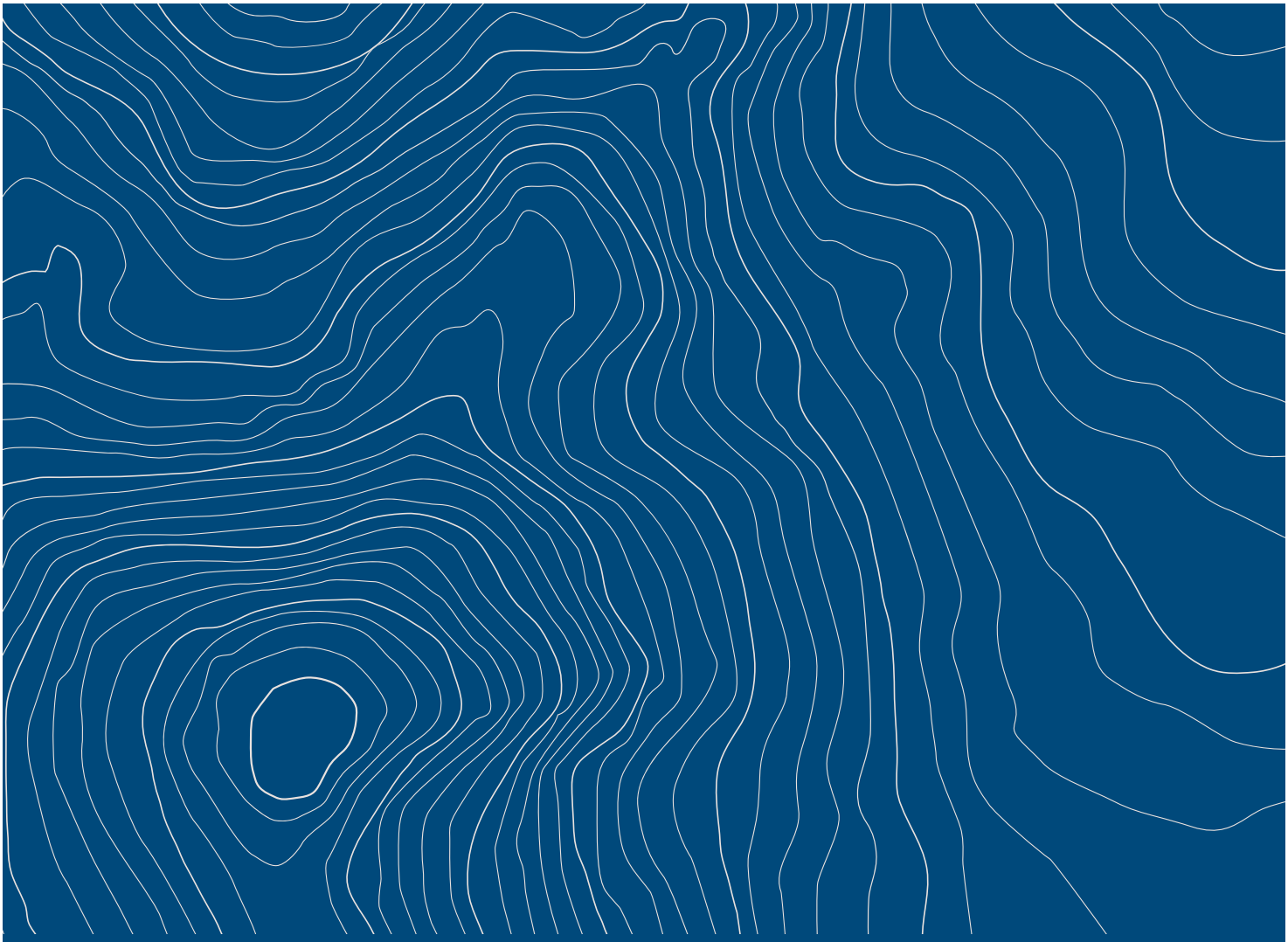

DublinArray
Generation for generations

EIAR Volume 4: Offshore Infrastructure Technical Appendices Appendix 4.3.6-5 Offshore Ornithology Migratory Collision Risk Modelling

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RWE Renewables Ireland Ltd.

Offshore Ornithology Migratory Collision Risk Modelling

Dublin Array Offshore Wind Farm

Revision	Date	Status	Author:	Checked by:	Approved by:
1.0	15/03/2024	Draft	JS	RI	JG
2.0	25/10/2024	Final	JS	RI	JG

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Acronyms

Term	Definition
BTO	British Trust for Ornithology
Dublin Array	Dublin Array Offshore Wind Farm
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
GIS	Geographical Information System
JNCC	Joint Nature Conservation Committee
km	Kilometres
mCRM	Migratory collision risk model
MDS	Maximum design scenario
MW	Megawatt
NPWS	National Parks and Wildlife Service
O&M	Operations and maintenance
RWE	RWE Renewables Ireland Ltd (a wholly owned subsidiary of RWE AG)
SOSS	Strategic Ornithological Support Services
SPA	Special Protection Area
UK	United Kingdom
WTG	Wind turbine generator

1 Introduction

1.1 Team competencies

1.1.1 Detailed below (Table 1–1) are the team competencies of those involved with the migratory collision risk model (mCRM) annex.

Table 1–1 mCRM assessment team competencies.

Discipline	Specialist	Qualifications	Experience
Ornithology	James Slingsby, GoBe	PhD, MSci	James is a senior ornithology consultant at GoBe, and formerly a marine environmental scientist at the University of the Highlands and Islands, with a strong background in statistical and quantitative research. He has experience in academic research and consultancy within environmental sciences specifically in the fields of marine seabird ecology, marine mammal ecology, marine renewable energy and remote sensing. His published scientific research is associated with the following fields: marine renewable energy, marine mammals, marine ornithology, uncrewed aerial vehicles and machine learning.
Ornithology	Jessica George, GoBe	MSc, BSc	Within her role as a senior ornithology consultant at GoBe, Jessica has developed a good understanding of offshore windfarm developments in regard to seabirds. Jessica has worked on projects in England, Scotland, Wales, Ireland, Isle of Man, the Netherlands and Poland (Baltic Sea). Jessica has focused on offshore ornithology OWF assessments, post consent monitoring and derogation (Article 6(4) of Habitats Directive), developing compensation measures for a variety of species.
Ornithology	Ryan Irvine, GoBe	BSc	Ryan has worked in ornithology for over 22 years with various roles with the JNCC, RSPB and consultancies. Ryan has gained vast experience in marine surveys of seabirds and cetaceans, report writing and data analysis. In his role at GoBe, Ryan has worked mainly on compensation and derogation work for a variety of seabirds (Article 6(4) of Habitats Directive) as well as working on ornithological assessments and various mCRM reports.

Discipline	Specialist	Qualifications	Experience
Ornithology	Colin Barton, Cork Ecology	BSc	Colin started work with JNCC as a marine surveyor in 1993, gaining experience in marine surveys of seabirds and cetaceans, along with report writing and data analysis. He also participated in surveys of breeding seabirds, including a nationally important common gull colony.

1.2 Project Background

1.2.1 Dublin Array is a proposed offshore wind farm on the Kish and Bray Banks. The Kish and Bray Banks are located, approximately 10 km off the east coast of Ireland, immediately south of Dublin city off the coast of counties Dublin and Wicklow. The offshore wind farm will be located within an area of approximately 59 km^2, in water depths ranging from 2 m to 50 m lowest astronomical tide (LAT). This technical annex has been produced to support the EIAR Offshore Ornithology chapter (3.6 Offshore Ornithology) and considers the potential impact to migratory birds that are not typically recorded in monthly surveys due to their movements over a short period of time and often at night or during bad weather (Wright *et al.,* 2012).

1.2.2 The Irish Sea is subject to pronounced passages of birds travelling to and from the UK, Europe and further afield (Stienen *et al.,* 2007). This includes the migratory movements of non-seabirds such as waders, wildfowl, passerines and non-passerines. Due to the mix of birds present, the Dublin Array area is used at different times of the year by birds (i) overwintering in the area; (ii) foraging from nearby breeding coastal colonies; and (iii) on post-breeding dispersal, migration and pre-breeding return.

1.3 Migratory Collision Risk Modelling

1.3.1 Assessing the potential impact from collision risk with wind turbines is an essential part of the EIA assessment process. The level of risk from collisions with turbines is estimated using Collision Risk Modelling (CRM). The species that are unlikely to be impacted are screened out and excluded from the modelling.

1.3.2 Site specific surveys were conducted for the Dublin Array area and surrounding area (4.3.6-1 Offshore Ornithology Technical Baseline). The results provide information for key seabird species for each biological period but are limited when it comes to migratory species, 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 , or at high altitudes, which makes recording their numbers extremely complex using standard methods.

1.3.3 To model the movements of migratory birds for Dublin Array the Marine Scotland Avian Migration Collision Risk Model Shiny Application ("mCRM App"; HiDef Aerial Surveying Ltd., 2024[1]) was used. Although this tool was developed for Scotland, the tool contains spatial coverage of species for use in Irish waters.

[1] Available at: https://hidefdevo.shinyapps.io/mCRM/ [Accessed March 2024].

2 Migratory CRM

2.1 Methodology

2.1.1 The migratory CRM was undertaken using the mCRM App. The mCRM App is a combination of the British Trust for Ornithology (BTO) Strategic Ornithological Support Services (SOSS) tool and a stochastic adaptation of the Band (2012) migration collision risk worksheet. The mCRM App was accessed via the 'Shiny App' interface, which is a user-friendly graphical interface accessible via a standard web-browser or within R statistical software (R Core Team, 2021) that uses an R code to estimate migratory collision risk (Donovan 2018). For this assessment the latest version of the mCRM App was downloaded and run locally within R (v0.4.1). The advantage of the mCRM App is that it provides a clear and transparent audit trail for all modelling runs, which enables regulators to easily access and reproduce the results of any modelling scenario.

2.1.2 The mCRM App provides two functions:

- Creates population estimates in wind farms by sampling migratory pathways via straight lines drawn between Irish, UK and non-UK countries; and
- Runs a stochastic version of the migratory CRM based on the population estimates and use-input parameters.

2.2 Inputs

Turbine parameters

2.2.1 A GIS shapefile of the Dublin Array array area footprint was added to the mCRM App. The OWF and turbine parameters used in the CRM are presented in Table 2–1 and Table 2–2. Upper and lower values for rotation speed and pitch were not included in the model because suitable information on rotor speed and pitch variability was not available. Note that the choice of value for determining the maximum and minimum collision rate depended on the relationship between each parameter and collision risk; in some cases, the larger parameter values lead to fewer estimated collisions. Based on UK standard practice, a 'Large Array Correction' factor was applied to the CRM, which takes into account multiple rows of WTGs which are common in large sized arrays.

Table 2–1: Turbine parameters for Option A, which was identified as the MDO.

Parameter	WTG A
Capacity (MW)	15.0
No. WTGs	50
Latitude (°N)	53.23
Width of array (km)	48.85
No. Blades	3
Rotor radius (m)	118
Max blade width (m)	8.5
Rotation Speed (RPM)	5.0
Rotation Speed SD	0
Blade Pitch (°)	2.4
Blade Pitch SD	0

Table 2–2: Predicted mean wind availability and downtime.

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind availability (%)	99	99	99	99	99	99	99	99	99	99	99	99
Mean downtime (%)	0	0	0	0	0	0	0	0	0	0	0	0
Mean downtime SD	0	0	0	0	0	0	0	0	0	0	0	0

Species selection and screening process

2.2.2 All species in the mCRM App were considered. If there was no overlap with the array area based on their migratory zones as defined in the tool (as defined in Woodward *et al.* (2023)), they were not considered further. The resulting list of species considered for migratory CRM is presented in Table 2–3, the species not included are avocet (*Recurvirostra avosetta*), bean goose (*Anser fabalis*), bittern (*Botaurus stellari*), dark-bellied brent goose (*Branta bernicla bernicla*), European white-fronted goose (*Anser albifrons albifrons*), Greenland barnacle goose (*Branta leucopsis*), honey buzzard (*Pernis apivorus*), Icelandic greylag goose (*Anser anser anser*), Montagu's harrier (*Circus pygargus*), nightjar (*Caprimulgus europaeus*), pink-footed goose (*Anser brachyrhynchus*), red-necked phalarope (*Phalaropus lobatus*), stone curlew (*Burhinus oedicnemus*), Svalbard barnacle goose (*Branta leucopsis*), Svalbard light-bellied brent goose (*Branta bernicla hrota*) and velvet scoter (*Melanitta fusca*). Northern gannet (*Morus bassanus*) was also not included as this species has been assessed in the Seabird CRM Technical Report (Part 1: Volume 4 of the EIAR: Appendix 4.3.7-2).

2.2.3 A screening exercise was then undertaken to identify which species require CRM, using a threshold based on the percentage of the population predicted to pass through the array area. If the percentage was equal to or greater than 1%, the species were screened in. Species below this threshold were screened out as the predicted impact would be so small that it would have no material impact on the population.

Table 2–3: Screening of migratory species whose flight paths are predicted to overlap with the Dublin Array array

Species	Number of individuals estimated to pass through the array	SD	% of migratory population estimated to pass through the array	Screened in/out
Bar-tailed godwit *Limosa lapponica*	50	16	0.3	Out
Black-tailed godwit *Limosa limosa*	1,455	254	1.5	In
Bewick's swan *Cygnus columbianus*	1	0	4.8	In
Black-throated diver *Gavia arctica*	11	3	0.9	Out
Canadian light-bellied brent goose *Branta bernicla hrota*	680	121	1.5	In
Common scoter *Melanitta nigra*	438	102	1.1	In
Corncrake *Crex crex*	175	35	1	In
Curlew *Numenius arquata*	743	155	1.1	In
Dotterel *Charadrius morinellus*	3	1	0.8	Out
Dunlin *Calidris alpina*	7,577	1385	1.4	In
Eider *Somateria mollissima*	525	101	1.6	In
Golden plover *Pluvialis apricaria*	7,926	1841	0.9	Out
Goldeneye *Bucephala clangula*	182	31	1.4	In
Great crested grebe *Podiceps cristatus*	70	12	2.4	In
Great northern diver *Gavia immer*	42	11	0.8	Out
Greenland white-fronted goose *Anser albifrons flavirostris*	167	29	1.7	In
Greenshank *Tringa nebularia*	17	4	1.2	In
Grey plover *Pluvialis squatarola*	36	7	1.2	In
Hen harrier *Circus cyaneus*	15	3	1.4	In

Species	Number of individuals estimated to pass through the array	SD	% of migratory population estimated to pass through the array	Screened in/out
Knot *Calidris canutus*	1,254	259	1.2	In
Lapwing *Vanellus vanellus*	1,048	190	1.2	In
Long-tailed duck *Clangula hyemalis*	197	36	1.5	In
Mallard *Anas platyrhynchos*	317	66	1.1	In
Marsh harrier *Circus aeruginosus*	31	6	1.2	In
Merlin *Falco columbarius*	55	11	1.3	In
Osprey *Pandion haliaetus*	5	2	0.7	Out
Oystercatcher *Haematopus ostralegus*	1,731	386	1.2	In
Pintail *Anas acuta*	66	16	1	In
Pochard *Aythya ferina*	145	27	1.3	In
Purple sandpiper *Calidris maritima*	74	17	1.1	In
Red-breasted merganser *Mergus serrator*	82	17	1.3	In
Redshank *Tringa totanus*	1,436	294	1.1	In
Red-throated diver *Gavia stellata*	73	20	0.8	Out
Ringed plover *Charadrius hiaticula*	1,058	205	1.3	In
Ruff *Calidris pugnax*	361	70	1.2	In
Sanderling *Calidris alba*	557	115	1	In
Scaup *Aythya marila*	39	8	1.6	In
Shelduck *Tadorna tadorna*	123	26	1.2	In
Short-eared owl *Asio flammeus*	161	31	1.1	In
Shoveler *Anas clypeata*	31	7	1.4	In
Slavonian grebe	12	3	1.1	In

Species	Number of individuals estimated to pass through the array	SD	% of migratory population estimated to pass through the array	Screened in/out
Podiceps auritus				
Snipe *Gallinago gallinago*	31,656	7092	1	In
Spotted crake *Porzana porzana*	1	0	3.8	In
Teal *Anas crecca*	1,595	362	1.1	In
Tufted duck *Aythya fuligula*	677	137	1	In
Turnstone *Arenaria interpres*	1,179	224	1.2	In
Whimbrel *Numenius phaeopus*	54	11	1.1	In
White-tailed eagle *Haliaeetus albicilla*	2	1	0.7	Out
Whooper swan *Cygnus cygnus*	231	47	0.9	Out
Wigeon *Anas penelope*	1,794	396	1	In
Wood sandpiper *Tringa glareola*	1	0	1.9	In

2.2.4 It is important to note that the species population estimates provided within the mCRM App defaults to the UK population sizes, which are not representative of Irish populations. To make it applicable to an OWF in the Irish Sea, the defined populations in the tool were altered to reflect a truer representation of the migratory pathways within the region. To determine appropriate populations and proportions passing the Irish Sea, several methods were used (using the Irish population within Burke *et al.* (2018)):

- For species with an easterly migration pathway to and from Ireland (e.g. Bewick's swan) the population was set at the Irish population in Burke *et al.* (2018);
- For species with a northerly or north-westerly migratory route to and from Ireland (e.g. light-bellied brent goose) a precautionary measure was used by adding 25% of the UK population (population derived in the mCRM App) to the Irish population (Burke *et al.,* 2018) to include any individuals from the south-western regions of the UK populations overflying the Irish Sea. If the Irish population plus the 25% of the UK population exceeded the flyway population, then the proportion of the population passing through the proposed development was set to one.

2.2.5 Where the all-Ireland populations were not provided in Burke *et al*. (2018), the default UK populations in the mCRM App were used with the following caveats applied:

- For migratory raptor species and snipe it was assumed that a conservative 50% of the UK population may fly over the Irish Sea during the migration period.
- For corncrake, which migrates north/south from its breeding range in the north-west of the UK that a precautionary 100% of the UK population was assumed to fly over the Irish Sea.

2.2.6 These methods for calculating the populations have also been discussed and agreed with other Irish Phase 1 Project (North Irish Sea Array (NISA) and Codling Wind Park).

Bird parameters

2.2.7 Pre-breeding and post-breeding migration seasons are defined within the mCRM App and are presented in Table 2–4. The species-specific biometric parameters used within CRM are also defined in the mCRM App and are presented in Table 2–5. Each flight type was set as "flapping".

Table 2–4. Defined migration seasons used in the mCRM tool.

Species	Pre-breeding	Post-breeding	Other
Black-tailed Godwit	Mar -May	Aug - Oct	NA
Bewick's Swan	Feb - Mar	Oct - Dec	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
Dunlin	Mar - May	Jun - Oct	NA
Eider	Mar - Apr	Oct - Nov	NA
Goldeneye	Feb - May	Aug - Dec	NA
Great crested Grebe	Mar - Jun	Jul - Nov	Feb - Mar
Greenland White-fronted Goose	Mar - Apr	Sep - Nov	NA
Greenshank	Mar - Jun	Aug - Nov	NA
Grey Plover	Mar - May	Jul - Sep	NA
Hen Harrier	Mar - May	Sep - 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
Oystercatcher	Jan - Mar	Jul - Nov	NA
Pintail	Mar - May	Aug - Nov	NA
Pochard	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
Ringed Plover	Mar - May	Aug - Oct	NA

Species	Pre-breeding	Post-breeding	Other
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
Slavonian Grebe	Feb - Apr	Aug - Oct	NA
Snipe	Mar - May	Aug - Oct	Oct - Dec
Spotted Crake	May - Jun	Jul - Oct	NA
Teal	Feb - May	Jul - Dec	NA
Tufted Duck	Apr - Jun	Sep - Oct	NA
Turnstone	Jan - Jun	Jul - Aug	NA
Whimbrel	Apr - Jun	Jun - Oct	NA
Wigeon	Mar - Apr	Aug - Nov	NA
Wood Sandpiper	Apr - May	Jul - Sep	NA

Table 2–5. Species biometrics used in the mCRM tool. Standard deviation (SD) included in brackets.

Species	Body length (m)	Wingspan (m)	Flight speed (ms^{-1})	Proportion at PCH	Avoidance Rate
Black-tailed Godwit	0.42 (0.02)	0.76 (0.02)	18.10 (6.00)	1	0.999 (0)
Bewick's Swan	1.21 (0.04)	1.96 (0.04)	24.00 (7.60)	0.50	0.988 (0.0009)
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)
Dunlin	0.18 (0.01)	0.40 (0.01)	15.30 (1.90)	1.00	0.999 (0)
Eider	0.60 (0.03)	0.94 (0.03)	17.34 (2.40)	0.25	0.985 (0.0008)
Goldeneye	0.46 (0.01)	0.72 (0.01)	20.30 (3.80)	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)
Greenland White-fronted Goose	0.72 (0.06)	1.48 (0.06)	18.75 (7.19)	1.00	0.999 (0.0001)
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)
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)
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)
Oystercatcher	0.42 (0.02)	0.83 (0.02)	13.00 (2.50)	1.00	0.999 (0)
Pintail	0.58 (0.02)	0.88 (0.02)	21.90 (2.00)	1.00	0.985 (0.0008)
Pochard	0.46 (0.01)	0.77 (0.01)	23.60 (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)

Species	Body length (m)	Wingspan (m)	Flight speed (ms^{-1})	Proportion at PCH	Avoidance Rate
Redshank	0.28 (0.01)	0.62 (0.01)	15.30 (4.10)	1.00	0.999 (0)
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)
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)
Whimbrel	0.41 (0.02	0.82 (0.02)	13.8 (0.40)	1.00	0.999 (0)
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)

Avoidance rates

2.2.8 Avoidance rates (AR) are a key parameter in the CRM, they take into consideration that birds will undertake avoidance behaviour in response to the presence of a wind farm to prevent collision. This can occur at three scales (Cook *et al.*, 2014); micro-avoidance (avoiding individual turbine blades); meso-avoidance (avoiding whole wind turbines, not just the rotor-swept area) and macro-avoidance (avoiding the whole wind farm array area and buffer). The AR used in CRM for each species, presented in Table 2–5, are set in the mCRM App as recommended by NatureScot and checked by Cook (*pers comm*). The AR used in the tool are based upon the most recent evidence (Woodward *et al.,* 2023).

Species biometrics

2.2.9 The species-specific biometric input parameters (body length and wingspan) used in the CRM are provided in Table 2–5. The biometrics for all species were taken as presented in the mCRM App, on the basis of the biometric data from Snow and Perrins (1998).

Seabird flight speeds

2.2.10 Species-specific flight speeds used in the CRM assessment are presented in Table 2–5. Flight speeds were taken as presented in the mCRM App as per Alerstam *et al.* (2007).

3.1.1 This section presents the outputs from the CRM analysis for each of the screened in migratory species. A summary of the results for each species for Option A is presented in Table 3–1, Option B in Table 3–2 and Option C in Table 3–3.

Table 3–1: Summary of annual collision estimates following the Dublin Array approach for Option A (50 WTGs).

Species	Pre-breeding	Post-breeding	Other	Total
Black-tailed godwit	0.014 ± 0.003	0.014 ± 0.003	0 ± 0	0.028 ± 0.004
Bewick's swan	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Black-throated diver	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Canadian light-bellied brent goose	0.004 ± 0.001	0.004 ± 0.001	0 ± 0	0.008 ± 0.001
Common scoter	0.064 ± 0.015	0.064 ± 0.015	0 ± 0	0.128 ± 0.021
Corncrake	0.008 ± 0.002	0.008 ± 0.002	0 ± 0	0.016 ± 0.003
Curlew	0.008 ± 0.002	0.008 ± 0.002	0 ± 0	0.016 ± 0.003
Dunlin	0.068 ± 0.012	0.068 ± 0.012	0 ± 0	0.136 ± 0.017
Eider	0.02 ± 0.004	0.02 ± 0.004	0 ± 0	0.04 ± 0.006
Goldeneye	0.026 ± 0.005	0.026 ± 0.005	0 ± 0	0.052 ± 0.007
Great crested grebe	0.003 ± 0.001	0.003 ± 0.001	0.003 ± 0.001	0.009 ± 0.002
Great northern diver	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Greenland white-fronted goose	0.002 ± 0.001	0.002 ± 0.001	0 ± 0	0.004 ± 0.001
Greenshank	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Grey plover	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Hen harrier	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Knot	0.012 ± 0.002	0.012 ± 0.002	0 ± 0	0.024 ± 0.003
Lapwing	0.01 ± 0.002	0.01 ± 0.002	0 ± 0	0.02 ± 0.003
Long-tailed duck	0.028 ± 0.005	0.028 ± 0.005	0 ± 0	0.056 ± 0.007
Mallard	0.049 ± 0.01	0.049 ± 0.01	0.049 ± 0.01	0.147 ± 0.017
Marsh harrier	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Merlin	0.006 ± 0.006	0.006 ± 0.006	0 ± 0	0.012 ± 0.008
Oystercatcher	0.017 ± 0.004	0.017 ± 0.004	0 ± 0	0.034 ± 0.006
Pintail	0.01 ± 0.002	0.01 ± 0.002	0 ± 0	0.02 ± 0.003
Pochard	0.021 ± 0.004	0.021 ± 0.004	0 ± 0	0.042 ± 0.006
Purple sandpiper	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Red-breasted merganser	0.012 ± 0.003	0.012 ± 0.003	0 ± 0	0.024 ± 0.004
Redshank	0.014 ± 0.003	0.014 ± 0.003	0 ± 0	0.028 ± 0.004
Ringed plover	0.01 ± 0.002	0.01 ± 0.002	0 ± 0	0.02 ± 0.003
Ruff	0.003 ± 0.001	0.003 ± 0.001	0 ± 0	0.006 ± 0.001
Sanderling	0.005 ± 0.001	0.005 ± 0.001	0 ± 0	0.01 ± 0.001
Scaup	0.006 ± 0.001	0.006 ± 0.001	0 ± 0	0.012 ± 0.001
Shelduck	0.01 ± 0.002	0.01 ± 0.002	0.01 ± 0.002	0.03 ± 0.003
Short-eared owl	0.008 ± 0.002	0.008 ± 0.002	0 ± 0	0.016 ± 0.003
Shoveler	0.005 ± 0.001	0.005 ± 0.001	0.005 ± 0.001	0.015 ± 0.002
Slavonian grebe	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Snipe	0.291 ± 0.065	0.291 ± 0.065	0.291 ± 0.065	0.873 ± 0.113

Species	Pre-breeding	Post-breeding	Other	Total
Spotted crake	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Teal	0.225 ± 0.053	0.225 ± 0.053	0 ± 0	0.45 ± 0.075
Tufted duck	0.096 ± 0.02	0.096 ± 0.02	0 ± 0	0.192 ± 0.028
Turnstone	0.011 ± 0.002	0.011 ± 0.002	0 ± 0	0.022 ± 0.003
Whimbrel	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Wigeon	0.262 ± 0.06	0.262 ± 0.06	0 ± 0	0.524 ± 0.085
Wood sandpiper	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Table 3–2 Summary of annual collision estimates following the Dublin Array approach for Option B (45 WTGs).

Species	Pre-breeding	Post-breeding	Other	Total
Black-tailed godwit	0.014 ± 0.003	0.014 ± 0.003	0 ± 0	0.028 ± 0.004
Bewick's swan	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Black-throated diver	0.004 ± 0.001	0.004 ± 0.001	0 ± 0	0.008 ± 0.001
Canadian light-bellied brent goose	0.063 ± 0.013	0.063 ± 0.013	0 ± 0	0.126 ± 0.018
Common scoter	0.008 ± 0.001	0.008 ± 0.001	0 ± 0	0.016 ± 0.001
Corncrake	0.007 ± 0.002	0.007 ± 0.002	0 ± 0	0.014 ± 0.003
Curlew	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Dunlin	0.062 ± 0.065	0.062 ± 0.065	0 ± 0	0.124 ± 0.092
Eider	0.019 ± 0.003	0.019 ± 0.003	0 ± 0	0.038 ± 0.004
Goldeneye	0.025 ± 0.005	0.025 ± 0.005	0 ± 0	0.05 ± 0.007
Great crested grebe	0.003 ± 0.001	0.003 ± 0.001	0.003 ± 0.001	0.009 ± 0.002
Great northern diver	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Greenland white-fronted goose	0.002 ± 0.001	0.002 ± 0.001	0 ± 0	0.004 ± 0.001
Greenshank	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Grey plover	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Hen harrier	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Knot	0.011 ± 0.002	0.011 ± 0.002	0 ± 0	0.022 ± 0.003
Lapwing	0.009 ± 0.002	0.009 ± 0.002	0 ± 0	0.018 ± 0.003
Long-tailed duck	0.027 ± 0.005	0.027 ± 0.005	0 ± 0	0.054 ± 0.007
Mallard	0.048 ± 0.01	0.048 ± 0.01	0.048 ± 0.01	0.144 ± 0.017
Marsh harrier	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Merlin	0.006 ± 0.005	0.006 ± 0.005	0 ± 0	0.012 ± 0.007
Oystercatcher	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Pintail	0.016 ± 0.003	0.016 ± 0.003	0 ± 0	0.032 ± 0.004
Pochard	0.009 ± 0.002	0.009 ± 0.002	0 ± 0	0.018 ± 0.003
Purple sandpiper	0.02 ± 0.004	0.02 ± 0.004	0 ± 0	0.04 ± 0.006
Red-breasted merganser	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Redshank	0.013 ± 0.003	0.013 ± 0.003	0 ± 0	0.026 ± 0.004
Ringed plover	0.01 ± 0.002	0.01 ± 0.002	0 ± 0	0.02 ± 0.003
Ruff	0.003 ± 0.001	0.003 ± 0.001	0 ± 0	0.006 ± 0.001
Sanderling	0.005 ± 0.001	0.005 ± 0.001	0 ± 0	0.01 ± 0.001
Scaup	0.005 ± 0.001	0.005 ± 0.001	0 ± 0	0.01 ± 0.001
Shelduck	0.009 ± 0.002	0.009 ± 0.002	0.009 ± 0.002	0.027 ± 0.003

Species	Pre-breeding	Post-breeding	Other	Total
Short-eared owl	0.008 ± 0.001	0.008 ± 0.001	0 ± 0	0.016 ± 0.001
Shoveler	0.004 ± 0.001	0.004 ± 0.001	0.004 ± 0.001	0.012 ± 0.002
Slavonian grebe	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Snipe	0.276 ± 0.065	0.276 ± 0.065	0.276 ± 0.065	0.828 ± 0.113
Spotted crake	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Teal	0.204 ± 0.047	0.204 ± 0.047	0 ± 0	0.408 ± 0.066
Tufted duck	0.091 ± 0.021	0.091 ± 0.021	0 ± 0	0.182 ± 0.03
Turnstone	0.01 ± 0.002	0.01 ± 0.002	0 ± 0	0.02 ± 0.003
Whimbrel	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Wigeon	0.243 ± 0.06	0.243 ± 0.06	0 ± 0	0.486 ± 0.085
Wood sandpiper	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Table 3–3: Summary of annual collision estimates following the Dublin Array approach for Option C (39 WTGs).

Species	Pre-breeding	Post-breeding	Other	Total
Black-tailed godwit	0.013 ± 0.002	0.013 ± 0.002	0 ± 0	0.026 ± 0.003
Bewick's swan	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Black-throated diver	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Canadian light-bellied brent goose	0.003 ± 0.001	0.003 ± 0.001	0 ± 0	0.006 ± 0.001
Common scoter	0.059 ± 0.013	0.059 ± 0.013	0 ± 0	0.118 ± 0.018
Corncrake	0.007 ± 0.002	0.007 ± 0.002	0 ± 0	0.014 ± 0.003
Curlew	0.007 ± 0.001	0.007 ± 0.001	0 ± 0	0.014 ± 0.001
Dunlin	0.061 ± 0.063	0.061 ± 0.063	0 ± 0	0.122 ± 0.089
Eider	0.018 ± 0.003	0.018 ± 0.003	0 ± 0	0.036 ± 0.004
Goldeneye	0.024 ± 0.005	0.024 ± 0.005	0 ± 0	0.048 ± 0.007
Great crested grebe	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Great northern diver	0.003 ± 0	0.003 ± 0	0.003 ± 0	0.009 ± 0
Greenland white-fronted goose	0.002 ± 0.001	0.002 ± 0.001	0 ± 0	0.004 ± 0.001
Greenshank	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Grey plover	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Hen harrier	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Knot	0.01 ± 0.002	0.01 ± 0.002	0 ± 0	0.02 ± 0.003
Lapwing	0.009 ± 0.002	0.009 ± 0.002	0 ± 0	0.018 ± 0.003
Long-tailed duck	0.026 ± 0.004	0.026 ± 0.004	0 ± 0	0.052 ± 0.006
Mallard	0.044 ± 0.009	0.044 ± 0.009	0.044 ± 0.009	0.132 ± 0.016
Marsh harrier	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Merlin	0.006 ± 0.005	0.006 ± 0.005	0 ± 0	0.012 ± 0.007
Oystercatcher	0.016 ± 0.004	0.016 ± 0.004	0 ± 0	0.032 ± 0.006
Pintail	0.009 ± 0.002	0.009 ± 0.002	0 ± 0	0.018 ± 0.003
Pochard	0.019 ± 0.004	0.019 ± 0.004	0 ± 0	0.038 ± 0.006
Purple sandpiper	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Red-breasted merganser	0.011 ± 0.002	0.011 ± 0.002	0 ± 0	0.022 ± 0.003
Redshank	0.013 ± 0.003	0.013 ± 0.003	0 ± 0	0.026 ± 0.004
Ringed plover	0.009 ± 0.002	0.009 ± 0.002	0 ± 0	0.018 ± 0.003
Ruff	0.003 ± 0.001	0.003 ± 0.001	0 ± 0	0.006 ± 0.001
Sanderling	0.005 ± 0.001	0.005 ± 0.001	0 ± 0	0.01 ± 0.001

Species	Pre-breeding	Post-breeding	Other	Total
Scaup	0.005 ± 0.001	0.005 ± 0.001	0 ± 0	0.01 ± 0.001
Shelduck	0.008 ± 0.002	0.008 ± 0.002	0.008 ± 0.002	0.024 ± 0.003
Short-eared owl	0.007 ± 0.002	0.007 ± 0.002	0 ± 0	0.014 ± 0.003
Shoveler	0.004 ± 0.001	0.004 ± 0.001	0.004 ± 0.001	0.012 ± 0.002
Slavonian grebe	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Snipe	0.263 ± 0.055	0.263 ± 0.055	0.263 ± 0.055	0.789 ± 0.095
Spotted crake	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Teal	0.198 ± 0.044	0.198 ± 0.044	0 ± 0	0.396 ± 0.062
Tufted duck	0.087 ± 0.021	0.087 ± 0.021	0 ± 0	0.174 ± 0.03
Turnstone	0.01 ± 0.002	0.01 ± 0.002	0 ± 0	0.02 ± 0.003
Whimbrel	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Wigeon	0.231 ± 0.055	0.231 ± 0.055	0 ± 0	0.462 ± 0.078
Wood sandpiper	0 ± 0	0 ± 0	0 ± 0	0 ± 0

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