Environmental Impact Assessment Report
Volume 3, Appendix 12.6: Offshore Ornithology Migratory Collision Risk Modelling

MarramWind Offshore Wind Farm

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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 MarramWind Offshore Wind Farm (hereafter, referred to as 'the Project'). This Appendix specifically relates to the potential for migratory non-seabirds 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 Option Agreement Area (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 Migratory Collision Risk Modelling

1.2.1.1 There is the potential for migratory birds flying through the OAA to collide with rotating blade of the turbines and any associated infrastructure. Migratory species are at risk when passing through the area on seasonal migration. The potential collision risk to each species can be estimated throughout the year by using CRM.

1.2.1.2 To characterise the baseline environment for offshore ornithology, 24 months of site-specific DAS have been completed for the Project, as detailed within **Appendix 12.1**. While the results of these surveys provide information on the likely abundance and distribution of key seabird species for each biological period, they also have limitations. In particular, neither these surveys nor any other existing generally applied survey methods are likely to provide reliable estimates of bird numbers during migration periods, particularly non-seabirds. This is due to the snapshot nature of baseline surveys, which has the potential to miss some species moving through in short pulses, in poor weather or at night (when no surveys take place), or at high altitudes, which makes recording their numbers extremely complex using standard methods.

1.2.1.3 One solution is to model migratory bird movements through the OAA using the Marine Scotland Avian Migration Collision Risk Model Shiny Application ("mCRM App"; HiDef Aerial Surveying Ltd., 2024). Hereafter, referred to as the 'mCRM tool'.

1.2.1.4 The use of the mCRM tool is not suitable for all bird species, in particular species that do not follow a point-to-point migration pattern (Alerstam, 1990). Many seabirds fall into this category (Wernham *et al.,* 2002), with some seabirds known to take longer routes, for example following the coastline in preference to a more direct route over land. The strategic review of birds on migration in Scottish waters (Woodward *et al.,* 2023) considered that "*Seabird exposure to offshore wind farms will be captured in the density estimates entered into the existing sCRM*."

1.2.1.5 Woodward *et al.* (2023) further stated that additional migratory modelling is not recommended for seabirds due to "*Distinguishing between migrant and resident seabirds is not possible" and "to avoid double-counting of collisions in seabirds, assessment of collision risk of seabirds is best undertaken using the existing model.*"

1.2.1.6 Therefore, in accordance with this recommendation, it is assumed that appropriate consideration of migratory collision risk for seabirds is already captured within **Appendix 12.3: Offshore Ornithology Collision Risk Modelling**.

2. Methods

2.1 Overview

2.1.1.1 CRM was conducted using the mCRM tool, a stochastic adaptation of the Band (2012) migration collision risk model, as advised in NautreScot guidance (NatureScot, 2025). The tool was accessed via the Shiny App interface - a user-friendly platform operable through a standard web browser or within R statistical software (R Core Team, 2021), which applies R code to estimate migratory collision risk (Donovan, 2017). The latest version (v0.3.0) of the tool was downloaded and run locally in R due to issues with uploading custom windfarm shapefiles within the online version. The model estimates the number of species-specific flightpaths intersecting the OAA and applies stochastic methods to predict associated mortality.

2.1.1.2 The approach to modelling also considered the information presented in The Scottish Government's strategic study of collision risk for birds on migration (Woodward *et al*., 2023) as advised by NatureScot (2025). Specifically, this study was used to determine relevant populations of migratory birds which are predicted to be present in Scottish waters, and consequently the proportion of birds at risk of collision with the OAA.

2.2 Species selection

2.2.1.1 Within the mCRM tool, 70 species are included for modelling potential migratory collisions. All species were considered and assessed as a precautionary approach with the exception of gannet (*Morus bassanus*), due to potential for collision risk whilst on migration already captured within modelling presented within **Appendix 12.3**.

2.2.1.2 The species included in the mCRM tool are provided in **Table 2.1** below, along with the total population in the UK (derived from the total biogeographic population and the proportion of the population passing through the UK, both derived from Woodward *et al*. (2023)). The percentage of this population at collision risk was derived by the mCRM tool based on the location of the Project. Notably, of the 69 species modelled, 20 were not predicted to pass through the OAA (**Table 2.1**). These 20 species are scoped out from further consideration due to lack of theoretical connectivity suggesting these species are not at risk of collision whilst on migration.

Table 2.1 Population estimates of species modelled within the mCRM and the proportion of the population at risk of collision with the Project

Species	Total population in UK based on Woodward *et al*., 2023 (individuals)	Percentage of the population at risk of collision with the Project (%)
Whooper swan (*Cygnus cygnus*)	39,990	2.9
Bewick's swan (*Cygnus columbianus bewickii*)	4,382	0.0
Taiga bean goose (*Anser fabalis*)	970	5.2
Pink-footed goose (*Anser brachyrhynchus*)	500,000	0.0

Species	Total population in UK based on Woodward *et al.*, 2023 (individuals)	Percentage of the population at risk of collision with the Project (%)
Greenland white-fronted goose (*Anser albifrons flavirostris*)	21,500	0.0
European white-fronted goose (*Anser albifrons albifrons*)	12,000	0.0
Icelandic greylag goose (*Anser anser*)	68,400	0.0
Svalbard barnacle goose (*Branta leucopsis*)	43,500	12.9
Greenland barnacle goose (*Branta leucopsis*)	72,000	0.0
Canadian light-bellied brent goose (*Branta bernicla hrota*)	37,000	0.0
Svalbard light-bellied brent goose (*Branta bernicla hrota*)	13,400	5.2
Dark-bellied brent goose (*Branta bernicla bernicla*)	99,170	0.0
Shelduck (*Tadorna tadorna*)	50,995	1.9
Wigeon (*Mareca penelope*)	480,000	1.6
Gadwall (*Mareca strepera*)	30,940	0.0
Teal (*Anas crecca*)	435,500	0.0
Mallard (*Anas platyrhynchos*)	823,600	1.8
Pintail (*Anas acuta*)	20,942	1.7
Shoveler (*Spatula clypeata*)	22,960	1.5
Pochard (*Aythya ferina*)	28,500	0.0
Tufted duck (*Aythya fuligula*)	155,000	1.6
Scaup (*Aythya marila*)	7,000	0.0
Long-tailed duck (*Clangula hyemalis*)	12,800	2.2
Eider (*Somateria mollissima*)	106,720	1.9
Common scoter (*Melanitta nigra*)	134,964	1.7
Velvet scoter (*Melanitta fusca*)	33,497	2.2
Goldeneye (*Bucephala clangula*)	37,500	2.3

Species	Total population in UK based on Woodward *et al.*, 2023 (individuals)	Percentage of the population at risk of collision with the Project (%)
Red-breasted merganser (*Mergus serrator*)	15,840	2.0
Goosander (*Mergus merganser*)	17,420	4.3
Oystercatcher (*Haematopus ostralegus*)	358,900	1.7
Ringed plover (*Charadrius hiaticula*)	225,600	1.2
Golden plover (*Pluvialis apricaria*)	3,135,000	1.6
Grey plover (*Pluvialis squatarola*)	124,000	2.0
Lapwing (*Vanellus vanellus*)	3,942,500	1.7
Knot (*Calidris canutus*)	360,000	1.8
Sanderling (*Calidris alba*)	200,000	1.7
Purple sandpiper (*Calidris maritima*)	24,400	2.3
Dunlin (*Calidris alpina*)	2,021,808	1.8
Ruff (*Calidris pugnax*)	31,000	2.0
Snipe (*Gallinago gallinago*)	2,331,000	1.7
Black-tailed godwit (*Limosa limosa*)	303,000	0.0
Bar-tailed godwit (*Limosa lapponica*)	680,000	1.7
Whimbrel (*Numenius phaeopus*)	936,000	1.4
Curlew (*Numenius arquata*)	141,100	2.1
Greenshank (*Tringa nebularia*)	7,200	1.9
Wood sandpiper (*Tringa glareola*)	54	2.2
Redshank (*Tringa totanus*)	747,000	1.6
Turnstone (*Arenaria interpres*)	347,000	1.6
Red-necked phalarope (*Phalaropus lobatus*)	20	0.0
Dotterel (*Charadrius morinellus*)	390	2.8
Avocet (*Recurvirostra avosetta*)	13,090	0.0

Species	Total population in UK based on Woodward *et al.*, 2023 (individuals)	Percentage of the population at risk of collision with the Project (%)
Stone curlew (*Burhinus oedicnemus*)	880	0.0
Marsh harrier (*Circus aeruginosus*)	2,576	2.1
Hen harrier (*Circus cyaneus*)	2,176	1.7
Montagu's harrier (*Circus pygargus*)	19	0.0
Osprey (*Pandion haliaetus*)	665	2.3
Merlin (*Falco columbarius*)	8,256	0.4
Short-eared owl (*Asio flammeus*)	14,880	1.7
Honey buzzard (*Pernis apivorus*)	137	0.0
White-tailed eagle (*Haliaeetus albicilla*)	296	0.0
Great northern diver (*Gavia immer*)	11,000	1.6
Black-throated diver (*Gavia arctica*)	1,180	2.6
Red-throated diver (*Gavia stellata*)	34,000	2.3
Bittern (*Botaurus stellaris*)	714	0.2
Great crested grebe (*Podiceps cristatus*)	1,380	0.0
Slavonian grebe (*Podiceps auritus*)	3,122	2.0
Spotted crake (*Porzana porzana*)	26	3.8
Corncrake (*Crex crex*)	16,960	1.9
Nightjar (*Caprimulgus europaeus*)	7,700	2.1

2.3 Migratory Collision Risk Modelling input parameters

2.3.1 Turbine parameters

2.3.1.1 The OAA boundary (as presented within **Volume 1, Chapter 4: Project Description** and **Volume 2, Figure 4.2: Offshore Red Line Boundary**) shapefile was loaded into the mCRM tool as required, alongside the turbine parameters presented in **Table 2.2**. The tool's inbuilt 'Large Array Correction' factor was applied to modelling based on the size and layout

of the Project. These parameters are consistent with collision risk modelling presented within **Appendix 12.3**, with the exception of array width due to mCRM measuring the value differently to what is required for the stochastic CRM (sCRM). As recommended within NatureScot's Guidance Note 7 (NatureScot, 2025) a worst case and best-case scenario are modelled to provide the range of potential collision risk posed by the Project.

Table 2.2 Turbine and array parameters used to inform CRM

Input parameter	Worst case design scenario	Most likely design scenario
Number of wind turbine generators (WTGs)	225	126
Number of blades per WTG	3	3
Rotor radius	118 metres (m)	163m
Maximum blade width	5.1m	10m
OAA width	19.81 kilometres (km)	19.81km
Latitude	58.16 degrees	58.16 degrees
Rotation speed	8.00 revolutions per minute (rpm)	7.62rpm
Average pitch at site mean speed	3.50 degrees	3.50 degrees

2.3.1.2 In addition to the aforementioned wind turbine parameters (**Table 2.2**), the estimated percentage of time in which the turbines are predicted to be operational per month (across all turbines) is included within modelling. This is based on the monthly wind availability and maintenance downtime values presented in **Table 2.3**.

Table 2.3 Predicted wind availability (per cent) and mean maintenance downtime (per cent) for the Project

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind availability (%)	97	96	96	94	93	92	90	92	95	97	97	96
Mean maintenance downtime (%)	3	4	4	6	7	8	10	8	5	3	3	4
Maintenance downtime standard deviation (SD)	0	0	0	0	0	0	0	0	0	0	0	0

2.3.2 Seasonal definitions

2.3.2.1 The default seasonal definitions within the mCRM tool were utilised and are presented in **Table 2.4**. For most species, two seasons (pre- and post-breeding migration) are specified, though for some species (for example, mallard), a third season of 'other' is identified as a period where other migratory movements (for example, moult migration) may occur for some species.

Table 2.4 Seasonal definitions used in the mCRM assessment

Species	Pre-breeding migration	Post-breeding migration	Other
Whooper swan	February to April	September to November	N/A
Bean goose	January to February	September to December	N/A
Svalbard barnacle goose	March to May	September to October	N/A
Svalbard light-bellied brent goose	March only	August to October	N/A
Shelduck	January to February	June to July	August to December
Wigeon	March to April	August to November	N/A
Mallard	April to June	September to October	January to March
Pintail	March to May	August to November	N/A
Shoveler	March to June	July to August	September to December
Tufted duck	April to June	September to October	N/A
Long-tailed duck	March to May	September to October	N/A
Eider	March to April	October to November	N/A
Common scoter	April to May	June to October	N/A
Velvet scoter	March to May	June to September	N/A
Goldeneye	February to May	August to December	N/A
Red-breasted merganser	April to July	August to November	N/A
Goosander	March to May	June to September	N/A

Species	Pre-breeding migration	Post-breeding migration	Other
Oystercatcher	January to March	July to November	N/A
Ringed plover	March to May	August to October	N/A
Golden plover	February to May	July to October	N/A
Grey plover	March to May	July to September	N/A
Lapwing	January to May	October to November	N/A
Knot	February to May	June to October	N/A
Sanderling	April to June	July to October	N/A
Purple sandpiper	March to May	July to November	N/A
Dunlin	March to May	June to October	N/A
Ruff	March to May	July to November	N/A
Snipe	March to May	August to October	October to December
Bar-tailed godwit	March to April	July to October	N/A
Whimbrel	March to June	June to October	N/A
Curlew	March to May	June to October	N/A
Greenshank	March to June	August to November	N/A
Wood sandpiper	April to May	July to September	N/A
Redshank	March to May	July to September	N/A
Turnstone	January to June	July to August	N/A
Dotterel	March to June	August to November	N/A
Marsh harrier	March to May	August to November	N/A
Hen harrier	March to May	Sep to November	N/A
Osprey	March to April	August to October	N/A
Merlin	March to May	August to November	N/A
Short-eared owl	March to May	July to October	N/A

Species	Pre-breeding migration	Post-breeding migration	Other
Great northern diver	December to June	August to November	N/A
Black-throated diver	March to May	August to November	N/A
Red-throated diver	February to June	July to September	N/A
Bittern	January to May	June to October	N/A
Slavonian grebe	February to April	August to October	N/A
Spotted crake	May to June	July to October	N/A
Corncrake	April to May	July to August	N/A
Nightjar	April to May	August to September	N/A

2.3.3 Species biometrics and behavioural data

2.3.3.1 Species biometric and behavioural data used in the mCRM assessment are presented in **Table 2.5** below. All parameters used are the default recommended values within the mCRM tool.

Table 2.5 Species biometric and behavioural data used in the mCRM tool

Species	Flight type	Body Length (SD)	Mean wingspan (SD)	Flight speed (SD)	Avoidance rate (SD)	Proportion at collision risk height
Whooper swan	Flapping	1.52 (0.04)	2.30 (0.04)	17.50 (4.20)	0.9880 (0.00090)	0.50
Bean goose	Flapping	0.75 (0.06)	1.58 (0.06)	15.80 (1.31)	0.9990 (0.00010)	1.00
Svalbard barnacle goose	Flapping	0.64 (0.04)	1.38 (0.04)	17.40 (1.08)	0.9990 (0.00010)	1.00
Svalbard light-bellied brent goose	Flapping	0.58 (0.02)	1.15 (0.02)	17.90 (6.10)	0.9990 (0.00010)	0.50
Shelduck	Flapping	0.62 (0.02)	1.12 (0.02)	18.20 (4.30)	0.9850 (0.00080)	0.50
Wigeon	Flapping	0.48 (0.02)	0.80 (0.02)	18.50 (2.00)	0.9850 (0.00080)	1.00
Mallard	Flapping	0.58 (0.02)	0.90 (0.02)	15.86 (2.00)	0.9850 (0.00080)	1.00
Pintail	Flapping	0.58 (0.02)	0.88 (0.02)	21.90 (2.00)	0.9850 (0.00080)	1.00
Shoveler	Flapping	0.48 (0.02)	0.77 (0.02)	18.30 (2.00)	0.9850 (0.00080)	1.00
Tufted duck	Flapping	0.44 (0.01)	0.70 (0.01)	21.10 (1.10)	0.9850 (0.00080)	1.00
Long-tailed duck	Flapping	0.44 (0.01)	0.76 (0.01)	19.70 (1.70)	0.9850 (0.00080)	1.00
Eider	Flapping	0.60 (0.03)	0.94 (0.03)	17.34 (2.40)	0.9850 (0.00080)	0.25
Common scoter	Flapping	0.49 (0.03)	0.84 (0.03)	22.10 (4.00)	0.9850 (0.00080)	1.00
Velvet scoter	Flapping	0.54 (0.03)	0.94 (0.03)	20.10 (4.70)	0.9850 (0.00080)	1.00
Goldeneye	Flapping	0.46 (0.01)	0.72 (0.01)	20.30 (3.80)	0.9850 (0.00080)	1.00
Red-breasted merganser	Flapping	0.55 (0.01)	0.78 (0.01)	22.00 (2.90)	0.9850 (0.00080)	1.00

Species	Flight type	Body Length (SD)	Mean wingspan (SD)	Flight speed (SD)	Avoidance rate (SD)	Proportion at collision risk height
Goosander	Flapping	0.62 (0.03)	0.90 (0.03)	19.70 (1.10)	0.9850 (0.00080)	1.00
Oystercatcher	Flapping	0.42 (0.02)	0.83 (0.02)	13.00 (2.50)	0.9850 (0.00080)	1.00
Ringed plover	Flapping	0.19 (0.01)	0.52 (0.01)	16.00 (1.10)	0.9990 (0.00000)	1.00
Golden plover	Flapping	0.28 (0.01)	0.72 (0.01)	16.50 (1.80)	0.9990 (0.00000)	1.00
Grey plover	Flapping	0.28 (0.01)	0.77 (0.01)	16.50 (1.80)	0.9990 (0.00000)	1.00
Lapwing	Flapping	0.30 (0.01)	0.84 (0.01)	12.80 (1.30)	0.9990 (0.00000)	1.00
Knot	Flapping	0.24 (0.01)	0.59 (0.01)	24.60 (3.30)	0.9990 (0.00000)	1.00
Sanderling	Flapping	0.20 (0.01)	0.42 (0.01)	21.40 (1.10)	0.9990 (0.00000)	1.00
Purple sandpiper	Flapping	0.21 (0.01)	0.44 (0.01)	15.30 (1.90)	0.9990 (0.00000)	1.00
Dunlin	Flapping	0.18 (0.01)	0.40 (0.01)	15.30 (1.90)	0.9990 (0.00000)	1.00
Ruff	Flapping	0.25 (0.01)	0.53 (0.01)	16.90 (1.81)	0.9990 (0.00000)	1.00
Snipe	Flapping	0.26 (0.01)	0.46 (0.01)	17.10 (2.70)	0.9990 (0.00000)	1.00
Bar-tailed godwit	Flapping	0.38 (0.02)	0.75 (0.02)	18.30 (2.10)	0.9990 (0.00000)	1.00
Whimbrel	Flapping	0.41 (0.02)	0.82 (0.02)	13.80 (0.40)	0.9990 (0.00000)	1.00
Curlew	Flapping	0.55 (0.02)	0.90 (0.02)	15.40 (3.30)	0.9990 (0.00000)	1.00
Greenshank	Flapping	0.32 (0.01)	0.69 (0.01)	12.30 (3.30)	0.9990 (0.00000)	1.00
Wood sandpiper	Flapping	0.20 (0.01)	0.56 (0.01)	9.60 (1.70)	0.9990 (0.00000)	1.00

Species	Flight type	Body Length (SD)	Mean wingspan (SD)	Flight speed (SD)	Avoidance rate (SD)	Proportion at collision risk height
Redshank	Flapping	0.28 (0.01)	0.62 (0.01)	15.30 (4.10)	0.9990 (0.00000)	1.00
Turnstone	Flapping	0.23 (0.01)	0.54 (0.01)	10.00 (3.30)	0.9990 (0.00000)	1.00
Dotterel	Flapping	0.21 (0.01)	0.60 (0.01)	16.50 (1.80)	0.9990 (0.00000)	1.00
Marsh harrier	Flapping	0.52 (0.02)	1.22 (0.02)	13.20 (2.90)	0.9990 (0.00000)	0.50
Hen harrier	Flapping	0.48 (0.02)	1.10 (0.02)	11.40 (1.10)	0.9950 (0.00010)	1.00
Osprey	Flapping	0.56 (0.02)	1.58 (0.02)	10.60 (3.10)	0.9950 (0.00010)	0.50
Merlin	Flapping	0.28 (0.02)	0.56 (0.02)	12.70 (5.80)	0.9950 (0.00010)	1.00
Short-eared owl	Flapping	0.38 (0.02)	1.02 (0.02)	9.70 (2.00)	0.9890 (0.00030)	1.00
Great northern diver	Flapping	0.80 (0.02)	1.37 (0.02)	19.50 (1.60)	0.9870 (0.00190)	0.25
Black-throated diver	Flapping	0.66 (0.02)	1.20 (0.02)	19.30 (2.10)	0.9950 (0.00001)	0.25
Red-throated diver	Flapping	0.61 (0.02)	1.11 (0.02)	18.60 (3.90)	0.9950 (0.00001)	0.25
Bittern	Flapping	0.75 (0.02)	1.30 (0.02)	8.80 (2.00)	0.9940 (0.00030)	1.00
Slavonian grebe	Flapping	0.34 (0.02)	0.62 (0.02)	21.13 (1.55)	0.9950 (0.00001)	1.00
Spotted crake	Flapping	0.23 (0.02)	0.40 (0.02)	13.00 (2.00)	0.9950 (0.00001)	1.00
Corncrake	Flapping	0.28 (0.02)	0.50 (0.02)	13.00 (2.00)	0.9950 (0.00001)	1.00
Nightjar	Flapping	0.27 (0.02)	0.60 (0.02)	9.72 (3.30)	0.9950 (0.00001)	1.00

3. Results

3.1.1.1 The outputs from the mCRM assessment are presented in **Table 3.1** for the worst-case design scenario and **Table 3.2** for the best-case design scenario. Please note that for some species, the impact for the best-case scenario was predicted to be higher than the worst-case scenario.

Table 3.1 Summary of annual migratory collision estimates for the Project based on the worst-case design scenario

Species	Pre-breeding migration	Post-breeding migration	Other	Total
Whooper swan	0.885 ± 0.196	0.894 ± 0.198	0.000 ± 0.000	1.779 ± 0.279
Bean goose	0.005 ± 0.001	0.005 ± 0.001	0.000 ± 0.000	0.01 ± 0.001
Svalbard barnacle goose	0.482 ± 0.057	0.491 ± 0.058	0.000 ± 0.000	0.973 ± 0.081
Svalbard light-bellied brent goose	0.030 ± 0.011	0.029 ± 0.011	0.000 ± 0.000	0.059 ± 0.016
Shelduck	0.915 ± 0.174	0.863 ± 0.164	0.905 ± 0.172	2.683 ± 0.295
Wigeon	8.717 ± 1.662	8.740 ± 1.666	0.000 ± 0.000	17.457 ± 2.353
Mallard	18.182 ± 3.300	18.768 ± 3.406	18.834 ± 3.418	55.784 ± 5.846
Pintail	0.427 ± 0.070	0.431 ± 0.071	0.000 ± 0.000	0.858 ± 0.100
Shoveler	0.364 ± 0.074	0.353 ± 0.071	0.374 ± 0.075	1.091 ± 0.127
Tufted duck	2.716 ± 0.451	2.804 ± 0.465	0.000 ± 0.000	5.52 ± 0.648
Long-tailed duck	0.310 ± 0.047	0.315 ± 0.048	0.000 ± 0.000	0.625 ± 0.067
Eider	0.606 ± 0.112	0.619 ± 0.114	0.000 ± 0.000	1.225 ± 0.160
Common scoter	2.770 ± 0.488	2.762 ± 0.487	0.000 ± 0.000	5.532 ± 0.689
Velvet scoter	0.120 ± 0.023	0.118 ± 0.023	0.000 ± 0.000	0.238 ± 0.033
Goldeneye	0.930 ± 0.164	0.936 ± 0.165	0.000 ± 0.000	1.866 ± 0.233
Red-breasted merganser	0.339 ± 0.056	0.350 ± 0.058	0.000 ± 0.000	0.689 ± 0.081
Goosander	0.889 ± 0.111	0.870 ± 0.108	0.000 ± 0.000	1.759 ± 0.155
Oystercatcher	0.503 ± 0.092	0.492 ± 0.090	0.000 ± 0.000	0.995 ± 0.129
Ringed plover	0.230 ± 0.049	0.231 ± 0.050	0.000 ± 0.000	0.461 ± 0.070
Golden plover	3.575 ± 0.645	3.528 ± 0.637	0.000 ± 0.000	7.103 ± 0.907
Grey plover	0.173 ± 0.030	0.169 ± 0.029	0.000 ± 0.000	0.342 ± 0.042

Species	Pre-breeding migration	Post-breeding migration	Other	Total
Lapwing	4.959 ± 0.917	5.053 ± 0.934	0.000 ± 0.000	10.012 ± 1.309
Knot	0.397 ± 0.067	0.391 ± 0.066	0.000 ± 0.000	0.788 ± 0.094
Sanderling	0.196 ± 0.033	0.197 ± 0.033	0.000 ± 0.000	0.393 ± 0.047
Purple sandpiper	0.036 ± 0.005	0.036 ± 0.005	0.000 ± 0.000	0.072 ± 0.007
Dunlin	2.185 ± 0.387	2.159 ± 0.382	0.000 ± 0.000	4.344 ± 0.544
Ruff	0.041 ± 0.007	0.041 ± 0.007	0.000 ± 0.000	0.082 ± 0.010
Snipe	2.577 ± 0.444	2.586 ± 0.446	2.641 ± 0.455	7.804 ± 0.777
Bar-tailed godwit	0.858 ± 0.149	0.845 ± 0.147	0.000 ± 0.000	1.703 ± 0.209
Whimbrel	1.012 ± 0.187	1.014 ± 0.188	0.000 ± 0.000	2.026 ± 0.265
Curlew	0.248 ± 0.043	0.245 ± 0.043	0.000 ± 0.000	0.493 ± 0.061
Greenshank	0.011 ± 0.002	0.011 ± 0.002	0.000 ± 0.000	0.022 ± 0.003
Wood sandpiper	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Red-throated diver	0.083 ± 0.013	0.082 ± 0.013	0.000 ± 0.000	0.165 ± 0.018
Turnstone	0.414 ± 0.104	0.398 ± 0.100	0.000 ± 0.000	0.812 ± 0.144
Dotterel	0.001 ± 0.000	0.001 ± 0.000	0.000 ± 0.000	0.002 ± 0.000
Marsh harrier	0.012 ± 0.002	0.012 ± 0.002	0.000 ± 0.000	0.024 ± 0.003
Hen harrier	0.016 ± 0.003	0.017 ± 0.003	0.000 ± 0.000	0.033 ± 0.004
Osprey	0.004 ± 0.001	0.004 ± 0.001	0.000 ± 0.000	0.008 ± 0.001
Merlin	0.038 ± 0.051	0.038 ± 0.051	0.000 ± 0.000	0.076 ± 0.072
Short-eared owl	0.110 ± 0.0200	0.109 ± 0.020	0.000 ± 0.000	0.219 ± 0.028
Great crested grebe	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Black-throated diver	0.003 ± 0.001	0.003 ± 0.001	0.000 ± 0.000	0.006 ± 0.001
Redshank	0.798 ± 0.159	0.781 ± 0.155	0.000 ± 0.000	1.579 ± 0.222
Bittern	0.001 ± 0.001	0.001 ± 0.001	0.000 ± 0.000	0.002 ± 0.001
Slavonian grebe	0.021 ± 0.004	0.020 ± 0.004	0.000 ± 0.000	0.041 ± 0.006
Spotted crake	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Corncrake	0.117 ± 0.020	0.114 ± 0.019	0.000 ± 0.000	0.231 ± 0.028
Nightjar	0.066 ± 0.024	0.066 ± 0.024	0.000 ± 0.000	0.132 ± 0.034

Table 3.2 Summary of annual migratory collision estimates for the Project based on the best-case design scenario

Species	Pre-breeding migration	Post-breeding migration	Other	Total
Whooper swan	0.772 ± 0.159	0.780 ± 0.160	0.000 ± 0.000	1.552 ± 0.226
Bean goose	0.005 ± 0.001	0.005 ± 0.001	0.000 ± 0.000	0.010 ± 0.001
Svalbard barnacle goose	0.456 ± 0.054	0.464 ± 0.055	0.000 ± 0.000	0.920 ± 0.077
Svalbard light-bellied brent goose	0.028 ± 0.010	0.028 ± 0.010	0.000 ± 0.000	0.056 ± 0.014
Shelduck	0.872 ± 0.159	0.823 ± 0.150	0.863 ± 0.157	2.558 ± 0.269
Wigeon	8.564 ± 1.625	8.587 ± 1.629	0.000 ± 0.000	17.151 ± 2.301
Mallard	17.430 ± 3.126	17.992 ± 3.227	18.055 ± 3.238	53.477 ± 5.538
Pintail	0.418 ± 0.068	0.422 ± 0.069	0.000 ± 0.000	0.840 ± 0.097
Shoveler	0.358 ± 0.072	0.347 ± 0.070	0.367 ± 0.074	1.072 ± 0.125
Tufted duck	2.710 ± 0.449	2.797 ± 0.463	0.000 ± 0.000	5.507 ± 0.645
Long-tailed duck	0.307 ± 0.047	0.313 ± 0.048	0.000 ± 0.000	0.620 ± 0.067
Eider	0.582 ± 0.106	0.594 ± 0.108	0.000 ± 0.000	1.176 ± 0.151
Common scoter	2.734 ± 0.476	2.725 ± 0.474	0.000 ± 0.000	5.459 ± 0.672
Velvet scoter	0.117 ± 0.022	0.114 ± 0.022	0.000 ± 0.000	0.231 ± 0.031
Goldeneye	0.921 ± 0.160	0.927 ± 0.161	0.000 ± 0.000	1.848 ± 0.227
Red-breasted merganser	0.334 ± 0.055	0.345 ± 0.056	0.000 ± 0.000	0.679 ± 0.078
Goosander	0.862 ± 0.106	0.842 ± 0.104	0.000 ± 0.000	1.704 ± 0.148
Oystercatcher	0.486 ± 0.086	0.476 ± 0.084	0.000 ± 0.000	0.962 ± 0.120
Ringed plover	0.236 ± 0.051	0.237 ± 0.051	0.000 ± 0.000	0.473 ± 0.072
Golden plover	3.589 ± 0.646	3.542 ± 0.638	0.000 ± 0.000	7.131 ± 0.908
Grey plover	0.173 ± 0.030	0.169 ± 0.029	0.000 ± 0.000	0.342 ± 0.042
Lapwing	4.889 ± 0.901	4.981 ± 0.918	0.000 ± 0.000	9.870 ± 1.286
Knot	0.407 ± 0.069	0.400 ± 0.068	0.000 ± 0.000	0.807 ± 0.097
Sanderling	0.203 ± 0.034	0.204 ± 0.034	0.000 ± 0.000	0.407 ± 0.048
Purple sandpiper	0.037 ± 0.006	0.037 ± 0.006	0.000 ± 0.000	0.074 ± 0.008
Dunlin	2.258 ± 0.399	2.231 ± 0.394	0.000 ± 0.000	4.489 ± 0.561

Species	Pre-breeding migration	Post-breeding migration	Other	Total
Ruff	0.042 ± 0.007	0.042 ± 0.007	0.000 ± 0.000	0.084 ± 0.010
Snipe	2.630 ± 0.450	2.639 ± 0.452	2.695 ± 0.461	7.964 ± 0.787
Bar-tailed godwit	0.854 ± 0.148	0.841 ± 0.146	0.000 ± 0.000	1.695 ± 0.208
Whimbrel	0.987 ± 0.182	0.989 ± 0.183	0.000 ± 0.000	1.976 ± 0.258
Curlew	0.237 ± 0.039	0.235 ± 0.039	0.000 ± 0.000	0.472 ± 0.055
Greenshank	0.011 ± 0.002	0.011 ± 0.002	0.000 ± 0.000	0.022 ± 0.003
Wood sandpiper	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Red-throated diver	0.080 ± 0.012	0.078 ± 0.012	0.000 ± 0.000	0.158 ± 0.017
Turnstone	0.413 ± 0.103	0.397 ± 0.099	0.000 ± 0.000	0.810 ± 0.143
Dotterel	0.001 ± 0.000	0.001 ± 0.000	0.000 ± 0.000	0.002 ± 0.000
Marsh harrier	0.011 ± 0.002	0.011 ± 0.002	0.000 ± 0.000	0.022 ± 0.003
Hen harrier	0.015 ± 0.003	0.016 ± 0.003	0.000 ± 0.000	0.031 ± 0.004
Osprey	0.004 ± 0.001	0.004 ± 0.001	0.000 ± 0.000	0.008 ± 0.001
Merlin	0.037 ± 0.042	0.037 ± 0.042	0.000 ± 0.000	0.074 ± 0.059
Short-eared owl	0.104 ± 0.018	0.103 ± 0.018	0.000 ± 0.000	0.207 ± 0.025
Great crested grebe	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Black-throated diver	0.003 ± 0.000	0.003 ± 0.001	0.000 ± 0.000	0.006 ± 0.001
Redshank	0.800 ± 0.154	0.783 ± 0.151	0.000 ± 0.000	1.583 ± 0.216
Bittern	0.001 ± 0.001	0.001 ± 0.001	0.000 ± 0.000	0.002 ± 0.001
Slavonian grebe	0.021 ± 0.004	0.021 ± 0.004	0.000 ± 0.000	0.042 ± 0.006
Spotted crake	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Corncrake	0.117 ± 0.019	0.114 ± 0.019	0.000 ± 0.000	0.231 ± 0.027
Nightjar	0.065 ± 0.024	0.065 ± 0.024	0.000 ± 0.000	0.130 ± 0.034

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5. Glossary of Terms and Abbreviations

5.1 Abbreviations

Acronym	Definition
CRM	Collision Risk Modelling
DAS	Digital Aerial Surveys
km	kilometre
m	metre
mCRM	Migration Collision Risk Model
OAA	Option Agreement Area
Rpm	Revolutions per minute
sCRM	Stochastic Collision Risk Modelling
SD	Standard Deviance

5.2 Glossary of terms

Term	Definition
Collision	An instance of one moving object or individual striking violently against another.
Collision Risk Model	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.
Flyway population	The number of individuals travelling along a flight path whilst on migration.
Migration	Migration is the regular, seasonal movement of birds between their breeding and non-breeding grounds.

MarramWind