MacArthur Green

West of Orkney Windfarm

Document Number WO1-WOW-PER-ENV-RPT-0037	
Revision	01
Approved Mr Stuart McAuley - Offshore Wind Power Limited Oct 2, 2024, 5:03 PM GMT+1:00	

West of Orkney Windfarm

Offshore Ornithology Additional Information

Appendix 3 – HRA and EIA: Collision Risk Modelling Technical Report

Date:	27 July 2024
Tel:	0141 342 5404
Web:	www.macarthurgreen.com
Address:	93 South Woodside Road |Glasgow | G20 6NT

Document Quality Record

Version	Status	Person Responsible	Date
0.1	Draft	Dr Sue O'Brien	08/05/2024
0.2	Reviewed	Dr Ross McGregor	16/05/2024
1	Internal Approval	Dr Sue O'Brien	18/05/2024
1.1	Client Review	Scott McCallum, Liz Foubister, Nicola Bain, Glen Tyler	27/05/2024
1.2	Updated following client, legal and technical review	Dr Mark Trinder, Dr Sue O'Brien, Nadia White	06/06/2024
1.3	Internal review	Dr Mark Trinder, Dr Nicola Goodship	25/07/2024
2	Internal Approval	Dr Mark Trinder	27/07/2024

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 Project Summary

1. Offshore Wind Power Limited (OWPL) ('the Applicant') is proposing the development of the West of Orkney Windfarm ('the Project'), an Offshore Wind Farm (OWF), located at least 23 kilometres (km) from the north coast of Scotland and 28 km from the west coast of Hoy, Orkney (**Figure 1-1**).

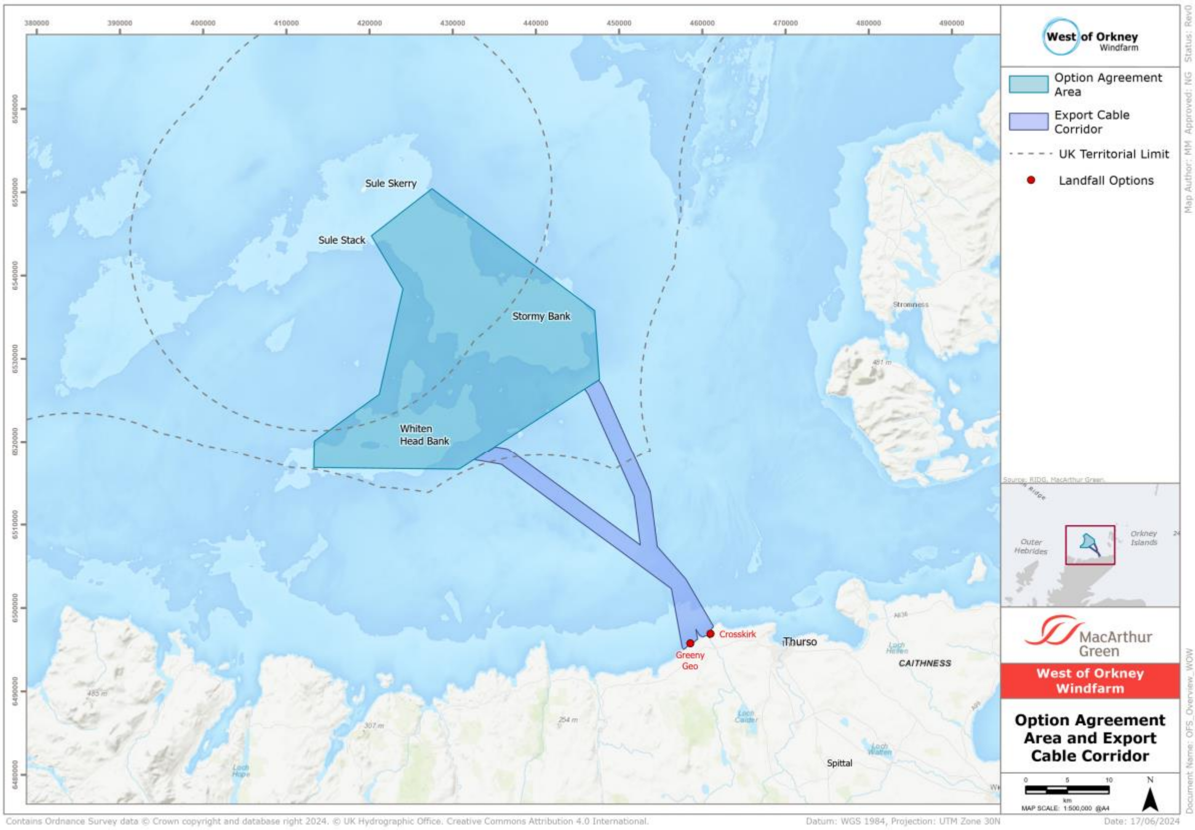

Figure 1-1. Location of the West of Orkney Windfarm Option Agreement Area (OAA) and Export Cable Corridor (ECC) which together, comprise the Offshore Project Area.

2. The Offshore Project will comprise up to 125 wind turbine generators (WTGs) with fixed-bottom foundations and up to five Offshore Substation Platforms (OSPs). The area within which the WTGs, OSPs and associated infrastructure will be located is the Option Agreement Area (OAA). The OAA covers an area of 657 km2. The export cables will be located within the Export Cable Corridor (ECC), with landfall options at Greeny Geo and/or Crosskirk in Caithness (**Figure 1-1**). The OAA and ECC together comprise the offshore Project area.

3. The Applicant submitted an application for consent under Section 36 of the Electricity Act 1989 and Marine Licences under Part 4 of the Marine (Scotland) Act 2010 and the Marine and Coastal Access Act 2009 to Scottish Ministers in September 2023 for the offshore components of the Project seaward of Mean High Water Springs (MHWS).

4. In accordance with relevant EIA Regulations[1], an Offshore Environmental Impact Assessment (EIA) Report was submitted to Marine Directorate – Licensing Operations Team (MD-LOT) as part of the Applicant's consent application (the 'Offshore EIA Report'). A Report to Information Appropriate Assessment (RIAA) was also submitted as part of the Offshore Application to provide the Competent Authority (MD-LOT) with the information required to assist them in undertaking an Appropriate Assessment (AA) for the offshore Project as required under the Conservation (Natural Habitats & c.) Regulations 1994 (as amended), the Conservation of Marine Habitats and Species Regulations 2017 and The Conservation of Habitats and Species Regulations 2017 (as amended) (hereafter referred to as the 'Habitats Regulations').

5. Following the review of the Applicant's application, and upon receipt of representations from consultees, MD-LOT issued a request for Additional Information on offshore ornithology. This report is part of the Ornithology Additional Information (OAI).

1.2 Relationship between the original application and the OAI

6. The Ornithology Additional Information (OAI) (see **Introduction to the Additional Ornithology Information** for structure of OAI and list of all reports) includes:

- an **Addendum to the Offshore EIA Report** in the form of a revised EIA chapter for Offshore and Intertidal Ornithology. All ornithology information in this report should be read in place of information in the original EIA chapter;
- an **Addendum to the RIAA**. All ornithology information in this report should be read in place of information in the original RIAA (with the exception of information on pre-application consultation);
- a set of nine technical appendices. This **Appendix 3 - EIA and HRA: Collision Risk Modelling Technical Report** is one of the nine technical appendices. These reports entirely replace the original Supporting Study 12: Offshore Ornithology Technical Supporting Study.

7. NatureScot's pre- and post-application Project-specific advice and online guidance notes[2] were followed throughout the OAI. To demonstrate this, reference to NatureScot's guidance and advice is made throughout the OAI, either in the text or in separate text boxes.

1.3 Purpose of this Report

8. This report provides information on estimated collision mortality arising from seabirds colliding with wind turbine generators (WTGs) during Project operation. The report also describes methods and parameters used to generate these estimates.

[1] *The relevant EIA Regulations include the Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017, the Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017, and the Marine Works (Environmental Impact Assessment) Regulations 2007.*

[2] Guidance Note 1: Guidance to support Offshore Wind Applications: Marine Ornithology - Overview | NatureScot

9. Collision estimates were generated using 24 months of digital aerial survey data, 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, Arctic tern, great skua and gannet.

1.4 Terminology

10. The following terminology is used in this report:

- Option Agreement Area (OAA): this is the area within which WTGs and other offshore Project infrastructure will be installed;
- Export Cable Corridor (ECC) is the area from the OAA to the landfall site in which the export cable will be placed;
- Offshore Project area comprises the OAA and ECC;
- OAA plus 2 km buffer: This includes a 2 km wide 'zone of influence' around the OAA, allowing for changes in bird behaviour (e.g. disturbance/displacement) in the vicinity of the OAA;
- OAA plus 4 km buffer: the OAA plus 4 km buffer was the area used for characterising baseline seabird numbers and distribution for the Project (see **Appendix 1 - EIA and HRA: Baseline Site Characterisation Technical Report**);
- WTG: Wind Turbine Generator.

2 METHODS

2.1 Summary of species at risk of collision

11. NatureScot, in Guidance Note 6[3], advised that collision risk and distributional responses (i.e. displacement and barrier effects) are the primary impact pathways for marine birds. As explained in the HRA Screening Report (refer to **Appendix 2 - HRA: HRA Screening Technical Report**), great black-backed gull and great skua were screened in for collision impact pathways, whereas Arctic tern, gannet and kittiwake were screened in for both collision and displacement impact pathways (refer to **Appendix 4 - EIA and HRA: Displacement Technical Report** for more information on displacement impacts).

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

- Arctic tern (*Sterna paradisaea*);
- European storm petrel (*Hydrobates pelagicus*);
- Northern gannet (*Morus bassanus*);
- Great black-backed gull (*Larus marinus*);
- Great skua (*Stercorarius skua*);
- Herring gull (*Larus argentatus*);
- Black-legged kittiwake (*Rissa tridactyla*);
- Manx shearwater (*Puffinus puffinus*);
- Migratory species.

13. European storm petrel and Manx shearwater generally fly too low to be at collision risk height, other than a possible increased risk of collision if attracted to lighting on WTGs. These two species were assessed using a qualitative approach in the **Addendum to the RIAA** and the **Addendum to the Offshore EIA Report**.

14. Herring gull are considered to be at risk of colliding with WTGs (Furness *et al*., 2013). However, no collision risk modelling was undertaken for herring gull as this species was recorded at very low densities in the OAA. Of the 27 monthly digital aerial surveys, herring gull were only recorded in flight in the OAA on three surveys and at a maximum density of 0.02 birds/km^2. Any herring gull collision mortality would be so low that no collision risk modelling was required to assess this impact for this species.

15. Collision risk for migratory species was not assessed quantitatively, as the work funded by the Scottish Government's Marine Directorate to develop a migratory collision risk model and strategic study of migratory species collision mortality, has not yet been published. A

[3] Guidance Note 6: Guidance to support Offshore Wind Applications - Marine Ornithology Impact Pathways for Offshore Wind Developments | NatureScot.

qualitative assessment of collision risk for migratory species was undertaken in the **Addendum to the RIAA** and **Addendum to the Offshore EIA Report.**

16. Collision risk modelling was undertaken for kittiwake, great black-backed gull, Arctic tern, great skua and gannet to estimate monthly, seasonal and annual collision mortalities for these five species.

2.2 Collision Risk Modelling

2.2.1 Deterministic and stochastic collision risk models

17. Until recently, deterministic collision risk modelling 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 avoidance behaviour undertaken by a bird when reacting to the offshore wind farm, turbine or blade.

18. 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 stochastic collision risk model (also known as StochLAB). Caneco (2022) made further updates and made several changes to improve model functionality (*pers. com.* Carl Donovan) to produce the most recent version of the model, known as 'sCRM'. This version is available as an online shiny app[4] and is the tool recommended by NatureScot for calculating collision mortality (see NatureScot Guidance Note 7[5]).

NatureScot Guidance Note 7 (2023):

We advise the use of:

the 2022 update to the sCRM tool shiny app (Caneco 2022). This update should also be used to run deterministic output (with seed specified to enable repeatability). We require that outputs for both stochastic and deterministic CRM are presented using this tool.

2.2.2 Model options

19. Band (2012) proposed assessing collision risk under three model options:

- Option 1 – Basic model: use of site-specific information on bird flight height distributions;
- Option 2 – Basic model: use of generic flight height distributions;

[4] sCRM (shinyapps.io). accessed 6th June 2024
[5] Guidance Note 7: Guidance to support Offshore Wind Applications: Marine Ornithology - Advice for assessing collision risk of marine birds | NatureScot.

- Option 3 – Extended model: risk of a bird colliding with a blade varying across a turbine blade at different points, using generic flight height distributions.

20. NatureScot, in Guidance Note 7[6] advised that Options 2 and 3 should be modelled and results presented for each CRM species. However, NatureScot has subsequently advised (NatureScot letter dated 27 March 2024) that only Option 2 should be presented, i.e. use of the Basic model with a generic flight height distribution (Johnston *et al*., 2014). Therefore, only Option 2 for the deterministic and stochastic CRMs were used to generate collision estimates, presented in this report.

NatureScot letter (27 March 2024):

When running CRM we only require:
o Most likely scenario (MLS) – option 2 (using the generic flight height dataset)
o Worst case scenario (WCS) – option 2 (using the generic flight height dataset)

2.3 Collision risk modelling input parameters

21. Collision risk models (CRM) require input information on densities of birds in flight, behavioural and physical characteristics of each bird species and wind farm/turbine properties.

2.3.1 Density of birds in flight in the offshore Project area

22. CRMs estimate the number of collisions for each calendar month. To do this, the CRM needs an estimate of density of birds in flight in the OAA, by calendar month. Consequently, surveys conducted in the same calendar month in different years need to be combined to generate a single estimate of density of birds in flight for that month.

NatureScot Guidance Note 2 (2023):
We advise that baseline characterisation should comprise two years of monthly surveys. Surveys should commence either at the start of the breeding season or the non-breeding season but not mid-way through a season, (i.e. surveys should commence in either March or October).

NatureScot letter (27 March 2024):
We agree with the approach to only use the 24 months of data collected from the start of the 2020 non-breeding season.

---

23. Density estimates of birds in flight were derived from digital aerial surveys of the OAA. The full digital aerial survey period was July 2020 to September 2022. However, NatureScot advised to only use data from complete seasons, starting in March or October and consequently to use 24 months of data (NatureScot letter dated 27 March 2024 and

[6] *Guidance Note 7: Guidance to support Offshore Wind Applications: Marine Ornithology - Advice for assessing collision risk of marine birds | NatureScot.*

NatureScot consultation meeting, 28 May 2024). Consequently, data from surveys carried out in July, August and September 2020 were not used in collision risk modelling.

24. An estimated monthly mean density and standard deviation (SD) was derived for each of the 12 calendar months from the 24 surveys carried out during October 2020 to September 2022. Note, no survey was carried out in January 2022 due to adverse weather conditions. Instead, two surveys were carried out in February 2022, one on 18 February and one on 26 February. The first survey (18 February 2022) was allocated to January to replace the missing survey.

25. Monthly mean densities and SDs were derived from the individual survey estimates using bootstraps. Each individual design-based estimate for each of the 24 surveys has a set of 1,000 bootstrap resampled density estimates (see **Appendix 1 - EIA and HRA: Baseline Site Characterisation Technical Report** for more details and **Annex 1N** for bootstrapped resampled density estimates). The bootstrapped resampled density estimates from each survey carried out in that calendar month were collated and a mean and standard deviation taken of all bootstrap estimates. For example, to derive a mean density and SD of birds in flight in the OAA for the calendar month of July, the 1,000 bootstrapped density estimates from the July 2021 survey and July 2022 survey were appended into a single data set of 2,000 values. The mean and SD of those 2,000 bootstrap estimates was then taken. This approach to calculating the SD when combining two surveys better reflects the range of variation in density across the two original surveys.

26. The mean density of birds in flight in each calendar month was used in the deterministic (Band) CRM. The bootstrap approach was used to capture uncertainty in density estimates in stochastic CRM, in the Caneco shiny app, sCRM. The tool uses 1,000 bootstrapped density estimates in a particular calendar month to generate a mean collision estimate and a measure of uncertainty around that collision estimate, e.g. standard deviation. To generate a set of 1,000 bootstrapped density estimates to input into the sCRM, from the two surveys (e.g. July 2021 and July 2022), the bootstrapped density estimates from each of the two surveys were appended, to create 2,000 bootstrap estimates for each calendar month, e.g. July. A subset of 1,000 of these was randomly selected and used as the density inputs for sCRM. These are provided in **Annex 3D** to enable the sCRM to be rerun.

2.3.2 Flight heights

27. 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[7] recommends using generic flight heights (Johnston *et al*., 2014, with associated corrigendum). This approach was used in the collision risk modelling.

[7] *Guidance Note 7: Guidance to support Offshore Wind Applications: Marine Ornithology - Advice for assessing collision risk of marine birds | NatureScot.*

NatureScot letter (27 March 2024):

When running CRM we only require:
o Most likely scenario (MLS) – option 2 (using the generic flight height dataset)
o Worst case scenario (WCS) – option 2 (using the generic flight height dataset)

2.3.3 Avoidance rates

28. 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 wind farm (macro avoidance), the turbine (meso avoidance) or the blade (micro avoidance).

29. 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 provided new avoidance rates for collision risk modelling in an (email dated 4 June 2024). These were used in collision risk modelling and are presented in **Table 2-1**.

30. On 15th August 2024, the SNCBs released the Joint advice note from the Statutory Nature Conservation Bodies (SNCBs) regarding bird collision risk modelling for offshore wind developments 2024 (JNCC et al., 2024). This joint advice note recommends use of slightly different avoidance rates to those recommended by NatureScot, in their Project-specific advice of 4 June 2024. On 15th August 2024, the Applicant was close to finalising the reports comprising the OAI and a full reassessment of collision mortality and associated apportioning of impacts to SPAs and rerunning of PVAs was not possible. Consequently, the collision mortality presented in this report is informed by avoidance rates provided in NatureScot's advice of June 2024 and not the SNCB advice note of August 2024.

2.3.3.1 Gannet macro-avoidance

31. There is evidence that gannet strongly avoid flying through offshore wind farms, i.e. that this species has high macro avoidance (Pavet *et al*., 2023). NatureScot's current advice is that they will accept a macro avoidance adjustment to densities of gannets in flight for the non-breeding season only and not for the breeding season (NatureScot letter dated 27 March 2024). However, no macro avoidance adjustment was applied when estimating gannet collisions, for either the breeding or non-breeding season. NatureScot were content with this approach when discussed at a post-application weekly consultation Meeting (14 May 2024).

NatureScot letter (27 March 2024):

With regards to the work undertaken by Natural England around macro-avoidance for gannet, we are not currently in a position to adopt the full recommendations of this work, we do however accept the outputs for gannet during the non-breeding season.

NatureScot Post-application Weekly Consultation Meeting (14th May 2024)

SO asked for clarity on NatureScot's recommendations re macro-avoidance for gannet. AR confirmed that whilst NatureScot have not published advice on this yet, NatureScot would accept an adjustment to input densities to CRM in the non-breeding season to accommodate gannet macro avoidance behaviour. SO indicated the OAI would not be applying any macro-avoidance adjustment for gannet during the breeding or non-breeding season.

2.3.4 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.

33. NatureScot have provided recommended biometrics and avoidance rates to the Project, by email (dated 4 June 2024). The biometrics and avoidance rates used in collision risk modelling are presented in **Table 2-1**.

Table 2-1 Species biometrics, including Nocturnal Activity Factor (NAF) and avoidance rates (AR) used in stochastic and deterministic CRMs to generate collision estimates. These parameter values were provided by NatureScot (by email 4 June 2024) and differ slightly to the more recent parameter values provided in the SNCB Joint Advice Note (JNCC *et al.*, 2024).

Species	Band (deterministic CRM) AR [a]	Stochastic CRM AR - mean (SD) [b]	Body length mean (metres) (SD) [c]	Wingspan mean (metres) (SD) [c]	Flight speed mean (m/s) (SD) [d]	NAF mean (SD) [e]	Flight type: Flapping or Gliding	% of flights upwind
Kittiwake	0.9924	0.9928 (0.0003)	0.39 (0.005)	1.08 (0.0625)	13.1 (0.4)	0.5 (0)	Flapping	50
Great black-backed gull	0.9936	0.9939 (0.0004)	0.71 (0.035)	1.58 (0.0375)	13.7 (1.2)	0.5 (0)	Flapping	50
Arctic tern	0.9902	0.9907 (0.0004)	0.34 (0.005)	0.8 (0.025)	10.9 (0.9)	0.125 (0)	Flapping	50
Great skua	0.9902	0.9907 (0.0004)	0.56 (0.0375)	1.36 (0.04)	14.9 (1.825)	0 (0)	Flapping	50
Gannet	0.9924	0.9928 (0.0003)	0.94 (0.0325)	1.72 (0.0375)	14.9 (0)	0.08 (0.1)	Gliding	50

a. Avoidance Rates for the Band model, i.e. deterministic CRM, are those presented in Appendix 1, Table 1 of NatureScot's letter dated 27 March 2024. The 'All gulls and terns rate' was used for Arctic tern.

b. Avoidance Rates for the stochastic CRM are those presented in Appendix 1, Table 2 of NatureScot's letter dated 27 March 2024. The 'All gulls and terns rate' was used for great skua and Arctic tern.

c. Body length and wind span biometrics were from Snow & Perrins, 1988.

d. All flight speeds were from Alerstam *et al.*, 2007, except for gannet and Arctic tern, which were from Pennycuick, 1997.

e. All nocturnal activity factors were based on Garthe & Hüppop, 2004, except gannet which is from Furness *et al.*, (2018).

2.3.5 Wind farm and turbine inputs

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

35. The Project will comprise up to 125 WTGs. However, the exact WTG model has not yet been confirmed. Multiple WTG design options are currently under consideration for the offshore Project. This flexibility is required to ensure the supply chain options at the point of construction can be met. The WTG design options under consideration are defined by their rotor diameter. In the original application, five WTGs were considered. However, NatureScot, in their letter of 27 March 2024, recommended that estimated collision for only the Most Likely Scenario (MLS) and Worst Case Scenario (WCS) should be presented. **Table 2-2** presents details of the WTG specifications.

Table 2-2. Wind farm and turbine specifications used in the collision risk modelling, for the MLS and the WCS

Input parameter	MLS	WCS
Number of turbines	125	125
No. of rotor blades	3	3
Maximum chord (m)	8.5	9
Rotor diameter (m)	265	330
Rotor radius (m)	132.5	165
Mean RPM ± SD	7.23 ±0.36	5.80 ± 0.29
Mean blade pitch (°) ± SD	6.5 ± 1.75	6.5 ± 1.75
Hub height above Highest Astronomical Tide (m)	157.2	189.7
Lower blade tip height (i.e. air gap) above HAT* (m)	24.7	24.7
Wind availability per month (%)	90.5	90.5
Mean downtime per month (%)	3.61	3.61
Latitude (°)	58.9	58.9
Wind Farm Width (km)	26.12	26.12
Tidal offset (m)	2.35	2.35

*HAT = Highest astronomical tide

2.3.6 Seasons

36. 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[8] and the Biologically Defined Minimum Population Scale (BDMPS) seasons (Furness, 2015).

37. Seasonal collision estimates were derived by summing collision estimates for all calendar months in that season. Where a season was split between the 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.

NatureScot consultation meeting advice (21 May 2024):

Breeding and non-breeding seasons are identified as follows:

- *Breeding season: birds are strongly associated with nest site – nesting, egg laying, provisioning young*
- *Non-breeding season: birds are more widely dispersed and not strongly associated with nest site. This period subsumes the 'breeding site attendance' periods defined in NS seasonal definitions guidance*

Non-breeding season apportioning is dependent on information within BDMPS (Furness 2015). Where Furness seasons overlap with NS breeding seasons Furness seasons should be foreshortened. For some species Furness identifies a single non-breeding (winter) period, for others there are also autumn and spring migration BDMPS which should be used.

For example, for gannet:
NS breeding site attendance period second half of Feb and first half of March becomes part of the non-breeding season. Main breeding season is as per NS guidance second half of March- end of Sept. Furness BDMPS for gannet is divided into separate Autumn and Spring migration periods Sept-Nov and Dec-Mar. The Spring period is foreshortened to exclude the second half of March to align with NS guidance. There is no migration-free winter period for gannet.

38. Where BDMPS seasons overlapped with the NatureScot breeding season, the mortality in that month was allocated to the breeding season rather than the non-breeding season, as per NatureScot advice (consultation meeting, 21 May 2024).

39. Annual collision estimates were found by summing collision estimates across all 12 calendar months.

Table 2-3. Definitions of breeding and non-breeding seasons according to NatureScot Guidance Note 9[8] 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)		
Arctic tern	May to August	September to April	Late April to May	July to early September	n/a
Great skua	Mid-April to mid-September	Mid-September to mid-April	March to April	August to October	November to February
Gannet	Mid-March to September	October to mid-March	December to March	September to November	n/a

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

Table 2-4. Summary table describing collision risk modelling parameters.

	Details of CRM	
Collision Risk Model	sCRM	
Tool version	Caneco (2022) shiny app v0.1.1 run online on 26th May and 6th June 2024	
Seed run number	100	
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 3A: survey densities and calendar month densities**)	
Wind farm and turbine parameters*	**Most Likely Scenario**	**Worst Case Scenario**
No. of turbines	125	125
Rotor diameter (m)	265	330
Avoidance rate**	**Deterministic (Band) CRM**	**Stochastic CRM Mean (SD)**
Kittiwake	0.9924	0.9928 (0.0003)
Great black-backed gull	0.9936	0.9939 (0.0004)
Arctic tern	0.9902	0.9907 (0.0004)
Great skua	0.9902	0.9907 (0.0004)
Gannet	0.9924	0.9928 (0.0003)

* see **Table 2-2** for full list of turbine and wind farm parameters

** see **Table 2-1** for full list of bird biometrics

3 RESULTS

3.1 Monthly mean densities of birds in flight by calendar month

40. An input to CRM is density of birds in flight in each calendar month. The format for the sCRM input is 1,000 bootstrap resampled estimates whereas deterministic (Band) CRM uses mean density of birds in flight. The 1,000 bootstrap estimates are provided in **Annex 3D: bootstrapped densities inputs to CRM**. Mean and SD of monthly density of birds in flight is presented in **Table 3-1**.

Table 3-1 Monthly mean density estimates and SDs, in parentheses, of birds in flight in the OAA by calendar month.
Values are the mean and SD of all bootstrap estimates from the two digital aerial surveys carried out in that calendar month. The mean densities were inputs to deterministic (Band) CRM.

	Mean and SD density of birds in flight within the OAA (birds/km²)											
Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kittiwake	0.07 (0.03)	0.23 (0.16)	0.86 (0.29)	0.28 (0.16)	0.07 (0.05)	0.04 (0.02)	0.63 (0.68)	0.01 (0.01)	0.13 (0.13)	0.63 (0.18)	0.2 (0.09)	0.05 (0.02)
Great black-backed gull	0.04 (0.03)	0.04 (0.03)	0 (0.01)	0 (0)	0 (0)	0.01 (0.02)	0 (0)	0 (0)	0 (0)	0.01 (0.01)	0.06 (0.04)	0.09 (0.08)
Arctic tern	0 (0)	0 (0)	0 (0)	0 (0)	0.01 (0.01)	0.07 (0.12)	0.01 (0.02)	0.01 (0.01)	0 (0)	0 (0)	0 (0)	0 (0)
Great skua	0 (0)	0 (0)	0 (0)	0.03 (0.03)	0 (0)	0 (0)	0.01 (0.01)	0.01 (0.01)	0 (0)	0 (0)	0 (0)	0 (0)
Gannet	0.01 (0.01)	0.07 (0.04)	0.13 (0.1)	0.3 (0.08)	0.24 (0.16)	0.21 (0.06)	0.3 (0.07)	0.32 (0.28)	0.49 (0.22)	0.58 (0.11)	0.01 (0.01)	0.03 (0.02)

3.2 Collision Estimates

3.2.1 Overview

41. The species with the highest estimated collisions was kittiwake, with an annual WCS sCRM estimate of 56 birds. Gannet had slightly lower estimated collisions with an annual WCS sCRM estimate of 45 birds. Great black-backed gull had considerably fewer estimated collisions, at an annual WCS sCRM estimate of 12 birds. Arctic tern and great skua had very low estimated annual collisions with a maximum of only 0.4 bird collisions, for both species. See **Table 4-1** for seasonal and annual summaries of estimated collision mortality.

3.2.2 Kittiwake

42. **Table 3-2** and **Table 3-3** provide monthly and annual estimated collisions for kittiwake, based on the stochastic CRM and deterministic CRM, respectively. Only the MLS and WCS using Option 2 in the CRM are presented, as advised by NatureScot (letter dated 27 March 2024).

43. Stochastic CRM estimated collisions were 52.7 (MLS) and 56.0 (WCS) kittiwakes per annum (**Table 3-2**). By comparison, deterministic CRM estimated collisions were higher, at 55.8 (MLS) and 59.3 (WCS) kittiwakes per annum (**Table 3-3**).

44. Estimated collisions were highest in March, July and October (**Table 3-2**). The July peak could be attributed to young birds fledging. However, zero records of juvenile kittiwakes were reported in 2020 or 2021 and only 1 of the 294 kittiwakes recorded in 2022 were classed as juveniles (see Table 14 of the Digital Aerial Survey Report, **Annex 1A: Digital video aerial survey report**). The other months of peak estimated mortality (March and October) could be caused by an influx of kittiwakes on spring and autumn passage to areas further north or south, respectively.

45. The variation (SD) around the mean kittiwake collisions was particularly high in July (SD = 14.4) but was also quite high in March (SD = 5.3) and October (SD = 3.4) (**Table 3-2**). As expected, this corresponds to the months of highest estimated collisions, i.e. the larger the number of estimated collisions, the greater the uncertainty around that estimate. The particularly high SD for the July collision estimate is due to a very high density of birds being recorded in the OAA in July 2022. The July 2022 mean density (1.22 birds/km^2) was much higher than the July 2021 mean density (0.12 birds/km^2) (see **Annex 3A: survey densities and calendar month densities** for density of birds in flight on each individual digital aerial survey).

46. **Table 3-4** provides seasonal estimates of kittiwake collisions. The majority of collision mortality occurred in the non-breeding season (38.2 birds), with approximately one-third of collisions occurring in the breeding season (17.9 birds). This was primarily due to the high collision estimates in March and October. A slightly higher number of collisions was estimated to occur in the spring migration BDMPS season (21.9 birds) compared with the autumn migration BDMPS season (16.3 birds).

Table 3-2. Kittiwake estimated collisions from the Caneco shiny app sCRM with Option 2 (generic flight height distribution) at 0.9928 (SD = 0.0003) avoidance rate for the MLS and WCS. Monthly values are the mean and standard deviation (S.D.) estimated collisions.

Scenario	Mean monthly collision mortality (S.D.)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MLS (Rotor diameter 265 m)	1.02 (0.39)	3.15 (2.22)	13.97 (5.03)	4.85 (2.73)	1.35 (0.92)	0.74 (0.41)	12.16 (13.55)	0.12 (0.18)	2.1 (2.15)	9.82 (3.19)	2.78 (1.32)	0.64 (0.31)	**52.70**
WCS (Rotor diameter 330 m)	1.09 (0.41)	3.35 (2.36)	14.85 (5.34)	5.16 (2.9)	1.44 (0.98)	0.79 (0.43)	12.93 (14.4)	0.12 (0.2)	2.23 (2.29)	10.44 (3.39)	2.96 (1.4)	0.68 (0.32)	**56.04**

Table 3-3. Kittiwake estimated collisions from the deterministic CRM (Band, 2012) with Option 2 (generic flight height distribution) at 0.9924 avoidance rate for the MLS and WCS. Monthly values are mean estimated collisions. Annual totals are calculated as the summed totals of the monthly estimates.

Scenario	Mean monthly collision mortality												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MLS (Rotor diameter 265 m)	1.08	3.35	14.81	5.07	1.48	0.80	12.76	0.13	2.21	10.46	3.00	0.69	**55.84**
WCS (Rotor diameter 330 m)	1.15	3.56	15.74	5.39	1.57	0.85	13.56	0.13	2.35	11.12	3.19	0.73	**59.34**

Table 3-4. Kittiwake seasonal collision estimate totals, based on sCRM WCS monthly mean estimates.

Season	Kittiwake Seasonal Collisions												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Seasonal total
Annual	1.09 (0.41)	3.35 (2.36)	14.85 (5.34)	5.16 (2.9)	1.44 (0.98)	0.79 (0.43)	12.93 (14.4)	0.12 (0.2)	2.23 (2.29)	10.44 (3.39)	2.96 (1.4)	0.68 (0.32)	**56.04**
Breeding season (NatureScot)	1.09	3.35	14.85	2.58*	1.44	0.79	12.93	0.12	2.23	10.44	2.96	0.68	17.86
Non-breeding season (NatureScot)	1.09	3.35	14.85	2.58*	1.44	0.79	12.93	0.12	2.23	10.44	2.96	0.68	38.18
Spring migration (BDMPS)	1.09	3.35	14.85	2.58*	1.44	0.79	12.93	0.12	2.23	10.44	2.96	0.68	21.87
Autumn migration (BDMPS)	1.09	3.35	14.85	5.16	1.44	0.79	12.93	0.12**	2.23	10.44	2.96	0.68	16.31

*Where months are split between breeding and non-breeding season, estimated collision mortality is split equally between the two seasons.
**Where the NatureScot breeding season overlaps with a BDMPS season, the collisions in that month are allocated to the breeding season and not the BDMPS season (as advised by NatureScot, 21 May 2024).

3.2.3 Great Black-backed Gull

47. **Table 3-5** and **Table 3-6** present monthly and annual estimated collisions for great black-backed gull, based on the stochastic CRM (in the Caneco shiny app) and a deterministic CRM (Band, 2012), respectively. Only the MLS and WCS using Option 2 in the CRM are presented, as advised by NatureScot (letter dated 27 March 2024).

48. Stochastic CRM estimated collisions were 11.4 (MLS) and 11.9 (WCS) great black-backed gulls per annum (**Table 3-5**). Deterministic CRM estimated collisions were very similar, at 11.0 (MLS) and 11.5 (WCS) great black-backed gull, per annum (**Table 3-6**).

49. Estimated collisions were highest in December, January and February, with peak collisions in December (**Table 3-5**). Few collisions were predicted to occur during the breeding season, with no collisions predicted for April, May, July, August and September. This was due to no great black-backed gulls being recorded in flight in the OAA in these months during the digital aerial survey programme.

50. **Table 3-7** provides seasonal estimates of great black-backed gull collisions. Note, the BDMPS report (Furness, 2015) identifies only a single non-breeding season that aligns with the NatureScot non-breeding season. Almost all collisions are predicted to occur in the non-breeding season (11.13 birds), with negligible collisions predicted for the breeding season (0.81 birds).

Table 3-5. Great black-backed gull estimated collisions from the Caneco shiny app sCRM with Option 2 (generic flight height distribution) at 0.9939 (SD = 0.0004) avoidance rate for the MLS and WCS. Monthly values are the mean and standard deviation (S.D.) estimated collisions.

Scenario	Mean monthly collision mortality (S.D.)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MLS (Rotor diameter 265 m)	1.68 (1.25)	1.56 (1.4)	0.24 (0.45)	0 (0)	0 (0)	0.78 (1.25)	0 (0)	0 (0)	0 (0)	0.30 (0.51)	2.67 (2.11)	4.21 (3.89)	**11.44**
WCS (Rotor diameter 330 m)	1.75 (1.31)	1.63 (1.46)	0.25 (0.47)	0 (0)	0 (0)	0.81 (1.3)	0 (0)	0 (0)	0 (0)	0.32 (0.53)	2.79 (2.2)	4.39 (4.06)	**11.94**

Table 3-6. Great black-backed gull estimated collisions from the deterministic CRM (Band, 2012) with Option 2 (generic flight height distribution) at 0.9936 avoidance rate for the MLS and MCS. Monthly values are mean estimated collisions. Annual totals are calculated as the summed totals of the monthly estimates.

Scenario	Mean monthly collision mortality												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MLS (Rotor diameter 265 m)	1.66	1.52	0.25	0	0	0.71	0	0	0	0.27	2.60	3.99	**11.00**
WCS (Rotor diameter 330 m)	1.74	1.59	0.26	0	0	0.74	0	0	0	0.28	2.72	4.16	**11.49**

Table 3-7. Great black-backed gull seasonal collision estimate totals, based on sCRM Worst Case Scenario monthly estimates.

Season	Great black-backed gull Seasonal Collisions												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Seasonal total
Annual	1.75	1.63	0.25	0	0	0.81	0	0	0	0.32	2.79	4.39	**11.94**
Breeding season (NatureScot)	1.75	1.63	0.25	0	0	0.81	0	0	0	0.32	2.79	4.39	**0.81**
Non-breeding season (NatureScot)	1.75	1.63	0.25	0	0	0.81	0	0	0	0.32	2.79	4.39	**11.13**
Non-breeding season (BDMPS)	1.75	1.63	0.25	0	0	0.81	0	0	0	0.32	2.79	4.39	**11.13**

3.2.4 Arctic Tern

51. **Table 3-8** and **Table 3-9** present monthly and annual estimated collisions for Arctic tern, based on the stochastic CRM (in the Caneco shiny app) and a deterministic CRM (Band, 2012), respectively. Only the MLS and WCS using Option 2 in the CRM are presented, as advised by NatureScot (letter dated 27 March 2024).

52. Estimated Arctic tern collisions were very low, varying from a total of 0.3-0.43 birds per annum, depending on the scenario and CRM.

53. **Table 3-10** provides seasonal estimates of Arctic tern collisions. All collisions were predicted to occur in the breeding season with no collisions in any of the other seasons.

Table 3-8. Arctic tern estimated collisions from the Caneco shiny app sCRM with Option 2 (generic flight height distribution) at 0.9907 (SD = 0.0004) avoidance rate for the MLS and WCS. Monthly values are the mean and standard deviation (S.D.) estimated collisions.

Scenario	Mean monthly collision mortality (S.D.)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MLS (Rotor diameter 265 m)	0 (0)	0 (0)	0 (0)	0 (0)	0.02 (0.06)	0.32 (0.9)	0.05 (0.11)	0.02 (0.04)	0 (0)	0 (0)	0 (0)	0 (0)	**0.41**
WCS (Rotor diameter 330 m)	0 (0)	0 (0)	0 (0)	0 (0)	0.02 (0.07)	0.34 (0.96)	0.05 (0.11)	0.02 (0.05)	0 (0)	0 (0)	0 (0)	0 (0)	**0.43**

Table 3-9 Arctic tern estimated collisions from the deterministic CRM (Band, 2012) with Option 2 (generic flight height distribution) at 0.9902 avoidance rate for the MLS and MCS. Monthly values are mean estimated collisions. Annual totals are calculated as the summed totals of the monthly estimates.

Scenario	Mean monthly collision mortality												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MLS (Rotor diameter 265 m)	0	0	0	0	0.02	0.23	0.04	0.01	0	0	0	0	**0.3**
WCS (Rotor diameter 330 m)	0	0	0	0	0.02	0.25	0.04	0.02	0	0	0	0	**0.33**

Table 3-10. Arctic tern seasonal collision estimate totals, based on sCRM Worst Case Scenario monthly estimates.

	Arctic tern Seasonal Collisions												
Season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Seasonal total
Annual	0	0	0	0	0.02	0.34	0.05	0.02	0	0	0	0	0.43
Breeding season (NatureScot)	0	0	0	0	0.02	0.34	0.05	0.02	0	0	0	0	**0.43**
Non-breeding season (NatureScot)	0	0	0	0	0.02	0.34	0.05	0.02	0	0	0	0	**0.0**
Spring migration (BDMPS)	0	0	0	0	0.02**	0.34	0.05	0.02	0	0	0	0	**0.0**
Autumn migration (BDMPS)	0	0	0	0	0.02	0.34	0.05**	0.02**	0	0	0	0	**0.0**

**Where the NatureScot breeding season overlaps with a BDMPS season, the collisions in that month are allocated to the breeding season and not the BDMPS season (as advised by NatureScot, 21 May 2024).

3.2.5 Great Skua

54. **Table 3-11** and **Table 3-12** present monthly and annual estimated collisions for great skua, based on the stochastic CRM (in the Caneco shiny app) and a deterministic CRM (Band, 2012), respectively. Only the MLS and WCS using Option 2 in the CRM are presented, as advised by NatureScot (letter dated 27 March 2024).

55. Estimated collisions were very low under both the MLS and WCS and for the deterministic and stochastic CRM, ranging from 0.26-0.38 birds per annum. The very few collisions were predicted to occur during April, July or August. No great skua were recorded in the OAA in flight in the other nine months.

56. **Table 3-13** presents seasonal estimates of great skua collisions. There were very few estimated collisions throughout the year, with estimated collisions of 0.25 birds in the breeding season and 0.13 birds in the non-breeding season.

Table 3-11. Great skua estimated collisions from the Caneco shiny app sCRM with Option 2 (generic flight height distribution) at 0.9907 (SD = 0.0004) avoidance rate for the MLS and WCS. Monthly values are the mean and standard deviation (S.D.) estimated collisions.

Scenario	Mean monthly collision mortality (S.D.)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MLS (Rotor diameter 265 m)	0 (0)	0 (0)	0 (0)	0.24 (0.39)	0 (0)	0 (0)	0.06 (0.13)	0.06 (0.12)	0 (0)	0 (0)	0 (0)	0 (0)	0.36
WCS (Rotor diameter 330 m)	0 (0)	0 (0)	0 (0)	0.26 (0.42)	0 (0)	0 (0)	0.06 (0.14)	0.06 (0.13)	0 (0)	0 (0)	0 (0)	0 (0)	0.38

Table 3-12. Great skua estimated collisions from the deterministic CRM (Band, 2012) with Option 2 (generic flight height distribution) at 0.9902 avoidance rate for the MLS and MCS. Monthly values are mean estimated collisions. Annual totals are calculated as the summed totals of the monthly estimates.

Scenario	Mean monthly collision mortality												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MLS (Rotor diameter 265 m)	0	0	0	0.18	0	0	0.04	0.04	0	0	0	0	0.26
WCS (Rotor diameter 330 m)	0	0	0	0.19	0	0	0.05	0.04	0	0	0	0	0.28

Table 3-13. Great skua seasonal collision estimate totals, based on sCRM Worst Case Scenario monthly estimates.

Season	Great skua Seasonal Collisions												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Seasonal total
Annual	0	0	0	0.26	0	0	0.06	0.06	0	0	0	0	**0.38**
Breeding season (NatureScot)	0	0	0	0.13*	0	0	0.06	0.06	0	0	0	0	**0.25**
Non-breeding season (NatureScot)	0	0	0	0.13*	0	0	0.06	0.06	0*	0	0	0	**0.13**
Spring migration (BDMPS)	0	0	0	0.13*	0	0	0.06	0.06	0	0	0	0	**0.13**
Autumn migration (BDMPS)	0	0	0	0.26	0	0	0.06	0.06**	0**	0	0	0	**0.0**
Winter season (BDMPS)	0	0	0	0.26	0	0	0.06	0.06	0	0	0	0	**0.0**

*Where months are split between breeding and non-breeding season, estimated collision mortality is split equally between the two seasons.
**Where the NatureScot breeding season overlaps with a BDMPS season, the collisions in that month are allocated to the breeding season and not the BDMPS season (as advised by NatureScot, 21 May 2024).

3.2.6 Gannet

57. **Table 3-14** and **Table 3-15** present monthly and annual estimated collisions for gannet, based on the stochastic CRM (in the Caneco shiny app) and a deterministic CRM (Band, 2012), respectively. Only the MLS and WCS using Option 2 in the CRM are presented, as advised by NatureScot (letter dated 27 March 2024).

58. Stochastic CRM estimated collisions were 42.7 (MLS) and 45.1 (WCS) gannets per annum (**Table 3-14**). Deterministic CRM estimated collisions were similar, at 41.2 (MLS) and 43.6 (WCS) gannets per annum (**Table 3-15**).

59. Estimated collisions were highest in July to October, with a peak of 7.2 gannet collisions per month in September and October (**Table 3-14**). This peak could be attributed to young birds fledging. The records of gannet aged as juvenile birds from the digital aerial survey were highest in September of both 2020 and 2021, with juveniles also recorded in October of each year, although records of juvenile birds were still a small proportion of all birds recorded in those months (see Table 28 of the Digital Aerial Survey Report **Annex 1A: Digital video aerial survey report**).

60. The SD around the mean estimated gannet collisions was particularly high in August (SD = 6.26). The months with the highest collision estimates also had the largest SDs (**Table 3-14**).

61. **Table 3-16** provides seasonal estimates of gannet collisions. The majority of collision mortality occurred in the breeding season (35.3 birds), with approximately one-quarter of collisions occurring in the non-breeding season (9.8 birds). Estimated collisions were very low in November to March, e.g. the estimated collisions during the BDMPS spring migration season was just 2 birds. More collisions were predicted to occur in the BDMPS autumn migration season (7.7 birds) but this was due to the high collision estimate in October.

Table 3-14. Gannet estimated collisions from the Caneco shiny app sCRM with Option 2 (generic flight height distribution) at 0.9928 (SD = 0.0003) avoidance rate for the MLS and WCS. Monthly values are the mean and standard deviation (S.D.) estimated collisions.

Scenario	Mean monthly collision mortality (S.D.)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MLS (Rotor diameter 265 m)	0.12 (0.13)	0.66 (0.55)	1.79 (1.72)	4.80 (2.46)	4.66 (4.11)	4.31 (2.28)	5.91 (2.97)	5.65 (5.95)	7.21 (4.77)	7.21 (3.53)	0.12 (0.14)	0.25 (0.26)	**42.69**
WCS (Rotor diameter 330 m)	0.12 (0.13)	0.70 (0.58)	1.89 (1.81)	5.07 (2.58)	4.92 (4.32)	4.55 (2.39)	6.24 (3.11)	5.96 (6.26)	7.61 (5.0)	7.61 (3.69)	0.12 (0.14)	0.27 (0.27)	**45.06**

Table 3-15. Gannet estimated collisions from the deterministic CRM (Band, 2012) with Option 2 (generic flight height distribution) at 0.9924 avoidance rate for the MLS and MCS. Monthly values are mean estimated collisions. Annual totals are calculated as the summed totals of the monthly estimates.

Scenario	Mean monthly collision mortality												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
MLS (Rotor diameter 265 m)	0.11	0.65	1.7	4.63	4.43	4.11	5.75	5.54	6.96	6.98	0.11	0.24	**41.21**
WCS (Rotor diameter 330 m)	0.11	0.69	1.8	4.9	4.69	4.35	6.08	5.87	7.37	7.38	0.12	0.25	**43.61**

Table 3-16. Gannet seasonal collision estimate totals, based on sCRM Worst Case Scenario monthly estimates.

Season	Gannet Seasonal Collisions												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Seasonal total
Annual	0.12	0.7	1.89	5.07	4.92	4.55	6.24	5.96	7.61	7.61	0.12	0.27	**45.06**
Breeding season (NatureScot)	0.12	0.7	0.945*	5.07	4.92	4.55	6.24	5.96	7.61	7.61	0.12	0.27	**35.30**
Non-breeding season (NatureScot)	0.12	0.7	0.945*	5.07	4.92	4.55	6.24	5.96	7.61	7.61	0.12	0.27	**9.77**
Spring migration (BDMPS)	0.12	0.7	0.945*	5.07	4.92	4.55	6.24	5.96	7.61	7.61	0.12	0.27	**2.04**
Autumn migration (BDMPS)	0.12	0.7	1.89	5.07	4.92	4.55	6.24	5.96	7.61**	7.61	0.12	0.27	**7.73**

*Where months are split between breeding and non-breeding season, estimated collision mortality is split equally between the two seasons.
**Where the NatureScot breeding season overlaps with a BDMPS season, the collisions in that month are allocated to the breeding season and not the BDMPS season (as advised by NatureScot, 21 May 2024).

4 SUMMARY

4.1 Collision Estimates used in the EIA and HRA Assessments

62. Mean estimated collisions by season and annually, for all five species for which CRM was undertaken, are summarised in **Table 4-1**. These values are taken from the collision estimates presented above for kittiwake, great black-backed gull, Arctic tern, great skua and gannet.

Table 4-1. Summary of seasonal and annual mean estimated collisions for all five species for which CRM was undertaken. Collisions are from sCRM, Option 2 using a generic flight height, for the WCS. n/a = no BDMPS season for that species.

Season	Breeding season (NatureScot)	Non-breeding season (NatureScot)	Non-breeding season (BDMPS)	Spring migration (BDMPS)	Autumn migration (BDMPS)	Winter season (BDMPS)	Annual
Kittiwake	17.86	38.18		21.87	16.31		**56.04**
Great black-backed gull	0.81	11.13	11.13				**11.94**
Arctic tern	0.43	0		0	0		**0.43**
Great skua	0.25	0.13		0.13	0	0	**0.38**
Gannet	35.3	9.77		2.04	7.73		**45.06**

REFERENCES

Alerstam, T., Rosén, M., Bäckman, J., Ericson, P.G.P. and Hellgren, O., 2007. Flight speeds among bird species: allometric and phylogenetic effects. PLoS Biology, 5: p.e197.

Band, B., 2012. Using a collision risk model to assess bird collision risks for offshore windfarms. SOSS report, Crown Estate.

Caneco, B. 2022. R scripts can be used via an online shiny app available at: sCRM (shinyapps.io).

Chamberlain, D.E., Rehfisch, M.R., Fox, A.D., Desholm, M. and Anthony, S.J., 2006. The effect of avoidance rates on bird mortality predictions made by wind turbine collision risk models. Ibis, 148: 198-202.

Cramp, S. & Simmons, K.E.L. 1983. Handbook of the Birds of Europe, the Middle East, and North Africa: The Birds of the Western Palearctic. Vol. III. Waders to Gulls. Oxford University Press.

Furness, R.W. 2015. Non-breeding season populations of seabirds in UK waters: Population sizes for Biologically Defined Minimum Population Scales (BDMPS). Natural England Commissioned Reports, Number 164.

Furness, R.W., Garthe, S., Trinder, M., Matthiopolous, J., Wanless, S., Jeglinski, J. 2018. Nocturnal flight activity of northern gannets *Morus bassanus* and implications for modelling collision risk at offshore wind farms. Environmental Impact Assessment Review. 73: 1-6.

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

Garthe, S. and Hüppop, O., 2004. Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. Journal of Applied Ecology, 41: 724-734.

Johnston, A., Cook, A.S., Wright, L.J., Humphreys, E.M. and Burton, N.H., 2014. Modelling flight heights of marine birds to more accurately assess collision risk with offshore wind turbines. Journal of Applied Ecology, 51: 31-41. https://doi.org/10.1111/1365-2664.12191.

JNCC, Natural England, Natural Resources Wales, NatureScot. 2024. Joint advice note from the Statutory Nature Conservation Bodies (SNCBs) regarding bird collision risk modelling for offshore wind developments. JNCC, Peterborough. Joint advice note from the Statutory Nature Conservation Bodies (SNCBs) regarding bird collision risk modelling for offshore wind developments | JNCC Resource Hub

Masden, E. 2015. Scottish Marine and Freshwater Science Vol 6 No 14: Developing an avian collision risk model to incorporate variability and uncertainty. Published by Marine Scotland Science. DOI: 10.7489/1659-1. http://www.scotland.gov.uk/Resource/0048/00486433.pdf.

McGregor, R. M., King, S., Donovan, C. R., Caneco, B., & Webb, A. 2018. A Stochastic Collision Risk Model for Seabirds in Flight. Marine Scotland. A Stochastic Collision Risk Model for Seabirds in Flight (pnnl.gov).

Ozsanlav-Harris, L., Inger, R. & Sherley, R. 2023. Review of data used to calculate avoidance rates for collision risk modelling of seabirds. JNCC Report 732, JNCC, Peterborough, ISSN 0963-8091.

Pavat, D., Harker, A.J., Humphries, G., Keogan, K., Webb, A. and Macleod, K. 2023. Consideration of avoidance behaviour of northern gannet (*Morus bassanus*) in collision risk modelling for offshore wind farm impact assessments. NECR490. Natural England. NECR512 Consideration of avoidance behaviour of northern gannet (Morus bassanus) in collision risk modelling for offshore wind farm impact assessments - NECR512 (naturalengland.org.uk).

Pennycuick, C.J., 1997. Actual and 'optimum' flight speeds: field data reassessed. Journal of Experimental Biology, 200: 2355-2361.

Snow, D.W. and Perrins, C.M. (eds) 1998. The Birds of the Western Palearctic, Concise edition. London Oxford University Press.