureScot (2020) guidance. Applying the seasonal period in NatureScot (2020) would give breeding season peaks of 16,393 (Jul) and 1,003 (May) and non-breeding peaks of 2,594 (Nov) and 465 (Mar) in the first and second survey years, respectively.

[3] For Gannet, only two values are in **bold** for Year 2, which highlights that March, being split between the Winter/Non-breeding and Breeding seasonal periods, represents the seasonal peak for both these periods. See in Year 1 that both March and April are in **bold**, therefore March is the Winter/Non-breeding peak, and April that of the Breeding season.

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Table 3.2: Mean Peak Population Estimates for Each Species According to Seasonal Period for the Bellrock Wind Farm Development Area Plus 2 km Buffer

Species	Mean Peak Population Estimate (Number of Individuals)			
	Breeding Season	Autumn Migration/Post-breeding Dispersal	Winter/Non-breeding	Spring Migration
Kittiwake	314	94	N/A	84
Guillemot	790	5,075	938	N/A
Razorbill	1,300	0	6	82
Puffin	360	N/A	344	N/A
Gannet	258	224	N/A	159

Table 3.3: Displacement and Mortality Rates Used in Matrices for Displacement Assessment

Species	Displacement Rate	Mortality Rates – Breeding season	Mortality Rates – Non-breeding Periods
Kittiwake	30%	1% and 3%	1% and 3%
Guillemot, Razorbill and Puffin	60%	3% and 5%	1% and 3%
Gannet	70%	1% and 3%	1% and 3%

3.2 SeabORD Approach

3.2.1 Model Overview

12. The SeabORD tool has been developed to predict impacts of displacement and barrier effects arising from OWFs on seabirds (Searle et al. 2018). It is a spatially explicit individual-based model that simulates the energetic consequences of displacement and barrier effects on the breeding populations, predicting impacts on foraging and reproductive success through the chick-rearing period, and subsequently on the annual survival rates of the adult birds (Searle et al. 2018).

13. Predicting impacts from displacement and barrier effects involves first running a baseline simulation in which simulated birds from one or more breeding colonies forage and provision themselves, and their chicks based on a series of 'rules' which underpin the model, with resultant predictions of adult and chick survival rates under baseline conditions. The adult survival rate is extrapolated over the non-breeding period based on adult body weight at the end of the chick rearing period, whilst the chick survival rate is determined at the end of the chick-rearing period. The simulation is then re-run under a scenario that assumes that a specified user-defined proportion of the simulated population is subject to either displacement or barrier effects (or both) from one or more specified OWF footprints. In this "impact" scenario, adult and chick survival rates vary from the baseline scenario as a result of:

- The energetic consequences of birds subject to barrier effects having to travel further to reach their chosen foraging locations; and
- Displaced birds from the OWF footprint travelling to different foraging locations, which may be closer or further away from their colonies and where they may encounter different levels of intra-specific competition.

14. Currently, the tool can model the energy budgets during the chick-rearing period (and hence predict effects on adult and chick survival rates) for kittiwake, guillemot, razorbill, and puffin.

15. However, for the offshore ornithology assessment for the Bellrock WFDA, guillemot was not modelled due to the lack of connectivity between the Bellrock WFDA and guillemot breeding populations (as determined in the Bellrock WFDA HRA Screening Report[6] (**Appendix 1.1 (Volume IV)**). The species modelled within SeabORD are therefore:

- Kittiwake;
- Razorbill; and
- Puffin.

16. SeabORD allows for a maximum of six colonies to be modelled in each simulation, thereby constraining the extent to which the predicted impacts from displacement and barrier effects can be considered across multiple colony populations. This is in contrast to the matrix approach

[6] NatureScot agreement with this conclusion was confirmed in email from NatureScot to the Applicant on 8 October 2024. Please see **Section 10.3** in **Chapter 10: Offshore Ornithology (Volume II)**.

(**Section 3.1**), for which effects can be estimated for all colonies identified as having potential connectivity with the project of interest via consideration of the associated apportioning estimates. Consequently, SeabORD modelling tends to be limited to considering effects on those populations that are qualifying features (or named components of seabird assemblage qualifying features) of seabird breeding colony Special Protection Areas (SPAs). Even then it is often possible to consider only a subset of all such populations that are deemed to have breeding season connectivity with the project of interest (e.g. HiDef, 2022), (Natural Power, 2024).

17. As outlined above, SeabORD modelling is based upon simulated birds from the relevant colony populations and (again, in contrast to the matrix approach - **Section 3.1**) does not use data collected from the baseline aerial surveys. The colony population sizes used for the modelling runs undertaken in this report are derived from the Seabirds Count census (Burnell et al. 2023) and are expressed as the number of breeding pairs, which for:

- Kittiwake is assumed to equate to the number of Apparently Occupied Nests (AON);
- Razorbill is assumed to equate to the number of individuals multiplied by 0.67 (i.e. half the value of the correction factor used to derive the total number of breeding adults for colony counts of this species – Burnell et al. 2023); and
- Puffin is assumed to equate to the number of Apparently Occupied Burrows (AOB), which is the count unit that has been used for all colonies on which modelling is undertaken.

18. For the purposes of the current assessment, SeabORD modelling is undertaken only for the Bellrock WFDA alone (i.e. not for the cumulative or in-combination modelling). The run times for SeabORD models for the Bellrock WFDA alone were substantial and any cumulative or in-combination scenarios involving multiple OWFs would likely be impractical on this basis alone. More importantly, the number of OWF projects contributing to the potential cumulative and in-combination effects on many of the relevant SPA populations is substantial, but the SeabORD tool is limited to considering effects from a maximum of five projects in any one simulation.

3.2.2 Modelled Special Protection Areas

19. As stated above, the species assessed using the SeabORD model are kittiwake, razorbill and puffin. For each species, the colony populations considered for inclusion were those identified as having breeding season connectivity with the Bellrock WFDA, as determined by the Bellrock WFDA being within the species' mean maximum foraging range plus 1 standard deviation (SD)[7] of the colony (Bellrock WFDA HRA Screening Report (**RIAA Part 1, Annex A (Volume VI)**); **Appendix 10.4: Offshore Ornithology Apportioning Report (Volume IV)**; (NatureScot, 2023c), (Woodward et al. 2019), (Woodward et al. 2024). Further shortlisting of colonies for inclusion (because a maximum of only six colonies can be modelled in any one simulation) focussed on those which are SPAs (and for which the species of interest is either a qualifying feature or a named component of the seabird assemblage qualifying feature), with these SPA populations included in the modelling if the apportioning calculations estimated that 5% or more of the predicted impacts from the Bellrock Wind Farm Infrastructure should be attributed to that SPA population (**Appendix 10.5:**

[7] For razorbill, the mean maximum foraging range plus 1 SD is calculated excluding data from Fair Isle for colonies to the south of the Pentland Firth and including data from the Fair Isle for colonies to the north of the Pentland Firth, as advised by NatureScot (2023c).

Offshore Ornithology Apportioning Report (Volume IV)). The one exception in this regard was the inclusion of the Buchan Ness to Collieston Coast SPA razorbill population. This population is neither a qualifying feature nor a named component of the seabird assemblage qualifying feature of this SPA. However, few razorbill colonies were identified as having breeding season connectivity with the Bellrock WFDA, and the Buchan Ness to Collieston Coast SPA population together with the Fowlsheugh SPA population accounts for over 99% of all breeding razorbills identified as having breeding season connectivity with the Bellrock WFDA.

20. **Table 3.4** details each SPA and the associated populations included in the SeabORD modelling, its corresponding co-ordinates and the number of breeding pairs for each species. Breeding pairs is the population metric used in these models as the SeabORD modelling is restricted to the chick-rearing period (Mobbs et al. 2018), (NatureScot, 2023a). For any SPA that comprised multiple, non-contiguous, breeding colonies (e.g. as is the case for kittiwake at the Troup, Pennan and Lion's Heads SPA), the central point of the relevant colony locations was taken as the point from which the model runs its simulations. If this central point fell on land, it was moved to be a few metres off the coast, as specified in the SeabORD user guide, which states that all colony points must not be on land as it will "*cause the flightpath-finding routines to give unpredictable results*" (Mobbs et al. 2018).

21. Given the SPAs included in the SeabORD modelling, the region within which the modelling scenarios were run was defined by latitudes of 54.5704 to 59.5000 and longitudes of 1.0387 to -4.1130.

Table 3.4: Special Protection Area Colonies Included in SeabORD Modelling Simulations, With Respective Coordinates and the Number of Breeding Pairs for Each Colony Population Included in the Modelling

SPA	Latitude (DD)	Longitude (DD)	Number of Breeding Pairs of Modelled Colony Populations[1]		
			Kittiwake	Razorbill	Puffin
Buchan Ness to Collieston Coast SPA	57.40083002	-1.835091877	11,295	3,903[2]	-
Coquet Island SPA	55.33510475	-1.538561931	-	-	25,029
East Caithness Cliffs SPA	58.26583966	-3.316923998	24,479	-	-
Farne Islands SPA	55.63108019	-1.630625484	4,402	-	43,752
Forth Islands SPA	56.1007845	-2.768492419	-	-	42,923
Fowlsheugh SPA	56.91641958	-2.182342656	14,039	9,422	-
St Abb's Head to Fast Castle SPA	55.92419468	-2.185041682	5,150	-	-

SPA	Latitude (DD)	Longitude (DD)	Number of Breeding Pairs of Modelled Colony Populations[1]		
			Kittiwake	Razorbill	Puffin
Troup, Pennan and Lion's Heads SPA	57.69319787	-2.269433203	10,616	-	-

Notes:

[1] Numbers of breeding pairs are derived from the Seabird Census counts (Burnell et al, 2023). See text for explanation of selection of colony populations for inclusion in the models.

[2] Razorbill is neither a qualifying feature nor a named component of the seabird assemblage for the Buchan Ness to Collieston Coast SPA - it has been included as after Fowlsheugh it is the most substantive colony in range and has a proportional weight of 26.88% (**Appendix 10.5: Offshore Ornithology Apportioning Report (Volume IV)**).

3.2.3 Key Modelling Assumptions

22. Several key assumptions need to be specified in undertaking modelling using SeabORD. These include:

- Seabird foraging locations: These can be determined by either colony-specific foraging probability density maps or according to a distance decay function whereby the probability of foraging declines with distance from the colony. For the modelling exercise undertaken for the Bellrock WFDA, the latter approach was used due to a lack of data for generating colony-specific probabilities. In this case, the maximum foraging range of each species was taken to be the mean maximum plus 1 Standard Deviation (SD) as determined in Woodward et al. (2019), with the default assumption of 95% used for the percentage of foraging locations assumed to occur within the specified foraging range;
- Prey distribution: This can be based upon input prey distribution maps or by assuming a uniform distribution of prey, with the latter approach used in this case (due to the absence of prey distribution data for the area of interest);
- Rates of displacement and barrier effects: These are user specified values and, following NatureScot advice[8], the assumed species-specific displacement rates for the SeabORD modelling exercise were as in **Table 3.3**, with 100% of displaced birds being subject to barrier effects (NatureScot, 2023a);
- Responses to displacement and barrier effects: It was assumed that birds occurring within the area defined by the Bellrock WFDA and a surrounding 2 km buffer were at risk of being displaced or subject to barrier effects. Displaced birds were assumed to select alternative foraging sites within 5 km of this zone of displacement (this being the default value populated by SeabORD). For birds subject to barrier effects, the flight trajectories resulting from avoidance of the Bellrock WFDA and 2 km buffer were determined using the 'A* pathfinding barrier navigation' option. This was selected over the alternative perimeter method because it

[8] Minutes of Bellrock WFDA Scoping Workshop held on 30 October 2023. See **Chapter 10: Offshore Ornithology (Volume II)**.

was assumed to be biologically more plausible on the basis it identifies the most energetically efficient route to the foraging location given avoidance of the Bellrock WFDA and 2 km buffer;

- Prey conditions: The impacts of displacement and barrier effect are modelled for years in which prey conditions are classed as 'poor', 'moderate' or 'good'. It was assumed that years of 'moderate' prey conditions were likely to be most representative of conditions prevailing at most colonies. The process for defining 'moderate' prey conditions is detailed in **Section 3.2.4**; and
- Sampling effort and number of matched-pair runs: SeabORD adopts an individual-based modelling approach so that the time taken to run simulations is directly related to the number of individuals involved in the model calculations. Due to the size of the colony populations modelled in the current exercise, simulations were limited to sampling 10% of these populations (with higher sampling effort resulting in impractical model run times). For the final model runs, 10 matched-pair simulations were performed, representing 10 runs which each use different prey values selected from the range of values determined in the prey calibration (**Section 3.2.4**) using a stratified random approach. Each of these simulations involved a baseline and an impact scenario, providing the matched pairs of outputs from which the output metrics were calculated.

23. The above assumptions and associated values as used in the SeabORD models for each of the three species are summarised in **Table 3.5**.

Table 3.5: Species Input Parameters for Both the Single and Final SeabORD Modelling Simulations

Variable	Kittiwake	Razorbill	Puffin
Maximum foraging range (km)	300.6	122.2	265.4
Percentage of foraging locations within foraging range (%)	95		
Prey distribution	Uniform		
Displacement rate (%)[1]	30	60	60
Percentage of displaced birds also barriered (%)	100		
Area within which displacement and barrier effects operate	Bellrock WFDA + 2 km buffer		
Distance from Bellrock WFDA within which displaced birds select alternative foraging location	5 km		
Method for determining flight routes of barriered birds	A* pathfinding barrier navigation		
Assumed prey conditions	Moderate		
Percentage of population sampled in simulations (%)	10		
Number of matched-pair simulations run	10		

Variable	Kittiwake	Razorbill	Puffin
Starting random seed	19,873		
Notes: [1] Values taken from Guidance Note 8 (NatureScot, 2023a), and as in **Table 3.3** for the matrix approach.			

3.2.4 Calibrating Prey Quantity Range

24. To produce results that are appropriate to each colony population of interest, the model must first be calibrated to determine the lower and upper prey level input parameters for each of these colony populations. To determine these prey levels, a series of single run simulations were undertaken for each colony population under baseline conditions (i.e. without the Bellrock Wind Farm Infrastructure being present) for a range of single prey input values. This was performed until the minimum and maximum prey values that resulted in 'moderate' conditions were identified, with 'moderate' conditions being defined according to species-specific thresholds for adult body mass loss and minimum chick survival rate (Mobbs et al. 2018), (**Table 3.6**). During the single run simulations, the modelling was based on sampling 5% of the colony population. This was due to the large number of simulations needed to derive the prey ranges for each colony population and the time required to run each simulation.

Table 3.6: Threshold Values for Adult Body Mass Loss and Minimum Chick Survival Rates Used to Determine the Lower and Upper Prey Quantity Bounds Which Correspond to Years in Which Conditions are Classed as 'Moderate'

Species	Adult Mass Loss (%)	Chick Survival (%)
Kittiwake	5.0 – 15.0	>11
Razorbill	3.5 – 10.5	>50
Puffin	3.5 – 10.5	>50

25. The prey quantity ranges derived from the calibration process and used in the final SeabORD models to predict the breeding season impacts of displacement and barrier effects resulting from the Bellrock Wind Farm Infrastructure are detailed in **Table 3.7**.

Table 3.7: The Prey Quantity Ranges as Determined to Represent 'Moderate' Conditions for Each Species and Colony and as Used in the Final SeabORD Models

Colony	Lower Prey Quantity (Grams Per Unit Volume)	Upper Prey Quantity (Grams Per Unit Volume)
Kittiwake		
Buchan Ness to Collieston Coast SPA	213	274
East Caithness Cliffs SPA	205	273

Colony	Lower Prey Quantity (Grams Per Unit Volume)	Upper Prey Quantity (Grams Per Unit Volume)
Farne Islands SPA	193	258
Fowlsheugh SPA	218	281
St Abb's Head to Fast Castle SPA	204	275
Troup, Pennan and Lion's Heads SPA	213	277
Razorbill		
Buchan Ness to Collieston Coast SPA	266	338
Fowlsheugh SPA	254	333
Puffin		
Coquet Island SPA	256	310
Farne Islands SPA	278	346
Forth Islands SPA	260	313

Table 3.8: Species Input Parameters for Both the Single and Final Simulations

Variable	Kittiwake	Razorbill	Puffin
Maximum foraging range (km)[1]	300.6	122.2	265.4
Proportion in range	0.95	0.95	0.95
% Susceptible to displacement[2]	30	60	60
% of displaced birds also barriered	100	100	100
Starting random seed	19,873	19,873	19,873

Notes:

[1] Foraging ranges from Woodward et al. (2019)

[2] Values taken from Guidance Note 8 (NatureScot, 2023a), also stated in Table 3.3 for the matrix approach.

4 Results

26. The following section presents the predicted mortality related to displacement from the O&M phase of the Bellrock Wind Farm Infrastructure using both the matrix approach and the SeabORD approach.

4.1 Matrix Approach

4.1.1 Displacement Mortality Estimates

27. The estimated potential seasonal and annual mortalities resulting from displacement due to the Wind Farm Infrastructure during the O&M phase are presented in **Table 4.1**. For guillemot, these outputs are shown as determined according to the seasonal periods both as advised for the Bellrock WFDA[9] and the generic NatureScot (2020) guidance.

28. The matrix outputs for each species according to seasonal period (including consideration of the potential mortality that would result from combinations of a wider range of displacement and mortality rates) are presented in **Annex A** of this Appendix.

Table 4.1: The Estimated Potential Seasonal and Annual Mortality of Seabird Species Due to the Bellrock Wind Farm Infrastructure During the Operation and Maintenance Period

Species	Mortality Rate[1]	Potential Mortality (Number of Individuals)				
		Breeding Season	Autumn Migration	Winter/Non-breeding	Spring Migration	Annual[2]
Kittiwake	Lower	0.9	0.3	N/A	0.3	1.5
	Upper	2.8	0.8	N/A	0.8	4.4
Guillemot	Lower	14.2	30.5	5.6	N/A	50.3
	Upper	23.7	91.4	16.9	N/A	132.0
Razorbill	Lower	23.4	0.0	0.0	0.6	24.0
	Upper	39.0	0.0	0.1	1.8	40.9
Puffin	Lower	6.5	N/A	2.1	N/A	8.5
	Upper	10.8	N/A	6.2	N/A	17.0
Gannet	Lower	1.8	1.6	N/A	1.1	4.5
	Upper	5.4	4.7	N/A	3.3	13.5

[9] Email from NatureScot to the Applicant on 8 October 2024. Please see **Section 10.3** in **Chapter 10: Offshore Ornithology (Volume II)**.

Species	Mortality Rate[1]	Potential Mortality (Number of Individuals)				
		Breeding Season	Autumn Migration	Winter/Non-breeding	Spring Migration	Annual[2]

Notes:

[1] Two mortality rates are advised for each species and seasonal period (see Table 3.3).

[2] Annual value may differ slightly to the sum of the seasonal values due to rounding errors.

4.1.2 Precaution Associated with Use of the Mean Peak Abundances

29. Given that the matrix approach uses the seasonal mean peak abundance, by definition, the resultant mortality estimates are derived from estimates that are unlikely to be representative of the typical abundance on the Bellrock WFDA plus 2 km buffer. To assess the potential consequences of this, the seasonal mean peak abundance estimates for each of the relevant species are compared with the mean abundance estimates (**Table 4.2**).

30. These comparisons show that the mean peak estimates are at least double the mean estimates in 11 of the 14 species-seasonal period combinations and can be almost five times higher (for razorbill in the breeding season). Overall, the mean values represent between 20 – 70% of the mean peak values, with the scale of the differences least for guillemot but relatively similar for the other four species (**Table 4.2**).

Table 4.2: Comparison of the Mean Peak Abundance and Mean Abundance Estimates by Seasonal Period for Each of the Five Species for Which Displacement Assessment is Undertaken

Species	Season	Mean Peak Population Estimate (Number of Individuals)	Mean Population Estimate (Number of Individuals)	Mean Estimate as a Percentage of the Mean Peak Estimate (%)
Kittiwake	Breeding season	314	92	29
	Autumn migration	94	34	36
	Spring migration	84	39	46
Guillemot	Breeding season	790	598	76
	Post-breeding dispersal	5,075	3,220	63
	Winter/non-breeding	938	836	89
Razorbill	Breeding season	1,300	266	20
	Autumn migration	0	0	0

Species	Season	Mean Peak Population Estimate (Number of Individuals)	Mean Population Estimate (Number of Individuals)	Mean Estimate as a Percentage of the Mean Peak Estimate (%)
	Winter/non-breeding	6	3	50
	Spring migration	82	39	48
Puffin	Breeding season	360	136	38
	Winter/non-breeding	344	77	22
Gannet	Breeding season	258	96	37
	Autumn migration	224	112	50
	Spring migration	159	45	28

4.2 SeabORD Approach

4.2.1 Output Metrics

31. As detailed in **Section 3.2.3**, it was not feasible to run models which simulated 100% of the breeding adults for each colony population that was modelled. Therefore, the outputs from the SeabORD modelling have been scaled up according to the percentage of the simulated populations on which the models were based (i.e. 10% in each case). This was done by multiplying the outputs by the inverse of the proportion modelled (i.e. 1/proportion, equating to 10 in this case), which gives an estimate of the predicted number of mortalities for the entire SPA population. It is the scaled values that are presented below.

32. The predicted additional mortalities for adult birds presented in **Table 4.3, Table 4.5** and **Table 4.7** refers to the percentage point change as determined by the difference in the annual survival rate of the whole adult population, as estimated during the baseline simulations (i.e. without the Bellrock Wind Farm Infrastructure) and as estimated in the simulations with the Bellrock Wind Farm Infrastructure present (i.e. when the simulated populations are subject to the resultant displacement and barrier effects). This is also the case for the predicted additional chick mortality, as presented in **Table 4.4, Table 4.6** and **Table 4.8**. In addition to the key outputs on changes to adult and chick survival (as presented in the Tables referred to above), supplementary outputs from the model runs on each of the three species are provided in **Annex C** of this Appendix.

33. Impacts on chicks are presented for ‘moderate’ year conditions only, in contrast to the impacts on adult survival rate which outputs for ‘poor’, ‘moderate’ and ‘good’ year conditions. No explanation for this discrepancy in the reporting of outputs was found within the SeabORD literature.

4.2.2 Kittiwake

34. Results of the SeabORD analysis carried out for kittiwake are presented in **Table 4.3** and **Table 4.4**, with supplementary outputs provided in **Annex C** of this Appendix.

35. The outputs of the SeabORD models for kittiwake indicate that the displacement and barrier effect impacts from the Bellrock Wind Farm Infrastructure will be greatest on the Farne Islands SPA colony, with a mean percentage point increase in the annual adult mortality rate of 0.023% (95% Confidence Interval (CI): -0.091% – 0.136%) in years of 'moderate' prey conditions. For all other kittiwake colonies modelled, there was no predicted change in the annual adult mortality rate due to the displacement and barrier effect impacts from the Bellrock Wind Farm Infrastructure for years of 'moderate' prey conditions.

36. In relation to chick mortality, the largest predicted impact (in terms of the mean values) was on the East Caithness Cliffs SPA colony, with a mean percentage point increase in mortality of 0.12% (95% CI: -0.35% – 0.59%). The modelling also predicted small increases in chick mortality (in terms of mean values) for the Buchan Ness to Collieston Coast SPA, Troup, Pennan and Lion's Heads SPA and Fowlsheugh SPA colonies but in all cases the mean percentage point increase was less than 0.1%, whilst the 95% CI values straddled zero (as was also true for predicted effects on the East Caithness Cliffs SPA colony). There was no predicted change to kittiwake chick mortality due to the displacement and barrier effect impacts from the Bellrock Wind Farm Infrastructure at either the Farne Islands SPA or St Abb's Head to Fast Castle SPA.

37. Overall, the SeabORD modelling outputs suggest little or no impacts of displacement and barrier effects from the Bellrock WFDA on SPA kittiwake breeding populations as a result of the Wind Farm Infrastructure. Any predicted increases in adult and chick mortality are small and in no cases are these increases statistically significant (with the 95% CIs straddling zero in all cases). Associated with this, the Bellrock WFDA is predicted to have little impact on travel costs for kittiwake from the different SPAs, as travel distances per timestep (timestep = 36 hours for kittiwake) increased by less than 0.50 km and the number of foraging trips per timestep either remained the same or increased by a trivial amount only (see additional outputs in **Table C 1** in **Annex C** of this Appendix).

38. Furthermore, the largest increases in mortality (in terms of mean values) are not associated with those SPA colonies at which the largest effects are expected on the basis of the apportioning calculations. The apportioning calculations estimate that both the Fowlsheugh SPA and Buchan Ness to Collieston Coast SPA colonies each account for approximately 20% of impacts associated with the Bellrock Wind Farm Infrastructure, whereas the East Caithness Cliffs SPA and Farne Islands SPA colonies are estimated to account for approximately 10% and 5% of impacts, respectively (**Appendix 10.5: Offshore Ornithology Apportioning Report (Volume IV)**). This suggests that apparent predicted increases (and differences between the SPA colonies) in the mean predicted changes to adult and chick mortality may simply result from stochastic effects within the SeabORD modelling process. The fact that the Bellrock WFDA is close to, or beyond, the mean maximum breeding season foraging range of kittiwake from their SPA colonies, together with the fact that tracking data (and associated modelling of foraging distributions) demonstrate that the Bellrock WFDA is beyond the main areas of usage of SPA kittiwake during the breeding season, provides further support for this contention (Wakefield et al. 2017, Cleasby et al. 2018, Woodward et al. 2019, Bogdanova et al. 2025, Bennett et al. 2025).

Table 4.3: Modelled Impacts of the Bellrock Wind Farm Infrastructure on the Annual Mortality of Breeding Adult Kittiwake at the Six Special Protection Areas Simulated for Different Prey Quantity Scenarios

Colony	Population Size (Number of Individuals)	Prey Quantity Year Type	Scaled Mortality (Number of Individuals)			Annual Survival Rate (%)		Mean Percentage Point Reduction in Mortality Rate (95% Confidence Intervals)	SD
			Baseline Scenario	Impact Scenario	Additional	Baseline Scenario	Impact Scenario		
Farne Islands SPA	8,800	Poor	3,135	3,134	-1	64.375%	64.386%	-0.011 (-0.097 – 0.074)	0.036
		Moderate	**1,908**	**1,910**	**2**	**78.318%**	**78.295%**	**0.023 (-0.091 – 0.136)**	**0.048**
		Good	1,231	1,231	0	86.011%	86.011%	0.000 (0.000 – 0.000)	0.000
Buchan Ness to Collieston Coast SPA	22,600	Poor	9,187	9,187	0	59.350%	59.350%	0.000 (-0.049 – 0.049)	0.021
		Moderate	**5,937**	**5,937**	**0**	**73.730%**	**73.730%**	**0.000 (0.000 – 0.000)**	**0.000**
		Good	3,649	3,648	0	83.854%	83.858%	-0.004 (-0.038 – 0.029)	0.014
East Caithness Cliffs SPA	48,960	Poor	18,341	18,341	0	62.539%	62.539%	0.000 (0.000 – 0.000)	0.000
		Moderate	**12,917**	**12,917**	**0**	**73.617%**	**73.617%**	**0.000 (0.000 – 0.000)**	**0.000**
		Good	7,600	7,602	2	84.477%	84.473%	0.004 (-0.016 – 0.025)	0.009
Fowlsheugh SPA	28,080	Poor	11,351	11,353	2	59.576%	59.569%	0.007 (-0.029 – 0.043)	0.015
		Moderate	**7,706**	**7,706**	**0**	**72.557%**	**72.557%**	**0.000 (0.000 – 0.000)**	**0.000**
		Good	4,703	4,402	-1	83.251%	83.255%	-0.004 (-0.030 – 0.023)	0.011
St Abb’s Head to Fast Castle SPA	10,300	Poor	3,863	3,863	0	62.495%	62.495%	0.000 (0.000 – 0.000)	0.000
		Moderate	**2,702**	**2,702**	**0**	**73.767%**	**73.767%**	**0.000 (0.000 – 0.000)**	**0.000**

Colony	Population Size (Number of Individuals)	Prey Quantity Year Type	Scaled Mortality (Number of Individuals)			Annual Survival Rate (%)		Mean Percentage Point Reduction in Mortality Rate (95% Confidence Intervals)	SD
			Baseline Scenario	Impact Scenario	Additional	Baseline Scenario	Impact Scenario		
		Good	1,519	1,520	1	85.252%	85.243%	0.010 (-0.063 – 0.083)	0.031
Troup, Pennan and Lion's Heads SPA	21,232	Poor	8,131	8,131	0	61.718%	61.718%	0.000 (0.000 – 0.000)	0.000
		Moderate	**5,661**	**5,661**	**0**	**73.347%**	**73.347%**	**0.000 (0.000 – 0.000)**	**0.000**
		Good	3,324	3,324	0	84.350%	84.350%	0.000 (0.000 – 0.000)	0.000

Notes:

Values are as scaled up to represent the entire SPA breeding population in each case and it is the estimates for years with 'moderate' prey quantity that are used in the assessment.

Table 4.4: Modelled Impacts of the Bellrock Wind Farm Infrastructure on Annual Kittiwake Chick Mortality at the Six Special Protection Areas Simulated

Colony	Mean Number of Chicks Hatched per Annum[1]	Scaled Mortality (Number of Chicks)			Mean Percentage Point Change in Mortality (95% Confidence Intervals)	SD
		Baseline Scenario	Impact Scenario	Additional		
East Caithness Cliffs SPA	24,479	11,942	11,945	3	0.012 (-0.035 – 0.059)	0.020
Buchan Ness to Collieston Coast SPA	11,295	4,717	4,718	1	0.009 (-0.146 – 0.164)	0.065
Troup, Pennan and Lion's Heads SPA	10,616	4,821	4,822	1	0.009 (-0.061 – 0.080)	0.030
Fowlsheugh SPA	14,039	6,400	6,401	1	0.007 (-0.089 – 0.103)	0.040
Farne Islands SPA	4,402	2,167	2,167	0	0.000 (0.000 – 0.000)	0.000
St Abb's Head to Fast Castle SPA	5,150	2,370	2,370	0	0.000 (0.000 – 0.000)	0.000

Notes:

[1] SeabORD assumes one chick per breeding pair.

Values are as scaled up to represent the entire SPA breeding population in each case.

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4.2.3 Razorbill

39. Results of the SeabORD analysis carried out for razorbill are presented in **Table 4.5** and **Table 4.6** with supplementary outputs provided in **Annex C** of this Appendix.

40. The outputs of the SeabORD models for razorbill indicate that displacement and barrier effects associated with the Bellrock Wind Farm Infrastructure are unlikely to negatively impact either the Buchan Ness to Collieston Coast SPA[10] or Fowlsheugh SPA populations in years of 'moderate' prey conditions. Thus, models predict a mean percentage point reduction of -0.013% (95% CI: -0.185% – 0.160%) in the annual adult mortality rate for the Buchan Ness to Collieston Coast SPA population and no change in the annual adult mortality rate for the Fowlsheugh SPA population (mean percentage point change = 0.000% (95% CI: 0.000% – 0.000%).

41. In relation to chick mortality, the SeabORD models predicted no changes for either SPA population.

42. The SeabORD modelling outputs suggest little or no impacts of displacement and barrier effects from the Bellrock Wind Farm Infrastructure on SPA razorbill breeding populations. It would be expected that the number of adult mortalities in scenarios with the Bellrock Wind Farm Infrastructure present would be higher than for the baseline scenarios and the fact that the opposite was true for the Buchan Ness to Collieston Coast SPA population in 'moderate' years is likely to be due to stochasticity in the modelling, combined with the small or negligible magnitude of effects associated with the Bellrock Wind Farm Infrastructure . This is supported by the very small difference in the mortalities across all three year types. The additional outputs displayed in **Table C 2** of **Annex C** in this Appendix also show that the Bellrock Wind Farm Infrastructure had little impact on travel costs for razorbill at this SPA as travel distance per timestep (Timestep = 24 hours for razorbill) decreased by 0.060 km and there was no difference in the number of foraging trips per timestep between scenarios.

[10] Noting that razorbill is neither a qualifying feature nor a named component of the seabird assemblage qualifying feature at this SPA (see **Section 3.2.2**).

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Table 4.5: Modelled Impacts of the Bellrock Wind Farm Infrastructure on Adult Razorbill During the Year, at the Two Special Protection Areas Simulated (Using the Scaled Mortality Values)

Colony	Scaled Population Size (Individuals)	Year Type	Scaled Baseline Mortality	Scaled Impact Mortality	Scaled Additional Mortalities	Baseline Survival Rate (%)	Impact Survival Rate (%)	Mean Percentage Point Reduction in Survival Rate (95% Confidence Intervals)	SD
Buchan Ness to Collieston Coast SPA	7,800	Poor	2,038	2,038	0	73.872%	73.872%	0.000 (0.000 – 0.000)	0.000
		Moderate	**1,098**	**1,097**	**-1**	**85.923%**	**85.936%**	**-0.013 (-0.185 – 0.160)**	**0.073**
		Good	563	563	0	92.782%	92.782%	0.000 (-0.143 – 0.143)	0.060
Fowlsheugh SPA	18,840	Poor	4,698	4,699	1	75.064%	75.058%	0.017 (-0.035 – 0.045)	0.017
		Moderate	**2,538**	**2,538**	**0**	**86.529%**	**86.529%**	**0.000 (0.000 – 0.000)**	**0.000**
		Good	1,513	1,513	0	91.969%	91.969%	0.000 (0.000 – 0.000)	0.000

Table 4.6: Mean Predicted Razorbill Chick Mortalities (Scaled to Represent the Whole Population) During the Chick Rearing Period With and Without Displacement and Barrier Effects from the Bellrock Wind Farm Infrastructure

Colony	Number of Chicks[1]	Scaled Baseline Mortalities	Scaled Impact Mortalities	Scaled Additional Mortalities	Percentage Additional Mortality (95% Confidence Intervals)	SD
Buchan Ness to Collieston Coast SPA	3,903	762	762	0	0.000 (0.000 – 0.000)	0.000
Fowlsheugh SPA	9,422	1,711	1,711	0	0.000 (0.000 – 0.000)	0.000

Notes:

[1] SeabORD assumes one chick per breeding pair

4.2.4 Puffin

43. Results of the SeabORD analysis carried out for puffin are presented in **Table 4.7** and **Table 4.8**, with supplementary outputs provided in **Annex C** of this Appendix.

44. The outputs of the SeabORD models for puffin indicate that the displacement and barrier effects associated with the Bellrock Wind Farm Infrastructure will have greatest impacts on the Forth Islands SPA population, with a mean percentage point increase in the annual adult mortality rate of 0.211% (95% CI: -1.401% - 1.822%) in years of 'moderate' prey conditions. The predicted effects on the annual adult mortality rates were substantially lower for both the Coquet Island SPA and Farne Islands SPA populations (for which the predicted mean increases were 0.018% (95% CI: -0.034% – 0.070%) and 0.005% (95% CI: -0.014% – 0.024%), respectively).

45. For chicks, the largest impact was also predicted for the Forth Islands SPA population, with a mean percentage point increase in mortality of 0.932% (95% CI: -5.983% – 7.847%) in a 'moderate' year. Predicted increases in chick mortality were substantially lower for the Coquet Island SPA and Farne Islands SPA populations (with mean increases of 0.28% (95% CI: -0.050% – 0.106%) and 0.007% (95% CI: -0.030% – 0.043%), respectively).

46. The model outputs as described above (and detailed in **Table 4.7** and **Table 4.8**) suggest marked differences in the magnitude of the impacts on the three SPA populations, which appears surprising given that the breeding season apportioning rates for all three populations are relatively high, at close to 20% or above (**Appendix 10.5: Offshore Ornithology Apportioning Report (Volume IV)**). In particular, the puffin colonies at the Forth Islands SPA and Farne Islands SPA are of similar size, whilst the distance between the Bellrock WFDA and both of these SPAs is also similar. Given this, such a marked difference in the predicted effects on the respective populations is unexpected and would warrant more detailed investigation of the underlying causes in the event that these outputs were to be relied upon for assessment purposes.

47. The additional outputs presented in **Table C 3** of **Annex C** in this Appendix also show that the Bellrock Wind Farm Infrastructure is predicted to have greatest impact on travel costs for puffin at the Forth Islands SPA, with the modelled travel distance increasing by 9.58 km per timestep (Timestep = 24 hours for puffin). This is an order of magnitude, or more, greater than predicted for either the Coquet Island SPA or Farne Islands SPA birds.

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Table 4.7: Modelled Impacts of the Bellrock Wind Farm Infrastructure on Adult Puffin During the Year, at the Three Special Protection Areas Simulated (Using the Scaled Mortality Values)

Colony	Scaled Population Size (Individuals)	Year Type	Scaled Baseline Mortality	Scaled Impact Mortality	Scaled Additional Mortalities	Baseline Survival Rate (%)	Impact Survival Rate (%)	Mean Percentage Point Reduction in Survival Rate (95% Confidence Intervals)	SD
Forth Islands SPA	85,840	Poor	20,510	20,718	208	76.107%	75.864%	0.242 (-1.595 – 2.080)	0.774
		Moderate	**14,341**	**14,522**	**181**	**83.293%**	**83.082%**	**0.211 (-1.401 – 1.822)**	**0.679**
		Good	8,201	8,336	135	90.446%	90.289%	0.157 (-1.013 – 1.328)	0.493
Coquet Island SPA	50,060	Poor	8,301	8,301	0	83.418%	83.418%	0.000 (-0.063 – 0.063)	0.027
		Moderate	**5,871**	**5,880**	**9**	**88.272%**	**88.254%**	**0.018 (-0.034 – 0.070)**	**0.022**
		Good	3,241	3,238	-3	93.526%	93.532%	-0.006 (-0.038 – 0.026)	0.013
Farne Islands SPA	87,500	Poor	14,329	14,335	6	83.624%	83.617%	0.007 (-0.019 – 0.033)	0.011
		Moderate	**10,450**	**10,454**	**4**	**88.057%**	**88.053%**	**0.005 (-0.014 – 0.024)**	**0.008**
		Good	5,682	5,689	7	93.506%	93.498%	0.008 (-0.010 – 0.026)	0.008

Table 4.8: Mean Predicted Puffin Chick Mortalities (Scaled to Represent the Whole Population) During the Chick Rearing Period With and Without Displacement and Barrier Effects from the Bellrock Wind Farm Infrastructure

Colony	Number of Chicks[1]	Scaled Baseline Mortalities	Scaled Impact Mortalities	Scaled Additional Mortalities	Percentage Additional Mortality (95% Confidence Intervals)	SD
Forth Islands SPA	42,923	8,734	9,134	400	0.932 (-5.983 – 7.847)	2.914
Coquet Island SPA	25,029	2,207	2,214	7	0.028 (-0.050 – 0.106)	0.033
Farne Islands SPA	43,752	2,606	2,609	3	0.007 (-0.030 – 0.043)	0.015

Notes:

[1] SeabORD assumes one chick per breeding pair

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Annex A: Displacement Matrices

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Note: Cells highlighted in blue identify the displacement and mortality rates considered in assessment.

Table A 1: Operational Displacement: Number of Kittiwake Mortalities Predicted During the Breeding Season

Mean		Mortality										
Displacement		1%	2%	3%	4%	5%	10%	20%	30%	50%	80%	100%
	10%	0	1	1	1	2	3	6	9	16	25	31
	20%	1	1	2	3	3	6	13	19	31	50	63
	30%	1	2	3	4	5	9	19	28	47	75	94
	40%	1	3	4	5	6	13	25	38	63	101	126
	50%	2	3	5	6	8	16	31	47	79	126	157
	60%	2	4	6	8	9	19	38	57	94	151	189
	70%	2	4	7	9	11	22	44	66	110	176	220
	80%	3	5	8	10	13	25	50	75	126	201	252
	90%	3	6	8	11	14	28	57	85	141	226	283
	100%	3	6	9	13	16	31	63	94	157	252	314

Table A 2: Operational Displacement: Number of Kittiwake Mortalities Predicted During Autumn Passage

Mean		Mortality										
Displacement		1%	2%	3%	4%	5%	10%	20%	30%	50%	80%	100%
	10%	0	0	0	0	0	1	2	3	5	8	9
	20%	0	0	1	1	1	2	4	6	9	15	19
	30%	0	1	1	1	1	3	6	8	14	23	28
	40%	0	1	1	2	2	4	8	11	19	30	38
	50%	0	1	1	2	2	5	9	14	23	38	47
	60%	1	1	2	2	3	6	11	17	28	45	56
	70%	1	1	2	3	3	7	13	20	33	53	66
	80%	1	2	2	3	4	8	15	23	38	60	75
	90%	1	2	3	3	4	8	17	25	42	68	85
	100%	1	2	3	4	5	9	19	28	47	75	94

Table A 3: Operational Displacement: Number of Kittiwake Mortalities Predicted During Spring Passage

Mean		Mortality										
Displacement		1%	2%	3%	4%	5%	10%	20%	30%	50%	80%	100%
	10%	0	0	0	0	0	1	2	3	4	7	8
	20%	0	0	1	1	1	2	3	5	8	14	17
	30%	0	1	1	1	1	3	5	8	13	20	25
	40%	0	1	1	1	2	3	7	10	17	27	34
	50%	0	1	1	2	2	4	8	13	21	34	42
	60%	1	1	2	2	3	5	10	15	25	41	51
	70%	1	1	2	2	3	6	12	18	30	47	59
	80%	1	1	2	3	3	7	14	20	34	54	68
	90%	1	2	2	3	4	8	15	23	38	61	76
	100%	1	2	3	3	4	8	17	25	42	68	84

Table A 4: Operational Displacement: Number of Guillemot Mortalities Predicted During the Breeding Season

Mean		Mortality										
Displacement		1%	2%	3%	4%	5%	10%	20%	30%	50%	80%	100%
	10%	1	2	2	3	4	8	16	24	40	63	79
	20%	2	3	5	6	8	16	32	47	79	126	158
	30%	2	5	7	9	12	24	47	71	119	190	237
	40%	3	6	9	13	16	32	63	95	158	253	316
	50%	4	8	12	16	20	40	79	119	198	316	395
	60%	5	9	14	19	24	47	95	142	237	379	474
	70%	6	11	17	22	28	55	111	166	277	442	553
	80%	6	13	19	25	32	63	126	190	316	506	632
	90%	7	14	21	28	36	71	142	213	356	569	711
	100%	8	16	24	32	40	79	158	237	395	632	790

Table A 5 Operational Displacement: Number of Guillemot Mortalities Predicted During Post-breeding Dispersal

Mean		Mortality										
Displacement		1%	2%	3%	4%	5%	10%	20%	30%	50%	80%	100%
	10%	5	10	15	20	25	51	102	152	254	406	508
	20%	10	20	30	41	51	102	203	305	508	812	1,015
	30%	15	30	46	61	76	152	305	457	761	1,218	1,523
	40%	20	41	61	81	102	203	406	609	1,015	1,624	2,030
	50%	25	51	76	102	127	254	508	761	1,269	2,030	2,538
	60%	30	61	91	122	152	305	609	914	1,523	2,436	3,045
	70%	36	71	107	142	178	355	711	1,066	1,776	2,842	3,553
	80%	41	81	122	162	203	406	812	1,218	2,030	3,248	4,060
	90%	46	91	137	183	228	457	914	1,370	2,284	3,654	4,568
	100%	51	102	152	203	254	508	1,015	1,523	2,538	4,060	5,075

Table A 6: Operational Displacement: Number of Guillemot Mortalities Predicted During the Non-breeding Season

Mean		Mortality										
Displacement		1%	2%	3%	4%	5%	10%	20%	30%	50%	80%	100%
	10%	1	2	3	4	5	9	19	28	47	75	94
	20%	2	4	6	8	9	19	38	56	94	150	188
	30%	3	6	8	11	14	28	56	84	141	225	281
	40%	4	8	11	15	19	38	75	113	188	300	375
	50%	5	9	14	19	23	47	94	141	235	375	469
	60%	6	11	17	23	28	56	113	169	281	450	563
	70%	7	13	20	26	33	66	131	197	328	525	657
	80%	8	15	23	30	38	75	150	225	375	600	750
	90%	8	17	25	34	42	84	169	253	422	675	844
	100%	9	19	28	38	47	94	188	281	469	750	938

Table A 9: Operational Displacement: Number of Razorbill Mortalities Predicted During the Breeding Season

Mean		Mortality										
Displacement		1%	2%	3%	4%	5%	10%	20%	30%	50%	80%	100%
	10%	1	3	4	5	7	13	26	39	65	104	130
	20%	3	5	8	10	13	26	52	78	130	208	260
	30%	4	8	12	16	20	39	78	117	195	312	390
	40%	5	10	16	21	26	52	104	156	260	416	520
	50%	7	13	20	26	33	65	130	195	325	520	650
	60%	8	16	23	31	39	78	156	234	390	624	780
	70%	9	18	27	36	46	91	182	273	455	728	910
	80%	10	21	31	42	52	104	208	312	520	832	1,040
	90%	12	23	35	47	59	117	234	351	585	936	1,170
	100%	13	26	39	52	65	130	260	390	650	1,040	1,300

Table A 10: Operational Displacement: Number of Razorbill Mortalities Predicted During Autumn Passage

Mean		Mortality										
Displacement		1%	2%	3%	4%	5%	10%	20%	30%	50%	80%	100%
	10%	0	0	0	0	0	0	0	0	0	0	0
	20%	0	0	0	0	0	0	0	0	0	0	0
	30%	0	0	0	0	0	0	0	0	0	0	0
	40%	0	0	0	0	0	0	0	0	0	0	0
	50%	0	0	0	0	0	0	0	0	0	0	0
	60%	0	0	0	0	0	0	0	0	0	0	0
	70%	0	0	0	0	0	0	0	0	0	0	0
	80%	0	0	0	0	0	0	0	0	0	0	0
	90%	0	0	0	0	0	0	0	0	0	0	0
	100%	0	0	0	0	0	0	0	0	0	0	0

Table A 11: Operational Displacement: Number of Razorbill Mortalities Predicted During Winter

Mean		**Mortality**										
Displacement		1%	2%	3%	4%	5%	10%	20%	30%	50%	80%	100%
	10%	0	0	0	0	0	0	0	0	0	0	1
	20%	0	0	0	0	0	0	0	0	1	1	1
	30%	0	0	0	0	0	0	0	1	1	1	2
	40%	0	0	0	0	0	0	0	1	1	2	2
	50%	0	0	0	0	0	0	1	1	1	2	3
	60%	0	0	0	0	0	0	1	1	2	3	4
	70%	0	0	0	0	0	0	1	1	2	3	4
	80%	0	0	0	0	0	0	1	1	2	4	5
	90%	0	0	0	0	0	1	1	2	3	4	5
	100%	0	0	0	0	0	1	1	2	3	5	6

Table A 12: Operational Displacement: Number of Razorbill Mortalities Predicted During Spring Passage

Mean		**Mortality**										
Displacement		1%	2%	3%	4%	5%	10%	20%	30%	50%	80%	100%
	10%	0	0	0	0	0	1	2	3	5	8	10
	20%	0	0	1	1	1	2	4	6	10	16	20
	30%	0	1	1	1	1	3	6	9	15	24	30
	40%	0	1	1	2	2	4	8	12	20	32	40
	50%	0	1	1	2	2	5	10	15	25	40	50
	60%	1	1	2	2	3	6	12	18	30	48	60
	70%	1	1	2	3	3	7	14	21	35	56	70
	80%	1	2	2	3	4	8	16	24	40	64	80
	90%	1	2	3	4	4	9	18	27	45	72	90
	100%	1	2	3	4	5	10	20	30	50	80	100

Table A 13: Operational Displacement: Number of Puffin Mortalities Predicted During the Breeding Season

Mean		Mortality										
Displacement		1%	2%	3%	4%	5%	10%	20%	30%	50%	80%	100%
	10%	0	1	1	1	2	4	7	11	18	29	36
	20%	1	1	2	3	4	7	14	22	36	58	72
	30%	1	2	3	4	5	11	22	32	54	86	108
	40%	1	3	4	6	7	14	29	43	72	115	144
	50%	2	4	5	7	9	18	36	54	90	144	180
	60%	2	4	6	9	11	22	43	65	108	173	216
	70%	3	5	8	10	13	25	50	76	126	201	252
	80%	3	6	9	12	14	29	58	86	144	230	288
	90%	3	6	10	13	16	32	65	97	162	259	324
	100%	4	7	11	14	18	36	72	108	180	288	360

Table A 14: Operational Displacement: Number of Puffin Mortalities Predicted During the Non-Breeding Season

Mean		Mortality										
Displacement		1%	2%	3%	4%	5%	10%	20%	30%	50%	80%	100%
	10%	0	1	1	1	2	3	7	10	17	28	34
	20%	1	1	2	3	3	7	14	21	34	55	69
	30%	1	2	3	4	5	10	21	31	52	83	103
	40%	1	3	4	6	7	14	28	41	69	110	138
	50%	2	3	5	7	9	17	34	52	86	138	172
	60%	2	4	6	8	10	21	41	62	103	165	206
	70%	2	5	7	10	12	24	48	72	120	193	241
	80%	3	6	8	11	14	28	55	83	138	220	275
	90%	3	6	9	12	15	31	62	93	155	248	310
	100%	3	7	10	14	17	34	69	103	172	275	344

Table A 15: Operational Displacement: Number of Gannet Mortalities Predicted During the Breeding Season

Mean		Mortality										
Displacement		1%	2%	3%	4%	5%	10%	20%	30%	50%	80%	100%
	10%	0	1	1	1	1	3	5	8	13	21	26
	20%	1	1	2	2	3	5	10	16	26	41	52
	30%	1	2	2	3	4	8	16	23	39	62	78
	40%	1	2	3	4	5	10	21	31	52	83	103
	50%	1	3	4	5	6	13	26	39	65	103	129
	60%	2	3	5	6	8	16	31	47	78	124	155
	70%	2	4	5	7	9	18	36	54	90	145	181
	80%	2	4	6	8	10	21	41	62	103	165	207
	90%	2	5	7	9	12	23	47	70	116	186	233
	100%	3	5	8	10	13	26	52	78	129	207	258

Table A 16: Operational Displacement: Number of Gannet Mortalities Predicted During Autumn Passage

Mean		Mortality										
Displacement		1%	2%	3%	4%	5%	10%	20%	30%	50%	80%	100%
	10%	0	0	1	1	1	2	4	7	11	18	22
	20%	0	1	1	2	2	4	9	13	22	36	45
	30%	1	1	2	3	3	7	13	20	34	54	67
	40%	1	2	3	4	4	9	18	27	45	72	89
	50%	1	2	3	4	6	11	22	34	56	89	112
	60%	1	3	4	5	7	13	27	40	67	107	134
	70%	2	3	5	6	8	16	31	47	78	125	157
	80%	2	4	5	7	9	18	36	54	89	143	179
	90%	2	4	6	8	10	20	40	60	101	161	201
	100%	2	4	7	9	11	22	45	67	112	179	224

Table A 17: Operational Displacement: Number of Gannet Mortalities Predicted During Spring Passage

Mean		Mortality										
Displacement		1%	2%	3%	4%	5%	10%	20%	30%	50%	80%	100%
	10%	0	0	0	1	1	2	3	5	8	13	16
	20%	0	1	1	1	2	3	6	10	16	25	32
	30%	0	1	1	2	2	5	10	14	24	38	48
	40%	1	1	2	3	3	6	13	19	32	51	64
	50%	1	2	2	3	4	8	16	24	40	64	80
	60%	1	2	3	4	5	10	19	29	48	76	96
	70%	1	2	3	4	6	11	22	33	56	89	112
	80%	1	3	4	5	6	13	25	38	64	102	127
	90%	1	3	4	6	7	14	29	43	72	115	143
	100%	2	3	5	6	8	16	32	48	80	127	159

Annex B: SeabORD Model Runtimes

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Table B 1: SeabORD Model Run Times

Species	Type of Run	Number of Runs	Percentage of Population Used	Total Duration of Runs (hh:mm)
Test Runs*	Test runs	10	-	08:52
Kittiwake	No ORD flight paths	2	0.1	04:02
	Prey calibration	31	0.1	06:43
	ORD flightpaths	1	0.1	01:55
	Final full run	6	0.1	25:00
Razorbill	Flight paths	1	0.1	01:01
	Prey calibration	21	0.1	00:56
	ORD flightpaths	1	0.1	04:00
	Final full run	2	0.1	01:15
Puffin	Flight paths	1	0.1	41:43
	Prey calibration	25	0.1	05:43
	ORD flightpaths	3	0.05	03:32
	Final full run	3	0.1	56:44
Totals	**-**	**107**	**-**	**165:26**

Notes:

*Test runs were conducted in the process of ensuring the tool was fully understood and useable before running the simulations used for this assessment - this includes runs where the simulations crashed.

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Annex C: Additional SeabORD Outputs

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Table C 1: Additional Output Metrics for Kittiwake Colonies Modelled in SeabORD

Colony	Scenario	Mean Adult Survival During Chick-rearing (SD) (%)	Initial Adult Mass (SD) (g)	Mean Adult Mass at The End of Chick-rearing Season (SD) (g)	Mass Loss During the Chick-rearing Season (g)	Scaled Mean Number of Adults Directly Impacted by the Bellrock Wind Farm Infrastructure (%)	Mean Difference in the Distance Flown Per Timestep (SD) (km)	Mean Difference in the Number of Trips Flown Per Timestep (SD)
Buchan Ness to Collieston Coast SPA	Baseline (no ORD)	100 (0.00)	372.839 (0.000)	341.160 (5.816)	31.679	N/A	0.251 (0.881)	-0.001 (0.006)
	Impact (with ORD)	100 (0.00)	372.839 (0.000)	341.161 (5.814)	31.678	1,600		
East Caithness Cliffs SPA	Baseline (no ORD)	100 (0.00)	372.283 (0.000)	341.698 (5.496)	30.586	N/A	-0.014 (0.208)	0.000 (0.002)
	Impact (with ORD)	100 (0.00)	372.283 (0.000)	341.696 (5.497)	30.587	880		
Farne Islands SPA	Baseline (no ORD)	100 (0.00)	370.765 (0.000)	340.718 (5.821)	30.048	N/A	0.191 (0.230)	0.000 (0.001)
	Impact (with ORD)	100 (0.00)	370.765 (0.000)	340.718 (5.819)	30.048	1,090		
Fowlsheugh SPA	Baseline (no ORD)	100 (0.00)	372.173 (0.000)	341.040 (5.473)	31.133	N/A	-0.328 (0.629)	-0.003 (0.003)
	Impact (with ORD)	100 (0.00)	372.173 (0.000)	341.038 (5.473)	31.134	1,640		
St Abb's Head to Fast Castle SPA	Baseline (no ORD)	100 (0.00)	373.387 (0.000)	341.830 (6.034)	31.557	N/A	0.447 (1.061)	0.003 (0.009)
	Impact (with ORD)	100 (0.00)	373.387 (0.000)	341.829 (6.033)	31.558	500		
Troup, Pennan and Lion's Heads SPA	Baseline (no ORD)	100 (0.00)	373.634 (0.000)	341.986 (5.764)	31.648	N/A	0.082 (0.176)	0.000 (0.001)
	Impact (with ORD)	100 (0.00)	373.634 (0.000)	341.986 (5.762)	31.648	1,090		

Table C 2: Additional Output Metrics for Razorbill Colonies Modelled in SeabORD

Colony	Scenario	Mean Adult Survival During Chick-rearing (SD) (%)	Initial Adult Mass (SD) (g)	Mean Adult Mass at the End of Chick-rearing Season (SD) (g)	Mass Loss During the Chick-Rearing Season (g)	Scaled Mean Number of Adults Directly Impacted by the Bellrock Wind Farm Infrastructure (%)	Mean Difference in the Distance Flown per Timestep (SD) (km)	Mean Difference in the Number of Trips Flown per Timestep (SD)
Buchan Ness to Collieston Coast SPA	Baseline (no ORD)	100 (0.00)	583.524 (0.000)	544.248 (10.201)	39.277	N/A	-0.060 (0.268)	0.000 (0.003)
	Impact (with ORD)	100 (0.00)	583.524 (0.000)	544.249 (10.198)	39.275	230		
Fowlsheugh SPA	Baseline (no ORD)	100 (0.00)	583.617 (0.000)	544.683 (10.615)	38.934	N/A	0.012 (0.058)	0.000 (0.001)
	Impact (with ORD)	100 (0.00)	583.617 (0.000)	544.682 (10.615)	38.935	230		

Table C 3: Additional Output Metrics for Puffin Colonies Modelled in SeabORD

Colony	Scenario	Mean Adult Survival During Chick-rearing (SD) (%)	Initial Adult Mass (SD) (g)	Mean Adult Mass at the End of Chick-rearing Season (SD) (g)	Mass Loss During the Chick-Rearing Season (g)	Scaled Mean Number of Adults Directly Impacted by the Bellrock Wind Farm Infrastructure (%)	Mean Difference in the Distance Flown per Timestep (SD) (km)	Mean Difference in the Number of Trips Flown per Timestep (SD)
Forth Islands SPA	Baseline (no ORD)	99.973 (0.030)	392.922 (0.000)	357.176 (8.277)	35.746	N/A	9.582 (30.429)	-0.097 (0.303)
	Impact (with ORD)	99.965 (0.046)	392.922 (0.000)	356.674 (9.082)	36.248	7,090		
Coquet Island SPA	Baseline (no ORD)	100 (0.000)	392.285 (0.000)	366.145 (8.209)	26.141	N/A	-0.152 (0.367)	-0.002 (0.004)
	Impact (with ORD)	100 (0.000)	392.285 (0.000)	366.140 (8.212)	26.145	5,800		
Farne Islands SPA	Baseline (no ORD)	100 (0.000)	392.377 (0.000)	378.438 (5.331)	13.940	N/A	0.117 (0.202)	-0.001 (0.002)
	Impact (with ORD)	100 (0.000)	392.377 (0.000)	378.433 (5.334)	13.944	11,390		

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Annex D: SeabORD Final Run Bird Density Output Maps

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Plate D 1: SeabORD Bird Density Output Map for the Buchan Ness to Collieston Coast SPA Kittiwake Colony

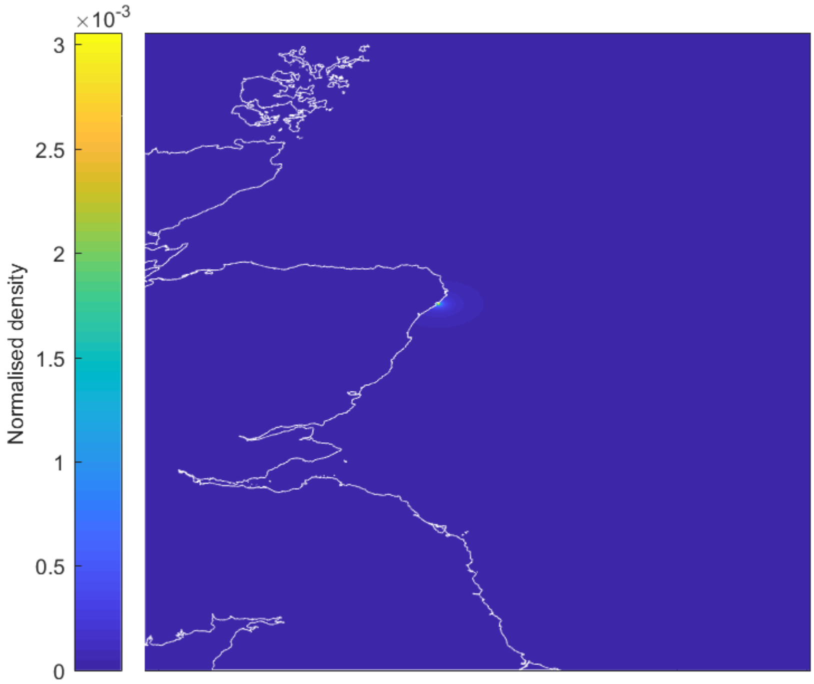

Plate D 2: SeabORD Bird Density Output Map for the East Caithness Cliffs SPA Kittiwake Colony

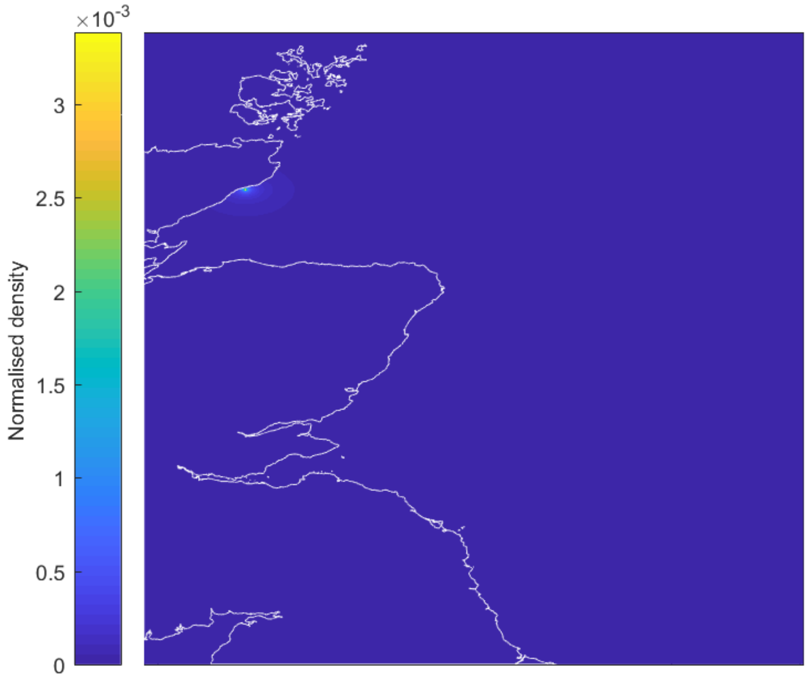

Plate D 3: SeabORD Bird Density Output Map for the Farne Islands SPA Kittiwake Colony

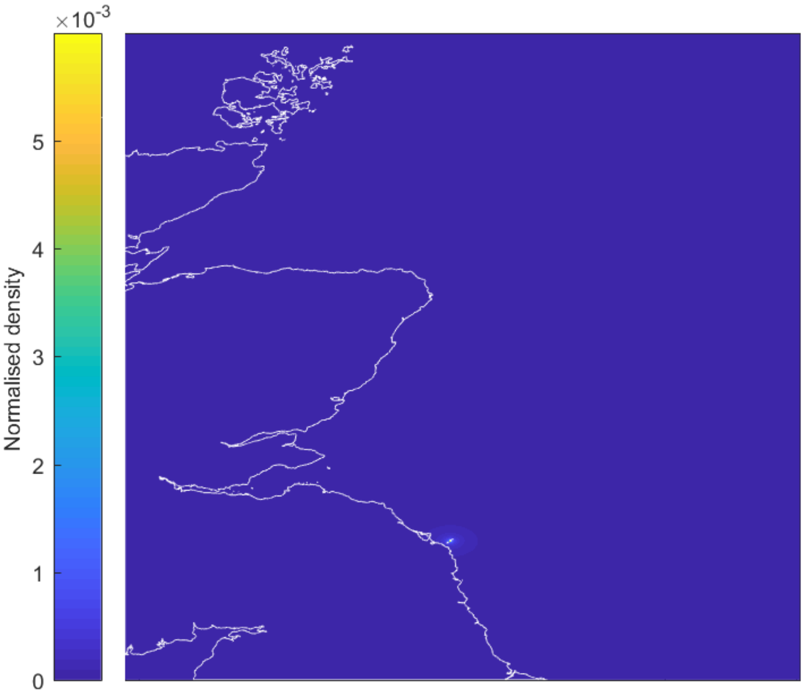

Plate D 4: SeabORD Bird Density Output Map for the St Abb's Head to Fast Castle SPA Kittiwake Colony

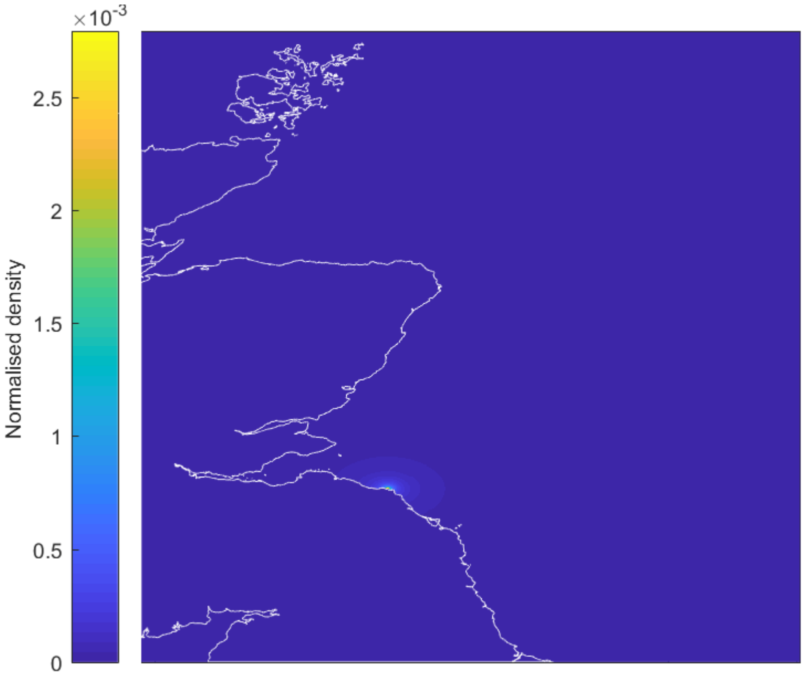

Plate D 5: SeabORD Bird Density Output Map for the Troup, Pennan and Lion's Head SPA Kittiwake Colony

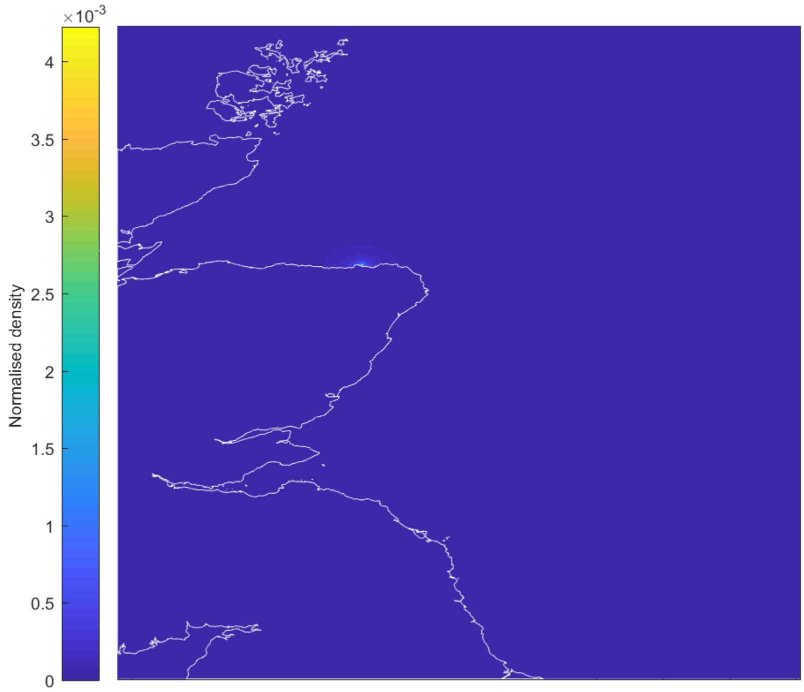

Plate D 6: SeabORD Bird Density Output Map for the Fowlsheugh SPA Kittiwake Colony

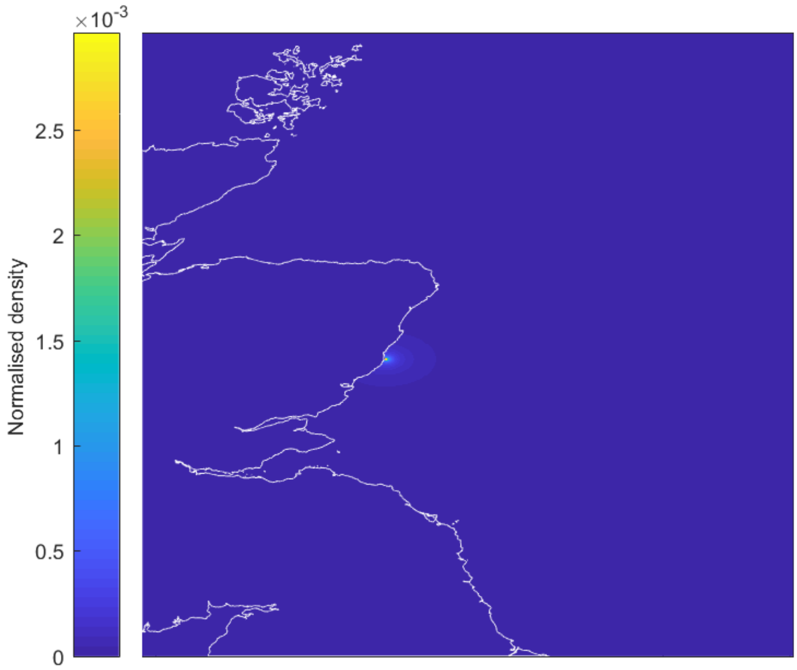

Plate D 7: SeabORD Bird Density Output Map for the Buchan Ness to Collieston Coast SPA Razorbill Colony

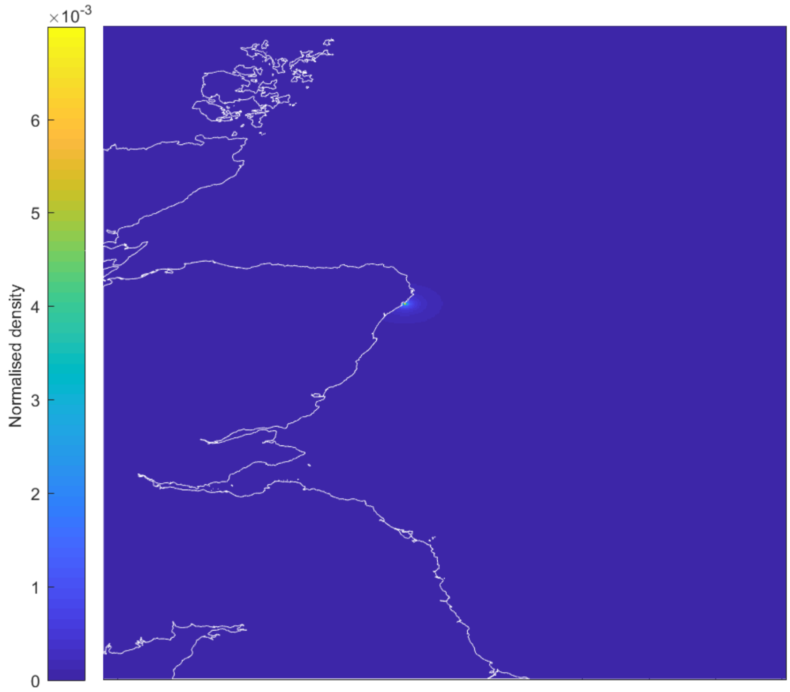

Plate D 8: SeabORD Bird Density Output Map for the Fowlsheugh SPA Razorbill Colony

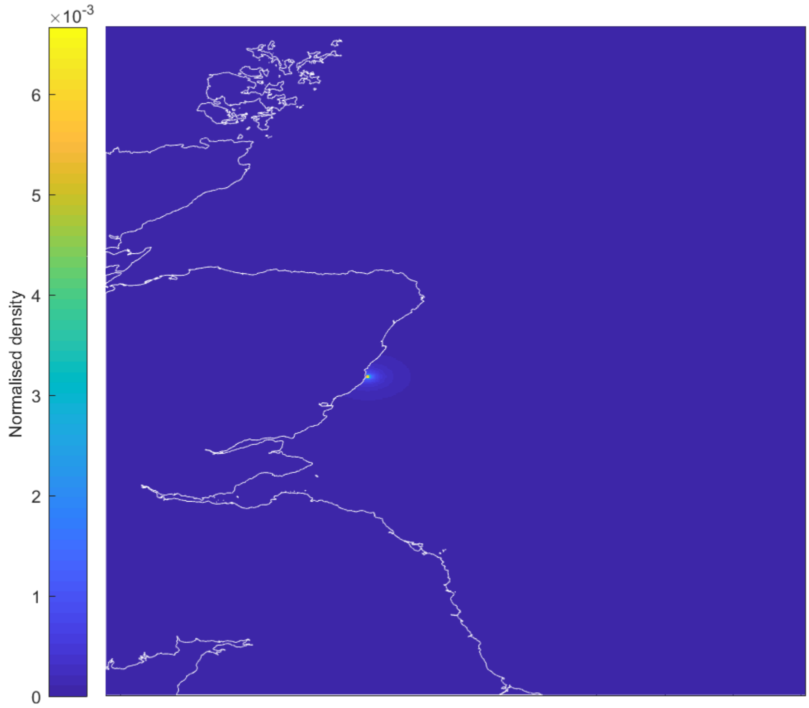

Plate D 9: SeabORD Bird Density Output Map for the Coquet Island SPA Puffin Colony

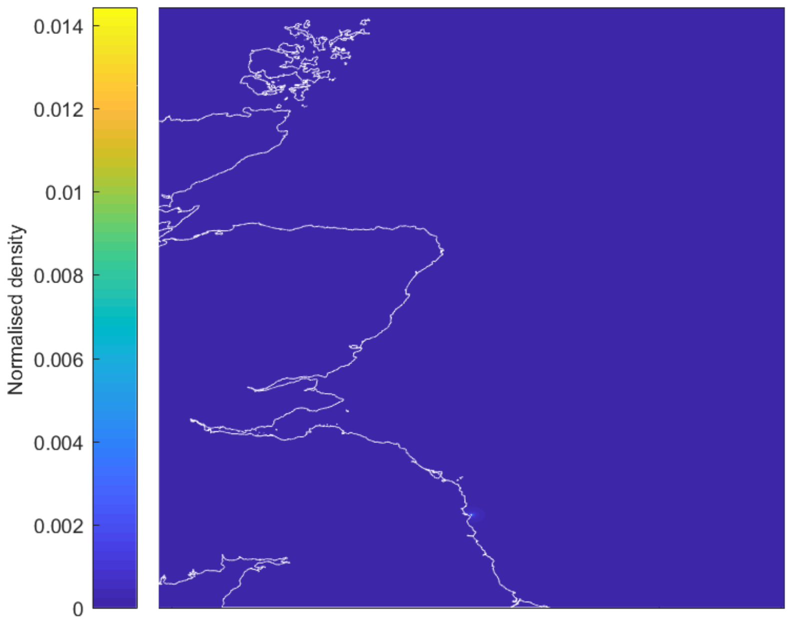

Plate D 10: SeabORD Bird Density Output Map for the Farne Islands SPA Puffin Colony

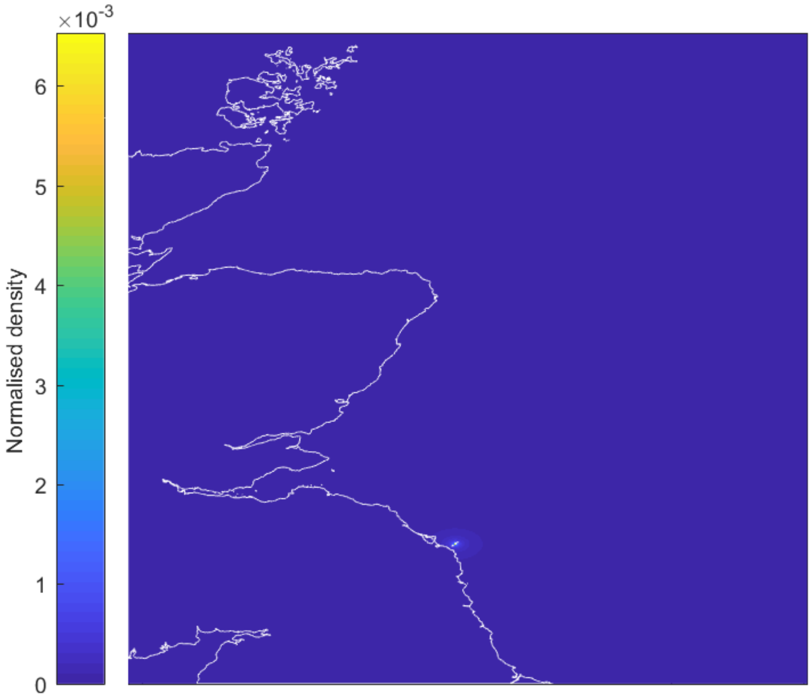

Plate D 11: SeabORD Bird Density Output Map for the Forth Islands SPA Puffin Colony