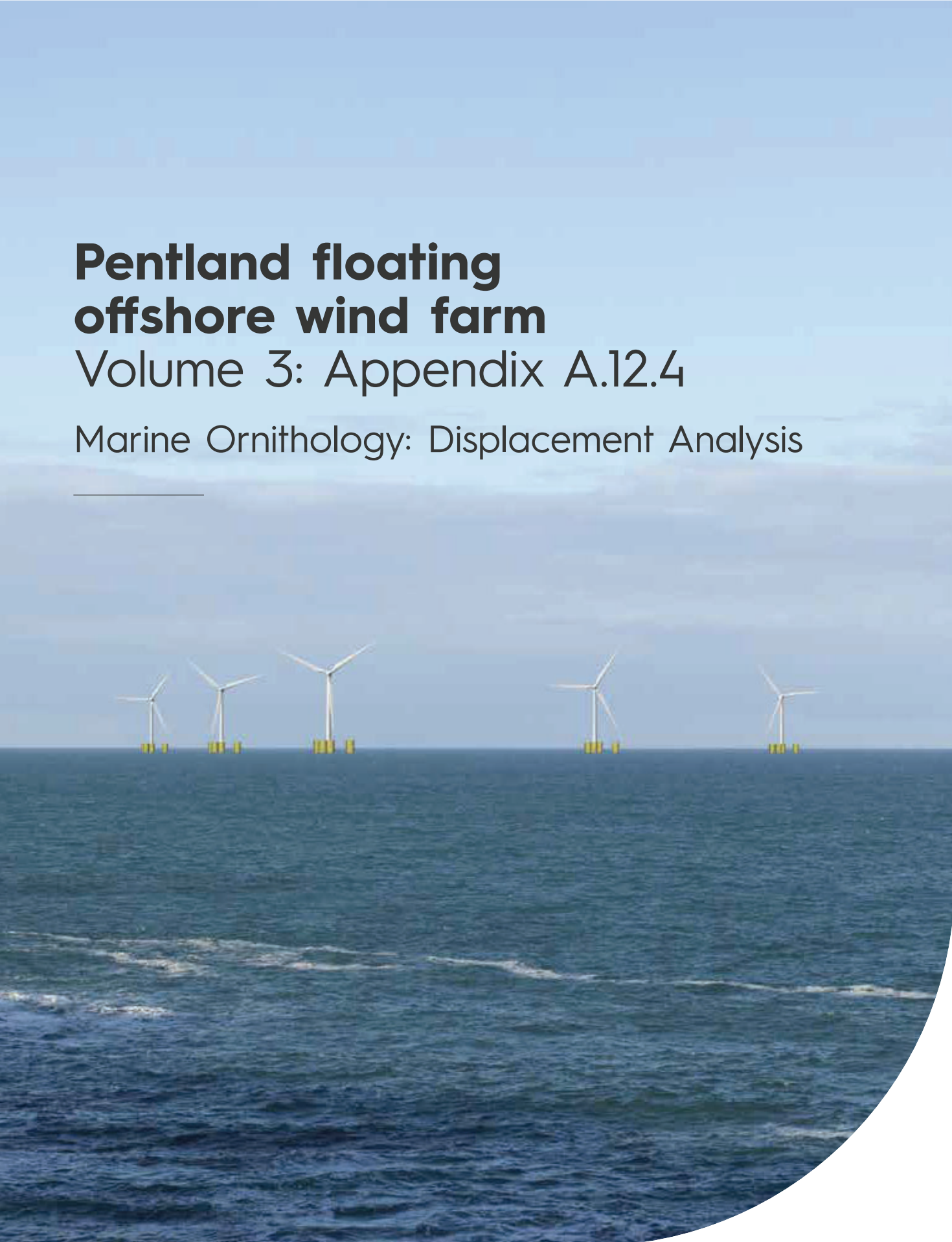


Pentland floating offshore wind farm

Volume 3: Appendix A.12.4

Marine Ornithology: Displacement Analysis



OFFSHORE EIAR (VOLUME 3): TECHNICAL APPENDICES

APPENDIX 12.4: MARINE ORNITHOLOGY –

DISPLACEMENT ANALYSIS

Document Title:	Pentland Floating Offshore Wind Farm Offshore EIAR
Document no.	GBPNTD-ENV-HDA-RP-00003
Project:	Pentland Floating Offshore Wind Farm
Originator Company	HiDef Aerial Surveying
Revision	01
Originator	Catriona Gall
Date	28.07.2022

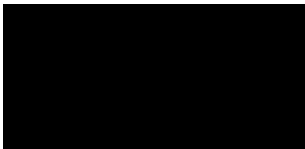
Revision History:

Revision	Date	Status	Originator	Reviewed	Approved
01	28.07.2022	Final	CG	AB	PM



Pentland Floating Offshore Wind Farm: Marine Ornithology 12.4 Technical Appendix - Displacement Analysis

Authorisations

Responsibility	Name	Signature	Date
Prepared by	Diane Pavat Catriona Gall	 	14/07/2022
Checked by	Kelly Macleod		14/07/2022
Approved by	Martin Scott		14/07/2022

Distribution List

Name	Organisation	Email Address
Marten Meynell	Xodus	
Nicola Bain	Xodus	
Andrew Blyth	COP	
Rebecca Marshall	COP	
Tamsin Watt	COP	
Peter Moore	COP	

Document History

Issue	Date	Status / Changes
1	01/04/2022	First draft for Xodus review
2	15/04/2022	Second draft incorporating Xodus comments
3	20/05/2022	Third draft incorporating Xodus/HWL comments and including SeabORD modelling
4	17/06/2022	Fourth draft incorporating Xodus/HWL/third-party review comments
5	28/06/2022	Fifth draft incorporating further third-party review comments
6	14/07/2022	Sixth draft incorporating final comments
7	27/07/2022	Final report

Contents

1	Introduction	1
2	Methods	3
2.1	SeabORD modelling.....	3
2.1.1	Introduction and scope of SeabORD.....	3
2.1.2	Modelling impacts against North Caithness Cliffs SPA.....	3
2.2	Displacement matrices	5
2.2.1	Spatial scales.....	5
2.2.2	Defined seasons.....	5
2.2.3	Mean seasonal peak population estimates.....	6
2.2.4	Displacement rates.....	6
2.2.5	Mortality rates	7
3	Results.....	8
3.1	SeabORD model outputs.....	8
3.2	Displacement matrices – seasonal summaries.....	9
4	Discussion and Conclusions	14
4.1	Comparing SeabORD outputs with use of displacement matrices.....	14
4.2	Consideration of estimated displacement mortalities in assessment	15
4.3	Kittiwake.....	15
4.4	Guillemot.....	16
4.5	Razorbill	17
4.6	Puffin.....	18
4.7	Fulmar.....	19
4.8	Gannet.....	19
4.9	Arctic tern	20
4.10	Great skua	20
5	References	21
Annex A	SeabORD technical description of method and input parameters.....	23
A1:	Calibration.....	23
A2:	Model input parameters and assumptions.....	23
A3:	Calculating prey ranges.....	24
A4:	Paired simulations.....	24
A5:	Bioenergetics in the model	26
A6:	Annual mortalities predicted by SeabORD.....	26
Annex B	SeabORD outputs	28

B1:	Kittiwake.....	28
B2:	Guillemot.....	30
B3:	Razorbill	32
B4:	Puffin.....	34
Annex C	Displacement matrices	36
C1:	Kittiwake.....	36
C2:	Guillemot.....	39
C3:	Razorbill	41
C4:	Atlantic puffin	45
C5:	Fulmar.....	49
C6:	Gannet.....	53
C7:	Arctic tern	56
C8:	Great skua	57

Tables

Table 1	Location of each sub-site in North Caithness Cliffs SPA and number of breeding pairs for input into SeabORD (conversion factor of 0.67 applied for the auk species) 4
Table 2	Defined seasons for species being assessed for displacement 6
Table 3	Displacement and mortality rates included for consideration in assessment..... 7
Table 4	Kittiwake seasonal displacement mortalities each year (numbers of birds) 9
Table 5	Guillemot seasonal displacement mortalities each year (numbers of birds)..... 10
Table 6	Razorbill seasonal displacement mortalities each year (numbers of birds)..... 10
Table 7	Puffin seasonal displacement mortalities each year (numbers of birds) – PFOWF Array Area plus 2 km buffer 11
Table 8	Puffin seasonal displacement mortalities each year (numbers of birds) – PFOWF Array Area alone..... 11
Table 9	Fulmar seasonal displacement mortalities each year (numbers of birds)..... 12
Table 10	Gannet seasonal displacement mortalities each year (numbers of birds) 12
Table 11	Arctic tern seasonal displacement mortalities each year (numbers of birds)..... 12
Table 12	Great skua seasonal displacement mortalities each year (numbers of birds)..... 13
Table 13	Kittiwake apportioned breeding season displacement mortalities each year 15
Table 14	Guillemot apportioned breeding season displacement mortalities each year 16
Table 15	Guillemot apportioned non-breeding season displacement mortalities each year 17
Table 16	Razorbill apportioned breeding season displacement mortalities each year 17
Table 17	Puffin apportioned breeding season displacement mortalities each year 18
Table 18	Fulmar apportioned breeding season displacement mortalities each year..... 19
Table 19	Gannet apportioned breeding season displacement mortalities each year 19
Table A1.1	Values used for running baseline and the final paired simulations 23
Table A3.1	Adult percentage body mass loss and percentage chick survival used to determine prey values used in the final paired simulations. Values taken from Mobbs <i>et al.</i> (2018). ... 24
Table A4.1	Prey quantity range used for each final paired simulation..... 25
Table A5.1	Behaviours of each individual determined by body mass 26
Table B1.1	Modelled impacts of the Offshore Development on adult kittiwake during the year, at the five sub-sites within North Caithness Cliffs SPA, during ‘poor’, ‘moderate’ and ‘good’ environmental conditions..... 28
Table B1.2	SeabORD outputs for kittiwake at each of the five sub-sites within North Caithness Cliffs SPA..... 29
Table B2.1	Modelled impacts of the Offshore Development on adult guillemot during the year, at the five sub-sites within North Caithness Cliffs SPA, during ‘poor’, ‘moderate’ and ‘good’ environmental conditions..... 30

Table B2.2	SeabORD outputs for guillemot at each of the five sub-sites within North Caithness Cliffs SPA.....	31
Table B3.1	Modelled impacts of the Offshore Development on adult razorbill during the year, at the five sub-sites within North Caithness Cliffs SPA, during 'poor', 'moderate' and 'good' environmental conditions.....	32
Table B3.2	SeabORD outputs for razorbill at each of the five sub-sites within North Caithness Cliffs SPA.....	33
Table B4.1	Modelled impacts of the Offshore Development on adult puffin during the year, at the five sub-sites within North Caithness Cliffs SPA, during 'poor', 'moderate' and 'good' environmental conditions.....	34
Table B4.2	SeabORD outputs for puffin at each of the five sub-sites within North Caithness Cliffs SPA.....	35
Table C1.1	Kittiwake displacement in the PFOWF Array Area + 2km buffer – breeding season	36
Table C1.2	Kittiwake displacement in the PFOWF Array Area + 2km buffer – autumn migration	37
Table C1.3	Kittiwake displacement in the PFOWF Array Area + 2km buffer – spring migration	38
Table C2.1	Guillemot displacement in the PFOWF Array Area + 2km buffer – breeding season	39
Table C2.2	Guillemot displacement in the PFOWF Array Area + 2km buffer – non-breeding season	40
Table C3.1	Razorbill displacement in the PFOWF Array Area + 2km buffer – breeding season..	41
Table C3.2	Razorbill displacement in the PFOWF Array Area + 2km buffer – non-breeding season	42
Table C3.3	Razorbill displacement in the PFOWF Array Area + 2km buffer – autumn migration	43
Table C3.4	Razorbill displacement in the PFOWF Array Area + 2km buffer – spring migration .	44
Table C4.1	Puffin displacement in the PFOWF Array Area + 2km buffer – breeding season	45
Table C4.2	Puffin displacement in the PFOWF Array Area + 2km buffer – non-breeding season	46
Table C4.3	Puffin displacement in the PFOWF Array Area only – breeding season	47
Table C4.4	Puffin displacement in the PFOWF Array Area only – non-breeding season.....	48
Table C5.1	Fulmar displacement in the PFOWF Array Area + 2km buffer – breeding season.....	49
Table C5.2	Fulmar displacement in the PFOWF Array Area + 2km buffer – non-breeding season	50
Table C5.3	Fulmar displacement in the PFOWF Array Area + 2km buffer – autumn migration..	51
Table C5.4	Fulmar displacement in the PFOWF Array Area + 2km buffer – spring migration.....	52
Table C6.1	Gannet displacement in the PFOWF Array Area + 2km buffer – breeding season	53
Table C6.2	Gannet displacement in the PFOWF Array Area + 2km buffer – autumn migration .	54
Table C6.3	Gannet displacement in the PFOWF Array Area + 2km buffer – spring migration....	55

Table C7.1	Arctic tern displacement in the PFOWF Array Area + 2km buffer – breeding season	56
Table C8.1	Great skua displacement in the PFOWF Array Area + 2km buffer – breeding season	57

Figures

Figure 1	North Caithness Cliffs SPA and sub-sites.....	5
----------	---	---

Acronyms and abbreviations

Acronyms / abbreviation	Full name
AON	Apparently Occupied Nests
BDMPS	Biologically Defined Minimum Population Scales
CEH	Centre of Ecology and Hydrology
COP	Copenhagen Offshore Partners
DEE	Daily Energy Expenditure
DER	Daily Energy Requirements
EIAR	Environmental Impact Assessment Report
GPS	Global Positioning System
JNCC	Joint Nature Conservation Committee
MROG	Marine Renewables Ornithology Group
MS-LOT	Marine Scotland Licensing Operations Team
MSP	Mean Seasonal Peak
MSS	Marine Scotland Science
NS	NatureScot
PFOWF	Pentland Floating Offshore Wind Farm
PVA	Population Viability Analysis
RIAA	Report to Inform the Appropriate Assessment
RSPB	Royal Society for the Protection of Birds
SMP	Seabird Monitoring Programme
SNCB	Statutory Nature Conservation Bodies
SPA	Special Protection Area

I Introduction

- 1 This Technical Appendix supports the assessment of displacement and barrier impacts undertaken for the Pentland Floating Offshore Wind Farm (PFOWF) Array and Offshore Export Cable(s) (the Offshore Development), as presented in the Offshore Environmental Impact Assessment Report (EIAR) (Volume 2) Chapter 12: Marine Ornithology, and in the Report to Inform the Appropriate Assessment (RIAA). Please refer to Technical Appendix 12.6 Marine Ornithology: Consultation Advice for a full account of the scoping and pre-application advice received on the approaches to displacement assessment, as referenced in this Technical Appendix.
- 2 Displacement is considered by Furness *et al.* (2013) and Bradbury *et al.* (2014) to be ‘a reduced number of birds occurring within or immediately adjacent to an offshore wind farm’. This happens when birds avoid the area of operational turbines and different species are more or less likely to display this behaviour, based on their biology. Statutory Nature Conservation Bodies (SNCB, 2017) guidance considers that both birds in flight and on the water may be displaced.
- 3 Barrier effects may occur when birds that would have previously flown through an offshore wind farm (on the way to a feeding, resting or nesting area) either stop short or detour around it (SNCB, 2017). In this regard, they may require higher energetic cost in deviating their flight paths (Masden *et al.*, 2010). For the purposes of assessment barrier effects are considered to apply to birds in flight and are usually considered together with displacement.
- 4 Furness *et al.* (2013), Bradbury *et al.* (2014) and Masden *et al.* (2010) consider the sensitivity of key seabird species to displacement and barrier effects. The following species recorded during digital aerial surveys in the PFOWF Array Area¹ and buffer (Technical Appendix 12.1 Marine Ornithology: Baseline Data) may be considered sensitive/vulnerable in this regard and are addressed in this technical appendix to inform the EIAR and RIAA, with northern fulmar and great skua included on a precautionary basis:
 - Black-legged kittiwake (*Rissa tridactyla*), hereafter ‘kittiwake’;
 - Common guillemot (*Uria aalge*), hereafter ‘guillemot’;
 - Razorbill (*Alca torda*);
 - Atlantic puffin (*Fratecula arctica*), hereafter ‘puffin’;
 - Northern fulmar (*Fulmarus glacialis*), hereafter ‘fulmar’;
 - Northern gannet (*Morus bassanus*); hereafter ‘gannet’;
 - Arctic tern (*Sterna paradisaea*); and
 - Great skua (*Stercorarius skua*).
- 5 Approaches to assessing displacement were considered at a joint workshop organised by the Marine Renewables Ornithology Group (MROG) held 6-7 May 2015, involving the SNCBs, Marine Scotland Science (MSS), the Royal Society for the Protection of Birds (RSPB) Scotland, environmental consultants and industry representatives.² The purpose of the workshop was to review new and existing evidence of seabird displacement from offshore wind farms, to consider the existing approaches to assessment of these impacts

¹ PFOWF Array Area: the area where the wind turbines will be located within the Offshore Site.

² [Seabird Displacement Impacts from Offshore Wind Farms: report of the MROG Workshop, 6-7th May 2015 | JNCC Resource Hub](#)

(both in the UK and abroad) and to work towards developing a more co-ordinated UK approach. Further to the workshop the SNCBs issued interim guidance (SNCB, 2017) promoting the use of ‘displacement matrices.’

- 6 Approaches to displacement assessment continue to be developed and understanding of these issues can be informed by the results of post-construction monitoring for operational wind farms. MSS commissioned the Centre of Ecology and Hydrology (CEH) to investigate the effects of potential displacement on key seabird species arising from proposed wind farms in the Forth and Tay. From this work ‘investigating the fate of displaced birds’, CEH have built an individual-based model known as ‘SeabORD’ to model the bio-energetic costs of displacement and barrier effects.³
- 7 The Scoping Opinion (MS-LOT, 2021) originally requested that SeabORD be used in assessment for the Offshore Development if tracking data were available. This is because the original version of the model required seabird tracking data to operate. As discussed at the pre-application meeting held with MSS, NatureScot (NS) and RSPB Scotland on 16 December 2021, it was not thought possible to use SeabORD because of the limited tracking data available for North Caithness Cliffs Special Protection Area (SPA); the closest SPA to the PFOWF Array Area and of most concern in respect of potential impacts.
- 8 CEH, however, have now developed an option within SeabORD that uses a ‘distance decay’ function which assumes that as the distance from the colony increases, the density of foraging birds decreases. This is a simpler version of the model which does not require the input of colony tracking data. It is this new option, which MSS and NS have now requested be used in their advice forwarded by Marine Scotland Licensing Operations Team (MS-LOT) on 31 March 2022.
- 9 This ‘distance decay’ version of SeabORD (v1.3) and its application to North Caithness Cliffs SPA is summarised in Section 2.1 of this appendix, with the input parameters used in the modelling presented in Annex A. SeabORD model outputs are summarised in Section 3.1 with key information presented in Annex B. The results of modelling and implications for overall assessment are discussed in Section 4.
- 10 The Scoping Opinion (MS-LOT, 2021) also requests provision of ‘displacement matrices’ following the approach advised in the SNCB interim guidance (SNCB, 2017). This method is discussed in Section 2.2, with a summary of seasonal displacement mortality estimates provided in Section 3.2 and outputs discussed in Section 4.
- 11 Section 4.1 provides a comparison between SeabORD outputs and displacement matrices, which helps to inform the assessment of displacement impacts presented in Section 12.6.2.2 of the Offshore EIAR (Volume 2) Chapter 12, Marine Ornithology and in the RIAA (see discussion below in Section 4.2).

³ [Fate of Displaced Birds \(marine.gov.scot\)](https://marine.gov.scot/fate-of-displaced-birds)

2 Methods

2.1 SeabORD modelling

- 12 As requested by MSS and NS (advice received 31 March 2022), the distance decay version of SeabORD (v1.3) has been used to model displacement and barrier effects potentially arising from the Offshore Development.

2.1.1 Introduction and scope of SeabORD

- 13 SeabORD was created by the CEH to quantify the fate of displaced and barrier-affected seabirds during the breeding season (Searle *et al.*, 2014; 2018). It is an individual-based modelling method which predicts the energetic consequences to seabirds due to any changes in their flight paths in the presence of offshore wind farms.
- 14 The method simulates the flightpaths of individual birds from identified breeding colonies to potential foraging areas in scenarios with and without wind farms present (Searle *et al.*, 2019). The information from these simulations is then used in bioenergetic equations which estimate the percentage body mass loss of the birds and therefore their survival.
- 15 Currently the software can be used to predict the impact of potential wind farms on four key species, each of which is of key concern in the ornithological impact assessment for the Offshore Development:
- Kittiwake
 - Guillemot
 - Razorbill; and
 - Puffin.
- 16 A more detailed technical description of each step in the modelling process is provided in Annex A, including the input parameters used.

2.1.2 Modelling impacts against North Caithness Cliffs SPA

- 17 The calculations presented in Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning indicate that most impacts from the Offshore Development potentially occurring to kittiwake, guillemot, razorbill and puffin are to be apportioned against their populations at North Caithness Cliffs SPA. It is the closest SPA to the PFOWF Array Area and is therefore the focus for SeabORD modelling.
- 18 As no tracking data were available for the SPA, SeabORD was run using the 'distance decay' function as described in Annex A.
- 19 North Caithness Cliffs SPA is shown in Figure 1. It comprises five sub-sites as indicated; Duncansby Head, Dunnet Head, Holburn Head, Melvich and Stroma. For the purposes of SeabORD modelling each of these sub-sites was treated separately within the model, as it would not be informative or biologically meaningful to try and model the SPA as a single unit. Population counts for the SPA and its five sub-sites were confirmed by the Joint Nature Conservation Committee (JNCC) in their email of 9 May 2022, as given in Annex A of Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning.

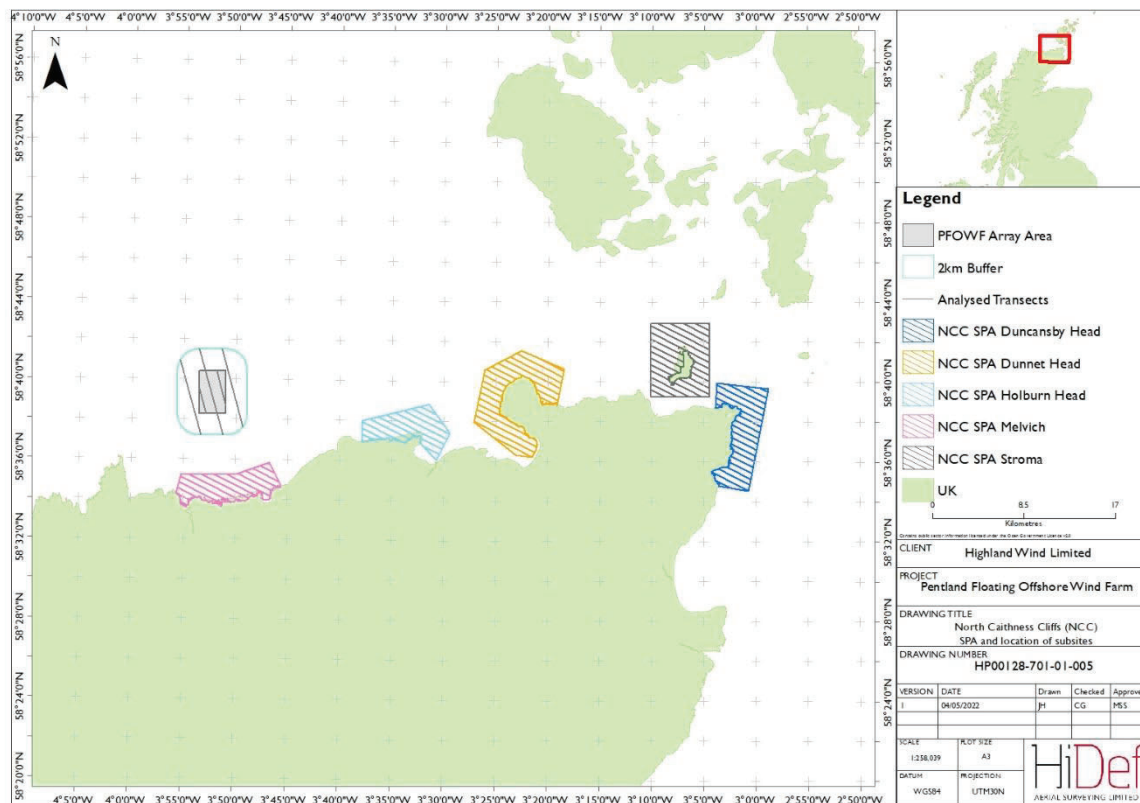
- 20 Each SPA sub-site; Duncansby Head, Dunnet Head, Holburn Head, Melvich and Stroma, were each represented by a single reference point as close to its midpoint along the coastline as possible (Table 1). SeabORD requires colony counts in breeding pairs, rather than individuals, so the counts for guillemot, razorbill and puffin have been converted (these species are surveyed and recorded as individuals for the Seabird Monitoring Programme (SMP)).
- 21 As agreed by MSS and NS (email dated 25 May 2022), the counts for each of these species were converted to breeding pairs using a conversion factor of 0.67, based on expert judgement and review of the available literature (Harris, 1989; Harris *et al.*, 2015a; 2015b). Kittiwake numbers are surveyed as Apparently Occupied Nests (AON) for the SMP and so did not need to be converted. Table 1 presents the breeding pairs used for input into SeabORD modelling.

Table 1 Location of each sub-site in North Caithness Cliffs SPA and number of breeding pairs for input into SeabORD (conversion factor of 0.67 applied for the auk species)

Colony	Latitude	Longitude	Kittiwake pairs	Guillemot pairs	Razorbill pairs	Puffin pairs
Duncansby Head	58.6209	-3.0212	584	12,872	1,226	12
Dunnet Head	58.6598	-3.4164	2,020	6,478	379	1,075
Holburn Head	58.6314	-3.5421	55	6,478	46	40
Melvich	58.5747	-3.8597	2,777	16,82	410	907
Stroma	58.6839	-3.1467	137	4,695	368	12

- 22 Although SeabORD requires the input data as breeding pairs, it then calculates numbers of individual birds for use in the model simulations by simply doubling the figures provided (i.e., doubling the figures in Table 1). Therefore, applying a conversion factor of 0.67 to calculate the input pairs (rather than 0.5) might be considered precautionary.

Figure 1 North Caithness Cliffs SPA and sub-sites



2.2 Displacement matrices

- 23 The factors set out in Sections 2.2.1 to 2.2.5 inform the use of displacement matrices and how they should be interpreted.

2.2.1 Spatial scales

- 24 As advised in SNCB (2017), displacement matrices are provided for each identified species (paragraph 4) for the PFOWF Array Area plus a 2 km buffer. The buffer is advised to take account of the fact that species may also be displaced from the area surrounding a wind farm, although this is likely to be to a lesser degree. For puffin, displacement matrices have also been provided for the PFOWF Array Area alone as discussed in Section 4 (paragraphs 57 – 61) with the outputs summarised in Table 8. SNCB (2017) guidance recognises that use of the 2 km buffer is a ‘worst case’ assumption so advises that the provision of matrices for the wind farm footprint alone (i.e., the PFOWF Array Area) will also be useful to contextualise potential impacts.

2.2.2 Defined seasons

- 25 As set out in SNCB (2017), displacement matrices are required for each species in the breeding and non-breeding seasons. The breeding season for seabirds is based on guidance in NatureScot (2020) and for the non-breeding season in Furness (2015): the report on Biologically Defined Minimum Population Scales (BDMPS), as set out in Table 2.
- 26 As can be seen in Table 2 for many of the species under consideration, there is sometimes overlap (and sometimes gaps) between the breeding and non-breeding seasons defined in the guidance. This matter is addressed in analysis of the survey data as presented in

Section 3.2 of Technical Appendix 12.1 Marine Ornithology: Baseline Data and discussed below in relation to the calculation of Mean Seasonal Peak (MSP) estimates for displacement assessment.

Table 2 Defined seasons for species being assessed for displacement

Species	Breeding season (NatureScot, 2020)	BDMPS (Furness, 2015)		
		Autumn migration	Non-breeding	Spring migration
Kittiwake	mid Apr - Aug	Aug - Dec	n/a	Jan - Apr
Guillemot	Apr - mid Aug	n/a	Aug - Feb	n/a
Razorbill	Apr - mid Aug	Aug - Oct	Nov - Dec	Jan - Mar
Puffin	Apr - mid Aug	n/a	mid Aug - Mar	n/a
Fulmar	Apr - mid Sep	Sep - Oct	Nov	Dec - Mar
Gannet	mid Mar - Sep	Sep - Nov	n/a	Dec - Mar
Arctic tern	May - Aug	Jul - mid Sep	n/a	Apr - May
Great skua	mid Apr - mid Sep	Aug - Oct	Nov - Feb	Mar - Apr

2.2.3 Mean seasonal peak population estimates

- 27 The monthly population estimates produced from HiDef's data analysis, reported in Technical Appendix 12.1 Marine Ornithology: Baseline Data, take account of:
 - Apportioning of birds identified to a species "group" (e.g., large auks) (sometimes referred to as 'non-ID' birds) between relevant species (Section 2.2.1 of Technical Appendix 12.1 Marine Ornithology: Baseline Data).
 - Adjustment of auk population estimates in relation to availability bias (Section 2.2.3 of Technical Appendix 12.1 Marine Ornithology: Baseline Data).
- 28 As set out in Technical Appendix 12.1 Marine Ornithology: Baseline Data, MSPs have been calculated from monthly population estimates for all birds (flying and on the water) present within the PFOWF Array Area plus 2 km buffer. These MSP population estimates are based on the two years of digital aerial survey data for each of the defined seasons for each species set out in Table 2.
- 29 Where there is an overlap in these defined seasons, i.e., for any peak count in an overlap month, it is preferentially assigned to the breeding season as advised by NS. This avoids any double-counting of birds in the estimation of MSPs. Where this has been necessary for a species, it is noted in the relevant summary in Section 3.2.

2.2.4 Displacement rates

- 30 Table 3 presents each species' displacement rates for use in assessment as advised by MSS, NS and RSPB Scotland (email of 7 December 2021). For those species where advice was not provided i.e., fulmar, great skua and Arctic tern, a judgement has been made based on comparison with the other species listed and informed by Furness *et al.* (2013) displacement scores.

- 31 The advised displacement rates are applied uniformly across the PFOWF Array Area plus 2 km buffer as set out in SNCB (2017) guidance and discussed in Section 2.2.1 above.
- 32 While Section 3.2 summarises outputs solely for the advised displacement rates, the full range of potential displacement rates for each species are reported in the matrices provided in Annex C.

2.2.5 Mortality rates

- 33 The fitness consequences of displacement on birds are two-fold; birds may require higher energetic expenditure deviating from their usual flight or foraging areas, whilst a loss of perceived and physical habitat may reduce available food resources, in turn risking some degree of potential mortality (Fox and Peterson, 2019; Fox *et al.*, 2006; Masden *et al.*, 2009).
- 34 This risk of mortality due to displacement depends on several factors, including the size of the wind farm, the amount of habitat lost, the distance deviated by birds in flight, the availability of suitable replacement habitat and, potentially, the level of increased competition. Levels of mortality are also likely to differ between season and species, based on their morphology, foraging range, foraging rates and seasonal energetic needs. such as when provisioning for chicks (Masden *et al.*, 2010).
- 35 MSS, NS and RSPB Scotland advice on potential mortality rates is also presented in Table 3. This updates their previous advice on all other wind farms consented in Scottish waters. Therefore, for the auk species, outputs at 1% are also provided to allow for comparison with the published figures in Marine Scotland's appropriate assessment for the Moray Firth wind farms. And outputs at 2% are also included for puffin and for kittiwake. These outputs from the displacement matrices are considered in relation to SeabORD predictions in Section 4.
- 36 For those species where advice was not provided i.e., fulmar, great skua and Arctic tern, expert judgement has been applied to determine appropriate mortality rates, based on comparison with the other species and informed by the available literature.

Table 3 Displacement and mortality rates included for consideration in assessment

Species	Percentage of birds displaced	Breeding season mortality	Non-breeding season mortality
Kittiwake	30%	1, 2 and 3%	1, 2 and 3%
Guillemot	60%	1, 3 and 5%	1 and 3%
Razorbill	60%	1, 2, 3 and 5%	1 and 3%
Puffin	60%	1, 2, 3 and 5%	1 and 3%
Fulmar	30%	1%	1%
Gannet	70%	1 and 3%	1 and 3%
Great skua	30%	1%	1%
Arctic tern	30%	1 and 3%	1%

3 Results

3.1 SeabORD model outputs

- 37 SeabORD model outputs are presented in Annex B as follows:
- Kittiwake (Table B1.1 and Table B1.2)
 - Guillemot (Table B2.1 and Table B2.2)
 - Razorbill (Table B3.1 and Table B3.2)
 - Puffin (Table B4.1 and Table B4.2)
- 38 Model outputs are presented separately for each SPA sub-site: Duncansby Head, Dunnet Head, Holburn Head, Melvich and Stroma. Baseline levels of adult mortality predicted by SeabORD have been sense-checked against the figures calculated by using each species' survival rate adopted for Population Viability Analysis (PVA), as reported in Table 1 of Technical Appendix 12.5, Marine Ornithology: Population Modelling. These are the default adult survival rates for each species advised by Horswill & Robinson (2015).
- 39 A factor of (*1-adult survival rate*) has been applied to each of the SPA sub-site populations of each species to calculate PVA baseline mortalities for comparison with SeabORD. The mortalities thus estimated are presented for each species in the column labelled 'PVA baseline mortalities' in Table B1.1 (kittiwake), Table B2.1 (guillemot), Table B3.1 (razorbill) and Table B4.1 (puffin) in Annex B.
- 40 Review of these 'PVA baseline mortalities' against the SeabORD model outputs (without any wind farm) indicates that SeabORD predictions appear reasonable for kittiwake, razorbill and puffin (with a baseline lying between moderate-good prey years for most of the SPA sub-sites). Slightly higher estimated mortalities are predicted by SeabORD for Melvich, the closest SPA sub-site to the PFOWF Array Area; this probably reflects the more realistic energetic costs to individuals that are captured by SeabORD as compared to the generic application of default adult survival rates across colonies.
- 41 In respect of guillemot, SeabORD may be over-predicting potential impacts as all the baseline estimates lie above the 'PVA baseline mortalities' derived from application of the adult survival rates (Table B2.1). Not only this but HiDef checked with the model authors whether an in-built scaling factor is applied to SeabORD outputs for those simulations where less than 100% of birds were modelled (in this case, 65% of guillemot numbers).
- 42 The model authors confirmed that a scaling factor is not automatically applied within the model, therefore it was agreed with them that for such simulations (modelling less than 100% of birds) it would be appropriate to multiply the relevant results by 1/the proportion of individuals within the simulation ($1/0.65$ for guillemot). In this regard, use of a scaling factor is a best approximation as SeabORD outputs may not scale linearly.
- 43 Table B2.1 presents the raw SeabORD outputs for guillemot, unscaled. The agreed scaling factor of $1/0.65$ has been subsequently applied to the 'difference in mortalities between scenarios' to scale from a figure of 3.60 guillemot mortalities (summed across the SPA sub-sites for a good prey year) to a corrected figure of 5.54 guillemot mortalities.

- 44 SeabORD modelling indicates no change to adult survival rates during the breeding season from any displacement / barrier effects caused by the Offshore Development against any of the four species modelled at North Caithness Cliffs SPA. Overall annual impacts were also predicted to be minimal against SPA populations; in moderate prey years there are up to 2.6 kittiwake mortalities (Table B1.1), 1.3 razorbill mortalities (Table B3.1) and 1.8 puffin mortalities (Table B4.1). In good prey years (probably more appropriate to consider for guillemot) there were up to 5.54 guillemot mortalities (applying an agreed scaling factor as noted above).

3.2 Displacement matrices – seasonal summaries

- 45 The displacement mortality estimates presented for each species below in Table 4 to Table 12 are pulled through from the displacement matrices (Annex C) and summarised by season as discussed in Section 2.2.2. For each species these are the mortality estimates calculated for the PFOWF Array Area plus 2 km buffer (as advised in SNCB, 2017) except for puffin where mortality estimates for the PFOWF Array Area alone are also presented (Table 7 and Table 8). All figures are calculated using the displacement and mortality rates presented in Table 3 and include no measure of uncertainty. Although not explicitly required, it has so far been usual practice to present displacement mortality estimates as whole birds as shown in the example matrix in the SNCB (2017) guidance. In this regard, fractions are rounded up or down to the nearest whole bird as presented in Table 4 – Table 12, but the actual matrix estimates to two decimal places are used when making comparisons to SeabORD in Section 4.1.

Table 4 Kittiwake seasonal displacement mortalities each year (numbers of birds)

Kittiwake displacement mortalities	Breeding season	BDMPS		
		Autumn migration	Non-breeding	Spring migration
	mid Apr - Aug	Aug-Dec	n/a	Jan - Apr
MSP	546	118	n/a	41
30% / 1%	2	0	n/a	0
30% / 2%	3	1	n/a	0
30% / 3%	5	1	n/a	0

Table 5 Guillemot seasonal displacement mortalities each year (numbers of birds)

Guillemot displacement mortalities	Breeding season	BDMPS		
		Autumn migration	Non-breeding	Spring migration
	Apr - mid Aug	n/a	Aug - Feb	n/a
MSP	1,146	n/a	650	n/a
60% / 1%	7	n/a	4	n/a
60% / 3%	21	n/a	12	n/a
60% / 5%	34	n/a	n/a*	n/a

*MSS/NS advise using 1% and 3% displacement mortality rates in the non-breeding season, therefore the 5% rate is non-applicable.

Table 6 Razorbill seasonal displacement mortalities each year (numbers of birds)

Razorbill displacement mortalities	Breeding season	BDMPS		
		Autumn migration	Non-breeding	Spring migration
	Apr - mid Aug	Aug - Oct	Nov - Dec	Jan - Mar
MSP	134	17	16	14
60% / 1%	1	0	0	0
60% / 2%	2	0	0	0
60% / 3%	2	0	0	0
60% / 5%	4	n/a*	n/a*	n/a*

*MSS/NS advise using 1% and 3% displacement mortality rates in the non-breeding season, therefore the 5% rate is non-applicable.

Table 7 Puffin seasonal displacement mortalities each year (numbers of birds) – PFOWF Array Area plus 2 km buffer

Puffin displacement mortalities	Breeding season	BDMPS		
		Autumn migration	Non-breeding	Spring migration
	Apr - mid Aug	n/a	mid Aug - Mar	n/a
MSP	6,521	n/a	6	n/a
60% / 1%	39	n/a	0	n/a
60% / 2%	78	n/a	0	n/a
60% / 3%	117	n/a	0	n/a
60% / 5%	196	n/a	n/a*	n/a

**MSS/NS advise using 1% and 3% displacement mortality rates in the non-breeding season, therefore the 5% rate is non-applicable. (The 2% rate is presented for information.)*

Table 8 Puffin seasonal displacement mortalities each year (numbers of birds) – PFOWF Array Area alone

Puffin displacement mortalities	Breeding season	BDMPS		
		Autumn migration	Non-breeding	Spring migration
	Apr - mid Aug	n/a	mid Aug - Mar	n/a
MSP PFOWF Array Area only	1,211	n/a	2	n/a
60% / 1%	7	n/a	0	n/a
60% / 2%	15	n/a	0	n/a
60% / 3%	22	n/a	0	n/a
60% / 5%	36	n/a	n/a*	n/a

**MSS/NS advise using 1% and 3% displacement mortality rates in the non-breeding season, therefore the 5% rate is non-applicable. (The 2% rate is presented for information.)*

Table 9 Fulmar seasonal displacement mortalities each year (numbers of birds)

Fulmar displacement mortalities	Breeding season	BDMPS		
		Autumn migration	Non-breeding	Spring migration
	Apr - mid Sep	Sep - Oct	Nov	Dec - Mar
MSP	1,067	30	34	199
30% / 1%	3	0	0	1

Table 10 Gannet seasonal displacement mortalities each year (numbers of birds)

Gannet displacement mortalities	Breeding season	BDMPS		
		Autumn migration	Non-breeding	Spring migration
	mid Mar - Sep	Sep - Nov	n/a	Dec - Mar
MSP	166	24	n/a	8
70% / 1%	1	0	n/a	0
70% / 3%	3	0	n/a	0

Table 11 Arctic tern seasonal displacement mortalities each year (numbers of birds)

Arctic tern displacement mortalities	Breeding season	BDMPS		
		Autumn migration	Non-breeding	Spring migration
	mid Mar - Sep	Sep - Nov	n/a	Dec - Mar
MSP	46	0	n/a	0
30% / 1%	0	0	n/a	0
30% / 3%	0	0	n/a	0

Table 12 Great skua seasonal displacement mortalities each year (numbers of birds)

Great skua displacement mortalities	Breeding season	BDMPS		
		Autumn migration	Non-breeding	Spring migration
	mid Apr - mid Sep	Aug - Oct	Nov - Feb	Mar - Apr
MSP	7	0	0	0
30% / 1%	0	0	0	0

4 Discussion and Conclusions

4.1 Comparing SeabORD outputs with use of displacement matrices

- 46 Outputs from SeabORD confirm that there would not appear to be any significant risk of displacement/barrier effects from the Offshore Development affecting kittiwake, guillemot, razorbill or puffin at North Caithness Cliffs SPA. There are zero impacts predicted on adult survival rates during the breeding season, and only minimal mortalities predicted to occur annually against the SPA populations of each species.
- 47 SeabORD model outputs for kittiwake (an estimate of 2.6 annual mortalities; Table B1.1), guillemot (an estimate of 5.54 annual mortalities after application of an 1/0.65 scaling factor to model outputs in Table B2.1); razorbill (an estimate of 1.3 annual mortalities; Table B3.1) and puffin (an estimate of 1.8 annual mortalities; Table B4.1) were compared against the non-apportioned and apportioned mortalities from the relevant displacement matrices as summarised in Section 3.2 and in the species summaries below (Section 4.3 – Section 4.6). For guillemot, summing the apportioned breeding and non-breeding mortality estimates from the displacement matrices (Table 14 and Table 15) accords well with SeabORD outputs when using displacement and mortality rates of 60% and 1%; giving a figure of 5.51 annual guillemot mortalities (compared to the 5.54 from SeabORD).
- 48 For kittiwake, apportioned displacement matrix estimates also align most closely with SeabORD when using a displacement rate of 30% and a mortality rate of 2%; calculated as 2.4 apportioned kittiwake mortalities (without rounding and totalled across breeding and non-breeding seasons), as compared to the 2.6 from SeabORD. (For reference, Table 13 gives the breeding season figures, using rounded figures from the displacement matrix prior to apportioning). For razorbill, it was the unapportioned displacement matrix estimates that most closely matched SeabORD when using a displacement rate of 60% and a mortality rate of 2%; calculated as a figure of 1.6 mortalities (with reference to Table 6 but using unrounded matrix outputs) compared to 1.3 from SeabORD.
- 49 The much lower apportioned razorbill mortality estimates presented in Table 16 are likely to be most related to use of the advised apportioning weighting, calculated as only 0.357 for North Caithness Cliffs SPA. This weighting largely results from the fact that there is a small razorbill population at North Caithness Cliffs SPA compared to the other SPAs within foraging range. However, as North Caithness Cliffs SPA lies so much closer to the PFOWF Array Area, it seems fair to assume that most of the (unapportioned) razorbill mortality estimates will relate to this SPA when such low numbers of birds are involved.
- 50 Finally, use of a displacement matrix appears to significantly over-estimate the potential levels of mortality in relation to puffin (Table 17). This links back to the very high numbers of puffin recorded on-site during the 8 June 2015 survey and the 15 June 2021 survey (Section 3.1 of Technical Appendix 12.1 Marine Ornithology: Baseline Data) which results in a MSP estimate (for June) that is a magnitude higher than for all other months. Section 4.4 discusses this anomaly further and compares the numbers of puffin mortalities estimated from the displacement matrix apportioned to North Caithness Cliffs SPA against the actual population count (breeding adults) recorded at the SPA.

4.2 Consideration of estimated displacement mortalities in assessment

- 51 While this report (Technical Appendix 12.4 Marine Ornithology: Displacement Analysis) provides the detailed outputs from SeabORD (Annex B), full displacement matrices (Annex C) and the associated seasonal summaries for advised rates of displacement and mortality (Section 3.2), it is only a subset of this information taken forward for consideration in Section 12.6.2.2 of the Offshore EIAR (Volume 2) Chapter 12, Marine Ornithology and in the RIAA.
- 52 For kittiwake, guillemot and puffin, the consequences of predicted impacts against the SPA populations at North Caithness Cliffs are modelled using PVA (Technical Appendix 12.5, Marine Ornithology: Population Modelling) and then considered further in the RIAA. For kittiwake this is the summed mortality from both collision risk modelling and displacement analysis, whereas for guillemot and puffin it is displacement only.
- 53 This PVA modelling includes cumulative / 'in combination' impact scenarios to address Beatrice, Moray East and Moray West offshore wind farms, also predicted to be impacting North Caithness Cliffs SPA. Further details of this modelling and PVA outputs are provided in Technical Appendix 12.5, Marine Ornithology: Population Modelling, with the significance of the results for each species considered in the RIAA, and also used to help inform the EIA judgements presented in Section 12.6.2.2 of the Offshore EIAR (Volume 2) Chapter 12, Marine Ornithology.
- 54 Note that the 'most recent population counts' provided in Table 13 – Table 19 are taken from the SMP database as further discussed in Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning.

4.3 Kittiwake

- 55 For information, the mortality estimates from the displacement matrix for kittiwake in the breeding season are apportioned between key SPA breeding colonies using the weightings derived from the MS apportioning tool (Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning) as presented in Table 13.

Table 13 Kittiwake apportioned breeding season displacement mortalities each year

SPA	Impact weighting (MS tool)	Most recent population count (AON)	Apportioned breeding season displacement mortalities (no. of birds)		
			30% / 1%	30% / 2 %	30% / 3 %
North Caithness Cliffs	0.717	5,568	1.43	2.15	3.59
East Caithness Cliffs	0.080	24,460	0.16	0.24	0.40
West Westray	0.063	2,755	0.13	0.19	0.32
Cape Wrath	0.025	3,622	0.05	0.08	0.13

- 56 SeabORD modelling predicts up to 2.6 annual displacement mortalities (breeding season and non-breeding season together) of kittiwake against the North Caithness Cliffs SPA population. Displacement impacts are minimal against all other SPAs (Table 13).

4.4 Guillemot

- 57 Estimated guillemot displacement mortalities in the breeding season are apportioned between key SPAs using the weightings derived from the MS apportioning tool (Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning) as presented in Table 14.

Table 14 Guillemot apportioned breeding season displacement mortalities each year

SPA	Impact weighting (MS tool)	Most recent population count (individuals)	Apportioned breeding season displacement mortalities (no. of birds)		
			60% / 1%	60% / 3%	60% / 5%
North Caithness Cliffs	0.695	38,863	4.87	14.60	23.63
Hoy	0.056	12,198	0.39	1.17	1.90
Marwick Head	0.045	2,755	0.32	0.95	1.53
East Caithness Cliffs	0.041	148,805	0.29	0.86	1.39
Sule Skerry / Sule Stack	0.040	10,068	0.28	0.84	1.36
Handa	0.034	54,664	0.24	0.71	1.16
West Westray	0.021	28,697	0.15	0.44	0.71
Cape Wrath	0.017	38,109	0.12	0.36	0.58

- 58 SeabORD modelling predicts up to 5.54 annual guillemot mortalities against the North Caithness Cliffs SPA population. In this regard, breeding and non-breeding mortality estimates from displacement matrices can be summed for comparison with SeabORD (i.e., adding together the figures in Table 14 and Table 15). As advised, there is a close match between outputs when a 60% displacement and 1% mortality rate are used in the matrix (paragraph 46), a figure of 5.51 annual guillemot mortalities. Non-breeding season mortality estimates presented in Table 15 have been apportioned between SPAs following the method advised for guillemot by NS as set out in Section 4.3 of Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning.
- 59 As noted above, potential guillemot displacement mortalities at North Caithness Cliffs SPA are considered further via PVA (Technical Appendix 12.5, Marine Ornithology: Population Modelling).

Table 15 **Guillemot apportioned non-breeding season displacement mortalities each year**

SPA	Impact weighting (NS)	Total non-breeding SPA population (individuals)	Apportioned non-breeding displacement mortalities (no. of birds)	
			60% / 1%	60% / 3%
North Caithness Cliffs	0.159	163,560	0.64	1.91
Hoy	0.021	21,924	0.08	0.25
Marwick Head	0.038	38,618	0.15	0.46
East Caithness Cliffs	0.360	370,620	1.44	4.32
Sule Skerry / Sule Stack	0.026	26,563	0.10	0.31
Handa	0.128	132,216	0.51	1.54
West Westray	0.115	117,972	0.46	1.38
Cape Wrath	0.092	95,209	0.37	1.10

4.5 Razorbill

- 60 Estimated razorbill displacement mortalities in the breeding season are apportioned between key SPAs using the weightings derived from the MS apportioning tool (Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning) as presented in Table 16.

Table 16 **Razorbill apportioned breeding season displacement mortalities each year**

SPA	Impact weighting (MS tool)	Most recent population count (individuals)	Apportioned breeding season displacement mortalities (no. of birds)		
			60% / 1%	60% / 3%	60% / 5%
North Caithness Cliffs	0.357	3,609	0.36	0.71	1.43
East Caithness Cliffs	0.162	30,003	0.16	0.32	0.65
Handa	0.159	8,207	0.16	0.32	0.64
West Westray	0.153	2,159	0.15	0.31	0.61
Cape Wrath	0.029	3,246	0.03	0.06	0.12

- 61 SeabORD modelling predicts up to 1.3 annual razorbill mortalities against North Caithness Cliffs SPA. In this regard, levels of predicted displacement impact on razorbill during the breeding season are not considered to be significant against any of the key SPAs (Table 16).

- 62 Non-breeding season displacement impacts on razorbill at North Caithness Cliffs SPA are addressed via SeabORD as noted above. For all other SPAs in Table 16, there are zero predicted razorbill mortalities in the non-breeding season (Table 6).

4.6 Puffin

- 63 Estimated puffin displacement mortalities in the breeding season are apportioned between key SPAs using the weightings derived from the MS apportioning tool (Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning) as presented in Table 17.

Table 17 Puffin apportioned breeding season displacement mortalities each year

SPA	Impact weighting (NS)	Most recent population count (individuals)	Apportioned breeding season displacement mortalities (no. of birds)			
			60%/1%	60%/2%	60%/3%	60%/5%
PFOWF Array Area plus 2 km buffer						
North Caithness Cliffs	0.698	3,053	27.22	54.44	81.67	136.80
Sule Skerry / Sule Stack	0.282	95,484	11.00	22.00	32.99	55.27
PFOWF Array Area alone						
North Caithness Cliffs	0.698	3,053	4.89	10.47	15.36	25.13
Sule Skerry / Sule Stack	0.282	95,484	1.97	4.23	6.20	10.15

- 64 SeabORD predicts up to 1.8 annual puffin mortalities against the North Caithness Cliffs SPA population. In this regard, use of the displacement matrix substantially over-estimates the likely displacement and barrier impacts from the Offshore Development even at the lowest 1% mortality rate and discounting the 2 km buffer.
- 65 If the North Caithness Cliffs SPA weighting (0.698) is applied to the MSP estimate for the PFOWF Array Area plus 2 km buffer (6,521 puffin) it can be seen that the resulting figure (4,551 puffin) is greater than the SPA population total (3,053 puffin). While the latter is a value for breeding adults only, it still indicates a probable over-estimation, either in the calculation of apportioning weightings, or in the assumptions applied to use of the displacement matrix.
- 66 As noted in paragraph 50, the population estimates for 8 June 2015 and 15 June 2021 were a magnitude higher than for all other months during the breeding season, Technical Appendix 12.1, Marine Ornithology: Baseline Data. As the digital aerial surveys are only a 'snapshot' in time it is unknown for how long these numbers were present on-site.
- 67 Puffin displacement mortalities at North Caithness Cliffs SPA are considered further via PVA as presented in Technical Appendix 12.5, Marine Ornithology: Population Modelling.

4.7 Fulmar

- 68 The estimated breeding season displacement mortality for fulmar (three birds) is apportioned between the key SPA colonies using the weightings derived from NatureScot (2018) guidance (Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning) as presented in Table 18.

Table 18 Fulmar apportioned breeding season displacement mortalities each year

SPA	Impact weighting (NS)	Most recent population count (AON)	Apportioned breeding season mortalities (no. of birds)
North Caithness Cliffs	0.925	13,405	2.78
Hoy	0.058	21,101	0.17

- 69 In the non-breeding season, there is a total estimated displacement mortality of one bird. For simplicity this has not been apportioned; it is added to the breeding season impacts to give a total of four displacement mortalities to consider against North Caithness Cliffs SPA.

4.8 Gannet

- 70 The estimated breeding season displacement mortalities for gannet (Table 19) are apportioned between the key SPA breeding colonies using the weightings derived from NatureScot (2018) guidance (Technical Appendix 12.2, Marine Ornithology: Connectivity and Apportioning) as presented in Table 19.

Table 19 Gannet apportioned breeding season displacement mortalities each year

SPA	Impact weighting (NS)	Most recent population count (AON)	Apportioned breeding season mortalities (no. of birds)	
			70% / 1%	70% / 3%
Sule Skerry / Sule Stack	0.527	9,065	0.53	1.58
Forth Islands	0.111	75,259	0.11	0.33
St Kilda	0.105	60,290	0.11	0.32
North Rona / Sula Sgeir	0.102	11,230	0.10	0.31
Hermaness / Saxa Vord / Valla Field	0.041	25,580	0.04	0.12
Noss	0.035	13,765	0.04	0.11
Troup / Pennan / Lion's Heads (non-SPA colony)	0.029	4,825	0.03	0.09
Fair Isle	0.027	4,971	0.03	0.08

- 71 These predicted displacement impacts to gannet are minimal during the breeding season and there are zero predicted displacement mortalities during the non-breeding season (Table 10).

4.9 Arctic tern

- 72 There are zero breeding or non-breeding displacement mortalities estimated for Arctic tern, therefore this impact is not considered further for this species.

4.10 Great skua

- 73 There are zero breeding or non-breeding displacement mortalities estimated for great skua, therefore this impact is not considered further for this species.

5 References

Bradbury, G., Trinder, M., Furness, R., Banks, A.N., Caldow, R.W.G. & Hume, D. (2014). Mapping seabird sensitivity to offshore wind farms. *PLoS ONE*, 9(9), e106366.

Fox, A.D., Desholm, M., Kahlert, J., Christensen, T.K. & Petersen, I.K. (2006). Information needs to support environmental impact assessment of the effects of European marine offshore wind farms on birds. *IBIS International Journal of Avian Science*, 148(1), 129-144.

Fox, A.D. & Peterson I.K. (2019). Offshore wind farms and their effects on birds. *Dansk Orn. Foren, Tidsskr.* 113, 86-101.

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, No.164.

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

Harris, M. P. (1989). Variation in the correction factor used for converting counts of individual guillemots *Uria aalge* into breeding pairs. *Ibis*, 131(1), 85-93.

Harris, M.P., Neweu, M.A. & Wanless, S. (2015a). The use of k values to convert counts of individual Razorbills *Alca torda* to breeding pairs. *Seabird*, 28, 30-36.

Harris, M. P., Heubeck, M., Newell, M. A. & Wanless, S. (2015b). The need for year-specific correction factors (k values) when converting counts of individual Common Guillemots *Uria aalge* to breeding pairs. *Bird Study*, 62(2), 276-279.

Masden, E.A., Haydon, D.T., Fox, A.D., Furness, R.W., Bullman, R. & Desholm, M. (2009). Barriers to movement: impacts of wind farms on migrating birds. *ICES Journal of Marine Science*, 66, 746-753.

Masden, E.A., Haydon, D.T., Fox, A.D. & Furness, R.W. (2010). Barriers to movement: modelling energetic costs of avoiding marine wind farms amongst breeding seabirds. *Marine Pollution Bulletin*, 60, 1085-1091.

Mobbs, D.C, Searle, K., Butler, A. & Daunt, F. (2018). *SeaBORD User Guide (v1.3)*. Centre for Ecology and Hydrology and BioSS. NEC05978.

MS-LOT (2021). Scoping Opinion adopted by the Scottish Ministers under: The Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017 and The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017. Pentland Floating Offshore Wind Farm Scoping Report. 28 September 2021.

Available Online at: https://marine.gov.scot/sites/default/files/pfowf_scoping_opinion.pdf [Accessed 29/09/2021].

NatureScot. (2018). *Interim Guidance on apportioning impacts from marine renewable developments to breeding seabird populations in SPAs*.

NatureScot. (2020). *Seasonal periods for birds in the Scottish marine environment*. Short Guidance Note Version 2. NatureScot.

Searle, K.R., Mobbs, D., Butler, A., Bogdanova, M., Freeman, S., Wanless, S. & Daunt, F. (2014). Population Consequences of Displacement from Proposed Offshore Wind Energy Developments for Seabirds Breeding at Scottish SPAs (CR/2012/03). Report to MSS.

Searle, K.R., Mobbs, D.C., Butler, A., Furness, R.W., Trinder, M.N. & Daunt, F. (2018). Finding out the fate of displaced birds (FCR/2015/19). Scottish Marine and Freshwater Science Vol 9 No 08.

SNCB. (2017). *Joint SNCB Interim displacement advice notice, Advice on how to present assessment information on the extent and potential consequences of seabird displacement from Offshore Wind Farm (OWF) developments.* SNCB.

Annex A SeabORD technical description of method and input parameters

A1: Calibration

- 1 To calibrate SeabORD for each species at each colony, 'single' simulations were run with no wind farms present. The only input values altered when running baseline simulations were the prey quantity (g per unit volume) with the rest of the values for each species being shown in Table A1.1.
- 2 Calibrating the model is important as the breeding season outputs in the final paired simulations will only use the values from the prey quantity (g per unit volume) range selected. Therefore, to produce realistic results the prey range should be set to values expected during typical or 'moderate' breeding seasons.

Table A1.1 Values used for running baseline and the final paired simulations

Variable	Kittiwake	Guillemot	Razorbill	Puffin
% of populations susceptible to displacement	30	60	60	60
% of those susceptible to displacement barrier	100	100	100	100
Maximum foraging range (km)	300.6	153.7	164.6	165.4
Proportion of individuals within range	0.975	0.975	0.975	0.975
Windfarm footprint border (km)	0.5	0.5	0.5	0.5
Windfarm footprint buffer (km)	5	5	5	5
Fraction of population used for baseline simulations	0.1	0.1	0.1	0.1

A2: Model input parameters and assumptions

- 3 The assumed percentage of the population susceptible to displacement was taken from the MSS and NS advised displacement rates for each species (Table 3).
- 4 Due to a lack of Global Positioning System (GPS) tracking data, the distance decay method was used to determine the foraging sites of individuals. This assumes that as the distance from the colony increases (modelled for each sub-site at North Caithness Cliffs using the

reference location point indicated in Table 1), the density of foraging birds is expected to decrease (Searle *et al.*, 2018). For each species, the foraging range used within the model was mean max plus one standard deviation, taken from Woodward *et al.* (2019), as advised by MSS and NS in relation to connectivity and apportioning (Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning). The proportion of foraging occurring within this identified range was set to 0.975 (Table A1.1). These input values were then used by SeabORD to determine the foraging location of each individual adult, at each timestep of the simulation.

- 5 It was assumed that all individuals susceptible to displacement would be barriered, that the windfarm footprint border would be 0.5 km and the buffer 5 km following the advice and examples provided by the developers of SeabORD (Searle *et al.*, 2018; Mobbs *et al.*, 2018).

A3: Calculating prey ranges

- 6 To determine the prey range expected during a 'moderate' breeding season (i.e., where environmental conditions are 'moderate') baseline simulations were run (i.e., simulations with no wind farms present). The only input parameters in the baseline 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. After running multiple baseline simulations, the outputs were compared to determine the appropriate lower and upper prey quantity values. 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 (Table A3.1).

Table A3.1 Adult percentage body mass loss and percentage chick survival used to determine prey values used in the final paired simulations. Values taken from Mobbs *et al.* (2018).

Species	Adult Mass Loss (%)		Chick Survival (%)
	Lower boundary	Upper boundary	Lower boundary
Kittiwake	5	15	11
Guillemot	3.5	10.5	49
Razorbill	3.5	10.5	50
Puffin	3.5	10.5	50

A4: Paired simulations

- 7 Once the upper and lower prey quantities were determined (Table A4.1) through the baseline simulations, they were then used to run the final paired simulation for each species at each colony. The paired simulations compare presence of a wind farm (the Offshore Development) against baseline conditions. Each pair selected a prey quantity within the range using random stratification and then simulated the breeding season with and without the Offshore Development present, meaning that 20 breeding seasons were simulated for each final simulation. For kittiwake, razorbill and puffin, 100% of the population were used during the final simulations. Due to its much larger size, 65% of the guillemot population was used in the simulations for this species (a figure of 33,800 individuals).

Table A4.1 Prey quantity range used for each final paired simulation

Species	Colony	Lower prey quantity (g per unit volume)	Upper prey quantity (g per unit volume)
Kittiwake	Duncansby Head	120	149
	Dunnet Head	125	146
	Holburn Head	128	147
	Melvich	132	161
	Stroma	120	144
Guillemot	Duncansby Head	293	353
	Dunnet Head	301	358
	Holburn Head	305	369
	Melvich	314	385
	Stroma	291	348
Razorbill	Duncansby Head	183	220
	Dunnet Head	301	358
	Holburn Head	305	369
	Melvich	314	385
	Stroma	291	248
Puffin	Duncansby Head	148	178
	Dunnet Head	152	187
	Holburn Head	155	192
	Melvich	163	197
	Stroma	149	207

- 8 During simulation seasons with the Offshore Development present, if individuals susceptible to displacement were assigned a foraging location within the wind farm footprint (the PFOWF Array Area) they were displaced into the buffer area. Furthermore, they would not be able to travel through the border surrounding the footprint when travelling from the colony to foraging sites.
- 9 Barrier navigation was set to 'Perimeter' for all simulations following the examples provided (Searle *et al.*, 2018; Mobbs *et al.*, 2018). This assumes that individuals travel in a straight line until they encounter an area they cannot travel through, either land, the wind farm footprint (the PFOWF Array Area) or the wind farm boundary. Once these areas are encountered individuals will follow the perimeter of these areas until they can travel in a straight line again.

A5: Bioenergetics in the model

- 10 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 were kept constant throughout the simulation.
- 11 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 foraging needed to meet individuals' Daily Energy Requirements (DER) and flying for each individual were generated by SeabORD and a minimum of one hour was 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.
- 12 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.
- 13 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 A5.1.

Table A5.1 Behaviours of each individual determined by body mass

Species	Age	% of initial mass	Behaviour for next timestep
All	Adult	>90	Stays at nest for the next timestep.
All	Adult	80-90	Leaves chick unattended to reach DER
All	Adult	<80	Abandon chick*
All	Adult	<60	Assumed to have died.
Puffin	Chick	60 – 80	Chick will go to the opening of the burrow, increasing the likelihood of death due to predation or harsh environmental conditions
All	Chick	<60	Assumed to have died.

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

- 14 Chick mortality can also occur during a timestep if the time an adult spends away from the nest is greater than the threshold determined by SeabORD. Predation risk was modelled to increase as the time left unattended increased until the specified threshold for each species.

A6: Annual mortalities predicted by SeabORD

- 15 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.

- 16 The baseline survival is equal to the mean value of sites with observed data on annual adult survival curated by the creators of SeabORD. Likewise, the shape of the logistic curve, which explains the relation between survival probability and body weight, is set by creators of SeabORD.
- 17 Annual mortality can be predicted by SeabORD in this way as presented in Table B1.1, Table B2.1, Table B3.1 and Table B4.1. This is possible even where there has been no predicted change to adult survival rates during the breeding season (as is the case for the Offshore Development).
- 18 As discussed in Section 3.1, the baseline levels of adult mortality predicted by SeabORD (for the baseline scenarios without presence of the Offshore Development) have been sense-checked against the figures calculated by applying the default adult survival rate for each species (Table A6.1) against each reference population for the SPA sub-sites (the most recent counts confirmed by JNCC, as presented in Annex A of Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning).

Table A6.1 Adult survival rates from Horswill & Robinson (2015)

Species	Adult survival rate (mean)	Standard deviation
Kittiwake	0.854	± 0.077
Guillemot	0.940	± 0.025
Razorbill	0.895	± 0.067
Puffin	0.906	± 0.083

- 19 A factor of (*1-adult survival rate*) has been applied to each of the SPA sub-site populations to calculate ‘PVA baseline mortalities’ for comparison with SeabORD outputs as presented in Table B1.1 (kittiwake), Table B2.1 (guillemot), Table B3.1 (razorbill) and Table B4.1 (puffin) in Annex B.

Annex B SeabORD outputs

BI: Kittiwake

Table BI.1 Modelled impacts of the Offshore Development on adult kittiwake during the year, at the five sub-sites within North Caithness Cliffs SPA, during 'poor', 'moderate' and 'good' environmental conditions

Sub-site	PVA baseline adult mortalities	Environmental Conditions	Adults not surviving the year				Difference in mortalities between scenarios
			Baseline (no wind farm)		Wind farm present		
			Mean	SD	Mean	SD	
Dunnet Head	590	Poor	1,439.40	59.62	1,440.30	59.37	0.90
		Moderate	955.80	43.97	956.50	43.97	0.70
		Good	517.50	32.35	518.10	32.28	0.60
Duncansby Head	170	Poor	423.80	13.55	423.70	13.44	0.10
		Moderate	277.60	10.44	277.80	9.92	0.20
		Good	163.20	10.65	163.10	10.65	0.10
Holburn Head	16	Poor	41.20	0.79	4.20	0.79	0.00
		Moderate	22.70	2.79	22.70	2.79	0.00
		Good	18.00	1.16	18.00	1.16	0.00
Melvich	811	Poor	2,410.80	59.33	2,413.70	60.36	2.90
		Moderate	1,633.30	59.51	1,634.90	58.60	1.60
		Good	1,039.20	47.24	1,040.50	47.89	1.30
Stroma	40	Poor	102.50	5.72	102.50	5.72	0.00
		Moderate	57.00	4.50	57.10	4.46	0.10
		Good	36.30	0.82	36.30	0.82	0.00

Table B I.2 SeabORD outputs for kittiwake at each of the five sub-sites within North Caithness Cliffs SPA

Output Variable	Scenario (wind farm present/not present)	Dunnet Head		Duncansby Head		Holburn Head		Melvich		Stroma	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	Both	4040		1168		110		5554		274	
Adult survival at end of breeding season (%)	Not present	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00
	Present	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00
Initial adult body mass (g)	Not present	372.17	0.00	374.99	0.00	370.51	0.00	372.64	0.00	373.53	0.00
	Present	372.17	0.00	374.99	0.00	370.51	0.00	372.64	0.00	373.53	0.00
Final adult body mass (g)	Not present	344.30	7.30	345.77	8.04	343.08	6.18	344.19	6.87	345.76	7.77
	Present	344.28	7.30	345.76	8.04	343.06	6.18	344.12	6.85	345.75	7.75
Difference between total distance flown with and without windfarms (km)		0.13	0.58	-0.56	1.16	2.57	0.80	7.24	1.73	1.19	0.37
Difference in the total number of trips carried out with and without windfarms		-0.03	0.02	-0.02	0.03	0.00	0.02	-0.09	0.05	0.00	0.01
Chicks not surviving the season	Not present	536.80	442.12	195.90	175.90	15.20	8.87	847.20	690.76	43.70	35.15
	Present	538.30	442.48	195.90	175.99	15.20	8.87	856.40	696.74	43.70	35.15
Additional mortality of chicks with windfarm present (%)		0.07	0.10	0.00	0.08	0.00	0.00	0.33	0.30	0.00	0.00
Number of adults directly impacted by the windfarm (displaced or barriered)	Present	447	-	59	-	15	-	1,660	-	14	-

B2: Guillemot

Table B2.1 Modelled impacts of the Offshore Development on adult guillemot during the year, at the five sub-sites within North Caithness Cliffs SPA, during 'poor', 'moderate' and 'good' environmental conditions

Sub-site	PVA baseline adult mortalities	Environmental Conditions	Adults not surviving the year				Difference in mortalities between scenarios
			Baseline (no wind farm)		Wind farm present		
			Mean	SD	Mean	SD	
Dunnet Head	580	Poor	1,980.50	25.78	1,981.40	25.04	0.90
		Moderate	1017.40	10.10	1,018.30	9.66	0.80
		Good	758.80	6.63	760.30	6.38	1.50
Duncansby Head	1153	Poor	3,608.70	16.83	3,609.60	16.68	0.90
		Moderate	1,766.20	7.05	1,767.50	8.00	1.30
		Good	1,454.70	11.48	1,455.80	12.04	1.10
Holburn Head	30	Poor	106.20	3.08	106.30	2.95	0.10
		Moderate	53.90	2.11	53.70	1.64	0.20
		Good	43.20	1.75	43.20	1.69	0.00
Melvich	151	Poor	604.40	17.46	609.00	18.25	4.60
		Moderate	329.80	8.47	331.80	8.90	2.00
		Good	274.40	9.91	274.90	10.71	0.50
Stroma	420	Poor	1,278.60	14.38	1,278.50	12.75	0.10
		Moderate	644.90	15.42	646.10	14.40	1.20
		Good	484.60	11.60	485.10	11.62	0.50

Table B2.2 SeabORD outputs for guillemot at each of the five sub-sites within North Caithness Cliffs SPA

Output Variable	Scenario (wind farm present/not present)	Dunnet Head		Duncansby Head		Holburn Head		Melvich		Stroma	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	Both	8422		16734		434		2186		6104	
Adult survival at end of breeding season (%)	Not present	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.000
	Present	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.000
Initial adult body mass (g)	Not present	920.67	0.00	920.33	0.00	920.73	0.00	918.55	0.00	919.76	0.000
	Present	920.67	0.00	920.33	0.00	920.73	0.00	918.55	0.00	919.76	0.000
Final adult body mass (g)	Not present	864.50	17.75	864.75	18.03	863.58	16.83	864.77	16.61	864.01	18.02
	Present	864.44	17.73	864.72	18.02	863.43	16.78	864.37	16.61	863.95	18.00
Difference between total distance flown with and without windfarms (km)		0.21	0.20	0.40	0.04	2.75	0.92	7.51	0.92	0.85	0.13
Difference in the total number of trips carried out with and without windfarms		-0.02	0.01	0.00	0.00	-0.01	0.02	-0.03	0.03	0.00	0.00
Chicks not surviving the season	Not present	638.70	475.58	1263.50	1015.00	40.80	30.02	154.60	112.43	488.30	376.43
	Present	639.70	476.20	1267.40	1017.36	41.10	30.27	157.40	115.43	489.90	377.46
Additional mortality of chicks with windfarm present (%)		0.02	0.04	0.05	0.04	0.14	0.31	0.26	0.30	0.05	0.06
Number of adults directly impacted by the windfarm (displaced or barriered)	Present	1,306	-	816	-	113	-	1,230	-	435	-

B3: Razorbill

Table B3.1 Modelled impacts of the Offshore Development on adult razorbill during the year, at the five sub-sites within North Caithness Cliffs SPA, during 'poor', 'moderate' and 'good' environmental conditions

Sub-site	PVA baseline adult mortalities	Environmental Conditions	Adults not surviving the year				Difference in mortalities between scenarios
			Baseline (no wind farm)		Wind farm present		
			Mean	SD	Mean	SD	
Dunnet Head	59	Poor	193.30	4.72	193.70	5.03	0.40
		Moderate	100.30	3.47	100.50	3.24	0.20
		Good	65.40	3.17	65.50	3.27	0.10
Duncansby Head	191	Poor	571.60	9.11	571.40	8.80	0.20
		Moderate	294.90	5.02	295.00	5.35	0.10
		Good	157.90	3.54	158.20	3.99	0.30
Holburn Head	7	Poor	23.90	1.85	23.90	1.10	0.00
		Moderate	14.40	1.08	14.50	1.58	0.10
		Good	6.70	1.77	6.70	0.68	0.00
Melvich	64	Poor	263.80	8.82	264.90	9.23	1.10
		Moderate	144.70	6.53	145.50	7.58	0.80
		Good	89.30	5.10	90.60	5.99	1.30
Stroma	58	Poor	162.60	6.75	162.20	6.55	0.40
		Moderate	92.60	4.74	92.70	4.81	0.10
		Good	36.60	2.01	37.10	1.79	0.50

Table B3.2 SeabORD outputs for razorbill at each of the five sub-sites within North Caithness Cliffs SPA

Output Variable	Scenario (wind farm present/not present)	Dunnet Head		Duncansby Head		Holburn Head		Melvich		Stroma	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	Both	758		2542		92		820		736	
Adult survival at end of breeding season (%)	Not present	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00
	Present	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00
Initial adult body mass (g)	Not present	581.56	0.00	583.31	0.00	581.81	0.00	584.37	0.00	583.02	0.00
	Present	581.56	0.00	583.31	0.00	581.81	0.00	584.37	0.00	583.02	0.00
Final adult body mass (g)	Not present	547.04	10.96	548.70	10.92	548.57	10.67	551.17	11.82	546.80	11.39
	Present	546.99	10.99	548.68	10.91	548.50	10.61	550.91	11.79	546.77	11.38
Difference between total distance flown with and without windfarms (km)		0.01	0.37	0.34	0.07	2.19	1.73	8.01	0.71	0.75	0.33
Difference in the total number of trips carried out with and without windfarms		-0.02	0.03	0.00	0.00	-0.01	0.04	-0.04	0.04	0.00	0.01
Chicks not surviving the season	Not present	44.60	27.77	176.00	114.55	5.80	4.78	55.30	39.08	49.30	40.63
	Present	44.60	27.66	176.60	114.81	5.80	4.78	56.90	41.07	49.40	40.82
Additional mortality of chicks with windfarm present (%)		0.00	0.12	0.05	0.07	0.00	0.00	0.39	0.69	0.03	0.15
Number of adults directly impacted by the windfarm (displaced or barriered)	Present	121	-	121	-	20	-	463	-	48	-

B4: Puffin

Table B4.1 Modelled impacts of the Offshore Development on adult puffin during the year, at the five sub-sites within North Caithness Cliffs SPA, during 'poor', 'moderate' and 'good' environmental conditions

Sub-site	PVA baseline adult mortalities	Environmental Conditions	Adults not surviving the year				Difference in mortalities between scenarios
			Baseline (no wind farm)		Wind farm present		
			Mean	SD	Mean	SD	
Dunnet Head	151	Poor	356.70	22.97	356.80	23.04	0.10
		Moderate	252.40	15.94	252.90	15.96	0.50
		Good	123.70	12.04	123.60	11.97	0.10
Duncansby Head*	2	Poor	0.00	0.00	0.00	0.00	0.00
		Moderate	5.00	0.00	5.00	0.00	0.00
		Good	1.00	0.00	1.00	0.00	0.00
Holburn Head	6	Poor	16.10	0.32	16.10	0.32	0.00
		Moderate	7.00	1.16	7.00	1.16	0.00
		Good	4.80	0.42	4.80	0.42	0.00
Melvich	127	Poor	378.60	11.76	381.20	12.11	2.60
		Moderate	311.70	8.73	313.00	9.56	1.30
		Good	157.30	4.06	158.20	4.44	0.90
Stroma	2	Poor	5.40	0.52	5.40	0.52	0.00
		Moderate	4.70	1.34	4.70	1.34	0.00
		Good	1.00	0.00	1.00	0.00	0.00

* It would be expected that the number of predicted mortalities would decrease as environmental conditions improve from 'poor' to 'good', and indeed this is reflected in the majority of the SeabORD outputs presented in this Annex. However, where there is an anomalous result (such as here for puffin at Duncansby Head) it cannot be explained without full access to the software.

Table B4.2 SeabORD outputs for puffin at each of the five sub-sites within North Caithness Cliffs SPA

Output Variable	Scenario (wind farm present/not present)	Dunnet Head		Duncansby Head		Holburn Head		Melvich		Stroma	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	Both	2150		24				1841		24	
Adult survival at end of breeding season (%)	Not present	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00
	Present	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00
Initial adult body mass (g)	Not present	392.93	0.00	392.67	0.00	391.51	0.00	392.10	0.00	391.54	0.00
	Present	392.93	0.00	392.67	0.00	391.51	0.00	392.10	0.00	391.54	0.00
Final adult body mass (g)	Not present	372.04	7.11	371.36	5.96	368.26	7.42	371.50	7.34	368.32	8.84
	Present	372.03	7.11	371.31	5.96	368.21	7.45	371.34	7.39	368.30	8.86
Difference between total distance flown with and without windfarms (km)		3.20	0.39	0.38	1.31	5.87	3.72	22.07	1.82	1.21	3.08
Difference in the total number of trips carried out with and without windfarms		-0.01	0.01	0.00	0.02	0.01	0.08	-0.06	0.03	-0.02	0.05
Chicks not surviving the season	Not present	61.80	4.89	0.00	0.00	1.00	0.00	64.70	10.73	1.00	0.00
	Present	61.90	5.20	0.00	0.00	1.00	0.00	64.90	11.32	1.00	0.00
Additional mortality of chicks with windfarm present (%)		0.01	0.03	0.00	0.00	0.00	0.00	0.02	0.07	0.00	0.00
Number of adults directly impacted by the windfarm (displaced or barriered)	Present	562	-	3	-	25	-	1,059	-	4	-

Annex C Displacement matrices

- I Shaded cells indicate the estimates for displacement and mortality rates (including those advised by Marine Scotland and NatureScot) that have been taken forward for the seasonal summaries, as presented in Section 3.2.
CI: Kittiwake

Table CI.1 Kittiwake displacement in the PFOWF Array Area + 2km buffer – breeding season

Kittiwake mid Apr-Aug	Mortality Level (% of displaced birds that die)													
	0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%	
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	
	10%	0	1	1	2	2	3	5	8	11	16	27	44	55
	20%	0	1	2	3	4	5	11	16	22	33	55	87	109
	30%	0	2	3	5	7	8	16	25	33	49	82	131	164
	40%	0	2	4	7	9	11	22	33	44	66	109	175	219
	50%	0	3	5	8	11	14	27	41	55	82	137	219	273
	60%	0	3	7	10	13	16	33	49	66	98	164	262	328
	70%	0	4	8	11	15	19	38	57	77	115	191	306	383
	80%	0	4	9	13	17	22	44	66	87	131	219	350	437
	90%	0	5	10	15	20	25	49	74	98	148	246	393	492
100%	0	5	11	16	22	27	55	82	109	164	273	437	546	

Table CI.2 Kittiwake displacement in the PFOWF Array Area + 2km buffer – autumn migration

Kittiwake Aug-Dec	Mortality Level (% of displaced birds that die)												
	0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	1	1	2	2	4	6	9	12
	20%	0	0	0	1	1	2	4	5	7	12	19	24
	30%	0	0	1	1	2	4	5	7	11	18	28	35
	40%	0	0	1	1	2	5	7	9	14	24	38	47
	50%	0	1	1	2	2	6	9	12	18	29	47	59
	60%	0	1	1	2	3	7	11	14	21	35	56	71
	70%	0	1	2	2	3	8	12	16	25	41	66	82
	80%	0	1	2	3	4	9	14	19	28	47	75	94
	90%	0	1	2	3	4	5	11	16	21	32	53	85
100%	0	1	2	4	5	6	12	18	24	35	59	94	118

Table CI.3 Kittiwake displacement in the PFOWF Array Area + 2km buffer – spring migration

Kittiwake Jan-Apr	Mortality Level (% of displaced birds that die)												
	0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	0	1	1	2	3	4
	20%	0	0	0	0	0	0	1	1	2	4	7	8
	30%	0	0	0	0	0	1	1	2	4	6	10	12
	40%	0	0	0	0	1	1	2	2	3	5	8	13
	50%	0	0	0	1	1	1	2	3	4	6	10	16
	60%	0	0	0	1	1	1	2	4	5	7	12	20
	70%	0	0	1	1	1	1	3	4	6	9	14	23
	80%	0	0	1	1	1	2	3	5	7	10	16	26
	90%	0	0	1	1	1	2	4	6	7	11	18	30
100%	0	0	1	1	2	2	4	6	8	12	20	33	41

C2: Guillemot

Table C2.1 Guillemot displacement in the PFOWF Array Area + 2km buffer – breeding season

Guillemot Apr - mid Aug	Mortality Level (% of displaced birds that die)												
	0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	1	2	3	5	6	11	17	23	34	57	92
	20%	0	2	5	7	9	11	23	34	46	69	115	183
	30%	0	3	7	10	14	17	34	52	69	103	172	275
	40%	0	5	9	14	18	23	46	69	92	137	229	367
	50%	0	6	11	17	23	29	57	86	115	172	286	458
	60%	0	7	14	21	27	34	69	103	137	206	344	550
	70%	0	8	16	24	32	40	80	120	160	241	401	641
	80%	0	9	18	27	37	46	92	137	183	275	458	733
	90%	0	10	21	31	41	52	103	155	206	309	515	825
100%	0	11	23	34	46	57	115	172	229	344	573	916	

Table C2.2 Guillemot displacement in the PFOWF Array Area + 2km buffer – non-breeding season

Guillemot Aug-Feb	Mortality Level (% of displaced birds that die)													
	0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%	
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	
	10%	0	1	1	2	3	3	7	10	13	20	33	52	65
	20%	0	1	3	4	5	7	13	20	26	39	65	104	130
	30%	0	2	4	6	8	10	20	29	39	59	98	156	195
	40%	0	3	5	8	10	13	26	39	52	78	130	208	260
	50%	0	3	7	10	13	16	33	49	65	98	163	260	325
	60%	0	4	8	12	16	20	39	59	78	117	195	312	390
	70%	0	5	9	14	18	23	46	68	91	137	228	364	455
	80%	0	5	10	16	21	26	52	78	104	156	260	416	520
	90%	0	6	12	18	23	29	59	88	117	176	293	468	585
100%	0	7	13	20	26	33	65	98	130	195	325	520	650	

C3: Razorbill

Table C3.1 Razorbill displacement in the PFOWF Array Area + 2km buffer – breeding season

Razorbill Apr-mid Aug		Mortality Level (% of displaced birds that die)													
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%	
Displacement Level (% of all birds on-site)		0%	0	0	0	0	0	0	0	0	0	0	0	0	
		10%	0	0	0	0	1	1	1	2	3	4	7	11	13
		20%	0	0	1	1	1	1	3	4	5	8	13	21	27
		30%	0	0	1	1	2	2	4	6	8	12	20	32	40
		40%	0	1	1	2	2	3	5	8	11	16	27	43	53
		50%	0	1	1	2	3	3	7	10	13	20	33	53	67
		60%	0	1	2	2	3	4	8	12	16	24	40	64	80
		70%	0	1	2	3	4	5	9	14	19	28	47	75	93
		80%	0	1	2	3	4	5	11	16	21	32	53	85	107
		90%	0	1	2	4	5	6	12	18	24	36	60	96	120
100%		0	1	3	4	5	7	13	20	27	40	67	107	134	

Table C3.2 Razorbill displacement in the PFOWF Array Area + 2km buffer – non-breeding season

Razorbill Nov-Dec	Mortality Level (% of displaced birds that die)													
	0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%	
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	
	10%	0	0	0	0	0	0	0	0	1	1	1	2	
	20%	0	0	0	0	0	0	1	1	1	2	3	3	
	30%	0	0	0	0	0	1	1	1	2	3	4	5	
	40%	0	0	0	0	0	1	1	1	2	3	5	7	
	50%	0	0	0	0	0	1	1	2	3	4	7	8	
	60%	0	0	0	0	0	1	2	2	3	5	8	10	
	70%	0	0	0	0	0	1	2	2	4	6	10	12	
	80%	0	0	0	0	1	1	1	2	3	4	7	11	14
	90%	0	0	0	0	1	1	2	2	3	5	8	12	15
100%	0	0	0	1	1	1	2	3	3	5	8	14	17	

Table C3.3 Razorbill displacement in the PFOWF Array Area + 2km buffer – autumn migration

Razorbill Aug - Oct	Mortality Level (% of displaced birds that die)												
	0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	0	0	0	1	1	2
	20%	0	0	0	0	0	0	0	1	1	2	2	3
	30%	0	0	0	0	0	0	1	1	1	2	4	5
	40%	0	0	0	0	0	1	1	1	2	3	5	6
	50%	0	0	0	0	0	1	1	2	2	4	6	8
	60%	0	0	0	0	0	1	1	2	3	5	7	9
	70%	0	0	0	0	0	1	2	2	3	5	9	11
	80%	0	0	0	0	0	1	2	2	4	6	10	12
	90%	0	0	0	0	1	1	2	3	4	7	11	14
100%	0	0	0	0	1	1	2	3	5	8	12	16	

Table C3.4 Razorbill displacement in the PFOWF Array Area + 2km buffer – spring migration

Razorbill Jan-Mar	Mortality Level (% of displaced birds that die)												
	0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	0	0	0	1	1	1
	20%	0	0	0	0	0	0	0	1	1	1	2	3
	30%	0	0	0	0	0	0	1	1	1	2	3	4
	40%	0	0	0	0	0	1	1	1	2	3	4	6
	50%	0	0	0	0	0	1	1	1	2	4	6	7
	60%	0	0	0	0	0	1	1	2	3	4	7	8
	70%	0	0	0	0	0	1	1	2	3	5	8	10
	80%	0	0	0	0	0	1	1	2	3	6	9	11
	90%	0	0	0	0	1	1	1	2	3	4	6	10
100%	0	0	0	0	1	1	1	2	3	4	7	11	14

C4: Atlantic puffin

Table C4.1 Puffin displacement in the PFOWF Array Area + 2km buffer – breeding season

Puffin Apr-mid Aug	Mortality Level (% of displaced birds that die)													
	0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%	
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	
	10%	0	7	13	20	26	33	65	98	130	196	326	522	652
	20%	0	13	26	39	52	65	130	196	261	391	652	1,043	1,304
	30%	0	20	39	59	78	98	196	293	391	587	978	1,565	1,956
	40%	0	26	52	78	104	130	261	391	522	783	1,304	2,087	2,608
	50%	0	33	65	98	130	163	326	489	652	978	1,630	2,608	3,260
	60%	0	39	78	117	157	196	391	587	783	1,174	1,956	3,130	3,913
	70%	0	46	91	137	183	228	456	685	913	1,369	2,282	3,652	4,565
	80%	0	52	104	157	209	261	522	783	1,043	1,565	2,608	4,173	5,217
	90%	0	59	117	176	235	293	587	880	1,174	1,761	2,934	4,695	5,869
100%	0	65	130	196	261	326	652	978	1,304	1,956	3,260	5,217	6,521	

Table C4.2 Puffin displacement in the PFOWF Array Area + 2km buffer – non-breeding season

Puffin mid Aug-Mar	Mortality Level (% of displaced birds that die)												
	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	0	0	0	0	0	1	1
20%	0	0	0	0	0	0	0	0	0	0	1	1	1
30%	0	0	0	0	0	0	0	0	0	1	1	2	2
40%	0	0	0	0	0	0	0	0	1	1	1	2	3
50%	0	0	0	0	0	0	0	0	1	1	2	3	3
60%	0	0	0	0	0	0	0	1	1	1	2	3	4
70%	0	0	0	0	0	0	0	1	1	1	2	4	5
80%	0	0	0	0	0	0	1	1	1	2	3	4	5
90%	0	0	0	0	0	0	1	1	1	2	3	5	6
100%	0	0	0	0	0	0	1	1	1	2	3	5	6

Table C4.3 Puffin displacement in the PFOWF Array Area only – breeding season

Puffin mid Aug-Mar	Mortality Level (% of displaced birds that die)													
	0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%	
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	
	10%	0	1	2	4	5	6	12	18	24	36	61	97	121
	20%	0	2	5	7	10	12	24	36	48	73	121	194	242
	30%	0	4	7	11	15	18	36	54	73	109	182	291	363
	40%	0	5	10	15	19	24	48	73	97	145	242	388	484
	50%	0	6	12	18	24	30	61	91	121	182	303	484	606
	60%	0	7	15	22	29	36	73	109	145	218	363	581	727
	70%	0	8	17	25	34	42	85	127	170	254	424	678	848
	80%	0	10	19	29	39	48	97	145	194	291	484	775	969
	90%	0	11	22	33	44	54	109	163	218	327	545	872	1,090
100%	0	12	24	36	48	61	121	182	242	363	606	969	1,211	

Table C4.4 Puffin displacement in the PFOWF Array Area only – non-breeding season

Puffin mid Aug-Mar	Mortality Level (% of displaced birds that die)												
	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	0	0	0	0	0	0	0
20%	0	0	0	0	0	0	0	0	0	0	0	0	0
30%	0	0	0	0	0	0	0	0	0	0	0	0	0
40%	0	0	0	0	0	0	0	0	0	0	0	0	1
50%	0	0	0	0	0	0	0	0	0	0	0	1	1
60%	0	0	0	0	0	0	0	0	0	0	0	1	1
70%	0	0	0	0	0	0	0	0	0	0	1	1	1
80%	0	0	0	0	0	0	0	0	0	0	1	1	1
90%	0	0	0	0	0	0	0	0	0	0	1	1	1
100%	0	0	0	0	0	0	0	0	0	0	1	1	2

C5: Fulmar

Table C5.1 Fulmar displacement in the PFOWF Array Area + 2km buffer – breeding season

Fulmar Apr - mid Sep	Mortality Level (% of displaced birds that die)													
	0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%	
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	
	10%	0	1	2	3	4	5	11	16	21	32	53	85	107
	20%	0	2	4	6	9	11	21	32	43	64	107	171	213
	30%	0	3	6	10	13	16	32	48	64	96	160	256	320
	40%	0	4	9	13	17	21	43	64	85	128	213	341	427
	50%	0	5	11	16	21	27	53	80	107	160	267	427	534
	60%	0	6	13	19	26	32	64	96	128	192	320	512	640
	70%	0	7	15	22	30	37	75	112	149	224	373	598	747
	80%	0	9	17	26	34	43	85	128	171	256	427	683	854
	90%	0	10	19	29	38	48	96	144	192	288	480	768	960
100%	0	11	21	32	43	53	107	160	213	320	534	854	1,067	

Table C5.2 Fulmar displacement in the PFOWF Array Area + 2km buffer – non-breeding season

Fulmar Nov	Mortality Level (% of displaced birds that die)												
	0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	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	3
	20%	0	0	0	0	0	1	1	1	2	3	5	7
	30%	0	0	0	0	1	1	2	2	3	5	8	10
	40%	0	0	0	0	1	1	2	3	4	7	11	14
	50%	0	0	0	1	1	1	2	3	5	8	14	17
	60%	0	0	0	1	1	1	2	4	6	10	16	20
	70%	0	0	0	1	1	1	2	4	7	12	19	24
	80%	0	0	1	1	1	1	3	4	5	8	14	22
	90%	0	0	1	1	1	2	3	5	6	9	15	24
100%	0	0	1	1	1	2	3	5	7	10	17	27	34

Table C5.3 Fulmar displacement in the PFOWF Array Area + 2km buffer – autumn migration

Fulmar Sep - Oct	Mortality Level (% of displaced birds that die)												
	0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	0	1	1	2	2	3
	20%	0	0	0	0	0	1	1	1	2	3	5	6
	30%	0	0	0	0	0	1	1	2	3	5	7	9
	40%	0	0	0	0	0	1	2	2	4	6	10	12
	50%	0	0	0	0	1	2	2	3	5	8	12	15
	60%	0	0	0	1	1	2	3	4	5	9	15	18
	70%	0	0	0	1	1	2	3	4	6	11	17	21
	80%	0	0	0	1	1	2	4	5	7	12	20	24
	90%	0	0	1	1	1	3	4	5	8	14	22	27
100%	0	0	1	1	1	2	3	5	6	9	15	24	30

Table C5.4 Fulmar displacement in the PFOWF Array Area + 2km buffer – spring migration.

Fulmar Dec - Mar	Mortality Level (% of displaced birds that die)												
	0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	1	1	2	3	4	6	10	16	20
	20%	0	0	1	1	2	4	6	8	12	20	32	40
	30%	0	1	1	2	2	6	9	12	18	30	48	60
	40%	0	1	2	2	3	8	12	16	24	40	64	80
	50%	0	1	2	3	4	10	15	20	30	50	80	100
	60%	0	1	2	4	5	12	18	24	36	60	96	119
	70%	0	1	3	4	6	14	21	28	42	70	111	139
	80%	0	2	3	5	6	16	24	32	48	80	127	159
	90%	0	2	4	5	7	18	27	36	54	90	143	179
100%	0	2	4	6	8	10	20	30	40	60	100	159	199

C6: Gannet

Table C6.1 Gannet displacement in the PFOWF Array Area + 2km buffer – breeding season

Gannet mid Mar-Sep		Mortality Level (% of displaced birds that die)												
		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	1	1	2	2	3	5	8	13	17
20%		0	0	1	1	1	2	3	5	7	10	17	27	33
30%		0	0	1	1	2	2	5	7	10	15	25	40	50
40%		0	1	1	2	3	3	7	10	13	20	33	53	67
50%		0	1	2	2	3	4	8	12	17	25	42	67	83
60%		0	1	2	3	4	5	10	15	20	30	50	80	100
70%		0	1	2	3	5	6	12	17	23	35	58	93	117
80%		0	1	3	4	5	7	13	20	27	40	67	107	133
90%		0	1	3	4	6	7	15	22	30	45	75	120	150
100%		0	2	3	5	7	8	17	25	33	50	83	133	166

Table C6.2 Gannet displacement in the PFOWF Array Area + 2km buffer – autumn migration

Gannet Sep-Nov	Mortality Level (% of displaced birds that die)													
	0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%	
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	
	10%	0	0	0	0	0	0	0	0	1	1	2	2	
	20%	0	0	0	0	0	0	0	1	1	2	4	5	
	30%	0	0	0	0	0	1	1	1	2	4	6	7	
	40%	0	0	0	0	0	1	1	2	3	5	8	9	
	50%	0	0	0	0	0	1	2	2	4	6	9	12	
	60%	0	0	0	0	1	1	2	3	4	7	11	14	
	70%	0	0	0	0	1	1	2	3	5	8	13	16	
	80%	0	0	0	1	1	1	2	3	4	6	9	15	19
	90%	0	0	0	1	1	1	2	3	4	6	11	17	21
100%	0	0	0	1	1	1	2	4	5	7	12	19	24	

Table C6.3 Gannet displacement in the PFOWF Array Area + 2km buffer – spring migration

Gannet Dec-Mar		Mortality Level (% of displaced birds that die)													
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%	
Displacement Level (% of all birds on-site)		0%	0	0	0	0	0	0	0	0	0	0	0	0	0
		10%	0	0	0	0	0	0	0	0	0	0	0	1	1
		20%	0	0	0	0	0	0	0	0	0	0	1	1	2
		30%	0	0	0	0	0	0	0	0	0	1	1	2	2
		40%	0	0	0	0	0	0	0	0	1	1	2	3	3
		50%	0	0	0	0	0	0	0	1	1	1	2	3	4
		60%	0	0	0	0	0	0	0	1	1	1	2	4	5
		70%	0	0	0	0	0	0	1	1	1	2	3	4	6
		80%	0	0	0	0	0	0	1	1	1	2	3	5	6
		90%	0	0	0	0	0	0	1	1	1	2	4	6	7
		100%	0	0	0	0	0	1	1	2	4	6	8		

C7: Arctic tern

Table C7.1 Arctic tern displacement in the PFOWF Array Area + 2km buffer – breeding season

Arctic tern mid Mar - Sep	Mortality Level (% of displaced birds that die)												
	0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	0	0	0	0	0	1	1	1	2	4	5
	20%	0	0	0	0	0	1	1	2	3	5	7	9
	30%	0	0	0	0	1	1	2	3	4	7	11	14
	40%	0	0	0	1	1	1	2	4	6	9	15	18
	50%	0	0	0	1	1	1	2	5	7	12	18	23
	60%	0	0	1	1	1	1	3	6	8	14	22	28
	70%	0	0	1	1	1	2	3	6	10	16	26	32
	80%	0	0	1	1	1	2	4	6	7	11	18	29
	90%	0	0	1	1	2	2	4	6	8	12	21	33
100%	0	0	1	1	2	2	5	7	9	14	23	37	46

C8: Great skua

Table C8.1 Great skua displacement in the PFOWF Array Area + 2km buffer – breeding season

Great skua mid Apr - mid Sep	Mortality Level (% of displaced birds that die)												
	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	0	0	0	0	0	1	1
20%	0	0	0	0	0	0	0	0	0	0	1	1	1
30%	0	0	0	0	0	0	0	0	0	1	1	2	2
40%	0	0	0	0	0	0	0	0	1	1	1	2	3
50%	0	0	0	0	0	0	0	1	1	1	2	3	4
60%	0	0	0	0	0	0	0	1	1	1	2	3	4
70%	0	0	0	0	0	0	0	1	1	1	2	4	5
80%	0	0	0	0	0	0	1	1	1	2	3	4	6
90%	0	0	0	0	0	0	1	1	1	2	3	5	6
100%	0	0	0	0	0	0	1	1	1	2	4	6	7