Cenos Offshore Windfarm Limited

Cenos EIA

Appendix 22 – Distributional Responses Report

ASSIGNMENT A100907-S01
DOCUMENT CEN001-FLO-CON-ENV-RPT-0071

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REV	DATE	DESCRIPTION	ISSUED	CHECKED	APPROVED	CLIENT
01	25/04/2024	First draft for Client review	MCS / LR	DP / GT	CC	Cenos
02	02/08/2024	Second draft for Client review	MCS	JH	JH	Cenos
03	16/08/2024	Third draft for Client review	MCS	JH	JH	Cenos
A01	05/12/2024	Final version to Client	RT	JH	JH	Cenos
A02	19/12/2024	Final version with minor revisions	LR	JH	JH	Cenos

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Tables

1 Introduction

1 Cenos Offshore Windfarm (hereafter 'the Project') is a proposed floating offshore wind farm, located approximately 200km offshore from the north-east coast of Aberdeen, Scotland. The Project is proposed by Cenos Offshore Windfarm Ltd. ('the Applicant') and is a Joint Venture (JV) between Flotation Energy (FE) and Vårgrønn As (Vårgrønn).

2 Within this report, the term 'distributional responses' refers to two key responses assessed for seabirds in relation to the presence of offshore wind farms (OWFs): displacement and barrier effects (NatureScot, 2023a).

3 Displacement is defined as 'a reduced number of birds occurring within or immediately adjacent to an offshore wind farm' (Furness *et al*., 2013; Bradbury *et al.,* 2014). This is a direct result of birds avoiding the area of operational turbines and the avoidance response is species dependent. For species which are less adaptive or have highly localised foraging ranges, any displacement impacts may have the potential to create population level effects. Advice from the UK Statutory Nature Conservation Bodies (SNCBs) (JNCC *et al*., 2022) considers that both birds in flight and on the water may be displaced.

4 Barrier effects may occur when birds that would have previously flown through an area (e.g. in transit to feeding, resting or nesting areas) either have to cease flying or alter their flight paths due to the presence of an OWF (JNCC *et al*., 2022), which may affect energetic costs (Masden *et al.,* 2010). For the purpose of this assessment, barrier effects only apply to birds in flight and are considered together with displacement to assess distributional responses. This Appendix of the Environmental Impact Assessment Report (EIAR) should be read in conjunction with EIAR Vol. 3, Chapter 12: Ornithology.

5 Bradbury *et al.* (2014), Furness *et al.* (2013), Masden *et al.* (2010) and Wade *et al.* (2016) consider the sensitivity of key seabird species to distributional responses (displacement and barrier effects). Following these as well as the NatureScot guidance (NatureScot, 2023a) and the project-specific advice received from NatureScot (received 2nd April 2024), the species listed below are considered as sensitive or vulnerable to distributional responses and are addressed in this Appendix:

- Black-legged kittiwake (*Rissa tridactyla*), hereafter 'kittiwake';
- Common guillemot (*Uria aalge*), hereafter 'guillemot';
- Atlantic puffin (*Fratercula arctica*), hereafter 'puffin'; and
- Northern gannet (*Morus bassanus*); hereafter 'gannet'.

6 The above species were selected using the joint SNCB interim advice (JNCC *et al.,* 2022) which advises species which score three or higher in either disturbance susceptibility or habitat specialisation from Bradbury *et al*. (2014) should be progressed to the matrix stage, in addition to gannet which should be included regardless of scores. This, combined with information from site-specific Digital Aerial Survey (DAS; Annex 4, EIAR Vol. 4, Appendix 16: Marine Mammal Baseline Report), supported inclusion of guillemot, puffin and gannet. Kittiwake is included following NatureScot representation and requests from MD-LOT for other Scottish projects.

7 Kittiwake, puffin and gannet are assessed for both the breeding and non-breeding seasons, whereas guillemot is only assessed for the non-breeding season. This is due to there being no guillemot breeding colonies within foraging range of the Project (using mean max foraging range from Woodward *et al.* (2019)). This was

discussed and agreed with NatureScot during the Scoping Workshop on 29th February 2024 and the subsequent written advice received 2nd April 2024.

8 The species were selected based on their sensitivity, as mentioned above, and abundance in the Project area. Presence of key species in site-specific DAS of the DAS Area (the Innovation and Targeted Oil and Gas (INTOG) 'E-a' Area plus a 4km buffer), the Array Area and the Array Area plus 2km buffer are presented alongside density and abundance estimates in EIAR Vol. 4, Appendix A19: Ornithology Baseline Report. Other species, such as razorbill (*Alca torda*) and red-throated diver (*Gavia stellata*), have also been identified as being susceptible to distributional responses, however, observed abundance in the area was too low to warrant inclusion in this assessment.

9 As discussed with NatureScot at the Ornithology Catch Up on 7th August 2024, fulmar (*Fulmaris glacialis*) will be assessed qualitatively for distributional responses. This information is presented in EIAR Vol. 3, Chapter 12: Ornithology and the Report to Inform Appropriate Assessment (RIAA).

10 The primary method of assessment used within this assessment is the matrix method presented in the joint SNCB interim guidance (JNCC *et al*., 2022), as agreed in the NatureScot advice (received 2nd April 2024). This method estimates the number of birds that may be expected to die as a result of distributional responses due to the presence of the Project.

11 SeabORD modelling was used to provide additional contextual information on the effect of the Project on distributional responses of seabirds during the chick rearing period. Modelling was undertaken for kittiwake and puffin only, as it is not possible to model gannet using SeabORD; guillemot were outside of foraging range during the breeding season.

12 Species-specific displacement rates were applied during analysis however, any predicted impacts are assumed to cover both displacement and barrier effects to effectively examine distributional responses as a whole.

2 Methods

2.1 Displacement matrices

2.1.1 Spatial scales

14 As advised in the interim joint SNCB guidance (JNCC *et al*., 2022) and NatureScot (2023a), displacement matrices are provided for each of the selected species for the Array Area plus a specified buffer area to take into account for species which may also be displaced from the area immediately surrounding a wind farm, although displacement is likely to occur to a lesser degree outwith the Array Area in comparison to inside. For the species of interest, the zone of influence extended to 2km beyond the Array Area boundary in line with guidance (NatureScot, 2023a). Therefore, all displacement matrices will be presented for the Array Area plus 2km buffer (Figure 1; EIAR Vol. 4, Appendix A19: Ornithology Baseline Report).

2.1.2 Seasonality

15 As recommended in the joint interim SNCB guidance (JNCC *et al*., 2022), displacement matrices are required for each species in the breeding and non-breeding seasons. Both breeding and non-breeding seasons follow the NatureScot (2023a) guidance and use those as detailed in NatureScot (2020) (Table 1). The seasons are defined as follows:

- Breeding season – birds strongly associated with nest site, including nesting, egg laying and provisioning young; and
- Non-breeding season – any period outwith the above, which may encompass birds over-wintering in an area and migration periods between breeding and wintering sites.

Table 1 Defined seasons for species being assessed for distributional responses (NatureScot, 2020)

Species	Breeding season	Non-breeding season
Kittiwake	Mid-Apr to Aug	Sep to mid-Apr
Guillemot	Apr to mid-Aug	mid-Aug to Mar
Puffin	Apr to mid-Aug	mid-Aug to Mar
Gannet	Mid-Mar to Sep	Oct to mid-Mar

2.1.3 Mean Seasonal Peaks

16 As advised in the joint interim SNCB guidance (JNCC *et al*., 2022) and NatureScot (2023a), displacement matrices use Mean Seasonal Peak (MSP) population estimates (Table 2). These are an average of peak counts over the two available years of survey data for each species, calculated for the breeding and non-breeding seasons. These are reproduced from EIAR Vol. 4, Appendix A19: Ornithology Baseline Report.

17 MSP confidence intervals were calculated from the bootstrap outputs from MRSea modelling. For both years, the 1,000 bootstrap runs were extracted for the MSP month and averaged per run across the two years. Confidence limits were subsequently calculated by taking the percentiles of the averaged bootstraps (2.5th and 97.5th percentile).

18 Where seasons started or ended halfway through the month, the 15th was used as a mid-month cut off, and surveys were assigned to a season based on the date that the survey was flown.

19 As noted above, the SNCB interim guidance (JNCC *et al*., 2022) defines displacement as affecting both birds on the water and in flight; therefore, the MSPs were calculated from monthly population estimates for all birds present within the Array Area plus 2km.

20 All estimates of density and abundance include 'unidentified' birds which have been ID apportioned (allocated) to species based on the relative abundance ratios of identified species within each category. More detail on apportioning of unidentified birds and the calculation of absolute estimates of density and abundance can be found in EIAR Vol. 4, Appendix A19: Ornithology Baseline Report.

21 For guillemot and puffin, density and abundance estimates have been adjusted to provide absolute estimates (accounting for animals diving at the time of the survey; i.e., adjusting for availability bias).

Table 2 Mean seasonal peak population estimates of key species per season within the Array Area plus 2km buffer

Species	Breeding season			Non-breeding season		
	Abundance estimate (ind)	Lower 95% confidence limit	Upper 95% confidence limit	Abundance estimate (ind)	Lower 95% confidence limit	Upper 95% confidence limit
Kittiwake	208	159	294	97	58	184
Guillemot	Not assessed			8319	7459	9041
Puffin	221	153	318	67	39	117
Gannet	216	132	314	263	190	362

2.1.4 Displacement and mortality rates

22 Displacement rates are species-specific, and those used in assessment are presented in Table 3, following NatureScot (2023a) guidance. The recommended displacement rates are applied uniformly across the Array Area plus 2km buffer as described in the SNCB guidance (JNCC *et al.*, 2022) and NatureScot (2023a). Section 3.1 summarises outputs for the advised displacement rates; while the full displacement matrices for each species are presented in Annex 1: Displacement matrices.

23 There are two ways in which displacement can result in fitness consequences (Fox *et al.*, 2006; Masden *et al.*, 2009; Fox and Peterson, 2019):

- The possibility of increased energetic expenditure from having to alter usual flight paths; and
- The reduction in food availability due to the loss of perceived and physical habitat.

24 Several factors influence the mortality risk due to displacement effects. The size of a windfarm impacts the distance deviated by birds in flight and the amount of habitat lost. There is also variation between different species and seasons due to morphological traits, foraging behaviour and seasonal energetic costs.

25 Recommended mortality rates during the breeding and non-breeding seasons are presented in Table 3 (NatureScot, 2023a).

Table 3 Displacement and mortality rates included for consideration in assessment (NatureScot, 2023a)

Species	Percentage of birds displaced	Breeding season mortality	Non-breeding season mortality
Kittiwake	30%	1% and 3%	1% and 3%
Guillemot	60%	Not assessed	1% and 3%
Puffin	60%	3% and 5%	1% and 3%
Gannet	70%	1% and 3%	1% and 3%

2.2 SeabORD modelling

2.2.1 Introduction and scope of SeabORD

26 Created by the UK Centre of Ecology and Hydrology (CEH), SeabORD is used to quantify the fate of seabirds impacted by displacement and barrier impacts during the breeding season (Searle *et al.,* 2014, 2018). It is an individual-based modelling approach which predicts the bio-energetic consequences to seabirds from changes in flight paths due to the presence of offshore wind farms.

27 SeabORD simulates the flightpaths of individual birds from identified breeding colonies to potential foraging areas in scenarios with and without additional wind farms present (Searle *et al*., 2019). Data are fed into bio-energetic equations which estimate the percentage body mass loss of each bird, acting as a proxy of survival. Refer to EIAR Vol. 4, Appendix A22: Distributional Responses Report - Annex 2 for further detail.

28 Currently the software can only be used to predict the potential impacts of windfarms on four species; kittiwake, guillemot, razorbill and puffin. As there are no Special Protection Areas (SPA) or non-SPA breeding guillemot colonies within the breeding season foraging range of the Project, this species was not assessed. For razorbill, the low observed abundance during DAS means that they are not included in SeabORD analysis for the Project. Therefore, only kittiwake and puffin were analysed using SeabORD.

29 Multiple scenarios were ran through SeabORD to determine the estimated mortality of birds due to the presence of the Project. The effect of distributional responses was assessed for the Project alone (Project alone scenario) as well as in combination with neighbouring OWFs (Cumulative scenario). Four other OWFs were included in analysis: European Offshore Wind Deployment Centre (EOWDC), Green Volt Windfarm, Hywind Scotland Pilot Project and Kincardine Floating Offshore Windfarm.

30 Four seabird colonies were included in the assessment; three for kittiwake (Fowlsheugh SPA, Buchan Ness to Collieston Coast SPA and Troup, Pennan and Lion's Head SPA) and one for puffin (Farne Islands SPA).

31 As there were no tracking data available for seabirds within these colonies, SeabORD was run using the 'distance decay' function as described in EIAR Vol. 4, Appendix A22: Distributional Responses Report - Annex 2.

3 Results

3.1 Predicted impacts: displacement matrices

32 Table 4 provides estimates of predicted mortality occurring due to distributional responses, as determined by species-specific rates of displacement and mortality. For each species, predicted mortalities are calculated for the Array Area plus 2km buffer and presented for the breeding and non-breeding seasons, where applicable. As standard practice, these estimates are detailed as 'whole birds' and therefore values are rounded up or down, where relevant.

33 Predicted mortalities are considered as a proportion of the regional population. Regional populations in the breeding season are derived from colony data extracted from the Seabird Monitoring Programme (SMP) based on species-specific foraging ranges while Biologically Minimum Population Scales (BDMPS; Furness 2015) are used in the non-breeding season. Refer to EIAR Vol. 4, Appendix A23: Regional Populations and Associated Colony Counts for more detail.

34 Current NatureScot guidance suggests that for guillemot during the non-breeding season, the population derived for the breeding season, using the species-specific mean-maximum foraging range (mmfr) + 1SD from Woodward *et al*. (2019) is used (NatureScot, 2023b). There are no guillemot colonies within breeding season mmfr + 1SD, therefore NatureScot request via written advice on the 2nd April 2024 that the BDMPS population be used to assess impacts to guillemot in the non-breeding season.

35 Within EIAR Vol. 3, Chapter 12: Ornithology, mortality from distributional responses is used to determine the percentage point change in adult survival in relation to the regional population. This metric is used to determine whether population level analysis is required, following NatureScot advice received in the Ornithology Catch Up on 7th August 2024 and subsequent written advice received 10th September 2024.

Table 4 Seasonal mortalities to regional populations of key species during the breeding and non-breeding seasons from displacement matrices, to the nearest whole bird. In parentheses are the percentages of regional populations that the mortalities represent. Only the results for species specific displacement and mortality rates (NatureScot, 2023a) are provided here

Species	Regional population (ind.)	Displacement mortalities (no. of birds)						
Displacement rate		**30%**		**60%**			**70%**	
Mortality rate		**1%**	**3%**	**1%**	**3%**	**5%**	**1%**	**3%**
Breeding season								
Kittiwake	231,732	1 (<0.001)	2 (<0.001)	-	-	-	-	-
Guillemot	Not assessed							
Puffin	215,019	-	-	-	4 (<0.001)	7 (<0.001)	-	-
Gannet	238,322	-	-	-	-	-	2 (<0.001)	5 (<0.001)
Non-breeding season								
Kittiwake	829,937*	0 (0.000)	1 (<0.001)	-	-	-	-	-
Guillemot	1,617,306	NA	-	50 (0.003)	150 (0.009)	-	-	-
Puffin	231,957	-	-	0 (0.000)	1 (<0.001)	-	-	-
Gannet	456,298*	-	-	-	-	-	2 (<0.001)	6 (<0.001)

Autumn migration population from Furness (2015) as mean seasonal peaks for both species occurred during this period

3.2 Predicted impacts: SeabORD model outputs

36 SeabORD outputs for kittiwake and puffin are presented in EIAR Vol. 4, Appendix A22: Distributional Responses Report - Annex 2. Outputs are presented separately for each of the SPAs for the Project-alone scenario and Cumulative (multiple OWFs) scenario.

37 For the Project alone scenario for kittiwake and puffin, the additional mortality caused by the presence of the Project was less than 0.01% (Table 7 and Table 11; EIAR Vol. 4, Appendix A22: Distributional Responses Report - Annex 2) for both puffin and kittiwake. The adult survival at the end of the breeding season for kittiwake was 100% with a negligible difference in the number of chicks not surviving the season with and without the Project being present (Table 8; EIAR Vol. 4, Appendix A22: Distributional Responses Report - Annex 2). The mean survival for adult puffin at the end of the breeding season was 99.999% and, like kittiwake, the difference between the number of chicks not surviving the breeding season with and without the Project was negligible (Table 12; EIAR Vol. 4, Appendix A22: Distributional Reponses Report - Annex 2).

38 In cumulative scenarios, which included four additional windfarms, additional mortality was under 0.5% for all SPAs for both kittiwake and puffin. The greatest additional mortality was estimated at Fowlsheugh SPA, under moderate conditions for kittiwake (0.412%) though adult survival at the end of the breeding season was 100% for all colonies. For puffin, adult survival was 99.999% (Table 14; EIAR Vol. 4, Appendix A22: Distributional Responses Report - Annex 2). With more windfarms present, fewer chicks were estimated to survive the season. Additional chick mortality was never predicted to be above 4.5%.

4 Discussion and Conclusions

4.1 Consideration of estimated displacement mortalities in assessment

39 This Appendix provides assessment of estimated mortalities of seabird species arising from distributional responses using displacement matrices (Section 3.1 and Annex 1: Displacement matrices) and SeabORD (Section3.2, and EIAR Vol. 4, Appendix A22: Distributional Responses Report – Annex 2). As part of EIA, the effect of these mortalities must be considered in the context of regional populations during both the breeding and non-breeding seasons.

40 The estimated mortality from distributional responses due to the presence of the Project on regional seabird populations during the breeding and non-breeding seasons using the matrix approach are presented in Table 4. These are detailed per species and per season, in the context of the most contemporaneous population counts to DAS of the Project. For the breeding season, the most recent population counts are taken directly from the Seabird Monitoring Programme (SMP) database, hosted by the British Trust for Ornithology (BTO), which can be made available upon request from BTO. The process of deriving the regional populations is detailed in EIAR Vol. 4, Appendix A23: Regional Populations and Associated Colony Counts. The non-breeding regional populations follow the Biologically Defined Minimum Population Scales (BDMPS) regions from Furness (2015). For kittiwake the BDMPS region is 'UK North Sea' and for guillemot, puffin and gannet the BDMPS region is 'UK North Sea and Channel'.

41 Estimated mortalities are higher in the breeding season for puffin whereas kittiwake and gannet have similar estimated mortality in both seasons; using both approaches, estimated mortalities from distributional responses are predicted to be low. Direct comparison between outputs from displacement matrices and SeabORD is challenging as the displacement matrices assess the impact in the context of species-specific regional populations whereas SeabORD focuses on the impact at the individual SPA/colony level, specifically those expected to have the greatest impact, given the location in relation to the Project.

42 Using the matrix approach, estimated mortality from distributional responses was below 0.01% of the regional populations for all species and seasons, indicating that the level of predicated impact to populations is likely to be low. Within EIAR Vol. 3, Chapter 12: Ornithology it is determined whether estimated mortality from distributional responses (combined with collision mortality for gannet and kittiwake), leads to a percentage point change in adult survival of equal to or more than 0.02%. This is additionally presented and discussed within EIAR Vol. 4, Appendix A25: Population Viability Analysis Report.

43 For the purpose of quantitative impact assessment, results using the matrix approach will be fed into Population Viability Analysis (PVA) (EIAR Vol. 4, Appendix A25: Population Viability Analysis Report) and the Habitats Regulation Appraisal (HRA), presented within the RIAA.

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Annex 1: Displacement matrices

Table 5 Kittiwake breeding season mean displacement mortalities in the Array Area plus 2km buffer (to the nearest whole bird). Blue cells highlighted the NatureScot (2023a) recommended displacement and mortality rates

Kittiwake (mid Aug – Aug)		Mortality rate (no. of birds)												
Displacement rate (% of all birds on-site)		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	1	1	1	2	3	4	6	10	17	21
	20%	0	0	1	1	2	2	4	6	8	13	21	33	42
	30%	0	1	1	2	3	3	6	9	13	19	31	50	63
	40%	0	1	2	3	3	4	8	13	17	25	42	67	83
	50%	0	1	2	3	4	5	10	16	21	31	52	83	104
	60%	0	1	3	4	5	6	13	19	25	38	63	100	125
	70%	0	1	3	4	6	7	15	22	29	44	73	117	146
	80%	0	2	3	5	7	8	17	25	33	50	83	133	167
	90%	0	2	4	6	8	9	19	28	38	56	94	150	188
	100%	0	2	4	6	8	10	21	31	42	63	104	167	208

Table 6 **Kittiwake non-breeding season mean displacement mortalities in the Array Area plus 2km buffer (to the nearest whole bird). Blue cells highlighted the NatureScot (2023a) recommended displacement and mortality rates**

Kittiwake (Sept – mid-Apr)		Mortality rate (no. of birds)												
Displacement rate (% of all birds on-site)		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	1	1	2	3	5	8	10
	20%	0	0	0	1	1	1	2	3	4	6	10	16	19
	30%	0	0	1	1	1	1	3	4	6	9	15	23	29
	40%	0	0	1	1	2	2	4	6	8	12	19	31	39
	50%	0	0	1	1	2	2	5	7	10	15	24	39	49
	60%	0	1	1	2	2	3	6	9	12	17	29	47	58
	70%	0	1	1	2	3	3	7	10	14	20	34	54	68
	80%	0	1	2	2	3	4	8	12	16	23	39	62	78
	90%	0	1	2	3	3	4	9	13	17	26	44	70	87
	100%	0	1	2	3	4	5	10	15	19	29	49	78	97

Table 7 Guillemot non-breeding season mean displacement mortalities in the Array Area plus 2km buffer (to the nearest whole bird). Blue cells highlighted the NatureScot (2023a) recommended displacement and mortality rates

Guillemot (mid Aug – Mar)		Mortality rate (no. of birds)												
Displacement rate (% of all birds on-site)		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	8	17	25	33	42	83	125	166	250	416	666	832
	20%	0	17	33	50	67	83	166	250	333	499	832	1,331	1,664
	30%	0	25	50	75	100	125	250	374	499	749	1,248	1,997	2,496
	40%	0	33	67	100	133	166	333	499	666	998	1,664	2,662	3,328
	50%	0	42	83	125	166	208	416	624	832	1,248	2,080	3,328	4,160
	60%	0	50	100	150	200	250	499	749	998	1,497	2,496	3,993	4,991
	70%	0	58	116	175	233	291	582	874	1,165	1,747	2,912	4,659	5,823
	80%	0	67	133	200	266	333	666	998	1,331	1,997	3,328	5,324	6,655
	90%	0	75	150	225	299	374	749	1,123	1,497	2,246	3,744	5,990	7,487
	100%	0	83	166	250	333	416	832	1,248	1,664	2,496	4,160	6,655	8,319

Table 8 Puffin breeding season mean displacement mortalities in the Array Area plus 2km buffer (to the nearest whole bird). Blue cells highlighted the NatureScot (2023a) recommended displacement and mortality rates

Puffin (Apr – mid-Aug)		Mortality rate (no. of birds)												
Displacement rate (% of all birds on-site)		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	1	1	1	2	3	4	7	11	18	22
	20%	0	0	1	1	2	2	4	7	9	13	22	35	44
	30%	0	1	1	2	3	3	7	10	13	20	33	53	66
	40%	0	1	2	3	4	4	9	13	18	27	44	71	89
	50%	0	1	2	3	4	6	11	17	22	33	55	89	111
	60%	0	1	3	4	5	7	13	20	27	40	66	106	133
	70%	0	2	3	5	6	8	15	23	31	46	77	124	155
	80%	0	2	4	5	7	9	18	27	35	53	89	142	177
	90%	0	2	4	6	8	10	20	30	40	60	100	159	199
	100%	0	2	4	7	9	11	22	33	44	66	111	177	221

Table 9 Puffin non-breeding season mean displacement mortalities in the Array Area plus 2km buffer (to the nearest whole bird). Blue cells highlighted the NatureScot (2023a) recommended displacement and mortality rates

Puffin (mid-Aug – Mar)		Mortality rate (no. of birds)												
Displacement rate (% of all birds on-site)		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	1	1	1	2	3	5	7
	20%	0	0	0	0	1	1	1	2	3	4	7	11	13
	30%	0	0	0	1	1	1	2	3	4	6	10	16	20
	40%	0	0	1	1	1	1	3	4	5	8	13	21	27
	50%	0	0	1	1	1	2	3	5	7	10	17	27	33
	60%	0	0	1	1	2	2	4	6	8	12	20	32	40
	70%	0	0	1	1	2	2	5	7	9	14	23	37	47
	80%	0	1	1	2	2	3	5	8	11	16	27	43	53
	90%	0	1	1	2	2	3	6	9	12	18	30	48	60
	100%	0	1	1	2	3	3	7	10	13	20	33	53	67

Table 10 Gannet breeding season mean displacement mortalities in the Array Area plus 2km buffer (to the nearest whole bird). Blue cells highlighted the NatureScot (2023a) recommended displacement and mortality rates

Gannet (mid-Mar – Sep)		Mortality rate (no. of birds)												
Displacement rate (% of all birds on-site)		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	1	1	1	2	3	4	6	11	17	22
	20%	0	0	1	1	2	2	4	6	9	13	22	35	43
	30%	0	1	1	2	3	3	6	10	13	19	32	52	65
	40%	0	1	2	3	3	4	9	13	17	26	43	69	86
	50%	0	1	2	3	4	5	11	16	22	32	54	86	108
	60%	0	1	3	4	5	6	13	19	26	39	65	104	130
	70%	0	2	3	5	6	8	15	23	30	45	76	121	151
	80%	0	2	3	5	7	9	17	26	35	52	86	138	173
	90%	0	2	4	6	8	10	19	29	39	58	97	156	194
	100%	0	2	4	6	9	11	22	32	43	65	108	173	216

Table 11 Gannet non-breeding season mean displacement mortalities in the Array Area plus 2km buffer (to the nearest whole bird). Blue cells highlighted the NatureScot (2023a) recommended displacement and mortality rates

Gannet (Oct – mid-Mar)		Mortality rate (no. of birds)												
Displacement rate (% of all birds on-site)		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	1	1	1	1	3	4	5	8	13	21	26
	20%	0	1	1	2	2	3	5	8	11	16	26	42	53
	30%	0	1	2	2	3	4	8	12	16	24	40	63	79
	40%	0	1	2	3	4	5	11	16	21	32	53	84	105
	50%	0	1	3	4	5	7	13	20	26	40	66	105	132
	60%	0	2	3	5	6	8	16	24	32	47	79	126	158
	70%	0	2	4	6	7	9	18	28	37	55	92	148	184
	80%	0	2	4	6	8	11	21	32	42	63	105	169	211
	90%	0	2	5	7	9	12	24	36	47	71	119	190	237
	100%	0	3	5	8	11	13	26	40	53	79	132	211	263

Cenos Offshore Windfarm EIAR (Volume 4) Appendix A22 – Distributional Responses Report – Annex 2: SeabORD

Authorisations

Review	Date	Prepared by	Checked by	Approved by	Comments
Rev01	02/08/2024	[Redacted] [redacted] [Redacted] [redacted] [Redacted] [redacted]	[Redacted] [redacted] [Redacted] [redacted]	[Redacted] [redacted]	First draft issued to Client
Rev02	13/08/2024	[Redacted] [redacted]	[Redacted] [redacted]		Second draft issued to Client
Rev03	08/10/2024	[Redacted] [redacted]	[Redacted] [redacted]		Third draft issued to Client
A01	05/12/2024	[Redacted] [redacted]	[Redacted] [redacted]	[Redacted] [redacted]	Final draft to Client

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Contents

Tables

1 Introduction

1 This Annex supports the assessment of distributional responses undertaken for the Cenos Offshore Windfarm (hereafter 'the Project'). The Project is a planned 50/50 joint venture (JV) between Flotation Energy (FE) and Vårgrønn. This Annex will provide additional contextual information from SeabORD modelling to support EIAR Vol. 4, Appendix A22: Distributional Responses Report.

2 Within this Annex, the term 'distributional responses' refers to two key responses assessed for seabirds in relation to the presence of offshore wind farms (OWFs): displacement and barrier effects (NatureScot, 2023). Further information is provided in EIAR Vol. 4, Appendix A22: Distributional Responses Report.

3 Following the approach proposed in the Scoping Workshop held 29th February 2024, the Scoping Report, and the subsequent agreement through the Scoping Opinion (received September 2024), the matrix method has been used as the primary method of assessing distributional responses for the Project (JNCC *et al.*, 2022), with modelling outputs from SeabORD (Mobbs *et al.,* 2018; Searle *et al.,* 2018) used to provide contextual information.

4 SeabORD is an individual-based modelling method developed by the UK Centre of Ecology and Hydrology (CEH) which assesses the bio-energetic impacts of distributional responses to individual birds as well as specific populations, quantified by the number of estimated mortalities. SeabORD simulates flight paths of individual birds from identified breeding colonies to potential foraging areas in the presence of single or multiple OWFs and compares these to flightpaths simulated with no OWFs present (Searle *et al.,* 2014; 2018; 2019). Activity budgets derived from these flight paths are then fed into bio-energetic equations which estimate the percentage body mass loss of the birds, which acts as a measure of survival.

5 Technically, within the simulations only the chick-rearing period is modelled. However, this will be referred to as the breeding period throughout this Annex.

6 SeabORD was run using a 'distance decay' function which assumes that as the distance from the colony increases, the density of foraging birds decreases. Distributional responses were assessed using SeabORD for the following species:

- Black-legged kittiwake (*Rissa tridactyla*), hereafter 'kittiwake'; and
- Atlantic puffin (*Fratercula arctica*), hereafter 'puffin'.

7 Currently, SeabORD is only able to predict the impact of distributional responses for the above species plus razorbill (*Alca torda*) and common guillemot (*Uria aalge*). For guillemot, there are no Special Protection Area (SPA) or non-SPA breeding colonies within breeding season foraging range of the Project, so the species is not assessed. This follows advice received for the Project from NatureScot on 2nd April 2024. Razorbill are not assessed for distributional responses for the Project due to low observed abundance in Digital Aerial Surveys (DAS), so are not included in SeabORD analysis.

8 Estimated mortality from distributional responses is estimated in relation to SPA and non-SPA breeding colonies. Colonies within the species-specific mean maximum foraging range plus one standard deviation (mmfr + 1SD) from the Project were derived during connectivity and apportioning (see EIAR Vol. 4, Appendix A24: Apportioning Report) for each species modelled, using foraging ranges presented in Woodward *et al.* (2019). SeabORD allows for up to six colonies to be included within the simulation. For this project, the SPA colonies included in the analysis for kittiwake and puffin are presented in Table 1.

Table 1 Special Protection Areas (SPAs) included in SeabORD analysis and the proportional weighting determined during breeding season apportioning (reported in EIAR Vol. 4, Appendix A24: Apportioning Report)

Species	Colony	Proportional Weighting
Kittiwake	Fowlsheugh SPA	0.23
	Buchan Ness to Collieston Coast SPA	0.16
	Troup, Pennan, Lion's Head SPA	0.12
Puffin	Farne Islands SPA	0.42

9 There is currently little guidance for using the SeabORD tool as part of the Environmental Impact Assessment (EIA) process and it was found that issues similar to those reported in Berwick Bank Offshore Wind Farm EIAR Vol. 3, Appendix 11.4, Annex D (SEE Renewables, 2022a) were encountered when running the tool. Due to the large run times associated with the model it was not possible to run the tool using the maximum of six colonies, therefore colonies which were most likely to be impacted by the Project were included in analysis.

10 As SeabORD only allows for six colonies to be included in simulations, colonies with the highest proportional weighting as presented in the EIAR Vol. 4, Appendix A24: Apportioning Report, were considered. The method used for apportioning determined whether sites had connectivity with the Project by measuring at-sea distance from the closest edge of the Project to the closest edge of the SPA (as per NatureScot advice received during Ornithology Consultation on 21st October 2024.

11 Three of the six kittiwake colonies with the highest proportional weighting as determined through apportioning (EIAR Vol. 4, Appendix A24: Apportioning Report), were included in SeabORD simulations (Table 1). East Caithness Cliffs SPA, Forth Islands SPA and St. Abbs to Fast Castle SPA, which had weightings of 0.13, 0.06 and 0.05 respectively, were excluded from SeabORD simulations.

12 Guidance provided alongside the SeabORD tool recommends users to use a central point along the coastline to represent each colony (Mobbs *et al.*, 2018). Due to this, the central point for East Caithness Cliffs SPA was found to be approximately 303km, outside of the mmfr + 1SD for kittiwake as per Woodward *et al.* (2019) (Table 3). As the model only allows for impacts to occur when individuals come into contact with the Project, if the Project is outside the foraging range of a colony only individuals from the colony that travel outside the foraging range (2.5%) have the possibility of being impacted. As it is unlikely that these colonies would have a high level of additional mortality caused by the Project, East Caithness Cliffs SPA was excluded from simulations.

13 Forth Islands SPA and St. Abbs Head to Fast Castle SPA were not included for kittiwake as estimated apportioning weightings were low (0.06 and 0.05 respectively). Both SPAs were also found to be further from the Project than those included in simulations, meaning they were likely to have smaller impacts than the SPAs modelled.

14 The final colonies included in SeabORD analysis for kittiwake are presented in Table 1.

15 The same approach was used for puffin as for kittiwake. Apportioning indicated three colonies with apportioning weightings greater than 0.00: Farne Islands SPA (0.42), Forth Islands SPA (0.42) and Coquet Island SPA (0.08) (EIAR Vol. 4, Appendix A21: Apportioning Report). However, both Forth Islands SPA and Coquet Island SPA were found to be approximately 265km from the site. As the mmfr + 1SD for puffin is 265.4km, it would be expected that only a small number of individuals from either of these SPAs could be impacted by the Project and were therefore not included within simulations.

16 Multiple scenarios were run through SeabORD to determine the estimated mortality of birds due to the presence of the Project during the breeding season. The effect of distributional responses was assessed for the Project (Project Alone scenario) and including other neighbouring OWFs (Cumulative scenario). SeabORD allows for up to five OWFs, including the Project, to be included in models. The OWFs selected were included based on proximity to the Project and if they had received consent at the time of analysis (December 2024). The OWFs which were considered in addition to the Project within the Cumulative scenario were:

- European Offshore Wind Deployment Centre (EOWDC);
- Green Volt Windfarm;
- Hywind Scotland Pilot Park Project, hereafter 'Hywind'; and
- Kincardine Floating Offshore Windfarm, hereafter 'Kincardine'.

2 Methods

2.1 Colony Specific Information

17 SeabORD requires each selected colony to be represented by a single point close to the coastline of the UK within the simulation. This point is used as the start and end point of foraging trips generated by the model. During 'single' calibration and final 'paired' simulations, the same points were used for each colony as shown in Table 2.

Table 2 Colony location and total number of pairs of key species per site

Colony	Longitude	Latitude	Number of pairs
Kittiwake			
Fowlsheugh SPA	-2.2003	56.9201	20,078
Buchan Ness to Collieston Coast SPA	-1.8357	57.4108	13,547
Troup, Pennan and Lion's Head SPA	-2.2511	57.6821	13,672
Puffin			
Farne Islands SPA	-1.6200	55.6325	43,752

18 Seabird colony data for SPA and non-SPA sites which were most contemporaneous to the time of site-specific DAS, from the UK and Ireland, were taken from the Seabird Monitoring Programme (SMP), hosted by the British Trust for Ornithology (BTO). This includes information from the fourth seabird census, the Seabird Count. The authors were provided with a full download of the SMP database from the BTO database spanning 1986 to 2023 from the BTO on 25th May 2023. These data were initially used and where applicable, substituted by more recent/contemporaneous data hosted on the online SMP database.

2.2 Calibration

19 To calibrate SeabORD for each species at each colony, 'single' simulations using 10% of the population were run with no wind farms present. The only input values altered when running calibration simulations were the prey quantity (gram per unit volume) to produce outputs for a range of prey quantity values which can then be compared. Other values used to run calibration and final paired simulations are presented in Table 3.

20 It is essential that the model is calibrated as the breeding season outputs in the final paired simulations will only use the values from the prey quantity (gram per unit volume) range selected. Therefore, to produce realistic results, the foraging range should be set to values expected during typical or 'moderate' breeding seasons.

Table 3 Values used to run calibration and final paired simulations

Variable	Kittiwake	Puffin
% of population susceptible to displacement	30	60
% of those susceptible to displacement barrier	100	100
Max foraging range +1SD (km)	300.6	265.4
Proportion of individuals within range	0.975	0.975
Barrier navigation	Perimeter	Perimeter
Footprint border (km)	2	2
Footprint buffer (km)	5	5
Prey distribution	Uniform	Uniform
% of population used for calibration simulations	10	10
% of population used for final paired simulations	20	60

2.2.1.1 Model input parameters and assumptions

21 Due to a lack of suitable Global Positioning System (GPS) tracking data for the colonies of interest, the distance decay method was used to determine the foraging sites of individuals. This assumes that as the distance from the colony increases, the density of foraging birds is expected to decrease (Searle *et al.*, 2018). For both species, the foraging range used within the model was mmfr + 1SD, taken from Woodward *et al.* (2019), as advised by NatureScot (NatureScot advice dated 2[nd] April 2024). The proportion of foraging occurring within this identified range was set to 0.975 (Table 3). This proportion was used to account for the fact that only a small number of individuals would be expected to fly further than the mmfr + 1SD defined foraging range. These input values were then used by SeabORD's distance decay function to determine the foraging location of each individual adult, at each timestep of the simulation.

22 The number of breeding pairs is used as an input for SeabORD, with the model assuming that every pair has one chick. However, this may not be as accurate for kittiwake, as the species can support broods of two to three chicks (Coulson, 2011). This may lead to the model underestimating the impact of OWFs on adult survival as it likely more foraging trips than predicted will be required to provision for two chicks, increasing energy expenditure.

23 The assumed percentage of the population susceptible to distributional responses (30% for kittiwake and 60% for puffin) followed NatureScot Guidance (NatureScot, 2023) and is the same as used in the matrix approach (see EIAR Vol. 4, Appendix A22: Distributional Responses Report). It was assumed that all individuals susceptible to displacement would also be susceptible to barrier effects. Thus, individuals were

either unimpacted by the presence of OWF(s) or susceptible to both types of distributional responses. The border surrounding the Array Area (representing the area birds will not be able to travel through) was set to 2km and the wind farm buffer (the area birds would be displaced to) set to 5km, following published SeabORD documentation (Searle *et al.*, 2018; Mobbs *et al.*, 2018).

2.2.1.2 Calculating prey ranges

24 To determine the prey range expected during a 'moderate' breeding season (i.e. where environmental conditions are 'moderate') calibration simulations were run (i.e. simulations with no additional wind farms present). The only input parameters in the calibration simulations which differed from those used in the final paired simulations were the upper and lower prey quantity values used to generate the uniform prey distribution (Table 3). After running multiple calibration simulations, the outputs were compared to values reported in the SeabORD user guide (Mobbs *et al.*, 2018) to determine the appropriate lower and upper prey quantity values used in the final paired simulations. The lower prey quantity value was determined by comparing the percentage adult mass loss and percentage chick survival to those expected during 'moderate' breeding seasons. For example, if adult mass loss (%) was found to fall within the lower and upper boundaries but chick survival (%) was found to fall below the lower boundary the prey value would fall into the 'poor' category. Whereas the upper prey value was determined by comparing the percentage adult mass loss only (Table 4).

Table 4 Adult percentage body mass loss and percentage chick survival used to determine prey values used in the final paired simulations (Mobbs *et al.*, 2018)

Species	Adult mass loss (%)		Chick survival (%)
	Lower boundary	Upper boundary	Lower boundary
Kittiwake	5	15	11
Puffin	3.5	10.5	50

25 As the adult mortalities predicted by SeabORD during 'moderate' conditions are used to estimate the number of mortalities during 'poor' and 'good' conditions (see Section 2.2.1.5 it is only required to calibrate the model to 'moderate' conditions).

2.2.1.3 Paired simulations

26 Once the upper and lower prey quantities were determined through the calibration simulations, the final paired simulation for each species at each colony were run (Table 5). The paired simulations compare the impact of the OWF(s) selected against baseline conditions. Each simulation consisted of 10 'pairs'.

27 The prey quantity selected for each pair of simulations came from within the prey range determined during calibration using random stratification. The breeding season with and without the selected wind farms present were then simulated, meaning that 20 breeding seasons were simulated for each final simulation. Some colonies had relatively high population sizes, which can negatively affect the run-time of simulations (SSE Renewables, 2022a). To manage run times, 20% of the population was simulated for kittiwake and 60% of the population was simulated for puffin.

Table 5 Prey quantity range used to simulate results for each colony during final paired simulations

Species	Colony	Lower prey quantity (g per unit volume)	Upper prey quantity (g per unit volume)
Kittiwake	Fowlsheugh SPA	172	248
	Buchan Ness to Collieston Coast SPA	221	291
	Troup, Pennan and Lion's Head SPA	223	292
Puffin	Farne Islands SPA	253	308

28 Within the simulations, if individuals susceptible to distributional responses were assigned a foraging location within the Array Area, they were displaced into the buffer.

29 Barrier navigation was set to 'Perimeter' for all simulations following the examples provided by Searle *et al.* (2018) and Mobbs *et al.* (2018). This assumes that displaced or barrier affected individuals will travel in a straight line until they encounter the border and cannot travel through. Once these areas are encountered individuals will follow the perimeter of these areas until they can travel in a straight line again. All individuals that encounter land will use the A* pathfinding option to find the shortest route around the land mass. A* pathfinding assumes that individuals will find the shortest flight path to navigate obstacles, as opposed to following the perimeter of the obstacle.

30 For each of the colonies, two paired simulations were run for the Project Alone scenario and the Cumulative Scenario, as described in Section 1.

2.2.1.4 Bioenergetics in the model

31 During each timestep of a simulation, adult birds were assigned a Daily Energy Expenditure (DEE). For the first timestep, the DEE was selected from a normal distribution of DEE values stored within SeabORD and for subsequent timesteps the DEE was set to match the energy expended by the individual in the previous timestep. DEE of chicks was kept constant throughout the simulation.

32 The daily activity budget of each adult consisted of four behaviours – foraging, flight, time spent at the colony and time spent on the sea surface. The time spent flying and foraging to meet individuals' Daily Energy Requirements (DER) were generated by SeabORD for each individual, with a minimum of one hour assigned to time spent on the sea surface for each timestep. The remaining time was assigned to time spent at the colony. Once the time spent carrying out each activity was generated, the DEE for the timestep could be calculated. The DER of each adult was calculated by combining the energy gained (DEE divided by an assimilation efficiency) and half of the DEE of chicks, as it was assumed that both parents contributed equally. If DEE was greater than DER, then adults would lose body mass.

33 At the end of each timestep the current mass of each individual was compared to their mass at the beginning of the season. This information was used to determine the behaviours carried by both adults and chicks as shown in Table 6. Chick mortality may occur during a timestep if the time an adult spends away from the

nest is greater than the threshold determined by SeabORD (Searle *et al.*, 2018). Predation risk was modelled to increase as the time left unattended increased until the specified threshold for each species.

Table 6 Behaviour of each individual determined by percentage of initial body mass

Species	Age	% of initial mass	Behaviour for next timestep
Both	Adult	>90	Stays at nest
	Adult	80-90	Leaves chick unattended to reach DER
	Adult	<80	Abandon chick*
	Adult	<60	Assumed dead
	Chick	<60	Assumed dead
Puffin	Chick	60 – 80	Chick to burrow opening, increased mortality from predation or environmental conditions

**If one parent abandons the chick, the other parent will also abandon the chick despite its own body mass*

2.2.1.5 Annual and additional mortalities predicted by SeabORD

34 To determine the annual survival of adults, the mass at the end of the breeding season of each individual is used. SeabORD assumes that there is a logistic relationship between mass at the end of the breeding season and the probability of adult survival during winter (Searle *et al.*, 2018). This requires two parameters, the 'baseline' survival and the slope associated with the impact of a change in adult mass upon the probability of survival. Both parameters are set by SeabORD.

35 The baseline survival is equal to the mean value of sites with observed data on annual adult survival and has been collated by the creators of SeabORD. Likewise, so is the shape of the logistic curve, which explains the relation between survival probability and body weight. Annual mortality is predicted by SeabORD and results are presented in Table 7 and Table 11 for the Project Alone scenario and Table 9 and Table 13 for the Cumulative scenario.

36 As final paired simulations for both kittiwake and puffin did not use the full populations reported in Table 1, the number of mortalities were scaled. A scaling factor (1/proportion of the population simulated) was used to estimate the impacts to the full population. This scaling factor assumes that the number of mortalities has a linear relationship with the proportion of the population simulated.

37 Additional mortality (%) represents the percentage change to mortality caused by the presence of wind farm(s) and is calculated using the following formula:

$$100\ x\ \frac{mortalities\ with\ wind\ farm(s)\ present\ -\ mortalities\ with\ no\ wind\ farm\ present}{total\ population\ size}$$

3 Results

3.1 Kittiwake

3.1.1 Project Alone scenario

38 The full results for the Project Alone scenario are presented in Table 7 and Table 8.

Table 7 Modelled impacts of the Project Alone scenario on adult kittiwake during 'poor', 'moderate' and 'good' environmental conditions. Scaled mortalities were calculated using a scaling factor of 1/0.2

SPA	Environmental conditions	Adults not surviving the year						Difference in scaled mortalities between scenarios	Additional mortality (%) caused by the presence of the Project
		No wind farm present			Wind farm present				
		Mean	SD	Scaled mortalities	Mean	SD	Scaled mortalities		
Fowlsheugh SPA*	Poor	2,883.500	126.294	14,417.500	2,883.900	126.284	14,419.500	2.000	0.005
	Moderate	1,893.000	83.894	9,465.000	1,893.300	84.009	9,466.500	1.500	0.004
	Good	1,120.000	64.907	5,600.000	1,120.400	64.607	5,602.000	2.000	0.005
Buchan Ness to Collieston Coast SPA*	Poor	2,295.700	29.911	11,478.500	2,295.500	29.684	11,477.500	-1.000	-0.004**
	Moderate	1,581.600	26.500	7,908.000	1,581.900	26.342	7,909.500	1.500	0.006
	Good	1,003.700	21.271	5,018.500	1,003.700	21.072	5,018.500	0.000	0.000
	Poor	2,359.800	35.928	11,799.000	2,359.700	35.975	11,798.500	-0.500	-0.002**

SPA	Environmental conditions	Adults not surviving the year						Difference in scaled mortalities between scenarios	Additional mortality (%) caused by the presence of the Project
		No wind farm present			Wind farm present				
		Mean	SD	Scaled mortalities	Mean	SD	Scaled mortalities		
Troup, Pennan and Lion's Head SPA	Moderate	1,639.900	21.005	8,199.500	1,639.900	21.005	8,199.500	0.000	0.000
	Good	996.800	27.046	4,984.000	996.800	27.046	4,984.000	0.000	0.000

**It is expected that as environmental conditions improve, the number of additional mortalities would decrease. However, in some cases this trend is not observed. One possible explanation is highlighted in a sensitivity analysis carried out for Berwick Bank Offshore Wind Farm (SSE Renewables, 2022b) that showed the relationship between adult mortality and prey quantity be neither linear nor monotonic.*

***Negative additional mortality (%), i.e. lower mortality with wind farms present, is not expected to occur in real life scenarios and is likely due to a combination of the random stochasticity within the model and the selected OWF(s) having little to no impact on simulated flight paths.*

Table 8 Kittiwake SeabORD outputs for the Project Alone scenario. Impacted adults refer to any adult that experienced distributional responses at least once during the simulation. Where breeding season is referenced, this applies only to the chick-rearing period

Output variable	Scenario	Fowlsheugh SPA		Buchan Ness to Collieston Coast SPA		Troup, Pennan and Lion's Head SPA	
		Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	-	8,032	-	5,418	-	5,468	-
Adult survival at end of breeding season (%)	No wind farm present	100.000	0.000	100.000	0.000	100.000	0.000
	Wind farm present	100.000	0.000	100.000	0.000	100.000	0.000
Initial adult body mass (g)	No wind farm present	372.949	0.000	372.126	0.000	371.949	0.000
	Wind farm present	372.949	0.000	372.126	0.000	371.949	0.000
Final adult body mass (g)	No wind farm present	342.887	5.812	341.996	5.907	342.114	5.775
	Wind farm present	342.882	5.811	341.990	5.904	342.111	5.773
Difference between total distance flown with and without wind farms (km)	-	0.242	0.143	0.020	0.525	0.093	0.268
Difference in the total number of	-	-0.001	0.002	-0.004	0.004	-0.002	0.002

Output variable	Scenario	Fowlsheugh SPA		Buchan Ness to Collieston Coast SPA		Troup, Pennan and Lion's Head SPA	
		Mean	SD	Mean	SD	Mean	SD
trips carried out with and without wind farms							
Chicks not surviving the season	No wind farm present	1,775.000	935.406	1,195.3	658.031	1,259.600	657.096
	Wind farm present	1,775.500	935.180	1,196.200	657.884	1,260.400	657.077
Additional mortality of chicks with wind farm present (%)	-	0.012	0.013	0.033	0.037	0.029	0.023
Number of adults directly impacted by the wind farm (displaced or barriered)	-	157	-	138	-	81	-

3.1.2 Cumulative scenario

The full results for the cumulative scenario are presented in Table 9 and Table 10.

Table 9 Modelled impacts of the Cumulative scenario on adult kittiwake during 'poor', 'moderate' and 'good' environmental conditions. Scaled mortalities were calculated using a scaling factor of 1/0.2

SPA	Environmental conditions	Adults not surviving the year						Difference in scaled mortalities between scenarios	Additional mortality (%) caused by the presence of OWFs
		No wind farm present			Wind farm present				
		Mean	SD	Scaled mortalities	Mean	SD	Scaled mortalities		
Fowlsheugh SPA	Poor	2,883.500	126.294	14,417.500	2,920.300	114.169	2,920.300	184.000	1.145
	Moderate	1,893.000	83.894	9,465.000	1,926.100	74.499	1,926.100	165.500	1.030
	Good	1,120.000	64.907	5,600.000	1,153.300	60.722	1,153.300	166.500	1.036
Buchan Ness to Collieston Coast SPA*	Poor	2,295.700	29.911	11,478.500	2,308.400	30.034	11,542.000	63.500	0.586
	Moderate	1,581.600	26.500	7,908.000	1,597.600	27.302	7,988.000	80.000	0.738
	Good	1,003.700	21.271	5,018.500	1,016.000	22.376	5,080.000	61.500	0.568
Troup, Pennan and Lion's Head SPA*	Poor	2,359.800	35.928	11,799.000	2,361.900	35.057	11,809.500	10.500	0.096
	Moderate	1,639.900	21.005	8,199.500	1,647.500	22.347	8,237.500	38.000	0.347

SPA	Environmental conditions	Adults not surviving the year						Difference in scaled mortalities between scenarios	Additional mortality (%) caused by the presence of OWFs
		No wind farm present			Wind farm present				
		Mean	SD	Scaled mortalities	Mean	SD	Scaled mortalities		
	Good	996.800	27.046	4,984.000	1,001.000	27.584	5,005.000	21.000	0.192

**It is expected that as environmental conditions improve, the number of additional mortalities would decrease. However, in some cases this trend is not observed. One possible explanation is highlighted in a sensitivity analysis carried out for Berwick Bank Offshore Wind Farm (SSE Renewables, 2022b) that showed the relationship between adult mortality and prey quantity be neither linear nor monotonic.*

Table 10 Kittiwake SeabORD outputs for the Cumulative scenario. Impacted adults refer to any adult that experienced distributional responses at least once during the simulation. Where breeding season is referenced, this applies only to the chick-rearing period

Output variable	Scenario	Fowlsheugh SPA		Buchan Ness to Collieston Coast SPA		Troup, Pennan and Lion's Head SPA	
		Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	-	8,032	-	5,418	-	5,468	-
Adult survival at end of breeding season (%)	No wind farm present	100.000	0.000	100.000	0.000	100.000	0.000
	Wind farm present	100.000	0.000	100.000	0.000	100.000	0.000
Initial adult body mass (g)	No wind farm present	372.949	0.000	372.126	0.000	371.949	0.000
	Wind farm present	372.949	0.000	372.126	0.000	371.949	0.000
Final adult body mass (g)	No wind farm present	342.887	5.812	341.996	5.907	342.114	5.775
	Wind farm present	342.221	5.620	341.575	5.815	342.002	5.739
Difference between total distance flown with and without wind farms (km)	-	48.751	3.656	-50.607	8.395	-14.745	4.056
Difference in the total number of	-	-1.557	0.044	-0.608	0.042	-0.190	0.033

Output variable	Scenario	Fowlsheugh SPA		Buchan Ness to Collieston Coast SPA		Troup, Pennan and Lion's Head SPA	
		Mean	SD	Mean	SD	Mean	SD
trips carried out with and without wind farms							
Chicks not surviving the season	No wind farm present	1,775.000	935.406	1,195.300	658.031	1,259.600	657.096
	Wind farm present	1,944.500	912.576	1,291.200	624.731	1,292.400	647.969
Additional mortality of chicks with wind farm present (%)	-	4.221	0.767	3.540	1.259	1.200	0.420
Number of adults directly impacted by the wind farm (displaced or barriered)	-	2,344	-	1,633	-	1,448	-

3.2 Puffin

3.2.1 Project Alone scenario

39 The full results for the Project Alone scenario are presented in Table 11 and Table 12.

Table 11 Modelled impacts of the Project Alone scenario on adult puffin during 'poor', 'moderate' and 'good' environmental conditions. Scaled mortalities were calculated using a scaling factor of 1/0.6

SPA	Environmental conditions	Adults not surviving the year						Difference in scaled mortalities between scenarios	Additional mortality (%) caused by the presence of the Project
		No wind farm present			Wind farm present				
		Mean	SD	Scaled mortalities	Mean	SD	Scaled mortalities		
Farne Islands SPA	Poor	9,892.7	20.2	16,487.8	9,893.9	20.4	16,489.8	2.0	0.002
	Moderate	7,222.1	22.2	12,036.8	7,222.8	22.6	12,038.0	1.2	0.001
	Good	3,926.8	21.9	6,544.7	3,927.0	21.7	6,545.0	0.3	0.000

Table 12 Puffin SeabORD outputs for the Project Alone scenario. Impacted adults refer to any adult that experienced distributional responses at least once during the simulation. Where breeding season is referenced, this applies only to the chick-rearing period

Output variable	Scenario	Farne Islands SPA	
		Mean	SD
Number of adult birds in simulation	-	52,502	-
Adult survival at end of breeding season (%)	No wind farm present	99.999	0.002
	Wind farm present	99.999	0.002
Initial adult body mass (g)	No wind farm present	392.7	0.0
	Wind farm present	392.7	0.0
Final adult body mass (g)	No wind farm present	369.6	7.4
	Wind farm present	369.6	7.4
Difference between total distance flown with and without wind farms (km)	-	0.246	0.032
Difference in the total number of trips carried out with and without wind farms	-	0.001	0.000
Chicks not surviving the season	No wind farm present	2,204.3	888.0
	Wind farm present	2,205.0	888.4

Output variable	Scenario	Farne Islands SPA	
		Mean	SD
Additional mortality of chicks with wind farm present (%)	-	0.003	0.006
Number of adults directly impacted by the wind farm (displaced or barriered)	-	1,040	-

3.2.2 Cumulative scenario

40 The full results for the cumulative scenario are presented in Table 13 and Table 14.

Table 13 Modelled impacts of the Cumulative scenario on adult puffin during 'poor', 'moderate' and 'good' environmental conditions. Scaled mortalities were calculated using a scaling factor of 1/0.6

SPA	Environmental conditions	Adults not surviving the year						Difference in scaled mortalities between scenarios	Additional mortality (%) caused by the presence of the OWFs
		No wind farm present			Wind farm present				
		Mean	SD	Scaled mortalities	Mean	SD	Scaled mortalities		
Farne Islands SPA	Poor	9,892.7	20.2	16,487.8	9,906.7	17.1	16,511.2	23.3	0.027
	Moderate	7,222.1	22.2	12,036.8	7,237.0	22.2	12,061.7	24.8	0.028
	Good	3,926.8	21.9	6,544.7	3,939.4	20.7	6,565.7	21.0	0.024

Table 14 Puffin SeabORD outputs for the Cumulative scenario. Impacted adults refer to any adult that experienced distributional responses at least once during the simulation. Where breeding season is referenced, this applies only to the chick-rearing period

Output variable	Scenario	Farne Islands SPA	
		Mean	SD
Number of adult birds in simulation	-	52,502	-
Adult survival at end of breeding season (%)	No wind farm present	99.999	0.002
	Wind farm present	99.999	0.002
Initial adult body mass (g)	No wind farm present	392.7	0.0
	Wind farm present	392.7	0.0
Final adult body mass (g)	No wind farm present	369.6	7.4
	Wind farm present	369.6	7.4
Difference between total distance flown with and without wind farms (km)	-	-0.907	0.337
Difference in the total number of trips carried out with and without wind farms	-	-0.009	0.003
Chicks not surviving the season	No wind farm present	2,204.3	888.0

Output variable	Scenario	Farne Islands SPA	
		Mean	SD
	Wind farm present	2,213.6	894.0
Additional mortality of chicks with wind farm present (%)	-	0.035	0.030
Number of adults directly impacted by the wind farm (displaced or barriered)	-	3,218	-

4 Discussion

41 SeabORD simulations for the Project Alone scenario suggested little impact on the mortality of both kittiwake and puffin. For both species, no colony was predicted to have an additional adult mortality greater than 0.010%, and all SPA colonies were predicted to have impacts of 0.006% or less during moderate conditions (Table 7 and Table 11).

42 As expected, it was found that additional mortality increased under the Cumulative Scenario, most likely due to the increased flight distance across the modelled period. For kittiwake, the presence of all wind farms cumulatively led to estimated additional mortalities of 283.5 adults across the three colonies under moderate conditions (Table 9). For puffin, estimated additional mortalities at Farne Islands SPA were calculated at 24.8 adults per year (Table 13).

43 From the simulations run for puffin, it was found that there was a mortality rate of approximately 0.1% or 0.8% of impacted, or displaced, individuals within the Project Alone and Cumulative scenarios respectively, lower than the 3-5% mortality rate regularly used in displacement matrices within quantitative assessment of Scottish offshore wind projects (Table 11 and Table 13). For kittiwake, it was found that the mortalities caused by the wind farm accounted for approximately 0.8% or 5.23% of the impacted individuals within the simulation for the Project Alone and Cumulative scenarios respectively (Table 7 and Table 9). Displacement matrices and a more detailed comparison of the two methods is presented in EIAR Vol. 4, Appendix A22: Distributional Responses Report.

44 SeabORD simulations could also be impacted by the prey distribution selected. As no appropriate GPS data were available, it was assumed that prey distribution was uniform. This is unlikely to occur in reality, with theories such as Ashmole's Halo documenting areas of low prey abundance surrounding seabird colonies due to predation from individuals at breeding colonies (Ashmole, 1963), which has also been identified in high-latitude seabird species (Patterson *et al.,* 2022). For the version of SeabORD available, it is only possible to include non-uniform prey distributions if GPS data for the species and colony of interest are available. These data must include the density of birds for locations within the simulation area for each of the colonies under consideration, with was unavailable for the Project.

45 As previously mentioned, the results in this Annex have been scaled using a scaling factor of 1/proportion of the population modelled. This was done to estimate the full number of mortalities that would be expected to occur if the whole population was included in models and assumes that the results of simulations will scale linearly. This could have impacts on the scaled number of mortalities estimated as it is not clear what the scale or direction of any changes in the proportion of population simulated would include.

46 As the model is parameterised using various sources of information or expert judgement, the uncertainty around these individual parameters is not always clearly stated. Thus, it is likely that the true level of uncertainty is unaccounted for by the model (Searle *et al*., 2022). Planned expansions and developments of the SeabORD model including some of the points mentioned, such as the issues surrounding uncertainty, and have been further described in Searle *et al*. (2022).

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