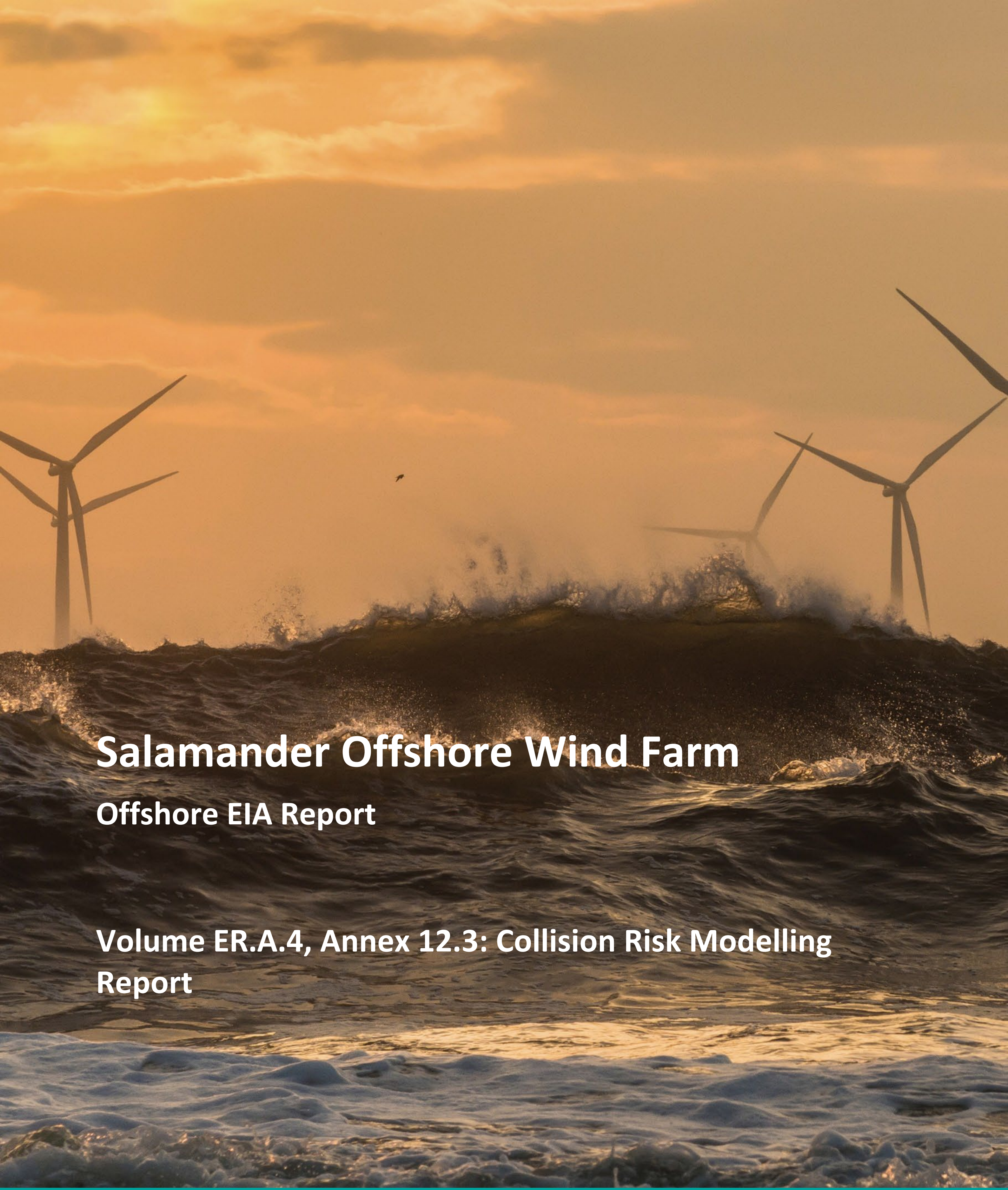

Salamander Offshore Wind Farm

Offshore EIA Report

Volume ER.A.4, Annex 12.3: Collision Risk Modelling Report

SALAMANDER

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Simply Blue Group

Salamander Offshore Wind Farm: Annex ER.A.4.12.3: Collision Risk Modelling Report

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Acronyms and abbreviations

Term	Definition
BDMPS	Biologically Defined Minimum Population Scales
BTO	British Trust for Ornithology
CRM	Collision Risk Modelling
DAS	Digital Aerial Survey
MD-LOT	Marine Directorate – Licensing Operations Team
mmfr	Mean-Max Foraging Range
RPM	Revolutions Per Minute
sCRM	Stochastic Collision Risk Modelling
SD	Standard Deviation
SMP	Seabird Monitoring Programme
SNCB	Statutory Nature Conservation Body
UK	United Kingdom
WTG	Wind Turbine Generator

1 Introduction

1 Salamander Offshore Wind Farm (hereafter 'the Salamander Project') is a proposed floating offshore wind farm, located approximately 35km off the northeast coast of Scotland, being developed by Salamander Wind Project Company Limited (formerly called Simply Blue Energy (Scotland) Limited), a joint venture between Simply Blue Group, Ørsted and Subsea7.

2 This Annex supports the assessment of the project alone collision risk for five seabird species within the Offshore Array Area (Figure 1; Annex ER.A.4.12.1: Offshore Ornithology Baseline Data).

3 Due to their life history strategies, some marine bird species are at risk of colliding with turbines in offshore wind farm developments. Birds may be injured or killed through collision with turbines and/or turbine blades. There are several approaches available to try to quantify the risk of collision to marine birds, by estimating the likelihood that a bird entering the swath of the turbine blades is likely to be struck, where the model assumes that a strike equates to mortality of the individual. The process of estimating potential collisions is known as Collision Risk Modelling (CRM).

4 Within CRM, it is initially assumed that birds do not take avoiding action, with the collision rate adjusted after the model is run, by incorporating *a priori* agreed avoidance rates. Avoidance rates are species-specific, and account for changes in bird behaviour to avoid collision on multiple scales, through complete avoidance of the wind farm (macro-avoidance) or alteration of the flight path within the wind farm (meso- and micro-avoidance).

5 Not all seabird species are sensitive to collision risk with offshore wind developments, as discussed in Furness *et al.* (2013) and Wade *et al* (2016). Considering Wade *et al.* (2016) and the density and abundance of species recorded during site-specific Digital Aerial Surveys (DAS) of the Offshore Array Area, the following species were taken forward for CRM:

- Black-legged kittiwake (*Rissa tridactyla*), hereafter 'kittiwake';
- Great black-backed gull (*Larus marinus*);
- Herring gull (*Larus argentatus*);
- Northern fulmar (*Fulmarus glacialis*), hereafter 'fulmar'; and
- Northern gannet (*Morus bassanus*), hereafter 'gannet'.

6 Uncertainty in the vulnerability of the species listed above to collision risk was identified as 'low' or 'very low' in Wade *et al.* (2016) in all cases, with vulnerability to collision moderate or high except for fulmar. Other species with high or moderate high vulnerability to collision as assessed by Wade *et al* (2016) were not recorded in sufficient numbers during site surveys to require analysis for collision risk (see Annex ER.A.4.12.1: Offshore Ornithology Baseline Data). Although fulmar has a very low vulnerability to collision as assessed by Wade *et al* (2016) it is one of the more abundant species in surveys and so was taken through collision risk modelling.

7 The Marine Directorate – Licensing Operations Team (MD-LOT) and NatureScot confirmed that stochastic CRM (sCRM) should be undertaken for the Project (Scoping Opinion dated 21st June 2023 and NatureScot advice on Scoping Report dated 5th May 2023) with outputs from using the deterministic method (Band, 2012) presented for context only (Appendix I: Input seabird densities and model outputs). A stochastic migration CRM tool (mCRM) is currently being developed; however, due to the lack of migratory species recorded within the Offshore Array Area during DAS, this analysis is not necessary. All analysis was performed using the StochLab R package produced by Caneco (2022), as requested by MD-LOT in the Scoping Opinion (Scoping Opinion dated 21st June 2023) and NatureScot advice on the Scoping Report (dated 5th May 2023). The use of the sCRM allows variation

around input parameters to be incorporated into the model to allow estimation of uncertainty around predicted values which is not possible using the deterministic model approach (Band, 2012).

2 Methods

2.1 Overview

8 The number of avian collisions can be estimated through:

$$FoT\ x\ Q2r\ x\ probability\ of\ collision$$

where:

FoT = Flux rate multiplied by the operational time of the wind farm,

Q2r = Proportion of flying birds at collision risk height

Probability of collision = the probability of a single bird colliding with a turbine assuming no avoidance behaviour

9 Both methods of predicting the number of collisions (sCRM and Band (2012)) can use two model frameworks: Basic and Extended. The Basic model uses site-based flight height or generic flight height distributions but assumes a uniform distribution of risk over the rotor swept area, while the Extended model also uses a flight height distribution but considers how risk varies over the area of the turbine blades. Depending on the nature of the seabird flight height data used, different 'Options' are selected (Masden, 2015):

- Option 1: Basic model: Proportion of birds at collision height (calculated manually) based on site-specific flight height data, which assumes a uniform distribution of risk over the extent of the rotor swept area.
- Option 2: Basic model: Proportion of birds at collision risk height (calculated automatically), based on a generic flight height distribution, also assuming a uniform distribution of risk over the rotor swept area.
- Option 3: Extended model: Proportion of birds at collision height calculated by integrating risk across a rotor swept area at different points along a generic flight height distribution.
- Option 4: Extended model: Proportion of birds at collision height calculated by integrating risk across a rotor swept area at different points using site-specific flight height distribution.

10 For assessment of the Salamander Project, Option 2 was selected, using a generic flight height distribution (Johnston *et al*., 2014a, 2014b), assuming uniform distribution of risk to birds within the rotor swept area. There were not enough site-specific flight height data for the Offshore Array Area for site-specific flight heights to be used. As mentioned in Section 3, the sCRM will primarily be used to assess collision risk, as it allows stochasticity to be integrated by randomly sampling from the statistical distributions of the input parameters to provide measures of uncertainty. Results from Band (2012) are provided for context in Appendix I: Input seabird densities and model outputs.

11 The generic flight height data presented in Johnston *et al*. (2014) are derived mainly from boat-based surveys from 32 sites in the North, Baltic and Irish Seas between 1998 and 2012. The advantage of using pooled data from these sites means there is a larger sample from which to derive seabird flight heights, compared to site-specific data. Individual flight heights were estimated with uncertainty, to allow variation in flight height estimation to be incorporated while improving the accuracy of flight height distributions.

12 Both stochastic and deterministic estimates were generated using the R package stochLAB (Caneco, 2022) which contains the functions that underpin the sCRM tool shiny app created by the same team. R code can be made available upon request. The seed used within the sCRM was 1234; 5,000 iterations were performed. The Standard Deviation (SD) around estimates is presented for assessment of collision mortality using the stochastic framework (sCRM).

2.2 Input parameters

2.2.1 Turbine parameters

13 One turbine scenario has been modelled for the Salamander Project, using the input parameters presented in Table 1. The outlined scenario involves seven turbines with a maximum rotor swept area of 343,612m^2 and an air gap of 22m. As only one scenario was modelled, the turbine scenario with an air gap of 22m represents both the 'worst-case' and 'most likely' scenarios.

14 The turbines are expected to be operational on average 94.5% of the time. This allows for downtime due to wind speed or scheduled/unscheduled maintenance activities. It is important to note that the generating capacity of the turbines has no influence on model outputs and will not function as a maximum design parameter.

Table 1 Salamander turbine parameter values

Turbine Parameter	Parameter Value
Latitude	57.616
Windfarm width (km)	8.7
Tidal offset (m)	n/a (floating WTGs)
No. turbines	7
No. blades	3
Rotor radius (m)	125
Max. blade width (m)	6.5
Rotation speed (RPM)	6.3
Pitch (degrees)	2.7
Max. rotor swept area (m^2)	343,612
Air gap	22m
Estimate of turbine downtime/operational time	3.3/94.5

2.2.2 Seabird parameters

15 CRM uses *a priori* agreed seabird parameters, as advised by NatureScot (2023). Following usual practice, flapping flight characteristics have been assumed for all species, bar gannet. Note that the flight speeds used within CRM (Pennycuick, 1997 and Alerstam *et al*., 2007) are likely to have a large degree of associated uncertainty, as they are based on very small sample sizes, ranging from two (kittiwake) to 32 (gannet). Flight speeds are also likely to be influenced by environmental conditions, the most notable of which is likely to be wind speed.

16 Seabird flight activity, e.g. the density of flying birds, within the Offshore Array Area is required therefore monthly mean densities of flying seabirds during the two years of DAS have been calculated. These are presented in Appendix I: Input seabird densities and model outputs.

17 Although uncertainty around these estimates is presented, it is not possible to apply these values when running CRM using the deterministic model framework (Band, 2012). Seabird parameters used in CRM are presented in Table 2.

Table 2 Seabird parameters used in Collision Risk Modelling. Standard deviation of body length and wingspan presented within parentheses

Species	Body length (m)	Wingspan (m)	Flight speed (m/s^{-1})	Nocturnal activity (%)	Flight type
Kittiwake	0.39 (0.005)	1.08 (0.0625)	13.1	25.0	Flapping
Great black-backed gull	0.71 (0.035)	1.58 (0.0375)	13.7	37.5	Flapping
Herring gull	0.60 (0.0225)	1.44 (0.03)	12.8	37.5	Flapping
Fulmar	0.45 (0.025)	1.07 (0.025)	13.0	80.0	Flapping
Gannet	0.935 (0.0325)	1.73 (0.0375)	14.9	8.0	Gliding

2.2.3 Avoidance rates

18 The Statutory Nature Conservation Bodies (SNCBs) provided advice on CRM avoidance rates (SNCBs, 2014) in response to Cook *et al.* (2014) and are presented in Table 3. NatureScot will shortly also be providing avoidance rates using collision data from both terrestrial and marine wind farms (Ozsanlav-Harris *et al*., 2023), shown in Table 3 and Table 4. Both sets of avoidance rates have been adopted for use in assessment using the deterministic (Band, 2012) and stochastic model framework (sCRM). The project-alone PVAs are based on the SNCBs (2014) avoidance rates only as no scenarios using the Ozsanlav-Harris et al. (2023) rates (i.e. the Applicant Approach) met the threshold for PVA. The cumulative assessment PVAs are based on the Ozsanlav-Harris et al. (2023) rates to align with the Applicant Approach to assessment, which informs the project alone and cumulative effects assessments.

Table 3 Stochastic Collision Risk Modelling (sCRM) avoidance rates and associated standard deviation

Species	Avoidance rate (SNCBs, 2014)	Avoidance rate (Ozsanlav-Harris *et al.*, 2023)
Kittiwake	0.989 (+/- 0.002)	0.993* (+/- 0.0003)
Great black-backed gull	0.995 (+/- 0.001)	0.994 (+/- 0.0004)
Herring gull	0.995 (+/- 0.001)	0.994 (+/- 0.0004)
Fulmar	0.990 (+/- 0.001)	0.991 (+/- 0.0002)
Gannet	0.989 (+/- 0.002)	0.993 (+/- 0.0003)

* *The all gull rate was used as recommended in NatureScot guidance*

Table 4 Deterministic Collision Risk Modelling (Band, 2012) avoidance rates (with +/- 2 standard deviations)

Species	Avoidance rate (SNCBs, 2014)	Avoidance rate (Ozsanlav-Harris *et al.*, 2023)
Kittiwake	0.989 (+/- 0.002)	0.992*
Great black-backed gull	0.995 (+/- 0.002)	0.994
Herring gull	0.995 (+/- 0.002)	0.994
Fulmar	0.990 (+/- 0.002)	0.990
Gannet	0.989 (+/- 0.002)	0.992

* *The all gull rate was used as recommended in NatureScot guidance*

2.2.4 Seasonality

19 Collision mortality estimates are presented annually and per season for each of the assessed species and are derived from population estimates of flying birds calculated per survey (see Annex ER.A.4.12.1: Offshore Ornithology Baseline Data). Within this assessment, both the breeding and non-breeding seasons follow NatureScot (2020) guidance (Table 5) and are defined as follows:

- **Breeding season** – birds strongly associated with nest site, including nesting, egg laying and provisioning young.
- **Non-breeding season** – any period outwith the above, which may encompass birds over-wintering in an area and migration periods between breeding and wintering sites.

Table 5 Defined seasons for assessed species (NatureScot, 2020)

Species	Breeding season	Non-breeding season
Kittiwake	mid Apr – Aug	Sep – mid Apr
Great black-backed gull	Apr – Aug	Sep – Mar
Herring gull	Apr – Aug	Sep – Mar
Fulmar	Apr – mid Sep	mid Sep – Mar
Gannet	mid Mar – Sep	Oct – mid Mar

20 Where a season starts or ends midway through a month, impacts were estimated per month and allocated 50:50 into each season from the split month, as applicable, following NatureScot guidance (NatureScot, 2023).

3 Results

21 Collision mortality estimates for each species from sCRM are presented by season (as defined in Table 5) and are presented for all birds (all colliding birds are assumed to be breeding adults). Within this section, results from the CRM are presented, based on seven turbines (22m air gap) (Table 6).

Collision mortality estimates calculated using the deterministic modelling framework (Band, 2012), for all avoidance rates are presented in Appendix I: Input seabird densities and model outputs.

Table 6 **Seasonal collision mortalities (number of birds) using SNCBs (2014) avoidance rates. Stochastic model outputs will be used in further analysis of impacts. Deterministic outputs shown here for context.**

Species	**Stochastic (sCRM)**				**Deterministic (Band, 2012)**			
	Avoidance rate	**Breeding season (SD)**	**Non-breeding season (SD)**	**Annual total (SD)**	**Avoidance rate**	**Breeding season**	**Non-breeding season**	**Annual total**
Kittiwake *Breeding season mid Apr - Aug* *Non-breeding season Sep – mid Aug*	0.989 (+/- 0.002)	23 (8)	3 (0)	**26 (8)**	0.989 (+/- 0.002)	22	2	**24**
Great black-backed gull *Breeding season Apr - Aug* *Non-breeding season Sep – Mar*	0.995 (+/- 0.001)	0 (0)	3 (1)	**3 (1)**	0.995 (+/- 0.002)	0	3	**3**
Herring gull *Breeding season Apr - Aug* *Non-breeding season Sep – Mar*	0.995 (+/- 0.001)	0 (0)	4 (2)	**4 (2)**	0.995 (+/- 0.002)	0	3	**3**
Fulmar *Breeding season Apr – mid Sep* *Non-breeding season mid Sep - Mar*	0.990 (+/- 0.001)	0 (1)	7 (8)	**7 (8)**	0.990 (+/- 0.002)	0	2	**2**

Species	**Stochastic (sCRM)**				**Deterministic (Band, 2012)**			
	Avoidance rate	**Breeding season (SD)**	**Non-breeding season (SD)**	**Annual total (SD)**	**Avoidance rate**	**Breeding season**	**Non-breeding season**	**Annual total**
Gannet *Breeding season mid Mar - Sep* *Non-breeding season Oct – mid Mar*	0.989 (+/- 0.002)	5 (3)	4 (1)	**9 (3)**	0.989 (+/- 0.002)	5	4	**9**

Table 7 **Seasonal collision mortalities (number of birds) using Ozsanlav-Harris *et al.* (2023) avoidance rates**

Species	Stochastic (sCRM)				Deterministic (Band, 2012)			
	Avoidance rate	Breeding season (SD)	Non-breeding season (SD)	Annual total (SD)	Avoidance rate	Breeding season	Non-breeding season	Annual total
Kittiwake *Breeding season mid Apr - Aug* *Non-breeding season Sep – mid Aug*	0.993 (+/- 0.0003)	14 (4)	0 (0)	**14 (4)**	0.992	15	0	**15**
Great black-backed gull *Breeding season Apr - Aug* *Non-breeding season Sep – Mar*	0.994 (+/- 0.0004)	0 (0)	3 (1)	**3(1)**	0.994	0	3	**3**
Herring gull *Breeding season Apr - Aug* *Non-breeding season Sep – Mar*	0.994 (+/- 0.0004)	0 (0)	5 (2)	**5 (2)**	0.994	0	3	**3**
Fulmar *Breeding season Apr – mid Sep* *Non-breeding season mid Sep - Mar*	0.991 (+/- 0.0002)	0 (0)	6 (7)	**6 (7)**	0.990	0	2	**2**
Gannet *Breeding season mid Mar – Sep* *Non-breeding season Oct – mid Mar*	0.993 (+/- 0.0003)	4 (2)	2 (1)	**6 (2)**	0.992	4	2	**6**

4 Discussion

22 The impact of estimated collisions is assessed in the context of species-specific regional populations for the breeding and non-breeding seasons for EIA purposes. Breeding season regional populations were derived using mean-max foraging range + 1SD (mmfr + 1SD) (Woodward *et al*., 2019) in conjunction with seabird colony data from the Seabird Monitoring Programme (SMP) hosted by the British Trust for Ornithology (BTO). For fulmar, since the foraging range encompasses all colonies within the UK and Ireland, the decision was made to restrict the breeding season range to sites on the north and east coasts of Scotland and northern England. Non-breeding season regional populations were taken from Furness (2015), Biologically Defined Minimum Population Scales (BDMPS). For more detail on how regional populations were calculated, and which colonies were included in analysis, please see Annex ER.A.4.12.8 Offshore Ornithology Regional Populations Report.

23 Following NatureScot advice, for guillemot and herring gull, non-breeding season regional populations were calculated using the breeding season mmfr + 1SD, as it is expected that the majority of the breeding season population will not disperse widely during the wintering period (see Buckingham *et al*. (2022) for more information on UK guillemot wintering distribution). For herring gull during the non-breeding period, an additional correction of 29.8% was applied to the breeding season regional population, to account for the influx of non-UK and west coast UK birds into the North Sea BDMPS during the non-breeding season, following NatureScot guidance and advice on Scoping Report (dated 5th May 2023).

24 Table 8 shows that annual collision estimates, even if all collisions are assumed to be breeding adult birds, are a negligible proportion of the regional populations of each of the species considered for collision assessment.

Table 8 Estimated collision mortalities (number of birds) using sCRM and SNCB 2014 avoidance rates, as a proportion of regional populations of key species during the breeding (adults only) and non-breeding (all ages) seasons. Standard deviation of estimated collisions presented in brackets

	Kittiwake	Great black-backed gull	Herring gull	Fulmar	Gannet
Breeding					
Regional population (adult individuals)	202,258	98	14,612	375,261	432,894
Estimated collisions (SD)	23 (8)	0 (0)	0 (0)	0 (1)	8 (3)
% of regional population	<0.001	-	-	<0.001	<0.001
Non-breeding					
Regional population (adult individuals)	627,816[a]	91,399	20,551	568,736	248,385 [a]
Estimated collisions (SD)	3 (0)	3 (1)	4 (2)	7 (8)	4 (1)
% of regional population	<0.001	<0.001	<0.001	<0.001	<0.001

a – spring migration population from Furness 2015, the smaller of the two non-breeding season estimates

4.1 Comparison of approaches

25 For most species, collision mortality estimates from sCRM and deterministic (Band, 2012) frameworks were largely similar (Table 6 and Table 7). For kittiwake, estimated collision mortality was the same between models when using the SNCBs (2014) avoidance rates. The predicted kittiwake mortalities during the breeding season remained similar between the two model types (difference of one bird), however, the SNCBs (2014) avoidance rates resulted in notably higher mortalities, compared to Ozsanlav-Harris *et al.* (2023).

26 Great black-backed gull estimated collision mortality was the same when comparing model outputs using the same avoidance rates; the estimated mortality was marginally lower using the deterministic (Band, 2012) model with SNCBs (2014) rates. Estimated collision mortality of herring gulls followed the same pattern between both avoidance rates, with slightly higher mortality predicted using sCRM.

27 Higher collision mortality was predicted for fulmar during the non-breeding season, with increased mortalities estimated using the sCRM. Model type did not appear to have much of an effect on the number of collision mortalities predicted for gannet, although using the interim advised avoidance rates (SNCBs, 2014) did affect results, with fewer collisions predicted using Ozsanlav-Harris *et al.* (2023) avoidance rates.

28 Despite providing similar results, estimated collision mortalities from sCRM are preferable to those derived using the deterministic model since measures of uncertainty and variability can be incorporated into the model. Presenting collision mortality estimates without including a measure of uncertainty greatly simplifies the complexity of interactions between birds and wind turbines while incorporating variability is crucial when considering how variable input parameters such as site-specific density estimates, flight speed and turbine parameters are likely to be (Masden, 2015).

5 References

Alerstam, T., Rosén, M., Bäckman, J., Ericson, P.G. and Jellgren, O. (2007). Flight speeds among bird species: allometric and phylogenic effects. *PLoS Biology*, 5(8), 197.

Band, W. (2012). *Using a collision risk model to assess bird collision risks for offshore wind farms*. Report to the Crown Estate Strategic Ornithological Services (SOSS).

Buckingham, L., Bogdanova, M.I., Green, J.A., Dunn, R.E., Wanless, S., Bennett, S., Bevan, R.M., *et al.* (2022). Interspecific variation in non-breeding aggregation: a multi-colony tracking study of two sympatric seabirds. *Marine Ecology Progress Series*, 684: 181-197

Caneco, B., Humphries, G., Cook, A. and Masden E. (2022). *Estimating bird collisions at offshore windfarms with stochLAB*. R package: URL https://hidef-aerial-surveying.github.io/stochLAB/.

Cook, A.S.C.P., Humphreys, E.M., Masden, E.A. and Burton, N.K.H. (2014). *The avoidance rates of collision between birds and offshore turbines*. Scottish Marine and Freshwater Science Volume 5, Number 16.

Furness, R.W. (2015). *Non-breeding season populations of seabirds in UK waters: Population sizes for Biologically Defined Minimum Population Scales (BDMPS)*. Natural England Commissioned Reports, No.164.

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

Johnston, A., Cook, A.S., Wright, L.J., Humphreys, E.M. & Burton, N.H. (2014). Modelling flight heights of marine birds to more accurately assess collision risk with offshore wind turbines. *Journal of Applied Ecology*, 51(1), 31-41.

Masden, E. (2015). *Developing an avian collision risk model to incorporate variability and uncertainty*. Scottish Marine and Freshwater Science. 6(14).

NatureScot. (2020). *Seasonal Periods for Birds in the Scottish Marine Environment*. NatureScot. Available at {Guidance note - Seasonal definitions for birds in the Scottish Marine Environment.pdf} [Accessed 17/05/2023].

NatureScot. (2023). Guid*ance Note 7: Guidance to support Offshore Wind Applications: Marine Ornithology - Advice for assessing the collision risk of marine birds*. NatureScot.

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

Pennycuick, C.J. (1997). Actual and 'Optimum' Flight speed: Field Data Reassessed. *Journal of Experimental Biology*, 200(17), 2355-2361

Statutory Nature Conservation Bodies (SNCBs). (2014). *Joint Response from the Statutory Nature Conservation Bodies to the Marine Scotland Science Avoidance Rate Review*. SNCB.

Wade. H.M., Masden, E.A., Jackson, A.C., and Furness, R.W. (2016) Incorporating data uncertainty when estimating potential vulnerability of Scottish Seabirds to marine energy developments. Marine Policy 70 108-113

Woodward, I., Thaxter, C. B., Owen, E. and Cook, A.S.C.P. (2019). *Desk-based revision of seabird foraging ranges used for HRA screening.* BTO research report number 724.

Appendix I: Input seabird densities and model outputs

29 The mean densities of key species used in sCRM and deterministic (Band, 2012) modelling are presented in Table 9. Estimated collision mortalities from sCRM are presented in Table 10 with deterministic outputs presented in Table 11.

30 The standard deviations of the mean densities of flying birds are calculated by way of a blocked bootstrap where transects of a survey are randomly sampled with replacement. These values represent the dispersion of the mean densities of the transects around the monthly mean that is used for generation of a population estimate. All other required input parameters were the same as detailed in Section 2.2.

Table 9 Mean density of flying birds within the Offshore Array Area (n/km^2)

Species		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kittiwake	Mean density	0.00	0.00	0.25	0.20	0.82	1.80	2.37	7.17	0.35	0.27	0.36	0.43
	Standard deviation	-	-	0.18	0.21	0.44	1.04	0.75	3.44	0.34	0.18	0.31	0.25
Great black-backed gull	Mean density	0.873	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00
	Standard deviation	0.32	-	-	-	-	-	-	-	-	-	0.15	-
Herring gull	Mean density	0.24	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.17	0.25
	Standard deviation	0.09	-	0.24	-	-	-	-	-	-	-	1.26	0.19
Fulmar	Mean density	2.71	0.69	0.35	0.26	0.50	0.28	1.29	1.14	0.60	0.25	19.39	1.12
	Standard deviation	1.27	0.28	0.40	0.08	0.21	0.17	0.27	0.25	0.21	0.24	4.23	0.49
Gannet	Mean density	0.13	0.00	0.39	0.13	0.64	0.54	0.12	1.60	0.47	0.22	1.70	0.00
	Standard deviation	0.12	-	0.31	0.12	0.41	0.31	0.17	0.56	0.31	0.22	0.63	-

Table 10 Estimated collision mortalities using the stochastic Collision Risk Model (sCRM)

Species	Avoidance rates	Jan (SD)	Feb (SD)	Mar (SD)	Apr (SD)	May (SD)	Jun (SD)	Jul (SD)	Aug (SD)	Sep (SD)	Oct (SD)	Nov (SD)	Dec (SD)
Kittiwake	SNCB (2014)	0 (0)	0 (0)	0 (0)	0 (0)	2 (1)	4 (2)	4 (2)	13 (7)	1 (0)	0 (0)	1 (0)	1 (0)
Kittiwake	Ozsanlav-Harris *et al.* (2023)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	2 (1)	3 (1)	8 (4)	0 (0)	0 (0)	0 (0)	0 (0)
Great black-backed gull	SNCB (2014)	2 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)	0 (0)
Great black-backed gull	Ozsanlav-Harris *et al.* (2023)	2 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)	0 (0)
Herring gull	SNCB (2014)	0 (0)	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (2)	0 (0)
Herring gull	Ozsanlav-Harris *et al.* (2023)	0 (0)	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (2)	1 (0)
Fulmar	SNCB (2014)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (1)	0 (1)	0 (0)	0 (0)	6 (8)	0 (1)
Fulmar	Ozsanlav-Harris *et al.* (2023)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	5 (7)	0 (0)
Gannet	SNCB (2014)	0 (0)	0 (0)	1 (1)	0 (0)	1 (1)	1 (1)	0 (0)	3 (2)	1 (1)	0 (0)	2 (1)	0 (0)

Species	**Avoidance rates**	**Jan (SD)**	**Feb (SD)**	**Mar (SD)**	**Apr (SD)**	**May (SD)**	**Jun (SD)**	**Jul (SD)**	**Aug (SD)**	**Sep (SD)**	**Oct (SD)**	**Nov (SD)**	**Dec (SD)**
Gannet	Ozsanlav-Harris *et al.* (2023)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	1 (1)	0 (0)	2 (1)	1 (0)	0 (0)	1 (1)	0 (0)

Table 11 **Estimated collision mortalities using the deterministic Collision Risk Model (Band, 2012)**

Species	Avoidance rates	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kittiwake	SNCB (2014)	0	0	0	0	2	3	4	13	1	0	0	1
Kittiwake	Ozsanlav-Harris *et al.* (2023)	0	0	0	0	1	2	3	9	0	0	0	0
Great black-backed gull	SNCB (2014)	2	0	0	0	0	0	0	0	0	0	1	0
Great black-backed gull	Ozsanlav-Harris *et al.* (2023)	2	0	0	0	0	0	0	0	0	0	1	0
Herring gull	SNCB (2014)	0	0	1	0	0	0	0	0	0	0	2	0
Herring gull	Ozsanlav-Harris *et al.* (2023)	0	0	1	0	0	0	0	0	0	0	2	0
Fulmar	SNCB (2014)	0	0	0	0	0	0	0	0	0	0	2	0
Fulmar	Ozsanlav-Harris *et al.* (2023)	0	0	0	0	0	0	0	0	0	0	2	0
Gannet	SNCB (2014)	0	0	1	0	1	1	0	3	1	0	2	0

Species	**Avoidance rates**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Gannet	Ozsanlav-Harris *et al.* (2023)	0	0	0	0	1	1	0	2	1	0	1	0