Technical Appendix 11.3: Collision Risk Modelling.

MachairWind Offshore Ornithology

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1.0 Introduction

1.1 Project Summary

1. Machairwind Limited ('the Applicant') is proposing the development of the MachairWind Windfarm ('the Project'), an Offshore Windfarm, located on the west coast of Scotland approximately 15 kilometres (km) to the northwest of Islay and approximately 12.4 km west of Colonsay at the closest point (**Figure 1**).

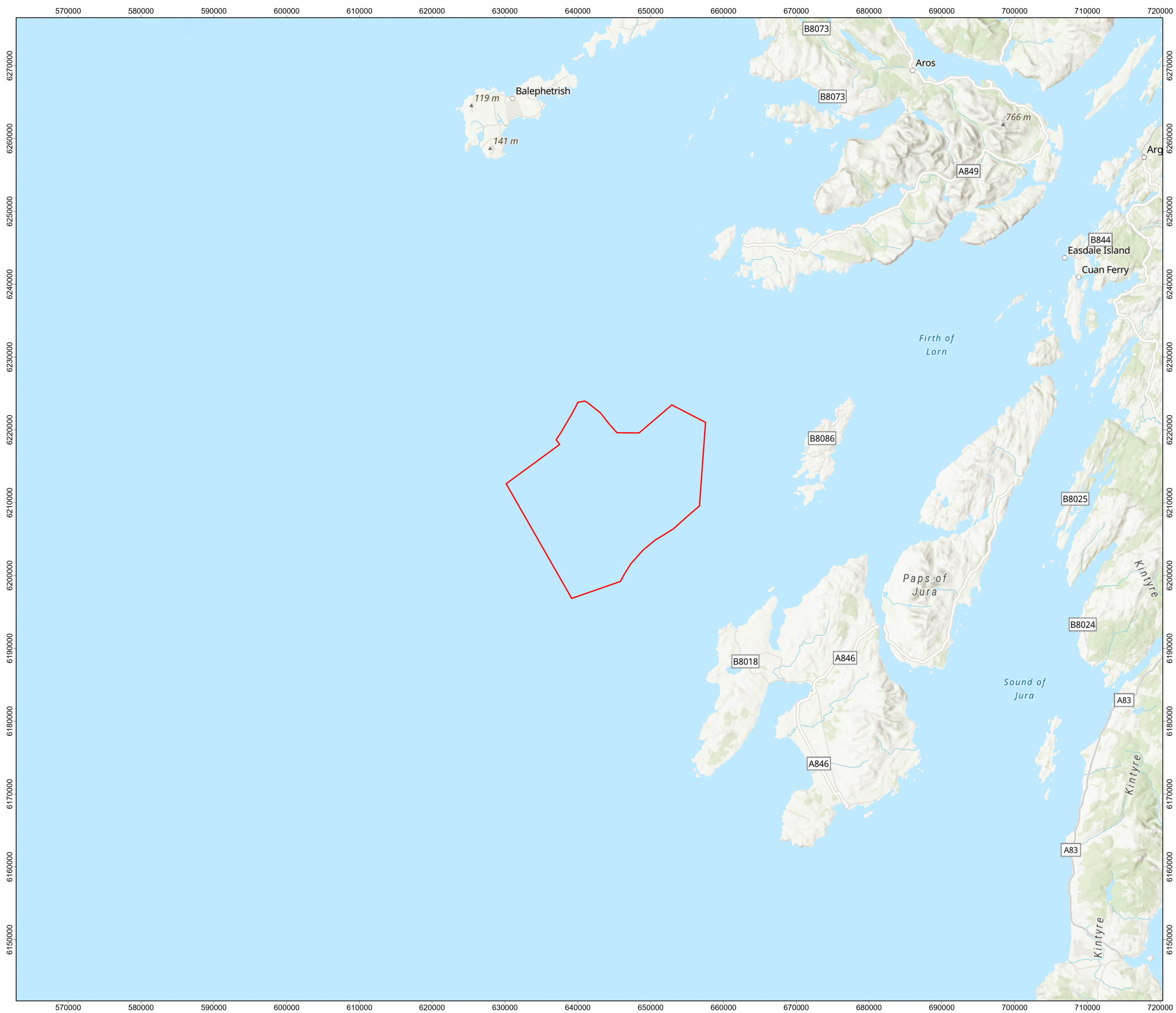
2. The Offshore Project will comprise up to 144 wind turbine generators (WTGs) with fixed-bottom foundations. The area within which the WTGs and associated infrastructure will be located is the Windfarm Development Area (WDA). The WDA covers an area of 448 km^2.

1.2 Purpose of this report

3. This **Technical Appendix 11.3: Collision Risk Modelling** report provides information on estimated collision mortality arising from marine bird species colliding with WTGs in the WDA during Project operation. This information is used in the impact assessments presented in **Chapter 11 Offshore Ornithology** of the Environmental Impact Assessment Report (EIAR) and the Report to Inform Appropriate Assessment (RIAA).

4. This technical appendix includes the following Annexes:
   - Annex 11.3A: Bootstrapped density inputs to sCRM;
   - Annex 11.3B: Deterministic CRM inputs and outputs;
   - Annex 11.3C: Collision Risk Modelling of Greenland white-fronted goose; and,
   - Annex 11.3D: Migratory Collision Risk Modelling.

5. Collision estimates were generated using 29 Digital Aerial Survey (DAS) samples (one sample is composed of one complete DAS survey per month, refer to **Technical Appendix 11.2: Baseline Site Characterisation** and **Annex 11.3A: Bootstrapped density inputs to sCRM**), using avoidance rates and other biometric data provided by NatureScot. The report presents the monthly, seasonal and annual estimated collisions used in the subsequent stages of the impact assessments, for kittiwake, great black-backed gull, herring gull, Arctic tern, common tern and gannet.



Windfarm Development Area (WDA)

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0 5 10 20 Kilometres

REV	REV DATE	GIS CREATOR	GIS REVIEWER	TECHNICAL CHECKER	TECHNICAL APPROVER
1	21/04/2026	MMM	MMM	NG/SO	NG/SO

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ScottishPower Renewables

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Name: MachairWind Windfarm Development Area

2.0 Methods

2.1 Species assessed for collision risk

6. Species selected for the collision risk assessment included those that met the following criteria:

- Species recorded flying regularly within the WDA in 29 DAS samples (i.e. a total of 10 or more birds recorded in flight across 29 DAS samples) between April 2021 to September 2023; and,
- Species considered susceptible to collision (refer to Furness et al., 2013).

7. The following species were identified as being at risk of collision with WTGs during Project operation:

- Arctic tern (*Sterna paradisaea*);
- Common tern (*Sterna hirundo*);
- European storm petrel (*Hydrobates pelagicus*);
- Gannet (*Morus bassanus*);
- Great black-backed gull (*Larus marinus*);
- Herring gull (*Larus argentatus*);
- Kittiwake (*Rissa tridactyla*); and,
- Manx shearwater (*Puffinus puffinus*).

8. Gulls and skuas are considered to be at risk of colliding with WTGs (Furness et al., 2013). However, no collision risk modelling was undertaken for any skua species or gull species except great black-backed gull and herring gull, due to Likely Significant Effects being screened out (refer to **HRA Screening Report**).

9. European storm-petrel and Manx shearwater were recorded flying in the WDA but these species generally fly too low to be at collision risk height (Furness et al., 2013), other than a possible increased risk of collision if attracted to lighting on WTGs. These two species were assessed using a semi-quantitative approach in the RIAA and the EIAR.

10. Quantitative collision risk for migratory species is assessed separately to marine bird species. Migratory species were assessed using the Scottish Government's Stochastic Collision Risk Model for migratory species recommended in NatureScot's Guidance Note 7[2] Collision risk modelling results for migratory species are presented in **Annex 11.3C: Migratory Collision Risk Modelling**.

11. NatureScot, in Guidance Note 6[1], advised that collision risk and distributional responses (i.e. displacement and barrier effects) are the primary impact pathways for marine birds. Arctic tern, common tern, gannet and kittiwake were assessed for both collision and displacement impact pathways (refer to **Technical Appendix 11.4: Displacement** report for more information on displacement impacts).

[1] NatureScot Guidance Note 6 (version 1 updated January 2023): https://www.nature.scot/doc/guidance-note-6-guidance-support-offshore-wind-applications-marine-ornithology-impact-pathways

2.2 Approach to CRM

12. NatureScot provides guidance on how to assess collision risk in their Guidance Note 7[2]. This guidance advises to assess collision risk using the 2022 update to the stochastic collision risk modelling (sCRM) tool shiny app (Caneco, 2022) and to present outputs for both stochastic and deterministic collision risk modelling (CRM) using this tool.

13. Until recently, deterministic CRM was undertaken using Microsoft Excel spreadsheets, implementing the model developed by Band (2012). The Band (2012) approach is a simple deterministic model that calculates the probability of a bird of a certain size moving at a set speed through a wind turbine rotor, being struck by a turbine blade of a certain size and moving at a set speed. An avoidance rate is then applied to account for behaviour undertaken by a bird when reacting to the offshore windfarm, turbine or blade and in the case of terrestrial windfarms as a correction to ensure that predicted numbers match observed numbers of collisions. That correction is not yet possible to make for offshore windfarms and so avoidance rates advised by NatureScot provide precautionary outputs.

14. A stochastic implementation of the Band (2012) model, written in 'R', was developed by Masden (2015) which was further refined by McGregor et al., (2018) and is referred to as the sCRM. Caneco (2022) made further updates to improve the sCRM model functionality. The R scripts produced by Caneco (2022) are packaged as stochLAB and can be used within R itself or via an online shiny app, which itself is a refinement of the sCRM of McGregor et al., (2018).

15. All three versions of the CRM - Band (2012), McGregor et al., (2018) and Caneco (2022) - are fundamentally the same and have the original Band (2012) calculations at their core, differing primarily in their user interfaces and (for the latter two) the option to run the model as a simulation with randomly generated input parameters and probabilistic results.

16. Stochastic collision mortality estimates presented in this technical appendix were calculated using stochLAB R scripts as recommended in NatureScot Guidance Note 7[2] using 'R' version 4.4.2 Patched (2024-12-10, nicknamed 'Pile of leaves', refer to **Section 2.4**). It was agreed with NatureScot at the Expert Topic Group meeting 4 (ETG 4, 2 December 2025) that R script rather than the sCRM tool shiny app (Caneco, 2022) was used to estimate collision mortality in an effort to streamline the calculation of collision mortality estimates; mortality estimates are essentially the same whether produced using R script or the sCRM tool shiny app.

17. NatureScot advised at the Expert Topic Group meeting 4 (ETG 4, 2 December 2025) that deterministic CRM modelling results should be presented, therefore deterministic CRM inputs and outputs are presented in **Annex 11.3B: Deterministic CRM inputs and outputs**.

18. Stochastic CRM is a better tool to estimate collision mortality because it captures uncertainty in collision risk modelling inputs and outputs, which deterministic CRM does not. Only sCRM results are used in offshore windfarm assessments, therefore, the EIAR and RIAA assessments are informed by the stochastic collision risk outputs presented in this appendix.

2.3 sCRM model options

19. NatureScot Guidance Note 7[2] states that as a minimum, the following two scenarios should be modelled and results presented for each CRM species:

- Most likely scenario (MLS) - Option 2 (using the generic flight height dataset); and
- Worst-case scenario (WCS) - Option 2 (using the generic flight height dataset).

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[2] NatureScot Guidance Note 7 (version 3 updated April 2025): Guidance Note 7: Guidance to support Offshore Wind Applications: Marine Ornithology - Advice for assessing collision risk of marine birds | NatureScot

20. Both model options are presented in this report. Breeding and non-breeding season totals for all CRM species, as well as the annual total, are calculated from the monthly outputs.

2.4 Summary of R script used for sCRM

21. sCRM was conducted through implementation of the “stochLAB” R package (Caneco, 2022), following NatureScot Guidance Note 7[2]. This package collates methodologies outlined in Masden (2015) to incorporate variability and uncertainty in collision risk modelling as an extension of the Band (2012) collision risk model. The stochLAB functions were run on a local instance of R to afford greater flexibility for outputs. As an overview, the stochLAB package incorporates the following information:

- BTO-derived flight-height distributions (**Section 2.5.2**);
- Species biometrics (flight speed, body length, wingspan, avoidance rates, nocturnal activity; refer to **Section 2.5.5**);
- Turbine design parameters (rotor radius, hub height, blade width, pitch, speed, number of turbines**, Section 2.5.6**), and
- Site-specific operational schedules including downtime and tidal adjustments to hub height (**Section 2.5.6**).

22. Monthly bird density data are supplied as bootstrap resamples (refer to **Section 2.5.1**), and these, together with flight-height distributions, form the basis for the stochastic procedure. For each of the six collision risk species (**Section 2.1**) and two offshore windfarm scenarios (**Section 2.5.6**), the model runs 1,000 iterations, repeatedly drawing from the bootstrapped inputs to simulate a wide range of possible outcomes.

23. The sCRM integrates these resampled inputs with the turbine specifications to estimate collision risk at monthly and annual scales. The approach quantifies uncertainty by producing distributions of predicted collisions, from which means, standard deviations, and 95% confidence intervals are derived. This method captures both biological variability (e.g., bird densities, flight behaviour) and technical uncertainty (e.g., turbine operation, tidal offset effects), delivering a probabilistic assessment of collision risk that is more robust than single deterministic runs.

2.5 Collision risk modelling input parameters

24. CRMs require input information on densities of birds in flight, behavioural and physical characteristics of each bird species and offshore windfarm/turbine properties. All input values presented in **Table 1** were agreed with NatureScot at the Expert Topic Group meeting 4 (ETG 4, 2 December 2025).

2.5.1 Bootstrap densities

25. Density estimates of birds in flight were derived from digital aerial surveys of the WDA. It was agreed with NatureScot to use a combination of Project and Third Party digital aerial survey data collected over 29 months between April 2021 to September 2023 for use in collision risk modelling (NatureScot letter dated 7 August 2025). Refer to **Technical Appendix 11.2: Baseline Site Characterisation** for an explanation of offshore ornithology survey areas.

26. For kittiwake, great black-backed gull, herring gull, Arctic tern and common tern, unidentified birds recorded in non-species-specific categories during digital aerial surveys (e.g. ‘small gull’, ‘large gull’ and ‘commic tern’) were apportioned to a species based on the relative abundance ratios of identified species within the category (i.e. kittiwake, great black-backed gull, herring gull, Arctic tern or common tern). Therefore, density estimates for these species used in the collision risk assessment included kittiwakes, great black-backed gulls, herring

gulls, Arctic terns and common terns recorded in non-species-specific categories. Refer to **Technical Appendix 11.2: Baseline Site Characterisation** for an explanation of species apportioning.

27. A bootstrap approach was used to capture uncertainty in the input density estimates, all bootstrap density estimates used in sCRM (1,000 bootstrapped density estimates per calendar month) are provided in **Annex 11.3A: Bootstrapped density inputs to sCRM**. For each calendar month, a set of 1,000 bootstrapped density estimates was generated from two DAS samples (e.g. January 2022 and January 2023) or three DAS samples (e.g. April 2021, April 2022 and April 2023); the bootstrapped density estimates from each of the two or three DAS samples were appended, to create 2,000 or 3,000 bootstrap estimates for each calendar month. A subset of 1,000 of these was randomly selected and used as the density inputs for sCRM.

2.5.2 Flight heights

28. For a bird to collide with a turbine, it needs to be flying at collision height, i.e. within the rotor swept area. NatureScot's Guidance Note 7[2] recommends using generic flight heights (Johnston et al., 2014, with associated corrigendum). This approach was used in the collision risk modelling.

2.5.3 Avoidance rates

29. Once the risk of a bird colliding with a turbine blade has been calculated, this is adjusted to account for avoidance behaviour by a bird as it approaches the offshore windfarm (macro avoidance), the turbine (meso avoidance) or the blade (micro avoidance).

30. Collision estimates are highly sensitive to the avoidance rate used in CRM (Chamberlain et al., 2006) and avoidance rates recommended by NatureScot have been adjusted several times over the years, as new evidence has become available. NatureScot Guidance Note 7 (**Appendix 1**, **Table 2**)[2] provides avoidance rates for sCRM (presented in **Table 1**), these rates were used.

2.5.4 Gannet macro avoidance

31. There is evidence that gannets strongly avoid flying through offshore windfarms, i.e. that this species has high macro avoidance (Pavat et al., 2023). For gannets, NatureScot Guidance Note 7[2] advises applying macro avoidance of 70% in the non-breeding season, based on the outputs from Pavat et al., (2023). The collision mortality estimates produced for gannet in **Table 16** and **Table 17** take account of a 70% macro avoidance applied to calendar months of January, February, October, November and December in the non-breeding season. The month of March is classified as part of the breeding season as well as the non-breeding season in NatureScot Guidance Note 9[3]. As both March DAS samples were recorded in the second half of March (March DAS samples include: 28 March 2022 and 19 + 23 March 2023, (refer to **Annex 11.3A: Bootstrapped density inputs to sCRM**)) gannets recorded in March were considered to be breeding, and therefore the 70% macro avoidance was not applied to March.

2.5.5 Bird biometrics

32. Collision risk models also require information on bird biometrics, such as flight speed and whether flight is flapping or gliding, body length and wingspan.

[3] NatureScot Guidance Note 9: Guidance Note 9 - Guidance to support Offshore Wind Applications: Seasonal periods for Birds in the Scottish Marine Environment | NatureScot

33. The biometrics and avoidance rates used in collision risk modelling are presented in **Table 1** Unless otherwise stated, values are provided in NatureScot Guidance Note 7[2] (**Appendix 1**, **Table 2**). For Arctic tern and common tern, flight speeds are taken from Alerstam et al., (2007), nocturnal activity factors are taken from Garthe and Hüppop (2004) and body length and wingspan measurements are from Snow and Perrins (1998).

Table 1: Species biometrics, including Nocturnal Activity Factor (NAF) and avoidance rates (AR) used in stochastic CRMs to generate collision estimates. All values are provided in NatureScot Guidance Note 7 (Appendix 1, Table 2) unless otherwise stated.

Species	Stochastic CRM AR - mean (SD)	Flight speed mean (m/s) (SD)	NAF mean (SD)	Body length (metres) (SD)	Wingspan mean (metres) (SD)	Flight type: Flapping or Gliding	% of flights upwind
Kittiwake	0.9929 (±0.0003)	13.1 (±0.40)	0.40 (±0.12)	0.39 (±0.005)	1.08 (±0.0625)	Flapping	50
Great black-backed gull	0.9940 (±0.0004)	13.7 (±1.20)	0.375 (±0.0637)	0.71 (±0.035)	1.58 (±0.0375)	Flapping	50
Herring gull	0.9940 (±0.0004)	12.8 (±1.80)	0.375 (±0.0637)	0.6 (±0.0225)	1.44 (±0.03)	Flapping	50
Arctic tern	0.9908 (±0.0004)	10.9 (±0.9)[a]	0.125 (±0)[b]	0.34 (±0.005)[c]	0.8 (±0.025)[c]	Flapping	50
Common tern	0.9908 (±0.0004)	10.9 (0.9)[a]	0.125 (±0)[b]	0.33 (±0.01)[c]	0.875 (±0.0525)[c]	Flapping	50
Gannet	0.9929[d] (±0.0003)	14.9 (±0)[e]	0.14 (±0.10)	0.94 (±0.0325)	1.72 (±0.0375)	Gliding	50

[a] Flight speed from Alerstam et al., (2007), consulted with NatureScot at Expert Topic Group meeting 3 (ETG 3, 2 October 2024), assuming flight speed of common tern is as measured for Arctic tern.

[b] Nocturnal Activity Factor from Garthe and Hüppop (2004), consulted with NatureScot at Expert Topic Group meeting 3 (ETG 3, 2 October 2024)

[c] Body length and wingspan from Snow & Perrins (1998), consulted with NatureScot at Expert Topic Group meeting 3 (ETG 3, 2 October 2024)

[d] Excluding macro-avoidance correction of 70% reduction required for nonbreeding season

[e] Gannet flight speed is incorrectly stated to have an SD of 0 in the JNCC and NatureScot guidance. The original data are from Pennycuick (1987) where the mean is given as 14.9 with an SD of 2, although the data advised by JNCC and NatureScot are for air speed and modelling should use ground speed.

2.5.6 Windfarm and turbine inputs

34. Collision risk models also need input information on the offshore windfarm, the number of turbines and properties of the individual turbines, as well as the proportion of time that the offshore windfarm is operational, i.e. removing collision risk for periods of downtime when turbines are not turning.

35. The Project will comprise up to 144 WTGs. NatureScot Guidance Note 7[2] recommends that estimated collision is presented for two scenarios for each CRM species including the Most Likely Scenario (MLS) and Worst Case Scenario (WCS). **Table 2** presents details of the WTG specifications for MLS and WCS.

36. The predicted monthly time that turbines will be operational (and therefore when collisions are possible) are presented in **Table 3**.

Table 2: Offshore windfarm and turbine specifications used in the collision risk modelling, for the Most Likely Scenario (MLS) and the Worst Case Scenario (WCS).

Input parameter	MLS	WCS
Rotor speed (RPM)	7.43 (±0.0001)	8.05 (±0.0001)
Rotor radius (m)	138	118
Maximum blade width (m)	7.5	6.5
Mean blade pitch (°)	3.50	3.50
Number of rotor blades	3	3
Hub height above Highest Astronomical Tide (HAT) (m)	166.40	146.40
Number of turbines	97	144
Mean windfarm width (km)	29 km	29 km
Latitude (°)	56.03°	56.03°
Tidal offset (m) (difference between HAT and mean sea level at the site)	2.16 m	2.16 m

Table 3: Offshore windfarm maintenance downtime and operational wind availability by month.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maintenance Downtime (%)	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
Maintenance Downtime (%) (SD)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Operational Wind Availability (%)	97.0%	96.1%	95.2%	92.4%	90.9%	90.3%	91.3%	92.1%	94.9%	96.5%	97.2%	96.6%

2.5.7 Seasons

37. NatureScot Guidance Note 7[2] advises to estimate the number of collisions for each season by compiling monthly collision estimates. Therefore, monthly estimates of collisions were summed to provide seasonal and annual collision estimates. For each species, the months allocated to each season were defined according to NatureScot Guidance Note 9[3] and the Biologically Defined Minimum Population Scale (BDMPS) seasons (Furness, 2015); refer to **Table 4** for details.

38. Seasonal collision estimates were derived by summing collision estimates for all calendar months in that season. Where a season was split between the NatureScot breeding and non-breeding season (e.g. April for kittiwake), the collision estimate for that calendar month was halved and assigned equally between the breeding and non-breeding seasons as advised in NatureScot Guidance Note 7[2].

39. For BDMPS spring and autumn seasons which overlap with NatureScot breeding seasons, collision estimates were allocated to the breeding season and not to the BDMPS period – this method follows the methodology used for recent offshore windfarm applications as advised by NatureScot, in their response to the Scoping Report (22 November 2024).

40. A summary of collision risk modelling parameters is provided in **Table 5**.

Table 4: Definitions of breeding and non-breeding seasons according to NatureScot Guidance Note 9[3] and BDMPS seasons according to Furness (2015).

Species	NatureScot seasons (Guidance Note 9)		BDMPS Seasons (Furness, 2015)		
	Breeding season	Non-breeding season	Spring migration	Autumn migration	Winter
Kittiwake	Mid-April to August	September to mid-April	January to April	August to December	n/a
Great black-backed gull	April to August	September to March	September to March (single non-breeding BDMPS season)		
Herring gull	April to August	September to March	September to February (single non-breeding BDMPS season)		
Arctic tern	May to August	September to April	Late April to May	July to early September	n/a
Common tern	May to mid-September	Mid-September to April	April to May	late July to early September	n/a
Gannet	Mid-March to September	October to mid-March	December to March	September to November	n/a

Table 5: Summary table describing collision risk modelling parameters.

Details of CRM		
Collision Risk Model	sCRM	
Tool version	'R' version 4.4.2 Patched (2024-12-10, nicknamed 'Pile of leaves')	
Model option	Option 2 (using the generic flight height dataset)	
Approach for estimating variability in monthly density data	Bootstrap approach	
Input flying bird density data	1,000 resampled bootstrapped estimates (derived from individual surveys in each calendar month, available in **Annex 11.3A: Bootstrap densities inputs to sCRM**)	
Windfarm and turbine parameters*	**Most Likely Scenario**	**Worst Case Scenario**
Number of turbines	97	144
Avoidance rate**	**Stochastic CRM Mean (SD)**	
Kittiwake	0.9929 (±0.0003)	
Great black-backed gull	0.9940 (±0.0004)	
Herring gull	0.9940 (±0.0004)	
Arctic tern	0.9908 (±0.0004)	
Common tern	0.9908 (±0.0004)	
Gannet	0.9929 (±0.0003)	
* see **Table 2** for full list of turbine and windfarm parameters		
** see **Table 1** for full list of bird biometrics		

3.0 Results of Collision estimates

3.1 Kittiwake

41. **Table 6** provides monthly and annual estimated collisions for kittiwake, based on stochastic CRM. MLS and WCS are presented using Option 2 in the CRM (NatureScot Guidance Note 7[2]). Estimated collisions were highest in November and December, kittiwake collisions totalled 132 (MLS) and 172 (WCS) individuals per annum.

42. **Table 7** provides seasonal estimates of kittiwake collisions under the WCS. The majority of collisions are predicted to occur in the non-breeding season (123.4 birds per annum), with lower collisions predicted for the breeding season (48.7 birds per annum). A higher number of collisions was estimated to occur in the autumn migration BDMPS season (86.9 birds per annum) compared with the spring migration BDMPS season (36.4 birds per annum).

Table 6: Kittiwake estimated collisions from the sCRM with Option 2 (generic flight height distribution) at 0.9929 (SD = 0.0003) avoidance rate for the MLS and WCS. Monthly values are the mean and standard deviation (S.D.) estimated collisions.

Scenario	Mean and SD monthly collision mortality													
	Mean / SD	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MLS	Mean	9.78	9.57	6.25	4.67	12.51	9.96	11.72	0.83	1.60	12.54	24.53	27.99	**131.97**
	SD	7.42	9.34	1.88	2.66	6.42	6.21	9.11	0.99	2.12	4.80	8.94	20.09	**37.31**
WCS	Mean	12.76	12.48	8.15	6.09	16.31	12.99	15.29	1.08	2.09	16.36	31.98	36.50	172.07
	SD	9.67	12.18	2.45	3.47	8.38	8.10	11.88	1.29	2.77	6.27	11.66	26.21	**48.73**

Table 7: Kittiwake seasonal collision estimated totals, based on sCRM WCS monthly mean estimates. Annual values are presented as mean (standard deviation).

Season	Kittiwake Seasonal Collisions												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Seasonal Total
Annual	12.76	12.48	8.15	6.09	16.31	12.99	15.29	1.08	2.09	16.36	31.98	36.50	**172.07 (48.73)**
Breeding season (NatureScot)	12.76	12.48	8.15	*3.05	16.31	12.99	15.29	1.08	2.09	16.36	31.98	36.50	**48.71 (18.05)**
Non-breeding season (NatureScot)	12.76	12.48	8.15	*3.05	16.31	12.99	15.29	1.08	2.09	16.36	31.98	36.50	**123.36 (40.46)**
Spring migration (BDMPS)	12.76	12.48	8.15	*3.05	16.31	12.99	15.29	1.08	2.09	16.36	31.98	36.50	**36.44 (17.04)**
Autumn migration (BDMPS)	12.76	12.48	8.15	6.09	16.31	12.99	15.29	**1.08	2.09	16.36	31.98	36.50	**86.92 (32.93)**
*Where months are split between NatureScot breeding and non-breeding seasons, estimated collision mortality is split equally between the two seasons. The BDMPS spring migration period also overlaps with NatureScot breeding season in the month of April; as 50% of the collisions in April are part of the breeding season, the other 50% of collisions in April are allocated to the spring BDMPS.													

Season	Kittiwake Seasonal Collisions												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Seasonal Total
** NatureScot breeding season overlaps with the autumn BDMPS season in August, the collisions in August are allocated to the breeding season and not the BDMPS autumn season.													

3.2 Great black-backed gull

43. **Table 8** provides monthly and annual estimated collisions for great black-backed gull, based on the stochastic CRM. MLS and WCS are presented using Option 2 in the CRM (NatureScot Guidance Note 7[2]). Stochastic CRM estimated collisions were very low in all calendar months. This was due to very few great black-backed gulls being recorded in flight in the WDA during the DAS programme (maximum of 26 birds in 29 DAS samples, **Annex 11.2E: Raw Counts**). Great black-backed gull collisions totalled 4.88 (MLS) and 6.45 (WCS) individuals per annum.

44. **Table 9** provides WCS seasonal estimates of great black-backed gull collisions. Almost all collisions are predicted to occur in the non-breeding season (6.2 birds per annum), with extremely few collisions predicted for the breeding season (0.2 birds per annum).

Table 8: Great black-backed gull estimated collisions from the sCRM with Option 2 (generic flight height distribution) at 0.9940 (SD = 0.0004) avoidance rate for the MLS and WCS. Monthly values are the mean and standard deviation (S.D.) estimated collisions.

Scenario	Mean and SD monthly collision mortality													
	Mean / SD	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MLS	Mean	0.72	0.56	0.23	0.00	0.00	0.00	0.16	0.00	0.17	0.17	1.31	1.57	**4.88**
	SD	0.72	0.68	0.39	0.00	0.00	0.00	0.38	0.00	0.34	0.31	1.12	1.20	**2.24**
WCS	Mean	0.95	0.74	0.30	0.00	0.00	0.00	0.21	0.00	0.22	0.22	1.73	2.08	**6.45**
	SD		0.90	0.52	0.00	0.00	0.00	0.50	0.00	0.45	0.42	1.48	1.58	**2.96**

Table 9: Great black-backed gull seasonal collision estimated totals, based on sCRM WCS monthly mean estimates. Annual values are presented as mean (standard deviation).

Season	Great black-backed gull Seasonal Collisions												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Seasonal Total
Annual	0.95	0.74	0.30	0.00	0.00	0.00	0.21	0.00	0.22	0.22	1.73	2.08	**6.45 (2.96)**
Breeding season (NatureScot)	0.95	0.74	0.30	0.00	0.00	0.00	0.21	0.00	0.22	0.22	1.73	2.08	**0.21 (0.50)**
Non-breeding season (NatureScot)	0.95	0.74	0.30	0.00	0.00	0.00	0.21	0.00	0.22	0.22	1.73	2.08	**6.24 (2.92)**
Non-breeding season (BDMPS)	0.95	0.74	0.30	0.00	0.00	0.00	0.21	0.00	0.22	0.22	1.73	2.08	**6.24 (2.92)**

3.3 Herring gull

45. **Table 10** provides monthly and annual estimated collisions for herring gull, based on the stochastic CRM. MLS and WCS are presented using Option 2 in the CRM (NatureScot Guidance Note 7[2]). Stochastic CRM estimated collisions were very low in all calendar months. This was due to very few herring gulls being recorded in flight in the WDA during the DAS programme (42 birds in 29 DAS samples, more than half of these birds were recorded in one DAS sample in December 2021**, Annex 11.2E: Raw Counts**). Herring gull collisions totalled 6.1 (MLS) and 8 (WCS) individuals per annum.

46. **Table 11** provides WCS seasonal estimates of herring gull collisions. Almost all collisions are predicted to occur in the non-breeding season (7.7 birds), with extremely few collisions predicted for the breeding season (0.3 bird).

Table 10: Herring gull estimated collisions from the sCRM with Option 2 (generic flight height distribution) at 0.9940 (SD = 0.0004) avoidance rate for the MLS and WCS. Monthly values are the mean and standard deviation (S.D.) estimated collisions.

Scenario	Mean and SD monthly collision mortality													
	Mean / SD	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MLS	Mean	0.59	0.14	0.00	0.00	0.00	0.00	0.14	0.12	0.00	0.29	1.55	3.25	**6.07**
	SD	1.00	0.26	0.00	0.00	0.00	0.00	0.31	0.28	0.00	0.42	0.87	3.68	**4.19**
WCS	Mean	0.78	0.19	0.00	0.00	0.00	0.00	0.18	0.16	0.00	0.38	2.05	4.28	**8.01**
	SD	1.32	0.35	0.00	0.00	0.00	0.00	0.41	0.37	0.00	0.55	1.14	4.86	**5.54**

Table 11: Herring gull seasonal collision estimated totals, based on sCRM WCS monthly mean estimates. Annual values are presented as mean (standard deviation).

Season	Herring gull Seasonal Collisions												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Seasonal Total
Annual	0.78	0.19	0.00	0.00	0.00	0.00	0.18	0.16	0.00	0.38	2.05	4.28	**8.01 (5.54)**
Breeding season (NatureScot)	0.78	0.19	0.00	0.00	0.00	0.00	0.18	0.16	0.00	0.38	2.05	4.28	**0.34 (0.55)**
Non-breeding season (NatureScot)	0.78	0.19	0.00	0.00	0.00	0.00	0.18	0.16	0.00	0.38	2.05	4.28	**7.68 (5.49)**
Non-breeding season (BDMPS)	0.78	0.19	0.00	0.00	0.00	0.00	0.18	0.16	0.00	0.38	2.05	4.28	**7.68 (5.49)**

3.4 Arctic tern

47. **Table 12** provides monthly and annual estimated collisions for Arctic tern, based on the stochastic CRM. MLS and WCS are presented using Option 2 in the CRM (NatureScot Guidance Note 7[2]). Stochastic CRM estimated collisions were very low in all calendar months. This was due to very few Arctic terns being recorded in flight in the WDA during the DAS programme (62 birds in 29 DAS samples, **Annex 11.2E: Raw Counts**). Arctic tern collisions totalled 0.48 (MLS) and 0.61 (WCS) individuals per annum.

48. **Table 13** provides WCS seasonal estimates of Arctic tern collisions. Almost all collisions are predicted to occur in the breeding season (0.59 birds per annum), with extremely few collisions predicted for the non-breeding season (0.02 birds per annum for autumn migration and 0.005 birds per annum for spring migration).

Table 12: Arctic tern estimated collisions from the sCRM with Option 2 (generic flight height distribution) at 0.9908 (SD = 0.0004) avoidance rate for the MLS and WCS. Monthly values are the mean and standard deviation (S.D.) estimated collisions.

Scenario	Mean and SD monthly collision mortality													
	Mean / SD	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MLS	Mean	0.000	0.000	0.000	0.004	0.132	0.012	0.122	0.195	0.012	0.000	0.000	0.000	**0.476**
	SD	0.000	0.000	0.000	0.011	0.295	0.030	0.285	0.368	0.035	0.000	0.000	0.000	**0.675**
WCS	Mean	0.000	0.000	0.000	0.005	0.169	0.015	0.157	0.252	0.016	0.000	0.000	0.000	**0.613**
	SD	0.000	0.000	0.000	0.014	0.382	0.038	0.369	0.478	0.045	0.000	0.000	0.000	**0.877**

Table 13: Arctic tern seasonal collision estimated totals, based on sCRM WCS monthly mean estimates. Annual values are presented as mean (standard deviation).

Season	Arctic tern Seasonal Collisions												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Seasonal Total
Annual	0.000	0.000	0.000	0.005	0.169	0.015	0.157	0.252	0.016	0.000	0.000	0.000	**0.613 (0.877)**
Breeding season (NatureScot)	0.000	0.000	0.000	0.005	0.169	0.015	0.157	0.252	0.016	0.000	0.000	0.000	**0.593 (0.860)**
Non-breeding season (NatureScot)	0.000	0.000	0.000	0.005	0.169	0.015	0.157	0.252	0.016	0.000	0.000	0.000	**0.020 (0.051)**
Spring migration (BDMPS)	0.000	0.000	0.000	0.005	*0.169	0.015	0.157	0.252	0.016	0.000	0.000	0.000	**0.005 (0.014)**
Autumn migration (BDMPS)	0.000	0.000	0.000	0.005	0.169	0.015	*0.157	*0.252	0.016	0.000	0.000	0.000	**0.016 (0.045)**

* Where NatureScot breeding season overlaps with the spring BDMPS season (May) and the autumn BDMPS season (July and August), the collisions in the BDMPS season are allocated to the breeding season and not the BDMPS season.

3.5 Common tern

49. **Table 14** provides monthly and annual estimated collisions for common tern, based on the stochastic CRM. MLS and WCS are presented using Option 2 in the CRM (NatureScot Guidance Note 7[2]). Stochastic CRM estimated collisions were very low in all calendar months. This was due to very few common terns being recorded in flight in the WDA during the DAS programme (21 birds in 29 DAS samples, **Annex 11.2E: Raw Counts**). Common tern collisions totalled 0.29 (MLS) and 0.37 (WCS) individuals per annum.

50. **Table 15** provides WCS seasonal estimates of common tern collisions. Almost all collisions are predicted to occur in the breeding season (0.33 birds per annum), with extremely few collisions predicted for the non-breeding season (0.03 birds per annum for spring migration and 0.02 birds per annum for autumn migration).

Table 14: Common tern estimated collisions from the sCRM with Option 2 (generic flight height distribution) at 0.9908 (SD = 0.0004) avoidance rate for the MLS and WCS. Monthly values are the mean and standard deviation (S.D.) estimated collisions.

Scenario	Mean and SD monthly collision mortality													
	Mean / SD	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MLS	Mean	0.000	0.000	0.000	0.020	0.000	0.000	0.028	0.214	0.024	0.000	0.000	0.000	**0.286**
	SD	0.000	0.000	0.000	0.039	0.000	0.000	0.052	0.365	0.048	0.000	0.000	0.000	**0.376**
WCS	Mean	0.000	0.000	0.000	0.026	0.000	0.000	0.037	0.276	0.031	0.000	0.000	0.000	**0.369**
	SD	0.000	0.000	0.000	0.051	0.000	0.000	0.067	0.472	0.063	0.000	0.000	0.000	**0.486**

Table 15: Common tern seasonal collision estimated totals, based on sCRM WCS monthly mean estimates. Annual values are presented as mean (standard deviation).

Season	Common tern Seasonal Collisions												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Seasonal Total
Annual	0.000	0.000	0.000	0.026	0.000	0.000	0.037	0.276	0.031	0.000	0.000	0.000	**0.369 (0.486)**
Breeding season (NatureScot)	0.000	0.000	0.000	0.026	0.000	0.000	0.037	0.276	*0.016	0.000	0.000	0.000	**0.328 (0.480)**
Non-breeding season (NatureScot)	0.000	0.000	0.000	0.026	0.000	0.000	0.037	0.276	*0.016	0.000	0.000	0.000	**0.041 (0.060)**
Spring migration (BDMPS)	0.000	0.000	0.000	0.026	**0.000	0.000	0.037	0.276	0.031	0.000	0.000	0.000	**0.026 (0.051)**
Autumn migration (BDMPS)	0.000	0.000	0.000	0.026	0.000	0.000	**0.037	**0.276	*0.016	0.000	0.000	0.000	**0.016 (0.031)**

*Where months are split between NatureScot breeding and non-breeding seasons (September), estimated collision mortality is split equally between the two seasons. The BDMPS autumn migration period also overlaps with NatureScot breeding season in the month of September; as 50% of the collisions in September are part of the breeding season, the other 50% of collisions in September are allocated to the autumn BDMPS.

Season	Common tern Seasonal Collisions												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Seasonal Total
** NatureScot breeding season overlaps with the autumn BDMPS season in July, August and September, all collisions in July and August are allocated to the breeding season and not the BDMPS autumn season.													

3.6 Gannet

51. **Table 16** provides monthly and annual estimated collisions for gannet, based on the stochastic CRM. MLS and WCS are presented using Option 2 in the CRM (NatureScot Guidance Note 7[2]). Stochastic CRM estimated collisions were low in all calendar months. This was due to a relatively low number of gannets being recorded in flight in the WDA during the DAS programme (241 birds in 29 DAS samples, **Annex 11.2E: Raw Counts**). A 70% macro avoidance was applied to gannet densities in the non-breeding months of January, February, October, November and December. Gannet collisions totalled 10.8 (MLS) and 14.2 (WCS) individuals per annum.

52. **Table 17** provides WCS seasonal estimates of gannet collisions. The majority of collisions (13.4 birds per annum) are predicted to occur in the breeding season, with very few collisions predicted for the non-breeding season (0.55 birds per annum for spring migration and 0.25 birds per annum for autumn migration).

Table 16: Gannet estimated collisions from the sCRM with Option 2 (generic flight height distribution) at 0.9929 (SD = 0.0003) avoidance rate for the MLS and WCS. Monthly values are the mean and standard deviation (S.D.) estimated collisions.

Scenario	Mean and SD monthly collision mortality												
	Mean / SD	*Jan	*Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	*Oct	*Nov	*Dec	Annual
MLS	Mean	0.01	0.03	0.71	0.82	2.86	1.96	0.83	1.59	1.81	0.16	0.03	0.03	**10.84**
	SD	0.03	0.04	0.49	0.67	3.14	1.42	0.82	1.12	1.28	0.13	0.04	0.03	**6.26**
WCS	Mean	0.02	0.04	0.94	1.08	3.75	2.57	1.09	2.09	2.38	0.21	0.04	0.03	**14.22**
	SD	0.03	0.05	0.64	0.88	4.12	1.87	1.08	1.48	1.68	0.17	0.06	0.04	**8.25**
*70% Macro Avoidance applied to collision estimates in the gannet non-breeding season months including January, February, October, November and December													

Table 17: Gannet seasonal collision estimated totals, based on sCRM WCS monthly mean estimates. Annual values are presented as mean (standard deviation).

Season	Gannet Seasonal Collisions											
	*Jan	*Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	*Oct	*Nov	*Dec	Seasonal Total
Annual	0.018	0.035	0.936	1.081	3.751	2.571	1.086	2.086	2.376	0.214	0.036	0.033	**14.22 (8.25)**
Breeding season (NatureScot)	0.018	0.035	**0.468	1.081	3.751	2.571	1.086	2.086	2.376	0.214	0.036	0.033	**13.42 (7.91)**
Non-breeding season (NatureScot)	0.018	0.035	**0.468	1.081	3.751	2.571	1.086	2.086	2.376	0.214	0.036	0.033	**0.80 (0.48)**
Spring migration (BDMPS)	0.018	0.035	**0.468	1.081	3.751	2.571	1.086	2.086	2.376	0.214	0.036	0.033	**0.55 (0.36)**
Autumn migration (BDMPS)	0.018	0.035	0.936	1.081	3.751	2.571	1.086	2.086	***2.376	0.214	0.036	0.033	**0.25 (0.19)**

Season	Gannet Seasonal Collisions												
	*Jan	*Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	*Oct	*Nov	*Dec	Seasonal Total
* 70% Macro Avoidance applied to collision estimates in the gannet non-breeding season months including January, February, October, November and December													
** Where months are split between NatureScot breeding and non-breeding seasons, estimated collision mortality is split equally between the two seasons. The BDMPS spring migration period also overlaps with NatureScot breeding season in the month of March; as 50% of the collisions in March are part of the breeding season, the other 50% of collisions in March are allocated to the spring BDMPS.													
*** NatureScot breeding season overlaps with the autumn BDMPS season in September, the collisions in September are allocated to the breeding season and not the BDMPS autumn season.													

4.0 Summary

4.1 Collision Estimates used in the EIA and HRA Assessments

53. Mean estimated collisions by season and annually, for all six species for which CRM was undertaken, are summarised in **Table 18**. These values are taken from the collision estimates presented above for kittiwake, great black-backed gull, herring gull, Arctic tern, common tern and gannet.

Table 18: Summary of WCS seasonal and annual mean estimated collisions for all six species for which CRM was undertaken. Summary of MLS annual mean estimated collisions for all six species is also presented. Collisions are from sCRM, Option 2 using a generic flight height.

Species	Breeding season (NatureScot) WCS	Non-breeding season (NatureScot) WCS	Non-breeding season (BDMPS) WCS	Spring migration (BDMPS) WCS	Autumn migration (BDMPS) WCS	Annual WCS	Annual MLS
Kittiwake	48.71	123.36		36.44	86.92	**172.07**	**131.97**
Great black-backed gull	0.21	6.24	6.24			**6.45**	**4.88**
Herring gull	0.34	7.68	7.68			**8.01**	**6.07**
Arctic tern	0.593	0.020		0.005	0.016	**0.613**	**0.476**
Common tern	0.328	0.041		0.026	0.016	**0.369**	**0.286**
Gannet	13.42	0.80		0.55	0.25	**14.22**	**10.84**

5.0 References

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