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Appendix 11.2: Offshore Ornithology Collision Risk Model Technical Report

Array EIA Report

2024

Revision	Comments	Author	Checker	Approver
FINAL	Final	RPS/NIRAS	RPS/NIRAS	RPS

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For and on behalf of Ossian OWFL	Paul Darnbrough	28 June 2024

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1. INTRODUCTION

1. This appendix presents the Collision Risk Modelling (CRM) processes undertaken for Ossian Offshore Wind Farm Limited (Ossian OWFL) (hereafter referred to as the "Applicant") to inform volume 2, chapter 11, incorporating, where relevant, site-specific data collected over 24 months between March 2021 to February 2023. This appendix includes CRM for regularly occurring seabird species at the Array.

2. BACKGROUND

2.1. OVERVIEW

2. During the operation and maintenance phase of the Array, the turning rotors of the wind turbines may present a risk of collision for seabirds. 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 result in population level impacts. Stationary structures, such as the tower, nacelle or non-operational rotors, are not expected to result in a material risk of collision.

3. Species differ in their susceptibility to collision risk, depending on their flight behaviour, avoidance responses, and the vulnerability of their populations to declines (Garthe and Hüppop, 2004; Furness *et al*., 2018; Furness and Wade, 2012; Wade *et al*., 2016). The structure and operation of the 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 (for example, MacArthur Green (2018) notes that fledging Manx shearwaters *Puffinus puffinus* and puffins *Fratercula arctica* are at potential risk of being attracted to lights), although there is little available evidence to quantify that risk.

4. The significance of collision mortality within an offshore wind farm on any given species of bird varies in response to the size of its population, the density of the population within the wind farm site, background annual mortality rates and estimated rates of avoidance. As a general rule, a single individual lost from a small population will have an increased significance in comparison to a single individual lost from a large population. The loss of an individual bird will also be more significant if it is lost from a species that has a low abundance and/or occurs at low density, is relatively long lived and reproduces at a low rate. The opposite is also true where birds are relatively abundant, have high densities within an area, are short lived and have high reproduction rates, where the impact of collision fatality at the population level can be considered to be of negligible magnitude, due to only causing a slight difference to the baseline conditions.

5. 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 lifespan of the operational wind farm) 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 resident 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.

2.2. COLLISION RISK MODELLING

6. CRM was undertaken using the stochastic Collision Risk Model (sCRM) developed by Marine Scotland (McGregor *et al*., 2018). 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 (or run deterministically). The sCRM can also be run directly in R (R Core Team, 2021) which can enable a greater number of scenarios to be run efficiently, by providing a spreadsheet of all desired input parameters. The user guide for the sCRM Shiny App provided by Marine Scotland (Donovan, 2017) has been followed for the modelling of collision impacts predicted for the Array.

7. The collision risk models incorporated guidance on recommended avoidance rates, bird size, flight speed, flight type and nocturnal activity scores following NatureScot Guidance Note 7 (NatureScot, 2023), alongside other parameter values where deemed appropriate. sCRM parameters therefore followed best available evidence (e.g. Garthe and Hüppop, 2004; Pennycuick, 1997; Gibb *et al*., 2017; Robinson, 2005). All proposed parameters are set out in Table 3.3.

8. The proportion of birds flying at collision risk height was determined using generic flight height data rather than site-specific data. This generic data was taken from Johnston *et al*. (2014). Collision risk models were therefore run using Options 2 and 3 of the sCRM (as explained in section 2.2.1).

2.2.1. SCRM MODEL OPTIONS

9. The Band (2012) model incorporates two approaches to calculating the risk of collision referred to as the 'Basic' and 'Extended' versions of the model. A key difference between these versions is the extent to which flight height patterns of seabirds are accounted (Band, 2012). The distribution of seabird flights across the sea is generally skewed towards lower altitudes. As outlined by Band (2012), there are three consequences of a skewed flight height distribution:

- the proportion of birds flying at risk height decreases as the height of the rotor (i.e. air gap) is increased;
- a greater proportion of birds miss the rotor where flights lie close to the bottom of the rotor swept area; and
- the collision risk, for birds passing through the lower parts of a rotor, is less than the average collision risk for the whole rotor.

10. The Basic model assumes a uniform distribution of flights across the rotor with a consistent risk of collision across the whole rotor swept area. The Extended model of Band (2012) accounts for the distribution of birds in addition to the differential risk across the rotor swept area. It should be noted that the use of the Basic model is precautionary as it does not account for the variability in risk of collision that occurs across a rotor swept area, with the risk of collision decreasing as the distance from the hub of the turbine increases. If this variability were to be taken into account it is likely that collision risk estimates would be lower as the vertical distribution of birds flying across water is skewed towards lower heights (i.e. those associated with a lower risk of collision within a rotor swept area).

11. Both the Basic and Extended models of Band (2012) allow for the use of four 'Options' termed Options 1-4. Options 1 and 2 use the Basic model with Options 3 and 4 utilising the Extended model. The difference between the two Options under each model is linked to the use of flight height data. Options 2 and 3 use generic data from Johnston *et al*. (2014) whereas Options 1 and 4 use site-specific data derived from site-specific surveys. As noted in paragraph 8, Options 2 and 3 were employed for the CRM of the Array.

3. METHODOLOGY

3.1. SPECIES OF CONSIDERATION

12. The process to identify Valued Ornithological Receptors (VORs) that may be affected by impacts associated with the Array is documented in volume 3, appendix 11.1 which includes determining if a species is sensitive to collision (although this is not a determinant of VOR), and considering connectivity to Special Protection Areas (SPAs). VORs that are then taken forward to undergo CRM are those that are:

- known to be vulnerable to collision risk (based on Wade *et al*., 2016; Bradbury *et al*., 2014) (Table 3.1); and
- recorded within the Array offshore ornithology study area with a population that is considered to be of importance, when compared against a relevant population scale thresholds (regional, national or international).

13. Table 3.1 identifies those VORs for which CRM is required based on the above criteria. The following species were selected for collision risk modelling:

- black-legged kittiwake *Rissa tridactyla* (hereafter kittiwake) (high vulnerability, national population importance);
- herring gull *Larus argentatus* (very high vulnerability, local population importance);
- lesser black-backed gull *Larus fuscus* (very high vulnerability, local population importance);
- northern fulmar *Fulmarus glacialis* (hereafter fulmar) (very low vulnerability, local population importance); and
- northern gannet *Morus bassanus* (hereafter gannet) (high vulnerability, local population importance).

Table 3.1: Identification of VORs for Which CRM is Required at the Array

VOR	Vulnerability to Collision Risk Impacts	Uncertainty Level Associated With Vulnerability Rating[1]	Importance of Population at the Array Offshore Ornithology Study Area[2]	CRM Required (Yes/No)
Kittiwake	High	Very Low	National	Yes – high vulnerability, species recorded in nationally important numbers at the Array offshore ornithology study area.
Herring gull	Very High	Very Low	Local	Yes – very high vulnerability, species recorded in locally important numbers at the Array offshore ornithology study area.
Lesser black-backed gull	Very High	Very Low	Local	
Sandwich tern *Sterna sandvicensis*	Very High	Low	Local	No – abundance of this species is not adequately captured by traditional baseline surveys and instead is better suited for migratory CRM.
Little tern *Sternula albifrons*	Moderate	Very High	Negligible	
Common tern *Sterna hirundo*	Moderate	Very Low	Local	
Arctic tern *Sterna paradisaea*	Moderate	Moderate	Negligible	
Great skua *Stercorarius skua*	High	Moderate	Local	
Guillemot *Uria aalge*	Very Low	Low	National	No – very low vulnerability, low - moderate associated uncertainty.
Razorbill *Alca torda*	Very Low	Low	National	
Puffin	Very Low	Moderate	Regional	
European storm petrel *Hydrobates pelagicus*	Low	Very High	Negligible	No – abundance of this species is not adequately captured by traditional baseline surveys and instead is better suited for migratory CRM.
Leach's storm petrel *Hydrobates leucorhous*	Low	Very High	Negligible	
Fulmar	Very Low	Low	Regional	Yes – very low vulnerability, species recorded in regionally important numbers at the Array offshore ornithology study area.
Manx shearwater	Very Low	High	Local	No – very low vulnerability, species recorded in local important numbers at the Array offshore ornithology study area.
Gannet	High	Very Low	Local	Yes – very high vulnerability, species recorded in local important numbers at the Array offshore ornithology study area.

3.2. SPECIES PARAMETERS

14. The sCRM incorporates several parameters relating to the birds and their behaviour, as well as physical parameters relating to the wind turbines, in order to provide a modelled 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 (NAF), which have some of the biggest influences on the predicted magnitude of risk.

15. The species biometric and behavioural parameters to be used for CRM are presented in Table 3.2. The modelling approach has incorporated those parameters recommended by NatureScot (2023) in addition to

[1] Uncertainty levels are taken from Wade *et al*. (2016).

[2] Population importance is based on the geographic scale of the Array offshore ornithology study area populations (i.e., whether it exceeds 1% of the local, regional, national or international population of that species). These population importance levels are set out in volume 3, appendix 11.1.

other values that seek to capture the uncertainty associated with various parameters used for CRM. A discussion on these parameters is provided in section 5. The parameters recommended by NatureScot are highlighted in bold.

Table 3.2: Seabird Parameters Used for CRM[3]. Parameters in Bold are NatureScot's (2023) Advised Values

Parameter	Source	Gannet	Kittiwake	Lesser Black-Backed Gull	Herring Gull	Fulmar[4]
Bird length (m)	Robinson (2005)	**0.94 (±0.0325)**	**0.39 (±0.005)**	**0.58 (±0.03)**	**0.60 (±0.0225)**	0.45 (±0.025)
Wingspan (m)	Robinson (2005)	**1.72 (±0.0375)**	**1.08 (±0.0625)**	**1.42 (±0.0375)**	**1.44 (±0.03)**	1.07 (±0.025)
Flight speed (m/s)	Alerstam *et al.* (2007)	-	**13.1 (±0.40)**	**13.1 (±1.90)**	**12.8 (±1.80)**	-
	Pennycuick (1987)	**14.9 (±0.00)**	-	-	-	13.0 (±0.00)
	Skov *et al.*, (2018) (Standard Deviation (SD))	13.33 (4.24)	8.71 (3.16)	9.8 (3.63)	9.8 (3.63)	-
NAF	Wade *et al.* (2016)	**0.08 (±0.10)** (4-8%)	0.375 (±0.0637) **(25-50%)**	0.375 (±0.0637) **(25-50%)**	0.375 (±0.0637) **(25-50%)**	0.75 (±0.00)
Flight type	NatureScot (2023)	**Gliding**	**Flapping**	**Flapping**	**Flapping**	Gliding
Proportion of flights upwind (%)	NatureScot (2023)	**50**	**50**	**50**	**50**	50
Avoidance rate (Basic model) (%)	Ozsanlav-Harris *et al.* (2023) (species-specific rate)	N/A	0.9979 (±0.0013)	0.9954 (±0.0003)	0.9952 (±0.0003)	-
	Ozsanlav-Harris *et al.* (2023) (all gull rate)	**0.9928 (±0.0003)**	**0.9928 (±0.0003)**	-	-	0.9928 (±0.0003)
	Ozsanlav-Harris *et al.* (2023) (large gull rate)	-	-	**0.9939 (±0.0004)**	**0.9939 (±0.0004)**	-
	Bowgen and Cook (2018)	-	0.994 (0.976-0.998)	0.997 (0.992-0.999)	0.997 (0.992-0.999)	-
Avoidance rate (Extended model) (%)	Ozsanlav-Harris *et al.* (2023) (species-specific rate)	N/A	0.9947 (±0.1295)	0.981 (±0.0022)	0.9504 (±0.0085)	-
	Ozsanlav-Harris *et al.* (2023) (all gull rate)	0.9258 (±0.0067)	-	-	-	0.9928 (±0.0003)
	Bowgen and Cook (2018)	-	0.980 (0.871-0.989)	0.990 (0.974-0.995)	0.990 (0.974-0.995)	-

16. Generic flight height distributions published by Johnston *et al*. (2014) were used in sCRM for the Array following standard practice.

3.3. DESIGN AND WIND TURBINE PARAMETERS

17. The Maximum Design Scenario (MDS) parameters for wind turbines required for CRM are presented in Table 3.3. The large array correction feature of the sCRM was not applied at this stage. This is an adjustment to the probability of bird collision to account for the depletion of bird density in later rows of a wind farm with a large array of wind turbines, and therefore, if applied it would be expected to very slightly decrease collision estimates.

Table 3.3: Wind Farm and Wind Turbine Parameters Used for CRM

Parameter	Parameter Value
Wind Farm	
Latitude	56.7°
Maximum number of wind turbines	265
Tidal offset (m) (Mean Sea Level (MSL))	1.8
Wind Turbine	
Number of rotor blades per wind turbine	3
Maximum chord width (m)	6.7
Average blade pitch (degrees)	10
Maximum rotor radius (m)	118
Maximum rotor speed (rpm)	8.4
Lower blade tip height above Highest Astronomical Tide (HAT) (m)	32.3
Minimum air gap at Lowest Astronomical Tide (LAT) (m)	36

[3] The number of decimal places given for values in Table 3.2 is determined by the source of the data.

[4] No recommended parameters are provided for fulmar in NatureScot (2023)

18. sCRM also requires information relating to the monthly proportion of time that wind turbines will be operational, taking into account maintenance activities and wind availability. Table 3.4 sets out the maximum proportions of time that wind turbines will be operational for each month of the year.

Table 3.4: Monthly Proportion of Time Wind Turbines at the Array will be Operational

Month	Wind Availability (%)	Mean Downtime (%)	Standard Deviation (SD) Downtime (%)
January	95	3	2
February	95	3	2
March	95	3	2
April	95	3	2
May	95	3	2
June	95	3	2
July	95	3	2
August	95	3	2
September	95	3	2
October	95	3	2
November	95	3	2
December	95	3	2

3.4. DENSITY ESTIMATES

19. Site-specific data have been collected over a DAS programme of 24 months between March 2021 to February 2023, encompassing the Array offshore ornithology survey area (as described in volume 3, appendix 11.1). Further information on the DAS undertaken for the Array and the methodologies used to derive population estimates is provided in volume 3, appendix 11.1.

20. Model-based estimates using the Marine Renewables Strategic environmental assessment (MRSea) package were produced in order to predict numbers across the Array alongside 95% confidence intervals to provide a level of uncertainty (refer to volume 3, appendix 11.4). Design-based estimates for bird numbers and densities in each month were also generated and compared to the MRSea estimates to provide additional validation of the MRSea outputs and provide estimates for months where low raw abundances prevented the use of the MRSea model. Where MRSea based densities were available those were used, and otherwise design-based densities were used, with MRSea being prioritised over design-based whenever available.

21. Densities of birds in flight were generated by multiplying the densities of all behaviours within the Array (generated from MRSea or design-based) 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 Array offshore ornithology survey area using the raw data. The proportion was calculated across the Array offshore ornithology survey area rather than just the Array to ensure the sample size was sufficient to generate a robust estimate of the proportion of birds in flight.

22. For example, if MRSea generated a density of ten kittiwake per km^2 in the Array for all behaviours, and there was a total of 2,000 kittiwake in the raw data for the Array offshore ornithology survey area, 600 of which were in flight, then the density of flying birds in the Array would then be calculated as (600 / 2,000 * 10 =) three kittiwake per km^2.

23. There were two density estimates for each calendar month due to the DAS covering two years of monthly samples. For running the sCRM, 1,000 bootstrapped density values were generated for each month using a mix of MRSea and design-based outputs. Under the assumption that overdispersion does not vary much among years, each of the two 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 monthly density estimates are shown in Table 3.5.

24. Table 4.1 to Table 4.10 show the expected number of collisions for each species, per month and per season for sCRM. Both monthly and seasonal values are taken from the combined two years of DAS data. Annex A shows the deterministic CRM expected number of collisions for each species, per month and per season.

Table 3.5: Density Estimates Used for CRM (MRSea-Based Where Available; Otherwise Design-Based)

Species		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kittiwake	**Mean**	0.045	0.095	0.272	0.043	0.966	0.368	0.282	0.029	0.035	0.055	0.245	0.085
	LCL	0.005	0.048	0.102	0.017	0.726	0.253	0.189	0.004	0.000	0.010	0.111	0.040
	UCL	0.100	0.141	0.589	0.091	1.294	0.507	0.431	0.065	0.090	0.105	0.470	0.145
Herring gull	**Mean**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.000
	LCL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	UCL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.015	0.000
Lesser black-backed gull	**Mean**	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	LCL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	UCL	0.000	0.000	0.000	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gannet	**Mean**	0.000	0.005	0.015	0.239	0.426	0.222	0.458	0.096	0.150	0.292	0.015	0.005
	LCL	0.000	0.000	0.002	0.106	0.305	0.155	0.551	0.060	0.086	0.179	0.000	0.000
	UCL	0.000	0.015	0.046	0.577	0.568	0.300	0.382	0.149	0.259	0.455	0.045	0.020
Fulmar	**Mean**	0.134	0.137	0.005	0.037	0.054	0.303	0.216	0.099	0.114	0.010	0.172	0.460
	LCL	0.079	0.084	0.000	0.020	0.022	0.203	0.095	0.040	0.061	0.000	0.127	0.366
	UCL	0.204	0.214	0.015	0.060	0.109	0.434	0.509	0.188	0.195	0.030	0.230	0.597

4. RESULTS

4.1. KITTIWAKE

25. The monthly expected number of collisions for kittiwake are presented in Table 4.1, and the expected number of collisions per season for kittiwake are presented in Table 4.2.

Table 4.1: Kittiwake Expected Collisions from sCRMs Across Months, Including SD. Results in Bold Reflect NatureScot's Guidance Parameters

Model Option	Avoidance Rate (out of 1.000)	Flight Speed (m/s)	sCRM Output	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Option 2	0.998	13.1	Expected collisions	0.15	0.30	1.17	0.19	4.47	1.71	1.36	0.13	0.15	0.21	0.85	0.27	10.94
			SD	0.13	0.18	0.86	0.13	2.49	0.94	0.81	0.11	0.14	0.16	0.59	0.17	6.72
Option 2	0.998	8.71	Expected collisions	0.13	0.25	0.98	0.16	3.74	1.44	1.14	0.11	0.13	0.17	0.71	0.23	9.19
			SD	0.12	0.17	0.77	0.12	2.31	0.89	0.73	0.10	0.13	0.15	0.54	0.17	6.19
Option 2	**0.993**	**13.1**	**Expected collisions**	**0.56**	**1.09**	**4.25**	**0.68**	**16.17**	**6.22**	**4.91**	**0.49**	**0.56**	**0.74**	**3.06**	**0.99**	**39.72**
			SD	**0.34**	**0.37**	**2.14**	**0.34**	**3.98**	**1.65**	**1.46**	**0.30**	**0.39**	**0.40**	**1.38**	**0.40**	**13.15**
Option 2	0.993	8.71	Expected collisions	0.46	0.91	3.52	0.57	13.41	5.16	4.07	0.40	0.46	0.62	2.55	0.82	32.95
			SD	0.30	0.33	1.85	0.30	3.74	1.53	1.32	0.25	0.34	0.34	1.24	0.34	11.88
Option 2	0.994	13.1	Expected collisions	0.50	0.99	3.88	0.60	14.36	5.59	4.43	0.44	0.50	0.65	2.74	0.90	35.60
			SD	0.65	1.07	4.52	0.71	14.47	5.67	4.60	0.56	0.63	0.75	3.06	1.02	37.73
Option 2	0.993	8.71	Expected collisions	0.41	0.81	3.24	0.51	11.97	4.61	3.66	0.37	0.42	0.56	2.30	0.72	29.58
			SD	0.57	0.91	4.47	0.63	12.51	4.92	4.04	0.53	0.61	0.70	2.74	0.80	33.42
Option 3	0.995	13.1	Expected collisions	0.07	0.15	0.61	0.09	2.22	0.84	0.66	0.07	0.08	0.10	0.40	0.13	5.42
			SD	0.20	0.42	2.02	0.23	6.15	2.35	1.76	0.21	0.24	0.32	1.16	0.35	15.43
Option 3	0.995	8.71	Expected collisions	0.08	0.15	0.59	0.10	2.21	0.85	0.67	0.06	0.07	0.11	0.42	0.14	5.44
			SD	0.22	0.43	1.75	0.29	5.87	2.20	1.76	0.20	0.21	0.36	1.30	0.42	15.00
Option 3	0.980	13.1	Expected collisions	0.03	0.05	0.21	0.03	0.82	0.31	0.25	0.02	0.03	0.04	0.15	0.05	2.00
			SD	0.02	0.03	0.16	0.02	0.47	0.18	0.15	0.02	0.03	0.03	0.11	0.03	1.26
Option 3	0.980	8.71	Expected collisions	0.03	0.06	0.22	0.03	0.82	0.32	0.25	0.02	0.03	0.04	0.16	0.05	2.01
			SD	0.03	0.04	0.17	0.03	0.50	0.19	0.16	0.02	0.03	0.03	0.12	0.04	1.34

Table 4.2: Kittiwake Expected Collisions from sCRMs Across Seasons[5], Including SD. Results in Bold Reflect NatureScot's Guidance Parameters

Model Option	Avoidance Rate (out of 1.000)	Flight Speed (m/s)	sCRM Output	Pre-Breeding (Jan – mid-Apr)	Breeding (mid-Apr – Aug)	Post-Breeding (Sep – Dec)	Total
Option 2	0.998	13.1	Expected collisions	1.72	7.75	1.47	10.94
			SD	1.23	4.43	1.07	6.72
Option 2	0.998	8.71	Expected collisions	1.44	6.51	1.24	9.19
			SD	1.11	4.09	0.99	6.19
Option 2	**0.993**	**13.1**	**Expected collisions**	**6.24**	**28.13**	**5.35**	**39.72**
			SD	**3.03**	**7.56**	**2.57**	**13.15**
Option 2	0.993	8.71	Expected collisions	5.17	23.33	4.45	32.95
			SD	2.63	7.00	2.25	11.88
Option 2	0.994	13.1	Expected collisions	5.67	25.14	4.79	35.60
			SD	6.60	25.66	5.46	37.73
Option 2	0.993	8.71	Expected collisions	4.72	20.86	4.00	29.58
			SD	6.26	22.31	4.84	33.42
Option 3	0.995	13.1	Expected collisions	0.87	3.83	0.72	5.42
			SD	2.76	10.59	2.08	15.43
Option 3	0.995	8.71	Expected collisions	0.86	3.84	0.74	5.44
			SD	2.53	10.18	2.29	15.00
Option 3	0.980	13.1	Expected collisions	0.31	1.42	0.27	2.00
			SD	0.23	0.84	0.20	1.26
Option 3	0.980	8.71	Expected collisions	0.32	1.43	0.27	2.01
			SD	0.24	0.88	0.21	1.34

[5] Seasons are set out in volume 3, appendix 11.1.

4.2. HERRING GULL

26. The monthly expected number of collisions for herring gull are presented in Table 4.3, and the expected number of collisions per season for herring gull are presented in Table 4.4.

Table 4.3: Herring Gull Expected Collisions from sCRMs Across Months, Including SD. Results in Bold Reflect NatureScot's Guidance Parameters

Model Option	Avoidance Rate (out of 1.000)	Flight Speed (m/s)	sCRM Output	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Option 2	0.995	12.8	Expected collisions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.21
			SD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.17
Option 2	0.995	9.8	Expected collisions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.19
			SD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.17
Option 2	**0.994**	**12.8**	**Expected collisions**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.25**	**0.00**	**0.25**
			SD	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.20**	**0.00**	**0.20**
Option 2	0.994	9.8	Expected collisions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.23
			SD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.19
Option 2	0.997	12.8	Expected collisions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.12
			SD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.14
Option 2	0.997	9.8	Expected collisions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.11
			SD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.14
Option 3	0.950	12.8	Expected collisions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.71
			SD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.65
Option 3	0.950	9.8	Expected collisions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.71
			SD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.64
Option 3	0.990	9.8	Expected collisions	9.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00
			SD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.12
Option 3	0.990	12.8	Expected collisions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.14
			SD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.12

Table 4.4: Herring Gull Expected Collisions from sCRMs Across Seasons, Including SD. Results in Bold Reflect NatureScot's Guidance Parameters

Model Option	Avoidance Rate (out of 1.000)	Flight Speed (m/s)	sCRM Output	Breeding (Apr – Aug)	Non-Breeding (Sep – Mar)	Total
Option 2	0.995	12.8	Expected collisions	0.00	2.24	2.24
			SD	0.00	1.18	1.18
Option 2	0.995	9.8	Expected collisions	0.00	2.03	2.03
			SD	0.00	1.12	1.12
Option 2	**0.994**	**12.8**	**Expected collisions**	**0.00**	**2.74**	**2.74**
			SD	**0.00**	**1.37**	**1.37**
Option 2	0.994	9.8	Expected collisions	0.00	2.45	2.45
			SD	0.00	1.26	1.26
Option 2	0.997	12.8	Expected collisions	0.00	1.33	1.33
			SD	0.00	1.19	1.19
Option 2	0.997	9.8	Expected collisions	0.00	1.20	1.20
			SD	0.00	1.12	1.12
Option 3	0.950	12.8	Expected collisions	0.00	7.53	7.53
			SD	0.00	4.34	4.34
Option 3	0.950	9.8	Expected collisions	0.00	7.38	7.38
			SD	0.00	4.28	4.28
Option 3	0.990	9.8	Expected collisions	0.00	1.53	1.53
			SD	0.00	0.84	0.84
Option 3	0.990	12.8	Expected collisions	0.00	1.50	1.50
			SD	0.00	0.81	0.81

4.3. LESSER BLACK-BACKED GULL

27. The monthly expected number of collisions for lesser black-backed gull are presented in Table 4.5, and the expected number of collisions per season for lesser black-backed gull are presented in Table 4.6.

Table 4.5: Lesser Black-Backed Gull Expected Collisions from sCRMs Across Months, Including SD. Results in Bold Reflect NatureScot's Guidance Parameters

Model Option	Avoidance Rate (out of 1.000)	Flight Speed (m/s)	sCRM Output	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Option 2	0.995	13.1	Expected collisions	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21
			SD	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19
Option 2	0.995	9.8	Expected collisions	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19
			SD	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
Option 2	**0.994**	**13.1**	**Expected collisions**	**0.00**	**0.00**	**0.00**	**0.26**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.26**
			SD	**0.00**	**0.00**	**0.00**	**0.23**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.23**
Option 2	0.994	9.8	Expected collisions	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23
			SD	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21
Option 2	0.997	13.1	Expected collisions	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12
			SD	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
Option 2	0.997	9.8	Expected collisions	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
			SD	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
Option 3	0.981	13.1	Expected collisions	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25
			SD	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25
Option 3	0.981	9.8	Expected collisions	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24
			SD	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24
Option 3	0.990	13.1	Expected collisions	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
			SD	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16
Option 3	0.990	9.8	Expected collisions	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
			SD	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15

Table 4.6: Lesser Black-Backed Gull Expected Collisions from sCRMs Across Seasons, Including SD. Results in Bold Reflect NatureScot's Guidance Parameters

Model Option	Avoidance Rate (out of 1.000)	Flight Speed (m/s)	sCRM Output	Breeding (mid-Mar – Aug)	Post-Breeding (Sep – Oct)	Non-Breeding (Nov – mid-Mar)	Total
Option 2	0.995	13.1	Expected collisions	0.21	0.00	0.00	0.21
			SD	0.19	0.00	0.00	0.19
Option 2	0.995	9.8	Expected collisions	0.19	0.00	0.00	0.19
			SD	0.17	0.00	0.00	0.17
Option 2	**0.994**	**13.1**	**Expected collisions**	**0.26**	**0.00**	**0.00**	**0.26**
			SD	**0.23**	**0.00**	**0.00**	**0.23**
Option 2	0.994	9.8	Expected collisions	0.23	0.00	0.00	0.23
			SD	0.21	0.00	0.00	0.21
Option 2	0.997	13.1	Expected collisions	0.12	0.00	0.00	0.12
			SD	0.14	0.00	0.00	0.14
Option 2	0.997	9.8	Expected collisions	0.11	0.00	0.00	0.11
			SD	0.14	0.00	0.00	0.14
Option 3	0.981	13.1	Expected collisions	0.25	0.00	0.00	0.25
			SD	0.25	0.00	0.00	0.25
Option 3	0.981	9.8	Expected collisions	0.24	0.00	0.00	0.24
			SD	0.24	0.00	0.00	0.24
Option 3	0.990	13.1	Expected collisions	0.14	0.00	0.00	0.14
			SD	0.16	0.00	0.00	0.16
Option 3	0.990	9.8	Expected collisions	0.14	0.00	0.00	0.14
			SD	0.15	0.00	0.00	0.15

4.4. GANNET

28. The monthly expected number of collisions for gannet are presented in Table 4.7, and the expected number of collisions per season for gannet are presented in Table 4.8.

Table 4.7: Gannet Expected Collisions from sCRMs Across Months, Including SD. Results in Bold Reflect NatureScot's Guidance Parameters

Model Option	Avoidance Rate (out of 1.000)	Flight Speed (m/s)	sCRM Output	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Option 2	**0.993**	**14.9**	**Expected collisions**	**0.00**	**0.06**	**0.24**	**4.25**	**7.55**	**4.07**	**8.37**	**1.62**	**2.20**	**3.60**	**0.17**	**0.06**	**32.18**
			SD	**0.00**	**0.06**	**0.24**	**3.41**	**4.42**	**2.39**	**4.72**	**1.02**	**1.44**	**2.28**	**0.18**	**0.07**	**20.24**
Option 2	0.993	13.33	Expected collisions	0.00	0.06	0.23	3.99	7.45	3.93	8.15	1.56	2.11	3.45	0.16	0.06	31.14
			SD	0.00	0.06	0.23	3.25	4.40	2.30	4.63	0.99	1.40	2.24	0.16	0.07	19.74
Option 3	0.953	14.9	Expected collisions	0.00	0.09	0.38	6.52	11.77	6.38	13.05	2.54	3.42	5.63	0.26	0.09	50.12
			SD	0.00	0.10	0.40	5.74	8.11	4.48	8.80	1.88	2.60	4.24	0.29	0.12	36.75
Option 3	0.953	13.33	Expected collisions	0.00	0.10	0.37	6.49	12.20	6.47	13.39	2.55	3.51	5.69	0.27	0.09	51.12
			SD	0.00	0.10	0.40	5.63	8.24	4.43	8.96	1.80	2.69	4.15	0.31	0.12	36.84

Table 4.8: Gannet Expected Collisions from sCRMs Across Seasons, Including SD. Results in Bold Reflect NatureScot's Guidance Parameters

Model Option	Avoidance Rate (out of 1.000)	Flight Speed (m/s)	sCRM Output	Breeding (mid-Mar – Sep)	Post-Breeding (Oct – Nov)	Pre-Breeding (Dec – mid-Mar)	Total
Option 2	**0.993**	**14.9**	**Expected collisions**	**28.18**	**3.76**	**0.24**	**32.18**
			SD	**17.53**	**2.46**	**0.25**	**20.24**
Option 2	0.993	13.33	Expected collisions	27.30	3.61	0.23	31.14
			SD	17.09	2.41	0.25	19.74
Option 3	0.953	14.9	Expected collisions	43.86	5.89	0.37	50.12
			SD	31.80	4.53	0.42	36.75
Option 3	0.953	13.33	Expected collisions	44.79	5.96	0.37	51.12
			SD	31.95	4.46	0.43	36.84

4.5. FULMAR

29. The monthly expected number of collisions for fulmar are presented in Table 4.9, and the expected number of collisions per season for fulmar are presented in Table 4.10.

Table 4.9: Fulmar Expected Collisions from sCRMs Across Months, Including SD

Model Option	Avoidance Rate (out of 1.000)	Flight Speed (m/s)	sCRM Output	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Option 2	0.99	13.0	Expected collisions	0.37	0.34	0.02	0.10	0.16	0.80	0.64	0.27	0.31	0.03	0.46	1.25	4.77
			SD	0.61	0.56	0.03	0.16	0.28	1.29	1.14	0.46	0.52	0.07	0.73	1.97	7.81
Option 3	0.99	13.0	Expected collisions	0.05	0.05	0.00	0.01	0.02	0.12	0.09	0.04	0.05	0.00	0.07	0.18	0.69
			SD	0.09	0.09	0.00	0.03	0.04	0.20	0.18	0.07	0.08	0.01	0.11	0.31	1.21

Table 4.10: Fulmar Expected Collisions from sCRMs Across Seasons, Including SD

Model Option	Avoidance Rate (out of 1.000)	Flight Speed (m/s)	sCRM Output	Breeding (Apr – mid-Sep)	Post-Breeding (mid-Sep – Oct)	Non-Breeding (Nov)	Pre-Breeding (Dec – Mar)	Total
Option 2	0.99	13.0	Expected collisions	2.13	0.19	0.46	1.99	4.77
			SD	3.59	0.33	0.73	3.17	7.81
Option 3	0.99	13.0	Expected collisions	0.31	0.03	0.07	0.29	0.69
			SD	0.56	0.05	0.11	0.49	1.21

5. DISCUSSION OF PARAMETER DEVIATIONS FROM GUIDELINES

30. This section sets out justifications for deviations from Statutory Nature Conservation Bodies (SNCB) advice, for the flight speed and avoidance rate parameters that were applied to each species undergoing CRM.

5.1. FLIGHT SPEEDS

31. For the species that have been identified for inclusion in CRM, with the exception of Manx shearwater, there are two different sources for bird flight speed. The first source being the flight speeds used by Cook *et al.* (2014), which were extracted either from Alerstam *et al.* (2007) or Pennycuick (1987) depending on the species. The second source being the flight speeds reported in Skov *et al.* (2018).

32. Alerstam *et al.* (2007) provides flight speed data 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.

33. Pennycuick (1987) provides flight speed data estimated using an ornithodolite[6]. 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).

34. 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.

35. A comparison of each of these sources for each species is provided in Table 5.1 in relation to sample size, location of studies, seasonality and location. The following sections discuss this information for each species.

[6] A bespoke device for measuring and recording the azimuth, elevation and range of birds in flight – for more details see Pennycuick (1987) and references therein.

Table 5.1: 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 (large gulls combined)
	Herring gull	18 tracks	
	Lesser black-backed gull	11 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	
	Herring gull	Two tracks in the northeast Passage. Other tracks in Sweden and the Arctic	
	Lesser black-backed gull	Sweden and the Arctic	
	Gannet	Pennycuick: 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	
	Herring gull	July and August 1994 (Alerstam and Gudmundsson, 1999)	
	Lesser black-backed gull	Mainly during the autumn (August to October) and spring (March to May) migration periods and also some in the winter (November and February). Migratory flights	
	Gannet	Pennycuick: 28 June to 09 July 1986	

5.1.1. KITTIWAKE

36. 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, during 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 were collected at the Thanet Offshore Wind Farm located 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 data points for kittiwake presented in Figure 5.1. 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 data points. However, there are still more data points in both the migration-free and full UK breeding season than in the Alerstam *et al.* (2007) study.

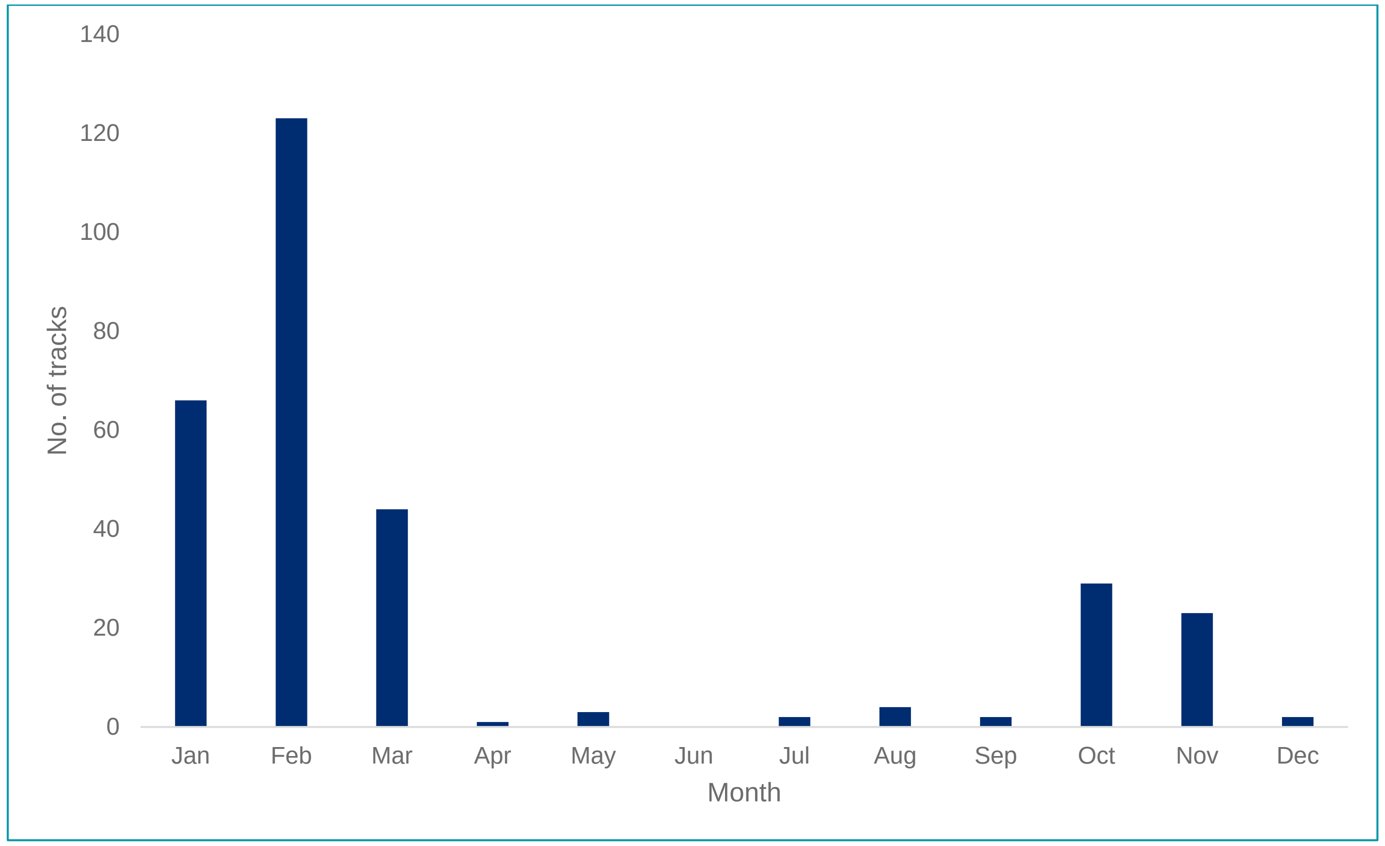

Figure 5.1: Number of Kittiwake Tracks in Each Month from Skov *et al.* (2018)

37. 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.

38. 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.

39. 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).

40. 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 Array will be 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 CRM.

5.1.2. HERRING GULL

41. 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 one standard deviation; Woodward *et al.*, 2019) from a number of breeding colonies, including one of considerable significance for the species (Havergate Island).

42. Fieldwork associated with Skov *et al.* (2018) was conducted across two years with the monthly distribution of data points for all three large gulls (both individually and combined) presented in Figure 5.2 The herring gull breeding season runs from March to August (full UK breeding season) with a migration-free breeding season running from May to July. There are therefore data points across all seasons relevant to herring gull.

43. 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 Array will be 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 herring gull due to the limited sample size and restricted seasonal coverage and it is therefore considered that it should not be used for CRM.

5.1.3. LESSER BLACK-BACKED GULL

44. 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 11 tracks for lesser black-backed 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 lesser black-backed gull was collected from birds observed in Sweden and the Arctic, presumably in the breeding season, based on the migratory movements of lesser black-backed gull, although this is not stated in Alerstam *et al.* (2007). The Skov *et al.* (2018) dataset was collected at the Thanet Offshore Wind Farm which is within the foraging range of

lesser black-backed gull (mean-maximum; Woodward *et al.*, 2019) from a number of breeding colonies, including one of considerable significance for the species (Havergate Island).

45. Fieldwork associated with Skov *et al.* (2018) was conducted across two years with the monthly distribution of data points for all three large gulls (both individually and combined) presented in Figure 5.2. The lesser black-backed gull breeding season runs from April to August (full UK breeding season) with a migration-free breeding season running from May to July. There are therefore data points across all seasons relevant to lesser black-backed gull, with fewer in winter months due many birds leaving UK waters, and more data in the breeding season compared to the Alerstam *et al.* (2007) study.

46. Based on the evidence presented above it is considered that the best available evidence in relation to flight speed for lesser 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 Array will be 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 lesser 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 CRM.

Figure 5.2: Number of Large Gull Tracks in Each Month from Skov *et al.* (2018)

47. Another study that investigated flight speeds of lesser black-backed gull was by Klaassen *et al.* (2012), which provides a flight speed on 10.7m/s. Eight birds were fitted with GPS transmitters with data available between 31 May 2007 and 1 June 2008, with a focus on migratory periods. The flight speed value estimated by Klaassen *et al.* (2012), is closer to that estimated by Skov *et al.* (2018) than the value estimated by Alerstam *et al.* (2007) and is also considered to be supported by more robust data than the flight speed estimated by Alerstam *et al.* (2007).

5.1.4. GANNET

48. 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 Appraisal (HRA) 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 data points for gannet presented in Figure 5.3. 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 data points across all seasons relevant to gannet with more in the breeding season than in the Pennycuick (1987) study.

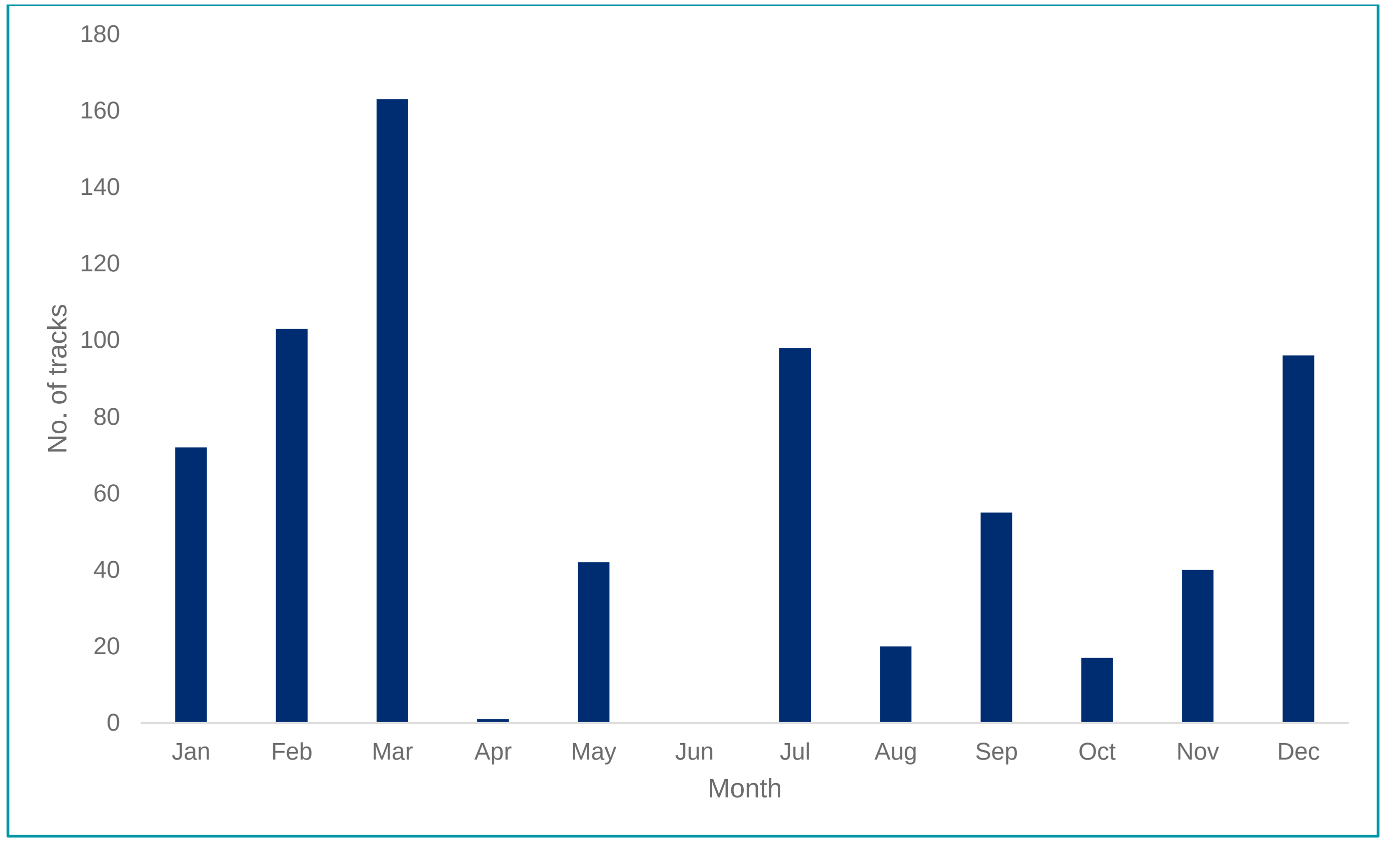

Figure 5.3: Number of Gannet Tracks in Each Month from Skov *et al.* (2018)

49. 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).

50. 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 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 Array will be 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 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 CRM.

5.1.5. OTHER CONSIDERATIONS

51. A sample size of 100 birds is considered adequate to provide a representative value for use in CRM for the proportion of birds at collision height (Natural England, 2013; Johnston *et al.*, 2014). 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 speed from Skov *et al.* (2018) would reach this threshold and be considered representative of flight speed behaviour.

5.1.6. CONCLUSION

52. In order to ensure assessments are presented that align with SNCBs' 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 CRM 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 Array. Any assessments based on these values will therefore have a high level of associated uncertainty.

5.2. AVOIDANCE RATES

53. The most recent review of avoidance rates for use in the Band (2012) CRM and the McGregor *et al.* 2018 sCRM is provided by Ozsanlav-Harris *et al.* (2023). The avoidance rates associated with this review are provided in Table 3.2, and align with NatureScot guidance (Appendix 1 of Guidance Note 7 (NatureScot, 2023)). Ozsanlav-Harris *et al.* (2023) identifies a key limitation in relation to the use of the Basic and Extended models of the Band (2012) CRM:

- Data used are primarily collected at onshore and coastal sites with very little offshore data. The flight height of birds differs between site-specific onshore data and offshore flight height data. As the data used in the report is primarily from onshore wind farms this leads to an under-estimation in avoidance rates for the Extended model and therefore it is recommended that the Basic model of the Band (2012) CRM is used.

54. The avoidance rates presented in Ozsanlav-Harris *et al.* (2023) will therefore over-estimate collision risk. To provide collision risk estimates calculated using the Extended model that are not over-estimates, the avoidance rates from Bowgen and Cook (2018) are also presented in Table 3.2. Bowgen and Cook (2018) used data from the ORJIP BCA study (Skov *et al.*, 2018) and therefore represent avoidance rates calculated using data in the offshore environment only. Limitations are highlighted with these avoidance rates. However, these create no more uncertainty than that associated with the avoidance rates from other studies. Assessments presented in the volume 2, chapter 11 will therefore take due account of all available evidence to determine the magnitude of effect for relevant species at the Array.

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ANNEX A: DESTERMINISTIC COLLISION RISK MODEL ESTIMATES

55. Please find Annex A attached to this document separately.

ANNEX B: MIGRATORY BIRD COLLISION RISK MODELLING TECHNICAL REPORT

56. Please find Annex B attached to this document separately.

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