Appendix 11.3: Offshore Ornithology Displacement Technical Report

Array EIA Report

2024

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TABLES

1. INTRODUCTION

1. Seabirds can be impacted by offshore wind farm developments in a number of ways, including collision, displacement, barrier effects and disturbance, as well as indirect impacts such as changes to prey availability. Disturbance as the result of activities during the construction, operation and maintenance, and decommissioning phases of an offshore wind farm has the potential to displace seabirds from the area of sea in which the activity is occurring. This in effect represents indirect habitat loss which would reduce the area available for feeding, loafing and moulting for seabird species that may occur at the Array.

2. In relation to offshore wind farm development, displacement is defined as a reduction in the number of seabirds occurring within or immediately adjacent to an offshore wind farm (Furness *et al*., 2013). Displacement, as an effect, may occur both in the area of the disturbance or development and to some distance beyond it – known as a 'buffer' (e.g. Mendel *et al*., 2014). The degree of displacement, both in terms of length of time and proportion of the original source population affected, may vary seasonally and between species.

3. This technical report presents the method and results of the matrix table approach to seabird displacement assessment resulting from the Array during, operation and maintenance phases. Displacement during the construction and decommissioning phase are considered to be much less than that experienced during operation and maintenance and only occur, if at all, during a short period of time. The matrix approach is deemed unnecessary due to the negligible and temporary nature of the impact and therefore not included in this report.

4. This technical report considers the most abundant seabird species recorded during the Digital Aerial Surveys (DAS) carried out between March 2021 and February 2023, in order to characterise the baseline for the assessment. A summary of the methods and results of the DAS are presented in volume 3, appendix 11.1.

5. This technical report also presents displacement matrices using predicted seabird abundances from Marine Renewables Strategic Environmental Assessment (MRSea) modelling outputs for black-legged kittiwake (hereafter kittiwake) *Rissa tridactyla*, razorbill *Alca torda*, guillemot *Uria aalge*, puffin *Fratercula arctica*, fulmar *Fulmarus glacialis* and northern gannet (hereafter gannet) *Morus bassanus*.

6. The analyses presented in this technical report have been informed by recent guidance published jointly by the United Kingdom (UK) Statutory Nature Conservation Bodies (SNCB, 2022a; SNCB, 2022b).

7. Displacement impacts associated with the Array plus a 2 km buffer (hereafter referred to as the 'displacement study area') are considered in this technical report.

2. BACKGROUND

8. Many groups of seabirds exhibit species-specific behavioural responses to operational offshore wind farms. These responses generally constitute an avoidance reaction in response to rotating wind turbines or vessel movements. Such a response can result in indirect habitat loss, as species avoid areas in which operational wind farms are present (Maclean *et al*., 2009; Langston, 2010).

9. Species differ greatly in their susceptibility to disturbance. Species sensitivity to disturbance in response to offshore wind farms has been quantified by Garthe and Hüppop (2004), Furness *et al*. (2013), Bradbury *et al*. (2014) and Wade *et al*. (2016). During the operation and maintenance phase, the presence of operational wind turbines has the potential to directly disturb seabirds, leading to displacement from the offshore wind farm, including an area of variable size (buffer) around it. In a review of studies from 20 operational offshore wind farms in Europe, Dierschke *et al.* (2016) assessed the extent of displacement or attraction of a number of seabird species. Whilst diver species and gannet showed consistent and strong avoidance behaviour of operational wind farms, fulmar, common scoter *Melanitta nigra*, Manx shearwater *Puffinus puffinus*, razorbill, guillemot, little gull *Hydrocoloeus minutus* and Sandwich tern *Thalasseus sandvicensis* showed less consistent displacement.

10. As the result of disturbance, displaced birds may move to areas already occupied by other birds and thus face higher intra/interspecific competition due to a higher density of individuals competing for the same resource. Alternatively, displaced birds may be forced to move into areas of lower quality (e.g. areas of lower prey availability). Such disturbance and resulting displacement could ultimately affect their demographic fitness (i.e. survival rates and breeding productivity) as well as potentially impacting on other birds in areas that displaced birds move to.

11. Changes in mortality levels of displaced birds have been established for waders (e.g. Burton *et al*. 2006). There is, however, a lack of empirical evidence on the consequence of displacement of seabirds, in terms of both their survival and productivity. In waterbirds such as waders, geese and seaducks, simulations using individual-based models (IBMs) have demonstrated changes to mortality as the result of changes in energy budgets of individuals (Pettifor *et al.,* 2000; West *et al.,* 2003; Kaiser *et al.,* 2002).

12. IBMs are rarely used to predict the fate of displaced seabirds due to offshore wind farms, and the resulting impacts on fitness (Topping and Petersen, 2011). One recent attempt to apply an IBM to displaced seabirds is the SeabORD model (Searle *et al.,* 2018). The original version of that tool is now deprecated; a new version is due to be released as part of the Cumulative Effects Framework but was not available at the time of writing this document (April 2024). It was agreed with NatureScot on 06 February 2024, that SeabORD would not be utilised within the assessment and only the matrix approach will be considered (refer to volume 2, chapter 11 for more detail).

13. The SNCBs have produced guidelines to assess seabird displacement associated with offshore wind farms (SNCB, 2022a; SNCB, 2022b). The guidelines promote the use of a displacement matrix approach (i.e. representing proportions of seabirds potentially displaced/dying as a result of an offshore wind farm development). The displacement assessment for the Array makes use of the displacement matrix approach.

3. METHODOLOGY

3.1. SPECIES FOR CONSIDERATION

14. The full process applied to identify Valued Ornithological Receptors (VORs) that may be affected by impacts associated with the Array (including, but not limited to, displacement impacts) is documented in volume 3, appendix 11.1. VORs that are potentially affected by displacement and therefore require further analysis are those:

- known to be vulnerable to displacement impacts[1] (based on Wade *et al*., 2016; Bradbury *et al*., 2014) (level of uncertainty also taken into account); and
- recorded within the Array offshore ornithology study area with a population that is considered to be of importance, when compared against a relevant population scale thresholds (regional, national or international).

[1] Vulnerability to displacement is one of several factors considered when identifying VORs. However, VORs could be selected for a range of reasons, and therefore, it is necessary to reassess vulnerability to displacement again at this stage for all VORs to identify those that could be affected by displacement.

15. Table 3.1 identifies those VORs for which displacement analysis is required based on the above criteria.

16. The following species were selected for displacement analysis:

- guillemot (high vulnerability, national population importance);
- razorbill (high vulnerability, national population importance);
- puffin (moderate vulnerability, regional population importance);
- fulmar (although vulnerability is very low, associated uncertainty level is high);
- gannet (high vulnerability); and
- kittiwake (although ruled out in Table 3.1, kittiwake has also been included due to recent evidence suggesting that the species can be sensitive to displacement from offshore wind farms (Peschko *et al*., 2020; Vanermen *et al*., 2016)).

Table 3.1: Identification of VORs for Which Analysis of Displacement for the Array is Required

VOR	Vulnerability to Displacement Impacts	Uncertainty Level Associated with Vulnerability Rating[2]	Importance of Population at the Array Offshore Ornithology Study Area[3]	Displacement Analysis Required (Yes/No)
Kittiwake	Low	Very Low	National	No – species recorded at national population importance, However, low vulnerability, with very low associated uncertainty gives confidence that this species does not require displacement analysis.
Herring gull *Larus argentatus*	Low	Very Low	Local	No – low vulnerability, very low associated uncertainty and species only recorded at local population importance.
Lesser black-backed gull *Larus fuscus*	Low	Very Low	Local	No – low vulnerability, very low associated uncertainty and species only recorded at local population importance.
Sandwich tern *Sterna sandvicensis*	Low	Low	Local	No – low vulnerability, low associated uncertainty and species only recorded at local population importance.
Little tern *Sternula albifrons*	Low	Moderate	Negligible	No – low vulnerability and species not recorded during baseline surveys.
Common tern *Sterna hirundo*	Low	Low	Local	No – low vulnerability, low associated uncertainty and species only recorded at local population importance.
Arctic tern *Sterna paradisaea*	Low	Moderate	Local	No – low vulnerability, moderate associated uncertainty and species only recorded at local population importance.
Great skua *Stercorarius skua*	Very Low	High	Local	No – low vulnerability (although high associated uncertainty) and species only recorded at local population importance.
Guillemot	High	Very Low	National	Yes – high vulnerability, species recorded in nationally important numbers at the Array offshore ornithology study area.
Razorbill	High	Very Low	National	Yes – high vulnerability, species recorded in nationally important numbers at the Array offshore ornithology study area.
Puffin	Moderate	Moderate	Regional	Yes – moderate vulnerability, species recorded in regionally important numbers at the Array offshore ornithology study area.
European storm petrel *Hydrobates pelagicus*	Very Low	Very High	Negligible	No – very low vulnerability and species not recorded during baseline surveys.
Leach's petrel *Hydrobates leucorhous*	Very Low	Very High	Negligible	No – very low vulnerability and species not recorded during baseline surveys.
Fulmar	Very Low	High	Regional	Yes – although vulnerability is very low, the associated uncertainty is high and species recorded in regionally important numbers at the Array offshore ornithology study area.
Manx shearwater	Very Low	Very High	Local	No – vulnerability is very low, and only low numbers were recorded of local population importance.
Gannet	High	Very Low	Local	Yes – high vulnerability. Therefore requires displacement analysis, despite only low numbers were recorded of local population importance.

[2] Uncertainty levels are taken from Wade *et al*. (2016).

[3] Population importance is based on the geographic scale of the Array offshore ornithology study area populations (i.e. whether it exceeds 1% of the local, regional, national or international population of that species). These population importance levels are set out in volume 3, appendix 11.1.

3.2. SEASONALITY

17. Bio-seasons used within the displacement assessment were defined according to the breeding, non-breeding and migratory periods (autumn and spring migration) based on NatureScot (2020) and Furness (2015), see Table 3.2.

Table 3.2: Seasonal Definitions as the Basis for Assessment, from NatureScot (2020) and Furness (2015)

Species	Pre-Breeding Season	Breeding Season	Post Breeding Season/	Non-Breeding
Kittiwake	Jan to mid-Apr	mid-Apr to Aug	Sept to Dec	
Guillemot		April to mid-Aug[1]		Mid-Aug to Mar
Razorbill	Jan to Mar	Apr to mid-Aug	mid-Aug to Oct	Nov to Dec
Puffin		April to mid-Aug		Mid-Aug to Mar
Fulmar	Dec to Mar	Apr to mid-Sept	Mid-Sept to Oct	Nov
Gannet	Dec to mid-Mar	Mid-Mar to Sept	Oct to Nov	

[1] The August 2023 survey count for guillemot is considered to reflect solely non-breeding abundances and not considered within the breeding season mean-max.

3.3. POPULATION ESTIMATES

18. Project specific data for the displacement study area has been collected by two years of DAS carried out between March 2021 and February 2023, encompassing the Array offshore ornithology survey area (as defined in volume 3, appendix 11.1). Further information on the DAS undertaken for the Array, and the methodologies used to derive population estimates is provided in volume 3, appendix 11.1.

19. For those species identified in section 3.1 (kittiwake, guillemot, razorbill, puffin, fulmar and gannet), a 2 km buffer around the Array is considered appropriate to inform assessment of displacement (the displacement study area). No VOR species for which a 4 km displacement buffer around the Array would typically be applied (i.e. those with a Very High vulnerability to displacement) were selected for inclusion in the analyses presented in this technical report. This is due to these species being absent during DAS of the Array offshore ornithology survey area.

20. Model based estimates using the MRSea package were produced in order to predict numbers across the Array offshore ornithology study area, alongside 95% confidence intervals to provide a level of uncertainty. Design-based estimates for bird numbers and densities in each month were also generated and compared to the MRSea estimates to provide additional validation of the MRSea outputs, and provide estimates for months where low raw abundances prevented the use of the MRSea model.

21. Table 4.2 to Table 4.19 show the design-based mortality estimates, and Table 4.20 to Table 4.36 show the MRSea-based mortality estimates for a range of displacement rates and mortality rates.

22. The primary data that informs the basis for the assessment of displacement effects are seasonal mean-peak population estimates, including seabirds both on the water and in flight. Seasonal mean-peak population estimates of each species were calculated using the defined seasons identified in Table 3.2 to provide the number of seabirds at risk of displacement impacts (as shown in Table 3.3). Peak abundances in each season for each species considered within the displacement assessment are outlined in a darker shaded colour within annex A of this technical report, with the respective seasons emphasised using different colours (green for pre-breeding, blue for breeding, red for post-breeding, and yellow for non-breeding).

Table 3.3: Seasonal Mean-Peak Abundances from Digital Aerial Survey Data (Design-Based Scenario) for Use in the Assessment for Each Bio-Season. MRSea Modelled Abundance Values are Shown in Brackets

Species	Pre-Breeding Season	Breeding Season	Post Breeding Season	Non-Breeding
Kittiwake	386 (581)	2,667 (3,183)	678 (566)	n/a
Guillemot	n/a	28,904 (27,247)	n/a	45,893 (48,340)
Razorbill	200 (224)	2,221 (2,608)	1,535 (1,493)	138 (138)
Puffin	n/a	2,341 (1,928)	n/a	1,478 (1,178)
Fulmar	688 (671)	2,256 (1,932)	509 (609)	435 (442)
Gannet	61 (42)	1,521 (1,393)	417 (775)	n/a

3.4. DISPLACEMENT AND MORTALITY RATES

23. Displacement rates are species-specific, and those used in assessment are presented in Table 3.4, following the NatureScot (2023) guidance. The advised displacement rates are applied uniformly across the displacement study area as described in the SNCB guidance (SNCB, 2022a; SNCB, 2022b), NatureScot (2023).

24. Mortality risk due to displacement depends on several factors, such as the size of the wind farm, which affects the amount of habitat lost, distance deviated by birds in flight, availability of suitable replacement habitat and, potentially, the level of increased competition. Mortality is also likely to differ with season and species, based on morphology, foraging range, foraging rates and seasonal energetic needs, such as when provisioning for chicks (Masden *et al*., 2010). Advised mortality rates during the breeding and non-breeding season are also presented in Table 3.4 (NatureScot, 2023).

25. In addition to the displacement and mortality rates provided by NatureScot (2023), rates based on recent evidence have also been modelled; ‘Developer Approach’.

26. For the Developer Approach, a displacement rate of 50% and mortality rate of 1% for auks was considered suitably precautionary for both the breeding and non-breeding season. APEM (2022a) undertook a review of auk displacement rates, and the Developer Approach aligns with their recommended maximum rate.

27. For the Developer Approach, the displacement and mortality rates for puffin (50% and 1%, respectively) follow rates discussed within the MacArthur Green 2019(a) and 2023 studies. The displacement rate for gannet (70%) was as advised by NatureScot (2023), whilst the mortality rate for gannet (1%) was chosen on the basis of previous recommendations from Natural England at the Norfolk Vanguard Development (MacArthur Green, 2019b).

28. The displacement rate for kittiwake (30%) was advised by NatureScot (2023) and is consistent with previous advice on Forth and Tay Projects (Marine Scotland, 2017). However, the Developer Approach applies a single mortality rate of 1%, which is within the range advised under the SNCB rates (1–3%). The mortality rate of 1% follows previous advice from the Marine Scotland on previous Forth & Tay projects (Marine Scotland, 2017).

29. In addition, further justification regarding the Applicant's preferred rate (the Developer Approach) is detailed in volume 2, chapter 11.

30. Displacement matrices are presented in section 0 for each of the selected species and their associated seasons. These matrices cover the complete range of potential displacement (i.e. 0% to 100%) and mortality rates (i.e. 0% to 100%), following recent SNCB guidance (SNCB, 2022a; NatureScot, 2023). However, as detailed above, NatureScot guidance rates are highlighted in yellow, while the Developer Approach is outlined in orange. Both sets of rates are presented in Table 3.4.

Table 3.4: Displacement and Mortality Rates for Use in the Assessment During Operation and Maintenance Phase

Species	Approach	Displacement Rate	Mortality Rates (Breeding Season)	Mortality Rates (Non-breeding Seasons)
Kittiwake	SNCB	30%	1% to 3%	1% to 3%
	Developer	30%	1%	1%
Guillemot	SNCB	60%	3% to 5%	1% to 3%
	Developer	50%	1%	1%
Razorbill	SNCB	60%	3% to 5%	1% to 3%
	Developer	50%	1%	1%
Puffin	SNCB	60%	3% to 5%	1% to 3%
	Developer	50%	1%	1%
Fulmar	SNCB	N/A		
	Developer	0% to 50%	0.5% to 2%	0.5% to 2%
Gannet	SNCB	70%	1% to 3%	1% to 3%
	Developer	70%	1%	1%

4. RESULTS

31. Displacement matrices using design-based abundance estimates are presented in section 4.1.

32. Displacement matrices using the model based abundance (MRSea) estimates are presented in section 4.2. These are provided for all species and associated seasons in months where available, and design-based estimates are used where model based estimates could not be calculated.

33. The seasons for each species align with Table 3.1 of volume 3 appendix 11.1, and it should be noted that not all species occur during all four seasons (post-breeding, breeding, post-breeding and non-breeding).

34. In each matrix the range of displacement and mortality rates following application of the NatureScot guidance rates are highlighted using cells filled with yellow, and the values following the application of the Developer Approach are outlined in orange (refer to Table 3.4 for the rates used).

4.1. DESIGN BASED SCENARIOS

4.1.1. KITTIWAKE

Table 4.1: Mean Predicted Kittiwake Mortality for the Displacement Study Area During Pre-Breeding Season (Design-Based)

Displacement Level (%)	Mortality (%)													
	1	**2**	**3**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
10	0	1	1	2	4	8	12	15	19	23	27	31	35	39
20	1	2	2	4	8	15	23	31	39	46	54	62	69	77
30	1	2	3	6	12	23	35	46	58	69	81	93	104	116
40	2	3	5	8	15	31	46	62	77	93	108	123	139	154
50	2	4	6	10	19	39	58	77	96	116	135	154	173	193
60	2	5	7	12	23	46	69	93	116	139	162	185	208	231
70	3	5	8	13	27	54	81	108	135	162	189	216	243	270
80	3	6	9	15	31	62	93	123	154	185	216	247	278	308
90	3	7	10	17	35	69	104	139	173	208	243	278	312	347
100	4	8	12	19	39	77	116	154	193	231	270	308	347	386

Table 4.2: Mean Predicted Kittiwake Mortality for the Displacement Study Area During the Breeding Season (Design-Based)

Displacement Level (%)	Mortality (%)													
	1	**2**	**3**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
10	3	5	8	13	27	53	80	107	133	160	187	213	240	267
20	5	11	16	27	53	107	160	213	267	320	373	427	480	533
30	8	16	24	40	80	160	240	320	400	480	560	640	720	800
40	11	21	32	53	107	213	320	427	533	640	747	853	960	1,067
50	13	27	40	67	133	267	400	533	667	800	933	1,067	1,200	1,333
60	16	32	48	80	160	320	480	640	800	960	1,120	1,280	1,440	1,600
70	19	37	56	93	187	373	560	747	933	1,120	1,307	1,493	1,680	1,867
80	21	43	64	107	213	427	640	853	1,067	1,280	1,493	1,707	1,920	2,133
90	24	48	72	120	240	480	720	960	1,200	1,440	1,680	1,920	2,160	2,400
100	27	53	80	133	267	533	800	1,067	1,333	1,600	1,867	2,133	2,400	2,667

Table 4.3: Mean Predicted Kittiwake Mortality for the Displacement Study Area During Post-Breeding Season (Design-Based)

Displacement Level (%)	Mortality (%)													
	1	2	3	5	10	20	30	40	50	60	70	80	90	100
10	1	1	2	3	7	14	20	27	34	41	47	54	61	68
20	1	3	4	7	14	27	41	54	68	81	95	108	122	136
30	2	4	6	10	20	41	61	81	102	122	142	163	183	203
40	3	5	8	14	27	54	81	108	136	163	190	217	244	271
50	3	7	10	17	34	68	102	136	170	203	237	271	305	339
60	4	8	12	20	41	81	122	163	203	244	285	325	366	407
70	5	9	14	24	47	95	142	190	237	285	332	380	427	475
80	5	11	16	27	54	108	163	217	271	325	380	434	488	542
90	6	12	18	31	61	122	183	244	305	366	427	488	549	610
100	7	14	20	34	68	136	203	271	339	407	475	542	610	678

4.1.2. GUILLEMOT

Table 4.4: Mean Predicted Guillemot Mortality for the Displacement Study Area During the Breeding Season (Design-Based)

Displacement Level (%)	Mortality (%)													
	1	2	3	5	10	20	30	40	50	60	70	80	90	100
10	29	58	87	145	289	578	867	1,156	1,445	1,734	2,023	2,312	2,601	2,890
20	58	116	173	289	578	1,156	1,734	2,312	2,890	3,468	4,047	4,625	5,203	5,781
30	87	173	260	434	867	1,734	2,601	3,468	4,336	5,203	6,070	6,937	7,804	8,671
40	116	231	347	578	1,156	2,312	3,468	4,625	5,781	6,937	8,093	9,249	10,405	11,562
50	145	289	434	723	1,445	2,890	4,336	5,781	7,226	8,671	10,116	11,562	13,007	14,452
60	173	347	520	867	1,734	3,468	5,203	6,937	8,671	10,405	12,140	13,874	15,608	17,342
70	202	405	607	1,012	2,023	4,047	6,070	8,093	10,116	12,140	14,163	16,186	18,210	20,233
80	231	462	694	1,156	2,312	4,625	6,937	9,249	11,562	13,874	16,186	18,499	20,811	23,123
90	260	520	780	1,301	2,601	5,203	7,804	10,405	13,007	15,608	18,210	20,811	23,412	26,014
100	289	578	867	1,445	2,890	5,781	8,671	11,562	14,452	17,342	20,233	23,123	26,014	28,904

Table 4.5: Mean Predicted Guillemot Mortality for the Displacement Study Area During the Non-Breeding Season (Design-Based)

	Mortality (%)													
Displacement Level (%)	**1**	**2**	**3**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
10	46	92	138	229	459	918	1,377	1,836	2,295	2,754	3,213	3,671	4,130	4,589
20	92	184	275	459	918	1,836	2,754	3,671	4,589	5,507	6,425	7,343	8,261	9,179
30	138	275	413	688	1,377	2,754	4,130	5,507	6,884	8,261	9,638	11,014	12,391	13,768
40	184	367	551	918	1,836	3,671	5,507	7,343	9,179	11,014	12,850	14,686	16,521	18,357
50	229	459	688	1,147	2,295	4,589	6,884	9,179	11,473	13,768	16,063	18,357	20,652	22,947
60	275	551	826	1,377	2,754	5,507	8,261	11,014	13,768	16,521	19,275	22,029	24,782	27,536
70	321	643	964	1,606	3,213	6,425	9,638	12,850	16,063	19,275	22,488	25,700	28,913	32,125
80	367	734	1,101	1,836	3,671	7,343	11,014	14,686	18,357	22,029	25,700	29,372	33,043	36,714
90	413	826	1,239	2,065	4,130	8,261	12,391	16,521	20,652	24,782	28,913	33,043	37,173	41,304
100	459	918	1,377	2,295	4,589	9,179	13,768	18,357	22,947	27,536	32,125	36,714	41,304	45,893

4.1.3. RAZORBILL

Table 4.6: Mean Predicted Razorbill Mortality for the Displacement Study Area During Pre-Breeding Season (Design-Based)

Displacement Level (%)	Mortality (%)													
	1	2	3	5	10	20	30	40	50	60	70	80	90	100
10	0	0	1	1	2	4	6	8	10	12	14	16	18	20
20	0	1	1	2	4	8	12	16	20	24	28	32	36	40
30	1	1	2	3	6	12	18	24	30	36	42	48	54	60
40	1	2	2	4	8	16	24	32	40	48	56	64	72	80
50	1	2	3	5	10	20	30	40	50	60	70	80	90	100
60	1	2	4	6	12	24	36	48	60	72	84	96	108	120
70	1	3	4	7	14	28	42	56	70	84	98	112	126	140
80	2	3	5	8	16	32	48	64	80	96	112	128	144	160
90	2	4	5	9	18	36	54	72	90	108	126	144	162	180
100	2	4	6	10	20	40	60	80	100	120	140	160	180	200

Table 4.7: Mean Predicted Razorbill Mortality for the Displacement Study Area During the Breeding Season (Design-Based)

Displacement Level (%)	Mortality (%)													
	1	**2**	**3**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
10	2	4	7	11	22	44	67	89	111	133	155	178	200	222
20	4	9	13	22	44	89	133	178	222	267	311	355	400	444
30	7	13	20	33	67	133	200	267	333	400	466	533	600	666
40	9	18	27	44	89	178	267	355	444	533	622	711	800	888
50	11	22	33	56	111	222	333	444	555	666	777	888	999	1,111
60	13	27	40	67	133	267	400	533	666	800	933	1,066	1,199	1,333
70	16	31	47	78	155	311	466	622	777	933	1,088	1,244	1,399	1,555
80	18	36	53	89	178	355	533	711	888	1,066	1,244	1,421	1,599	1,777
90	20	40	60	100	200	400	600	800	999	1,199	1,399	1,599	1,799	1,999
100	22	44	67	111	222	444	666	888	1,111	1,333	1,555	1,777	1,999	2,221

Table 4.8: Mean Predicted Razorbill Mortality for the Displacement Study Area During Post-Breeding Season (Design-Based)

Displacement Level (%)	Mortality (%)													
	1	2	3	5	10	20	30	40	50	60	70	80	90	100
10	2	3	5	8	15	31	46	61	77	92	107	123	138	154
20	3	6	9	15	31	61	92	123	154	184	215	246	276	307
30	5	9	14	23	46	92	138	184	230	276	322	368	414	461
40	6	12	18	31	61	123	184	246	307	368	430	491	553	614
50	8	15	23	38	77	154	230	307	384	461	537	614	691	768
60	9	18	28	46	92	184	276	368	461	553	645	737	829	921
70	11	21	32	54	107	215	322	430	537	645	752	860	967	1,075
80	12	25	37	61	123	246	368	491	614	737	860	982	1,105	1,228
90	14	28	41	69	138	276	414	553	691	829	967	1,105	1,243	1,382
100	15	31	46	77	154	307	461	614	768	921	1,075	1,228	1,382	1,535

Table 4.9: Mean Predicted Razorbill Mortality for the Displacement Study Area During the Non-Breeding Season (Design-Based)

Displacement Level (%)	Mortality (%)													
		1	2	3	5	10	20	30	40	50	60	70	80	90	100
	10	0	0	0	1	1	3	4	6	7	8	10	11	12	14
	20	0	1	1	1	3	6	8	11	14	17	19	22	25	28
	30	0	1	1	2	4	8	12	17	21	25	29	33	37	41
	40	1	1	2	3	6	11	17	22	28	33	39	44	50	55
	50	1	1	2	3	7	14	21	28	34	41	48	55	62	69
	60	1	2	2	4	8	17	25	33	41	50	58	66	74	83
	70	1	2	3	5	10	19	29	39	48	58	67	77	87	96
	80	1	2	3	6	11	22	33	44	55	66	77	88	99	110
	90	1	2	4	6	12	25	37	50	62	74	87	99	111	124
	100	1	3	4	7	14	28	41	55	69	83	96	110	124	138

4.1.4. PUFFIN

Table 4.10: Mean Predicted Puffin Mortality for the Displacement Study Area During the Breeding Season (Design-Based)

Displacement Level (%)	Mortality (%)													
	1	**2**	**3**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
10	2	5	7	12	23	47	70	94	117	140	164	187	211	234
20	5	9	14	23	47	94	140	187	234	281	328	375	421	468
30	7	14	21	35	70	140	211	281	351	421	492	562	632	702
40	9	19	28	47	94	187	281	375	468	562	655	749	843	936
50	12	23	35	59	117	234	351	468	585	702	819	936	1,053	1,171
60	14	28	42	70	140	281	421	562	702	843	983	1,124	1,264	1,405
70	16	33	49	82	164	328	492	655	819	983	1,147	1,311	1,475	1,639
80	19	37	56	94	187	375	562	749	936	1,124	1,311	1,498	1,686	1,873
90	21	42	63	105	211	421	632	843	1,053	1,264	1,475	1,686	1,896	2,107
100	23	47	70	117	234	468	702	936	1,171	1,405	1,639	1,873	2,107	2,341

Table 4.11: Mean Predicted Puffin Mortality for the Displacement Study Area During the Non-Breeding Season (Design-Based)

Displacement Level (%)	Mortality (%)													
	1	**2**	**3**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
10	1	3	4	7	15	30	44	59	74	89	103	118	133	148
20	3	6	9	15	30	59	89	118	148	177	207	236	266	296
30	4	9	13	22	44	89	133	177	222	266	310	355	399	443
40	6	12	18	30	59	118	177	236	296	355	414	473	532	591
50	7	15	22	37	74	148	222	296	369	443	517	591	665	739
60	9	18	27	44	89	177	266	355	443	532	621	709	798	887
70	10	21	31	52	103	207	310	414	517	621	724	827	931	1,034
80	12	24	35	59	118	236	355	473	591	709	827	946	1,064	1,182
90	13	27	40	66	133	266	399	532	665	798	931	1,064	1,197	1,330
100	15	30	44	74	148	296	443	591	739	887	1,034	1,182	1,330	1,478

4.1.5. FULMAR

Table 4.12: Mean Predicted Fulmar Mortality for the Displacement Study Area During Pre-Breeding Season (Design-Based)

	Mortality (%)													
Displacement Level (%)	0.5	1	2	5	10	20	30	40	50	60	70	80	90	100
1	0	0	0	0	1	1	2	3	3	4	5	6	6	7
5	0	0	1	2	3	7	10	14	17	21	24	28	31	34
10	0	1	1	3	7	14	21	28	34	41	48	55	62	69
20	1	1	3	7	14	28	41	55	69	83	96	110	124	138
30	1	2	4	10	21	41	62	83	103	124	144	165	186	206
40	1	3	6	14	28	55	83	110	138	165	193	220	248	275
50	2	3	7	17	34	69	103	138	172	206	241	275	309	344
60	2	4	8	21	41	83	124	165	206	248	289	330	371	413
70	2	5	10	24	48	96	144	193	241	289	337	385	433	481
80	3	6	11	28	55	110	165	220	275	330	385	440	495	550
90	3	6	12	31	62	124	186	248	309	371	433	495	557	619
100	3	7	14	34	69	138	206	275	344	413	481	550	619	688

Table 4.13: Mean Predicted Fulmar Mortality for the Displacement Study Area During the Breeding Season (Design-Based)

Displacement Level (%)	Mortality (%) 0.5	1	2	5	10	20	30	40	50	60	70	80	90	100
1	0	0	0	1	2	5	7	9	11	14	16	18	20	23
5	1	1	2	6	11	23	34	45	56	68	79	90	101	113
10	1	2	5	11	23	45	68	90	113	135	158	180	203	226
20	2	5	9	23	45	90	135	180	226	271	316	361	406	451
30	3	7	14	34	68	135	203	271	338	406	474	541	609	677
40	5	9	18	45	90	180	271	361	451	541	632	722	812	902
50	6	11	23	56	113	226	338	451	564	677	789	902	1,015	1,128
60	7	14	27	68	135	271	406	541	677	812	947	1,083	1,218	1,353
70	8	16	32	79	158	316	474	632	789	947	1,105	1,263	1,421	1,579
80	9	18	36	90	180	361	541	722	902	1,083	1,263	1,444	1,624	1,804
90	10	20	41	101	203	406	609	812	1,015	1,218	1,421	1,624	1,827	2,030
100	11	23	45	113	226	451	677	902	1,128	1,353	1,579	1,804	2,030	2,256

Table 4.14: Mean Predicted Fulmar Mortality for the Displacement Study Area During Post-Breeding Season Design-Based)

Displacement Level (%)	Mortality (%)													
	0.5	1	2	5	10	20	30	40	50	60	70	80	90	100
1	0	0	0	0	1	1	2	2	3	3	4	4	5	5
5	0	0	1	1	3	5	8	10	13	15	18	20	23	25
10	0	1	1	3	5	10	15	20	25	31	36	41	46	51
20	1	1	2	5	10	20	31	41	51	61	71	81	92	102
30	1	2	3	8	15	31	46	61	76	92	107	122	137	153
40	1	2	4	10	20	41	61	81	102	122	143	163	183	204
50	1	3	5	13	25	51	76	102	127	153	178	204	229	255
60	2	3	6	15	31	61	92	122	153	183	214	244	275	305
70	2	4	7	18	36	71	107	143	178	214	249	285	321	356
80	2	4	8	20	41	81	122	163	204	244	285	326	366	407
90	2	5	9	23	46	92	137	183	229	275	321	366	412	458
100	3	5	10	25	51	102	153	204	255	305	356	407	458	509

Table 4.15: Mean Predicted Fulmar Mortality for the Displacement Study Area During the Non-Breeding Season (Design-Based)

		Mortality (%)													
		0.5	1	2	5	10	20	30	40	50	60	70	80	90	100
Displacement Level (%)	1	0	0	0	0	0	1	1	2	2	3	3	3	4	4
	5	0	0	0	1	2	4	7	9	11	13	15	17	20	22
	10	0	0	1	2	4	9	13	17	22	26	30	35	39	44
	20	0	1	2	4	9	17	26	35	44	52	61	70	78	87
	30	1	1	3	7	13	26	39	52	65	78	91	104	117	131
	40	1	2	3	9	17	35	52	70	87	104	122	139	157	174
	50	1	2	4	11	22	44	65	87	109	131	152	174	196	218
	60	1	3	5	13	26	52	78	104	131	157	183	209	235	261
	70	2	3	6	15	30	61	91	122	152	183	213	244	274	305
	80	2	3	7	17	35	70	104	139	174	209	244	278	313	348
	90	2	4	8	20	39	78	117	157	196	235	274	313	352	392
	100	2	4	9	22	44	87	131	174	218	261	305	348	392	435

4.1.6. GANNET

Table 4.16: Mean Predicted Gannet Mortality for the Displacement Study Area During Pre-Breeding Season (Design-Based)

Displacement Level (%)	Mortality (%)													
	1	2	3	5	10	20	30	40	50	60	70	80	90	100
10	0	0	0	0	1	1	2	2	3	4	4	5	5	6
20	0	0	0	1	1	2	4	5	6	7	9	10	11	12
30	0	0	1	1	2	4	5	7	9	11	13	15	16	18
40	0	0	1	1	2	5	7	10	12	15	17	20	22	24
50	0	1	1	2	3	6	9	12	15	18	21	24	27	31
60	0	1	1	2	4	7	11	15	18	22	26	29	33	37
70	0	1	1	2	4	9	13	17	21	26	30	34	38	43
80	0	1	1	2	5	10	15	20	24	29	34	39	44	49
90	1	1	2	3	5	11	16	22	27	33	38	44	49	55
100	1	1	2	3	6	12	18	24	31	37	43	49	55	61

Table 4.17: Mean Predicted Gannet Mortality for the Displacement Study Area During the Breeding Season (Design-Based)

	Mortality (%)													
Displacement Level (%)	1	2	3	5	10	20	30	40	50	60	70	80	90	100
10	2	3	5	8	15	30	46	61	76	91	106	122	137	152
20	3	6	9	15	30	61	91	122	152	182	213	243	274	304
30	5	9	14	23	46	91	137	182	228	274	319	365	411	456
40	6	12	18	30	61	122	182	243	304	365	426	487	547	608
50	8	15	23	38	76	152	228	304	380	456	532	608	684	760
60	9	18	27	46	91	182	274	365	456	547	639	730	821	912
70	11	21	32	53	106	213	319	426	532	639	745	851	958	1,064
80	12	24	36	61	122	243	365	487	608	730	851	973	1,095	1,216
90	14	27	41	68	137	274	411	547	684	821	958	1,095	1,232	1,368
100	15	30	46	76	152	304	456	608	760	912	1,064	1,216	1,368	1,521

Table 4.18: Mean Predicted Gannet Mortality for the Displacement Study Area During Post-Breeding Season (Design-Based)

Displacement Level (%)	Mortality (%)													
	1	2	3	5	10	20	30	40	50	60	70	80	90	100
10	0	1	1	2	4	8	13	17	21	25	0	33	38	42
20	1	2	3	4	8	17	25	33	42	50	58	67	75	83
30	1	3	4	6	13	25	38	50	63	75	88	100	113	125
40	2	3	5	8	17	33	50	67	83	100	117	133	150	167
50	2	4	6	10	21	42	63	83	104	125	146	167	188	209
60	3	5	8	13	25	50	75	100	125	150	175	200	225	250
70	3	6	9	15	29	58	88	117	146	175	204	234	263	292
80	3	7	10	17	33	67	100	133	167	200	234	267	300	334
90	4	8	11	19	38	75	113	150	188	225	263	300	338	375
100	4	8	13	21	42	83	125	167	209	250	292	334	375	417

4.2. MRSea BASED RESULTS

4.2.1. KITTIWAKE

Table 4.19: Mean Predicted Kittiwake Mortality Based on MRSea Modelled Data for the Displacement Study Area During Pre-Breeding Season

Displacement Level (%)	Mortality (%)													
	1	**2**	**3**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
10	1	1	2	3	6	12	17	23	29	35	41	46	52	58
20	1	2	3	6	12	23	35	46	58	70	81	93	105	116
30	2	3	5	9	17	35	52	70	87	105	122	139	157	174
40	2	5	7	12	23	46	70	93	116	139	163	186	209	232
50	3	6	9	15	29	58	87	116	145	174	203	232	261	290
60	3	7	10	17	35	70	105	139	174	209	244	279	314	348
70	4	8	12	20	41	81	122	163	203	244	285	325	366	407
80	5	9	14	23	46	93	139	186	232	279	325	372	418	465
90	5	10	16	26	52	105	157	209	261	314	366	418	470	523
100	6	12	17	29	58	116	174	232	290	348	407	465	523	581

Table 4.20: Mean Predicted Kittiwake Mortality Based on MRSea Modelled Data for the Displacement Study Area During the Breeding Season

Displacement Level (%)	Mortality (%)													
	1	2	3	5	10	20	30	40	50	60	70	80	90	100
10	3	6	10	16	32	64	95	127	159	191	223	255	286	318
20	6	13	19	32	64	127	191	255	318	382	446	509	573	637
30	10	19	29	48	95	191	286	382	477	573	668	764	859	955
40	13	25	38	64	127	255	382	509	637	764	891	1,018	1,146	1,273
50	16	32	48	80	159	318	477	637	796	955	1,114	1,273	1,432	1,591
60	19	38	57	95	191	382	573	764	955	1,146	1,337	1,528	1,719	1,910
70	22	45	67	111	223	446	668	891	1,114	1,337	1,560	1,782	2,005	2,228
80	25	51	76	127	255	509	764	1,018	1,273	1,528	1,782	2,037	2,292	2,546
90	29	57	86	143	286	573	859	1,146	1,432	1,719	2,005	2,292	2,578	2,865
100	32	64	95	159	318	637	955	1,273	1,591	1,910	2,228	2,546	2,865	3,183

Table 4.21: Mean Predicted Kittiwake Mortality Based on MRSea Modelled Data for the Displacement Study Area During Post-Breeding Season

Displacement Level (%)	Mortality (%)													
	1	**2**	**3**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
10	1	1	2	3	6	11	17	23	28	34	40	45	51	57
20	1	2	3	6	11	23	34	45	57	68	79	91	102	113
30	2	3	5	8	17	34	51	68	85	102	119	136	153	170
40	2	5	7	11	23	45	68	91	113	136	159	181	204	227
50	3	6	8	14	28	57	85	113	142	170	198	227	255	283
60	3	7	10	17	34	68	102	136	170	204	238	272	306	340
70	4	8	12	20	40	79	119	159	198	238	277	317	357	396
80	5	9	14	23	45	91	136	181	227	272	317	362	408	453
90	5	10	15	25	51	102	153	204	255	306	357	408	459	510
100	6	11	17	28	57	113	170	227	283	340	396	453	510	566

4.2.2. GUILLEMOT

Table 4.22: Mean Predicted Guillemot Mortality Based on MRSea Modelled Data for the Displacement Study Area During the Breeding Season

Displacement level (%)	Mortality (%)													
	1	2	3	5	10	20	30	40	50	60	70	80	90	100
10	49	99	148	247	494	989	1,483	1,977	2,472	2,966	3,461	3,955	4,449	4,944
20	99	198	297	494	989	1,977	2,966	3,955	4,944	5,932	6,921	7,910	8,899	9,887
30	148	297	445	742	1,483	2,966	4,449	5,932	7,416	8,899	10,382	11,865	13,348	14,831
40	198	395	593	989	1,977	3,955	5,932	7,910	9,887	11,865	13,842	15,820	17,797	19,775
50	247	494	742	1,236	2,472	4,944	7,416	9,887	12,359	14,831	17,303	19,775	22,247	24,719
60	297	593	890	1,483	2,966	5,932	8,899	11,865	14,831	17,797	20,764	23,730	26,696	29,662
70	346	692	1,038	1,730	3,461	6,921	10,382	13,842	17,303	20,764	24,224	27,685	31,145	34,606
80	395	791	1,186	1,977	3,955	7,910	11,865	15,820	19,775	23,730	27,685	31,640	35,595	39,550
90	445	890	1,335	2,225	4,449	8,899	13,348	17,797	22,247	26,696	31,145	35,595	40,044	44,493
100	494	989	1,483	2,472	4,944	9,887	14,831	19,775	24,719	29,662	34,606	39,550	44,493	49,437

Table 4.23: Mean Predicted Guillemot Mortality Based on MRSea Modelled Data for the Displacement Study Area During the Non-Breeding Season

Displacement Level (%)	Mortality (%)													
	1	2	3	5	10	20	30	40	50	60	70	80	90	100
10	48	97	145	242	483	967	1,450	1,934	2,417	2,900	3,384	3,867	4,351	4,834
20	97	193	290	483	967	1,934	2,900	3,867	4,834	5,801	6,768	7,734	8,701	9,668
30	145	290	435	725	1,450	2,900	4,351	5,801	7,251	8,701	10,151	11,602	13,052	14,502
40	193	387	580	967	1,934	3,867	5,801	7,734	9,668	11,602	13,535	15,469	17,403	19,336
50	242	483	725	1,209	2,417	4,834	7,251	9,668	12,085	14,502	16,919	19,336	21,753	24,170
60	290	580	870	1,450	2,900	5,801	8,701	11,602	14,502	17,403	20,303	23,203	26,104	29,004
70	338	677	1,015	1,692	3,384	6,768	10,151	13,535	16,919	20,303	23,687	27,071	30,454	33,838
80	387	773	1,160	1,934	3,867	7,734	11,602	15,469	19,336	23,203	27,071	30,938	34,805	38,672
90	435	870	1,305	2,175	4,351	8,701	13,052	17,403	21,753	26,104	30,454	34,805	39,156	43,506
100	483	967	1,450	2,417	4,834	9,668	14,502	19,336	24,170	29,004	33,838	38,672	43,506	48,340

4.2.3. RAZORBILL

Table 4.24: Mean Predicted Razorbill Mortality Based on MRSea Modelled Data for the Displacement Study Area During Pre-Breeding Season

Displacement Level (%)	Mortality (%)													
	1	2	3	5	10	20	30	40	50	60	70	80	90	100
10	0	0	1	1	2	4	7	9	11	13	16	18	20	22
20	0	1	1	2	4	9	13	18	22	27	31	36	40	45
30	1	1	2	3	7	13	20	27	34	40	47	54	60	67
40	1	2	3	4	9	18	27	36	45	54	63	72	80	89
50	1	2	3	6	11	22	34	45	56	67	78	89	101	112
60	1	3	4	7	13	27	40	54	67	80	94	107	121	134
70	2	3	5	8	16	31	47	63	78	94	110	125	141	156
80	2	4	5	9	18	36	54	72	89	107	125	143	161	179
90	2	4	6	10	20	40	60	80	101	121	141	161	181	201
100	2	4	7	11	22	45	67	89	112	134	156	179	201	224

Table 4.25: Mean Predicted Razorbill Mortality Based on MRSea Modelled Data for the Displacement Study Area During the Breeding Season

	Mortality (%)													
Displacement Level (%)	**1**	**2**	**3**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
10	3	5	8	13	26	52	78	104	130	156	183	209	235	261
20	5	10	16	26	52	104	156	209	261	313	365	417	469	522
30	8	16	23	39	78	156	235	313	391	469	548	626	704	782
40	10	21	31	52	104	209	313	417	522	626	730	834	939	1,043
50	13	26	39	65	130	261	391	522	652	782	913	1,043	1,173	1,304
60	16	31	47	78	156	313	469	626	782	939	1,095	1,252	1,408	1,565
70	18	37	55	91	183	365	548	730	913	1,095	1,278	1,460	1,643	1,825
80	21	42	63	104	209	417	626	834	1,043	1,252	1,460	1,669	1,877	2,086
90	23	47	70	117	235	469	704	939	1,173	1,408	1,643	1,877	2,112	2,347
100	26	52	78	130	261	522	782	1,043	1,304	1,565	1,825	2,086	2,347	2,608

Table 4.26: Mean Predicted Razorbill Mortality Based on MRSea Modelled Data for the Displacement Study Area During Post-Breeding Season

	Mortality (%)													
Displacement Level (%)	1	2	3	5	10	20	30	40	50	60	70	80	90	100
10	1	3	4	7	15	30	45	60	75	90	104	119	134	149
20	3	6	9	15	30	60	90	119	149	179	209	239	269	299
30	4	9	13	22	45	90	134	179	224	269	313	358	403	448
40	6	12	18	30	60	119	179	239	299	358	418	478	537	597
50	7	15	22	37	75	149	224	299	373	448	522	597	672	746
60	9	18	27	45	90	179	269	358	448	537	627	716	806	896
70	10	21	31	52	104	209	313	418	522	627	731	836	940	1,045
80	12	24	36	60	119	239	358	478	597	716	836	955	1,075	1,194
90	13	27	40	67	134	269	403	537	672	806	940	1,075	1,209	1,343
100	15	30	45	75	149	299	448	597	746	896	1,045	1,194	1,343	1,493

Table 4.27: Mean Predicted Razorbill Mortality Based on MRSea Modelled Data for the Displacement Study Area During the Non-Breeding Season

Displacement Level (%)	Mortality (%)													
	1	2	3	5	10	20	30	40	50	60	70	80	90	100
10	0	0	0	1	1	3	4	6	7	8	10	11	12	14
20	0	1	1	1	3	6	8	11	14	17	19	22	25	28
30	0	1	1	2	4	8	12	17	21	25	29	33	37	41
40	1	1	2	3	6	11	17	22	28	33	39	44	50	55
50	1	1	2	3	7	14	21	28	34	41	48	55	62	69
60	1	2	2	4	8	17	25	33	41	50	58	66	74	83
70	1	2	3	5	10	19	29	39	48	58	67	77	87	96
80	1	2	3	6	11	22	33	44	55	66	77	88	99	110
90	1	2	4	6	12	25	37	50	62	74	87	99	111	124
100	1	3	4	7	14	28	41	55	69	83	96	110	124	138

4.2.4. PUFFIN

Table 4.28: Mean Predicted Puffin Mortality Based on MRSea Modelled Data for the Displacement Study Area During the Breeding Season

	Mortality (%)													
Displacement Level (%)	**1**	**2**	**3**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
10	2	4	6	10	19	39	58	77	96	116	135	154	174	193
20	4	8	12	19	39	77	116	154	193	231	270	308	347	386
30	6	12	17	29	58	116	174	231	289	347	405	463	521	578
40	8	15	23	39	77	154	231	308	386	463	540	617	694	771
50	10	19	29	48	96	193	289	386	482	578	675	771	868	964
60	12	23	35	58	116	231	347	463	578	694	810	925	1,041	1,157
70	13	27	40	67	135	270	405	540	675	810	945	1,080	1,215	1,350
80	15	31	46	77	154	308	463	617	771	925	1,080	1,234	1,388	1,542
90	17	35	52	87	174	347	521	694	868	1,041	1,215	1,388	1,562	1,735
100	19	39	58	96	193	386	578	771	964	1,157	1,350	1,542	1,735	1,928

Table 4.29: Mean Predicted Puffin Mortality Based on MRSea Modelled Data for the Displacement Study Area During the Non-Breeding Season

Displacement Level (%)	Mortality (%)													
	1	**2**	**3**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
10	1	2	4	6	12	24	35	47	59	71	82	94	106	118
20	2	5	7	12	24	47	71	94	118	141	165	189	212	236
30	4	7	11	18	35	71	106	141	177	212	247	283	318	354
40	5	9	14	24	47	94	141	189	236	283	330	377	424	471
50	6	12	18	29	59	118	177	236	295	354	412	471	530	589
60	7	14	21	35	71	141	212	283	354	424	495	566	636	707
70	8	16	25	41	82	165	247	330	412	495	577	660	742	825
80	9	19	28	47	94	189	283	377	471	566	660	754	848	943
90	11	21	32	53	106	212	318	424	530	636	742	848	955	1,061
100	12	24	35	59	118	236	354	471	589	707	825	943	1,061	1,178

4.2.5. FULMAR

Table 4.30: Mean Predicted Fulmar Mortality Based on MRSea Modelled Data for the Displacement Study Area During Pre-Breeding Season

Displacement Level (%)	Mortality (%)													
	0.5	1	2	5	10	20	30	40	50	60	70	80	90	100
1	0	0	0	0	1	1	2	3	3	4	5	5	6	7
5	0	0	1	2	3	7	10	13	17	20	23	27	30	34
10	0	1	1	3	7	13	20	27	34	40	47	54	60	67
20	1	1	3	7	13	27	40	54	67	80	94	107	121	134
30	1	2	4	10	20	40	60	80	101	121	141	161	181	201
40	1	3	5	13	27	54	80	107	134	161	188	215	241	268
50	2	3	7	17	34	67	101	134	168	201	235	268	302	335
60	2	4	8	20	40	80	121	161	201	241	282	322	362	402
70	2	5	9	23	47	94	141	188	235	282	329	376	422	469
80	3	5	11	27	54	107	161	215	268	322	376	429	483	536
90	3	6	12	30	60	121	181	241	302	362	422	483	543	604
100	3	7	13	34	67	134	201	268	335	402	469	536	604	671

Table 4.31: Mean Predicted Fulmar Mortality Based on MRSea Modelled Data for the Displacement Study Area During the Breeding Season

Displacement Level (%)	Mortality (%)													
	0.5	1	2	5	10	20	30	40	50	60	70	80	90	100
1	0	0	0	1	2	4	6	8	10	12	14	15	17	19
5	0	1	2	5	10	19	29	39	48	58	68	77	87	97
10	1	2	4	10	19	39	58	77	97	116	135	155	174	193
20	2	4	8	19	39	77	116	155	193	232	270	309	348	386
30	3	6	12	29	58	116	174	232	290	348	406	464	522	580
40	4	8	15	39	77	155	232	309	386	464	541	618	696	773
50	5	10	19	48	97	193	290	386	483	580	676	773	869	966
60	6	12	23	58	116	232	348	464	580	696	811	927	1,043	1,159
70	7	14	27	68	135	270	406	541	676	811	947	1,082	1,217	1,352
80	8	15	31	77	155	309	464	618	773	927	1,082	1,236	1,391	1,546
90	9	17	35	87	174	348	522	696	869	1,043	1,217	1,391	1,565	1,739
100	10	19	39	97	193	386	580	773	966	1,159	1,352	1,546	1,739	1,932

Table 4.32: Mean Predicted Fulmar Mortality Based on MRSea Modelled Data for the Displacement Study Area During Post-Breeding Season

	Mortality (%)													
Displacement Level (%)	0.5	1	2	5	10	20	30	40	50	60	70	80	90	100
1	0	0	0	0	1	1	2	2	3	4	4	5	5	6
5	0	0	1	2	3	6	9	12	15	18	21	24	27	30
10	0	1	1	3	6	12	18	24	30	37	43	49	55	61
20	1	1	2	6	12	24	37	49	61	73	85	97	110	122
30	1	2	4	9	18	37	55	73	91	110	128	146	164	183
40	1	2	5	12	24	49	73	97	122	146	171	195	219	244
50	2	3	6	15	30	61	91	122	152	183	213	244	274	305
60	2	4	7	18	37	73	110	146	183	219	256	292	329	366
70	2	4	9	21	43	85	128	171	213	256	299	341	384	426
80	2	5	10	24	49	97	146	195	244	292	341	390	439	487
90	3	5	11	27	55	110	164	219	274	329	384	439	493	548
100	3	6	12	30	61	122	183	244	305	366	426	487	548	609

Table 4.33: Mean Predicted Fulmar Mortality Based on MRSea Modelled Data for the Displacement Study Area During the Non-Breeding Season

Displacement Level (%)	Mortality (%)													
	0.5	1	2	5	10	20	30	40	50	60	70	80	90	100
1	0	0	0	0	0	1	1	2	2	3	3	4	4	4
5	0	0	0	1	2	4	7	9	11	13	15	18	20	22
10	0	0	1	2	4	9	13	18	22	27	31	35	40	44
20	0	1	2	4	9	18	27	35	44	53	62	71	80	88
30	1	1	3	7	13	27	40	53	66	80	93	106	119	133
40	1	2	4	9	18	35	53	71	88	106	124	141	159	177
50	1	2	4	11	22	44	66	88	110	133	155	177	199	221
60	1	3	5	13	27	53	80	106	133	159	186	212	239	265
70	2	3	6	15	31	62	93	124	155	186	216	247	278	309
80	2	4	7	18	35	71	106	141	177	212	247	283	318	353
90	2	4	8	20	40	80	119	159	199	239	278	318	358	398
100	2	4	9	22	44	88	133	177	221	265	309	353	398	442

4.2.6. GANNET

Table 4.34: Mean Predicted Gannet Mortality Based on MRSea Modelled Data for the Displacement Study Area During Pre-Breeding Season

Displacement Level (%)	Mortality (%)													
	1	2	3	5	10	20	30	40	50	60	70	80	90	100
10	0	0	0	0	0	1	1	2	2	3	3	3	4	4
20	0	0	0	0	1	2	3	3	4	5	6	7	8	8
30	0	0	0	1	1	3	4	5	6	8	9	10	11	13
40	0	0	1	1	2	3	5	7	8	10	12	14	15	17
50	0	0	1	1	2	4	6	8	11	13	15	17	19	21
60	0	1	1	1	3	5	8	10	13	15	18	20	23	25
70	0	1	1	1	3	6	9	12	15	18	21	24	27	30
80	0	1	1	2	3	7	10	14	17	20	24	27	30	34
90	0	1	1	2	4	8	11	15	19	23	27	30	34	38
100	0	1	1	2	4	8	13	17	21	25	30	34	38	42

Table 4.35: Mean Predicted Gannet Mortality Based on MRSea Modelled Data for the Displacement Study Area During the Breeding Season

Displacement Level (%)	Mortality (%)													
		1	2	3	5	10	20	30	40	50	60	70	80	90	100
	10	1	3	4	7	14	28	42	56	70	84	97	111	125	139
	20	3	6	8	14	28	56	84	111	139	167	195	223	251	279
	30	4	8	13	21	42	84	125	167	209	251	292	334	376	418
	40	6	11	17	28	56	111	167	223	279	334	390	446	501	557
	50	7	14	21	35	70	139	209	279	348	418	487	557	627	696
	60	8	17	25	42	84	167	251	334	418	501	585	668	752	836
	70	10	19	29	49	97	195	292	390	487	585	682	780	877	975
	80	11	22	33	56	111	223	334	446	557	668	780	891	1,003	1,114
	90	13	25	38	63	125	251	376	501	627	752	877	1,003	1,128	1,253
	100	14	28	42	70	139	279	418	557	696	836	975	1,114	1,253	1,393

Table 4.36: Mean Predicted Gannet Mortality Based on MRSea Modelled Data for the Displacement Study Area During Post-Breeding Season

Displacement Level (%)	Mortality (%)													
	1	**2**	**3**	**5**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
10	1	2	2	4	8	16	23	31	39	47	54	62	70	78
20	2	3	5	8	16	31	47	62	78	93	109	124	140	155
30	2	5	7	12	23	47	70	93	116	140	163	186	209	233
40	3	6	9	16	31	62	93	124	155	186	217	248	279	310
50	4	8	12	19	39	78	116	155	194	233	271	310	349	388
60	5	9	14	23	47	93	140	186	233	279	326	372	419	465
70	5	11	16	27	54	109	163	217	271	326	380	434	489	543
80	6	12	19	31	62	124	186	248	310	372	434	496	558	620
90	7	14	21	35	70	140	209	279	349	419	489	558	628	698
100	8	16	23	39	78	155	233	310	388	465	543	620	698	775

5. SUMMARY

35. Table 5.1 provides a summary of the results of the displacement analyses undertaken for each species in sections 4.1 and 4.2.

Table 5.1: Summary of Displacement Analyses Undertaken for the Displacement Study Area

Species	Project Phase	Season	Approach	Displacement Rates (%)	Mortality Rates (%)	Displacement Mortality (Range) (Design Based)	Displacement Mortality (Range) (MRSea)
Kittiwake	Operation and Maintenance	Pre-breeding	SNCB	30%	1% to 3%	1 to 3	2 to 5
			Developer	30%	1%	1	2
		Breeding	SNCB	30%	1% to 3%	8 to 24	10 to 29
			Developer	30%	1%	8	10
		Post-breeding	SNCB	30%	1% to 3%	2 to 6	2 to 5
			Developer	30%	1%	2	2
Guillemot	Operation and Maintenance	Breeding	SNCB	60%	3% to 5%	520 to 867	490 to 817
			Developer	50%	1%	145	136
		Non-breeding	SNCB	60%	1% to 3%	275 to 826	290 to 870
			Developer	50%	1%	229	242
Razorbill	Operation and Maintenance	Pre-breeding	SNCB	60%	1% to 3%	1 to 4	1 to 4
			Developer	50%	1%	1	1
		Breeding	SNCB	60%	3% to 5%	40 to 67	47 to 78
			Developer	50%	1%	11	13
		Post-breeding	SNCB	60%	1% to 3%	9 to 28	9 to 27
			Developer	50%	1%	8	7
		Non-breeding	SNCB	60%	1% to 3%	1 to 2	1 to 2
			Developer	50%	1%	1	1
Puffin	Operation and Maintenance	Breeding	SNCB	60%	3% to 5%	42 to 70	35 to 58
			Developer	50%	1%	12	10
		Non-breeding	SNCB	60%	1% to 3%	9 to 27	7 to 21
			Developer	50%	1%	7	6

Species	Project Phase	Season	Approach	Displacement Rates (%)	Mortality Rates (%)	Displacement Mortality (Range) (Design Based)	Displacement Mortality (Range) (MRSea)
Fulmar	Operation and Maintenance	Pre-breeding	SNCB	N/A	N/A	N/A	N/A
			Developer	0% to 50%	0.5% to 2%	0 to 7	0 to 7
		Breeding	SNCB	N/A	N/A	N/A	N/A
			Developer	0% to 50%	0.5% to 2%	0 to 23	0 to 19
		Post-breeding	SNCB	N/A	N/A	N/A	N/A
			Developer	0% to 50%	0.5% to 2%	0 to 5	0 to 6
		Non-breeding	SNCB	N/A	N/A	N/A	N/A
			Developer	0% to 50%	0.5% to 2%	0 to 4	0 to 4
Gannet	Operation and Maintenance	Pre-breeding	SNCB	70%	1% to 3%	0 to 1	0 to 1
			Developer	70%	1%	0	0
		Breeding	SNCB	70%	1% to 3%	11 to 32	10 to 29
			Developer	70%	1%	11	10
		Post-breeding	SNCB	70%	1% to 3%	3 to 9	5 to 16
			Developer	70%	1%	3	5

6. DISCUSSION

36. The range of displacement and mortality rates provided above is in line with that typically recommended for the assessment of impacts of offshore wind farms (e.g. SNCB, 2022a).

37. Displacement rates can be empirically inferred on the basis of a change in density between before and after the construction of an offshore wind farm. However, even so there is uncertainty; individual studies may struggle to fully attribute a causal relationship with the construction of an offshore wind farm, given that seabird abundance distribution is known to show spatial and temporal variation as a result of a wide range of biotic and abiotic factors (Pérez-Lapenã *et al.*, 2010). Furthermore, there is evidence that displacement rates may vary regionally; for example, it has been noted that red-throated diver displacement rates and buffers recorded in the German Bight appear to be higher than those recorded in UK waters (MacArthur Green, 2019). This may be due to ecological conditions, such as the density of birds and distribution of available habitat, or it may be a behavioural response that depends on the visual backdrop and the extent of background vessel traffic in the region. Given the potential for regional variation in displacement rates, it is noteworthy that a recent study at Beatrice Offshore Windfarm, located in the Moray Firth approximately 190 km from the Array, found no evidence of auk displacement (MacArthur Green, 2023). Overall, a recent review found reported auk displacement rates ranging from +112% (i.e. attraction) to -75% (APEM, 2022a). For gannet, a review found displacement rates ranging from no significant effect to 98% displacement within an array area (APEM, 2022b).

38. Mortality rates are harder to quantify. It is acknowledged that even the concept of estimating the impact of displacement by means of applying a mortality rate to displaced birds is flawed (SNCB, 2022a; Searle *et al.*, 2018). Impacts will not solely accrue by means of mortality of displaced individuals. Displacement may lead to mortality of non-displaced individuals as a result of increased competition. During the breeding season, displacement may impact survival of juveniles if the foraging success of parents is reduced or if nests are left unattended for longer. Displacement may also have sub-lethal effects that lead to population-level impacts, for example reduced productivity as a result of an increased incidence of missed breeding, or reduced clutch size if a breeding attempt is made. These complications make estimating a displacement-consequent mortality rate from empirical observation currently an intractable problem. However, studies which have considered mortality rates (reviewed in APEM, 2022a,b) found the evidence is incompatible with a 10% mortality rate for either auks or gannets, and that the best supported position is a negligible impact on mortality rates.

39. Therefore, whilst this report provides a range of displacement and mortality rates, it should be recognised that the upper end of this range is considered to be highly over-precautionary and not supported by available evidence, especially regarding displacement-consequent mortality. The lower end of the ranges provided is more plausible, but even the lower end is considered to include an element of precaution given the range of results provided in the literature, including studies in Scottish waters, finding lower or negligible displacement and mortality rates.

7. REFERENCES

APEM (2022a). *Review of evidence to support auk displacement and mortality rates in relation to offshore wind farms*. APEM Scientific Report P00007416. Ørsted, January 2022.

APEM (2022b). *Gannet Displacement and Mortality Evidence Review*. APEM Scientific Report P00007416. Ørsted, March 2022.

Bradbury, G., Trinder, M., Furness, B., Banks, A.N., Caldow, R.W. and Hume, D. (2014). *Mapping seabird sensitivity to offshore wind farms*. PloS one, 9(9), p.e106366.

Burton, N.H.K., Rehfisch, M.M., Clark, N.A. and Dodd, S.G. (2006). *Impacts of sudden winter habitat loss on the body condition and survival of Redshank Tringa totanus*. J. Appl. Ecol. 43: 464–473.

Cook, A.S., Humphreys, E.M., Bennet, F., Masden, E.A. and Burton, N.H., (2018). *Quantifying avian avoidance of offshore wind turbines: current evidence and key knowledge gaps*. Marine environmental research, 140, pp.278-288.

Dierschke V., Furness R.W. and Garthe S. (2016). *Seabirds and offshore wind farms in European waters: Avoidance and attraction*. Biological Conservation 202: 59-68.

Furness, R.W. (2015). *Non-breeding season populations of seabirds in UK waters: Population sizes for Biologically Defined Minimum Population Scales (BDMPS)*. Natural England Commissioned Reports (164).

Furness, R.W., Wade, H.M., Robbins, A.M.C. and Masden, E.A. (2012). *Assessing the sensitivity of seabird populations to adverse effects from tidal stream turbines and wave energy devices*. ICES J. Mar. Sci., 69, 1466–1479.

Furness R. W., Wade, H. M. and Masden E.A. (2013). *Assessing vulnerability of marine bird populations to offshore wind farms* . Journal of Environmental Management 119 pp.56-66.

Garthe, S and Hüppop, O. (2004). *Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index.* Journal of Applied Ecology, 41, 724-734.

Kaiser, M., Elliott, A., Galanidi, M., Ivor, E., Rees, S., Caldow, R., Stillman, R., Sutherland, W. and Showler, D. (2002). *Predicting the Displacement of Common Scoter Melanitta nigra from Benthic Feeding Areas Due to Offshore Windfarms (Report No. COWRIE-BEN-03-2002)*. Report by Bangor University. Report for Collaborative Offshore Wind Research into the Environment (COWRIE).

Krijgsveld, K.L., Fijn, R.C., Japink, M., van Horssen, P.W., Heunks, C., Collier, M.P., Poot, M.J.M., Beuker, D. and Dirksen, S. (2011). *Effect Studies Offshore Wind Farm Egmond aan Zee: Final report on fluxes, flight altitudes and behaviour of flying birds*. Bureau Waardenburg Report No 10-219.

Langston, R.H.W. (2010). *Offshore wind farms and birds: Round 3 zones, extensions to Round 1 and 2 sites and Scottish Territorial Waters*. RSPB Research Report No. 39.

Leopold, M. F., Dijkman, E. M., and Teal, L. R. (2011). *Local Birds in and around the Offshore wind Farm Egmond aan Zee (OWEZ) (No. C187/11).* IMARES.

MacArthur Green (2019). *Norfolk Vanguard Offshore Wind Farm. The Applicant Responses to First Written Questions. Appendix 3.3 – Operational Auk and Gannet Displacement: update and clarification.*

MacArthur Green (2023). *Beatrice Offshore Wind Farm. Year 2 Post-construction Ornithological Monitoring Report*.

Maclean, I.M.D., Wright, L.J., Showler, D.A., and Rehfisch, M.M. (2009). *A review of assessment method-ologies for offshore wind farms.* British Trust for Ornithology Report, commissioned by COWRIE Ltd.

Mendel, B., Kotzerka, J., Sommerfeld, J., Schwemmer, H., Sonntag, N. and Garthe, S. (2014). *Effects of the alpha ventus offshore test site on distribution patterns, behaviour and flight heights of seabirds*. In Ecological Research at the Offshore Windfarm alpha ventus (pp. 95-110). Springer Fachmedien Wiesbaden.

NatureScot (2020). *Seasonal Periods for Birds in the Scottish Marine Environment*. Short Guidance Note Version 2. October 2020.

NatureScot (2023). *Guidance Note 8: Guidance to support Offshore Wind Applications: Marine Ornithology Advice for assessing the distributional responses, displacement and barrier effects of Marine birds*. Available at: https://www.nature.scot/professional-advice/planning-and-development/planning-and-development-advice/renewable-energy/marine-renewables/advice-marine-renewables-development. Accessed on: 11 September 2023.

Pérez-Lapenã, B. K. Wijnberg, M., Hulscher, S. J. M. H & Stein, A. (2010). *Environmental impact assessment of offshore wind farms: a simulation-based approach*. Journal of Applied Ecology 47: 1110–1118.

Peschko, V., Mendel, B., Müller, S., Markones, N., Mercker, M. and Garthe, S. (2020). *Effects of offshore windfarms on seabird abundance: Strong effects in spring and in the breeding season*. Marine Environmental Research. 162, pp. 1-12.

Pettifor, R.A., Caldow, R.W.G., Rowcliffe, J.M., Goss-Custard, J.D. and Black, J.M. (2000). *Spatially explicit, individual-based, behavioural models of the annual cycle of two migratory goose populations*. J. Appl. Ecol. 37:103–35.

Royal Haskoning DHV (2013). *Thanet Offshore Wind Farm Ornithological Monitoring 2012-2013 (Post-construction Year 3)*. Royal HaskoningDHV Report for Vattenfall Wind Power Limited.

RWE Renewables UK (2022). *Awel y Môr Offshore Wind Farm Category 6:.Environmental Statement Volume 2, Cahpter 4: Offshore Ornithology*. Available at: https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010112/EN010112-000190-6.2.4_AyM_ES_Volume2_Chapter4_OffshoreOrnithology_vFinal.pdf. Accessed on: 06 October 2023.

Searle, K.R., Mobbs, D.C., Butler, A., Furness, R.W., Trinder, M.N. and Daunt, F. (2018) *Finding out the fate of displaced birds*. Scottish Marine and Freshwater Science. 9(8): 149.

Skov, H., Heinänen, S., Norman, T., Ward, R.M., Méndez-Roldán, S. and Ellis, I. (2018). *ORJIP Bird Collision and Avoidance Study*. Final report – April 2018. The Carbon Trust. 247 pp.

SNCB (2022a). *Joint SNCB Note Interim Displacement Advice Note.* Available at: https://data.jncc.gov.uk/data/9aecb87c-80c5-4cfb-9102-39f0228dcc9a/joint-sncb-interim-displacement-advice-note-2022.pdf. Accessed on: 11 September 2023.

SNCB (2022b). *Joint SNCB interim advice on the treatment of displacement for red-throated diver*. Available at: https://data.jncc.gov.uk/data/9aecb87c-80c5-4cfb-9102-39f0228dcc9a/interim-sncb-advice-rtd-displacement-buffer.pdf. Accessed on: 11 September 2023.

Topping, C. and Petersen, I.K. (2011). *Report on a red-throated diver agent-based model to assess the cumulative impact from offshore wind farms*. Report commissioned by Vattenfall A/S. Aarhus University, DCE – Danish Centre for Environment and Energy.

Vallejo, G. C., Grellier, K., Nelson, E. J., McGregor, R. M., Canning, S. J., Caryl, F. M. and McLean, N. (2017). *Responses of two marine top predators to an offshore wind farm*. Ecology and Evolution, 7(21), pp. 8698-8708.

Vanermen, N., Stienen, E.W.M., Courtens, W., Onkelinx, T., Van de walle, M. and Verstraete, H. (2016). *Bird monitoring at offshore wind farms in the Belgian part of the North Sea - Assessing seabird displacement effects*. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2013 (INBO.R.2013.755887). Instituut voor Natuur- en Bosonderzoek, Brussels.

Wade, H.M., Masden E.M., Jackson, A.C. and Furness, R.W. (2016). *Incorporating data uncertainty when estimating potential vulnerability of Scottish seabirds to marine renewable energy developments*. Marine Policy, 70, 108-113.

West, A.D., Goss-Custard, J.D., McGrorty, S., Stillman, R.A., Durell, S.E.A. le V. Dit, Stewart, B., Walker, P., Palmer, D.W. and Coates, P. (2003). *The Burry shellfishery and oystercatchers: using a behaviour-based model to advise on shellfishery management policy*. Marine Ecology Progress Series, 248: 279-292.

ANNEX A: ORNITHOLOGY DATA FOR DISPLACEMENT ASSESSMENT

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

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