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Erebus: Offshore Ornithology 11.3 Technical Appendix - Collision Risk Modelling

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1 Introduction

1 Offshore windfarms may have a number of effects on bird populations:

- Displacement – birds may partially or totally avoid a windfarm and hence be displaced from the underlying habitat.
- Barrier effects – birds may use more circuitous routes to fly between, for example, breeding and foraging grounds, and thus use up more energy to acquire food.
- Habitat effects – birds may be attracted or displaced by changes in marine habitats and prey abundance as a consequence of the windfarm.
- Collision risk – birds may be injured or killed by an encounter or collision with turbines or rotor blades.

2 This Technical Appendix focuses on the last of these and provides a quantification of the impact for consideration in the Environmental Statement (ES) Volume 1, Chapter 11: Offshore Ornithology and in Volume 3, Technical Appendix 8.3: Report to Inform Appropriate Assessment.

3 Furness *et al.* (2013) consider the sensitivities of key seabird species to these effects and come up with a ranking that we have used to identify the species of concern at Erebus (hereafter 'the Project') that may be subject to collision risk. These species are:

- Gannet *Morus bassanus*
- Kittiwake *Rissa tridactyla*
- Lesser black-backed gull *Larus fuscus*
- Great black-backed gull *Larus marinus*
- Herring gull *Larus argentatus*
- Manx shearwater *Puffinus puffinus*
- Guillemot *Uria aalge*

4 Collision risk modelling provides a consistent and quantitative method for estimating the risk that a bird entering the 'risk window', the sweep of the turbine blades, could be struck. As such it assumes no avoiding action, and this is factored in subsequently using an agreed avoidance rate. Birds will take avoiding action to avoid being struck, whether this is avoiding the wind farm completely (macro-avoidance) or altering their flight path in proximity to the turbine blades (meso and micro-avoidance).

5 There are limitations to the modelling but it provides a standard approach to estimating relative risk to the seabird species of concern.

6 This report presents the input parameters and outputs for collision risk modelling using the R-code from the stochastic collision risk model shiny app. A copy of the code can be made available on request. The outputs have been manually checked for gannet and for kittiwake and confirmed to be correct.

2 Methods

2.1 Stochastic collision risk model

7 The stochastic collision risk model (sCRM) (McGregor *et al.*, 2018) builds on the previous Band model (2012) for offshore wind farms and incorporates a measure of uncertainty and variability within the input parameters. It estimates the risk of birds entering the proposed wind farm site and colliding with the turbine blades.

2.2 Input parameters

8 The input parameters used in the collision risk modelling (CRM) are detailed below. These include details on turbine scenario, turbine operation, seabird biometric information, mean densities for each species recorded during digital aerial survey work, model option and avoidance rates.

2.2.1 Turbine scenarios

9 The applicant has provided three scenarios for modelling: a ten turbine (9.5 MW), seven turbine (14 MW) and six turbine (16-18 MW) scenario. The parameters for each scenario are presented in Table 1.

Table 1. Parameter values used in the stochastic CRM for each turbine scenario

Parameter	Turbine scenario		
	9.5 MW	14 MW	16-18 MW
Latitude (degrees)	51.4	51.4	51.4
Windfarm width (km)	7	7	7
Tidal offset (m)	0	0	0
No. turbines	10	7	6
No. blades	3	3	3
Rotor radius (m)	87	111	121
Air gap (m)	22	22	22
Max. blade width (m)	5.8	5.8	5.8
Upper blade height (m)	196	244	270
Rotation speed (rpm)	9.9	9.9	9.9
Pitch (degrees)	2	2	2

10 Appendix 11.3A presents the full outputs for each turbine scenario. The summary of seasonal collision mortalities uses the outputs for the 'most realistic' turbine scenario, which is the seven 14MW turbine scenario; identified by the applicant as most likely to be developed.

2.2.2 Turbine operation

11 The turbines are not operational 100% of the time and there is turbine downtime due to wind speed (either too low or too high for effective turbine operation) and maintenance activities (either scheduled or unscheduled). These aspects are quantified in Table 2 and taken account of in the collision risk modelling.

12 In Table 2, item 1 refers to downtime when wind is <3 m/s, and item 2 refers to downtime when wind is >28 m/s. Items 3 and 4 refer to anticipated downtime hours due to scheduled (item 3) and unscheduled (item 4) turbine maintenance.

Table 2. Proposed operational hours of turbines for each month, percentage of available hours operational and downtime.

Month	Downtime hours				Total downtime hours	Hours in month	% of time operational	Overall % downtime
	Item 1	Item 2	Item 3	Item 4				
Jan	23.0	5.2	0	12	40.2	744	99.95	0.05
Feb	22.7	4.5	0	12	39.2	672	99.94	0.06
Mar	37.1	1.3	0	12	50.4	744	99.93	0.07
Apr	55.9	0.4	0	12	68.3	720	99.91	0.09
May	62.5	0	10	12	84.5	744	99.89	0.11
Jun	68.6	0	10	12	90.6	720	99.87	0.13
Jul	65.4	0	10	12	87.4	744	99.88	0.12
Aug	62.2	0	10	12	84.2	744	99.89	0.11
Sep	44.8	0.2	0	12	57.0	720	99.92	0.08
Oct	29.3	2.2	0	12	43.5	744	99.94	0.06
Nov	26.1	1.8	0	12	39.9	720	99.94	0.06
Dec	20.3	5.5	0	12	37.8	744	99.95	0.05

2.2.3 Seabird parameters

13 The sCRM uses agreed seabird parameters taken from Pennycuick (1997); Alerstam *et al.* (2007) and Furness *et al.* (2018). In Table 3, body length, wingspan and flight speed are the generic values used in the sCRM (McGregor *et al.*, 2018), with the exception of flight speed for gannet and for Manx shearwater where it has been calculated from site specific tracking data as discussed in section 11.4.5 of Chapter 11: Offshore Ornithology (Davies *et al.*, 2021; Langley and Votier, 2021).

Table 3. Biometric and behavioural input parameters for each species

Species	Body length (m)	Wingspan (m)	Flight speed (m/sec)	Nocturnal activity	Flight type (flapping – worst case or gliding)
Gannet	0.935	1.73	13.1	0	Flapping
Kittiwake	0.39	1.08	13.1	0.25	Flapping
Lesser black backed gull	0.58	1.43	12.8	0.5	Flapping
Great black-backed gull	0.71	1.58	13.7	0.5	Flapping
Herring gull	0.595	1.44	12.8	0.5	Flapping
Manx shearwater	0.34	0.83	9.4	0.5	Flapping
Guillemot	0.395	0.67	19.1	0.25	Flapping

2.2.4 Seabird monthly densities

14 For CRM the input data required are monthly means of the densities of flying seabirds. The densities are calculated as the monthly means across the two years of survey work – see Appendix 11.3A of this report for the values used in assessment for each species. The estimates include a measure of uncertainty, the standard deviation, which is inputted to the model. The values presented in Appendix 11.3A are calculated from the full list of monthly densities and standard deviations for each species given in Volume 3, Technical Appendix 11.1: Baseline Data.

2.2.5 Model option

15 sCRM model option 1 uses site-specific data on flight height. The proportion of birds flying at collision risk height was calculated from the digital aerial survey data using HiDef's flight height analysis tool – see section 2.2.3 Flight height analysis of Volume 3, Technical Appendix 11.1: Baseline Data. This information is presented in Table 4 for each turbine scenario and species; with the exception of Manx shearwater and guillemot (where flight height could not be estimated using the HiDef analysis tool).

Table 4. Site-specific proportion of birds flying at collision risk height

Species	9.5 MW	14 MW	16-18 MW
	22-196m	22-244m	22-270m
Gannet	0.593	0.593	0.593
Kittiwake	0.488	0.488	0.488
Herring gull	0.6	0.6	0.6
Lesser black backed gull	0.667	0.722	0.772
Great black-backed gull	0.333	0.333	0.333
Manx shearwater	n/a	n/a	n/a
Guillemot	n/a	n/a	n/a

16 sCRM model option 2 uses the generic flight height data collated in Johnston *et al.* (2014) from a range of wind farm sites around the UK.

2.2.6 Avoidance rates

17 Following advice from Natural Resources Wales (NRW), email dated 22nd October 2021, the avoidance rates presented in SNCB guidance have been used (SNCB 2014). For the sCRM, variance around the choice of avoidance rate is captured by the model and reported in the measure of the standard deviation.

Table 5. CRM avoidance rates for each species modelled

Species	SNCB advice	
	Option 1	Option 2
Gannet	0.989	0.989
Kittiwake	0.989	0.989
Herring gull	0.995	0.995
Lesser black backed gull	0.995	0.995
Great black-backed gull	0.995	0.995
Manx shearwater	n/a	0.98
Guillemot	n/a	0.98

3 Results

18 sCRM realistic worst-case mortality estimates are presented by season, based on seasons defined in Furness (2015), giving a migration free breeding season and biologically defined minimum population scales (BDMPS) for the non-breeding season.

19 Seasonal standard deviations are calculated by squaring the monthly estimates of standard deviation (as presented in Appendix 11.3A for each species) to obtain the variance, summing these variances together and then taking the square root of the summed total.

3.1 Gannet

20 For gannet, seasonal collision mortalities are presented for the seven 14 MW (most realistic) turbine scenario and model option 1 of the CRM which uses site-specific flight height data (worst case). Data are presented as seasonal totals (the sum of the monthly mortality estimates) with the associated standard deviation. This gives an indication of the uncertainty around the estimates and can be used for any population modelling required. Full collision risk outputs are presented in Appendix 11.3A for each turbine scenario and model option. As a 'worst case' all birds are assumed to be adults and are not apportioned by age class.

Table 6. Gannet seasonal collision mortalities (numbers of birds)

Gannet collision mortalities	Migration free breeding season	BDMPS		
		autumn migration	non-breeding	spring migration
	Apr - Aug	Sep - Nov	n/a	Dec - Mar
Seasonal mortality	87.80	13.70	n/a	13.62
Standard deviation	25.46	6.45	n/a	4.51

3.2 Kittiwake

21 For kittiwake, seasonal collision mortalities are presented for the seven 14 MW (most realistic) turbine scenario and model option 1 of the sCRM which uses site-specific flight height data (worst case). Data are presented for the seasonal totals (sum of the monthly mortality estimates) and their associated seasonal standard deviation. Full collision risk outputs are presented in Appendix 11.3A for each turbine scenario and model option. As a 'worst case' all birds are assumed to be adults and are not apportioned by age class.

Table 7. Kittiwake seasonal collision mortalities (numbers of birds)

Kittiwake collision mortalities	Migration free breeding season	BDMPS		
		autumn migration	non-breeding	spring migration
	May - Jul	Aug - Dec	n/a	Jan - Apr
Seasonal mortality	0.77	37.64	n/a	19.11
Standard deviation	0.58	12.19	n/a	5.64

3.3 Lesser black-backed gull

22 For lesser black-backed gull, seasonal collision mortalities are presented for the seven 14 MW (most realistic) turbine scenario and model option 1 of the CRM which uses site-specific flight height data (worst case). Data are presented for the seasonal totals (sum of the monthly mortality estimates) and their associated seasonal standard deviation. Full collision risk outputs are presented in Appendix 11.3A for each turbine scenario and model option. As a 'worst case' all birds are assumed to be adults and are not apportioned by age class.

Table 8. Lesser black-backed gull seasonal collision mortalities (numbers of birds)

Lesser black-backed gull collision mortalities	Migration free breeding season	BDMPS		
		autumn migration	non-breeding	spring migration
	May - Jul	Aug-Oct	Nov-Feb	Mar-Apr
Seasonal mortality	6.24	0.49	0.00	0.00
Standard deviation	2.52	0.34	0.00	0.00

3.4 Great black-backed gull

23 For great black-backed gull, seasonal collision mortalities are presented for the seven 14 MW (most realistic) turbine scenario and model option 1 of the CRM which uses site-specific flight height data (worst case). Data are presented for the seasonal totals (sum of the monthly mortality estimates) and their associated seasonal standard deviation. Full collision risk outputs are presented in Appendix 11.3A for each turbine scenario and model option. As a 'worst case' all birds are assumed to be adults and are not apportioned by age class.

Table 9. Great black-backed gull seasonal collision mortalities (numbers of birds)

Great black-backed gull collision mortalities	Migration free breeding season	BDMPS		
		autumn migration	non-breeding	spring migration
	May - Jul	n/a	Sep - Mar	n/a
Seasonal mortality	0.00	n/a	0.67	n/a
Standard deviation	0.00	n/a	0.34	n/a

3.5 Herring gull

24 For herring gull, seasonal collision mortalities are presented for the seven 14 MW (most realistic) turbine scenario and model option 1 of the CRM which uses site-specific flight height data (worst case). Data are presented for the seasonal totals (sum of the monthly mortality estimates) and their associated seasonal standard deviation. Full collision risk outputs are presented in Appendix 11.3A for each turbine scenario and model option. As a 'worst case' all birds are assumed to be adults and are not apportioned by age class.

Table 10. Herring gull seasonal collision mortalities (numbers of birds)

Herring gull collision mortalities	Migration free breeding season	BDMPS		
		autumn migration	non-breeding	spring migration
	Mar - Aug	n/a	Sep-Feb	n/a
Seasonal mortality	2.32	n/a	1.45	n/a
Standard deviation	1.21	n/a	0.68	n/a

3.6 Manx shearwater

25 For Manx shearwater, seasonal collision mortalities are presented for the seven 14 MW (most realistic) turbine scenario and model option 2 based on generic flight data (Johnston *et al.*, 2014) (because no site-specific flight height information is available from the digital aerial survey work). Data are presented for the seasonal totals (sum of the monthly mortality estimates) and their associated seasonal standard deviation. Full collision risk outputs are presented in Appendix 11.3A for each turbine scenario and model option. As a 'worst case' all birds are assumed to be adults and are not apportioned by age class.

Table 11. Manx shearwater seasonal collision mortalities (numbers of birds)

Manx shearwater collision mortalities	Migration free breeding season	BDMPS		
		autumn migration	non-breeding	spring migration
	Jun - Jul	Aug-Oct	n/a	Dec-Mar
Seasonal mortality	0.00	0.00	n/a	0.00
Standard deviation	0.00	0.00	n/a	0.00

3.7 Guillemot

26 For guillemot, seasonal collision mortalities are presented for the seven 14 MW (most realistic) turbine scenario and model option 2 based on generic flight data (Johnston *et al.*, 2014) (because no site-specific flight height information is available from the digital aerial survey work). Data are presented for the seasonal totals (sum of the monthly mortality estimates) and their associated seasonal standard deviation. Full collision risk outputs are presented in Appendix 11.3A for each turbine scenario and model option. As a 'worst case' all birds are assumed to be adults and are not apportioned by age class.

Table 12. Guillemot seasonal collision mortalities (numbers of birds)

Guillemot collision mortalities	Migration free breeding season	BDMPS		
		autumn migration	non-breeding	spring migration
	Mar-Jun	n/a	Aug-Feb	n/a
Seasonal mortality	1.46	n/a	1.71	n/a
Standard deviation	1.70	n/a	1.64	n/a

4 Discussion and Conclusions

27 Full collision risk outputs for each species are presented in Appendix 11.3A.

28 Assessment has been based on the turbine scenario 'most likely' to be developed: this is the seven 14 MW turbine scenario. However, outputs for the ten 9.5 MW turbine scenario and the six 16-18 MW turbine scenario are presented for context.

29 Assessment has been based on the 'worst case' model option. In this case it is model option 1 that gives rise to the highest collision risk estimates. This uses site-specific flight height data as given in Table 4, which results in more birds flying at collision risk height than given in the Johnston *et al.* (2014) generic flight height data. For Manx shearwater and for guillemot only model option 2 could be used as there are no accurate site-specific measures of flight height for these species from the digital aerial survey work.

30 Once collision mortality estimates have been divided by season, they can be considered in impact assessment; environmental impact assessment (EIA) as reported in ES Chapter 11: Offshore Ornithology, and Habitats Regulations Appraisal (HRA) as addressed in Volume 3, Technical Appendix 8.3: Report to Inform Appropriate Assessment.

31 For EIA, impacts during the breeding season are considered against the defined regional populations given in Pritchard *et al.* (2021). Impacts during the non-breeding season are considered against each relevant BDMPS, as defined by Furness (2015). For HRA, all impacts are apportioned to the relevant Special Protection Areas (SPAs) using the method set out in Volume 3, Technical Appendix 11.2: Apportioning for breeding season impacts and the approach articulated in Appendix 11.3B of this document for the non-breeding season.

4.1 Gannet

32 The breeding season impacts can be apportioned between SPAs using the weightings given in Volume 3, Technical Appendix 11.2: Apportioning. For gannet, 99.5% of birds are apportioned to Grassholm SPA, giving a breeding season sCRM mortality estimate of 88 birds.

33 In the non-breeding season, data in Furness (2015) can be used to calculate the percentage of birds in the BDMPS that are from Grassholm SPA and thus derive a weighting that can be used to apportion non-breeding season impacts back to the breeding population. The method is described and the calculations presented Appendix 11.3B of this document.

34 During autumn migration the proportion of the BDMPS population that is from Grassholm is 23.7% which gives an estimate of three mortalities which can be assigned against the SPA. During spring migration the proportion of the BDMPS population that is from Grassholm is 19.6% which gives an estimate of three mortalities which can be assigned against the SPA.

35 Therefore, the annual total of predicted gannet collision mortalities at Grassholm SPA is 94 birds. As a 'worst case' this impact has been considered in combination with the predicted displacement impacts (Volume 3, Technical Appendix 11.4: Displacement) and the implications of total mortality considered further through use of a population viability analysis (Volume 3, Technical Appendix 11.5: Population Viability Analysis).

4.2 Kittiwake

36 The breeding season impacts can be apportioned between SPAs using the weightings given in Volume 3, Technical Appendix 11.2: Apportioning. For kittiwake, 81.7% of birds are apportioned to Skomer, Skokholm and Seas off Pembrokeshire SPA, giving a breeding season sCRM mortality estimate of one bird.

37 In the non-breeding season, data in Furness (2015) can be used to calculate the percentage of birds in the BDMPS that are from Skokholm and Seas off Pembrokeshire SPA, and thus derive a weighting that can be used to apportion non-breeding season CRM impacts back to the breeding population. The method is described in this document in Appendix 11.3B and the calculations presented.

38 During autumn migration, the proportion of the BDMPS population that is from Skokholm and Seas off Pembrokeshire SPA is 0.2% which gives an estimate of effectively zero mortalities to assign against the SPA. During spring migration, the proportion of the BDMPS population that is from Skokholm and Seas off Pembrokeshire SPA is 0.3% which gives an estimate of effectively zero mortalities to assign against the SPA.

39 Therefore, the annual total of predicted kittiwake collision mortalities at Skokholm and Seas off Pembrokeshire SPA is one bird. As a ‘worst case’ this impact is considered in combination with the predicted displacement impacts (Volume 3, Technical Appendix 11.4: Displacement) against the SPA population.

4.3 Lesser black-backed gull

40 The breeding season impacts can be apportioned between SPAs using the weightings given in Volume 3, Technical Appendix 11.2: Apportioning. For lesser black-backed gull, 97.8% of birds are apportioned to Skomer, Skokholm and Seas off Pembrokeshire SPA, giving a breeding season sCRM mortality estimate of six birds. Impacts are also considered against the regional breeding population from Pritchard *et al.* (2021).

41 No birds were recorded on-site during the non-breeding season and thus the predicted collision mortalities are zero over this period.

4.4 Great black-backed gull

42 There were no great black-backed gull recorded in the proposed development site during the breeding season and so predicted collisions are zero for this period. In the non-breeding season there is one predicted collision and this can be considered against the BDMPS population.

4.5 Herring gull

43 Herring gull were recorded only intermittently on-site and so the predicted collisions for this species are low. There is an estimated risk of two collisions during the breeding season and one collision during the non-breeding season. There are no SPAs within foraging range so the breeding season impacts are considered against the regional numbers reported in Pritchard *et al.* (2021). In the non-breeding season the impacts are considered against the relevant BDMPS (Furness, 2015).

4.6 Manx shearwater

44 Predicted collisions to Manx shearwater are zero because no birds were predicted to be at potential collision risk height using Johnston *et al.* (2014) flight height data. Although flight height could not be measured from the digital aerial survey data, the available tracking data also confirms a maximum flight height of 17.5m (Davies *et al.*, 2021) and maximum potential height of 20 m (Tim Guilford, pers. comm.), below the lowest sweep of the rotor blades.

4.7 Guillemot

45 Predicted collisions to guillemot are very low because few birds were predicted to be at potential collision risk height using Johnston *et al.* (2014) flight height data. In the breeding season there is one predicted collision and in the non-breeding season there are two predicted collisions.

46 The breeding season impacts can be apportioned to Skomer, Skokholm and Seas off Pembrokeshire SPA (75.4% of birds), see Volume 3, Technical Appendix 11.2: Apportioning giving a mortality estimate of one bird. During the non-breeding season the proportion of the BDMPS population that is from Skokholm and Seas off Pembrokeshire SPA is 4.3% which gives an estimate of effectively zero mortalities to assign against the SPA.

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6 Appendix 11.3A – Monthly mean input densities and collision risk outputs for each species, model option and turbine scenario

6.1 Gannet

Table 13. Gannet monthly mean input flying bird densities

Monthly densities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	0.05	0.66	0.79	1.28	1.22	1.32	0.44	1.95	0.95	0.27	0.09	0.05
Standard deviation	0.09	0.37	0.37	0.60	0.68	0.81	0.37	1.84	0.70	0.13	0.11	0.09

Table 14. Gannet CRM model option 1 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9.5 MW	Mean	0.70	6.11	9.63	18.31	21.42	24.30	9.21	37.52	12.93	2.97	1.03	0.67
9.5 MW	Standard deviation	0.49	3.24	4.65	8.84	11.40	12.98	5.61	24.58	7.95	1.46	0.76	0.47
14 MW	Mean	0.58	4.74	7.78	14.70	16.76	18.70	7.03	30.61	10.57	2.28	0.85	0.52
14 MW	Standard deviation	0.41	2.58	3.66	7.01	8.93	10.69	4.51	19.61	6.32	1.14	0.57	0.38
16-18 MW	Mean	0.52	4.56	7.32	13.66	16.17	18.21	6.93	29.33	9.95	2.11	0.79	0.49
16-18 MW	Standard deviation	0.38	2.41	3.57	6.43	8.00	9.80	4.26	18.61	5.89	1.10	0.54	0.36

Table 15. Gannet CRM model option 2 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9.5 MW	Mean	0.12	1.10	1.73	3.28	3.84	4.33	1.64	6.65	2.31	0.53	0.18	0.12
9.5 MW	Standard deviation	0.10	0.74	1.08	2.04	2.50	2.87	1.20	5.01	1.70	0.33	0.16	0.10
14 MW	Mean	0.10	0.83	1.37	2.60	2.95	3.30	1.25	5.36	1.84	0.40	0.15	0.09
14 MW	Standard deviation	0.09	0.56	0.85	1.67	1.98	2.35	0.97	4.10	1.34	0.25	0.12	0.08
16-18 MW	Mean	0.09	0.81	1.29	2.43	2.86	3.21	1.23	5.14	1.78	0.37	0.14	0.09
16-18 MW	Standard deviation	0.08	0.55	0.85	1.56	1.89	2.25	0.96	4.01	1.33	0.25	0.12	0.08

6.2 Kittiwake

Table 16. Kittiwake monthly mean input flying bird densities

Monthly densities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	2.63	0.78	0.09	0.00	0.00	0.05	0.00	0.09	0.00	1.05	2.20	2.58
Standard deviation	0.84	0.33	0.11	0.00	0.00	0.09	0.00	0.11	0.00	0.42	2.53	0.88

Table 17. Kittiwake CRM model option 1 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9.5 MW	Mean	19.12	5.83	1.23	0.00	0.00	1.07	0.00	1.34	0.00	9.17	22.06	18.28
9.5 MW	Standard deviation	6.96	2.67	0.83	0.00	0.00	0.77	0.00	0.96	0.00	3.92	14.46	7.08
14 MW	Mean	14.01	4.24	0.86	0.00	0.00	0.77	0.00	1.07	0.00	6.76	16.34	13.47
14 MW	Standard deviation	5.28	1.90	0.59	0.00	0.00	0.58	0.00	0.76	0.00	2.91	10.68	5.06
16-18 MW	Mean	12.38	3.76	0.77	0.00	0.00	0.68	0.00	0.93	0.00	5.97	14.06	11.66
16-18 MW	Standard deviation	4.50	1.69	0.51	0.00	0.00	0.51	0.00	0.61	0.00	2.60	9.55	4.40

Table 18. Kittiwake CRM model option 2 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9.5 MW	Mean	4.61	1.41	0.30	0.00	0.00	0.26	0.00	0.32	0.00	2.21	5.32	4.41
9.5 MW	Standard deviation	1.76	0.68	0.20	0.00	0.00	0.19	0.00	0.24	0.00	1.00	3.56	1.81
14 MW	Mean	3.42	1.04	0.21	0.00	0.00	0.19	0.00	0.26	0.00	1.65	3.99	3.30
14 MW	Standard deviation	1.35	0.48	0.14	0.00	0.00	0.14	0.00	0.19	0.00	0.73	2.67	1.30
16-18 MW	Mean	3.05	0.92	0.19	0.00	0.00	0.17	0.00	0.23	0.00	1.47	3.44	2.86
16-18 MW	Standard deviation	1.18	0.43	0.13	0.00	0.00	0.13	0.00	0.15	0.00	0.66	2.36	1.12

6.3 Lesser black-backed gull

Table 19. Lesser black-backed gull monthly mean input flying bird densities

Monthly densities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	0.00	0.00	0.00	0.00	0.00	0.43	0.39	0.05	0.00	0.00	0.00	0.00
Standard deviation	0.00	0.00	0.00	0.00	0.00	0.26	0.26	0.06	0.00	0.00	0.00	0.00

Table 20. Lesser black-backed gull CRM model option 1 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9.5 MW	Mean	0.00	0.00	0.00	0.00	0.00	4.02	3.54	0.60	0.00	0.00	0.00	0.00
9.5 MW	Standard deviation	0.00	0.00	0.00	0.00	0.00	2.23	2.14	0.43	0.00	0.00	0.00	0.00
14 MW	Mean	0.00	0.00	0.00	0.00	0.00	3.20	3.04	0.49	0.00	0.00	0.00	0.00
14 MW	Standard deviation	0.00	0.00	0.00	0.00	0.00	1.83	1.73	0.34	0.00	0.00	0.00	0.00
16-18 MW	Mean	0.00	0.00	0.00	0.00	0.00	2.85	2.70	0.44	0.00	0.00	0.00	0.00
16-18 MW	Standard deviation	0.00	0.00	0.00	0.00	0.00	1.58	1.54	0.31	0.00	0.00	0.00	0.00

Table 21. Lesser black-backed gull CRM model option 2 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9.5 MW	Mean	0.00	0.00	0.00	0.00	0.00	1.54	1.35	0.23	0.00	0.00	0.00	0.00
9.5 MW	Standard deviation	0.00	0.00	0.00	0.00	0.00	0.95	0.91	0.18	0.00	0.00	0.00	0.00
14 MW	Mean	0.00	0.00	0.00	0.00	0.00	1.12	1.06	0.17	0.00	0.00	0.00	0.00
14 MW	Standard deviation	0.00	0.00	0.00	0.00	0.00	0.71	0.65	0.13	0.00	0.00	0.00	0.00
16-18 MW	Mean	0.00	0.00	0.00	0.00	0.00	1.00	0.95	0.15	0.00	0.00	0.00	0.00
16-18 MW	Standard deviation	0.00	0.00	0.00	0.00	0.00	0.62	0.59	0.12	0.00	0.00	0.00	0.00

6.4 Great black-backed gull

Table 22. Great black-backed gull monthly mean input flying bird densities

Monthly densities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.14
Standard deviation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.12

Table 23. Great black-backed gull CRM model option 1 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9.5 MW	Mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.60
9.5 MW	Standard deviation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.38
14 MW	Mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.46
14 MW	Standard deviation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.30
16-18 MW	Mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.44
16-18 MW	Standard deviation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.28

Table 24. Great black-backed gull CRM model option 2 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9.5 MW	Mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.56
9.5 MW	Standard deviation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.36
14 MW	Mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.43
14 MW	Standard deviation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.29
16-18 MW	Mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.41
16-18 MW	Standard deviation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.27

6.5 Herring gull

Table 25. Herring gull monthly mean input flying bird densities

Monthly densities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	0.00	0.22	0.13	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.04
Standard deviation	0.00	0.13	0.25	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.09

Table 26. Herring gull CRM model option 1 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9.5 MW	Mean	0.00	1.39	1.78	0.00	0.00	0.00	1.27	0.00	0.00	0.00	0.00	0.54
9.5 MW	Standard deviation	0.00	0.79	1.31	0.00	0.00	0.00	0.93	0.00	0.00	0.00	0.00	0.42
14 MW	Mean	0.00	1.03	1.31	0.00	0.00	0.00	1.01	0.00	0.00	0.00	0.00	0.42
14 MW	Standard deviation	0.00	0.60	0.96	0.00	0.00	0.00	0.73	0.00	0.00	0.00	0.00	0.31
16-18 MW	Mean	0.00	0.91	1.19	0.00	0.00	0.00	0.87	0.00	0.00	0.00	0.00	0.39
16-18 MW	Standard deviation	0.00	0.5	0.85	0.00	0.00	0.00	0.63	0.00	0.00	0.00	0.00	0.28

Table 27. Herring gull CRM model option 2 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9.5 MW	Mean	0.00	0.65	0.84	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.25
9.5 MW	Standard deviation	0.00	0.38	0.63	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.20
14 MW	Mean	0.00	0.48	0.62	0.00	0.00	0.00	0.47	0.00	0.00	0.00	0.00	0.20
14 MW	Standard deviation	0.00	0.29	0.47	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.15
16-18 MW	Mean	0.00	0.43	0.56	0.00	0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.19
16-18 MW	Standard deviation	0.00	0.25	0.42	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.14

6.6 Manx shearwater

Table 28. Manx shearwater monthly mean input flying bird densities

Monthly densities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	0.00	0.00	0.00	0.09	0.57	2.03	1.00	0.82	0.81	0.00	0.00	0.00
Standard deviation	0.00	0.00	0.00	0.11	0.97	2.69	0.38	0.59	0.54	0.00	0.00	0.00

Table 29. Manx shearwater model option 2 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9.5 MW	Mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.5 MW	Standard deviation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14 MW	Mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14 MW	Standard deviation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16-18 MW	Mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16-18 MW	Standard deviation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

6.7 Guillemot

Table 30. Guillemot monthly mean input flying birds densities

Monthly densities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	0.30	0.22	1.14	0.92	0.35	0.17	0.09	0.13	0.00	0.77	1.44	1.28
Standard deviation	0.25	0.11	1.04	0.47	0.13	0.10	0.16	0.11	0.00	0.43	0.95	0.92

Table 31. Guillemot option 2 mortality estimates

Turbine scenario	Monthly mortalities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9.5 MW	Mean	0.18	0.12	0.87	0.63	0.27	0.14	0.12	0.12	0.00	0.50	0.81	0.71
9.5 MW	Standard deviation	0.36	0.21	1.76	1.12	0.47	0.27	0.24	0.24	0.00	0.91	1.54	1.35
14 MW	Mean	0.14	0.09	0.68	0.47	0.21	0.10	0.10	0.09	0.00	0.35	0.55	0.49
14 MW	Standard deviation	0.28	0.16	1.38	0.90	0.39	0.20	0.22	0.18	0.00	0.68	1.07	0.98
16-18 MW	Mean	0.13	0.08	0.62	0.45	0.19	0.10	0.09	0.08	0.00	0.32	0.53	0.46
16-18 MW	Standard deviation	0.24	0.14	1.18	0.85	0.34	0.19	0.17	0.16	0.00	0.61	1.01	0.9

7 Appendix 11.3B – Apportioning for CRM in the non-breeding season

47 This apportioning method for CRM in the non-breeding season was submitted to NRW and JNCC for comment during the pre-application process. It uses data from Furness (2015) on biologically defined minimum population scales (BDMPS) to calculate the number of birds from each SPA as a proportion of the total BDMPS population; the tables for each species are presented in Appendix A of the report.

48 Where appropriate, this allows non-breeding season impacts to be apportioned back to breeding SPA populations and allows both breeding and non-breeding season impacts to be considered together against the reference population of concern.

49 The non-breeding apportioning calculations are provided for the three species which require it: gannet, kittiwake and guillemot.

7.1 Gannet

Gannet have two migration BDMPS one during autumn and one during spring.

7.1.1 Autumn

Contribution of gannet from Grassholm SPA to the 'UK western waters and Channel'.
Total number of SPA adults and immatures – 129,506 birds.
Total birds for 'UK western waters and Channel' – 545,954 birds.
Grassholm SPA birds as proportion of total birds – 0.237

Refer to Furness (2015), Appendix A, Table 15, page 315.

7.1.2 Spring

Contribution of gannet from Grassholm SPA to the 'UK western waters and Channel'.
Total number of SPA adults and immatures – 129,506 birds.
Total birds for 'UK western waters and Channel' – 661,888 birds.
Grassholm SPA birds as proportion of total birds – 0.196

Refer to Furness (2015), Appendix A, Table 17, page 317.

7.2 Kittiwake

Kittiwake have two migration BDMPS one during autumn and one during spring.

7.2.1 Autumn

Contribution of kittiwake from Skomer, Skokholm and Pembrokeshire coast SPA to the 'UK western waters and Channel'.
Total number of SPA adults and immatures – 1,990 birds.
Total birds for 'UK western waters and Channel' – 911,586 birds.
Skomer, Skokholm and Pembrokeshire coast SPA birds as proportion of total birds – 0.002

Refer to Furness (2015), Appendix A, Table 48, page 350.

7.2.2 Spring

Contribution of kittiwake from Skomer, Skokholm and Pembrokeshire coast SPA to the 'UK western waters and Channel'.
Total number of SPA adults and immatures – 2,408 birds.
Total birds for 'UK western waters and Channel' – 691,526 birds.
Skomer, Skokholm and Pembrokeshire coast SPA birds as proportion of total birds – 0.003

Refer to Furness (2015) – Appendix A – Table 50, page 354.

7.3 Guillemot

Guillemot have one non-breeding BDMPS from August to February.

7.3.1 Non-breeding BDMPS

Contribution from Skomer, Skokholm and Pembrokeshire coast SPA to the 'UK western waters and Channel'.
Total number of SPA adults and immatures – 48,639 birds.
Total birds for 'UK western waters and Channel' – 1,139,220 birds.
Skomer, Skokholm and Pembrokeshire coast SPA birds as proportion of total birds – 0.043

Refer to Furness (2015) – Appendix A – Table 63, page 377.