Pentland floating offshore wind farm

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Marine Ornithology: Collision Risk Modelling

PENTLAND FLOATING OFFSHORE WIND FARM

OFFSHORE EIAR (VOLUME 3): TECHNICAL APPENDICES

APPENDIX 12.3: MARINE ORNITHOLOGY – COLLISION RISK MODELLING

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7	27/07/2022	Final report

Contents

Tables

Acronyms and abbreviations

Acronyms / abbreviation	Full name
AON	Apparently Occupied Nests
BDMPS	Biologically Defined Minimum Population Scales
CRM	Collision Risk Modelling
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
HiDef	HiDef Aerial Surveying Limited
HWL	Highland Wind Limited
km	Kilometre
m	Metre
MS-LOT	Marine Scotland Licensing Operations Team
MSS	Marine Scotland Science
MW	Megawatt
NS	NatureScot
ORJIP	Offshore Renewables Joint Industry Programme
PFOWF	Pentland Floating Offshore Wind Farm
RIAA	Report to Inform the Appropriate Assessment
RPM	Revolution Per Minute
RSPB	Royal Society for Protection of Birds
s	Second
SD	Standard Deviation
SNCBs	Statutory Nature Conservation Bodies
SPA	Special Protection Area

1 Introduction

1 This Technical Appendix supports the assessment of collision impacts undertaken for the Pentland Floating Offshore Wind Farm (PFOWF) Array and the 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 approach and methodology for Collision Risk Modelling (CRM), all of which has been adopted for assessment as reported in this Technical Appendix.

2 Collision is a possible impact from offshore wind farm developments whereby birds may be injured or killed by a collision with turbines and/or rotor blades. Band (2012) provides a consistent and quantitative method for assessing offshore collision risk, estimating the likelihood that a bird entering the 'risk window', the sweep of the turbine blades, could be struck. The model assumes a strike equates to mortality. The methodology for CRM is further discussed in Section 2.1.

3 The calculation within CRM assumes that birds do not take avoiding action, and this is instead factored in subsequently, by applying an agreed avoidance rate. The avoidance rate accounts for changes in bird behaviour to avoid being struck, whether this is by avoiding the wind farm completely (macro-avoidance) or altering their flight path within the wind farm footprint (meso- and micro-avoidance).

4 Furness *et al.* (2013) consider the sensitivities of key seabird species to collision risk. The following species recorded during digital aerial surveys in the PFOWF Array Area[1] (Technical Appendix 12.1 Marine Ornithology: Baseline Data) may be subject to this risk:

- Black-legged kittiwake (*Rissa tridactyla*), hereafter 'kittiwake';
- Northern fulmar (*Fulmarus glacialis*), hereafter 'fulmar';
- Northern gannet (*Morus bassanus*); hereafter 'gannet'
- Arctic tern (*Sterna paradisaea*);
- Great black-backed gull (*Larus marinus*);
- Great skua (*Stercorarius skua*); and
- Herring gull *(Larus argentatus*).

5 This appendix presents the input parameters and outputs for CRM using deterministic Band (2012). Input parameters are discussed and presented in Section 2, and the outputs for each species are presented in Section 3. Monthly input densities of flying birds are discussed in Section 2.2.4 and presented in Annex A: CRM input densities and model outputs.

6 Marine Scotland Science (MSS) and NatureScot (NS) have confirmed that they would like deterministic CRM undertaken for the Offshore Development (email dated 31 March

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

2022). Therefore, CRM has been undertaken using the Band (2012) spreadsheets, which provide the same outputs as would be given by the "bandcrm()" function in the stochLAB package (https://github.com/HiDef-Aerial-Surveying/stochLAB) in program R. Outputs are presented in Annex A: CRM input densities and model outputs, and copies of the working spreadsheets can be provided on request.

2 Methods

2.1 Band (2012) spreadsheets

7 The Band (2012) spreadsheets are a deterministic version of the CRM, modelled in Excel using macros and cell-to-cell calculations. The overall approach to CRM is described in Band (2012) and summarised as follows:

- **Step 1.** Assemble data on the number of flights which, in the absence of birds being displaced or taking other avoiding action, or being attracted to the wind farm, are potentially at risk from wind farm turbines.
- **Step 2.** Use this flight activity data to estimate the potential number of bird transits through the turbine rotors.
- **Step 3.** Calculate the probability of collision during a single bird rotor transit.
- **Step 4.** Multiply these to yield the potential collision mortality rate for the bird species in question, allowing for the proportion of time that turbines are not operational, assuming current bird use of the site and that no avoiding action is taken.
- **Step 5.** Allow for the proportion of birds likely to avoid the turbine, either because they have been displaced around it or because they take evasive action; and allow for any attraction.

8 The spreadsheets undertake the calculations for Steps 2-5 using the following input parameters.

2.2 Input parameters

9 The input parameters used in the CRM for the Offshore Development are detailed below. These include details on the turbine scenario, turbine operation, seabird biometric information, mean and maximum densities for each species recorded during digital video aerial survey work, model option and avoidance rates.

2.2.1 Turbine scenario

10 Two turbine scenarios have been modelled for the Offshore Development as set out below with the input parameters presented in Table 1:

- 'Worst case' for CRM (and 'most likely' to be developed); seven 14 MW turbines, a maximum rotor swept area of 316,673 m^2.
- Minimum number of turbines at maximum height; five 18 MW turbines, a maximum rotor swept area of 265,465 m^2.

11 Whilst the exact model and number of turbines as not yet been decided modelling these two scenarios will allow any configuration of turbines up to the maximum of seven to be deployed with the total combined maximum rotor swept area not to exceed 316,673 m^2, as well as the other maximum values shown in Table 1. Undertaking CRM for these two scenarios ensures that the worst case for collision risk has been assessed, as well as allowing for context. Please note that the generating capacity of the turbines has no bearing on the model, and therefore does not function as a maximum parameter.

Table 1 The PFOWF Array Area turbine parameter values

Parameter	Turbine scenario	
	14 MW	**18 MW***
Latitude (degrees)	58°39'21.50"N	
Windfarm width (km)	2.5 (east-west)	
Tidal offset (m)	n/a (floating wind farm)	
No. turbines	7	5
No. blades	3	3
Rotor radius (m)	120	130
Air gap (m)	35	35
Max. blade width (m)	9	10
Rotation speed (RPM)	10	10
Pitch (degrees)	10	10
Max rotor swept area (m^2)	316,673	265,465
Estimate of turbine downtime / operational time (%)	5 / 95	5 / 95

**CRM has been undertaken for the five 18 MW turbines for context and the model outputs for this scenario are presented for information only, not taken forward into assessment. In this regard, assessment is based on the worst case (that being the largest rotor swept area) for collision risk resulting from seven turbines with a rotor radius of 120 m.*

12 HWL has committed to a 35 m air gap between the lowest sweep of the rotor blades and the sea. This acts as embedded mitigation, as set out in Section 12.4.9 of the Offshore EIAR (Volume 2) Chapter 12: Marine Ornithology.

2.2.2 Turbine operation

13 The turbine is assumed to be operational 95% of the time to allow for downtime due to wind speed (either too low or too high for effective turbine operation) and maintenance activities (either scheduled or unscheduled).

2.2.3 Seabird parameters

14 CRM uses agreed seabird parameters taken from Pennycuick (1997), Alerstam *et al.* (2007) and Furness *et al.* (2018); as advised by MSS and NS. According to general practice, gliding flight has been used for gannet and flapping flight for all other species. These seabird parameters are presented in Table 2.

Table 2 Seabird biometric and behavioural input parameters for CRM

Species	Body length (m)	Wingspan (m)	Flight speed (m/s^{-1})	Nocturnal activity factor	Flight type (flapping or gliding)
Kittiwake	0.39	1.08	13.1	2.00	Flapping
Fulmar	0.48	1.07	13.0	4.00	Flapping
Gannet	0.94	1.72	14.9	1.32	Gliding
Arctic tern	0.34	0.80	10.9	2.00	Flapping
Great black-backed gull	0.71	1.58	13.7	3.00	Flapping
Great skua	0.56	1.36	14.9	1.00	Flapping
Herring gull	0.60	1.44	12.8	3.00	Flapping

15 Note that the flight speeds used for the CRM (Pennycuick, 1997 and Alerstam *et al.*, 2007) are subject to uncertainty as they are based on very small sample sizes, ranging from two (kittiwake) to 32 (gannet). Moreover, bird flight speeds are highly variable and dependent on environmental factors, most notably wind direction. Recent work at the Thanet Offshore wind farm (Skov *et al.*, 2018) has provided flight speed estimates for some of these species (sample sizes provided in brackets): 13.33 m/s for gannet (n=683); 8.71 m/s for kittiwake (n=287); and 9.80 m/s for herring and great black-backed gulls (n=790). These numbers are based on much larger sample sizes, so are more robust estimates. The use of the values advised by MSS and NS therefore represent a high level of precaution; as highlighted by Scottish Ministers in their appropriate assessment for Moray West (Scottish Ministers, 2019). There is ongoing work to try and improve estimates of bird flight speed particularly for use in CRM (e.g., Skov *et al.*, 2018), but at present the values given in Table 2 are the ones advised for use by MSS and NS.

2.2.4 Seabird monthly densities

16 CRM also requires an estimate of seabird flight activity within the PFOWF Array Area; in this regard, monthly mean and monthly maximum densities of flying seabirds across the two years of digital aerial surveys have been calculated, as presented in Annex A: CRM input densities and model outputs. Standard Deviations (SDs) are also calculated to give a measure of the variability in the density estimates and are included in Annex A. However, it is not possible to use the SDs around the density estimates when undertaking CRM using the deterministic Band (2012) spreadsheets.

2.2.5 Model option

17 Band (2012) includes basic and extended offshore CRM models:

- **Basic** – this assumes a uniform distribution of bird flight heights in the collision 'risk window' between the lowest and highest levels of the rotors.
- **Extended** – this accounts for the actual flight height distribution of the birds which, for most seabirds, is skewed towards lower heights above the sea surface. Flying at such heights means that where birds are present within the 'risk window' they are skewed towards the lower extremities of the turbine blades i.e., there is not a uniform distribution. The extended model takes account of this skewed distribution and may better reflect the potential risk.

18 There are two further options for each of the basic and extended models, depending on the flight height data used (as discussed in Section 2.2.6):

- **Option 1** – uses the basic model with proportion of birds at risk height derived from site survey data.
- **Option 2** – uses the basic model with proportion of birds at risk height derived from generic flight height data.
- **Option 3** – uses the extended model with proportion of birds at risk height derived from generic flight height data.
- **Option 4** – uses the extended model with proportion of birds at risk height derived from site survey data of birds.

19 NS (in the Scoping Opinion) request CRM outputs for model options 2 and 3, for 'worst case' and 'most likely' turbine scenarios; for the Offshore Development these scenarios are one and the same, the seven 14 MW turbines (Table 1). For context, CRM has also been undertaken for the five 18 MW turbines but the model outputs for this scenario are presented for information only and not taken forward in the assessment.

20 Model outputs for each scenario, the monthly collision estimates for each species, are presented in Annex A: CRM input densities and model outputs. The model outputs for the seven 14 MW turbine (worst case / most likely) scenario are then summarised by season and presented in Section 3, Results. Kittiwake, fulmar, gannet, Arctic tern and great skua have been modelled using the basic model, option 2. Great black-backed gull and herring gull have been modelled using the extended model, option 3.

2.2.6 Seabird flight heights

21 Options 1 and 4 of the Band collision risk models require site-specific flight height data. HiDef Aerial Surveying Limited (HiDef) have been developing an approach to determining the flight heights of flying birds recorded during their digital video aerial surveys. This uses a photogrammetry method whereby the lengths of birds at height are compared to lengths of reference samples near the sea surface to calculate possible flight heights. The method has been shared with MSS, NS and the Royal Society for the Protection of Birds (RSPB) Scotland for their consideration, with a manuscript currently in the process of being peer-reviewed for publication (Humphries *et al.* (in review)). As neither Option 1 or 4 are requested in the Scoping Opinion (Marine Scotland Licensing Operations (MS-LOT), 2021), this site-specific flight height analysis has not been carried out.

22 Generic flight height data has been collated and analysed by Johnston *et al.* (2014) and are required for option 2 and option 3 of CRM. The data are derived from boat-based surveys, pooled from 32 sites in the North, Baltic and Irish Seas and from predominantly coastal areas. The data were collected monthly over 15 years between 1998 and 2012, providing a larger pool of information from which to derive flight heights compared to a single site. The data were modelled to produce a continuous flight height distribution in one metre bands, from 0-300 m. The flight height of a single bird is estimated by the observer with uncertainty, and this modelling approach takes the uncertainty in individual flight height estimates into account. This improves the accuracy of the estimated flight height distribution when compared with individual birds categorised into height bands.

2.2.7 Avoidance rates

23 The Statutory Nature Conservation Bodies (SNCBs) provided advice on CRM avoidance rates in response to the Cook *et al.* (2014) report (SNCB, 2014). These rates have been adopted for use in assessment as presented in Table 3 below. Collision mortality estimates for these avoidance rates (and including RSPB Scotland's recommendation of 0.98 for gannet) are presented in Annex A: CRM input densities and model outputs.

Table 3 CRM avoidance rates (+/- 2 SD) taken from SNCB (2014)

Species	SNCB advice	
	Option 2	Option 3
Kittiwake	0.989 *(0.987–0.991)*	-
Fulmar	0.980 *(0.978–0.982)*	-
Gannet	0.989 *(0.987–0.991)*	-
Arctic tern	0.980 *(0.978–0.982)*	-
Great black-backed gull	-	0.989 *(0.987–0.991)*
Great skua	0.980 *(0.978–0.982)*	-
Herring gull	-	0.990 *(0.988–0.992)*

24 Note that the avoidance rates in Table 3 can be regarded as precautionary, as is evidenced by a subsequent report by Bowgen & Cook (2018) using data from a two-year Bird Collision Avoidance Study funded by ORJIP (Offshore Renewables Joint Industry Programme) to inform their analysis. They found that for the 'basic' Band model (options 1 & 2), avoidance rates of 0.995 and 0.990 were more appropriate for gannet and kittiwake respectively, while for the 'extended' Band model (option 3) 0.993 was more appropriate

for large gulls. The authors concluded that even using these higher rates of avoidance, there is still precaution in the estimated collision mortalities. The precautionary nature of avoidance rates was another factor noted by Scottish Ministers in their appropriate assessment for Moray West (Scottish Ministers, 2019).

3 Results

25 Collision mortality estimates for each species (Tables 4 -10) are presented by season, based on the breeding seasons defined by NatureScot (2020) and the non-breeding seasons defined by Furness (2015). There is some overlap between these advised seasons so where this makes a difference to assessment (i.e., to the seasonal CRM totals provided), the mortality estimates for the overlapping month are preferentially assigned to the breeding season. Where it has been necessary to do this, the fact is noted in the species summary.

26 In the following summaries, the collision mortality estimates are provided for 'all birds' i.e., all birds are assumed to be adults, as advised by NS in the Scoping Opinion.

27 This seasonal summary of collision mortality estimates is provided for the worst case scenario, based on the scenario of seven 14 MW turbines (maximum rotor swept area of 316,673 m^2). These are the mortality estimates taken forward for assessment in the Offshore EIA (Volume 2) Chapter 12: Marine Ornithology and apportioned to relevant Special Protection Areas (SPAs) in Section 4 below, Discussion and Conclusions. The outputs for the 18 MW scenario are included for context in Annex A.

3.1 Kittiwake

28 For kittiwake, seasonal collision mortalities are presented in Table 4, based on the CRM basic model, option 2. The estimated collision mortalities in August are assigned to the breeding season as advised in paragraph 25.

Table 4 Kittiwake seasonal collision mortalities each year (numbers of birds), model option 2

Kittiwake collision mortalities	Breeding season (NatureScot)	Biologically Defined Minimum Population Scales (BDMPS)		
		autumn migration	non-breeding	spring migration
	Apr - Aug	Aug - Dec	n/a	Jan - Apr
CRM mean density	7	1	n/a	0
CRM max density	12	3	n/a	0

3.2 Fulmar

29 For fulmar, seasonal collision mortalities are presented in Table 5, based on the CRM basic model, option 2.

Table 5 Fulmar seasonal collision mortalities each year (numbers of birds), model option 2

Fulmar collision mortalities	Breeding season (NatureScot)	BDMPS		
		autumn migration	non-breeding	spring migration
	Apr - mid Sep	Sep - Oct	Nov	Dec - Mar
CRM mean/max densities	0	0	0	0

3.3 Gannet

30 For gannet, seasonal collision mortalities are presented in Table 6, based on the CRM basic model, option 2. The estimated collision mortalities in September are assigned to the breeding season as advised in paragraph 23.

Table 6 Gannet seasonal collision mortalities each year (numbers of birds), model option 2

Gannet collision mortalities	Breeding season (NatureScot)	BDMPS		
		autumn migration	non-breeding	spring migration
	mid-March - Sep	Sep - Nov	n/a	Dec - Mar
CRM mean density	2	0	n/a	0
CRM max density	4	0	n/a	0

3.4 Arctic tern

31 For Arctic tern, seasonal collision mortalities are presented in Table 7, based on the CRM basic model, option 2.

Table 7 Arctic tern seasonal collision mortalities each year (numbers of birds), model option 2

Arctic tern collision mortalities	Breeding season (NatureScot)	BDMPS		
		autumn migration	non-breeding	spring migration
	May - Aug	Jul - mid Sep	mid Aug - Apr	Apr - May
CRM mean/max densities	0	0	0	0

3.5 Great black-backed gull

32 For great black-backed gull, seasonal collision mortalities are presented in Table 8, based on the CRM extended model, option 3.

Table 8 Great black-backed gull seasonal collision mortalities each year (number of birds), model option 3

Great black-backed gull collision mortalities	Breeding season (NatureScot)	BDMPS		
		autumn migration	non-breeding	spring migration
	Apr - Aug	n/a	Sep - Mar	n/a
CRM mean density	0	n/a	0	n/a
CRM max density	0	n/a	3	n/a

3.6 Great skua

33 For great skua, seasonal collision mortalities are presented in Table 9, based on the CRM basic model, option 2.

Table 9 Great skua seasonal collision mortalities each year (numbers of birds), model option 2

Great skua collision mortalities	Breeding season (NatureScot)	BDMPS		
		autumn migration	non-breeding	spring migration
	mid Apr – mid Sep	Aug - Oct	Nov - Feb	Mar - Apr
CRM mean/max densities	0	0	0	0

3.7 Herring gull

34 For herring gull, seasonal collision mortalities are presented in Table 10, based on the CRM extended model, option 3.

Table 10 Herring gull seasonal collision mortalities each year (numbers of birds), model option 3

Herring gull collision mortalities	Breeding season (NatureScot)	BDMPS		
		autumn migration	non-breeding	spring migration
	Apr - Aug	n/a	Sep-Feb	n/a
CRM mean/max densities	0	n/a	0	n/a

4 Discussion and Conclusions

35 Significance of the total estimated collision mortalities for each season and each species (as set out in Section 3, Results) is considered under Environmental Impact Assessment (EIA) in Section 12.6.2.1 of the Offshore EIAR (Volume 2) Chapter 12: Marine Ornithology. In the species summaries below the estimated collision mortalities are apportioned between key SPAs (Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning). These SPA impacts, including any cumulative / 'in combination' impacts against each SPA, are addressed in the RIAA.

4.1 Kittiwake

36 The estimated breeding season collision mortality for kittiwake is apportioned between the key SPA breeding colonies using the weightings derived from the MSS apportioning tool (Technical Appendix 12.2: Marine Ornithology: Connectivity and Apportioning) as presented in Table 11.

Table 11 Kittiwake apportioned breeding season collision mortalities

SPA	Impact weighting (MSS tool)	Most recent population count (AON*)	Apportioned breeding season collision mortalities	
			Mean density	Max density
North Caithness Cliffs	0.717	5,568	5.02	8.60
East Caithness Cliffs	0.080	24,460	0.56	0.96
West Westray	0.063	2,755	0.44	0.76
Cape Wrath	0.025	3,622	0.18	0.30
Marwick Head	0.025	1,812	0.18	0.30

**AON: Apparently Occupied Nests*

37 In the non-breeding season, the estimated kittiwake collision mortalities for autumn migration are:

- one bird for mean density inputs
- three birds for maximum density outputs

38 There are zero mortalities (either mean or maximum densities) during spring migration. Non-breeding season apportioning has been undertaken for kittiwake at North Caithness Cliffs SPA using the weightings derived from the BDMPS report, a value of 0.023, as set out in Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning. This gives further collision mortalities of 0.02 birds (mean densities) and 0.07 birds (maximum densities) to assign against the SPA in addition to breeding season impacts.

39 Kittiwake collision mortalities at North Caithness Cliffs SPA are considered for the Offshore Development alone and in combination with other relevant development, as set out in the RIAA.

40 Population viability analysis (PVA) has been undertaken to model the population consequences of these collision mortalities at the SPA, as reported in Technical Appendix 12.5 Marine Ornithology: Population Modelling.

41 Further consideration of the significance of impacts for the North Caithness Cliffs SPA kittiwake population is given in the RIAA. Estimated impacts are so low against the other SPAs in Table 11 that no non-breeding apportioning has been undertaken in this regard. Consideration of the significance of these impacts against the other SPA kittiwake populations is also given in the RIAA.

4.2 Fulmar

42 There are zero estimated collision mortalities in either the breeding or the non-breeding season, therefore there is no further consideration of collision risk in respect of fulmar.

4.3 Gannet

43 The estimated breeding season collision mortalities for gannet (mean and max densities) 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 12.

Table 12 Gannet apportioned breeding season collision mortalities

SPA	Impact weighting (NS)	Most recent population count (individuals)	Apportioned breeding season collision mortalities	
			Mean density	Max density
Sule Skerry / Sule Stack	0.527	18,130	1.05	2.10
Forth Islands	0.111	150,518	0.22	0.44
St Kilda	0.105	120,580	0.21	0.84
North Rona / Sula Sgeir	0.102	22,460	0.20	0.41
Hermaness / Saxa Vord / Valla Field	0.041	51,160	0.08	0.16
Noss	0.035	27,530	0.07	0.14
Troup / Pennan / Lion`s Heads (Site of Special Scientific Interest feature)	0.029	9,650	0.06	0.12
Fair Isle	0.027	9,942	0.05	0.11

44 In the non-breeding season, there are zero estimated collision mortalities of gannet, so this matter is not considered further.

4.4 Arctic tern

45 Arctic terns were only recorded in the PFOWF Array Area in June and July at minimal densities. Zero collision mortalities have therefore been estimated for Arctic tern and no further consideration is required for this species in respect of collision risk.

4.5 Great black-backed gull

46 Up to three collision mortalities have been estimated for great black-backed gull during the non-breeding season (using maximum densities). These impacts are considered against a BDMPS population of 91,399 birds (Section 12.4.4.8, Offshore EIAR (Volume 2) Chapter 12: Marine Ornithology) and determined to be not significant.

4.6 Great skua

47 Great skua were only recorded in the PFOWF Array Area during the breeding season at minimal densities. Zero collision mortalities have therefore been estimated for great skua and no further consideration is required for this species in respect of collision risk.

4.7 Herring gull

48 Herring gull were only recorded in the PFOWF Array Area during October at a minimal density. Zero collision mortalities have therefore been estimated for herring gull and no further consideration is required for this species in respect of collision risk.

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Annex A CRM input densities and model outputs

The standard deviation of the density is calculated by way of a blocked bootstrap where transects of a survey are randomly sampled with replacement. These values represent the dispersion of the mean densities of the transects around the monthly mean that is used for generation of a population estimate.

A1: Kittiwake

Table A1.1 Kittiwake flying bird densities

Monthly densities (n/km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly mean	0.11	0.31	0.57	0.10	0.30	5.17	3.15	0.50	0.11	0.40	2.01	0
Standard deviation	*0.20*	*0.40*	*0.29*	*0.20*	*0.07*	*1.93*	*1.13*	*0.29*	*0.14*	*0.60*	*1.11*	*0*
Monthly max	0.29	0.57	0.98	0.25	0.36	8.10	4.95	0.83	0.24	0.97	3.02	0

Table A1.2 Kittiwake CRM model option 2 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
14 MW	Mean density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	4 *(4-5)*	3 *(2-3)*	0 *(0)*	0 *(0)*	0 *(0)*	1 *(1-1)*	0 *(0)*
14 MW	Max density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	1 *(1-1)*	0 *(0)*	0 *(0-0)*	7 *(7-8)*	4 *(4-5)*	1 *(1-1)*	0 *(0)*	1 *(0-1)*	2 *(1-2)*	0 *(0)*
18 MW	Mean density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	4 *(3-4)*	2 *(2-3)*	0 *(0)*	0 *(0)*	0 *(0)*	1 *(1-1)*	0 *(0)*
18 MW	Max density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	1 *(0-1)*	0 *(0)*	0 *(0)*	6 *(5-7)*	3 *(3-4)*	1 *(0-1)*	0 *(0)*	0 *(0-1)*	1 *(1-2)*	0 *(0)*

A2: Fulmar

Table A2.1 Fulmar monthly mean input flying bird densities

Monthly densities (n/km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	2.02	1.12	3.19	0.58	0.90	0.19	0.10	0.89	0.63	0	0.41	0
Standard deviation	*1.15*	*0.49*	*0.88*	*0.40*	*0.64*	*0.35*	*0.20*	*0.52*	*0.42*	*0*	*0.4*	*0*
Monthly max	3.62	1.77	4.52	0.92	1.76	0.58	0.25	1.45	1.21	0	0.77	0

Table A2.2 Fulmar CRM model option 2 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
14 MW	Mean density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
14 MW	Max density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
18 MW	Mean density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
18 MW	Max density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*

A3: Gannet

Table A3.1 Gannet monthly mean input flying bird densities

Monthly densities (n/km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	0	0	0.10	0	0	0.07	0	1.09	2.24	0.11	0	0
Standard deviation	*0*	*0*	*0.20*	*0*	*0*	*0*	*0*	*0.78*	*1.15*	*0.14*	*0*	*0*
Monthly max	0	0	0.30	0	0	0.20	0	2.33	3.53	0.25	0	0

Table A3.2 Gannet CRM model option 2 mortality estimates

Scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
14 MW	Mean density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	1 *(1-1)*	1 *(1-2)*	0 *(0)*	0 *(0)*	0 *(0)*
14 MW	Mean density CRM mortalities with 0.98 avoidance rate	0	0	0	0	0	0	0	1	3	0	0	0
14 MW	Max density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	2 *(1-2)*	2 *(2-3)*	0 *(0)*	0 *(0)*	0 *(0)*
14 MW	Max density CRM mortalities with 0.98 avoidance rate	0	0	0	0	0	0	0	3	4	0	0	0
18 MW	Mean density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	1 *(1-1)*	1 *(1-1)*	0 *(0)*	0 *(0)*	0 *(0)*
18 MW	Mean density CRM mortalities with 0.98 avoidance rate	0	0	0	0	0	0	0	1	2	0	0	0
18 MW	Max density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	1 *(1-2)*	2 *(1-2)*	0 *(0)*	0 *(0)*	0 *(0)*
18 MW	Max density CRM mortalities with 0.98 avoidance rate	0	0	0	0	0	0	0	3	3	0	0	0

A4: Arctic tern

Table A4.1 Arctic tern monthly mean input flying bird densities

Monthly densities (n/km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	0	0	0	0	0	0.34	0.21	0	0	0	0	0
Standard deviation	*0*	*0*	*0*	*0*	*0*	*0.21*	*0.30*	*0*	*0*	*0*	*0*	*0*
Monthly max	0	0	0	0	0	0.52	0.49	0	0	0	0	0

Table A4.2 Arctic tern model option 2 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
14 MW	Mean density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
14 MW	Max density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
18 MW	Mean density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
18 MW	Max density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*

A5: Great black-backed gull

Table A5.1 Great black-backed gull monthly mean input flying bird densities

Monthly densities (n/km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	0.43	0.10	0.21	0	0	0	0	0	0	0	0.11	0.31
Standard deviation	*0.29*	*0.20*	*0.40*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0.14*	*0.25*
Monthly max	0.77	0.25	0.61	0	0	0	0	0	0	0	0.36	0.52

Table A5.2 Great black-backed gull option 3 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
14 MW	Mean density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0-1)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
14 MW	Max density CRM mortalities *(+/- 0.2% avoidance)*	1 *(1-1)*	0 *(0)*	1 *(1-1)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	1 *(0-1)*
18 MW	Mean density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
18 MW	Max density CRM mortalities *(+/- 0.2% avoidance)*	1 *(1-1)*	0 *(0)*	1 *(0-1)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0-1)*

A6: Great skua

Table A6.1 Great skua monthly mean input flying bird densities

Monthly densities (n/km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	0	0	0	0	0.11	0.07	0	0	0	0	0	0
Standard deviation	*0*	*0*	*0*	*0*	*0.20*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Monthly max	0	0	0	0	0.24	0.16	0	0	0	0	0	0

Table A6.2 Great skua option 2 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
14 MW	Mean density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
14 MW	Max density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
18 MW	Mean density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
18 MW	Max density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*

A7: Herring gull

Table A7.1 Herring gull monthly mean input flying bird densities

Monthly densities (n/km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	0	0	0	0	0	0	0	0	0	0.10	0	0
Standard deviation	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0.20*	*0*	*0*
Monthly max	0	0	0	0	0	0	0	0	0	0.24	0	0

Table A7.2 Herring gull option 3 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
14 MW	Mean density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
14 MW	Max density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
18 MW	Mean density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
18 MW	Max density CRM mortalities *(+/- 0.2% avoidance)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*