



Spiorad na Mara Offshore Wind Farm

Offshore Project

Environmental Impact Assessment Report

Appendix 14.3: Collision Risk Model Report, Volume 2c

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1 INTRODUCTION

1.1 OVERVIEW

1.1.1.1 This appendix of the Environmental Impact Assessment Report (EIAR) presents the collision risk modelling approach undertaken for the marine and nearshore elements (i.e. seaward of Mean High Water Springs (MHWS)) components of the proposed Sporad na Mara Offshore Wind Farm (hereafter referred to as 'the Offshore Project'), with respect to marine ornithology. This appendix accompanies **Chapter 14: Marine and Nearshore Ornithology, Volume 2a** of the EIAR.

1.1.1.2 This appendix should be read in conjunction with **Chapter 3: Project Description, Volume 1a** and the relevant parts of the following chapters and appendices:

- **Appendix 14.1: Ornithology Baseline Report, Volume 2c;**
- **Appendix 14.2: Displacement Report, Volume 2c;**
 - **Annex 14.2.1: Ornithology Displacement Data, Volume 2c;**
- **Appendix 14.6: EIA Ornithology Consultation, Volume 2c;**
- **Offshore Report to Inform Appropriate Assessment (RIAA).**

1.1.1.3 This appendix focusses on collision risk to regularly occurring seabird species, with collision risk modelling for migratory seabirds, waterbirds and terrestrial bird species presented in **Appendix 14.4: Migratory Collision Risk Modelling Report, Volume 2c.**

1.1.2 PROJECT BACKGROUND

1.1.2.1 Sporad na Mara Limited (hereafter referred to as 'the Applicant') is proposing to develop the Project. The Project is an offshore wind farm (OWF) that will consist of up to 60 fixed-bottom wind turbine generators (WTGs).

1.1.2.2 The Project will include both offshore and onshore infrastructure. This Offshore EIAR supports the application for the offshore components of the Project as outlined in **Chapter 1: Introduction, Volume 1a.** The offshore components of the Project (the Offshore Project) includes all infrastructure and activities located seaward of MHWS) within the Array Area and Offshore Cable Area of Search (OCAS) (**Figure 1.2: Offshore Project Location, Volume 1b**). Further detailed information is provided in **Chapter 3, Volume 1a.**

1.1.2.3 The Offshore Project is situated off the northwest coast of Isle of Lewis/*Eilean Leòdhais* and the Array Area is located approximately 5-13 km offshore and is approximately 161 km² in size. It will comprise WTGs, foundations, Offshore Cables, Offshore Substation Platform (OSP) (if required), and Landfall. The Array Area combined with the OCAS is defined as the Offshore Project Boundary. The water depths across the Array Area range from 37 m-67 m with the southwest corner of the

Array Area reaching 72 m. The proposed WTGs and fixed foundations will be located within a Turbine Area of approximately 140 km², within the Array Area.

1.2 PURPOSE AND SCOPE OF THIS APPENDIX

- 1.2.1.1 During the operation and maintenance phase of the Offshore Project, the turning rotors of the wind turbines may present a risk of collision for seabirds. Stationary structures, such as the tower, nacelle, or rotors when they are not operating, are not anticipated to present a material risk of collision. When a collision occurs between a turning rotor blade and a bird, it is assumed to result in direct mortality of the bird. This could potentially result in population level impacts.
- 1.2.1.2 Species differ in their susceptibility to collision risk depending on their flight behaviour, 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 the wind turbines can also affect the risk to birds, with factors influencing the magnitude of risk including rotor speed, blade size, pitch angle, and height above the sea surface. Artificial lighting may also affect 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.
- 1.2.1.3 The ability of seabirds to detect and manoeuvre around wind turbine blades is also a factor that is considered when modelling and assessing the risk. It is therefore standard practice to calculate differing levels of avoidance for different species or species groups. Avoidance rates are applied to collision risk models (CRMs) based on available literature and expert advice about seabird behaviour and their flight response to wind turbines in order to predict more realistic levels of impact.
- 1.2.1.4 The effects of increased mortality on populations due to collisions with turbines are generally considered to be long-term, lasting throughout the operational wind farm's lifespan. In the model, it is assumed that collision rate does not decrease in response to losses in the population. In reality, effects may change over time. For example, birds, particularly those residents near the wind farm, may become habituated to the presence of turbines. Additionally, 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.
- 1.2.1.5 This appendix is set out with the following sections:
- Section 2: Methodology;
 - Section 2.1: Species for consideration;
 - Section 2.2: Collision risk modelling;
 - Section 2.3: Modelling parameters;
 - Section 2.4: Flight heights;
 - Section 2.5: Wind farm and turbine parameters;

- Section 2.6: Density estimates;
- Section 3: Results;
- Section 4: Consideration of uncertainty;
- Section 6: References;
- Annex 14.3.1: Deterministic collision risk estimates.

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 the Offshore Project is documented in **Appendix 14.1, Volume 2c**.

2.1.1.2 The following criteria are used to determine which VORs may be potentially affected by collision risk and therefore require collision risk modelling:

- 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 Offshore Ornithology Study Area (defined as the Turbine Area plus 4 km buffer) is considered to be of importance, when compared against relevant population scale thresholds (regional, national or international) as described in **Table 3-2 of Appendix 14.1, Volume 2c**. Further consideration was given to the numbers of birds found within the Turbine Area specifically, as only birds that enter the Turbine Area are at risk from colliding with turbines.

2.1.1.3 **Table 2-1** identifies those VORs which were recorded during the Digital Aerial Surveys (DAS) that were carried out between March 2022 and February 2024, and based on the criteria described above, which of these VORs require collision risk modelling. The VORs taken forward for collision risk modelling are highlighted green in **Table 2-1**.

Table 2-1: Identification of VORs for which collision risk modelling the Offshore Project is required.

VOR	Vulnerability to Collision	Importance of Population at the Offshore Ornithology Study Area	Collision Risk Modelling Required (Yes/No)
Black-legged kittiwake <i>Rissa tridactyla</i> (hereafter kittiwake)	High	Local	Yes – High sensitivity to collision, recorded flying in abundant numbers within the Turbine Area, international conservation status, local importance.
Black-headed gull <i>Chroicocephalus ridibundus</i>	High	Negligible	No – low abundance (not recorded within the Turbine Area).

VOR	Vulnerability to Collision	Importance of Population at the Offshore Ornithology Study Area	Collision Risk Modelling Required (Yes/No)
Common gull <i>Larus canus</i>	Very high	Negligible	No – low abundance (not recorded within the Turbine Area) ¹ .
Great black-backed gull <i>Larus marinus</i>	Very high	Local (some months only)	Yes – Very high sensitivity to collision, recorded flying within the Turbine Area, international conservation status, local importance.
Herring gull <i>Larus argentatus</i>	Very high	Local	Yes – Very high sensitivity to collision, recorded flying within the Turbine Area. Inclusion for CRM requested by NatureScot (NatureScot advice provided on 8 th May 2025).
Common tern <i>Sterna hirundo</i>	Moderate	Negligible	No – low abundance (not recorded within the Turbine Area). Migratory CRM undertaken for this species and presented within Section 2.2 of Appendix 14.4, Volume 2c.
Arctic tern <i>Sterna paradisaea</i>	Moderate	Regional (during breeding season only)	Yes - moderate sensitivity to collision, recorded flying in significant numbers within the Turbine Area, national conservation status, regional importance.
Great skua <i>Stercorarius skua</i>	High	Negligible	No – low abundance (not recorded within the Turbine Area). Migratory CRM undertaken for this species and presented within Section 2.2 of Appendix 14.4, Volume 2c.
Arctic skua <i>Stercorarius parasiticus</i>	High	Negligible	No – low abundance (not recorded within the Turbine Area). Migratory CRM undertaken for this species and presented within Section 2.2 of Appendix 14.4, Volume 2c.
Guillemot <i>Uria aalge</i>	Very low	Local	No – Very low vulnerability to collision
Razorbill <i>Alca torda</i>	Very low	Regional	No – Very low vulnerability to collision

¹ Inclusion of common gull for CRM was requested by NatureScot (NatureScot advice provided on 8th May 2025). However, due to the absence of any birds recorded within the turbine area, there is no data to undertake CRM on, and therefore, common gull has not been taken forward for CRM.

VOR	Vulnerability to Collision	Importance of Population at the Offshore Ornithology Study Area	Collision Risk Modelling Required (Yes/No)
Black guillemot <i>Cepphus grylle</i>	Very low	Regional (non-breeding season only)	No – Very low vulnerability to collision
Atlantic puffin <i>Fratercula arctica</i> (hereafter puffin)	Very low	Local	No – Very low vulnerability to collision
Red-throated diver <i>Gavia stellata</i>	Moderate	Negligible	No – low abundance (not recorded within the Turbine Area). Migratory CRM undertaken for this species and presented within Section 2.1 of Appendix 14.4, Volume 2c.
Great northern diver <i>Gavia immer</i>	Moderate	Negligible	No – low abundance (not recorded within the Turbine Area). Migratory CRM undertaken for this species and presented within Section 2.1 and 2.2 of Appendix 14.4, Volume 2c.
Fulmar <i>Fulmarus glacialis</i>	Very low	Local	Yes – included on a precautionary basis
Manx shearwater <i>Puffinus puffinus</i>	Very low	Local	Yes – species requested by SNCBs
Northern gannet <i>Morus bassanus</i> (hereafter gannet)	High	Local	Yes - High sensitivity to collision, recorded flying in abundant numbers within the Turbine Area, local importance.
Cormorant <i>Phalacrocorax carbo</i>	High	Negligible	No – low abundance (not recorded in the Turbine Area)
Shag <i>Gulosus aristotelis</i>	Moderate	Negligible	No – low abundance (not recorded within the Turbine Area)

2.1.1.4 The following species were selected for collision risk modelling:

- Kittiwake (High vulnerability to collision, international conservation status, local importance);
- Great black-backed gull (Very high vulnerability to collision, regional conservation status, local importance);
- Herring gull (Very high vulnerability to collision, regional conservation status, local importance, also SNCB requested species);
- Arctic tern (moderate vulnerability to collision, abundant species within the Turbine Area, national conservation status, regional importance);
- Fulmar (included on a precautionary basis);

- Manx shearwater (SNCB requested species);
- Gannet (high vulnerability to collision, international conservation status, local importance).

2.1.1.5 Fulmar was included on a precautionary basis, despite having a very low vulnerability to collision impacts and only a local population importance within the Offshore Ornithology Study Zone, as fulmar has been assessed for collision risk for numerous other offshore wind developments.

2.1.1.6 Manx shearwater has been included following consultation with NatureScot and other stakeholders. It should be noted that stakeholders highlighted the potential for CRM using flight height data from Johnston *et al.* (2014) to underestimate collision risk to Manx shearwater, if birds exhibit disorientation due to lighting. An assessment of the potential for lighting to lead to such impacts is included in Section 14.9 of **Chapter 14, Volume 2a**. There is insufficient data or evidence available to inform a revised approach to collision risk modelling for Manx shearwater, and therefore the results presented in this report are considered the best available quantitative assessment of collision risk.

2.1.1.7 This report focuses on regularly occurring seabirds, whose densities within the Turbine Area are considered to be adequately characterised by the DAS. It is acknowledged that migratory movements may be inadequately characterised by DAS, and therefore a separate assessment is carried out for those species, as detailed in **Appendix 14.4, Volume 2c**. It should be noted that Arctic tern is included in both this report and **Appendix 14.4, Volume 2c**, as Arctic tern were recorded in regionally important numbers in the DAS, but this may not fully capture the extent of passage through the Turbine Area. However, the results in this report and **Appendix 14.4, Volume 2c** should be considered as alternative approaches and not summed, as it is likely that the majority of the birds recorded in the DAS were migratory birds (given the low numbers of breeding birds at colonies within foraging range of the Turbine Area, and the peak abundances in DAS being recorded in July, towards the end of the breeding season when many birds will already be migrating).

2.2 COLLISION RISK MODELLING

2.2.1.1 Collision risk modelling was undertaken using the new update Stochastic Collision Risk Model (sCRM) by Caneco and Humphries (2022) which is based on the stochLAB R package as recommended by Joint Nature Conservation Committee (JNCC) *et al.* (2024) and NatureScot (2025). The sCRM provides a user-friendly 'Shiny App' online interface which 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. Modelling was conducted using 5,000 iterations with a random seed of 1234.

2.2.1.2 The approach to modelling incorporates the newly published guidance on recommended avoidance rates, bird size, flight speed, flight type and nocturnal activity scores (NatureScot, 2025)).

The SNCB guidance document only provided values for 4 of the species considered in this CRM Appendix: kittiwake, herring gull, great black-backed gull and gannet. sCRM parameters for other species (i.e. Arctic tern, Manx shearwater and gannet) therefore followed best available evidence (e.g. Garthe and Hüppop, 2004; Pennycuick, 1997; Gibb *et al.*, 2017; Robinson, 2005). In addition, other values that seek to capture the uncertainty associated with various parameters used for collision risk modelling have also been used. All proposed parameters are set out in **Table 2-2** and **Table 2-3**.

- 2.2.1.3 In line with NatureScot guidance (NatureScot, 2025), collision risk modelling was conducted both stochastically, incorporating variation in input parameters, and deterministically, without incorporating standard deviation (SD) into the model inputs. Stochastic results are presented within the main body of the report, while outputs from the deterministic model are provided in **Annex 14.3.1, Volume 2c**.

2.3 MODELLING PARAMETERS

2.3.1 SPECIES PARAMETERS

- 2.3.1.1 The sCRM incorporates several parameters relating to the 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, bird flight speed and nocturnal activity factors, which have some of the biggest influences on the predicted magnitude of risk. This is discussed in relevant sections below (see Section 4.1 for discussion of flight speeds and Section 4.2 for discussion of avoidance rates).
- 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 the SNCBs (JNCC *et al.*, 2024; NatureScot, 2025) in addition to other values that seek to capture the uncertainty associated with various parameters used for collision risk modelling. A discussion on these parameters is provided in Section 3.8.
- 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 CRM guidance (JNCC *et al.*, 2024) and NatureScot guidance (NatureScot, 2025) 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. Therefore, in the collision risk modelling undertaken for the Offshore Project, a 70% macro-avoidance rate was applied across the non-breeding season for gannet, as defined in NatureScot (2020), via a

correction to input densities. Additionally, for completion purposes, collision risk has also been presented without accounting for macro avoidance.

Table 2-2: Species biometrics and input parameters (± 1 SD, where relevant) for collision risk modelling.

Parameter	Source	Kittiwake	Great black-backed gull	Herring gull	Arctic tern	Fulmar	Manx shearwater	Gannet
Bird length (m)	NatureScot (2025)	0.39 (± 0.005)	0.71 (± 0.035)	0.60 (± 0.0225)	N/A	N/A	N/A	0.94 (± 0.0325)
	Robinson (2005)	N/A	N/A	N/A	0.34 (± 0.065)	0.45 (± 0.025)	0.34 (± 0.020)	N/A
Wingspan (m)	NatureScot (2025)	1.08 (± 0.0625)	1.58 (± 0.0375)	1.44 (± 0.03)	N/A	N/A	N/A	1.72 (± 0.0375)
	Robinson (2005)	N/A	N/A	N/A	0.70 (± 0.06)	1.07 (± 0.025)	0.82 (± 0.032)	N/A
Flight speed (m/s)	NatureScot (2025)	13.1 (± 0.40)	13.7 (± 1.20)	12.8 (± 1.80)	N/A	N/A	N/A	14.90 (± 0.000)
	Skov <i>et al.</i> (2018)	8.71 (± 3.16)	9.8 (± 3.63)	9.8 (± 3.63)	N/A	N/A	N/A	13.33 (± 4.24)
	Pennycuick (1987)	N/A	N/A	N/A	N/A	13.0 (± 0.00)	11.46 (± 2.23)	N/A
	Alerstam <i>et al.</i> , (2007)	N/A	N/A	N/A	10.9 (± 0.9)	N/A	N/A	N/A
Nocturnal activity factor	NatureScot (2025)	0.40 (± 0.12)	0.375 (± 0.0637)	0.375 (± 0.0637)	N/A	N/A	N/A	0.14 (± 0.10)
	Wade <i>et al.</i> (2016)	N/A	N/A	N/A	0.000 (± 0.000)	0.75 (± 0.00)	1.000 (± 0.00)	N/A
Flight type	NatureScot (2025)	Flapping	Flapping	Flapping	N/A	N/A	N/A	Gliding
	NatureScot (2023)	N/A	N/A	N/A	Flapping	Flapping	Flapping	N/A
	NatureScot (2025)	50	50	50	N/A	N/A	N/A	50

Parameter	Source	Kittiwake	Great black-backed gull	Herring gull	Arctic tern	Fulmar	Manx shearwater	Gannet
Proportion of flights upwind (%)	NatureScot (2023)	N/A	N/A	N/A	50	50	50	N/A
Avoidance rate (Stochastic model) (%)	NatureScot (2025)	0.9929 (± 0.0003)	0.9940 (± 0.0004)	0.9940 (±0.0004)	0.9908 (± 0.0004)	0.9929 (± 0.0003)	0.9929 (± 0.0003)	0.9929 (± 0.0003)
	Ozsanlav-Harris <i>et al.</i> (2023) (species specific rate)	0.9979 (± 0.0013)	0.9991 (± 0.0002)	0.9952 (±0.0003)	N/A	N/A	N/A	N/A
	Ozsanlav-Harris <i>et al.</i> (2023) (all gull rate)	N/A	N/A	N/A	N/A	0.9928 (± 0.0003)	0.9928 (± 0.0003)	N/A
	Ozsanlav-Harris <i>et al.</i> (2023) (gulls and terns rate)	N/A	N/A	N/A	0.9907 (±0.0004)	N/A	N/A	N/A
Avoidance rate (Deterministic model) (%)	NatureScot (2025)	0.9923	0.9936	0.9936	0.9902	0.9923	0.9923	0.9923
	Ozsanlav-Harris <i>et al.</i> (2023) (species specific rate)	0.9970	0.9991	0.9952	N/A	N/A	N/A	N/A
	Ozsanlav-Harris <i>et al.</i> (2023) (all gull rate)	N/A	N/A	N/A	N/A	0.9924	0.9924	N/A
	Ozsanlav-Harris <i>et al.</i> (2023) (gulls and terns rate)	N/A	N/A	N/A	0.9713	N/A	N/A	N/A

2.4 FLIGHT HEIGHTS

- 2.4.1.1 The proportion of birds flying at collision risk height was determined using generic flight height data rather than site-based data due to the SNCB currently not endorsing the use of Light Detection and Ranging (LiDAR) as a method for collecting flight height data to parameterise CRMs due to the lack of an established body of scientific evidence. These generic data were taken from Johnston *et al.*, 2014. Collision risk models were run using Option 2 only of the sCRM following standard practice and guidance (NatureScot, 2025; JNCC *et al.*, 2024; NatureScot, 2025), and with the large array correction applied.
- 2.4.1.2 Option 2 applies the “basic” version of the CRM, as defined by Band (2012), modelling collision risk assuming birds at potential collision height are uniformly distributed across the rotor-swept zone, based on generic flight height distribution data from Johnston *et al.*, 2014, and geometry of the turbine.

2.5 WIND FARM AND TURBINE PARAMETERS

- 2.5.1.1 The parameters for the 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 turbine scenario that provides the highest number of collisions and therefore a worst case.

Table 2-3: Wind turbine parameters in the MDS for collision risk modelling.

Parameter used in the sCRM ²	Parameter value (±SD, where relevant)
Wind farm	
Latitude	58.42
Maximum number of wind turbines	60
Tidal offset (m)	2.27
Wind farm width (E-W) (km)	21.3
Operational downtime (all months)	2%
Turbine	
Number of rotor blades per wind turbine	3
Chord width (m)	5.3
Average blade pitch (degrees)	4.8 (±6.2)
Rotor radius (m)	118
Average rotation speed (rpm)	8.4 (±1.98)
Upper blade tip height (above Mean Sea Level (MSL))	293.8 m
Air gap (Highest Astronomical Tide (HAT)) (m)	27.73
Air gap (MSL) (m)	30

² Parameter values presented are specific to the wind turbine option 1 model (see **Chapter 3, Volume 1a**).

Table 2-4: Monthly wind availability statistics for CRM.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind Availability (%)	98.4	98.1	97.4	94.4	93.2	92.6	89.9	92.2	94.5	97.8	98.3	96.8

2.6 DENSITY ESTIMATES

- 2.6.1.1 Site-specific data have been collected over a DAS programme of 24 months between March 2022 and February 2024, encompassing the Offshore Ornithology Survey Area. Further information on the DAS undertaken for the Offshore Project and the methodologies used to derive population estimates is provided in **Appendix 14.1, Volume 2c**.
- 2.6.1.2 As set out in Section 4.3 of **Appendix 14.1, Volume 2c** model-based estimates using the Marine Renewables Strategic environmental assessment (MRSea) package were produced for 5 species (gannet, kittiwake, guillemot, razorbill and puffin) in line with NatureScot guidance (NatureScot, 2023) in order to predict numbers across the Turbine Area alongside 95% confidence intervals to provide a level of uncertainty. Of the species selected for CRM, model-based estimates were established for kittiwake and gannet. Design-based estimates for abundances and densities of all species in each month were also generated and compared to the model-based estimates to provide additional validation of the model-based outputs and provide estimates for months where low raw abundances prevented the use of MRSea modelling. Where model-based densities were available those were used, and otherwise design-based densities were used, with model-based being prioritised over design-based whenever available as in line with NatureScot guidance (NatureScot, 2023). All densities are inclusive of apportionment of unidentified birds (as described in Section 4 of **Appendix 14.1, Volume 2c**).
- 2.6.1.3 For model-based estimates, densities of birds in flight were generated by multiplying the densities of all behaviours within the Turbine Area by the proportion of birds in flight. The proportion of birds in flight of each species was calculated for each month separately, across the entire Offshore Ornithology Survey Area using the raw data. The proportion was calculated across the Offshore Ornithology Survey Area rather than just the Turbine Area to ensure the sample size was sufficient to generate a robust estimate of the proportion of birds in flight.
- 2.6.1.4 For example, if MRSea generated a density of 10 kittiwake per km² in the Turbine Area for all behaviours, and there was a total of 2,000 kittiwake in the raw data for the Offshore Ornithology Survey Area, 600 of which were in flight, then the density of flying birds in the Turbine Area would then be calculated as $(600/2,000) * 10 = 3$ kittiwake per km².
- 2.6.1.5 Design-based abundance and density estimates were calculated separately for flying, sitting and all behaviours, with the estimates for flying birds being used for CRM.

2.6.1.6 For running the sCRM, the mean and SD of the density in each month were used as inputs. There were 2 density estimates for each calendar month due to the DAS covering 2 years of monthly samples. Under the assumption that overdispersion does not vary much among years, each of the 2 monthly estimates and confidence limits were averaged (i.e. the mean taken for each month). This approach was taken as opposed to generating separate outputs for each DAS, because ultimately those outputs would need to be averaged to generate an average impact, resulting in the same outcome. The SDs were combined by taking the square root of the average of the variances, using the following formula:

$$\text{combined SD} = \sqrt{\frac{(SD_1^2) + (SD_2^2)}{2}}$$

2.6.1.7 Sections 2.6.2 to 2.6.8 set out the density estimates for kittiwake, great black-backed gull, herring gull, Arctic tern, fulmar, Manx shearwater and gannet. For the tables set out in Sections 2.6.2 to 2.6.8, estimates used directly within sCRM collision risk are highlighted green.

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2.6.2 KITTIWAKE

2.6.2.1 The monthly density estimates for kittiwake are shown in **Table 2-5**. Some of the density estimates represent design-based estimates, which were used as substitutes where model-based estimates were unavailable for a given month, these are indicated with an asterisk. As stated previously in Section 2.6, for input into the sCRM, the 2 annual estimates for each month were averaged to produce a single mean value representing typical monthly density across the survey period.

Table 2-5: Density estimates used for kittiwake collision risk modelling

Survey Year	Estimate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year 1	Mean	3.532	0.665	0.046	0.030	0.193	0.000*	0.002	0.000*	0.000*	1.265	0.676	0.230
	LCI	2.840	0.461	0.018	0.010	0.135	0.000*	0.000	0.000*	0.000*	0.913	0.477	0.151
	UCI	4.467	0.950	0.174	0.137	0.311	0.000*	0.054	0.000*	0.000*	1.890	0.982	0.397
Year 2	Mean	0.064	0.698	0.393	0.064*	0.015	0.000	0.016	0.000*	0.000*	0.065	0.185	0.251
	LCI	0.007	0.483	0.203	0.007*	0.004	0.000	0.004	0.000*	0.000*	0.023	0.120	0.155
	UCI	0.193	1.056	0.890	0.193*	0.088	0.000	0.076	0.000*	0.000*	0.223	0.371	0.489
Average	Mean	1.798	0.682	0.220	0.047	0.104	0.000	0.009	0.000	0.000	0.665	0.430	0.240
	LCI	1.423	0.472	0.110	0.009	0.070	0.000	0.002	0.000	0.000	0.468	0.299	0.153
	UCI	2.330	1.003	0.532	0.165	0.199	0.000	0.065	0.000	0.000	1.057	0.676	0.443
	SD	2.452	0.024	0.245	0.024	0.126	0.000	0.010	0.000	0.000	0.848	0.347	0.015

LCI- Lower Confidence Interval; UCI- Upper Confidence Interval; *design-based density estimate

2.6.3 GREAT BLACK-BACKED GULL

2.6.3.1 The monthly density estimates for great black-backed gull are shown in **Table 2-6**. All density estimates for great black-backed gull are design-based. As stated previously in Section 2.6, for input into the sCRM, the 2 annual estimates for each month were averaged to produce a single mean value representing typical monthly density across the survey period.

Table 2-6: Density estimates used for great black-backed gull collision risk modelling

Survey Year	Estimate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year 1	Mean	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.064	0.000
	LCI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000
	UCI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000
Year 2	Mean	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.071
	LCI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007
	UCI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250
Average	Mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.032	0.036
	LCI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.004	0.004
	UCI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.125	0.125
	SD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.045	0.050

2.6.4 HERRING GULL

2.6.4.1 The monthly density estimates for herring gull are shown in **Table 2-7**. All density estimates for herring gull are design-based. As stated previously in Section 2.6, for input into the sCRM, the 2 annual estimates for each month were averaged to produce a single mean value representing typical monthly density across the survey period.

Table 2-7: Density estimates used for herring gull collision risk modelling

Survey Year	Estimate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year 1	Mean	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	LCI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	UCI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Year 2	Mean	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.185	0.000
	LCI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.021	0.000
	UCI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.513	0.000
Average	Mean	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.093	0.000
	LCI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.000
	UCI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.257	0.000
	SD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.131	0.000

2.6.5 ARCTIC TERN

2.6.5.1 The monthly density estimates for Arctic tern are shown in **Table 2-8**. Whilst apportionment of “commic” terns (unidentified common or Arctic tern) was not carried out in the results presented in Section 8.9 of **Appendix 14.1, Volume 2c** for the purpose of CRM, all records of “commic” tern were apportioned to Arctic tern. All density estimates for Arctic tern are design-based. As stated previously in Section 2.6, for input into the sCRM, the 2 annual estimates for each month were averaged to produce a single mean value representing typical monthly density across the survey period.

Table 2-8: Density estimates used for Arctic tern collision risk modelling

Survey Year	Estimate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year 1	Mean	0.000	0.000	0.000	0.000	1.455	0.121	0.820	0.000	0.000	0.000	0.000	0.000
	LCI	0.000	0.000	0.000	0.000	0.164	0.014	0.135	0.000	0.000	0.000	0.000	0.000
	UCI	0.000	0.000	0.000	0.000	4.122	0.371	1.996	0.000	0.000	0.000	0.000	0.000
Year 2	Mean	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.064	0.000	0.000	0.000	0.000
	LCI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000
	UCI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000
Average	Mean	0.000	0.000	0.000	0.000	0.728	0.061	0.410	0.032	0.000	0.000	0.000	0.000
	LCI	0.000	0.000	0.000	0.000	0.082	0.007	0.068	0.004	0.000	0.000	0.000	0.000
	UCI	0.000	0.000	0.000	0.000	2.061	0.186	0.998	0.125	0.000	0.000	0.000	0.000
	SD	0.000	0.000	0.000	0.000	1.029	0.086	0.580	0.045	0.000	0.000	0.000	0.000

2.6.6 FULMAR

2.6.6.1 The monthly density estimates for fulmar are shown in **Table 2-9**. All density estimates for fulmar are design-based. As stated previously in Section 2.6, for input into the sCRM, the 2 annual estimates for each month were averaged to produce a single mean value representing typical monthly density across the survey period.

Table 2-9: Density estimates used for fulmar collision risk modelling

Survey Year	Estimate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year 1	Mean	0.057	0.378	1.127	0.193	0.185	0.000	0.442	0.185	0.499	0.000	0.185	1.134
	LCI	0.007	0.128	0.385	0.021	0.021	0.000	0.128	0.021	0.121	0.000	0.021	0.257
	UCI	0.185	0.749	2.161	0.385	0.435	0.000	0.877	0.371	0.934	0.000	0.442	2.475
Year 2	Mean	0.456	0.000	1.391	0.442	0.456	0.064	0.635	0.257	0.128	0.000	0.000	0.649

Survey Year	Estimate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	LCI	0.064	0.000	0.692	0.064	0.128	0.007	0.193	0.029	0.014	0.000	0.000	0.278
	UCI	0.963	0.000	2.196	1.013	0.834	0.193	1.148	0.628	0.314	0.000	0.000	1.084
Average	Mean	0.257	0.189	1.259	0.317	0.321	0.032	0.538	0.221	0.314	0.000	0.093	0.891
	LCI	0.036	0.064	0.538	0.043	0.075	0.004	0.160	0.025	0.068	0.000	0.011	0.267
	UCI	0.574	0.374	2.179	0.699	0.635	0.096	1.013	0.499	0.624	0.000	0.221	1.779
	SD	0.282	0.267	0.187	0.176	0.192	0.045	0.136	0.050	0.262	0.000	0.131	0.343

2.6.7 MANX SHEARWATER

2.6.7.1 The monthly density estimates for Manx shearwater are shown in **Table 2-10**. All density estimates for Manx shearwater are design-based. As stated previously in Section 2.6, for input into the sCRM, the 2 annual estimates for each month were averaged to produce a single mean value representing typical monthly density across the survey period.

Table 2-10: Density estimates used for Manx shearwater collision risk modelling

Survey Year	Estimate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year 1	Mean	0.000	0.000	0.000	0.100	0.000	0.000	0.620	0.050	0.000	0.000	0.000	0.000
	LCI	0.000	0.000	0.000	0.007	0.000	0.000	0.135	0.000	0.000	0.000	0.000	0.000
	UCI	0.000	0.000	0.000	0.321	0.000	0.000	1.241	0.157	0.000	0.000	0.000	0.000
Year 2	Mean	0.000	0.000	0.000	0.000	0.000	0.000	0.128	0.000	0.000	0.000	0.000	0.000
	LCI	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000
	UCI	0.000	0.000	0.000	0.000	0.000	0.000	0.321	0.000	0.000	0.000	0.000	0.000
Average	Mean	0.000	0.000	0.000	0.050	0.000	0.000	0.374	0.025	0.000	0.000	0.000	0.000
	LCI	0.000	0.000	0.000	0.004	0.000	0.000	0.071	0.000	0.000	0.000	0.000	0.000
	UCI	0.000	0.000	0.000	0.160	0.000	0.000	0.781	0.078	0.000	0.000	0.000	0.000
	SD	0.000	0.000	0.000	0.071	0.000	0.000	0.348	0.035	0.000	0.000	0.000	0.000

2.6.8 GANNET

2.6.8.1 The monthly density estimates for gannet are shown in **Table 2-11** and **Table 2-12**. **Table 2-11** shows densities with 70% macro avoidance in the non-breeding incorporated while **Table 2-12** shows density estimate with no macro-avoidance incorporated. Some of the density estimates represent design-based estimates, which were used as substitutes where model-based estimates were unavailable for a given month, these are indicated with an asterisk. As stated previously in Section 2.6, for input into the sCRM, the 2 annual estimates for each month were averaged to produce a single mean value representing typical monthly density across the survey period.

Table 2-11: Density estimates used for gannet collision risk modelling with 70% macro-avoidance in the non-breeding season

Survey Year	Estimate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year 1	Mean	0.049	0.000*	0.028	0.371	0.117	0.325	0.628	2.881	0.295	0.360	0.019*	0.000*
	LCI	0.032	0.000*	0.012	0.260	0.033	0.208	0.427	1.451	0.143	0.244	0.002*	0.000*
	UCI	0.086	0.000*	0.162	0.528	0.675	0.535	1.012	8.100	0.629	0.600	0.056*	0.000*
Year 2	Mean	0.000*	0.000*	0.018	0.186	0.202	0.620	0.562	0.098	0.320	0.000*	0.000*	0.017*
	LCI	0.000*	0.000*	0.005	0.129	0.126	0.415	0.386	0.032	0.191	0.000*	0.000*	0.002*
	UCI	0.000*	0.000*	0.103	0.295	0.342	0.971	0.881	0.358	0.779	0.000*	0.000*	0.058*
Average	Mean	0.024	0.000	0.023	0.279	0.160	0.473	0.595	1.490	0.308	0.180	0.010	0.009
	LCI	0.016	0.000	0.009	0.195	0.080	0.312	0.407	0.742	0.167	0.122	0.001	0.001
	UCI	0.043	0.000	0.133	0.412	0.509	0.753	0.947	4.229	0.704	0.300	0.028	0.029
	SD	0.035	0.000	0.007	0.131	0.060	0.209	0.047	1.968	0.018	0.255	0.014	0.012

Table 2-12: Density estimates used for gannet collision risk modelling assuming no macro-avoidance in the non-breeding season

Survey Year	Estimate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year 1	Mean	0.163	0.000*	0.028	0.371	0.117	0.325	0.628	2.881	0.295	1.200	0.064*	0.000*
	LCI	0.105	0.000*	0.012	0.260	0.033	0.208	0.427	1.451	0.143	0.813	0.007*	0.000*
	UCI	0.288	0.000*	0.162	0.528	0.675	0.535	1.012	8.100	0.629	1.999	0.185*	0.000*
Year 2	Mean	0.000*	0.000*	0.018	0.186	0.202	0.620	0.562	0.098	0.320	0.000*	0.000*	0.057*
	LCI	0.000*	0.000*	0.005	0.129	0.126	0.415	0.386	0.032	0.191	0.000*	0.000*	0.007*
	UCI	0.000*	0.000*	0.103	0.295	0.342	0.971	0.881	0.358	0.779	0.000*	0.000*	0.193*
Average	Mean	0.082	0.000	0.023	0.279	0.160	0.473	0.595	1.490	0.308	0.600	0.032	0.029
	LCI	0.053	0.000	0.009	0.195	0.080	0.312	0.407	0.742	0.167	0.407	0.004	0.004
	UCI	0.144	0.000	0.133	0.412	0.509	0.753	0.947	4.229	0.704	1.000	0.093	0.097
	SD	0.115	0.000	0.007	0.131	0.060	0.209	0.047	1.968	0.018	0.849	0.045	0.040

3 RESULTS

3.1 KITTIWAKE

3.1.1.1 The predicted number of collisions for kittiwake are presented in **Table 3-1**.

Table 3-1: Predicted collisions for kittiwake associated with the Offshore Project under Option 2 of the stochastic collision risk model

Flight speed (m/s)	Estimate	Avoidance rate (%)	Collision risk estimates												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
13.1 (± 0.40)	Mean	0.9929	10.097	2.448	1.314	0.217	0.726	0.000	0.059	0.000	0.000	4.017	1.833	0.836	21.547
	SD	(± 0.0003)	7.269	0.552	0.883	0.112	0.493	0.000	0.040	0.000	0.000	2.806	1.172	0.211	8.971
	Mean	0.9979	2.994	0.730	0.394	0.065	0.215	0.000	0.017	0.000	0.000	1.196	0.546	0.250	6.406
	SD	(± 0.0013)	3.049	0.480	0.398	0.054	0.148	0.000	0.017	0.000	0.000	1.214	0.531	0.168	4.915
8.71 (± 3.16)	Mean	0.9929	8.202	1.981	1.066	0.175	0.585	0.000	0.048	0.000	0.000	3.234	1.485	0.676	17.451
	SD	(± 0.0003)	6.397	0.619	0.765	0.099	0.424	0.000	0.034	0.000	0.000	2.404	1.023	0.226	8.427
	Mean	0.9979	2.461	0.588	0.317	0.052	0.175	0.000	0.014	0.000	0.000	0.961	0.455	0.201	5.214
	SD	(± 0.0013)	2.781	0.414	0.331	0.048	0.182	0.000	0.014	0.000	0.000	0.999	0.455	0.144	4.394

3.2 GREAT BLACK-BACKED GULL

3.2.1.1 The predicted number of collisions for great black-backed gull are presented in **Table 3-2**.

Table 3-2: Predicted collisions for great black-backed gull associated with the Offshore Project under Option 2 of the stochastic collision risk model

Flight speed (m/s)	Estimate	Avoidance rate (%)	Collision risk estimates													
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total	
13.7 (± 1.20)	Mean	0.9940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.709	0.775	1.484
	SD	(± 0.0004)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.508	0.552	0.790
	Mean	0.9991	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.107	0.117	0.224
	SD	(± 0.0002)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.082	0.090	0.133
9.8 (± 3.63)	Mean	0.9940	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.611	0.669	1.280
	SD	(± 0.0004)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.464	0.501	0.729
	Mean	0.9991	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.091	0.100	0.192
	SD	(± 0.0002)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.073	0.079	0.118

3.3 HERRING GULL

3.3.1.1 The predicted number of collisions for herring gull are presented in **Table 3-3**.

Table 3-3: Predicted collisions for herring gull associated with the Offshore Project under Option 2 of the stochastic collision risk model

Flight speed (m/s)	Estimate	Avoidance rate (%)	Collision risk estimates													
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total	
12.8 (± 1.80)	Mean	0.9940 (±0.0004)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.647	0.000	1.647
	SD		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.224	0.000
	Mean	0.9952 (±0.0003)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.318	0.000	1.318
	SD		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.975	0.000	0.975
9.8 (±3.63)	Mean	0.9940 (±0.0004)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.457	0.000	1.457
	SD		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.127	0.000	1.127
	Mean	0.9952 (±0.0003)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.163	0.000	1.163
	SD		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.894	0.000	0.894

3.4 ARCTIC TERN

3.4.1.1 The predicted number of collisions for Arctic tern are presented in **Table 3-4**.

Table 3-4: Predicted collisions for Arctic tern associated with the Offshore Project under Option 2 of the stochastic collision risk model

Flight speed (m/s)	Estimate	Avoidance rate (%)	Collision risk estimates												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
10.9 (± 0.9)	Mean	0.9908	0.000	0.000	0.000	0.000	1.030	0.088	0.596	0.040	0.000	0.000	0.000	0.000	1.754
	SD	(± 0.0004)	0.000	0.000	0.000	0.000	1.525	0.130	0.880	0.059	0.000	0.000	0.000	0.000	2.254
	Mean	0.9907	0.000	0.000	0.000	0.000	1.041	0.089	0.602	0.041	0.000	0.000	0.000	0.000	1.773
	SD	(±0.0004)	0.000	0.000	0.000	0.000	1.541	0.131	0.890	0.059	0.000	0.000	0.000	0.000	2.278

3.5 FULMAR

3.5.1.1 The predicted number of collisions for fulmar are presented in **Table 3-5**.

Table 3-5: Predicted collisions for fulmar associated with the Offshore Project under Option 2 of the stochastic collision risk model

Flight speed (m/s)	Estimate	Avoidance rate (%)	Collision risk estimates												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
13.0 (± 0.00)	Mean	0.9929	0.199	0.159	0.754	0.195	0.208	0.030	0.314	0.130	0.212	0.000	0.081	0.496	2.778
	SD	(± 0.0003)	0.376	0.302	1.146	0.336	0.366	0.056	0.489	0.201	0.390	0.000	0.156	0.825	4.206
	Mean	0.9928	0.202	0.162	0.765	0.197	0.211	0.030	0.319	0.132	0.215	0.000	0.082	0.503	2.817
	SD	(± 0.0003)	0.381	0.306	1.162	0.341	0.371	0.057	0.496	0.204	0.396	0.000	0.158	0.836	4.265

3.6 MANX SHEARWATER

3.6.1.1 The predicted number of collisions for Manx shearwater are presented in **Table 3-6**.

Table 3-6: Predicted collisions for Manx shearwater associated with the Offshore Project under Option 2 of the stochastic collision risk model

Flight speed (m/s)	Estimate	Avoidance rate (%)	Collision risk estimates													
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total	
11.46 (± 2.23)	Mean	0.9929	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	SD	(± 0.0003)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Mean	0.9928	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	SD	(± 0.0003)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

3.7 GANNET

3.7.1 WITH 70% MACRO-AVOIDANCE

3.7.1.1 The predicted number of collisions for gannet with 70% macro-avoidance applied to the non-breeding season are presented in **Table 3-7**.

Table 3-7: Predicted collisions for gannet associated with the Offshore Project with macro-avoidance accounted for under Option 2 of the stochastic collision risk model

Flight speed (m/s)	Estimate	Avoidance rate (%)	Collision risk estimates												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
14.90 (± 0.000)	Mean	0.9929	0.128	0.000	0.104	1.419	0.914	2.826	3.386	11.899	1.398	1.159	0.052	0.041	23.327
	SD	(± 0.0003)	0.120	0.000	0.064	1.011	0.600	1.926	1.723	10.612	0.713	1.039	0.049	0.039	14.746
13.33 (± 4.24)	Mean	0.9929	0.121	0.000	0.099	1.348	0.868	2.684	3.217	11.304	1.328	1.101	0.050	0.039	22.159
	SD	(± 0.0003)	0.114	0.000	0.061	0.964	0.572	1.838	1.648	10.119	0.682	0.989	0.046	0.037	14.084

3.7.2 ASSUMING NO MACRO-AVOIDANCE

3.7.2.1 The predicted number of collisions for gannet assuming no macro-avoidance are presented in **Table 3-8**.

Table 3-8: Predicted collisions for gannet associated with the Offshore Project assuming a flapping flight type and with no macro-avoidance included within modelling under Option 2 of the stochastic collision risk model

Flight speed (m/s)	Estimate	Avoidance rate (%)	Collision risk estimates												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
14.90 (± 0.000)	Mean	0.9929	0.424	0.000	0.104	1.418	0.912	2.814	3.386	11.741	1.401	3.893	0.170	0.135	26.398
	SD	(± 0.0003)	0.389	0.000	0.064	1.004	0.599	1.921	1.723	10.152	0.718	3.514	0.159	0.124	15.880
13.33 (± 4.24)	Mean	0.9929	0.391	0.000	0.099	1.325	0.875	2.654	3.227	11.184	1.328	3.722	0.158	0.129	25.092
	SD	(± 0.0003)	0.372	0.000	0.063	0.962	0.591	1.919	1.735	10.156	0.713	3.450	0.149	0.124	15.898

3.8 SUMMARY

- 3.8.1.1 Collision risk estimates have been presented using two sets of flight speed and avoidance rate values: one based on the SNCB-recommended parameters, and another informed by recent post-construction monitoring studies (e.g. Skov *et al.*, 2018; Ozsanlav-Harris *et al.*, 2023) as shown within Section 3 for each species considered within CRM. A discussion on the variability and uncertainty associated with these different sources is provided in Section 4.
- 3.8.1.2 The collision estimates presented in **Table 3-9** align with SNCB advice (NatureScot, 2025) and will be used in the assessments presented in Section 14.9 of **Chapter 14, Volume 2a**, and the Offshore Report to Inform the Appropriate Assessment. Alternative estimates as shown within Section 3 which are based on recent evidence and are included within in Section 14.9 of **Chapter 14, Volume 2a**, and the Offshore RIAA to support discussion and contextual interpretation of risk.

Table 3-9: Predicted collision risk estimates for concerned species using SNCB advocated parameters for use in assessment

Species	Estimate	Collision risk estimates												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Kittiwake	Mean	10.097	2.448	1.314	0.217	0.726	0.000	0.059	0.000	0.000	4.017	1.833	0.836	21.547
	SD	7.269	0.552	0.883	0.112	0.493	0.000	0.040	0.000	0.000	2.806	1.172	0.211	8.971
Great black-backed gull	Mean	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.709	0.775	1.484
	SD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.508	0.552	0.790
Herring gull	Mean	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.647	0.000	1.647
	SD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.224	0.000	1.224
Arctic tern	Mean	0.000	0.000	0.000	0.000	1.030	0.088	0.549	0.040	0.000	0.000	0.000	0.000	1.707
	SD	0.000	0.000	0.000	0.000	1.525	0.130	0.812	0.059	0.000	0.000	0.000	0.000	2.199
Fulmar	Mean	0.199	0.159	0.754	0.195	0.208	0.030	0.314	0.130	0.212	0.000	0.081	0.496	2.778
	SD	0.376	0.302	1.146	0.336	0.366	0.056	0.489	0.201	0.390	0.000	0.156	0.825	4.206

Species	Estimate	Collision risk estimates												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Manx shearwater	Mean	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	SD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gannet	Mean	0.128	0.000	0.104	1.419	0.914	2.826	3.386	11.899	1.398	1.159	0.052	0.041	23.327
	SD	0.120	0.000	0.064	1.011	0.600	1.926	1.723	10.612	0.713	1.039	0.049	0.039	14.746

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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 2 alternative sources for bird flight speed. The first source being either Alerstam *et al.* (2007) or Pennycuick (1987) (recommended in NatureScot, 2025), with the second source being Skov *et al.* (2018). Whilst NatureScot has not provided detailed commentary surrounding their recommendation, Natural England has 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 Alerstam *et al.* (2007) provides flight speed data collected using tracking radar measurements from 5 sites in southern Sweden and on 2 expeditions to the Arctic between 1979-1999. 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.

4.1.1.3 Pennycuick (1987) provides flight speed data estimated using an ornithodolite. Observations of birds were made during the breeding season on the island of Foula/Fughlaigh, Shetland/Sealtainn 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).

4.1.1.4 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.

4.1.1.5 Of the species undergoing CRM in this technical report, alternative flight speed data is available for gannet, kittiwake, herring gull and great-black backed gull. A comparison of each of these sources for these 4 is provided in **Table 4-1** in relation to sample size, location of studies, seasonality and location. Sections 4.1.2 to 4.1.5 discuss this information for each species.

Table 4-1: Comparison of data sources for bird flight speed.

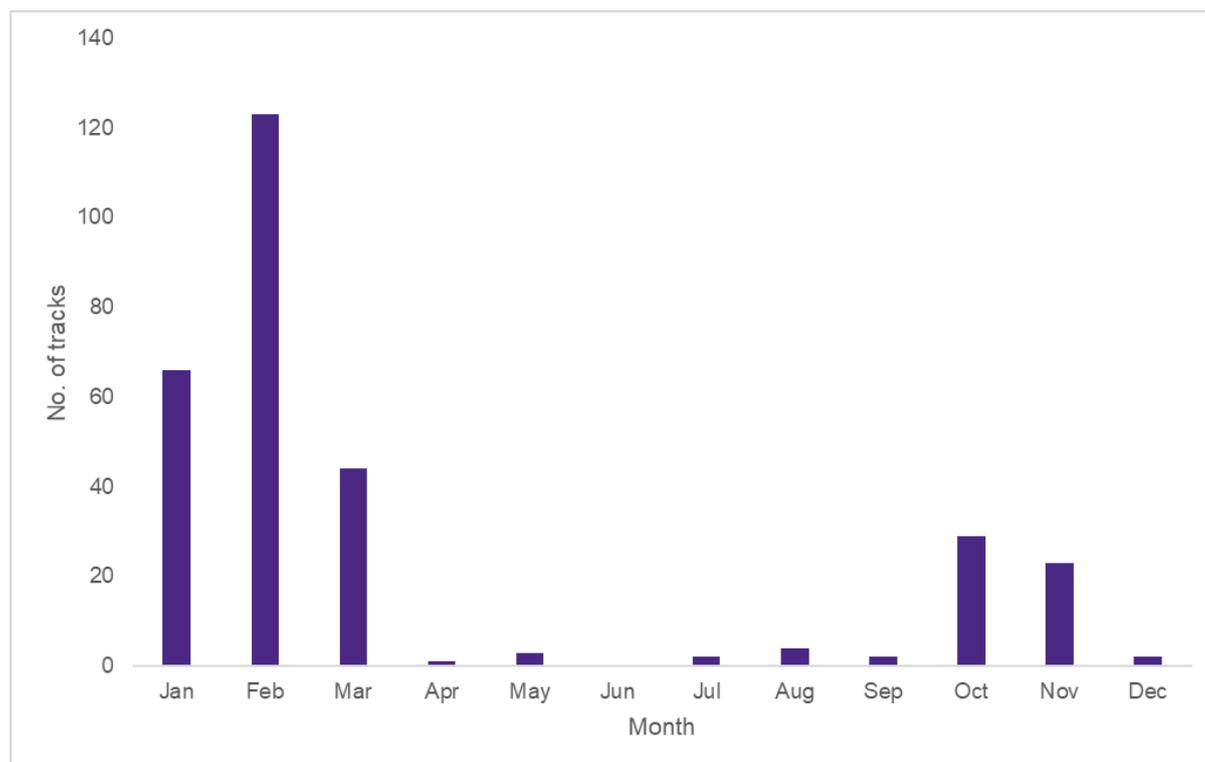
Dataset feature	Species	Alerstam <i>et al.</i> (2007) Pennycuick (1987)	Skov <i>et al.</i> (2018)
Sample size	Gannet	32 observations	683 tracks
	Kittiwake	2 tracks	287 tracks
	Herring gull	18 tracks	790 tracks
	Great black-backed gull	4 tracks	790 tracks
Location	Gannet	Pennycuick: Foula, Shetland/ <i>Sealtainn</i>	Thanet offshore wind farm, south North Sea, offshore of Kent, England
	Kittiwake	Northeast Passage	
	Herring gull	Sweden and the Arctic	
	Great black-backed gull	Sweden and the Arctic	
Seasonality	Gannet	Pennycuick: 28 June to 9 July 1986	Fieldwork undertaken between July 2014 and April 2016 covering all months. The occurrence of each species on a monthly basis is discussed below (see Sections 4.1.2, 4.1.3, 4.1.4 and 4.1.5)
	Kittiwake	July and August 1994 (Alerstam and Gudmundsson, 1999)	
	Herring gull	Unknown	
	Great black-backed gull	Unknown	

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 2 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. 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 1 SD; 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 2 years with the monthly distribution of datapoints for kittiwake presented in **Plate 4-1**. The kittiwake breeding season runs from March-August (full UK breeding season) with a migration-free breeding season running from May-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.

Plate 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 7.26-15.9 m/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, Global Positioning System (GPS) transmitters, laser rangefinder and car speedometer. Royal Haskoning DHV (2020) suggests that kittiwake exhibit an average flight speed of 10.8 m/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 9.2 m/s and 10.6 m/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-11 August 2007. Elliot *et al.* (2014) collected data

from 10 incubating birds (30 May-16 June 2013). The flight speeds estimated from these 2 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 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 the Offshore Project is located (i.e. not close to large breeding colonies). 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.

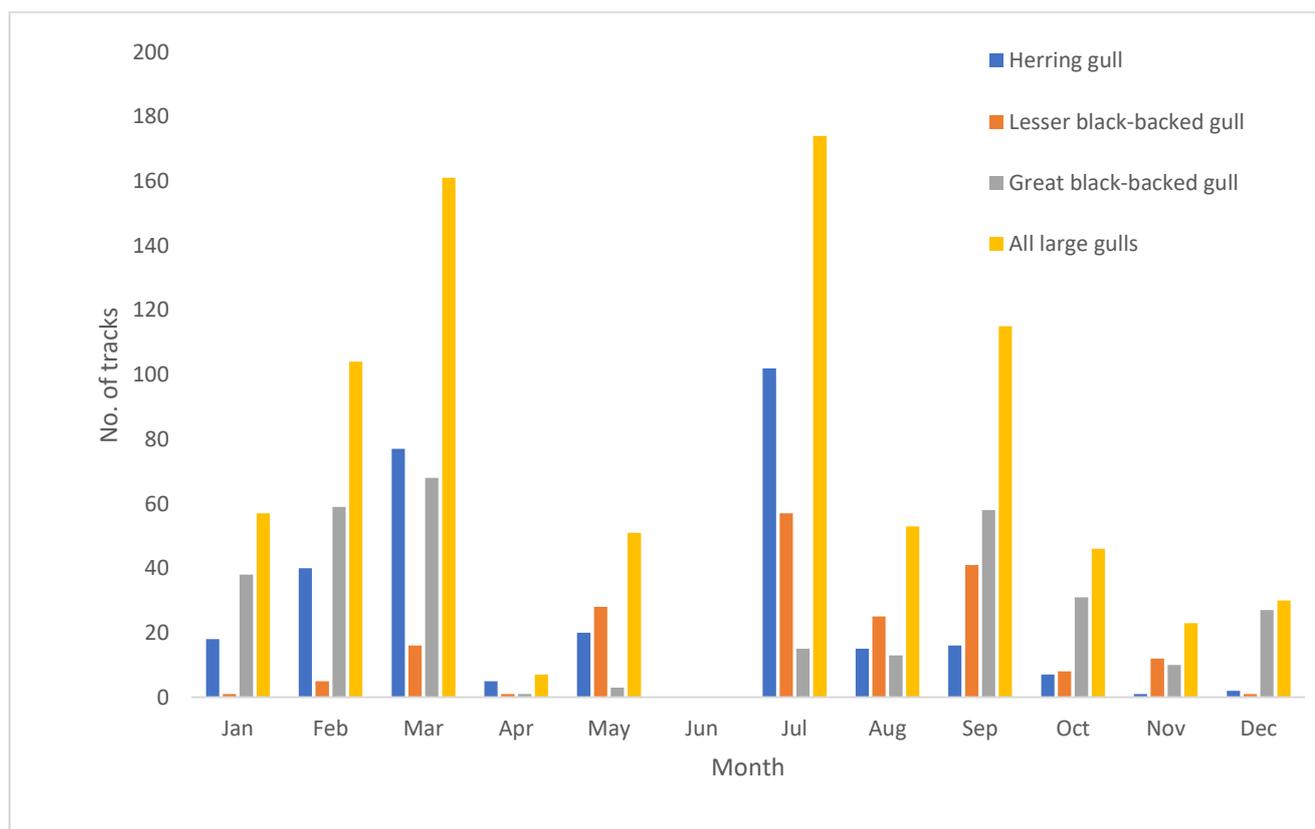
4.1.3 GREAT BLACK-BACKED GULL

- 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 4 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 2 years with the monthly distribution of datapoints for all 3 large gulls (both individually and combined) presented in **Plate 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 the Offshore Project more accurately (if indeed a difference between seasons exists) with few breeding colonies in close proximity to the Offshore Project.
- 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 2 GPS transmitter studies, the first from 3 great black-backed gulls tagged on Swedish Islands in the Baltic Sea (including a single bird migrating to the UK) and the second from 5 great black-backed gulls tagged in the Kattegat. The first of these datasets estimated a flight speed of 12.1-12.5 m/s with the second predicting a flight speed of 10.3-10.8 m/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 1 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 the Offshore Project is located (i.e. not close to 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.

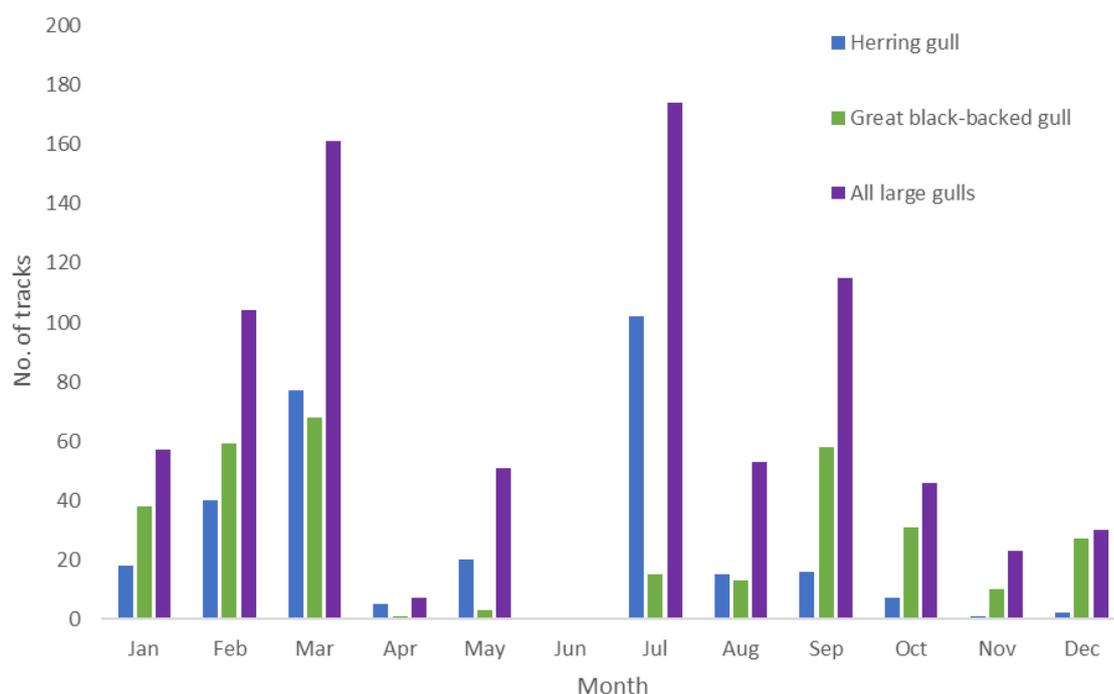
Plate 4-2: Number of large gull tracks in each month from Skov *et al.* (2018).



4.1.4 HERRING GULL

- 4.1.4.1 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 compared to the sample size associated with the flight speed value from Alerstam *et al.* (2007) of 18 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 data used by Alerstam *et al.* (2007) to estimate flight speeds for herring gull is based on birds observed in Sweden and the Arctic. Two tracks were obtained during the breeding season (Alerstam and Gudmundsson, 1999) but it is not known when the remaining tracks were observed. The Skov *et al.* (2018) dataset was collected at the Thanet Offshore Wind Farm which is within the foraging range of herring gull (mean-maximum plus 1 SD; Woodward *et al.*, 2019) from a number of breeding colonies, including 1 of considerable significance for the species (Havergate Island).
- 4.1.4.2 Fieldwork associated with Skov *et al.* (2018) was conducted across 2 years with the monthly distribution of datapoints for all 3 large gulls (both individually and combined) presented in **Plate 4-3**. The herring gull breeding season runs from March-August (full UK breeding season) with a migration-free breeding season running from May-July. There are therefore datapoints across all seasons relevant to herring gull.
- 4.1.4.3 Based on the evidence presented above it is considered that the best available evidence in relation to flight speed for herring 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 the Offshore Project is located (i.e. limited connectivity with large breeding colonies based on the paucity of birds in baseline surveys undertaken at the Offshore Project) 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 herring 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.

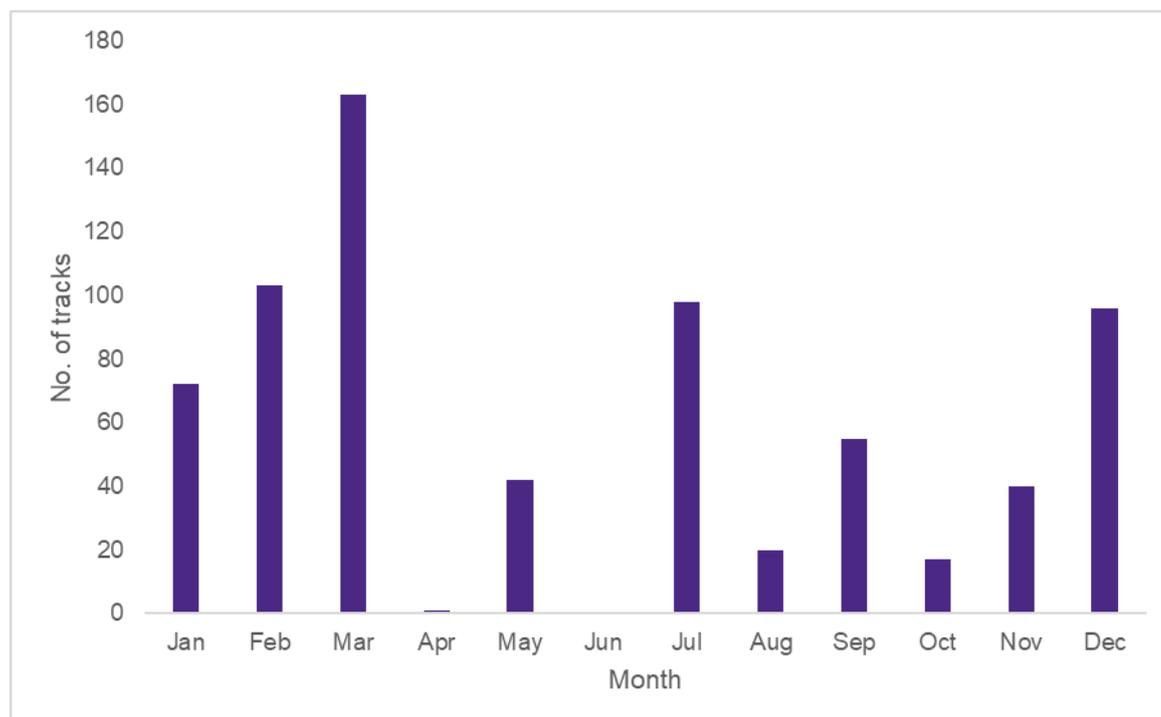
Plate 4-3: Number of large gull tracks in each month from Skov *et al.* (2018)



4.1.5 GANNET

4.1.5.1 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 was collected on the island of Foula/*Fughlaigh*, Shetland/*Sealtainn*, 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 1 SD which is used to identify connectivity for the purposes of Habitat Regulations Appraisal screening) of gannet (Woodward *et al.*, 2019) of a breeding colony. Fieldwork associated with Skov *et al.* (2018) was conducted across 2 years with the monthly distribution of datapoints for gannet presented in **Plate 4-4**. The gannet breeding season runs from March-September (full UK breeding season) with a migration-free breeding season running from April-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.

Plate 4-4: Number of gannet tracks in each month from Skov *et al.* (2018).



4.1.5.2 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 Pennycuik (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 Pennycuik (1987), is closer to that estimated by Skov *et al.* (2018) than the value estimated by Pennycuik (1987).

4.1.5.3 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 Pennycuik (1987). 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 the Offshore Project is located (i.e. not close to large breeding colonies). The value from Skov *et al.* (2018) also reflects the behaviour of gannet throughout the annual cycle and not the behaviour of birds close to a breeding colony as in Pennycuik (1987). The value presented by Pennycuik (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.

4.1.6 OTHER CONSIDERATIONS

4.1.6.1 There is no specific recommendation of the number of data points required for robust assessment of flight speeds from NatureScot or other SNCBs. However, a sample size of 100 birds has been deemed adequate to provide a representative value for use in collision risk modelling for the proportion of birds at collision height (Natural England, 2013). 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 speed from Skov *et al.* (2018) would reach this threshold and be considered representative of flight speed behaviour.

4.1.7 CONCLUSION

4.1.7.1 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 the Offshore Project. 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). 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 sCRM:

"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."

4.2.1.2 As stated in Ozsanlav-Harris *et al.* (2023), behaviour of birds offshore and onshore can differ affecting flight height distributions. Assessments presented in Section 14.9 of **Chapter 14, Volume 2a** and Section 8.6 of the **Offshore RIAA** will therefore take due account of all available evidence to determine the magnitude of effect for relevant species at the Offshore Project.

4.2.1.3 The research conducted by Ozsanlav-Harris *et al.* (2023) reviews the approach to calculate the avoidance rate of specific species and groupings, comparing this to the approach by Cook (2021). The Ozsanlav-Harris *et al.* (2023) dataset (**Table 4-2**) contains information on collision data from 23

monitoring reports of 19 wind farms (including 1 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 4-2** reaches this threshold for all species except kittiwake. However, NatureScot (2025) has recommended that 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 other gulls for which data is available.

- 4.2.1.4 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 herring gull, lesser black-backed gull and great black-backed gull, represents 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 3 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.
- 4.2.1.5 Uncertainty associated with all avoidance rates, and especially species-specific rates, is captured as part of the modelling process through the use of the stochastic collision risk model and SD values.
- 4.2.1.6 **Table 4-2** sets out the species-specific avoidance rates as taken from Ozsanlav-Harris *et al.* (2022). The second column of **Table 4-2** shows the avoidance rates, presented in the format: median rate (SD; 95% confidence interval). The third column of **Table 4-2** shows the sample size presented as number of report-years.

Table 4-2: Species-specific Avoidance Rates from Ozsanlav-Harris *et al.* (2023).

Species/species group	Basic stochastic collision risk model Avoidance Rate	Sample size (number of report years contributing data to avoidance rate calculation)
Kittiwake	0.9979 (0.0013; 0.9955 – 0.9993)	3
Great black-backed gull	0.9991 (0.0002; 0.9987 – 0.9994)	10
Gull	0.9928 (0.0003; 0.9921 – 0.9934)	36
Large gull	0.9939	31

Species/species group	Basic stochastic collision risk model Avoidance Rate	Sample size (number of report years contributing data to avoidance rate calculation)
	(0.0004; 0.9931 – 0.9947)	
Small gull	0.9949 (0.0002; 0.9944 – 0.9954)	29
Gulls & terns	0.9907 (0.0004; 0.9899 – 0.9914)	38

5 GLOSSARY OF TERMS AND ABBREVIATIONS

5.1.1.1 A list of key terms and acronyms used in this appendix are provided in **Table 5-1** and **Table 5-2**.

Table 5-1: Acronyms and abbreviations

Term	Definition
BCA	Bird Collision Avoidance
CRM	Collision Risk Model
DAS	Digital Aerial Survey
EIAR	Environmental Impact Assessment Report
GPS	Global Positioning System
HAT	Highest Astronomical Tide
IBM	Individual-Based Model
JNCC	Joint Nature Conservation Committee
LCI	Lower Confidence Interval
LiDAR	Light Detection and Ranging
MDS	Maximum Design Scenario
MHWS	Mean High Water Springs
MRSea	Marine Renewables Strategic Environmental Assessment (R package)
MSL	Mean Sea Level
OCAS	Offshore Cable Area of Search
ORJIP	Offshore Renewables Joint Industry Programme
OSP	Offshore Substation Platform
OWF	Offshore Wind Farm
RIAA	Report to Inform Appropriate Assessment
sCRM	Stochastic Collision Risk Model
SD	Standard Deviation
SNCBs	Statutory Nature Conservation Bodies
UCI	Upper Confidence Interval
UK	United Kingdom
VOR	Valued Ornithological Receptors
WTG	Wind Turbine Generators

Table 5-2: Glossary

Term	Meaning
Array Area	The offshore area within which the offshore wind turbine generators (WTGs), associated foundations, Offshore Cables, and Offshore Substation Platform (OSP) (if required), will be located. This area encompasses the Turbine Area that will contain all above water surface infrastructure (WTGs/OSP) and an additional area within

Term	Meaning
	which further below water infrastructure (foundations and cables) may also be located.
Offshore Ornithology Study Area	The area over which potentially significant impacts from the Offshore Project have the most potential to occur to ornithological receptors, consisting of the Turbine Area plus a 4 km buffer (excluding land).
Offshore Ornithology Survey Area	The area covered by DAS, consisting of the Array Area plus a 10 km buffer (excluding land).
Offshore Project	The components of the Sporad na Mara offshore wind farm (the Project) located seaward of Mean High Water Springs (MHWS).
Turbine Area	A reduced area within the Array Area where above water surface infrastructure would be located i.e. wind turbine generators (WTG) and Offshore Substation Platform (OSP) (if required). This area has been developed and refined through stakeholder engagement and environmental assessment.

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7 ANNEX 14.3.1: DETERMINISTIC COLLISION RISK ESTIMATES

7.1.1.1 As part of NatureScot guidance (NatureScot, 2025), collision risk models were also to be run deterministically in order for stochastic estimates to be compared and validated. As such, the deterministic estimates for each species under the range of parameters modelled (as outlined in Section 2.3.1) are shown within **Table 7-1** to **Table 7-8**. Modelling was conducted using a random seed of 1234.

Table 7-1: Predicted collisions for kittiwake associated with the Offshore Project under Option 2 of the stochastic collision risk model, with models ran deterministically

Flight speed (m/s)	Avoidance rate (%)	Collision risk estimates												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
13.1	0.9923	7.030	2.619	1.020	0.223	0.544	0.000	0.046	0.000	0.000	2.936	1.678	0.896	16.993
	0.9970	2.739	1.020	0.397	0.087	0.212	0.000	0.018	0.000	0.000	1.144	0.654	0.349	6.621
8.71	0.9923	5.330	1.985	0.773	0.169	0.412	0.000	0.035	0.000	0.000	2.226	1.272	0.679	12.883
	0.9970	2.077	0.774	0.301	0.066	0.161	0.000	0.014	0.000	0.000	0.867	0.496	0.265	5.019

Table 7-2: Predicted collisions for great black-backed gull associated with the Offshore Project under Option 2 of the stochastic collision risk model, with models ran deterministically

Flight speed (m/s)	Avoidance rate (%)	Collision risk estimates													
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total	
13.7	0.9936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.421	0.451	0.872
	0.9991	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.059	0.063	0.123
9.8	0.9936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.349	0.374	0.724
	0.9991	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.049	0.053	0.102

Table 7-3: Predicted collisions for herring gull associated with the Offshore Project under Option 2 of the stochastic collision risk model, with models ran deterministically

Flight speed (m/s)	Avoidance rate (%)	Collision risk estimates													
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total	
13.7	0.9936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.054	0.000	1.054
	0.9952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.791	0.000	0.791
9.8	0.9936	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.900	0.000	0.900
	0.9952	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.675	0.000	0.675

Table 7-4: Predicted collisions for Arctic tern associated with the Offshore Project under Option 2 of the stochastic collision risk model, with models ran deterministically

Flight speed (m/s)	Avoidance rate (%)	Collision risk estimates												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
10.9	0.9902	0.000	0.000	0.000	0.000	0.466	0.041	0.265	0.019	0.000	0.000	0.000	0.000	0.791
	0.9713	0.000	0.000	0.000	0.000	1.365	0.119	0.776	0.055	0.000	0.000	0.000	0.000	2.316

Table 7-5: Predicted collisions for fulmar associated with the Offshore Project under Option 2 of the stochastic collision risk model, with models ran deterministically

Flight speed (m/s)	Avoidance rate (%)	Collision risk estimates												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
13.0	0.9923	0.028	0.019	0.143	0.035	0.037	0.004	0.060	0.025	0.034	0.000	0.010	0.094	0.488
	0.9924	0.028	0.019	0.141	0.034	0.036	0.004	0.059	0.024	0.033	0.000	0.010	0.093	0.482

Table 7-6: Predicted collisions for Manx shearwater associated with the Offshore Project under Option 2 of the stochastic collision risk model, with models ran deterministically

Flight speed (m/s)	Avoidance rate (%)	Collision risk estimates												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
11.46	0.9923	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.9924	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 7-7: Predicted collisions for gannet associated with the Offshore Project with macro-avoidance accounted for under Option 2 of the stochastic collision risk model, with models ran deterministically

Flight speed (m/s)	Avoidance rate (%)	Collision risk estimates												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
14.90	0.9923	0.074	0.000	0.099	1.314	0.869	2.639	3.235	7.486	1.335	0.708	0.032	0.026	17.816
13.33	0.9923	0.070	0.000	0.094	1.244	0.823	2.498	3.063	7.089	1.265	0.670	0.030	0.024	16.869

Table 7-8: Predicted collisions for gannet associated with the Offshore Project assuming a flapping flight type and with no macro-avoidance included within modelling under Option 2 of the stochastic collision risk model, with models ran deterministically

Flight speed (m/s)	Avoidance rate (%)	Collision risk estimates												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
14.90	0.9923	0.252	0.000	0.099	1.314	0.869	2.639	3.235	7.486	1.335	2.359	0.102	0.082	19.772
13.33	0.9923	0.239	0.000	0.094	1.242	0.822	2.496	3.060	7.080	1.263	2.231	0.096	0.078	18.700