Offshore Environmental Impact Assessment Report
Volume 3, Appendix 12.3: Offshore Ornithology Collision Risk Modelling

MarramWind Offshore Wind Farm

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MarramWind

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Checked by:	WSP UK Limited
Approved by:	MarramWind Limited

Contents

1. Introduction

1.1 Project background

1.1.1.1 This Appendix presents the findings of a study of intertidal and offshore ornithology features that characterise the area that may be influenced by the MarramWind Offshore Wind Farm (hereafter, referred to as ‘the Project’). This Appendix specifically relates to the potential for birds in flight to collide with offshore Project infrastructure in the marine environment.

1.1.1.2 A separate report (**Appendix 12.1: Offshore and Intertidal Ornithology Baseline Report**) provides the baseline characterisation of the OAA through the data obtained from digital aerial surveys (DAS). This collision risk modelling (CRM) technical Appendix has been produced to support **Volume 1, Chapter 12: Offshore and Intertidal Ornithology**.

1.2 Collision risk modelling

1.2.1.1 There is the potential for seabirds flying through the OAA to collide with rotating blade of the turbines and any associated infrastructure, which may result in mortality (Drewitt and Langston, 2006; Skov *et al*., 2018; Ozszanlav-Harris *et al*., 2023). This potential risk of collision can be modelled in order to provide an estimate of the number of collisions predicted for key seabird species.

1.2.1.2 On review of the 24 months of site-specific DAS data, six key seabird species have been identified for which potential collision risk should be considered in relation to the Project. This is based on their predicted density and frequency of records across the 24 months of DAS (**Appendix 12.1**), combined with the species perceived risk of collision (Bradbury *et al*., 2014; Oszanlav-Harris *et al*., 2023; NatureScot, 2025). The species being considered are as follows:

- kittiwake (*Rissa tridactyla*);
- great black-backed gull (*Larus marinus*);
- herring gull (*Larus argentatus*);
- lesser black-backed gull (*Larus fuscus*);
- great skua (*Stercorarius skua*); and
- gannet (*Morus bassanus*).

1.2.1.3 To note, migratory collision risk has also been modelled for seabirds, waders, passerines, raptors and wildfowl that may intersect the OAA whilst undertaking annual migratory movements, with detailed methods and results presented separately in **Appendix 12.6: Ornithology Migratory Collision Risk Modelling**.

2. Methods

2.1 Guidance and models

2.1.1.1 CRM was undertaken using the latest stochastic Collision Risk Modelling (sCRM) tool, which was developed by Marine Scotland (Caneco and Humphries, 2022). This tool is recommended within the latest NatureScot CRM guidance (NatureScot, 2024) and has been agreed as appropriate through consultation with NatureScot as evidenced in Table 12.1 in **Volume 1, Chapter 12: Offshore and Intertidal Ornithology**. The Band (2012) offshore CRM model is the basis upon which the sCRM is built and incorporates variation and/ or statistical uncertainty around the parameters used for the calculation of collision frequency. The stochastic CRM (sCRM) was accessed via the 'Shiny App' interface, which is a user-friendly graphical user interface accessible via a standard web-browser that uses a stochLAB R package to estimate collision risk. The advantages of using the 'Shiny App' are that users are not required to use any R code, are not required to install or maintain R, updates to the model are made directly to the server so are immediately programmed to users, and it is publicly available and free to access. The sCRM provides a clear and transparent audit trail for all modelling runs, which enables regulators to easily assess and reproduce the results of any modelling scenario.

2.1.1.2 As per the Band (2012) model, the sCRM can generate collision estimates by two different methods (basic and extended models), each of which have two different options. The basic model assumes a uniform flight height distribution across the rotor swept heights, whilst the extended model uses species-specific modelled flight height distributions to account for variation in the distribution of flights across the rotor swept heights (Band, 2012; Johnston *et al*., 2014a, b). Seabird flight height distributions tend to be skewed towards the lower rotor swept heights, where collision risk is lower (Band, 2012). For most species the extended model results in a lower collision estimates than the basic for a given avoidance rate and set of wind farm parameters.

2.1.1.3 Each of the basic and extended models can be run using either site-specific flight height data (i.e. as collected from the OAA in question) or generic flight height data, which is derived from pre-construction surveys for wind farm developments at 32 sites in the UK and elsewhere in Europe (Johnston *et al*., 2014a, b). This gives rise to 'Band Option 1' (site-specific flight height data) and 'Band Option 2' (generic flight height data) for the basic model, and 'Band Option 3' (generic flight height data) and 'Band Option 4' (site-specific flight height data) for the extended model (Band, 2012).

2.1.1.4 NatureScot's Guidance Note 7 (NatureScot, 2025) does not recommend the use of extended models for CRM (Band Option 3 and 4). For the Project, no site-specific flight heights were collected using a method that NatureScot agrees as appropriate to inform Band Option 1 outputs (see Table 12.1 in **Volume 1, Chapter 12: Offshore and Intertidal Ornithology**), therefore only Band Option 2 is considered within this Appendix.

2.1.1.5 CRM can also be conducted either stochastically, by incorporating variability into input parameters and quantifying uncertainty in the resulting outputs, or deterministically, using fixed input values without accounting for uncertainty. As per NatureScot's Guidance Note 7 (2025), both options are run and presented in this Appendix.

2.2 Seasons used in impact assessments

2.2.1.1 Seasonal periods taken forward for CRM impact assessment are presented in **Table 2.1**. The seasons described in the NatureScot's Guidance Note 9 (NatureScot, 2020) are used for all species.

2.2.1.2 For species with seasons that have split months (great skua, lesser black-backed gull, kittiwake and gannet) the following was adopted, as agreed through consultation with NatureScot (see Table 12.1 in **Volume 1, Chapter 12: Offshore and Intertidal Ornithology**).

- Great skua and lesser black-backed gull were not recorded within their respective split months, therefore no action required.
- Kittiwake and lesser black-backed gull CRM outputs for April and March respectively were divided by two, with one half assigned to the breeding season and the other to the non-breeding season.
- Gannet CRM outputs for March were divided by two, with one half assigned to the breeding season and the other to the non-breeding season. To ensure macro avoidance was appropriately accounted for in March, two different March densities were modelled, which included and excluded incorporation of macro avoidance. The impact prediction for March inclusive of macro avoidance was halved and assigned to the non-breeding season, whilst the March impact prediction excluding macro avoidance was halved and assigned to the breeding season.

Table 2.1 Seasonal periods used in the Project CRM impact assessment

Species	**Season**	
	Breeding	**Non-breeding**
Kittiwake	Mid-April to August.	September to Mid-April.
Great black-backed gull	April to August.	September to March.
Herring gull	April to August.	September to March.
Lesser black-backed gull	Mid-March to August	September to mid-March
Great skua	Mid-April to mid-September	Mid-September to mid-April.
Gannet	Mid-March to September.	October to Mid-March.

2.3 CRM input parameters

2.3.1.1 The species-specific biological parameters that are recommended within NatureScot's Guidance Note 7 (2025) guidance were used in the CRM, along with the wind farm and wind turbine generator (WTG) parameters associated with each scenario being considered.

2.3.2 Turbine Parameters

2.3.2.1 As recommended within NatureScot's Guidance Note 7 (NatureScot, 2025) a worst case and most likely scenario have been modelled to provide the range of potential collision risk posed by the Project. The WTG and OAA input parameters for the two scenarios being considered for the Project are outlined in **Table 2.2**. Footprint width was calculated as the longitudinal width of the footprint of the Project. Latitude, used to estimate the number of hours of daylight per month across the year, was calculated from the centroid of the OAA.

Minimum air gap reflects the lowest blade tip height above the highest astronomical tide (HAT).

Table 2.2 WTG and OAA parameters used to inform CRM

Input parameter	Value (standard deviation (SD) (where appropriate))	
	Worst case design scenario	Most likely design scenario
Number of WTGs	225	126
Number of blades per WTG	3	3
Rotor radius	118m	163m
Minimum air gap relative to HAT	21.79m HAT	21.79m HAT
Maximum blade width	5.10m (0.00m)	10.00m (0.00m)
Tidal offset to MSL	1.21m	1.21m
Maximum footprint width	41.37m	41.37m
Latitude	58.16 degrees	58.16 degrees
Rotation speed	8.00 (0.00) revolutions per minute (rpm).	7.62 (0.00) rpm.
Average pitch at site mean speed	3.50 (0.00) degrees.	3.50 (0.00) degrees.

2.3.2.2 In addition to the aforementioned WTG and OAA parameters (**Table 2.2**), the estimated percentage of time in which the WTGs are predicted to be operational per month (across all turbines) is included within modelling. This is based on monthly wind availability and anticipated maintenance downtime, with these values presented in **Table 2.3** and **Table 2.4** respectively. For both modelled scenarios, wind availability and maintenance downtime is expected to be the same.

Table 2.3 Predicted wind availability (%)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
%	97	96	96	94	93	92	90	92	95	97	97	96

Table 2.4 Predicted maintenance downtime (%)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	3	4	4	6	7	8	10	8	5	3	3	4
SD	0	0	0	0	0	0	0	0	0	0	0	0

2.3.3 Species biometrics

2.3.3.1 For each of the species being considered for collision risk, physical and behavioural characteristics were used to inform the CRM. The parameters are as follows:

- flight height distribution data (m);
- bird length (m);
- wingspan (m);
- flight speed (m/s);
- nocturnal activity factor (NAF);
- flight type; and
- flight upwind (%).

2.3.3.2 All the parameter values included within CRM follow those recommended within NatureScot's Guidance Note 7 (NatureScot, 2025) and are summarised within **Table 2.5**. Appropriateness of such recommended parameters to inform CRM is detailed within **Volume 1, Chapter 12: Offshore and Intertidal Ornithology**.

2.3.4 Avoidance rates

2.3.4.1 A key element of collision risk modelling is the inclusion of a value for avoidance behaviour, as this is exhibited by most bird species in response to the presence of WTGs. Different species are expected to exhibit differing degrees of avoidance behaviour to the presence of wind farms (Ozsanlav-Harris *et al.,* 2023).

2.3.4.2 NatureScot's Guidance Note 7 (2025) recommended avoidance rates were used for the CRM, with the values included for each species presented in **Table 2.5**. Following NatureScot's guidance (NatureScot, 2025), the avoidance rates for either 'large gull' or 'all gull' species, as provided in Ozsanlav-Harris *et al*. (2023) were used. Species-specific avoidance rates are provided within the same paper. However, they are not currently recommended in the latest NatureScot guidance as they consider the data insufficient for deriving species-specific rates.

Table 2.5 Species biometric data, behavioural measures and avoidance rates used in sCRM as advised by the latest NatureScot advice note (NatureScot, 2025). Standard deviations for each value are presented in brackets for the stochastic model

Species	Body length (m)	Wingspan (m)	Flight speed (m/s)	Nocturnal activity as a proportion or percentage	Avoidance rate	Flights upwind (%)	Flight type
Stochastic model							
Kittiwake	0.39 (±0.005)	1.08 (±0.0625)	13.1 (±0.4)	0.4 (±0.1200)	0.9929 (±0.0003)	50	Flapping
Great black-backed gull	0.71 (±0.0350)	1.58 (±0.0375)	13.7 (±1.2)	0.375 (±0.0637)	0.9940 (±0.0004)	50	Flapping
Herring gull	0.60 (±0.0225)	1.44 (±0.030)	12.8 (±1.8)	0.375 (±0.0637)	0.9940 (±0.0004)	50	Flapping
Lesser black-backed gull	0.58 (±0.0300)	1.42 (±0.0375)	13.1 (±1.9)	0.3 (±0.1800)	0.9940 (±0.0004)	50	Flapping
Great skua	0.56	1.36	14.9	0.125	0.9908 (±0.0004)	50	Flapping
Gannet	0.94 (±0.0325)	1.72 (±0.0375)	14.9 (±0.0)	0.14 (±0.1000)	0.9929 (±0.0003)	50	Gliding
Deterministic model							
Kittiwake	0.39	1.08	13.1	40%	0.9923	50	Flapping
Great black-backed gull	0.71	1.58	13.7	25 to 50%	0.9936	50	Flapping
Herring gull	0.60	1.44	12.8	25 to 50%	0.9936	50	Flapping
Lesser black-backed gull	0.58	1.42	13.1	30%	0.9936	50	Flapping
Great skua	0.56	1.36	14.9	0.125	0.9902	50	Flapping
Gannet	0.94	1.72	14.9	14%	0.9923	50	Gliding

2.3.5 Density of birds in flight

Stochastic modelling

2.3.5.1 As recommended in NatureScot's Guidance Note 7 (NatureScot, 2025), to account for variability and statistical uncertainty around monthly densities of flying seabirds within the sCRM, at least 1,000 samples from a distribution of mean densities are required to inform CRM. For the Project, density estimates were calculated following two different methods; design-based density estimation as described in **Appendix 12.1**, and MRSea modelling as described in **Appendix 12.5: Offshore Ornithology MRSea Report**. For the purposes of CRM only design-based density estimates are used. This is due to the MRSea results being incompatible with the recommended format for density inclusion within NatureScot's Guidance Note 7 (NatureScot, 2025), when accounting for apportionment of unidentified individuals.

2.3.5.2 Design-based density estimates were produced as part of abundance calculations (methods of which are detailed within **Appendix 12.1**) and are expressed as the average number of birds in flight per square kilometre in the OAA, per month. A variability statistic was generated using a non-parametric bootstrap approach by re-sampling 1,000 times (per survey year) with replacements from the raw counts for each individual transect (Buckland *et al.,* 2004). The density was calculated for each of these 1,000 bootstrap samples (per survey year) and upper and lower 95% CIs of these 1,000 values were taken as the variability of the statistic over the population (Efron and Tibshirani, 1993).

2.3.5.3 As some individuals in a given survey may not be identified to species level, such individuals should be, where appropriate, attributed into the monthly densities and abundance estimates. This is based upon an apportionment of the group level individuals between those species within that group, proportionally based on the abundance of each species. During this apportionment process, non-parametric bootstrap samples generated as part of abundance estimate calculations are apportioned individually. For example, individuals identified to group level as 'gull species' may have a mean density of 0.5 individuals/km^2, however this density might range from 0.0 to 0.9 individuals/km^2 across the bootstrap samples. Similarly, the densities for the individual gull species (e.g. kittiwake, great black-backed gull) will also vary between the bootstrap samples. To allow for this variation between bootstrap samples in the number of individuals identified to group level as well as in the species proportions each bootstrap sample is apportioned individually, and a set of apportioned bootstrap samples are obtained. This ensures that uncertainty in species-level abundances as well as group-level abundances is fully accounted for within the final apportioned abundance estimates.

2.3.5.4 Due to poor weather conditions off the north-east coast of Scotland at the time the DAS surveys were flown (particularly during the winter months), interruptions occurred to the scheduled consecutive monthly DAS programme as detailed within **Appendix 12.1**. DAS were however conducted in each of the 12 calendar months across the 24-month survey period, and 24 DAS were flown within 24 successive months (two DAS flown in July and November 2022, and March 2023, three DAS flown in February 2023) (**Table 2.6**). This approach was presented to and agreed by NatureScot during engagement in relation to the DAS survey report in February 2023 (see Table 12.1 in **Volume 1, Chapter 12: Offshore and Intertidal Ornithology**).

2.3.5.5 In order to get equal 2,000 bootstrap samples certain surveys were used as a proxy for missing months. This is outlined in **Table 2.6**. To account for variability and statistical uncertainty around monthly densities, at least 1,000 samples from a distribution of mean densities were used within CRM, as recommended in the latest NatureScot's Guidance Note 7 (NatureScot, 2025). The value of 2,000 is taken from the 1,000 bootstrap samples from year one of DAS data combined with the 1,000 bootstrap samples taken from year two of DAS data.

2.3.5.6 Within the August 2021 survey, a significant attraction effect was observed within the OAA relating to the presence of a fishing vessel (an image from the DAS showing the vessel and the attracted birds is provided within **Appendix 12.5**), notably inflating the gannet and great skua density estimates. The approach to accounting for this attraction effect was discussed with NatureScot during consultation. It was recommended that the August 2021 survey should be excluded from consideration and replaced with the next-highest peak abundance month, which is September 2021 for flying gannets and July 2021 for flying great skua within the OAA. The 2,000 bootstrapped density estimates for the month of August is therefore made up of September 2021 and August 2022 survey bootstrapped estimates for gannet and July 2021 and August 2022 survey bootstrapped estimates for great skua.

2.3.5.7 Within the sCRM tool, model outputs were selected to be provided monthly, rather than annually or by season. Monthly mean collision estimates and associated 95% confidence limits are presented for the stochastic model in **Appendix A**. If required, bootstrap density estimates used within the stochastic CRM can be provided on request.

Table 2.6 Survey months flown, surveys assigned values and surveys assigned to each month for bootstrap densities used in sCRM tool.

Survey	Month flown	Date flown	Assigned month and year	Year assigned to each month for bootstrap densities
1	April 2021.	15 April 2021.	April 2021.	1
2	May 2021.	15 May 2021 and 16 May 2021.	May 2021.	1
3	June 2021.	06 June 2021.	June 2021.	1
4	July 2021.	24 July 2021.	July 2021.	1
5	August 2021.	13 August 2021.	August 2021.	1
6	September 2021.	20 September 2021.	September 2021.	1
7	October 2021.	04 October 2021.	October 2021.	1
8	December 2021.	13 December 2021 and 15 December 2021.	December 2021.	1
9	January 2022.	15 January 2022 and 18 January 2022.	January 2022.	1
10	March 2022.	01 March 2022.	March 2022.	1
11	April 2022.	14 April 2022.	April 2022.	2
12	May 2022.	02 May 2022.	May 2022.	2
13	July number 1 of 2022.	05 July 2022.	June 2022.	2

Survey	Month flown	Date flown	Assigned month and year	Year assigned to each month for bootstrap densities
14	July number 2 of 2022.	18 July 2022.	July 2022.	2
15	August 2022.	11 August 2022.	August 2022.	2
16	September 2022.	24 September 2022.	September 2022.	2
17	October 2022.	13 October 2023.	October 2022.	2
18	November number 1 of 2022.	09 November 2022.	November 2021 and November 2022.	1, 2
19	November number 2 of 2022.	21 November 2022.	December 2022.	2
20	February number 1 of 2023.	05 February 2023.	January 2023.	2
21	February number 2 of 2023.	12 February 2023.	February 2022.	1
22	February number 3 of 2023.	18 February 2023.	February 2023.	2
23	March number 1 of 2023.	09 March 2023.	March 2023.	2
24	March number 2 of 2023.	19 March 2023.	March 2023.	2

Table notes: Cells in brown indicate an average of two survey bootstraps were used. Cells in grey indicate proxy months either side of the missing month were used. Cells in green indicate bootstraps from the same month but different year were used.

Deterministic modelling

2.3.5.8 Average density of birds in flight within the OAA was calculated from the bootstrapped samples and used to inform deterministic modelling, the results of which are provided in **Table 2.7**, along with 95% confidence limits for context.

Macro avoidance

2.3.5.9 The high levels of macro-avoidance behaviours observed by gannets (APEM, 2014; Dierschke *et al.,* 2016; APEM, 2022) is acknowledged within the latest Joint Statutory Nature Conservation Bodies (SNCBs) CRM guidance (SNCB, 2024). As agreed during consultation with NatureScot, a macro avoidance has been applied to the non-breeding season density estimates. A reduction of 70% (corresponding with the displacement rate recommended by NatureScot (2023) for gannet) has been applied to the non-breeding season bootstrapped estimates prior to inclusion within CRM.

2.3.5.10 CRM was run for all months both including and excluding macro-avoidance with full outputs presented in **Appendix A** and **Appendix B** for stochastic and deterministic modelling respectively. However, only relevant outputs are presented in **Section 3** below (i.e. macro-avoidance applied to non-breeding season months only).

Table 2.7 Average flying densities (birds/km^2) of seabird species in the OAA and associated 95% confidence limits

Species	January	February	March	April	May	June	July	August	September	October	November	December
Kittiwake	0.040 (0.039 to 0.041)	0.124 (0.120 to 0.127)	0.084 (0.085 to 0.083)	0.270 (0.258 to 0.283)	0.213 (0.208 to 0.218)	0.006 (0.005 to 0.006)	0.203 (0.194 to 0.213)	0.175 (0.171 to 0.180)	0.006 (0.005 to 0.006)	0.064 (0.062 to 0.066)	0.081 (0.079 to 0.082)	0.071 (0.068 to 0.075)
Great black-backed gull	0.111 (0.107 to 0.114)	0.017 (0.016 to 0.018)	0.023 (0.022 to 0.024)	0.028 (0.027 to 0.030)	0.006 (0.005 to 0.006)	0.000 (0.000 to 0.000)	0.000 (0.000 to 0.000)	0.000 (0.000 to 0.000)	0.012 (0.011 to 0.012)	0.017 (0.017 to 0.018)	0.023 (0.022 to 0.023)	0.036 (0.035 to 0.037)
Herring gull	0.036 (0.034 to 0.037)	0.000 (0.000 to 0.000)	0.003 (0.003 to 0.003)	0.005 (0.005 to 0.006)	0.006 (0.005 to 0.006)	0.000 (0.000 to 0.000)	0.000 (0.000 to 0.000)	0.000 (0.000 to 0.000)	0.000 (0.000 to 0.000)	0.000 (0.000 to 0.000)	0.046 (0.045 to 0.047)	0.029 (0.028 to 0.031)
Lesser black-backed gull	0.000 (0.000 to 0.000)	0.000 (0.000 to 0.000)	0.000 (0.000 to 0.000)	0.000 (0.000 to 0.000)	0.000 (0.000 to 0.000)	0.000 (0.000 to 0.000)	0.000 (0.000 to 0.000)	0.000 (0.000 to 0.000)	0.000 (0.000 to 0.000)	0.000 (0.000 to 0.000)	0.000 (0.000 to 0.000)	0.006 (0.006 to 0.007)
Gannet (with macro-avoidance)	0.007 (0.007 to 0.007)	0.014 (0.014 to 0.014)	0.013 (0.013 to 0.014)	0.043 (0.040 to 0.047)	0.076 (0.072 to 0.080)	0.039 (0.037 to 0.040)	0.022 (0.021 to 0.023)	0.070 (0.063 to 0.077)	0.089 (0.084 to 0.094)	0.073 (0.072 to 0.075)	0.011 (0.010 to 0.011)	0.007 (0.007 to 0.007)
Gannet (without macro-avoidance)	0.024 (0.023 to 0.025)	0.047 (0.045 to 0.048)	0.044 (0.043 to 0.046)	0.144 (0.141 to 0.148)	0.255 (0.251 to 0.259)	0.128 (0.127 to 0.130)	0.074 (0.073 to 0.075)	0.234 (0.227 to 0.241)	0.296 (0.291 to 0.301)	0.245 (0.239 to 0.251)	0.035 (0.034 to 0.036)	0.024 (0.023 to 0.025)

Table note: Numbers in brackets represent confidence limits based on the pooled bootstrap density estimates.

3. Results

3.1.1.1 For each of the five seabird species modelled, a summary of predicted collisions from stochastic modelling is provided below. The CRM results are provided by season for each species, with monthly outputs also presented in the form of bar charts based on the worst case scenario impact predictions. A summary of monthly CRM results is provided in **Appendix A** (stochastic) and **Appendix B** (deterministic).

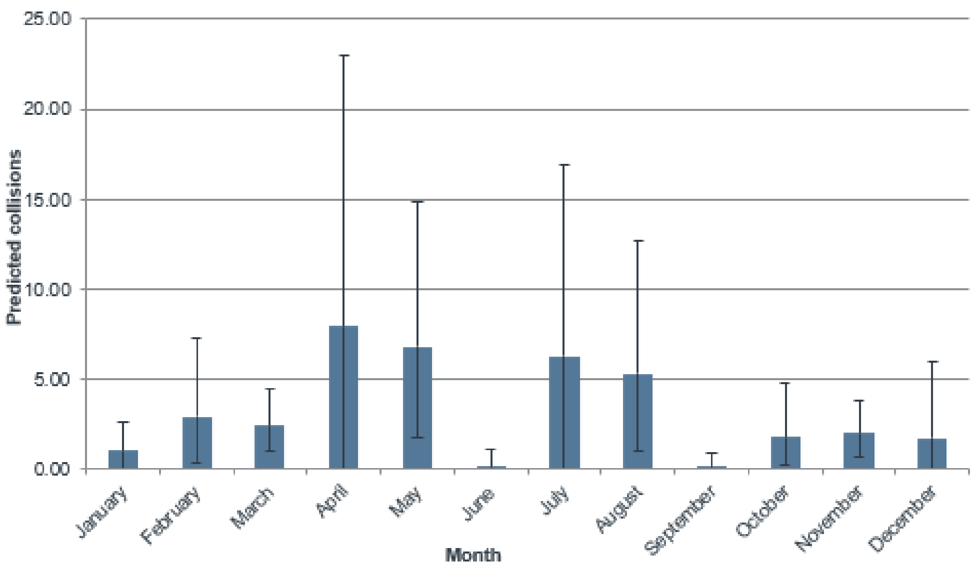
3.2 Kittiwake

3.2.1.1 The seasonal and annual predicted collision values for kittiwake are presented in **Table 3.1** and **Plate 3.1**.

Table 3.1 Seasonal and annual kittiwake collision mortalities

Seasons	Months	Predicted collisions (mean individuals (95% confidence interval (CI))	
		Worst case design scenario	Most likely design scenario
Breeding	**Mid-April to August**	22.54 (2.80 to 57.04).	22.04 (2.98 to 56.75).
Non-breeding	**September to mid-April**	16.06 (2.28 to 41.46).	15.59 (1.73 to 39.87).
Annual		38.60 (5.08 to 98.50).	37.63 (4.72 to 96.62).

Plate 3.1 Kittiwake monthly collision estimates (worst case design scenario) and associated 95% confidence intervals



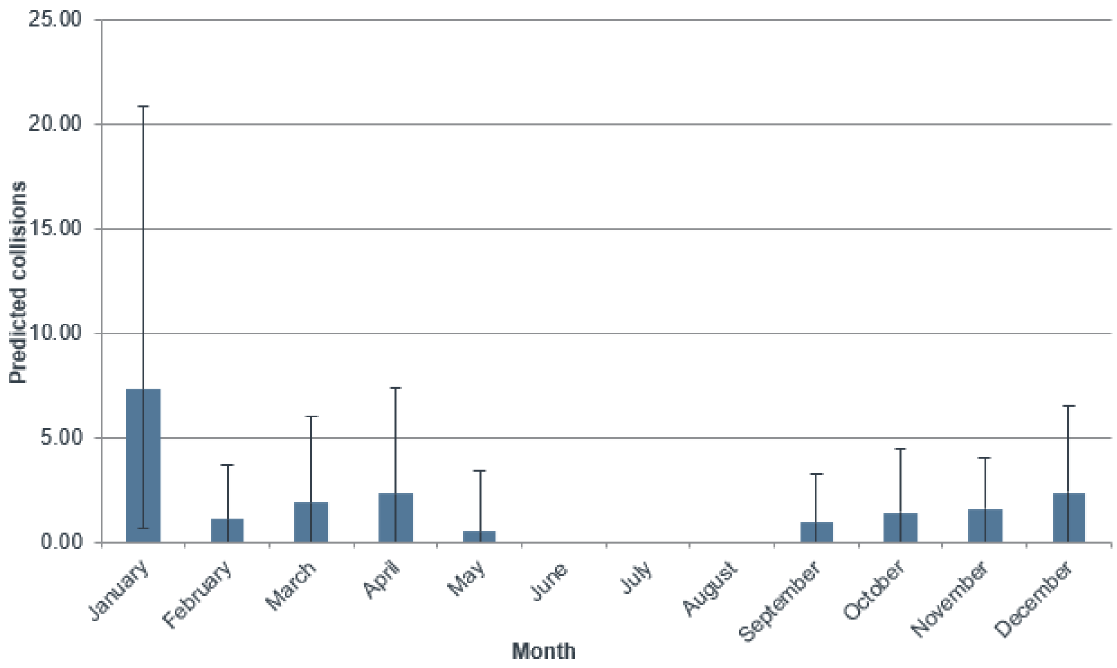
3.3 Great black-backed gull

3.3.1.1 The seasonal and monthly predicted collision values for great black-backed gull are presented in **Table 3.2** and **Plate 3.2** respectively.

Table 3.2 Seasonal and annual great black-backed gull collision mortalities

Seasons	Months	Predicted collisions (mean individuals (95% CI))	
		Worst case design scenario	Most likely design scenario
Breeding	**April to August**	2.84 (0.00 to 10.75).	2.69 (0.00 to 10.02).
Non-breeding	**September to March**	16.66 (0.64 to 48.79).	15.88 (0.00 to 45.35).
Annual		19.50 (0.64 to 59.94).	18.57 (0.00 to 55.38).

Plate 3.2 Great black-backed gull monthly collision estimates (worst case design scenario) and associated 95% confidence intervals



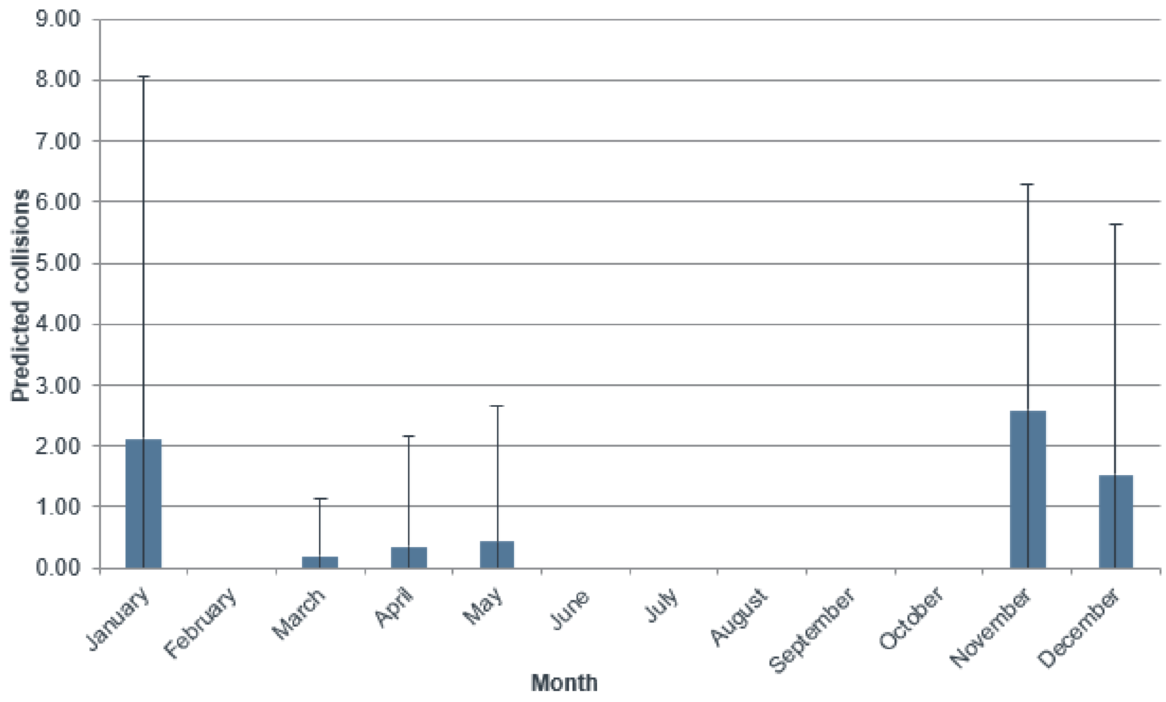
3.4 Herring gull

3.4.1.1 The seasonal and monthly predicted collision values for herring gull are presented in **Table 3.3** and **Plate 3.3** respectively.

Table 3.3 Seasonal and annual herring gull collision mortalities

Seasons	Months	Predicted collisions (mean individuals (95% CI))	
		Worst case design scenario	Most likely design scenario
Breeding	**April to August**	0.78 (0.00 to 4.84).	0.81 (0.00 to 4.38).
Non-breeding	**September to March**	6.44 (0.00 to 21.14).	6.03 (0.00 to 20.61).
Annual		7.23 (0.00 to 25.98).	6.84 (0.00 to 25.00).

Plate 3.3 Herring gull monthly collision estimates (worst case design scenario) and associated 95% confidence intervals



3.5 Lesser black-backed gull

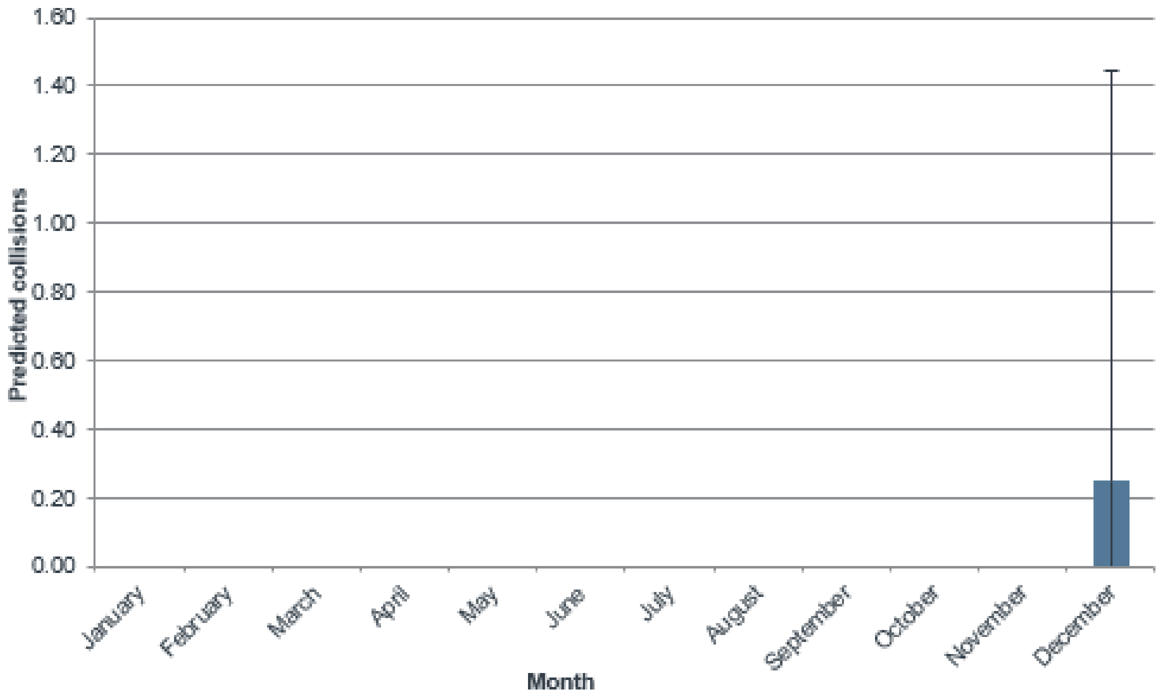
3.5.1.1 The seasonal and monthly predicted collision values for lesser black-backed gull are presented in **Table 3.4** and **Plate 3.4** respectively.

Table 3.4 Seasonal and annual lesser black-backed gull collision mortalities

Seasons	Months	Predicted collisions (mean individuals (95% CI))	
		Worst case design scenario	Most likely design scenario
Breeding	**Mid-March to August**	0.00 (0.00 to 0.00).	0.00 (0.00 to 0.00).
Non-breeding	**September to mid-March**	0.25 (0.00 to 1.45).	0.27 (0.00 to 1.80).
Annual		0.25 (0.00 to 1.45).	0.27 (0.00 to 1. 80).

Table note: the impact value for the best-case design scenario has been assessed within **Volume 1, Chapter 12: Offshore and Intertidal Ornithology** due to predicting a marginally greater impact. The reason for the most likely design scenario predicting the greatest impact is likely due to stochasticity within modelling, combined with the minimal impact predicted for either design.

Plate 3.4 Lesser black-backed gull monthly collision estimates (worst case design scenario) and associated 95% confidence intervals



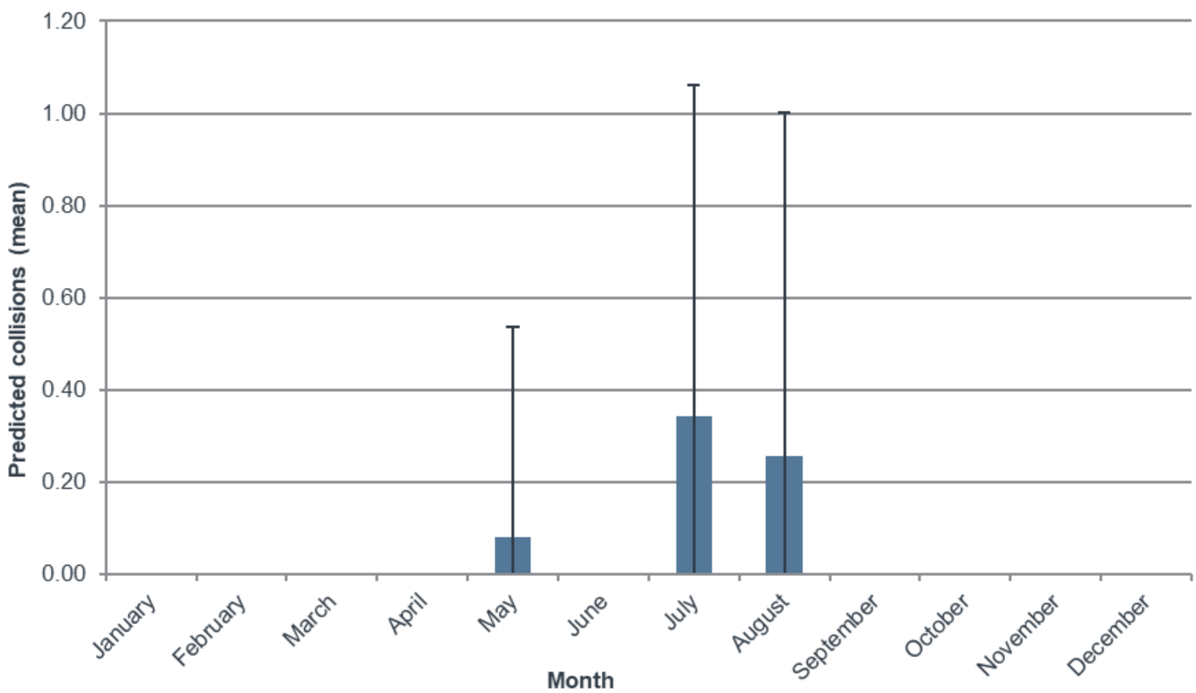
3.6 Great skua

3.6.1.1 The seasonal and monthly predicted collision values for great skua are presented in **Table 3.5** and **Plate 3.5** respectively.

Table 3.5 Seasonal and annual great skua collision mortalities

Seasons	Months	Predicted collisions (mean individuals (95% CI))	
		Worst case design scenario	Most likely design scenario
Breeding	**May to August**	0.68 (0.00 to 2.60).	0.68 (0.00 to 2.60).
Non-breeding	**September to April**	0.00 (0.00 to 0.00).	0.00 (0.00 to 0.00).
Annual		0.68 (0.00 to 2.60).	0.68 (0.00 to 2.60).

Plate 3.5 Great skua monthly collision estimates (worst case design scenario) and associated 95% confidence intervals



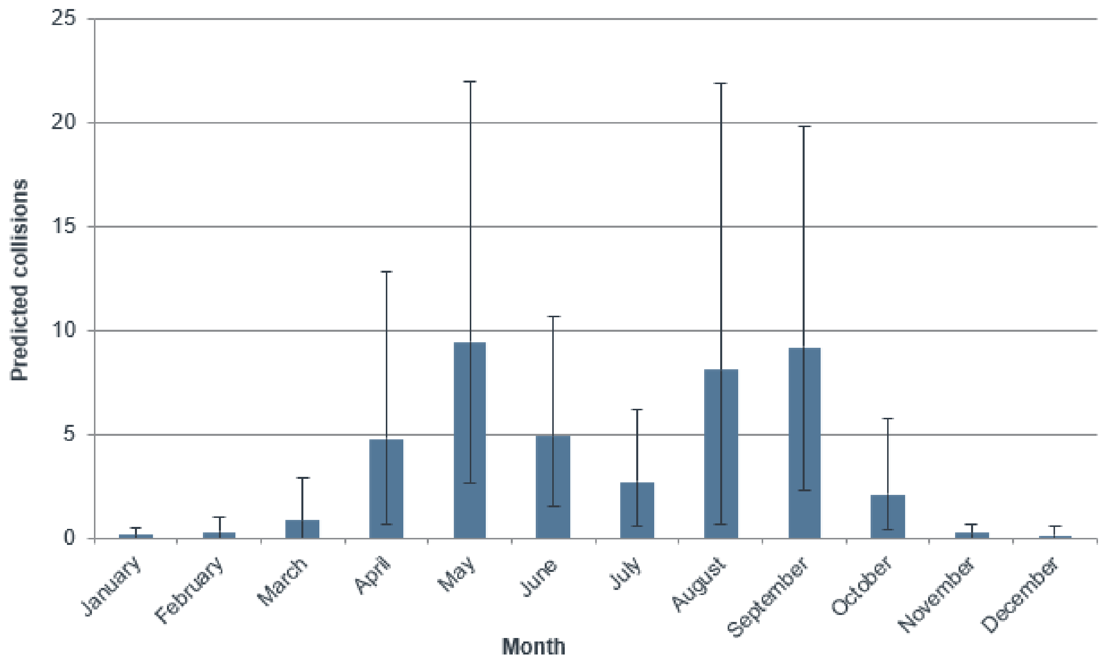
3.7 Gannet

3.7.1.1 The seasonal and monthly predicted collision values for gannet are presented in **Table 3.6** and **Plate 3.6** respectively.

Table 3.6 Seasonal and annual gannet collision mortalities

Seasons	Months	Predicted collisions	
		Worst case design scenario	Most likely design scenario
Breeding	**Mid-March to September**	39.77 (8.47 to 95.52).	36.54 (7.71 to 89.89).
Non-breeding	**October to mid-March**	3.18 (0.39 to 9.25).	3.00 (0.35 to 8.63).
Annual		42.95 (8.86 to 104.77).	39.54 (8.05 to 98.52).

Plate 3.6 Gannet monthly collision estimates (worst case design scenario) and associated 95% confidence intervals



4. References

APEM, (2014). *Assessing northern gannet avoidance of offshore windfarms*. APEM Scientific Report P512775. East Anglia Offshore Wind Ltd, June 2014.

APEM, (2022). *Gannet displacement and mortality evidence review*. APEM Scientific Report P00007416 Ørsted March 2022.

Band, W., (2012) *Using a collision risk model to assess bird collision risks for offshore wind farms*. The Crown Estate Strategic Ornithological Support Services (SOSS) report SOSS-02. http://www.bto.org/science/wetland-and-marine/soss/projects. [Accessed 15 August].

Bradbury, G., Trinder, M., Furness, B., Banks, A.N. and Caldow, D.N., (2017). *Correction: Mapping Seabird Sensitivity to Offshore Wind Farms. PLOS ONE* 12(1): e0170863.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. and Thomas, L., (2004). *Advanced Distance Sampling*. Oxford University Press, Oxford.

Caneco, B. and Humphries, G., (2022). *HiDef Aerial Surveying stochLAB.* [online] Available at: https://www.github.com/HiDef-Aerial-Surveying/stochLAB [Accessed: 15 August 2025].

Dierschke, V., Furness, R.W. and Garthe, S., (2016). *Seabirds and offshore wind farms in European waters: Avoidance and attraction. Biological Conservation*, 202: 59-68.

Drewitt, A.L. and Langston, R.H.W., (2006). *Assessing the impacts of wind farms on birds*. *Ibis*. 148: 29–42.

Efron, B., and Tibshirani, R.J., (1993). *An introduction to the bootstrap*. London: Chapman and Hall.

Johnston, A., Cook, A.S.C.P., Wright, L.J., Humphreys, E.M. and Burton, N.H.K., (2014a). *Modelling flight heights of marine birds to more accurately assess collision risk with offshore wind turbines*. *Journal of Applied Ecology,* 51: 31–41.

Johnston, A., Cook, A.S.C.P., Wright, L.J., Humphreys, E.M. and Burton, N.H.K., (2014b). *Corrigendum to Modelling flight heights of marine birds to more accurately assess collision risk with offshore wind turbines. Journal of Applied Ecology*. 51: 1126–1130.

NatureScot, (2025). *Guidance Note 7: Guidance to support Offshore Wind Applications: Marine Ornithology - Advice for assessing collision risk of marine birds*. [online] Available at: https://www.nature.scot/doc/guidance-note-7-guidance-support-offshore-wind-applications-marine-ornithology-advice-assessing [Accessed: 15 August 2025].

NatureScot, (2023*). Guidance Note 8: Guidance to support Offshore Wind Applications: Marine Ornithology Advice for assessing the distributional responses, displacement and barrier effects of Marine birds*. [online] Available at https://www.nature.scot/doc/guidance-note-8-guidance-support-offshore-wind-applications-marine-ornithology-advice-assessing [Accessed: 15 August 2025].

Ozsanlav-Harris, L., Inger, R. and Sherley, R., (2022). *Review of data used to calculate avoidance rates for collision risk modelling of seabirds.* JNCC Report 732 (Research and review report), JNCC, Peterborough.

Skov, H., Heinänen, S., Norman, T., Ward, R.M., Méndez-Roldán, S. and Ellis, I., (2018*). ORJIP Bird Collision and Avoidance Study*. Final report – April 2018. *The Carbon Trust*. United Kingdom. 247 pp.

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

5. Glossary and Abbreviations

5.1 Abbreviations

Acronym	Definition
CI	Confidence Interval
CRM	Collision Risk Modelling
DAS	Digital Aerial Surveys
HAT	Highest Astronomical Tide
km	kilometres
m	metre
NAF	Nocturnal Activity Factor
OAA	Option Agreement Area
rpm	revolutions per minute
sCRM	Stochastic Collision Risk Modelling
SD	Standard Deviation
SNCBs	Statutory Nature Conservation Bodies
WTG	Wind Turbine Generators

5.2 Glossary of terms

Term	Definition
Collision	An instance of one moving object or individual striking violently against another.
Collision Risk Model (CRM)	General term to describe the method of estimating the collision risk of seabirds (estimated mortality) to operational turbines, which could be either deterministic or stochastic.
MRSea	MRSea is a package developed in R (R Core Team, 2024) used for identifying spatially explicit changes in the spatial distribution and abundance of seabirds over time and across an offshore development site. MRSea modelling is recommended on the basis that it may offer greater facility in understanding the variation in distribution in response to environmental variables.

Appendix A
Predicted Monthly Stochastic CRM results

Table A.1 Monthly stochastic CRM outputs for worst-case design scenario

Month	Kittiwake			Great black-backed gull			Herring gull			Lesser black-backed gull			Great skua			Gannet (with macro-avoidance)			Gannet (without macro-avoidance)		
	Mean	**2.5%**	**97.5%**	**Mean**	**2.5%**	**97.5%**	**Mean**	**2.5%**	**97.5%**	**Mean**	**2.5%**	**97.5%**	**Mean**	**2.5%**	**97.5%**	**Mean**	**2.5%**	**97.5%**	**Mean**	**2.5%**	**97.5%**
January	1.01	0.00	2.68	7.32	0.64	20.86	2.12	0.00	8.06	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.49	0.53	0.00	1.61
February	2.91	0.33	7.33	1.13	0.00	3.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	1.03	1.04	0.00	3.28
March	2.46	1.00	4.44	1.89	0.00	6.00	0.20	0.00	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	1.42	1.28	0.00	4.41
April	7.96	0.00	22.96	2.32	0.00	7.36	0.35	0.00	2.18	0.00	0.00	0.00	0.00	0.00	0.00	1.45	0.19	3.88	4.77	0.66	12.83
May	6.83	1.77	14.86	0.52	0.00	3.39	0.43	0.00	2.66	0.00	0.00	0.00	0.08	0.00	0.54	2.92	0.77	6.59	9.46	2.64	21.96
June	0.17	0.00	1.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.47	0.45	3.25	4.90	1.53	10.64
July	6.26	0.00	16.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	1.06	0.81	0.18	1.89	2.70	0.62	6.15
August	5.30	1.04	12.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	1.00	2.45	0.22	7.03	8.11	0.70	21.91
September	0.16	0.00	0.88	0.94	0.00	3.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.78	0.72	6.42	9.20	2.32	19.81
October	1.81	0.25	4.77	1.43	0.00	4.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.11	0.39	5.76	7.04	1.24	19.07
November	2.01	0.70	3.87	1.58	0.00	4.00	2.59	0.00	6.29	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.70	0.81	0.00	2.28
December	1.72	0.00	6.00	2.37	0.00	6.50	1.53	0.00	5.64	0.25	0.00	1.45	0.00	0.00	0.00	0.14	0.00	0.55	0.46	0.00	1.65
Total	**38.60**	**5.08**	**98.50**	**19.50**	**0.64**	**59.54**	**7.23**	**0.00**	**25.98**	**0.25**	**0.00**	**1.45**	**0.68**	**0.00**	**2.60**	**15.27**	**2.92**	**39.01**	**50.29**	**9.71**	**125.61**

Table A.2 Monthly stochastic CRM outputs for best-case design scenario

Month	Kittiwake			Great black-backed gull			Herring gull			Lesser black-backed gull			Great skua			Gannet (with macro-avoidance)			Gannet (without macro-avoidance)		
	Mean	2.5%	97.5%	Mean	2.5%	97.5%	Mean	2.5%	97.5%	Mean	2.5%	97.5%	Mean	2.5%	97.5%	Mean	2.5%	97.5%	Mean	2.5%	97.5%
January	0.97	0.00	2.70	7.11	0.00	19.36	1.98	0.00	7.02	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.49	0.49	0.00	1.55
February	2.89	0.34	6.92	1.06	0.00	3.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.98	1.09	0.00	3.56
March	2.35	0.81	4.16	1.79	0.00	5.93	0.19	0.00	1.23	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	1.25	1.22	0.00	4.25
April	7.89	0.00	22.43	2.22	0.00	7.27	0.38	0.00	2.17	0.00	0.00	0.00	0.00	0.00	0.00	1.38	0.17	3.72	4.27	0.53	11.54
May	6.67	1.88	14.85	0.46	0.00	2.75	0.43	0.00	2.22	0.00	0.00	0.00	0.08	0.00	0.54	2.71	0.78	6.06	9.12	2.47	20.36
June	0.18	0.00	1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.38	0.42	3.08	4.52	1.32	9.93
July	6.01	0.00	17.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	1.06	0.76	0.16	1.85	2.46	0.53	5.53
August	5.23	1.10	12.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	1.00	2.26	0.21	6.07	7.19	0.65	21.19
September	0.17	0.00	0.83	0.94	0.00	3.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.58	0.66	5.56	8.37	2.19	19.22
October	1.74	0.00	4.77	1.32	0.00	4.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.98	0.35	5.32	6.32	1.06	17.11
November	1.93	0.59	3.78	1.42	0.00	3.75	2.44	0.00	6.36	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.69	0.75	0.00	2.20
December	1.59	0.00	5.50	2.24	0.00	5.71	1.43	0.00	6.01	0.27	0.00	1.80	0.00	0.00	0.00	0.14	0.00	0.54	0.45	0.00	1.56
Total	**37.63**	**4.72**	**96.62**	**18.57**	**0.00**	**55.38**	**6.84**	**0.00**	**25.00**	**0.27**	**0.00**	**1.80**	**0.68**	**0.00**	**2.60**	**14.25**	**2.75**	**35.59**	**46.24**	**8.77**	**117.99**

Appendix B
Predicted Monthly Deterministic CRM Results

Table B.1 Monthly deterministic CRM outputs for worst-case design scenario

Month	Kittiwake	Great black-backed gull		Herring gull		Lesser black-backed gull	Great skua	Gannet	
	Value	25% NAF	50% NAF	25% NAF	50% NAF	Value	Value	Gannet (with macro-avoidance)	Gannet (without macro-avoidance)
January	1.08	6.43	8.79	1.82	2.49	0.00	0.00	0.16	0.54
February	3.22	0.99	1.27	0.00	0.00	0.00	0.00	0.33	1.11
March	2.65	1.69	2.04	0.19	0.23	0.00	0.00	0.41	1.37
April	8.62	2.16	2.47	0.34	0.39	0.00	0.00	1.45	4.84
May	7.40	0.52	0.57	0.45	0.50	0.00	0.09	2.92	9.74
June	0.21	0.00	0.00	0.00	0.00	0.00	0.00	1.49	4.95
July	6.72	0.00	0.00	0.00	0.00	0.00	0.37	0.82	2.73
August	5.70	0.00	0.00	0.00	0.00	0.00	0.26	2.46	8.19
September	0.19	0.88	1.04	0.00	0.00	0.00	0.00	2.80	9.34
October	1.96	1.19	1.48	0.00	0.00	0.00	0.00	2.12	7.08
November	2.18	1.35	1.81	2.37	3.16	0.00	0.00	0.25	0.82
December	1.82	1.95	2.73	1.38	1.92	0.36	0.00	0.15	0.50
Total	**41.73**	**17.16**	**22.20**	**6.55**	**8.69**	**0.36**	**0.72**	**15.36**	**51.20**

Table B.2 Monthly deterministic CRM outputs for best-case design scenario

Month	Kittiwake	Great black-backed gull		Herring gull		Lesser black-backed gull	Great skua	Gannet	
	Value	25% NAF	50% NAF	25% NAF	50% NAF	Value	Value	Gannet (with macro-avoidance)	Gannet (without macro-avoidance)
January	1.07	5.97	8.17	1.71	2.34	0.00	0.00	0.15	0.51
February	3.18	0.92	1.18	0.00	0.00	0.00	0.00	0.31	1.04
March	2.62	1.57	1.90	0.18	0.22	0.00	0.00	0.39	1.29
April	8.51	2.00	2.29	0.32	0.36	0.00	0.00	1.37	4.56
May	7.31	0.48	0.53	0.42	0.47	0.00	0.09	2.75	9.18
June	0.20	0.00	0.00	0.00	0.00	0.00	0.00	1.40	4.67
July	6.64	0.00	0.00	0.00	0.00	0.00	0.37	0.77	2.57
August	5.63	0.00	0.00	0.00	0.00	0.00	0.26	2.32	7.72
September	0.18	0.82	0.97	0.00	0.00	0.00	0.00	2.64	8.80
October	1.93	1.10	1.38	0.00	0.00	0.00	0.00	2.00	6.67
November	2.16	1.26	1.68	2.22	2.96	0.00	0.00	0.23	0.77
December	1.80	1.81	2.54	1.29	1.81	0.25	0.00	0.14	0.47
Total	**41.23**	**15.94**	**20.62**	**6.14**	**8.15**	**0.25**	**0.72**	**14.48**	**48.25**

MarramWind