Morven South Offshore Wind Array Project

Environmental Impact Assessment Report

Volume 3, Annex 11.2: Offshore Ornithology Collision Risk Modelling Report

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1 Introduction

1.1 Background

1.1.1.1 During the operations and maintenance (O&M) phase of the Morven South Offshore Wind Array Project (hereafter "Morven South"), the turning rotors of the wind turbines may present a risk of collision for seabirds. Stationary structures, such as the tower, nacelle or when rotors are not operating, are not expected to result in a material risk of collision. When a collision occurs between the turning rotor blade and the bird, it is assumed to result in direct mortality of the bird, which could potentially result in population level impacts.

1.1.1.2 Species differ in their susceptibility to collision risk, depending on their flight behaviour and avoidance responses, and the vulnerability of their populations (Garthe and Hüppop, 2004; Furness *et al*. 2013; Bradbury *et al*., 2014; Wade *et al*., 2016). The structure and operation of wind turbines can also affect the risk to birds, with factors such as rotor speed, blade size, pitch angle and height above the sea surface all influencing the magnitude of risk. Artificial lighting may also change the risk for some species (e.g. shearwaters and petrels), although there is little available evidence to quantify the extent of change to the risk.

1.1.1.3 The ability of seabirds to detect and manoeuvre around wind turbine blades is also a factor that is considered when modelling and assessing risk. In response to this it is standard practice to apply differing levels of avoidance for different species or species groups. Avoidance rates are applied to collision risk estimates to predict levels of impact more realistically, based on available literature and expert advice about seabird behaviour and their flight response to wind turbines.

1.1.1.4 In general, the effects of increased mortality on populations due to collisions with wind turbines are considered to be long-term (i.e. throughout the operational wind farm's lifespan) and it is assumed that in the model, collision rate does not decrease in response to losses in the population. In reality, effects may change over time, as birds, particularly those residents near the wind farm, may become habituated to the presence of wind turbines, or external factors such as changes in fishing activities, may alter the attractiveness of the wind farm area to birds, thereby changing activity levels within it.

1.2 Aim of the report

1.2.1.1 This technical report presents the collision risk modelling approach undertaken for Morven South to inform Volume 2 Chapter 11: Offshore Ornithology and Volume 2, Chapter 2.3: Report to Inform Appropriate Assessment Part 3: SPA and Ramsar Site Assessments of the HRA (hereafter 'RIAA Part 3'), incorporating, where relevant site specific data collected between October 2021 and September 2023. This Annex focusses on collision risk to regularly occurring seabird species, with collision risk modelling for migratory seabirds and waterbirds presented in Volume 3, Annex 11.3: Offshore Ornithology Collision Risk Modelling Report: Migratory.

2 Methodology

2.1 Species for consideration

2.1.1.1 The process to identify Valued Ornithological Receptors (VORs) that may be affected by impacts associated with Morven South is documented in Volume 3, Annex 11.1: Offshore Ornithology Baseline Characterisation Report. Those VORs that are potentially affected by collision risk are those that are:

- Known to be vulnerable to collision risk (based on Wade *et al*., 2016; Bradbury *et al*., 2014) (Table 2.1) (i.e. a score of moderate or higher) with the uncertainty level associated with the vulnerability scores also taken into account.
- Where the population of the species observed at the Morven South Offshore Ornithology Baseline Characterisation Study Area is considered to be of importance, when compared against a relevant population scale threshold (regional, national or international), as described in Volume 3, Annex 11.1: Offshore Ornithology Baseline Characterisation Report.

2.1.1.2 Table 2.1 identifies those VORs for which collision risk modelling is required based on the above criteria.

Table 2.1: Identification of Valued Ornithological Receptors for which collision risk modelling is required

VOR	Vulnerability to collision risk impacts	Uncertainty level associated with vulnerability rating	Importance of population at Morven South	Collision risk modelling required (Yes/No)
Kittiwake **(*Rissa tridactyla*)**	High	Very Low	Local	Yes – high vulnerability, despite populations of the species being of only local importance the species was recorded in all surveys.
Little gull **(*Hydrocoloeus minutus*)**	Moderate	N/A	Negligible	No –species not recorded during baseline surveys however, abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 3, Annex 11.3: Offshore Ornithology Collision Risk Modelling Report: Migratory.
Great black-backed gull **(*Larus marinus*)**	Very High	Low	Local	Yes – very high vulnerability, species recorded during multiple baseline surveys.
Sandwich tern **(*Thalasseus sandvicensis*)**	Very High	Low	Negligible	No – species recorded in only one survey with densities observed considered unlikely to result in a measurable effect. Abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 3, Annex 11.3: Offshore Ornithology Collision Risk Modelling Report: Migratory.

VOR	Vulnerability to collision risk impacts	Uncertainty level associated with vulnerability rating	Importance of population at Morven South	Collision risk modelling required (Yes/No)
Little tern **(*Sternula albifrons*)**	Moderate	Very High	Negligible	No –species not recorded during baseline surveys however, abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 3, Annex 11.3: Offshore Ornithology Collision Risk Modelling Report: Migratory.
Roseate tern **(*Sterna dougallii*)**	High	Very High	Negligible	No –species not recorded during baseline surveys however, abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 3, Annex 11.3: Offshore Ornithology Collision Risk Modelling Report: Migratory.
Common tern **(*Sterna Hirundo*)**	Moderate	Very Low	Local	No –species not recorded during baseline surveys however, abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 3, Annex 11.3: Offshore Ornithology Collision Risk Modelling Report: Migratory.

VOR	Vulnerability to collision risk impacts	Uncertainty level associated with vulnerability rating	Importance of population at Morven South	Collision risk modelling required (Yes/No)
Arctic tern **(*Sterna paradisaea*)**	Moderate	Moderate	National	No –whilst species was recorded in three surveys the abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 3, Annex 11.3: Offshore Ornithology Collision Risk Modelling Report: Migratory.
Great skua **(*Stercorarius skua*)**	High	Moderate	Local	No – species recorded in one survey with densities observed considered unlikely to result in a measurable effect. Abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 3, Annex 11.3: Offshore Ornithology Collision Risk Modelling Report: Migratory.
Arctic skua **(*Stercorarius parasiticus*)**	High	Moderate	Negligible	No –species not recorded during baseline surveys however, abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 3, Annex 11.3: Offshore Ornithology Collision Risk Modelling Report: Migratory.
Common guillemot **(*Uria aalge*)**	Very Low	Low	Regional	No – very low vulnerability, low associated uncertainty.
Razorbill **(*Alca torda*)**	Very Low	Low	Regional	No – very low vulnerability, low associated uncertainty.

VOR	Vulnerability to collision risk impacts	Uncertainty level associated with vulnerability rating	Importance of population at Morven South	Collision risk modelling required (Yes/No)
Puffin **(*Fratercula arctica*)**	Very Low	Moderate	Local	No – very low vulnerability, moderate associated uncertainty.
European storm petrel **(*Hydrobates pelagicus*)**	Low	Very High	Negligible	No – species recorded in only three surveys with densities observed considered unlikely to result in a measurable effect. Abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 3, Annex 11.3: Offshore Ornithology Collision Risk Modelling Report: Migratory.
Leach's petrel **(*Oceanodroma leucorhoa*)**	Low	Very High	Negligible	No – species not recorded during baseline surveys however, abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 3, Annex 11.3: Offshore Ornithology Collision Risk Modelling Report: Migratory.
Fulmar **(*Fulmarus glacialis*)**	Very Low	Low	Local	No – very low vulnerability, low associated uncertainty. Wade *et al*. (2016) indicates that the species does not fly at collision height (20 to 150 m). Conclusion agreed with NatureScot (11 July 2025).

VOR	Vulnerability to collision risk impacts	Uncertainty level associated with vulnerability rating	Importance of population at Morven South	Collision risk modelling required (Yes/No)
Manx shearwater ***(Puffinus puffinus)***	Very Low	High	Regional	No – vulnerability is very low, although the associated uncertainty is very high. Although population estimates surpassed importance thresholds, the species was only recorded in two baseline surveys
Gannet **(*Morus bassanus*)**	High	Very Low	Local	Yes – high vulnerability, recorded in majority of baseline surveys.

2.1.1.3 The following species were selected for collision risk modelling:

- Kittiwake (high vulnerability, species recorded in all surveys);
- Great black-backed gull (very high vulnerability, species recorded in multiple baseline surveys);
- Gannet (high vulnerability, species recorded in majority of surveys).

2.1.1.4 As part of the assessments undertaken for the Morven North Offshore Wind Array Project (hereafter "Morven North"), which is located on the northern boundary of Morven South, herring gull was also identified for consideration in collision risk modelling. Herring gull is not considered for collision risk modelling at Morven South as the species was only recorded in small numbers and was therefore not identified as a VOR. Further detail is provided in Volume 3, Annex 11.1: Offshore Ornithology Baseline Characterisation Report.

2.2 Collision risk modelling

2.2.1.1 Collision risk modelling was undertaken using the Stochastic Collision Risk Model (sCRM) (Caneco and Humphries, 2022) which is based on the stochLAB R package as recommended by JNCC *et al*. (2024) and NatureScot (2025). The sCRM allows for variability in input parameters to be incorporated into the model, producing predicted collision estimates with associated uncertainty. Additionally, the sCRM provides a useful audit trail of input parameters and outputs, enabling reviewers to easily assess and reproduce the results of any modelling scenario. Following NatureScot (2025), modelling has been undertaken using deterministic and stochastic modelling approaches. Modelling using the stochastic approach was conducted using 5,000 iterations with a random seed of 1234.

2.2.1.2 The collision risk models incorporate guidance on recommended avoidance rates, bird size, flight speed, flight type and nocturnal activity scores (JNCC *et al*., 2024; NatureScot, 2025). All proposed parameters are set out in Table 2.2 and Table 2.3.

2.3 Modelling parameters

2.3.1 Species parameters

2.3.1.1 The sCRM incorporates several parameters relating to birds and their behaviour, as well as physical parameters relating to the wind turbines, to provide the mechanistic prediction of collision risk. It is necessary to incorporate degrees of both variability and uncertainty in some of those parameters to ensure that the risk is not under or over-estimated. It is, however widely acknowledged that additive layers of precaution in all parameters may lead to overestimation of risk. This is particularly the case in relation to avoidance rates and bird flight speed, which have some of the biggest influences on the predicted magnitude of risk. This is discussed in Section 4.

2.3.1.2 The species biometric and behavioural parameters to be used for collision risk modelling are presented in Table 2.2. The modelling approach has incorporated those parameters recommended by NatureScot (NatureScot, 2025) in addition to other values that seek to capture the uncertainty associated with various parameters used for collision risk modelling. Column 2 in Table 2.2 identifies to which position (SNCB (Statutory Nature Conservation Body) or Applicant) each parameter value is applicable. A discussion on these parameters is provided in Section 4.

2.3.1.3 Gannet exhibit a strong macro-avoidance response to offshore wind farms which is not currently captured in available avoidance rates. The joint SNCB Collision Risk Modelling (CRM) guidance (JNCC *et al*., 2024) and NatureScot (2025) guidance both discuss this issue and suggest that it should be accounted for by applying a percentage reduction to input densities for gannet. NatureScot (2025) recommends the application of a 70% reduction in the non-breeding season only as it is considered that there is insufficient evidence regarding gannet behaviour around wind farms near to Scottish SPAs although the NatureScot (2025) guidance does not state what constitutes 'near'. JNCC *et al*. (2024) does not provide specific advice on the magnitude of the reduction to apply but Natural England have recommended the use of a 70% reduction for all seasons for recent projects in English waters. As this advice conflicts with that of NatureScot (2025), CRM has been undertaken utilising uncorrected density data (i.e. not reduced by 70% in any season), with any corrections then applied to the resulting collision risk estimates for relevant seasons within relevant assessments in RIAA Part 3. This provides the same result as if the reduction were applied to density data but simplifies the modelling process.

Table 2.2: Species biometrics and input parameters for Collision Risk Modelling

Parameter	Position	Source	Kittiwake	Great black-backed gull	Gannet
Bird length (m)	Applicant and SNCB	JNCC *et al.* (2024)	0.39 (±0.005)	0.71 (±0.035)	0.94 (±0.0325)
Wingspan (m)	Applicant and SNCB	JNCC *et al.* (2024)	1.08 (±0.0625)	1.58 (±0.0375)	1.72 (±0.0375)
Flight speed (m/s)	SNCB	Alerstam *et al.* (2007)/JNCC *et al.* (2024)	13.1 (± 0.40)	13.7 (± 1.20)	-
	SNCB	Pennycuick (1997) /JNCC *et al.* (2024)	-	-	14.9 (± 0)
	Applicant	Skov *et al.* (2018)	8.71 (±3.16)	9.8 (±3.63)	13.33 (±4.24)
Nocturnal activity factor	Applicant and SNCB	Cook *et al.* (2023)	0.40 (±0.12)	-	0.14 (±0.10)
	Applicant and SNCB	Garthe and Hüppop (2004)	-	0.375 (±0.0637)	-
Flight type	Applicant and SNCB	JNCC *et al.* (2024)	Flapping	Flapping	Gliding
Proportion of flights upwind (%)	Applicant and SNCB	JNCC *et al.* (2024)	50	50	50
Avoidance rate (Basic model) (%)	Applicant (gannet) SNCB (kittiwake and gannet)	Ozsanlav-Harris *et al.* (2023) (all gull rate)	0.9929 (±0.0003)	-	0.9929 (±0.0003)
	SNCB	Ozsanlav-Harris *et al.* (2023) (large gull rate)	-	0.9940 (±0.0004)	-
	Applicant	Ozsanlav-Harris *et al.* (2023) (species-specific rate)	0.9979 (±0.0013)	0.9991 (±0.0002)	-

Parameter	Position	Source	Kittiwake	Great black-backed gull	Gannet
Avoidance rate (Deterministic) (%)	Applicant and SNCB (gannet) SNCB (kittiwake)	Ozsanlav-Harris *et al.* (2023) (all gull rate)	0.9923(±0.0001)	-	0.9923(±0.0001)
	SNCB	Ozsanlav-Harris *et al.* (2023) (large gull rate)	-	0.9936 (±0.0002)	-
	Applicant	Ozsanlav-Harris *et al.* (2023) (species-specific rate)	0.9970 (±0.0015)	0.9991 (±0.0002)	-

2.4 Flight heights

2.4.1.1 The proportion of birds flying at collision risk height has been determined using generic flight height data. These generic data were taken from Johnston *et al.*, 2014. Collision risk models were therefore run using Option 2 of the sCRM.

2.5 Wind farm and wind turbine parameters

2.5.1.1 The parameters for the wind turbine scenario represented by the Maximum Design Scenario (MDS) as required for collision risk modelling are presented in Table 2.3. The MDS represents the wind turbine scenario that provides the highest number of collisions and therefore represents the scenario that would result in the greatest potential impact. In addition, following NatureScot (2025), collision risk modelling has also been conducted incorporating the most likely design scenario (Table 2.3). The assessments conducted in Volume 2 Chapter 11: Offshore Ornithology and RIAA Part 3 use collision risk estimates calculated using the maximum design scenario with collision risk estimates reflecting the most likely wind turbine scenario presented in this technical report for context.

2.5.1.2 The large array correction feature of the sCRM was not applied at this stage as this does not have a meaningful effect on collision risk estimates (although if applied it would be expected to very slightly decrease collision estimates).

Table 2.3: Wind turbine parameters in the maximum design scenario for collision risk modelling

Parameter[1]	Parameter value (standard deviation, where relevant)	
	Maximum design scenario	Most likely scenario
Wind farm		
Latitude	56.543167	56.543167
Max. number of wind turbines	95	67
Tidal offset (m) (Mean Sea Level (MSL))	1.71	1.71
Wind farm width (E-W) (km)	16.4	16.4
Wind turbine		
Wind turbine model (MW)	17	24
Number of rotor blades per wind turbine	3	3
Max. chord width (m)	6.8	7.4
Average blade pitch (degrees)	5.5 (5.83)	5.5 (5.83)
Max. rotor radius (m)	125	140
Average rotation speed (rpm)	6.1 (1.42)	5.4 (1.29)
Minimum blade clearance above Lowest Astronomical Tide (LAT) (m)	34	34
Minimum blade clearance above Highest Astronomical Tide (HAT) (m)	30.35	30.35
Wind availability (%) (all months)	99	99
Mean downtime per month (%) (all months) (SD)	1 (2.11)	1 (2.11)

2.6 Density estimates

2.6.1.1 Digital aerial surveys of Morven North and Morven South were undertaken between January 2021 and September 2023. Further information on the aerial surveys undertaken for Morven South and the methodologies used to derive density estimates is provided in the Volume 3, Annex 11.1: Offshore Ornithology Baseline Characterisation Report. During pre-application consultation with NatureScot (see Volume 1, Chapter 5: Consultation) it was advised that due to the planned application date for Morven South (Quarter 2, 2026) only data from October 2021 to September 2023 (representing the standard 24 months of baseline data) should be used for baseline characterisation to avoid data being older than the five year data cut-off at the point of application (NatureScot, 2023b). To inform collision risk modelling data for flying birds from the Morven South Boundary has been used.

2.6.1.2 When modelling using the stochastic version of the collision risk model, there is a requirement that monthly density estimates over several year's surveying be pooled, such that they can be used in

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[1] Parameter values presented are specific to the wind turbine option one model (Volume 1, Chapter 3: Project Description).

sCRM. The preferred format of these is as a bootstrapped distribution (1,000 resamples). There are multiple potential approaches to pooling such estimates, with differing inferential aspects.

2.6.1.3 Bootstraps (1,000 resamples) have been generated for each of the months within years, from their extant density surface models; for example, 1,000 draws are taken for each of May 2022 and 2023. These bootstraps may be nonparametric bootstrapping (resampled transects) in the case of design-based estimates, or parametric bootstraps arising from a GAM-based model. For the resample of a month, an average is taken over years. This provides a distribution of 1,000 resamples for each month, each of which is the average over several years. This was conducted for each species and region of interest for flying birds e.g. flying kittiwakes within the Morven South Boundary.

2.6.1.4 These bootstrap distributions are realisations of the sampling distribution for the inter-annual mean density, for a given month. Uncertainty around the monthly density estimates within a year is naturally propagated to the overarching bootstrap distribution, with equal weighting given to each of the contributing years. The bootstraps for the pooled estimates are expected to tend towards unimodal distributions under this construction. Note, averages can be validly conducted over each of the bootstraps, as these are random with respect to each other over years. It follows that there is an assumption of independence between years, this is reasonable as any potential dependencies are unable to be estimated.

2.6.1.5 When run deterministically, the collision risk model requires a single mean density estimate for each month. These have been obtained by averaging the 1,000 bootstraps obtained following the above approach. Mean densities are provided in Table 2.4.

Table 2.4: Mean density estimates (birds/km2) used for Collision Risk Modelling

Species	Mean monthly density (birds/km2)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kittiwake	0.05	0.03	0.07	0.17	0.26	0.34	0.22	0.06	0.00	0.06	0.06	0.18
Great black-backed gull	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Gannet	0.01	0.01	0.08	0.14	0.31	0.25	0.41	0.42	0.06	0.10	0.00	0.01

3 Results

3.1 Overview

3.1.1.1 Collision risk estimates for all species using stochastic and deterministic modelling approaches are provided in the sections 3.2 to 3.4. All values in the following tables are provided to one decimal place and therefore the total of monthly values may not equal the annual totals. Collision risk estimates are presented using two scenarios, one utilising the values for flight speed and avoidance rate advocated by the SNCBs and another using the values for flight speed and avoidance rate advocated by the Applicant. A discussion on the uncertainty and variability associated with the different sources used for flight speed values and avoidance rates is provided in Section 4.

3.2 Kittiwake

3.2.1 Stochastic model

3.2.1.1 The predicted number of collisions for kittiwake using a stochastic model are presented in Table 3.1. Confidence metrics associated with these estimates are presented in Confidence metrics associated with collision risk estimates. Those presented in bold will be considered in the assessments presented in Volume 2 Chapter 11: Offshore Ornithology and RIAA Part 3.

Table 3.1: Predicted collisions for kittiwake associated with Morven South, using a stochastic model

Wind turbine scenario (MW)	Model Option	Flight speed (m/s)	Avoidance rate (%)	Collision risk estimate (no. of collisions)												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
17	**2**	**13.1**	**0.9929**	**0.3**	**0.2**	**0.5**	**1.1**	**2.0**	**2.6**	**1.6**	**0.4**	**0.0**	**0.3**	**0.3**	**1.0**	**10.2**
		8.71	**0.9979**	**0.1**	**0.0**	**0.1**	**0.3**	**0.4**	**0.6**	**0.4**	**0.1**	**0.0**	**0.1**	**0.1**	**0.2**	**2.4**
24	2	13.1	0.9929	0.2	0.1	0.3	0.8	1.4	1.9	1.3	0.3	0.0	0.3	0.2	0.7	7.6
		8.71	0.9979	0.0	0.0	0.1	0.2	0.3	0.4	0.3	0.1	0.0	0.1	0.1	0.2	1.7

3.2.2 Deterministic model

3.2.2.1 The predicted number of collisions for kittiwake using a deterministic model are presented in Table 3.2.

Table 3.2: Predicted collisions for kittiwake associated with Morven South, using a deterministic model

Wind turbine scenario (MW)	Model Option	Flight speed (m/s)	Avoidance rate (%)	Collision risk estimate (no. of collisions)												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
17	2	13.1	0.9923	0.3	0.2	0.5	1.2	2.1	2.8	1.8	0.5	0.0	0.4	0.3	1.0	11.2
		8.71	0.9970	0.1	0.1	0.1	0.3	0.6	0.8	0.5	0.1	0.0	0.1	0.1	0.3	3.2
24	2	13.1	0.9923	0.2	0.1	0.4	0.9	1.6	2.1	1.4	0.3	0.0	0.3	0.3	0.8	8.5
		8.71	0.9970	0.1	0.0	0.1	0.3	0.5	0.6	0.4	0.1	0.0	0.1	0.1	0.2	2.4

3.3 Great black-backed gull

3.3.1 Stochastic model

3.3.1.1 The predicted number of collisions for great black-backed gull using a stochastic model are presented in Table 3.3. Confidence metrics associated with these estimates are presented in Confidence metrics associated with collision risk estimates. Those presented in bold will be considered in the assessments presented in Volume 2 Chapter 11: Offshore Ornithology and RIAA Part 3.

Table 3.3: Predicted collisions for great black-backed gull associated with Morven South using a stochastic model

Wind turbine scenario (MW)	Model Option	Flight speed (m/s)	Avoidance rate (%)	Collision risk estimate (no. of collisions)												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
17	2	13.7	0.9940	0.5	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	1.5
		9.8	0.9991	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
24	2	13.7	0.9940	0.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	1.1
		9.8	0.9991	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1

3.3.2 Deterministic model

3.3.2.1 The predicted number of collisions for great black-backed gull using a deterministic model are presented in Table 3.4.

Table 3.4: Predicted collisions for great black-backed gull associated with Morven South, using a deterministic model

Wind turbine scenario (MW)	Model Option	Flight speed (m/s)	Avoidance rate (%)	Nocturnal activity factor (%)	Collision risk estimate (no. of collisions)												
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
17	2	13.7	0.9936	25	0.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	1.2
				50	0.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	1.6
		9.8	0.9991	25	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
				50	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
24	2	13.7	0.9936	25	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.9
				50	0.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	1.2
		9.8	0.9991	25	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
				50	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1

3.4 Gannet

3.4.1 Stochastic model

3.4.1.1 The predicted number of collisions for gannet using a stochastic model are presented in Table 3.5. Confidence metrics associated with these estimates are presented in Confidence metrics associated with collision risk estimates. Those presented in bold will be considered in the assessments presented in Volume 2 Chapter 11: Offshore Ornithology and RIAA Part 3.

Table 3.5: Predicted collisions for gannet associated with Morven South using a stochastic model

Turbine scenario (MW)	Model Option	Flight speed (m/s)	Avoidance rate (%)	Collision risk estimate (no. of collisions)												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
17	**2**	**14.9**	**0.9929**	**0.1**	**0.0**	**0.5**	**1.0**	**2.5**	**2.0**	**3.5**	**3.3**	**0.4**	**0.6**	**0.0**	**0.1**	**13.9**
		13.33	**0.9929**	**0.1**	**0.0**	**0.4**	**0.9**	**2.3**	**1.9**	**3.1**	**2.9**	**0.4**	**0.5**	**0.0**	**0.1**	**12.5**
24	2	14.9	0.9929	0.0	0.0	0.3	0.7	1.8	1.5	2.5	2.3	0.3	0.4	0.0	0.0	10.0
		13.33	0.9929	0.0	0.0	0.3	0.7	1.7	1.5	2.3	2.2	0.3	0.4	0.0	0.0	9.5

3.4.2 Deterministic model

3.4.2.1 The predicted number of collisions for gannet using a deterministic model are presented in Table 3.6.

Table 3.6: Predicted collisions for gannet associated with Morven South, using a deterministic model

Turbine scenario (MW)	Model Option	Flight speed (m/s)	Avoidance rate (%)	Collision risk estimate (no. of collisions)												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
17	2	14.9	0.9923	0.1	0.0	0.4	0.9	2.3	2.0	3.2	3.0	0.4	0.6	0.0	0.1	13.0
		13.33	0.9923	0.1	0.0	0.4	0.9	2.2	1.8	3.0	2.8	0.4	0.5	0.0	0.1	12.1
24	2	14.9	0.9923	0.0	0.0	0.3	0.7	1.7	1.5	2.4	2.3	0.3	0.4	0.0	0.0	9.7
		13.33	0.9923	0.0	0.0	0.3	0.6	1.6	1.4	2.2	2.1	0.3	0.4	0.0	0.0	9.0

4 Consideration of uncertainty

4.1 Flight speeds

4.1.1.1 For the species that have been identified for inclusion in collision risk modelling, there are essentially two alternative sources for bird flight speed. The first source being either Alerstam *et al*. (2007) or Pennycuick (1987) with the second source being Skov *et al*., 2018. Natural England have previously raised concerns with the flight speed values estimated in Skov *et al*. (2018) (Natural England, 2018):

- "Data was collected from a single site during the non-breeding season;
- Flight speeds from Skov *et al*., (2018) are markedly lower than those from other published studies (e.g. Alerstam *et al*., 2007, Pennycuick, 1987)."

4.1.1.2 Whilst NatureScot recommend the use of flight speed data from Alerstam *et al*. (2007) or Pennycuick (1987), any justification for the use of these sources over Skov *et al*. (2018) has not been provided.

4.1.1.3 Alerstam *et al*. (2007) provides flight speed data for a range of bird species collected using tracking radar measurements from five sites in southern Sweden and on two expeditions to the Arctic between 1979 and 1999. This dataset was supplemented with an extensive additional dataset again of tracking radar measurements of birds in migratory flight in Switzerland, Germany, Israel and Spain.

4.1.1.4 Pennycuick (1987) provides flight speed data for a more limited range of species estimated using an ornithodolite. Observations of birds were made during the breeding season on the island of Foula, Shetland specifically from the southern tip of the island where 'continuous streams of birds could usually be seen flying around the South Ness, between the main breeding areas on the western cliffs and feeding areas to the east' (Pennycuick, 1987).

4.1.1.5 Skov *et al*. (2018) reports on data from the Offshore Renewables Joint Industry Programme (ORJIP) Bird Collision Avoidance (BCA) study. This study generated one of the most extensive datasets of observations of seabird behaviour in and around an operational offshore wind farm (Thanet Offshore Wind Farm, Kent, England). This includes species-specific data gathered throughout the year on flight speed which can inform the estimation of more realistic flux of birds through rotor swept areas.

4.1.1.6 A comparison of each of these sources for each species is provided in Table 4.1 in relation to sample size, location of studies, seasonality and location. Sections 4.1.2 to 4.1.4 discuss this information for each species.

Table 4.1: Comparison of data sources for bird flight speed

Dataset feature	Species	Alerstam *et al*., 2007 / Pennycuick,1987	Skov *et al*., 2018
Sample size	Kittiwake	2 tracks	287 tracks
	Great black-backed gull	4 tracks	790 tracks
	Gannet	32 observations	683 tracks
Location	Kittiwake	Northeast Passage	Thanet Offshore Wind Farm, south North Sea, offshore of Kent, England
	Great black-backed gull	Sweden and the Arctic	
	Gannet	Foula, Shetland	
Seasonality	Kittiwake	July and August 1994 (Alerstam and Gudmundsson, 1999)	Fieldwork undertaken between July 2014 and April 2016 covering all months. The occurrence of each species on a monthly basis is discussed below
	Great black-backed gull	Unknown	
	Gannet	Pennycuick: 28 June to 9 July 1986	

4.1.2 Kittiwake

4.1.2.1 The study with the largest sample size for kittiwake was the ORJIP BCA study (Skov *et al*. 2018) with a sample size of 287 tracks compared to two tracks in Alerstam *et al*. (2007). The flight speed data used by Alerstam *et al*. (2007) to estimate flight speeds for kittiwake was collected in the Northeast Passage an area of sea between the Atlantic and Pacific oceans along the Arctic coasts of Norway and Russia in July and August. Therefore, this dataset does not provide any flight speed data relevant to kittiwake in non-breeding seasons. Kittiwake do breed in various places in the Northeast Passage but due to the limited number of kittiwake detected it is likely that radar observation sites were not located near to a breeding colony. The Skov *et al*. (2018) data was collected at the Thanet Offshore Wind Farm which is within the foraging range of kittiwake (mean-maximum and mean-maximum plus one standard deviation; Woodward *et al*., 2019) from a number of breeding colonies, albeit colonies consisting of fewer than 1,000 birds. Fieldwork associated with Skov *et al*. (2018) was conducted across two years with the monthly distribution of datapoints for kittiwake presented in Figure 4.1. The kittiwake breeding season runs from March to August (full UK breeding season) with a migration-free breeding season running from May to July. The limited number of breeding birds in close proximity to the Thanet Offshore Wind Farm is reflected in the distribution of datapoints. However, there are still more datapoints in both the migration-free and full UK breeding season than in the Alerstam *et al*. (2007) study.

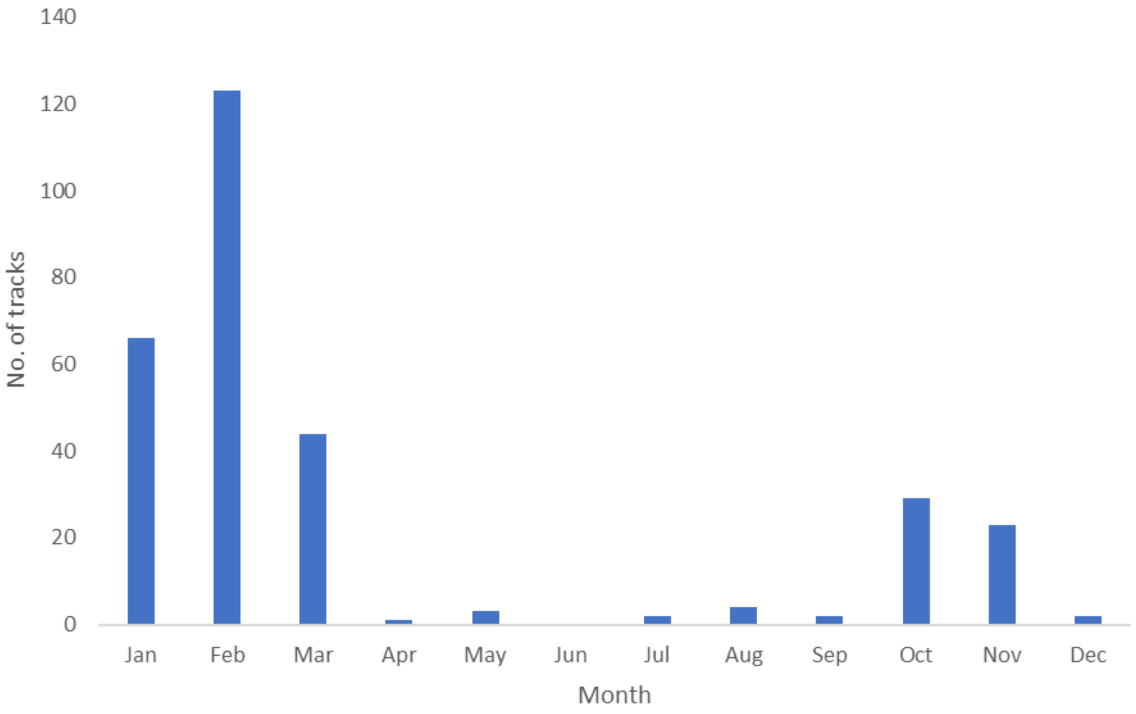

Figure 4.1: Number of kittiwake tracks in each month from Skov *et al*. (2018)

4.1.2.2 A thorough review of studies, that provided flight speed estimates for kittiwake, was undertaken by Royal HaskoningDHV (2020) which determined a range of flight speeds of 7.26m/s to 15.9m/s. Of the studies reviewed all had sample sizes of less than 20 birds, except Skov *et al*. (2018) and Elliott *et al*. (2014; both in terms of the number of tracks) with all providing limited coverage of the annual cycle of kittiwake. In addition, the techniques used to estimate flight speed differ between the studies. Techniques included ornithodolite, tracking radar, seawatch timing, GPS transmitters, laser rangefinder and car speedometer. Royal HaskoningDHV (2020) suggests that kittiwake exhibit an average flight speed of 10.8m/s. However, this average does not take account of the limitations, or the sample size associated with each study.

4.1.2.3 Royal HaskoningDHV (2020) also highlights that the Band (2012) CRM requires that the flight speed input reflects the ground speed of birds and not the air speed. The flight speed value from Alerstam *et al*. (2007) refers to air speed and is therefore not suitable for use in collision risk modelling undertaken using the Band (2012) CRM.

4.1.2.4 Two studies that provide flight speed data in the breeding season are Kotzerka *et al*. (2010) and Elliott *et al*. (2014). These studies estimated flight speed values of 9.2m/s and 10.6m/s respectively. Both studies were conducted at the same breeding colony (Middleton Island, Alaska) using GPS data loggers with the Elliot *et al*. (2014) study also using accelerometers. Kotzerka *et al*. (2010) collected data from 14 birds between 01 July and 11 August 2007. Elliot *et al*. (2014) collected data from 10 incubating birds (30 May to 16 June 2013). The flight speeds estimated from these two studies provide flight speed values closer to that estimated by Skov *et al*. (2018) compared to Alerstam *et al*. (2007).

4.1.2.5 Based on the evidence presented above it is considered that the best available evidence in relation to flight speed for kittiwake is the value presented by Skov *et al*. (2018) with this value supported by a larger sample size collected across all seasons than the value presented by Alerstam *et al*. (2007). The value presented by Alerstam *et al*. (2007) is not considered representative of the flight speed of kittiwake due to the limited sample size and restricted seasonal coverage and it is therefore considered that it should not be used for collision risk modelling.

4.1.3 Great black-backed gull

4.1.3.1 Skov *et al*. (2018) provides a single flight speed for large gull species. This value has an associated sample size of 790 tracks. This is considerably larger than the sample size associated with the flight speed value from Alerstam *et al*. (2007) which is comprised of four tracks for herring gull and only 33 tracks if the flight speed values for lesser black-backed gull, herring gull and great black-backed gull were combined. The flight speed data used by Alerstam *et al*. (2007) to estimate flight speeds for great black-backed gull is based on birds observed in Sweden and the Arctic and it is not known when during the annual cycle these tracks were observed. The Skov *et al*. (2018) dataset was collected at the Thanet Offshore Wind Farm which is not within the foraging range of great black-backed gull from any significant breeding colonies.

4.1.3.2 Fieldwork associated with Skov *et al*. (2018) was conducted across two years with the monthly distribution of datapoints for all three large gulls (both individually and combined) presented in Figure 4.2. The great black-backed gull breeding season runs from late March to August (full UK breeding season) with a migration-free breeding season running from May to July. There are therefore datapoints across all seasons relevant to great black-backed gull, albeit with fewer datapoints during the migration-free breeding season but still more than that included in Alerstam *et al*. (2007) dataset. However, a dataset comprising mainly of datapoints in the non-breeding season will likely reflect the behaviour of great black-backed gull at Morven South more accurately (if indeed a difference between seasons exists) with great black-backed gulls only recorded in flight at Morven South outside of the breeding season (January, February and November).

4.1.3.3 Another study that investigated flight speeds of great black-backed gull was by Gyimesi *et al*. (2017). This study reports results from two GPS transmitter studies, the first from three great black-backed gulls tagged on Swedish Islands in the Baltic Sea (including a single bird migrating to the UK) and the second from five great black-backed gulls tagged in the Kattegat. The first of these datasets estimated a flight speed of 12.1m/s to 12.5m/s with the second predicting a flight speed of 10.3m/s to 10.8m/s. The studies reviewed by Gyimesi *et al*. (2017) comprised low sample sizes with at least some of the data from the breeding season, potentially limiting comparability with Skov *et al*. (2018). In addition, a recent study suggests that great black-backed gulls are adversely affected when tagged (Lopez *et al*., 2023) and although this observation is based on breeding success (and mortality in one case) it is possible that this may also influence other behaviours.

4.1.3.4 Based on the evidence presented above it is considered that the best available evidence in relation to flight speed for great black-backed gull is the value presented by Skov *et al*. (2018) with this value supported by a larger sample size collected across all seasons than the value presented by Alerstam *et al*. (2007). The data associated with Skov *et al*. (2018) were also collected in UK waters in an area of sea that is considered similar to that in which Morven South is located (i.e. limited connectivity with large breeding colonies) and more is known about the methodology employed to capture flight speed data. The value presented by Alerstam *et al*. (2007) is not considered representative of the flight speed of great black-backed gull due to the limited sample size and restricted seasonal coverage and it is therefore considered that it should not be used for collision risk modelling.

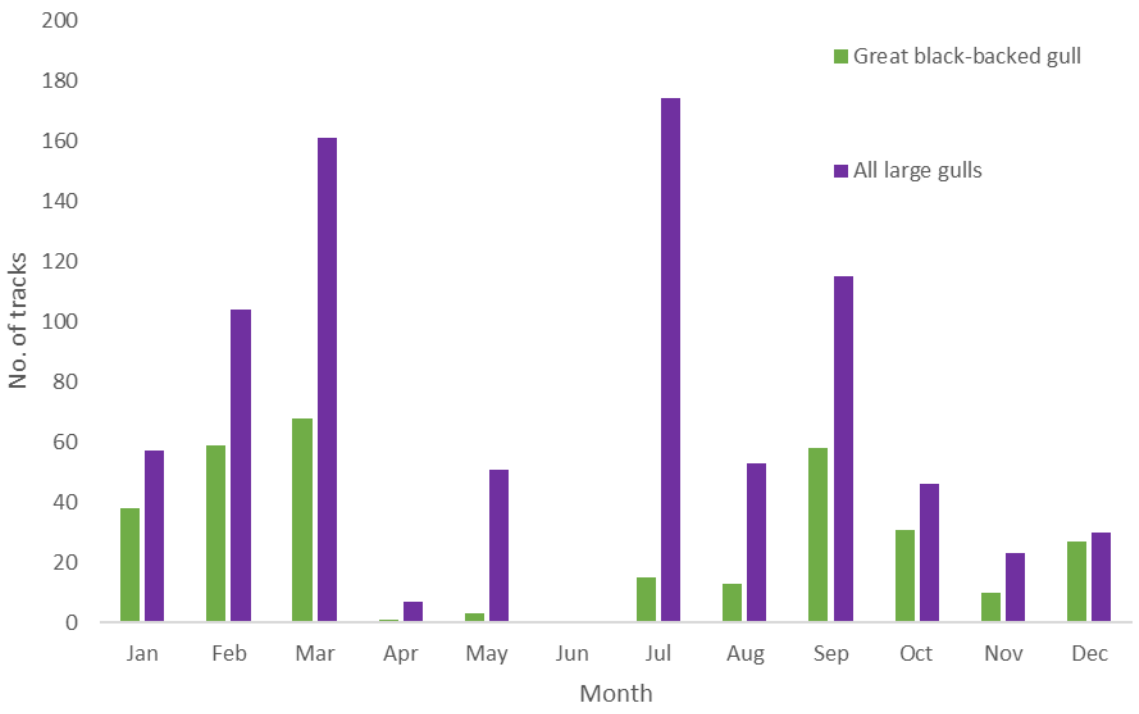

Figure 4.2: Number of large gull tracks in each month from Skov *et al*. (2018)

4.1.4 Gannet

4.1.4.1 The study with the largest sample size for flight speed for gannet is the ORJIP BCA study (Skov *et al*., 2018) with a sample size of 683 tracks compared to 32 observations in Pennycuick (1987). The flight speed data collected by Pennycuick (1987) was collected on the island of Foula, Shetland, close to a breeding colony of gannet during the breeding season. Therefore, this dataset does not provide any flight speed data relevant to gannet in non-breeding seasons. In addition, the data collected may be confounded due to the proximity of the breeding colony with birds flying at different speeds, perhaps due to being on approach or having just left the colony The Skov *et al*. (2018) data was collected at the Thanet Offshore Wind Farm which, although not located close to a breeding colony is within the foraging range (mean-maximum plus one standard deviation which is used to identify connectivity for the purposes of Habitat Regulations Assessment screening) of gannet (Woodward *et al*., 2019) of a breeding colony. Fieldwork associated with Skov *et al*. (2018) was conducted across two years with the monthly distribution of datapoints for gannet presented in Figure 4.3. The gannet breeding season runs from March to September (full UK breeding season) with a migration-free breeding season running from April to August. Therefore, there are datapoints across all seasons relevant to gannet with more in the breeding season than in the Pennycuick (1987) study. No tracks were recorded in June.

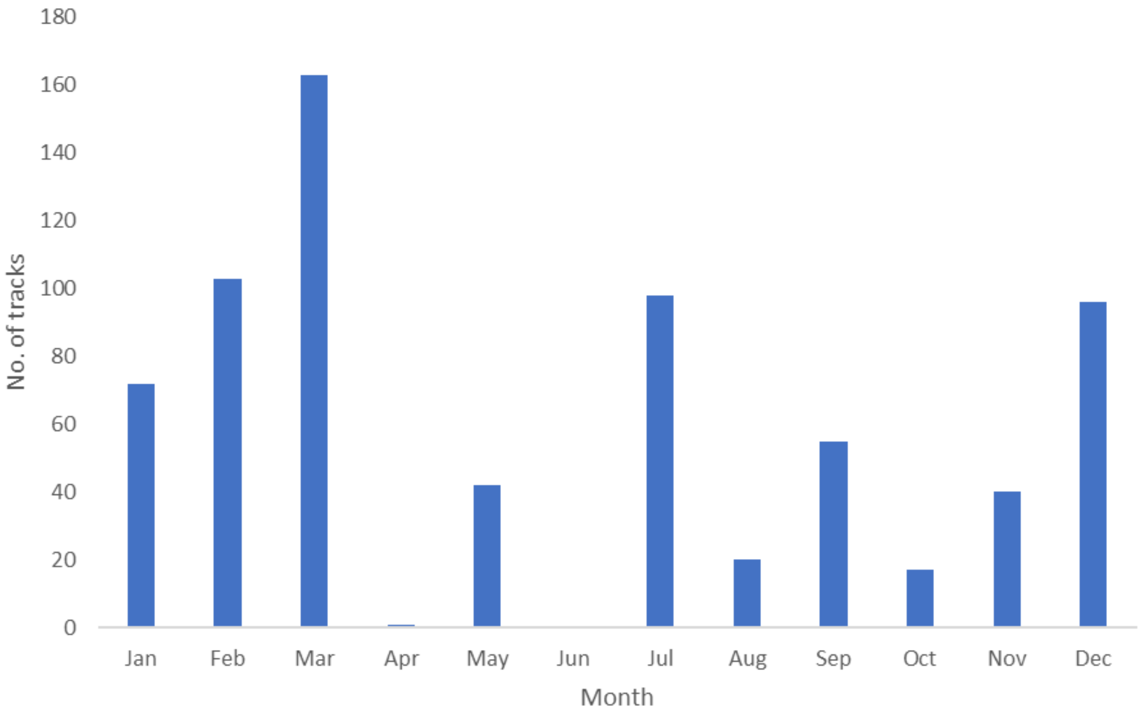

Figure 4.3: Number of gannet tracks in each month from Skov *et al*. (2018)

4.1.4.2 Another study that investigated flight speed of gannet, Pettex *et al*., (2012) estimated a flight speed of 13.5 m/s. This study deployed GPS data loggers on breeding gannet. This study therefore has the same limitations as Pennycuick (1987) providing data in the breeding season only, however, does provide a much larger dataset (341 foraging trips undertaken by 101 birds). This value, despite the associated limitations albeit with a larger sample size than Pennycuick (1987), is closer to that estimated by Skov *et al*. (2018) than the value estimated by Pennycuick (1987).

4.1.4.3 Based on the evidence presented above it is considered that the best available evidence in relation to flight speed for gannet is the value presented by Skov *et al*. (2018) with this value supported by a larger sample size collected across all seasons than the value presented by Pennycuick (1987). The value from Skov *et al*. (2018) reflects the behaviour of gannet throughout the annual cycle and not the behaviour of birds close to a breeding colony as in Pennycuick (1987). The value presented by Pennycuick (1987) is not considered representative of the flight speed of gannet due to the limited sample size, restricted seasonal coverage and the location of the study which is biased towards birds at a breeding colony it is therefore considered that it should not be used for collision risk modelling.

4.1.5 Other considerations

4.1.5.1 A sample size of 100 birds is considered adequate to provide a representative value for use in collision risk modelling for the proportion of birds at collision height (Natural England, 2013). A robust sample size has not been defined for bird flight speed, mainly as data for this parameter are not collected on a site specific basis. However, as flight speed is an in flight behaviour similar to flight height, it is considered reasonable to apply this 100-bird threshold to the derivation of flight speed values. If this were to be applied, then only the flight speeds from Skov *et al*. (2018) would reach this threshold and be considered representative of flight speed behaviour.

4.1.6 Conclusion

4.1.6.1 In order to ensure assessments are presented that align with Statutory Nature Conservation Bodies advice, collision risk estimates calculated using the flight speed values recommended by these organisations will form part of the assessment. However, it is considered that these values do not fully represent the best available evidence for any of the species for which collision risk modelling is required. It has previously been suggested that the values from Alerstam *et al*. (2007) and Pennycuick (1987) are precautionary, however, based on the information presented here it is considered that the flight speed values from Alerstam *et al*. (2007) and Pennycuick (1987) are not representative of the flight speed behaviour of the species for which CRM is required. Modelling conducted utilising these values will therefore provide collision risk estimates that are not accurate and do not represent the likely impact from Morven South. Any assessments based on these values will therefore have a high level of associated uncertainty.

4.2 Avoidance rates

4.2.1.1 The most recent review of avoidance rates for use in the Band (2012) CRM is provided by Ozsanlav-Harris *et al*. (2023) 2. The avoidance rates associated with this review are provided in Table 4.2. Ozsanlav-Harris *et al*. (2023) identifies a key limitation in relation to the use of these avoidance rates in the Band (2012) CRM:

4.2.1.2 The data is still primarily collected at onshore and coastal sites with very little offshore data therefore these avoidance rates may not fully capture the offshore behaviour of seabirds.

4.2.1.3 As stated in Oszanlav-Harris *et al*. (2023), behaviour of birds offshore and onshore can differ affecting flight height distributions. Avoidance rates calculated using data collected in only the offshore environment are provided in Bowgen and Cook (2018). A comparison between the avoidance rates provided in Bowgen and Cook (2018) and those from Oszanlav-Harris *et al*. (2023) is provided in Table 4.2.

Table 4.2: Comparison of avoidance rates estimated by Oszanlav-Harris *et al*. (2023) and Bowgen and Cook (2018)

Dataset feature	Avoidance rates		
	Oszanlav-Harris *et al*. (2023)/Lang *et al*. (2024)		Bowgen and Cook (2018)
	Species-specific	Species group	
Kittiwake	0.9979	0.9929	0.994
Great black-backed gull	0.9991	0.9940	0.997

4.2.1.4 The avoidance rates estimates for kittiwake and great black-backed gull by Bowgen and Cook (2018) fall within the range of avoidance rates estimates by Oszanlav-Harris *et al*. (2023). For kittiwake and great black-backed gull this would therefore suggest that the use of the range of avoidance rates applicable to kittiwake and great black-backed gull in Oszanlav-Harris *et al*. (2023) is appropriate.

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[2] A follow up analysis was conducted by Lang *et al.* (2024) providing avoidance rates for the updated version of the stochastic CRM. This conducted the same analysis as Ozsanlav-Harris *et al.* (2023) with a few minor changes and therefore Ozsanlav-Harris *et al.* (2023) is referenced in this report with Lang *et al.* (2024) referenced where specifically required

4.2.1.5 Whilst limitations are highlighted with the avoidance rates estimated by Bowgen and Cook (2018), these limitations are not considered to create any more uncertainty than that associated with the avoidance rates from other studies.

4.2.1.6 The research conducted by Ozsanlav-Harris *et al*. (2023) reviews the approach to calculate the avoidance rate of specific species and species groups, comparing this to the approach by Cook (2021). The Ozsanlav-Harris *et al*. (2023) dataset (Table 4.3) contains information on collision data from 23 monitoring reports of 19 wind farms (including one offshore), encompassing 11 species or species groups spanning the years 2000 to 2019. Cook (2021) suggests that a minimum of 10 sites may be used as an arbitrary threshold sample size to inform the selection of species-specific avoidance rates over group-specific estimates. The species-specific rates calculated for all species in Table 4.3 reaches this threshold for all species except kittiwake. However, NatureScot (2025) recommends the “all gull” rate be used for kittiwake. The “all gull” rate is calculated using data from all species of gull and may therefore not reflect the behaviour of kittiwake, a much more marine-based species, than all other gulls for which data is available.

4.2.1.7 Using the grouped species avoidance rates result in higher predicted collision mortalities. However, as species-specific rates are calculated from robust analysis, it is considered that the species-specific rate, specifically for great black-backed gull, represent the best available evidence for use in collision risk modelling. The species-specific rates create no more uncertainty than that associated with the grouped avoidance rates, which incorporate data from species that although superficially similar, may exhibit differences in flight behaviour that can affect avoidance behaviour. This is illustrated by the differences in species-specific avoidance rates for the two species of large gull. For kittiwake, it is considered appropriate to present collision risk estimates calculated applying both the ‘all gull’ rate and species-specific rate. By doing so the assessments will capture the uncertainty with both the ‘all gull’ rate, which is calculated based on data from species that exhibit different flight behaviour than the more marine-based kittiwake and the species-specific rate for kittiwake which has a lower associated sample size than suggested as being appropriate for a robust rate.

4.2.1.8 Uncertainty associated with all avoidance rates, and especially species-specific rates, is captured as part of the modelling process through the use of the sCRM and standard deviation values.

Table 4.3: Species-specific Avoidance Rates from Ozsanlav-Harris *et al*. (2023)/Lang *et al*. (2024)[3]

Species/species group	Basic sCRM AR	Sample size (no. of report years contributing data to avoidance rate calculation)
Kittiwake	0.9979 (0.0013; 0.9954 – 0.9992)	3
Great black-backed gull	0.9991 (0.0002; 0.9987 – 0.9994)	10
All gull	0.9929 (0.0003; 0.9922 – 0.9935)	36
Largegull	0.9940 (0.0003; 0.9932 – 0.9948)	31

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[3] Avoidance rate presented as a median rate (standard deviation; 95% confidence interval). Sample size presented as number of report-years and number of bird flights through wind turbine rotor-swept area contributing data to calculate avoidance rate from CRM

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Appendix A Confidence metrics associated with collision risk estimates

A.1 Kittiwake

Table A. 1: Collision risk estimates for kittiwake using a stochastic mode, including confidence metrics.

Wind turbine scenario (MW)	Model option	Flight speed (m/s)	Avoidance rate (%)	Confidence metric	Collision risk estimates (no. of collisions)												
					Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
17	2	13.1	0.9929	mean	0.3	0.2	0.5	1.1	2.0	2.6	1.6	0.4	0.0	0.3	0.3	1.0	10.2
				sd	0.1	0.1	0.2	0.3	0.6	0.7	0.6	0.3	0.0	0.2	0.2	0.3	3.7
				median	0.2	0.2	0.4	1.1	1.9	2.5	1.6	0.4	0.0	0.3	0.3	0.9	9.8
				2.5% pctl	0.1	0.0	0.1	0.6	1.0	1.4	0.7	0.0	0.0	0.0	0.1	0.4	4.3
				97.5% pctl	0.5	0.4	1.0	1.8	3.3	4.2	2.9	1.2	0.0	0.8	0.6	1.7	18.5
		8.71	0.9979	mean	0.1	0.0	0.1	0.3	0.4	0.6	0.4	0.1	0.0	0.1	0.1	0.2	2.4
				sd	0.1	0.0	0.1	0.2	0.3	0.4	0.3	0.1	0.0	0.1	0.1	0.2	1.9
				median	0.0	0.0	0.1	0.2	0.4	0.5	0.3	0.1	0.0	0.1	0.1	0.2	1.9
				2.5% pctl	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3
				97.5% pctl	0.2	0.1	0.4	0.8	1.4	1.7	1.2	0.4	0.0	0.3	0.2	0.7	7.5
24	2	13.1	0.9929	mean	0.2	0.1	0.3	0.8	1.4	1.9	1.3	0.3	0.0	0.3	0.2	0.7	7.6
				sd	0.1	0.1	0.2	0.2	0.4	0.5	0.4	0.2	0.0	0.2	0.1	0.2	2.8
				median	0.2	0.1	0.3	0.8	1.4	1.9	1.2	0.3	0.0	0.2	0.2	0.7	7.3
				2.5% pctl	0.0	0.0	0.1	0.4	0.7	0.9	0.5	0.0	0.0	0.0	0.0	0.3	3.1
				97.5% pctl	0.4	0.3	0.7	1.3	2.5	3.1	2.2	0.9	0.0	0.7	0.5	1.3	13.8
		8.71	0.9979	mean	0.0	0.0	0.1	0.2	0.3	0.4	0.3	0.1	0.0	0.1	0.1	0.2	1.7

Wind turbine scenario (MW)	Model option	Flight speed (m/s)	Avoidance rate (%)	Confidence metric	Collision risk estimates (no. of collisions)												
					Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
				sd	0.0	0.0	0.1	0.1	0.2	0.3	0.2	0.1	0.0	0.1	0.0	0.1	1.3
				median	0.0	0.0	0.1	0.2	0.3	0.4	0.2	0.0	0.0	0.0	0.0	0.1	1.4
				2.5% pctl	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2
				97.5% pctl	0.1	0.1	0.3	0.5	1.0	1.3	0.8	0.3	0.0	0.2	0.2	0.5	5.2

A.2 Great black-backed gull

Table A. 2: Collision risk estimates for great black-backed gull using a stochastic mode, including confidence metrics.

Wind turbine scenario (MW)	Model option	Flight speed (m/s)	Avoidance rate (%)	Confidence metric	Collision risk estimates (no. of collisions)												
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
17	2	13.7	0.9940	mean	0.5	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	1.5
				sd	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	1.1
				median	0.4	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	1.3
				2.5% pctl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				97.5% pctl	1.3	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	3.9
		9.8	0.9991	mean	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
				sd	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
				median	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
				2.5% pctl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				97.5% pctl	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.5
24	2	13.7	0.9940	mean	0.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	1.1
				sd	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.8
				median	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	1.0
				2.5% pctl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				97.5% pctl	0.9	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	2.9
		9.8	0.9991	mean	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
				sd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
				median	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
				2.5% pctl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Wind turbine scenario (MW)	Model option	Flight speed (m/s)	Avoidance rate (%)	Confidence metric	Collision risk estimates (no. of collisions)												
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
				97.5% pctl	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.4

A.3 Gannet

Table A. 3: Collision risk estimates for gannet using a stochastic mode, including confidence metrics.

Wind turbine scenario	Model option	Flight speed (m/s)	Avoidance rate (%)	Confidence metric	Collision risk estimates (no. of collisions)												
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
17	2	14.9	0.9929	mean	0.1	0.0	0.5	1.0	2.5	2.0	3.5	3.3	0.4	0.6	0.0	0.1	13.9
				sd	0.1	0.1	0.3	0.7	1.6	1.4	2.3	1.7	0.3	0.4	0.0	0.1	9.0
				median	0.0	0.0	0.4	0.8	2.2	1.7	2.9	3.0	0.3	0.5	0.0	0.0	12.0
				2.5% pctl	0.0	0.0	0.1	0.1	0.5	0.3	0.6	0.8	0.1	0.1	0.0	0.0	2.6
				97.5% pctl	0.3	0.2	1.3	2.9	6.3	5.7	8.9	7.0	1.1	1.6	0.0	0.2	35.5
		13.33	0.9929	mean	0.1	0.0	0.4	0.9	2.3	1.9	3.1	2.9	0.4	0.5	0.0	0.1	12.5
				SD	0.1	0.1	0.3	0.7	1.5	1.4	2.0	1.7	0.3	0.4	0.0	0.1	8.4
				median	0.0	0.0	0.3	0.7	1.9	1.5	2.6	2.6	0.3	0.4	0.0	0.0	10.5
				2.5% pctl	0.0	0.0	0.1	0.1	0.4	0.4	0.5	0.6	0.1	0.1	0.0	0.0	2.3
				97.5% pctl	0.3	0.2	1.3	2.7	6.1	5.4	7.9	6.9	1.0	1.4	0.0	0.2	33.3
24	2	14.9	0.9929	mean	0.0	0.0	0.3	0.7	1.8	1.5	2.5	2.3	0.3	0.4	0.0	0.0	10.0
				sd	0.1	0.0	0.2	0.5	1.2	1.0	1.7	1.3	0.2	0.3	0.0	0.1	6.5
				median	0.0	0.0	0.3	0.6	1.5	1.3	2.0	2.1	0.2	0.4	0.0	0.0	8.4
				2.5% pctl	0.0	0.0	0.1	0.1	0.4	0.3	0.4	0.6	0.0	0.1	0.0	0.0	1.9
				97.5% pctl	0.2	0.1	0.9	1.9	4.6	3.8	6.5	5.1	0.8	1.1	0.0	0.2	25.2

Wind turbine scenario	Model option	Flight speed (m/s)	Avoidance rate (%)	Confidence metric	Collision risk estimates (no. of collisions)												
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
		13.33	0.9929	mean	0.0	0.0	0.3	0.7	1.7	1.5	2.3	2.2	0.3	0.4	0.0	0.0	9.5
				sd	0.1	0.0	0.2	0.5	1.2	1.0	1.6	1.3	0.2	0.3	0.0	0.1	6.4
				median	0.0	0.0	0.3	0.5	1.4	1.2	1.8	2.0	0.2	0.3	0.0	0.0	7.9
				2.5% pctl	0.0	0.0	0.1	0.1	0.3	0.2	0.4	0.5	0.0	0.1	0.0	0.0	1.6
				97.5% pctl	0.2	0.2	0.9	1.9	4.6	4.2	6.1	5.2	0.8	1.2	0.0	0.2	25.4