Code: UKCAL-CWF-CON-EIA-RPT-00007-7B41

Volume 7B Proposed Development (Offshore) Appendices

Appendix 6-5 Migratory Collision Risk Modelling Technical Report

Caledonia Offshore Wind Farm Ltd

5th Floor Atria One, 144 Morrison Street, Edinburgh, EH3 8EX

OW
OCEAN WINDS

Volume 7B Appendix 6-5 Migratory Collision Risk Modelling Technical Report

Code	UKCAL-CWF-CON-EIA-RPT-00007-7B41
Revision	Issued
Date	18 October 2024

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

CRM	Collision Risk Modelling
DAS	Digital Aerial Survey
DE	Design Envelope
EIAR	Environment Impact Assessment Report
GIS	Geographical Information System
mCRM	Migratory Collision Risk Modelling
O&M	Operation and Maintenance
OWF	Offshore Wind Farm
SD	Standard Deviation
WCS	Worst-case Scenario
WTG	Wind Turbine Generator

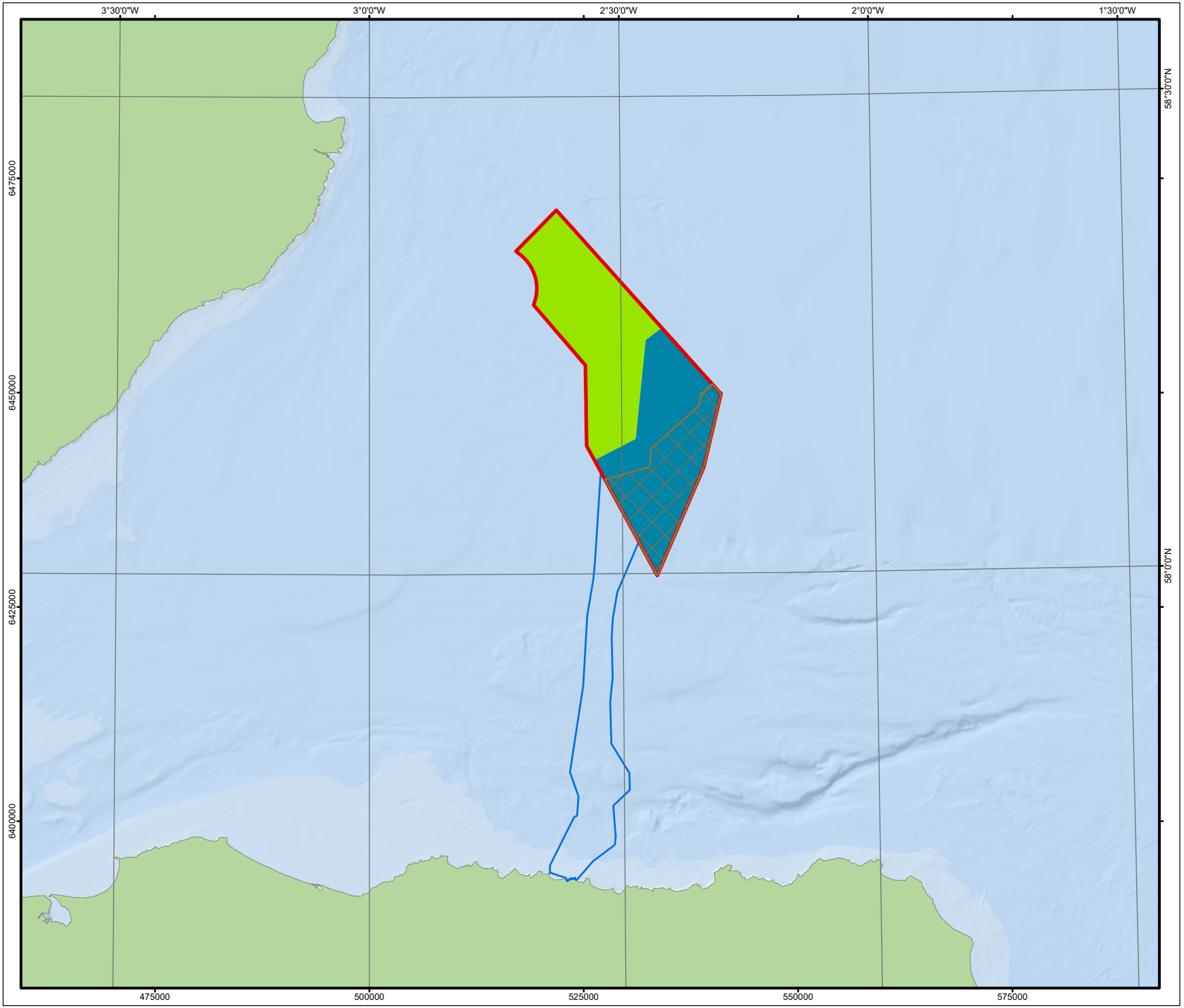
1 Introduction

1.1 Overview

1.1.1.1 This appendix provides background information and methodology of the migratory collision risk modelling (mCRM) scenarios carried out for of the Proposed Development (Offshore), located in the Moray Firth, Scotland. This includes the Caledonia Offshore Wind Farm (OWF) (i.e., Array Area) and the Caledonia Offshore Export Cable Corridor (OECC) seaward of Mean High-Water Springs (MHWS). Results are presented for migratory birds identified as requiring consideration of potential migratory collision risk from the Proposed Development (Offshore).

1.1.1.2 The Proposed Development (Offshore) will be developed in two phases (see Volume 1, Chapter 5: Proposed Development Phasing), referred to as Caledonia North and Caledonia South (see Figure 1-1). The Array Areas of the two phases are referred to as the Caledonia North Site and the Caledonia South Site. It is assumed that construction of the two application areas could be progressed in either order (e.g., Caledonia North constructed in the first phase, then Caledonia South in the second phase, or vice-versa) or at the same time. This has been assessed within a single Environmental Impact Assessment Report (EIAR) covering the Proposed Development (Offshore) as well as Caledonia North and Caledonia South alone.

1.1.1.3 mCRM has been carried out separately for Caledonia North, Caledonia South and the Caledonia OWF (i.e., the Caledonia North Site and Caledonia South Site combined) to estimate the potential risk of collision to migratory birds for each spatial extent. The predicted mortalities for Caledonia North, Caledonia South and the Caledonia OWF have been presented as a worst-case scenario (WCS); i.e., the largest number of the smallest turbines considered within the Design Envelope (DE) for the Proposed Development (Offshore). The Caledonia OWF WCS is based on the maximum number of turbines (bottom-fixed and floating) that could be constructed, rather than an addition of Caledonia North and Caledonia South, as to base the design on this assumption would overestimate any potential impacts (see Volume 1, Chapter 6: Site Selection and Alternatives). The WCS for the Caledonia OWF is being progressed within the cumulative and in-combination assessments. For more information on the DE, refer to Volume 1, Chapter 3: Proposed Development Description (Offshore) and Volume 1, Chapter 5: Proposed Development Phasing.



Caledonia OWF
Caledonia North Array Area
Caledonia South Array Area
Proposed Floating Area
Offshore Export Cable Corridor

0 5 10 15 20 km

REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	19/09/2024	Approved	EV	BB	DH

CALEDONIA Offshore Wind Farm

GoBe APEMGroup

CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_ORN_MAP_00151
CONTRACTOR REV: 01

GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)

DRAWING TITLE

Figure 1-1: Location of the Caledonia OWF, Caledonia North and Caledonia South, and Offshore Export Cable Corridor

STATUS: Approved
SCALE: 1:600,000
DRAWING NUMBER: N/A
SHEET NO: 01 of 01
REV: N/A

1.2 Migratory Collision Risk Modelling

1.2.1.1 Migratory bird species have been scoped in for the potential impact from collision risk in the operation and maintenance (O&M) phase.

1.2.1.2 Assessing the potential impact of collision risk of key ornithology receptors with wind turbines is an important part of the EIAR process. Collision Risk Modelling (CRM) is used to estimate the level of risk associated with turbine collisions, with species that are unlikely to be affected scoped out and thus excluded from the modelling.

1.2.1.3 Site specific digital aerial surveys (DAS) were conducted for the Caledonia OWF, Caledonia North Site and Caledonia South Site and its surroundings (see Volume 7B, Appendix 6-1: Offshore Ornithology Baseline Characterisation Report). The surveys provide information on key seabird species for each defined season but have limitations in capturing migratory species, especially non-seabirds. This is largely due to the nature of the baseline surveys providing a snapshot of data that may miss species passing through the site, particularly during adverse weather, or at night (when surveys are not conducted), or at high altitudes, making it challenging to record their numbers using standard methods. Therefore, a method is required to estimate the potential collision risk of migratory birds without relying on the DAS baseline data.

1.2.1.4 To model the potential impact of the Caledonia OWF on the movements of migratory birds, the Marine Directorate Avian Migration Collision Risk Model Shiny Application ('mCRM Application'; HiDef Aerial Surveying Ltd., 2024[1]) was used.

1.2.1.5 In line with NatureScot (2023[2]) guidance, the potential risk to migratory birds flying through the Caledonia OWF has been assessed on a seasonal basis using the mCRM Application. The focus of this assessment is to identify the potential interaction of migratory species passing through the Caledonia OWF and not species that are in the area for long periods of time, which are considered separately in Volume 7B, Appendix 6-3: Offshore Ornithology Collision Risk Modelling Technical Report.

1.2.1.6 The use of the mCRM Application is not suitable for all bird species, in particular seabirds. The strategic review of birds on migration in Scottish waters (Woodward *et al*., 2023[3]) considered that:

"*Seabird exposure to offshore wind farms will be captured in the density estimates entered into the existing sCRM*".

1.2.1.8 Woodward *et al*. (2023[3]) 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*".

1.2.1.9 Therefore, in accordance with this recommendation, it is assumed that appropriate consideration of migratory collision risk for seabirds is already captured within the modelling presented within Volume 7B, Appendix 6-3: Offshore Ornithology Collision Risk Modelling Technical Report.

2 Species Selection and Scoping Process

2.1 mCRM Scoping Methodology

2.1.1.1 As summarised in the flowchart below (Figure 2-1), the first step in the scoping process is to identify species whose migratory routes may overlap with the Proposed Development (Offshore). A review of the recently published strategic study of collision risk for birds on migration (Woodward *et al.,* 2023[3]) was used to identify migratory overlap. Work package one of Woodward *et al.* (2023[3]) reviewed the migratory routes for a total of 70 bird species and provides visual depictions of potential migratory flyways. Species were initially scoped in or out depending on whether their migratory pathway overlapped with the Caledonia OWF, Caledonia North Site and Caledonia South Site footprints during migration. A total of 57 species were identified as having migratory routes which may overlap with the Proposed Development (Offshore) (Table 5-1).

2.1.1.2 The next step in the scoping process then considered the extent of potential connectivity, based on the percentage of the total UK population predicted to cross the Proposed Development (Offshore) on migration. For species where less than 1% of the UK population was predicted to intersect the Proposed Development (Offshore), these species were scoped out for further consideration. The limit of less than 1% was set based on experience from modelling undertaken for other projects within the UK, such as Awel y Môr, Rampion 2 and Hornsea Four. The exception to this rule was if there is species-specific evidence of an elevated risk of a significant impact from collisions for a particular species. Following the second stage of the scoping process, a total of 45, 38 and 49 species were taken through for collision modelling using the mCRM application for the Caledonia North Site, Caledonia South Site and Caledonia OWF respectively, following the methods detailed in Section 3 and subsequent results presented in Section 4.

2.2 Scoping Results

2.2.1.1 The results of the initial scoping method are presented in Table 5-1. The final species included in the mCRM assessment for the Caledonia OWF, Caledonia North Site and Caledonia South Site are presented within the respective annexes:

- Volume 7B, Appendix 6-5, Annex 1: Migratory Collision Risk Modelling Results (Caledonia OWF);
- Volume 7B, Appendix 6-5, Annex 2: Migratory Collision Risk Modelling Results (Caledonia North); and
- Volume 7B, Appendix 6-5, Annex 3: Migratory Collision Risk Modelling Results (Caledonia South).

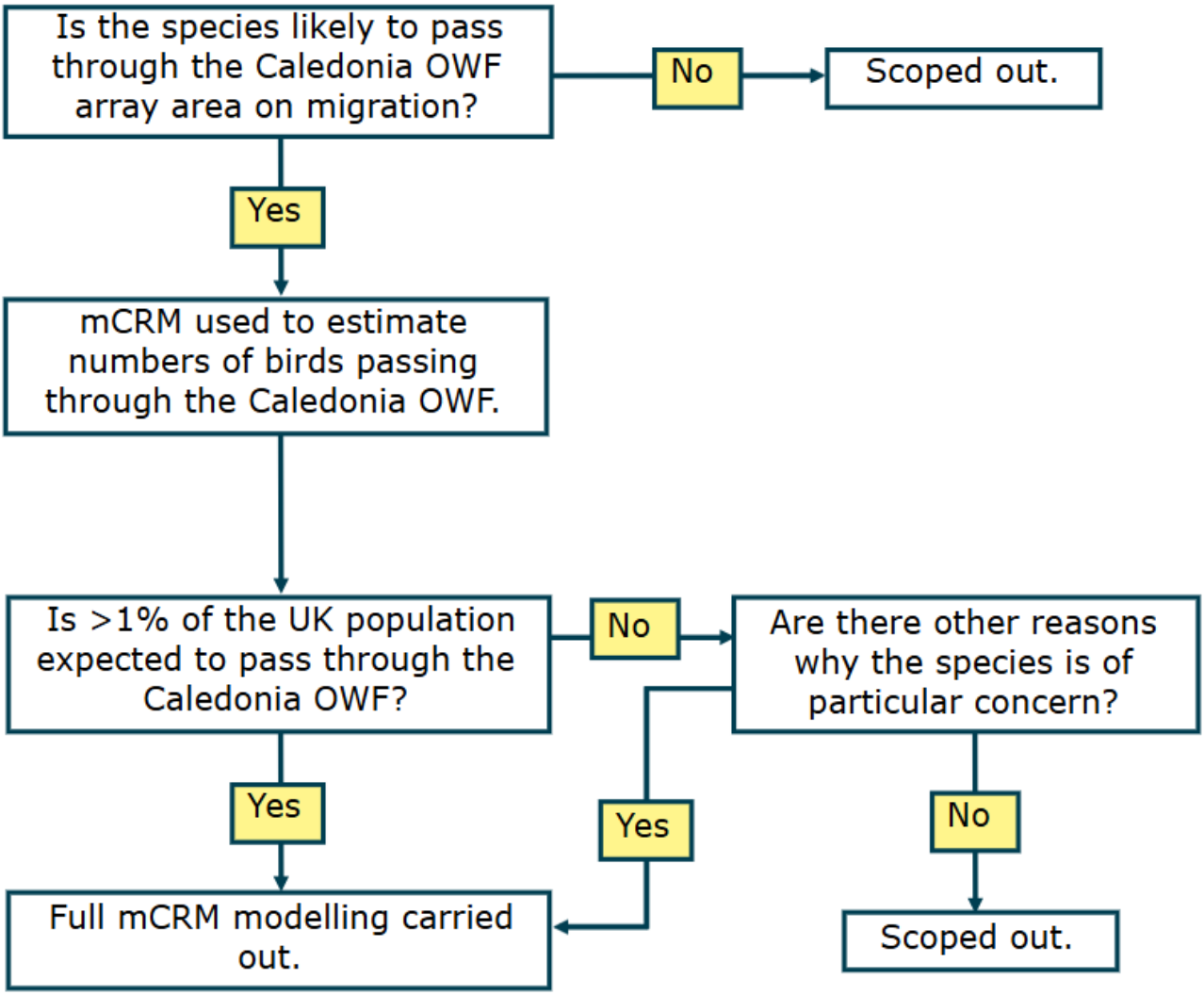


Figure 2-1: Flowchart illustrating the scoping approach for mCRM.

3 Migratory CRM

3.1 Methodology

3.1.1.1 As requested within the NatureScot (2023[2]) guidance, mCRM was assessed using the mCRM Application. This application is a stochastic adaptation of the SOSSMAT migration assessment tool (Wright *et al*., 2012[4]) and Band (2012[5]) migration collision risk worksheets, accessible through the user-friendly 'Shiny Application' interface available in standard web browsers or within the R statistical software (R Core Team, 2021[6]). For this assessment, the latest version of the mCRM (v0.4.1) was downloaded and run locally within R (13 May 2024).

3.2 Migratory CRM Input Parameters

3.2.1 Turbine Parameters

3.2.1.1 A Geographical Information System (GIS) shapefile of the footprint of the Caledonia OWF, Caledonia North and Caledonia South were used within the mCRM Application with the appropriate Wind Turbine Generator (WTG) and OWF parameters for each run of the model (Table 3-1 to Table 3-3).

3.2.1.2 Whilst the design for Caledonia North consists entirely of bottom-fixed foundation WTGs, the design for Caledonia South (and thus the Caledonia OWF) includes an option for the inclusion of floating foundation WTGs; refer to Volume 1, Chapter 3: Proposed Development Description (Offshore) for further details.

3.2.1.3 Two options have been presented for the Caledonia North Site:

- 47 fixed turbines; and
- 77 fixed turbines.

3.2.1.4 Three options are presented for the Caledonia South Site:

- 24 fixed turbines and 29 floating turbines;
- 47 fixed turbines; and
- 39 fixed turbines and 39 floating turbines.

3.2.1.5 Three options are presented for the Caledonia OWF:

- 140 fixed turbines;
- 62 fixed turbines and 29 floating turbines; and
- 84 fixed turbines.

3.2.1.6 Table 3-4 provides wind resource and turbine downtime parameters relevant for all scenarios: bottom-fixed, floating and combined (where applicable). These values are presented as the maximum design options for each site. The standard deviation (SD) for average rotation speed and average pitch were set to 0 due to lack of data. However, since it is known that the outputs of CRM are relatively insensitive to these parameters (Chamberlain *et al.*, 2006[7]), it is considered that the sensitivity of the model to their SDs is lower still. The exclusion of these parameters therefore does not substantially impact the outcome of the modelling exercise.

Table 3-1: OWF and WTG parameters used for mCRM for the Caledonia North Site.

Parameter	WTG 1 (N) Fixed	WTG 2 (N) Fixed
Number of WTGs	47	77
Latitude (degrees)	58.26	58.26
Width (km)	29.5	29.5
Number of blades	3	3
Rotor radius (m)	155	118
Blade width (m)	7.5	7.5
Average pitch (º)	2	2
Average pitch SD (º)	No data (assumed 0)	No data (assumed 0)
Rotation speed (rpm)	8.4	8.4
Rotation speed SD (rpm)	No data (assumed 0)	No data (assumed 0)

Table 3-2: OWF and WTG parameters used for mCRM for the Caledonia South Site.

Parameter	WTG 1 (S)		WTG 2 (S)	WTG 3 (S)	
	Fixed	Floating	Fixed	Fixed	Floating
Number of WTGs	24	29	47	39	39
Latitude (degrees)	58.13	58.13	58.13	58.13	58.13
Width (km)	28.90	28.90	28.90	28.90	28.90
Number of blades	3	3	3	3	3
Rotor radius (m)	155	145	155	118	118
Blade width (m)	7.50	7.50	7.50	7.50	7.50
Average pitch (º)	2	2	2	2	2
Average pitch SD (º)	No data (assumed 0)	No data (assumed 0)	No data (assumed 0)	No data (assumed 0)	No data (assumed 0)
Rotation speed (rpm)	8.4	8.4	8.4	8.4	8.4
Rotation speed SD (rpm)	No data (assumed 0)	No data (assumed 0)	No data (assumed 0)	No data (assumed 0)	No data (assumed 0)

Table 3-3: OWF and WTG parameters used for mCRM for the Caledonia OWF.

Parameter	WTG 1	WTG 2		WTG 3
	Fixed	Fixed	Floating	Fixed
Number of WTGs	140	62	29	84
Latitude (degrees)	58.19	58.19	58.19	58.19
Width (km)	44.0	44.0	44.0	44.0
Number of blades	3	3	3	3
Rotor radius (m)	118	155	145	155
Blade width (m)	7.50	7.50	7.50	7.50
Average pitch (º)	2	2	2	2
Average pitch SD (º)	No data (assumed 0)	No data (assumed 0)	No data (assumed 0)	No data (assumed 0)
Rotation speed (rpm)	8.4	8.4	8.4	8.4
Rotation speed SD (rpm)	No data (assumed 0)	No data (assumed 0)	No data (assumed 0)	No data (assumed 0)

Table 3-4: Operational parameters used within the mCRM for bottom-fixed and floating turbines.

Month	Wind Availability (%)	Mean Downtime (%)	SD Downtime (%)
January	97.90	2.10	1.37
February	97.18	2.82	2.31
March	96.33	3.67	2.39
April	95.64	4.36	2.31
May	93.71	6.29	2.85
June	92.83	7.17	3.07
July	91.66	8.34	3.64
August	92.81	7.19	3.37
September	95.00	5.00	2.78
October	96.66	3.34	1.96
November	98.30	1.70	1.14
December	97.80	2.20	2.38

3.2.2 Species Biometrics and Migration Seasons

3.2.2.1 The species UK population sizes of birds scoped in for the assessment of collision risk are provided within the mCRM Application as default. The species population estimates and proportion of birds potentially at risk of collision from the Caledonia OWF, Caledonia North Site and Caledonia South Site (for all scenarios) are calculated within the mCRM Application separately for each WTG scenario (Table 3-1 to Table 3-3) and are presented in respective annexes:

- Volume 7B, Appendix 6-5, Annex 1: Migratory Collision Risk Modelling Results (Caledonia OWF);
- Volume 7B, Appendix 6-5, Annex 2: Migratory Collision Risk Modelling Results (Caledonia North); and
- Volume 7B, Appendix 6-5, Annex 3: Migratory Collision Risk Modelling Results (Caledonia South).

3.2.2.2 The defined pre-breeding and post-breeding migration seasons used for the scoped in species assessed for mCRM are defined in Table 3-5, and are as presented in the mCRM Application.

3.2.2.3 The species-specific parameters used within the mCRM are presented in Table 3-6. All parameters were set at the default values within the Application. The seasonal definitions are provided as default within the tool. Species that have an additional migratory season outside the pre-breeding and post-breeding season, were defined as "Other".

Table 3-5: Defined migration season used within the mCRM Application.

Species	Pre-breeding	Post-breeding	Other
Bar-tailed godwit	Mar - Apr	Jul - Oct	NA
Bean goose	Jan - Feb	Sep - Dec	NA
Bittern	Jan - May	Jun - Oct	NA
Black-tailed godwit	Mar - May	Jun - Oct	NA
Black-throated diver	Mar - May	Aug - Nov	NA
Canadian light-bellied brent goose	Mar - May	Aug - Oct	NA
Common scoter	Apr - May	Jun - Oct	NA
Corncrake	Apr - May	Jul - Aug	NA
Curlew	Mar - May	Jun - Oct	NA
Dotterel	Mar - Jun	Aug - Nov	NA
Dunlin	Mar - May	Jun - Oct	NA
Eider	Mar - Apr	Oct - Nov	NA
Golden plover	Feb - May	Jul - Oct	NA
Goldeneye	Feb - May	Aug - Dec	NA
Goosander	Mar - May	Jun - Sep	NA
Great crested grebe	Mar - Jun	Jul - Nov	Feb - Mar
Great northern diver	Dec - Jun	Aug - Nov	NA
Greenshank	Mar - Jun	Aug - Nov	NA
Grey plover	Mar - May	Jul - Sep	NA

Species	Pre-breeding	Post-breeding	Other
Hen harrier	Mar - May	Sep - Nov	NA
Icelandic greylag goose	Mar - Apr	Oct - Nov	NA
Knot	Feb - May	Jun - Oct	NA
Lapwing	Jan - May	Oct - Nov	NA
Long-tailed duck	Mar - May	Sep - Oct	NA
Mallard	Apr - Jun	Sep - Oct	Jan - Mar
Marsh harrier	Mar - May	Aug - Nov	NA
Merlin	Mar - May	Aug - Nov	NA
Nightjar	Apr - May	Aug - Sep	NA
Osprey	Mar - Apr	Aug - Oct	NA
Oystercatcher	Jan - Mar	Jul - Nov	NA
Pink-footed goose	Mar - Apr	Sep - Oct	NA
Pintail	Mar - May	Aug - Nov	NA
Purple sandpiper	Mar - May	Jul - Nov	NA
Red-breasted merganser	Apr - Jul	Aug - Nov	NA
Redshank	Mar - May	Jul - Sep	NA
Red-throated diver	Feb - Jun	Jul - Sep	NA
Ringed plover	Mar - May	Aug - Oct	NA
Ruff	Mar - May	Jul - Nov	NA
Sanderling	Apr - Jun	Jul - Oct	NA
Scaup	Feb - May	Sep - Nov	NA
Shelduck	Jan - Feb	Jun - Jul	Aug - Dec
Short-eared owl	Mar - May	Jul - Oct	NA
Shoveler	Mar - Jun	Jul - Aug	Sep - Dec

Species	Pre-breeding	Post-breeding	Other
Slavonian grebe	Feb - Apr	Aug - Oct	NA
Snipe	Mar - May	Aug - Oct	Oct - Dec
Spotted crake	May - Jun	Jul - Oct	NA
Svalbard barnacle goose	Mar - May	Sep - Oct	NA
Svalbard light-bellied brent goose	Mar - Mar	Aug - Oct	NA
Teal	Feb - May	Jul - Dec	NA
Tufted duck	Apr - Jun	Sep - Oct	NA
Turnstone	Jan - Jun	Jul - Aug	NA
Velvet scoter	Mar - May	Jun - Sep	NA
Whimbrel	Apr - Jun	Jun - Oct	NA
White-tailed eagle	Apr - May	Aug - Oct	NA
Whooper swan	Feb - Apr	Sep - Nov	NA
Wigeon	Mar - Apr	Aug - Nov	NA
Wood sandpiper	Apr - May	Jul - Sep	NA

Table 3-6: Species biometrics used in the mCRM Application with associated Standard Deviation (SD).

Species	Body Length (m)	Body Length SD	Wingspan (m)	Wingspan SD	Flight Speed (ms^{-1})	Flight Speed SD	Proportion at Potential Collision Height	Avoidance Rate	Avoidance Rate SD
Bar-tailed godwit	0.38	0.02	0.75	0.02	18.30	2.10	1.00	0.999	0
Bean goose	0.75	0.06	1.58	0.06	15.80	1.31	1.00	0.999	0.0001
Bittern	0.75	0.02	1.30	0.02	8.80	2.00	1.00	0.995	0.00001
Black-tailed godwit	0.42	0.02	0.76	0.02	18.10	6.00	1.00	0.999	0
Black-throated diver	0.66	0.02	1.20	0.02	19.30	2.10	0.25	0.995	0.00001
Canadian light-bellied brent goose	0.58	0.02	1.15	0.02	17.90	6.10	0.50	0.999	0.0001
Common scoter	0.49	0.03	0.84	0.03	22.10	4.00	1.00	0.985	0.0008
Corncrake	0.28	0.02	0.50	0.02	13.00	2.00	1.00	0.995	0.00001
Curlew	0.55	0.02	0.90	0.02	15.40	3.30	1.00	0.999	0
Dotterel	0.21	0.01	0.60	0.01	16.50	1.80	1.00	0.999	0
Dunlin	0.18	0.01	0.40	0.01	15.30	1.90	1.00	0.999	0

Species	Body Length (m)	Body Length SD	Wingspan (m)	Wingspan SD	Flight Speed (ms^{-1})	Flight Speed SD	Proportion at Potential Collision Height	Avoidance Rate	Avoidance Rate SD
Eider	0.60	0.03	0.94	0.03	17.34	2.40	0.25	0.985	0.0008
Golden plover	0.28	0.01	0.72	0.01	16.50	1.80	1.00	0.999	0
Goldeneye	0.46	0.01	0.72	0.01	20.30	3.80	1.00	0.985	0.0008
Goosander	0.62	0.03	0.90	0.03	19.70	1.10	1.00	0.985	0.0008
Great crested grebe	0.48	0.02	0.88	0.02	21.13	1.55	1.00	0.995	0.00001
Great northern diver	0.80	0.02	1.37	0.02	19.50	1.60	0.25	0.995	0.00001
Greenshank	0.32	0.01	0.69	0.01	12.30	3.30	1.00	0.999	0
Grey plover	0.28	0.01	0.77	0.01	16.50	1.80	1.00	0.999	0
Hen harrier	0.48	0.02	1.10	0.02	11.40	1.10	1.00	0.995	0.0001
Icelandic greylag goose	0.82	0.03	1.64	0.03	12.00	4.90	0.50	0.9996	0
Knot	0.24	0.01	0.59	0.01	24.60	3.30	1.00	0.999	0
Lapwing	0.30	0.01	0.84	0.01	12.80	1.30	1.00	0.999	0

Species	Body Length (m)	Body Length SD	Wingspan (m)	Wingspan SD	Flight Speed (ms^{-1})	Flight Speed SD	Proportion at Potential Collision Height	Avoidance Rate	Avoidance Rate SD
Long-tailed duck	0.44	0.01	0.76	0.01	19.70	1.70	1.00	0.985	0.0008
Mallard	0.58	0.02	0.90	0.02	15.86	2.00	1.00	0.985	0.0008
Marsh harrier	0.52	0.02	1.22	0.02	13.20	2.90	0.50	0.995	0.0001
Merlin	0.28	0.02	0.56	0.02	12.70	5.80	1.00	0.989	0.0003
Nightjar	0.27	0.02	0.60	0.02	9.72	3.30	1.00	0.995	0.00001
Osprey	0.56	0.02	1.58	0.02	10.60	3.10	0.50	0.995	0.0003
Oystercatcher	0.42	0.02	0.83	0.02	13.00	2.50	1.00	0.999	0
Pink-footed Goose	0.68	0.06	1.52	0.06	16.90	0.16	0.50	0.9999	0.0002
Pintail	0.58	0.02	0.88	0.02	21.90	2.00	1.00	0.985	0.0008
Purple sandpiper	0.21	0.01	0.44	0.01	15.30	1.90	1.00	0.999	0
Red-breasted merganser	0.55	0.01	0.78	0.01	22.00	2.90	1.00	0.985	0.0008
Redshank	0.28	0.01	0.62	0.01	15.30	4.10	1.00	0.999	0

Species	Body Length (m)	Body Length SD	Wingspan (m)	Wingspan SD	Flight Speed (ms^{-1})	Flight Speed SD	Proportion at Potential Collision Height	Avoidance Rate	Avoidance Rate SD
Red-throated diver	0.61	0.02	1.11	0.02	18.60	3.90	0.25	0.995	0.00001
Ringed plover	0.19	0.01	0.52	0.01	16.00	1.10	1.00	0.999	0
Ruff	0.25	0.01	0.53	0.01	16.90	1.81	1.00	0.999	0
Sanderling	0.20	0.01	0.42	0.01	21.40	1.10	1.00	0.999	0
Scaup	0.46	0.01	0.78	0.01	21.10	2.00	1.00	0.985	0.0008
Shelduck	0.62	0.02	1.12	0.02	18.20	4.30	0.50	0.985	0.0008
Short-eared owl	0.38	0.02	1.02	0.02	9.70	2.00	1.00	0.995	0.0001
Shoveler	0.48	0.02	0.77	0.02	18.30	2.00	1.00	0.985	0.0008
Slavonian grebe	0.34	0.02	0.62	0.02	21.13	1.55	1.00	0.995	0.00001
Snipe	0.26	0.01	0.46	0.01	17.10	2.70	1.00	0.999	0
Spotted crake	0.23	0.02	0.40	0.02	13.00	2.00	1.00	0.995	0.00001
Svalbard barnacle goose	0.64	0.04	1.38	0.04	17.40	1.08	1.00	0.999	0.0001

Species	Body Length (m)	Body Length SD	Wingspan (m)	Wingspan SD	Flight Speed (ms^{-1})	Flight Speed SD	Proportion at Potential Collision Height	Avoidance Rate	Avoidance Rate SD
Svalbard light-bellied brent goose	0.58	0.02	1.15	0.02	17.90	6.10	0.50	0.999	0.0001
Teal	0.36	0.02	0.61	0.02	17.40	1.60	1.00	0.985	0.0008
Tufted duck	0.44	0.01	0.70	0.01	21.10	1.10	1.00	0.985	0.0008
Turnstone	0.23	0.01	0.54	0.01	10.00	3.30	1.00	0.999	0
Velvet scoter	0.54	0.03	0.94	0.03	20.10	4.70	1.00	0.985	0.0008
Whimbrel	0.41	0.02	0.82	0.02	13.80	0.40	1.00	0.999	0
White-tailed eagle	0.80	0.02	2.20	0.02	14.40	1.04	1.00	0.987	0.0019
Whooper swan	1.52	0.04	2.30	0.04	17.50	4.20	0.50	0.988	0.0009
Wigeon	0.48	0.02	0.80	0.02	18.50	2.00	1.00	0.985	0.0008
Wood sandpiper	0.20	0.01	0.56	0.01	9.60	1.70	1.00	0.999	0

4 Results

4.1.1.1 The outputs from the mCRM assessment for each of the species are presented in this section for the WCS, specifically for the Caledonia North Site (Table 4-1), Caledonia South Site (Table 4-2) and the Caledonia OWF (Table 4-3). Results are presented by biologically relevant season.

4.1.1.2 Estimated annual collisions have been compared between scenarios to determine the majority WCS (Table 4-4). Where results deviate from the majority, the totals have been highlighted with an asterisk. The full results for estimated seasonal collisions for each species within the Caledonia OWF, Caledonia North Site and Caledonia South Site are presented within respective annexes:

- Volume 7B, Appendix 6-5, Annex 1: Migratory Collision Risk Modelling Results (Caledonia OWF);
- Volume 7B, Appendix 6-5, Annex 2: Migratory Collision Risk Modelling Results (Caledonia North); and
- Volume 7B, Appendix 6-5, Annex 3: Migratory Collision Risk Modelling Results (Caledonia South).

Table 4-1: Summary of estimated mean seasonal migratory collisions (± SD) for the Caledonia North Site, presenting the WCS (WTG 2 (N)).

Species	Pre-breeding	Post-breeding	Other	Total
Bar-tailed godwit	0.204 ± 0.042	0.200 ± 0.041	0 ± 0	0.404 ± 0.059
Bean goose	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Black-throated diver	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Corncrake	0.021 ± 0.005	0.021 ± 0.004	0 ± 0	0.042 ± 0.006
Curlew	0.049 ± 0.009	0.048 ± 0.009	0 ± 0	0.097 ± 0.013
Dotterel	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Dunlin	0.485 ± 0.092	0.477 ± 0.090	0 ± 0	0.962 ± 0.129
Eider	0.124 ± 0.027	0.126 ± 0.027	0 ± 0	0.250 ± 0.038
Golden plover	0.866 ± 0.156	0.85 ± 0.154	0 ± 0	1.716 ± 0.219
Goldeneye	0.170 ± 0.037	0.170 ± 0.037	0 ± 0	0.340 ± 0.052
Goosander	0.145 ± 0.022	0.142 ± 0.022	0 ± 0	0.287 ± 0.031
Great northern diver	0.005 ± 0.001	0.005 ± 0.001	0 ± 0	0.010 ± 0.001
Greenshank	0.002 ± 0	0.002 ± 0	0 ± 0	0.004 ± 0
Grey plover	0.029 ± 0.005	0.028 ± 0.005	0 ± 0	0.057 ± 0.007
Hen harrier	0.004 ± 0.001	0.004 ± 0.001	0 ± 0	0.008 ± 0.001
Knot	0.074 ± 0.015	0.073 ± 0.015	0 ± 0	0.147 ± 0.021
Lapwing	0.979 ± 0.213	0.992 ± 0.216	0 ± 0	1.971 ± 0.303
Long-tailed duck	0.058 ± 0.011	0.058 ± 0.011	0 ± 0	0.116 ± 0.016
Mallard	4.768 ± 0.957	4.858 ± 0.975	4.924 ± 0.989	14.55 ± 1.687
Marsh harrier	0.002 ± 0	0.002 ± 0	0 ± 0	0.004 ± 0
Osprey	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Oystercatcher	0.104 ± 0.023	0.102 ± 0.022	0 ± 0	0.206 ± 0.032
Pintail	0.078 ± 0.018	0.078 ± 0.018	0 ± 0	0.156 ± 0.025
Purple sandpiper	0.007 ± 0.001	0.007 ± 0.001	0 ± 0	0.014 ± 0.001

Species	Pre-breeding	Post-breeding	Other	Total
Red-breasted merganser	0.070 ± 0.014	0.072 ± 0.015	0 ± 0	0.142 ± 0.021
Redshank	0.092 ± 0.020	0.090 ± 0.019	0 ± 0	0.182 ± 0.028
Red-throated diver	0.016 ± 0.003	0.016 ± 0.003	0 ± 0	0.032 ± 0.004
Ringed plover	0.058 ± 0.012	0.058 ± 0.012	0 ± 0	0.116 ± 0.017
Ruff	0.008 ± 0.002	0.008 ± 0.002	0 ± 0	0.016 ± 0.003
Sanderling	0.050 ± 0.01	0.050 ± 0.01	0 ± 0	0.100 ± 0.014
Shelduck	0.130 ± 0.027	0.123 ± 0.026	0.128 ± 0.027	0.381 ± 0.046
Short-eared owl	0.025 ± 0.005	0.025 ± 0.005	0 ± 0	0.050 ± 0.007
Slavonian grebe	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Snipe	1.432 ± 0.283	1.426 ± 0.282	1.467 ± 0.290	4.325 ± 0.494
Spotted crake	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Svalbard barnacle goose	0.031 ± 0.005	0.031 ± 0.005	0 ± 0	0.062 ± 0.007
Svalbard light-bellied brent goose	0.003 ± 0.001	0.003 ± 0.001	0 ± 0	0.006 ± 0.001
Tufted duck	0.623 ± 0.138	0.634 ± 0.14	0 ± 0	1.257 ± 0.197
Turnstone	0.111 ± 0.028	0.107 ± 0.027	0 ± 0	0.218 ± 0.039
Velvet scoter	0.014 ± 0.004	0.014 ± 0.004	0 ± 0	0.028 ± 0.006
Whimbrel	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
White-tailed eagle	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Whooper swan	0.166 ± 0.035	0.167 ± 0.036	0 ± 0	0.333 ± 0.050
Wigeon	1.949 ± 0.453	1.943 ± 0.451	0 ± 0	3.892 ± 0.639
Wood sandpiper	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Table 4-2: Summary of estimated mean seasonal migratory collisions (± SD) for the Caledonia South Site, presenting the WCS (WTG 3 (S)).

Species	Pre-breeding	Post-breeding	Other	Total
Bar-tailed godwit	0.183 ± 0.035	0.179 ± 0.034	0 ± 0	0.362 ± 0.049
Bean goose	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Black-throated diver	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Corncrake	0.021 ± 0.004	0.02 ± 0.004	0 ± 0	0.041 ± 0.006
Curlew	0.043 ± 0.01	0.043 ± 0.01	0 ± 0	0.086 ± 0.014
Dotterel	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Dunlin	0.425 ± 0.094	0.418 ± 0.092	0 ± 0	0.843 ± 0.132
Eider	0.119 ± 0.025	0.121 ± 0.025	0 ± 0	0.24 ± 0.035
Goldeneye	0.143 ± 0.033	0.144 ± 0.034	0 ± 0	0.287 ± 0.047*
Goosander	0.151 ± 0.023	0.148 ± 0.022	0 ± 0	0.299 ± 0.032
Greenshank	0.002 ± 0	0.002 ± 0	0 ± 0	0.004 ± 0*
Grey plover	0.029 ± 0.006	0.029 ± 0.006	0 ± 0	0.058 ± 0.008*
Hen harrier	0.003 ± 0.001	0.003 ± 0.001	0 ± 0	0.006 ± 0.001*
Knot	0.08 ± 0.019	0.078 ± 0.019	0 ± 0	0.158 ± 0.027
Lapwing	0.929 ± 0.222	0.942 ± 0.225	0 ± 0	1.871 ± 0.316
Long-tailed duck	0.062 ± 0.011	0.063 ± 0.011	0 ± 0	0.125 ± 0.016*
Mallard	4.169 ± 0.795	4.248 ± 0.81	4.306 ± 0.821	12.723 ± 1.401
Marsh harrier	0.002 ± 0.001	0.002 ± 0.001	0 ± 0	0.004 ± 0.001*
Osprey	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0*
Oystercatcher	0.105 ± 0.023	0.103 ± 0.022	0 ± 0	0.208 ± 0.032
Pintail	0.082 ± 0.019	0.083 ± 0.019	0 ± 0	0.165 ± 0.027
Purple sandpiper	0.007 ± 0.001	0.007 ± 0.001	0 ± 0	0.014 ± 0.001*

Species	Pre-breeding	Post-breeding	Other	Total
Red-breasted merganser	0.064 ± 0.012	0.066 ± 0.012	0 ± 0	0.13 ± 0.017
Red-throated diver	0.015 ± 0.003	0.015 ± 0.003	0 ± 0	0.03 ± 0.004*
Ruff	0.007 ± 0.002	0.007 ± 0.002	0 ± 0	0.014 ± 0.003*
Sanderling	0.044 ± 0.009	0.044 ± 0.009	0 ± 0	0.088 ± 0.013*
Shelduck	0.125 ± 0.029	0.119 ± 0.028	0.124 ± 0.029	0.368 ± 0.05*
Short-eared owl	0.022 ± 0.005	0.021 ± 0.005	0 ± 0	0.043 ± 0.007
Slavonian grebe	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0*
Spotted crake	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Svalbard barnacle goose	0.03 ± 0.005	0.03 ± 0.005	0 ± 0	0.06 ± 0.007
Svalbard light-bellied brent goose	0.003 ± 0.001	0.003 ± 0.001	0 ± 0	0.006 ± 0.001
Turnstone	0.091 ± 0.023	0.088 ± 0.022	0 ± 0	0.179 ± 0.032
Velvet scoter	0.015 ± 0.003	0.014 ± 0.003	0 ± 0	0.029 ± 0.004*
Whimbrel	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0*
Whooper swan	0.168 ± 0.036	0.169 ± 0.036	0 ± 0	0.337 ± 0.051*
Wigeon	2.049 ± 0.412	2.042 ± 0.411	0 ± 0	4.091 ± 0.582
Wood sandpiper	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Note, results that deviate from WCS WTG 3 (S) have been highlighted with an asterisk ('*').				

Table 4-3: Summary of estimated mean seasonal migratory collisions (± SD) for the Caledonia OWF, presenting the WCS (WTG 1).

Species	Pre-breeding	Post-breeding	Other	Total
Bar-tailed godwit	0.357 ± 0.057	0.35 ± 0.056	0 ± 0	0.707 ± 0.08
Bean goose	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Black-throated diver	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Common scoter	0.786 ± 0.148	0.779 ± 0.147	0 ± 0	1.565 ± 0.209
Corncrake	0.037 ± 0.007	0.036 ± 0.007	0 ± 0	0.073 ± 0.01
Curlew	0.087 ± 0.014	0.085 ± 0.014	0 ± 0	0.172 ± 0.02
Dotterel	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Dunlin	0.802 ± 0.149	0.79 ± 0.147	0 ± 0	1.592 ± 0.209
Eider	0.226 ± 0.036	0.23 ± 0.037	0 ± 0	0.456 ± 0.052
Golden plover	1.438 ± 0.228	1.413 ± 0.224	0 ± 0	2.851 ± 0.32
Goldeneye	0.304 ± 0.053	0.305 ± 0.053	0 ± 0	0.609 ± 0.075
Goosander	0.269 ± 0.032	0.263 ± 0.032	0 ± 0	0.532 ± 0.045
Great northern diver	0.008 ± 0.001	0.008 ± 0.001	0 ± 0	0.016 ± 0.001
Greenshank	0.004 ± 0.001	0.004 ± 0.001	0 ± 0	0.008 ± 0.001
Grey plover	0.053 ± 0.011	0.052 ± 0.011	0 ± 0	0.105 ± 0.016
Hen harrier	0.006 ± 0.001	0.006 ± 0.001	0 ± 0	0.012 ± 0.001
Knot	0.130 ± 0.028	0.128 ± 0.027	0 ± 0	0.258 ± 0.039
Lapwing	1.706 ± 0.289	1.729 ± 0.293	0 ± 0	3.435 ± 0.412
Long-tailed duck	0.115 ± 0.019	0.115 ± 0.019	0 ± 0	0.23 ± 0.027
Mallard	8.135 ± 1.348	8.288 ± 1.373	8.401 ± 1.392	24.824 ± 2.375
Marsh harrier	0.004 ± 0.001	0.004 ± 0.001	0 ± 0	0.008 ± 0.001
Nightjar	0.012 ± 0.004	0.012 ± 0.004	0 ± 0	0.024 ± 0.006

Species	Pre-breeding	Post-breeding	Other	Total
Osprey	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Oystercatcher	0.192 ± 0.036	0.187 ± 0.035	0 ± 0	0.379 ± 0.050
Pintail	0.143 ± 0.025	0.144 ± 0.026	0 ± 0	0.287 ± 0.036
Purple sandpiper	0.012 ± 0.002	0.012 ± 0.002	0 ± 0	0.024 ± 0.003
Red-breasted merganser	0.123 ± 0.023	0.126 ± 0.023	0 ± 0	0.249 ± 0.033
Redshank	0.147 ± 0.03	0.143 ± 0.029	0 ± 0	0.290 ± 0.042
Red-throated diver	0.028 ± 0.004	0.027 ± 0.004	0 ± 0	0.055 ± 0.006
Ringed plover	0.102 ± 0.017	0.101 ± 0.017	0 ± 0	0.203 ± 0.024
Ruff	0.014 ± 0.003	0.014 ± 0.003	0 ± 0	0.028 ± 0.004
Sanderling	0.084 ± 0.014	0.084 ± 0.014	0 ± 0	0.168 ± 0.020
Scaup	0.032 ± 0.007	0.033 ± 0.007	0 ± 0	0.065 ± 0.010
Shelduck	0.219 ± 0.047	0.207 ± 0.044	0.216 ± 0.046	0.642 ± 0.079
Short-eared owl	0.042 ± 0.008	0.041 ± 0.008	0 ± 0	0.083 ± 0.011
Shoveler	0.106 ± 0.021	0.104 ± 0.021	0.109 ± 0.022	0.319 ± 0.037
Slavonian grebe	0.002 ± 0.001	0.002 ± 0.001	0 ± 0	0.004 ± 0.001
Snipe	2.407 ± 0.415	2.397 ± 0.413	2.467 ± 0.425	7.271 ± 0.723
Spotted crake	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Svalbard barnacle goose	0.059 ± 0.008	0.059 ± 0.008	0 ± 0	0.118 ± 0.011
Svalbard light-bellied brent goose	0.005 ± 0.002	0.005 ± 0.001	0 ± 0	0.01 ± 0.002
Tufted duck	0.983 ± 0.171	1.001 ± 0.174	0 ± 0	1.984 ± 0.244
Turnstone	0.179 ± 0.038	0.173 ± 0.037	0 ± 0	0.352 ± 0.053

Species	Pre-breeding	Post-breeding	Other	Total
Velvet Scoter	0.026 ± 0.005	0.025 ± 0.005	0 ± 0	0.051 ± 0.007
Whimbrel	0.002 ± 0	0.002 ± 0	0 ± 0	0.004 ± 0
White-tailed eagle	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Whooper swan	0.284 ± 0.056	0.285 ± 0.057	0 ± 0	0.569 ± 0.080
Wigeon	3.559 ± 0.66	3.549 ± 0.658	0 ± 0	7.108 ± 0.932
Wood sandpiper	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Table 4-4: Summary of the WCS for the Caledonia North Site, Caledonia South Site and Caledonia OWF.

Site	Majority WCS
Caledonia North Site	WTG 2 (N): 77 bottom-fixed WTGs
Caledonia South Site	WTG 3 (S): 39 bottom-fixed WTGs, 39 floating WTGs
Caledonia OWF	WTG 1: 140 bottom-fixed WTGs

5 Species Scoped in for mCRM

5.1.1.1 Table 5-1 lists the species initially scoped in for mCRM assessment.

Table 5-1: Species initially scoped in for mCRM assessment.

Species Scoped in for mCRM			
Bar-tailed godwit (*Limosa lapponica*)	Bean goose (*Anser fabalis*)	Bittern (*Botaurus stellaris*)	Black-tailed godwit (*Limosa limosa*)
Black-throated diver (*Gavia arctica*)	Canadian light-bellied brent goose (*Branta bernicla hrota*)	Common scoter (*Melanitta nigra*)	Corncrake (*Crex crex*)
Curlew (*Numenius arquata*)	Dotterel (*Charadrius morinellus*)	Dunlin (*Calidris alpina*)	Eider (*Somateria mollissima*)
Golden plover (*Pluvialis apricaria*)	Goldeneye (*Bucephala clangula*)	Goosander (*Mergus merganser*)	Great crested grebe (*Podiceps cristatus*)
Great northern diver (*Gavia immer*)	Greenshank (*Tringa nebularia*)	Grey plover (*Pluvialis squatarola*)	Hen harrier (*Circus cyaneus*)
Icelandic greylag goose (*Anser anser*)	Knot (*Calidris canutus*)	Lapwing (*Vanellus vanellus*)	Long-tailed duck (*Clangula hyemalis*)
Mallard (*Anas platyrhynchos*)	Marsh harrier (*Circus aeruginosus*)	Merlin (*Falco columbarius*)	Nightjar (*Caprimulgus europaeus*)
Osprey (*Pandion haliaetus*)	Oystercatcher (*Haematopus ostralegus*)	Pink-footed goose (*Anser brachyrhynchus*)	Pintail (*Anas acuta*)
Purple sandpiper (*Calidris maritima*)	Red-breasted merganser (*Mergus serrator*)	Redshank (*Tringa totanus*)	Red-throated diver (*Gavia stellata*)
Ringed plover (*Charadrius hiaticula*)	Ruff (*Calidris pugnax*)	Sanderling (*Calidris alba*)	Scaup (*Aythya marila*)
Shelduck (*Tadorna tadorna*)	Short-eared owl (*Asio flammeus*)	Shoveler (*Anas clypeata*)	Slavonian grebe (*Podiceps auritus*)
Snipe (*Gallinago gallinago*)	Spotted crake (*Porzana porzana*)	Svalbard barnacle goose (*Branta leucopsis*)	Svalbard light-bellied brent goose (*Branta bernicla hrota*)
Teal (*Anas crecca*)	Tufted duck (*Aythya fuligula*)	Turnstone (*Arenaria interpres*)	Velvet scoter (*Melanitta fusca*)

Species Scoped in for mCRM			
Whimbrel (*Numenius phaeopus*)	White-tailed eagle (*Haliaeetus albicilla*)	Whooper swan (*Cygnus cygnus*)	Wigeon (*Anas penelope*)
Wood sandpiper (*Tringa glareola*)			

6 References

[1] HiDef Aerial Surveying Ltd (2024) 'mCRM: Avian Migration Collision Risk Model. R package version f0.4.1'. Available at: https://hidefdevo.shinyapps.io/mCRM/ (Accessed 13/05/2024)

[2] NatureScot (2023) 'Guidance Note 7: Guidance to support Offshore Wind Applications: Marine Ornithology – Advice for assessing collision risk of marine birds'. Available at: https://www.nature.scot/doc/guidance-note-7-guidance-support-offshore-wind-applications-marine-ornithology-advice-assessing (Accessed 15/05/2024)

[3] Woodward, I., Franks, S., Bowgen, K., Davies, J., Green, R., Griffin, L., Mitchell, C., O'Hanlon, N., Pollock, C., Rees, E., Tremlett, C., Wright, L. and Cook, A. (2023) 'Strategic study of collision risk for birds on migration and further development of the stochastic collision risk modelling tool'. Report by Scottish Government

[4] Wright, L.J., Ross-Smith, V.H., Austin, G.E., Massimino, D., Dadam, D., Cook, A.S.C.P., Calbrade, N.A. and Burton, N.H.K. (2012) 'Assessing the risk of offshore wind farm development to migratory birds designated as features of UK Special Protection Areas (and other Annex 1 species)'. Strategic Ornithological Support Services Project SOSS-05. 592

[5] Band, W. (2012) 'Using a collision risk model to assess bird collision risks for offshore windfarms'. March 2012

[6] R Core Team (2021) 'R: A language and environment for statistical computing'. R Foundation for Statistical Computing, Vienna, Austria

[7] Chamberlain, D.E., Rehfisch, M.M., Fox, A.D., Desholm, M. and Anthony, S.J. (2006) 'The Effect of Avoidance Rates on Bird Mortality Predictions Made by Wind Turbine Collision Risk Models'. Ibis 148(s1): 198–202

Caledonia Offshore Wind Farm
5th Floor, Atria One
144 Morrison Street
Edinburgh
EH3 8EX

www.caledoniaoffshorewind.com

OCEAN WINDS