Environmental Impact Assessment Report
Volume 3, Appendix 12.2: Offshore Ornithology Displacement Modelling

MarramWind Offshore Wind Farm

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MarramWind

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Contents

1. Introduction

1.1 Project background

1.1.1.1 This Appendix presents the findings of a study of intertidal and offshore ornithology features that characterise the area that may be influenced by MarramWind Offshore Wind Farm (hereafter, referred to as 'the Project'). This Appendix specifically relates to the potential for distributional responses of bird species to occur as a result of Project activities and the presence of offshore Project infrastructure in the marine environment.

1.1.1.2 A separate report (**Appendix 12.1: Offshore and Intertidal Ornithology Baseline Report**) provides the baseline characterisation of the Option Agreement Area (OAA) through the data obtained from Digital Aerial Surveys (DAS). This displacement modelling Appendix has been produced to support **Volume 1, Chapter 12: Offshore and Intertidal Ornithology**.

1.2 Distributional response analysis

1.2.1.1 There is the potential for disturbance and displacement of seabirds to occur due to the presence of Wind Turbine Generators (WTGs) being sited in an area of sea utilised by seabirds. Barrier effects can also be created through the presence of these WTGs, which can consequently alter the flight paths of seabirds to less energy efficient routes. It is not usually possible to distinguish between displacement effects and barrier effects and so the distributional response analysis provided within this Appendix incorporates both together, as recommended by NatureScot (NatureScot, 2023; Statutory Nature Conservation Bodies [SNCBs], 2022). Distributional response effects relate to indirect habitat loss due to the potential reduction in area available for foraging, loafing and moulting for disturbance sensitive seabird species.

1.2.1.2 In addition to the potential distributional response effects from operational WTGs, there is also potential for the construction and decommissioning of the WTGs to cause distributional responses of sensitive seabird species. It must be noted that the potential impacts in the construction and decommissioning stages are more restricted both temporally and spatially for floating WTGs when compared to monopile structures. This reduced impact in the construction stage has been recognised by NatureScot during consultation (see Table 12.1 in **Volume 1, Chapter 12: Offshore and Intertidal Ornithology**) and agreement gained that there is no requirement to assess distributional responses from construction and decommissioning of the OAA.

1.2.1.3 The presence of vessels associated with the installation of the export cable corridor and vessels transiting to and from the OAA may also potentially disturb and subsequently displace seabirds. The assessment of vessel disturbance presented within **Volume 1, Chapter 12: Offshore and Intertidal Ornithology** is on a qualitative basis only as agreed through consultation with NatureScot (Table 12.1 in **Volume 1, Chapter 12: Offshore and Intertidal Ornithology**) and therefore not considered within this Appendix further.

1.2.1.4 Upon review of the abundance and frequency of species recorded within the site-specific DAS data (see **Appendix 12.1**), and in accordance with NatureScot's recommendations of priority species they consider to be sensitive to displacement (NatureScot, 2023), five seabird species have been identified for assessment of distributional response effects within the OAA and relevant buffers:

- kittiwake (*Rissa tridactyla*);
- guillemot (*Uria aalge*);

- razorbill (*Alca torda*);
- puffin (*Fratercula arctica*); and
- gannet (*Morus bassanus*).

2. Methods

2.1 SeabORD versus matrix approach

2.1.1.1 As summarised within NatureScot's Guidance Note 8 (NatureScot, 2023), there are two approaches that are currently recommended at the time of drafting for quantification of distributional response effects.

2.1.1.2 The first method is SeabORD, which is an Individual-Based Model approach to estimating the impact of displacement applicable for kittiwake, guillemot, razorbill and puffin. The model developer (Searle *et al.,* 2018) describes SeabORD as a simulation model that aims

"*to predict the time/energy budgets of breeding seabirds during the chick-rearing period and translates these into projections of adult annual survival and productivity for each individual and at the population level. The model simulates foraging decisions of individual seabirds under the assumption that they are acting in accordance with optimal foraging theory, minimising time away from offspring whilst maximising energy gain. In the model, foraging behaviour of individual seabirds is driven by prey availability, travel costs, provisioning requirements for offspring, and at-sea density of conspecifics. The model estimates productivity and adult survival, the latter resulting from estimates of adult mass at the end of the breeding season. To determine ORD (Offshore Renewable Device) effects, baseline scenarios are compared with scenarios containing one or more ORDs*."

2.1.1.3 The second method is known as the 'matrix approach', which was developed jointly by UK SNCBs (SNCBs, 2022). The matrix approach presents the potential risk of displacement in tabular format, based on a range of possible displacement and mortality rates from 0% to 100% applied to the estimated abundance of a particular species within a specified Zone of Influence. Presentation of the potential level of impact based on a displacement range of 0% to 100% is recommended due to the uncertainty in the behavioural response species will exhibit to the presence of the offshore wind farm development. However, the use of emerging evidence from post-construction monitoring studies can be used to infer the likely behavioural responses of species to offshore wind farm developments and these can be highlighted accordingly on the matrix table.

2.1.1.4 The Project has consulted with NatureScot on which method(s) should be utilised to inform distributional response effects. As detailed within (Table 12.1 in **Volume 1, Chapter 12: Offshore and Intertidal Ornithology**), it was agreed with NatureScot that only the matrix approach is required at this stage, due to SeabORD currently undergoing further development to allow for the model to be run in the R programming language. The methods and results presented within this Appendix are therefore based on the matrix approach only.

2.2 Buffers for distributional responses

2.2.1.1 The scale of the potential distributional response effect that is applied in this Appendix follows the recommendations provided within NatureScot's Guidance Note 8 (NatureScot, 2023; SNCBs, 2022). For each of the five receptor species, displacement matrices are presented for the OAA and surrounding 2 kilometre (km) buffer. These are split into species-specific seasons (**Table 2.1**) as well as an annual total.

2.3 Data sources for displacement matrices

2.3.1.1 A total of 24 months of DAS were conducted across the OAA plus buffers from April 2021 through to March 2023. The data recorded within these surveys form the basis of distributional response analyses presented. Full details of the site-specific surveys are available in **Appendix 12.1**.

2.3.2 Data limitations

2.3.2.1 Data derived from high-resolution DAS surveys of the OAA and buffers are the only data source used within this Appendix. A full description of the DAS methodology and the offshore surveyed area can be found in **Appendix 12.1**. In terms of characterising the baseline environment, this data is considered the most reliable source for offshore ornithology.

2.4 Presentation of distributional responses by seasons

2.4.1.1 The usage of the marine area within the Offshore Red Line Boundary area by seabirds may differ seasonally, therefore assessments are undertaken on a seasonal basis. The seasonal definitions presented within this Appendix are derived from NatureScot Guidance Note 9 (NatureScot, 2020) as agreed through consultation (see Table 12.1 in **Volume 1, Chapter 12: Offshore and Intertidal Ornithology**). The species-specific seasons and the constituent months are presented in **Table 2.1**. A full overview of seasonal usage of the Project area by key species is provided in **Appendix 12.1**.

2.4.1.2 To assist visual presentation of the data, colour coding has been applied to the tables to represent the different seasons (**Table 2.1**). Each species has its own set of months that define the breeding season and non-breeding season. The colour used to define the breeding season is yellow and the colour used to define the non-breeding season is green.

Table 2.1 Seasonal colour coding

Season	Kittiwake	Guillemot	Razorbill	Puffin	Gannet
Breeding	Mid-April to August.	April to mid-August.	April to mid-August.	April to mid-August.	Mid-March to September.
Non-breeding	September to mid-April.	Mid-August to March.	Mid-August to March.	Mid-August to March.	October to mid-March.

2.4.1.3 For instances where seasons extend only halfway through a given month it was agreed with NatureScot (see Table 12.1 in **Volume 1, Chapter 12: Offshore and Intertidal Ornithology** for details) that data collected from surveys up to the 15th of the month would be classified as early to mid-month, and data after the 15th would be classified as late-month. This has been applied with the following exceptions:

- For kittiwake, the April 2021 survey (flown on the 15th) and the April 2022 survey (flown on the 14th) were concluded as being breeding season months, due to the abundance recorded being broadly similar to the increases in abundance recorded within the respective months of August 2021 and 2022 at the end of breeding season. Both the April and August movement of kittiwakes through the Project relate to either returning to or dispersing from breeding colonies.

- For gannet, the second March survey in 2023 (flown on the 19th) was concluded as being a non-breeding season due to the abundance recorded being comparable to March 2022 survey (flown on the 1st) and the first March 2023 survey (flown on the 9th).

2.5 Seasonal mean peak abundance

2.5.1.1 To inform the matrix approach, seasonal mean peak abundances have been calculated from the 24 months of DAS, as recommended in NatureScot's Guidance Note 8 (NatureScot, 2023). The seasonal mean peak abundance is calculated as the highest recorded monthly abundance within each season and survey year, averaged across the two years' of data. Calculating season abundance in such a way is highly precautionary, as it is highly unlikely that the abundance within a given season remains consistent across the entire season, especially when considering such peaks are usually characterised by temporary passage movements or moulting flocks.

2.5.1.2 Two methods have been used to calculate predicted abundance for the Project as recommended within NatureScot's Guidance Note 8 (NatureScot, 2023):

- design-based abundance estimation as described and presented within **Appendix 12.1**; and
- MRSea analysis as described and presented within **Appendix 12.5: Offshore Ornithology MRSea Modelling Report**.

2.5.1.3 On completion of both modelling approaches, the appropriateness of both datasets to inform assessments for the Project were reviewed as detailed within **Appendix 12.5**. Model-based abundance estimates were used where a complete season of results was available. Design-based abundance estimates were selected where a full season of model-based abundances were not available or where they were deemed unsuitable. This resulted in the use of model-based abundances for the kittiwake and gannet breeding seasons alone and the use of design-based for all other seasons and species (guillemot, razorbill and puffin).

2.5.1.4 Although the model-based abundances were fully available for guillemot, they were deemed unsuitable due to the significant difference from the design-based estimates. The apportioned and availability bias corrected estimates derived from MRSea modelling were consistently lower suggesting these results maybe underestimations. Over half of the model-based confidence intervals showed no overlap with the design-based confidence intervals showing a persistent divergence in results.

2.5.1.5 For species with unusually high counts in a single survey, some of which were artificially inflated by the presence of fishing vessels, MRSea mean peak abundance estimates were concluded as being most appropriate for informing the impact assessments. For gannet, the month of August 2021 is also excluded from mean peak abundance calculations due to the attraction effect of a fishing vessel recorded within the Project (an image from the DAS showing the vessel and the attracted birds is provided within **Appendix 12.5**). The species and seasons for which MRSea abundance estimates were used are indicated in **Table 2.2** .

2.5.1.6 The calculated seasonal mean peak abundances for the OAA and 2km buffer used to inform distributional response effects are presented in **Table 2.2** . These values are inclusive of all recorded behaviours, apportionment of unidentified individuals and corrected for availability bias where applicable. As per the joint SNCB Interim Displacement Advice Note (SNCBs, 2022), the full dataset of abundance estimates is provided in **Appendix 12.1** and **Appendix 12.5**, from which mean peak abundances have been derived. The upper and lower 95% confidence limits for the OAA and 2km buffer mean peak abundances are provided in **Appendix A**.

Table 2.2 Seasonal mean peak abundances in the OAA and 2km buffer (all behaviours)

Season	Survey area	Kittiwake (individuals)	Guillemot (individuals)	Razorbill (individuals)	Puffin (individuals)	Gannet (individuals)
Breeding	OAA	671	12,562	275	400	368
	OAA plus 2km buffer.	890	16,989	356	554	642
Non-breeding	OAA.	124	3,934	925	36	228
	OAA plus 2km buffer.	144	5,237	1,214	50	304
Annual*	OAA.	795	16,496	1,200	436	596
	OAA plus 2km buffer.	1,034	22,226	1,570	604	946

Table notes: Cells highlighted in orange indicate design-based mean peak abundance estimates. Cells highlighted purple indicate MRSea mean peak abundance estimates. *Annual includes the cumulative total of the breeding and non-breeding mean peak abundances combined.

3. Results

3.1.1.1 The Sections below present the displacement matrices for each of the five species included for assessment of distributional response effects (**Table 3.1** to **Table 3.15**). The matrices presented include those for the breeding season, non-breeding season and annual total. Each matrix uses the mean peak abundance estimates for each species in each season to show the potential number of individuals subject to mortality if between 0% to 100%% displacement and 0% to 100% mortality was to occur. Colour coding is used to visually present both the Developers and guidance (NatureScot's) preferred displacement and mortality rates for assessment. Corresponding literature sources used to inform likely displacement and consequent mortality rates are discussed within **Volume 1, Chapter 12: Offshore and Intertidal Ornithology**.

3.2 Kittiwake displacement matrices

Table 3.1 Kittiwake breeding season displacement matrix (mid-April to August) based on an abundance of 890 individuals for the OAA plus 2km buffer

Displacement (%)	Mortality rates (%)															
	0	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	1	2	3	4	4	5	6	7	8	9
10	0	1	2	3	4	4	9	18	27	36	45	53	62	71	80	89
20	0	2	4	5	7	9	18	36	53	71	89	107	125	142	160	178
30	0	3	5	8	11	13	27	53	80	107	134	160	187	214	240	267
40	0	4	7	11	14	18	36	71	107	142	178	214	249	285	320	356
50	0	4	9	13	18	22	45	89	134	178	223	267	312	356	401	445
60	0	5	11	16	21	27	53	107	160	214	267	320	374	427	481	534
70	0	6	12	19	25	31	62	125	187	249	312	374	436	498	561	623
80	0	7	14	21	28	36	71	142	214	285	356	427	498	570	641	712
90	0	8	16	24	32	40	80	160	240	320	401	481	561	641	721	801
100	0	9	18	27	36	45	89	178	267	356	445	534	623	712	801	890

Table notes: Cells highlighted in orange shows the Guidance approach preferred range of displacement and mortality rates (30% displacement and 1% to 3% mortality). No Applicant preferred rates are provided for Kittiwake. On review of available evidence, it is concluded that there is insufficient evidence to justify a requirement to assess kittiwake for distributional responses.

Table 3.2 Kittiwake non-breeding season displacement matrix (September to mid-April) based on an abundance of 144 individuals for the OAA plus 2km buffer

Displacement (%)	Mortality rates (%)															
	0	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
10	0	0	0	0	1	1	1	3	4	6	7	9	10	12	13	14
20	0	0	1	1	1	1	3	6	9	12	14	17	20	23	26	29
30	0	0	1	1	2	2	4	9	13	17	22	26	30	35	39	43
40	0	1	1	2	2	3	6	12	17	23	29	35	40	46	52	58
50	0	1	1	2	3	4	7	14	22	29	36	43	50	58	65	72
60	0	1	2	3	3	4	9	17	26	35	43	52	60	69	78	86
70	0	1	2	3	4	5	10	20	30	40	50	60	71	81	91	101
80	0	1	2	3	5	6	12	23	35	46	58	69	81	92	104	115
90	0	1	3	4	5	6	13	26	39	52	65	78	91	104	117	130
100	0	1	3	4	6	7	14	29	43	58	72	86	101	115	130	144

Table notes: Cells highlighted in orange shows the Guidance approach preferred range of displacement and mortality rates (30% displacement and 1% to 3% mortality). No Applicant preferred rates are provided for Kittiwake. On review of available evidence, it is concluded that there is insufficient evidence to justify a requirement to assess kittiwake for distributional responses.

Table 3.3 Kittiwake annual displacement matrix based on an abundance of 1,034 individuals for the OAA plus 2km buffer

Displacement (%)	Mortality rates (%)															
	0	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	1	1	2	3	4	5	6	7	8	9	10
10	0	1	2	3	4	5	10	21	31	41	52	62	72	83	93	103
20	0	2	4	6	8	10	21	41	62	83	103	124	145	165	186	207
30	0	3	6	9	12	16	31	62	93	124	155	186	217	248	279	310
40	0	4	8	12	17	21	41	83	124	165	207	248	290	331	372	414
50	0	5	10	16	21	26	52	103	155	207	259	310	362	414	465	517
60	0	6	12	19	25	31	62	124	186	248	310	372	434	496	558	620
70	0	7	14	22	29	36	72	145	217	290	362	434	507	579	651	724
80	0	8	17	25	33	41	83	165	248	331	414	496	579	662	744	827
90	0	9	19	28	37	47	93	186	279	372	465	558	651	744	838	931
100	0	10	21	31	41	52	103	207	310	414	517	620	724	827	931	1,034

3.3 Guillemot displacement matrices

Table 3.4 Guillemot breeding season displacement matrix (April to mid-August) based on an abundance of 16,989 individuals for the OAA plus 2km buffer

Displacement (%)	Mortality rates (%)															
	0	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2	3	5	7	8	17	34	51	68	85	102	119	136	153	170
10	0	17	34	51	68	85	170	340	510	680	849	1,019	1,189	1,359	1,529	1,699
20	0	34	68	102	136	170	340	680	1,019	1,359	1,699	2,039	2,378	2,718	3,058	3,398
30	0	51	102	153	204	255	510	1,019	1,529	2,039	2,548	3,058	3,568	4,077	4,587	5,097
40	0	68	136	204	272	340	680	1,359	2,039	2,718	3,398	4,077	4,757	5,436	6,116	6,796
50	0	85	170	255	340	425	849	1,699	2,548	3,398	4,247	5,097	5,946	6,796	7,645	8,495
60	0	102	204	306	408	510	1,019	2,039	3,058	4,077	5,097	6,116	7,135	8,155	9,174	10,193
70	0	119	238	357	476	595	1,189	2,378	3,568	4,757	5,946	7,135	8,325	9,514	10,703	11,892
80	0	136	272	408	544	680	1,359	2,718	4,077	5,436	6,796	8,155	9,514	10,873	12,232	13,591
90	0	153	306	459	612	765	1,529	3,058	4,587	6,116	7,645	9,174	10,703	12,232	13,761	15,290
100	0	170	340	510	680	849	1,699	3,398	5,097	6,796	8,495	10,193	11,892	13,591	15,290	16,989

Table notes: Cells highlighted in orange shows the Guidance approach preferred range of displacement and mortality rates (60% displacement and 3% to 5% mortality). Cells highlighted purple provide the Applicant's preferred range of displacement and mortality rates (0% to 50% displacement and 0% to 1% mortality).

Table 3.5 Guillemot non-breeding season displacement matrix (mid-August to March) based on an abundance of 5,237 individuals for the OAA plus 2km buffer

Displacement (%)	Mortality rates (%)															
	0	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	1	1	2	2	3	5	10	16	21	26	31	37	42	47	52
10	0	5	10	16	21	26	52	105	157	209	262	314	367	419	471	524
20	0	10	21	31	42	52	105	209	314	419	524	628	733	838	943	1,047
30	0	16	31	47	63	79	157	314	471	628	785	943	1,100	1,257	1,414	1,571
40	0	21	42	63	84	105	209	419	628	838	1,047	1,257	1,466	1,676	1,885	2,095
50	0	26	52	79	105	131	262	524	785	1,047	1,309	1,571	1,833	2,095	2,356	2,618
60	0	31	63	94	126	157	314	628	943	1,257	1,571	1,885	2,199	2,514	2,828	3,142
70	0	37	73	110	147	183	367	733	1,100	1,466	1,833	2,199	2,566	2,932	3,299	3,666
80	0	42	84	126	168	209	419	838	1,257	1,676	2,095	2,514	2,932	3,351	3,770	4,189
90	0	47	94	141	189	236	471	943	1,414	1,885	2,356	2,828	3,299	3,770	4,242	4,713
100	0	52	105	157	209	262	524	1,047	1,571	2,095	2,618	3,142	3,666	4,189	4,713	5,237

Table notes: Cells highlighted in orange shows the Guidance approach preferred range of displacement and mortality rates (60% displacement and 1% to 3% mortality). Cells highlighted purple provide the Applicant's preferred range of displacement and mortality rates (50% displacement and 0% to 1% mortality).

Table 3.6 Guillemot annual displacement matrix based on an abundance of 22,226 individuals for the OAA plus 2km buffer

Displacement (%)	Mortality rates (%)															
	0	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2	4	7	9	11	22	44	67	89	111	133	156	178	200	222
10	0	22	44	67	89	111	222	445	667	889	1,111	1,334	1,556	1,778	2,000	2,223
20	0	44	89	133	178	222	445	889	1,334	1,778	2,223	2,667	3,112	3,556	4,001	4,445
30	0	67	133	200	267	333	667	1,334	2,000	2,667	3,334	4,001	4,667	5,334	6,001	6,668
40	0	89	178	267	356	445	889	1,778	2,667	3,556	4,445	5,334	6,223	7,112	8,001	8,890
50	0	111	222	333	445	556	1,111	2,223	3,334	4,445	5,556	6,668	7,779	8,890	10,001	11,113
60	0	133	267	400	533	667	1,334	2,667	4,001	5,334	6,668	8,001	9,335	10,668	12,002	13,335
70	0	156	311	467	622	778	1,556	3,112	4,667	6,223	7,779	9,335	10,890	12,446	14,002	15,558
80	0	178	356	533	711	889	1,778	3,556	5,334	7,112	8,890	10,668	12,446	14,224	16,002	17,780
90	0	200	400	600	800	1,000	2,000	4,001	6,001	8,001	10,001	12,002	14,002	16,002	18,003	20,003
100	0	222	445	667	889	1,111	2,223	4,445	6,668	8,890	11,113	13,335	15,558	17,780	20,003	22,226

3.4 Razorbill displacement matrices

Table 3.7 Razorbill breeding season displacement matrix (April to mid-August) based on an abundance of 356 individuals for the OAA plus 2km buffer

Displacement (%)	Mortality rates (%)															
	0	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	1	1	1	2	2	2	3	3	4
10	0	0	1	1	1	2	4	7	11	14	18	21	25	28	32	36
20	0	1	1	2	3	4	7	14	21	28	36	43	50	57	64	71
30	0	1	2	3	4	5	11	21	32	43	53	64	75	85	96	107
40	0	1	3	4	6	7	14	28	43	57	71	85	100	114	128	142
50	0	2	4	5	7	9	18	36	53	71	89	107	125	142	160	178
60	0	2	4	6	9	11	21	43	64	85	107	128	150	171	192	214
70	0	2	5	7	10	12	25	50	75	100	125	150	174	199	224	249
80	0	3	6	9	11	14	28	57	85	114	142	171	199	228	256	285
90	0	3	6	10	13	16	32	64	96	128	160	192	224	256	288	320
100	0	4	7	11	14	18	36	71	107	142	178	214	249	285	320	356

Table notes: Cells highlighted in orange shows the Guidance approach preferred range of displacement and mortality rates (60% displacement and 3% to 5% mortality). Cells highlighted purple provide the Applicant's preferred range of displacement and mortality rates (50% displacement and 0% to 1% mortality).

Table 3.8 Razorbill non-breeding season displacement matrix (mid-August to March) based on an abundance of 1,214 individuals for the OAA plus 2km buffer

Displacement (%)	Mortality rates (%)															
	0	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	1	1	2	4	5	6	7	8	10	11	12
10	0	1	2	4	5	6	12	24	36	49	61	73	85	97	109	121
20	0	2	5	7	10	12	24	49	73	97	121	146	170	194	219	243
30	0	4	7	11	15	18	36	73	109	146	182	219	255	291	328	364
40	0	5	10	15	19	24	49	97	146	194	243	291	340	388	437	486
50	0	6	12	18	24	30	61	121	182	243	304	364	425	486	546	607
60	0	7	15	22	29	36	73	146	219	291	364	437	510	583	656	728
70	0	8	17	25	34	42	85	170	255	340	425	510	595	680	765	850
80	0	10	19	29	39	49	97	194	291	388	486	583	680	777	874	971
90	0	11	22	33	44	55	109	219	328	437	546	656	765	874	983	1,093
100	0	12	24	36	49	61	121	243	364	486	607	728	850	971	1,093	1,214

Table notes: Cells highlighted in orange shows the Guidance approach preferred range of displacement and mortality rates (60% displacement and 1% to 3% mortality). Cells highlighted purple provide the Applicant's preferred range of displacement and mortality rates (50% displacement and 0% to 1% mortality).

Table 3.9 Razorbill annual displacement matrix based on an abundance of 1,570 individuals for the OAA plus 2km buffer

Displacement (%)	Mortality rates (%)															
	0	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	1	1	2	3	5	6	8	9	11	13	14	16
10	0	2	3	5	6	8	16	31	47	63	79	94	110	126	141	157
20	0	3	6	9	13	16	31	63	94	126	157	188	220	251	283	314
30	0	5	9	14	19	24	47	94	141	188	236	283	330	377	424	471
40	0	6	13	19	25	31	63	126	188	251	314	377	440	502	565	628
50	0	8	16	24	31	39	79	157	236	314	393	471	550	628	707	785
60	0	9	19	28	38	47	94	188	283	377	471	565	659	754	848	942
70	0	11	22	33	44	55	110	220	330	440	550	659	769	879	989	1,099
80	0	13	25	38	50	63	126	251	377	502	628	754	879	1,005	1,130	1,256
90	0	14	28	42	57	71	141	283	424	565	707	848	989	1,130	1,272	1,413
100	0	16	31	47	63	79	157	314	471	628	785	942	1,099	1,256	1,413	1,570

3.5 Puffin displacement matrices

Table 3.10 Puffin breeding season displacement matrix (April to mid-August) based on an abundance of 554 individuals for the OAA plus 2km buffer

Displacement (%)	Mortality rates (%)															
	0	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	1	1	2	2	3	3	4	4	5	6
10	0	1	1	2	2	3	6	11	17	22	28	33	39	44	50	55
20	0	1	2	3	4	6	11	22	33	44	55	66	78	89	100	111
30	0	2	3	5	7	8	17	33	50	66	83	100	116	133	150	166
40	0	2	4	7	9	11	22	44	66	89	111	133	155	177	199	222
50	0	3	6	8	11	14	28	55	83	111	139	166	194	222	249	277
60	0	3	7	10	13	17	33	66	100	133	166	199	233	266	299	332
70	0	4	8	12	16	19	39	78	116	155	194	233	271	310	349	388
80	0	4	9	13	18	22	44	89	133	177	222	266	310	355	399	443
90	0	5	10	15	20	25	50	100	150	199	249	299	349	399	449	499
100	0	6	11	17	22	28	55	111	166	222	277	332	388	443	499	554

Table notes: Cells highlighted in orange shows the Guidance approach preferred range of displacement and mortality rates (60% displacement and 3% to 5% mortality). Cells highlighted purple provide the Applicant's preferred range of displacement and mortality rates (50% displacement and 0% to 1% mortality).

Table 3.11 Puffin non-breeding season displacement matrix (mid-August to March) based on an abundance of 50 individuals for the OAA plus 2km buffer

Displacement (%)	Mortality rates (%)															
	0	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
10	0	0	0	0	0	0	1	1	2	2	3	3	4	4	5	5
20	0	0	0	0	0	1	1	2	3	4	5	6	7	8	9	10
30	0	0	0	0	1	1	2	3	5	6	8	9	11	12	14	15
40	0	0	0	1	1	1	2	4	6	8	10	12	14	16	18	20
50	0	0	1	1	1	1	3	5	8	10	13	15	18	20	23	25
60	0	0	1	1	1	2	3	6	9	12	15	18	21	24	27	30
70	0	0	1	1	1	2	4	7	11	14	18	21	25	28	32	35
80	0	0	1	1	2	2	4	8	12	16	20	24	28	32	36	40
90	0	0	1	1	2	2	5	9	14	18	23	27	32	36	41	45
100	0	1	1	2	2	3	5	10	15	20	25	30	35	40	45	50

Table notes: Cells highlighted in orange shows the Guidance approach preferred range of displacement and mortality rates (60% displacement and 1% to 3% mortality). Cells highlighted purple provide the Applicant's preferred range of displacement and mortality rates (50% displacement and 0% to 1% mortality).

Table 3.12 Puffin annual displacement matrix based on an abundance of 604 individuals for the OAA plus 2km buffer

Displacement (%)	Mortality rates (%)															
	0	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	1	1	2	2	3	4	4	5	5	6
10	0	1	1	2	2	3	6	12	18	24	30	36	42	48	54	60
20	0	1	2	4	5	6	12	24	36	48	60	72	85	97	109	121
30	0	2	4	5	7	9	18	36	54	72	91	109	127	145	163	181
40	0	2	5	7	10	12	24	48	72	97	121	145	169	193	217	242
50	0	3	6	9	12	15	30	60	91	121	151	181	211	242	272	302
60	0	4	7	11	14	18	36	72	109	145	181	217	254	290	326	362
70	0	4	8	13	17	21	42	85	127	169	211	254	296	338	381	423
80	0	5	10	14	19	24	48	97	145	193	242	290	338	387	435	483
90	0	5	11	16	22	27	54	109	163	217	272	326	381	435	489	544
100	0	6	12	18	24	30	60	121	181	242	302	362	423	483	544	604

3.6 Gannet displacement matrices

Table 3.13 Gannet breeding season displacement matrix (mid-March to September) based on an abundance of 642 individuals for the OAA plus 2km buffer

Displacement (%)	Mortality rates (%)															
	0	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	1	1	2	3	3	4	4	5	6	6
10	0	1	1	2	3	3	6	13	19	26	32	38	45	51	58	64
20	0	1	3	4	5	6	13	26	38	51	64	77	90	103	115	128
30	0	2	4	6	8	10	19	38	58	77	96	115	135	154	173	192
40	0	3	5	8	10	13	26	51	77	103	128	154	180	205	231	257
50	0	3	6	10	13	16	32	64	96	128	160	192	225	257	289	321
60	0	4	8	12	15	19	38	77	115	154	192	231	269	308	346	385
70	0	4	9	13	18	22	45	90	135	180	225	269	314	359	404	449
80	0	5	10	15	21	26	51	103	154	205	257	308	359	411	462	513
90	0	6	12	17	23	29	58	115	173	231	289	346	404	462	520	577
100	0	6	13	19	26	32	64	128	192	257	321	385	449	513	577	642

Table notes: Cells highlighted in orange shows the Guidance approach preferred range of displacement and mortality rates (70% displacement and 1% to 3% mortality). Cells highlighted purple provide the Applicant's preferred range of displacement and mortality rates (60% to 80% displacement and 0% to 1% mortality). Cells in green highlight area of overlap between the Guidance and Applicant's approach preferred rates.

Table 3.14 Gannet non-breeding season displacement matrix (October to mid-March) based on an abundance of 304 individuals for the OAA plus 2km buffer

Displacement (%)	Mortality rates (%)															
	0	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	1	1	1	2	2	2	2	3	3
10	0	0	1	1	1	2	3	6	9	12	15	18	21	24	27	30
20	0	1	1	2	2	3	6	12	18	24	30	36	43	49	55	61
30	0	1	2	3	4	5	9	18	27	36	46	55	64	73	82	91
40	0	1	2	4	5	6	12	24	36	49	61	73	85	97	109	122
50	0	2	3	5	6	8	15	30	46	61	76	91	106	122	137	152
60	0	2	4	5	7	9	18	36	55	73	91	109	128	146	164	182
70	0	2	4	6	9	11	21	43	64	85	106	128	149	170	192	213
80	0	2	5	7	10	12	24	49	73	97	122	146	170	195	219	243
90	0	3	5	8	11	14	27	55	82	109	137	164	192	219	246	274
100	0	3	6	9	12	15	30	61	91	122	152	182	213	243	274	304

Table notes: Cells highlighted in orange shows the Guidance approach preferred range of displacement and mortality rates (70% displacement and 1% to 3% mortality). Cells highlighted purple provide the Applicant's preferred range of displacement and mortality rates (60% to 80% displacement and 0% to 1% mortality). Cells in green highlight area of overlap between the Guidance and Applicant's approach preferred rates.

Table 3.15 Gannet annual displacement matrix based on an abundance of 946 individuals for the OAA plus 2km buffer

Displacement (%)	Mortality rates (%)															
	0	**1**	**2**	**3**	**4**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9	9
10	0	1	2	3	4	5	9	19	28	38	47	57	66	76	85	95
20	0	2	4	6	8	9	19	38	57	76	95	113	132	151	170	189
30	0	3	6	9	11	14	28	57	85	113	142	170	199	227	255	284
40	0	4	8	11	15	19	38	76	113	151	189	227	265	303	340	378
50	0	5	9	14	19	24	47	95	142	189	236	284	331	378	425	473
60	0	6	11	17	23	28	57	113	170	227	284	340	397	454	511	567
70	0	7	13	20	26	33	66	132	199	265	331	397	463	529	596	662
80	0	8	15	23	30	38	76	151	227	303	378	454	529	605	681	756
90	0	9	17	26	34	43	85	170	255	340	425	511	596	681	766	851
100	0	9	19	28	38	47	95	189	284	378	473	567	662	756	851	946

4. References

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5. Glossary of Terms and Abbreviations

5.1 Abbreviations

Acronym	Definition
DAS	Digital Aerial Surveys
km	kilometres
OAA	Option Agreement Area
SNCBs	UK Statutory Nature Conservation Bodies
WTGs	Wind Turbine Generators

5.2 Glossary of terms

Term	Definition
Barrier effect	A barrier is a physical factor that limits the migration, or free movement of individuals or populations, thus requiring them to divert from their intended path in order to reach their original destination. This effect is expected to increase the energy expenditure of birds if they have to fly around the area in question in order to reach their goal. A key distinction between barrier and displacement is that birds experiencing barrier effects typically travel longer distances (for instance, to some point beyond the offshore wind farm) and did not intend to forage / utilise the offshore wind farm site itself, but some area beyond it (SNCBs, 2022).
MRSea	MRSea is a package developed in R (R Core Team, 2024) used for identifying spatially explicit changes in the spatial distribution and abundance of seabirds over time and across an offshore development site. MRSea modelling is recommended on the basis that it may offer greater facility in understanding the variation in distribution in response to environmental variables.
SeabORD	A model that predicts the time / energy budgets for four species of UK seabirds (puffin, guillemot, kittiwake and razorbill) during the chick-rearing period and translates these into projections of population level adult annual survival and productivity. This is used to estimate the population consequences of displacement and barrier effects from proposed offshore renewable energy developments.

Appendix A
Means of 95% Confidence Limits for Abundance

The mean of the upper and lower 95% confidence limits for the mean peak abundances presented in **Table 2.2** are presented below for each species (**Table A1**). Mean peak abundances are calculated by averaging the highest (peak) monthly value within a bio-season each year (full methods are provided in (**Appendix 12.1**). To derive the upper and lower 95% confidence limits for the mean peak abundances, the upper and lower confidence limits for each peak abundance estimate are used.

For example, if in the non-breeding bio-season the peak count was in January of the first year and February of the second year, then the upper and lower confidence limits for those same months were used when calculating the mean. So the upper confidence limits for January and February would be averaged and the lower values would be averaged. This would provide a mean of the upper and lower confidence limit for the mean peak abundance.

Table A1 Seasonal mean peak abundance 95% confidence intervals in the OAA and 2km buffer (all behaviours)

Season	Survey area	Kittiwake	Guillemot	Razorbill	Puffin	Gannet
Breeding	OAA.	340 to 1,444.	10,782 to 14,593.	137 to 448.	260 to 553.	257 to 477.
	OAA plus 2km buffer.	439 to 1,975.	14,898 to 19,294.	197 to 551.	376 to 751.	448 to 949.
Non-breeding	OAA.	64 to 191.	3,391 to 4,443.	640 to 1,272.	6 to 70.	152 to 315.
	OAA plus 2km buffer.	84 to 224.	4,566 to 5,909.	900 to 1,575.	11 to 99.	213 to 405.
Annual	OAA.	404 to 1635.	14,172 to 19,036.	776 to 1,720.	266 to 623.	409 to 792.
	OAA plus 2km buffer.	523 to 2,199.	19,463 to 25,202.	1,097 to 1,126.	387 to 850.	661 to 1,354.

Table notes: Cells highlighted in orange indicate design-based mean peak abundance estimates. Cells highlighted purple indicate MRSea mean peak abundance estimate.

MarramWind