MONA OFFSHORE WIND PROJECT

Environmental Statement

Volume 6, Annex 5.4: Offshore ornithology migratory bird Collision Risk Modelling technical report

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Glossary

Term	Meaning
Air Gap	The gap between the mean sea level and the lowest point of a wind turbine rotor blade.
Applicant	Mona Offshore Wind Limited.
Avoidance	Probability that a bird takes successful evasive action to avoid collision with a wind turbine.
Collision risk	Risk of a bird lethally colliding with a wind turbine within a wind farm.
Collision risk model	A model that calculates collision risk for a species within a wind farm based on a set of wind turbines and bird species specific parameters. Collision risk models can be run deterministically or stochastically.
Large Array Correction	Adjustment to the probability of bird collision to account for the depletion of bird density in later rows of a wind farm with a large array of wind turbines.
Lowest Astronomical Tide	The lowest level of the sea surface with respect to the land.
Maximum Design Scenario	The wind farm design scenario that is considered the worst case from the perspective of collision risk.
Mean Sea Level	The average level of the sea surface with respect to the land.
Ornithology	Ornithology is a branch of zoology that concerns the study of birds.
Parameter	Parameters are the input elements of a model that together affect the output of a model. In collision risk models, examples of parameters are the number of wind turbines and the length of the bird. All input parameters are described in Table 1.5 and Table 1.6.

Acronyms

Term	Meaning
BTO	British Trust for Ornithology
CRM	Collision Risk Model
GIS	Geographical Information System
LAT	Lowest Astronomical Tide
MDS	Maximum Design Scenario
MSL	Mean Sea Level
SOSS	Strategic Ornithological Support Services
SOSSMAT	Strategic Ornithological Support Services Migration Assessment Tool
SPA	Special Protection Area

Units

Unit	Description
km	Kilometres
km^2	Square kilometres
m	Metres
m/s	Metres per second
RPM	Rotations per minute
%	Percentage

1 Migratory bird Collision Risk Modelling technical report

1.1 Introduction

1.1.1.1 This technical report covers the potential impacts as a result of collision risk from the Mona Offshore Wind Project, on migratory waterbird and seabird species. For the purposes of this analysis migratory waterbirds refers to species of ducks, geese, waders and terrestrial birds that are features of UK Special Protection Areas (SPAs). Migratory seabirds were defined as divers, shearwaters, petrels, gannets, cormorants, skuas, gulls, terns and auks.

1.1.1.2 During the operations and maintenance phase of the Mona Offshore Wind Project, the turning rotors of the wind turbines may present a risk of collision for birds that cross the Mona Array Area during their migration. Stationary structures, such as the tower, nacelle or rotors when not operating, are not expected to result in a material risk of collision. When a collision occurs between the turning rotor blade and the bird, it is assumed to result in direct mortality of the bird, which potentially could result in population level impacts.

1.1.1.3 This migratory collision risk modelling technical report provides numbers of predicted collisions of migratory bird species based on the species/populations identified to be at risk of crossing the Mona Array Area. The assessment includes migratory seabirds which are not considered in the collision risk modelling for seabirds provided in Volume 6, Annex 5.3: Offshore ornithology migratory bird collision risk modelling technical report of the Environmental Statement.

1.2 Consultation

1.2.1.1 A summary of the key issues raised during consultation activities undertaken to date specific to offshore ornithology is presented in Table 1.1 below, together with how these issues have been considered in the production of this migratory bird collision risk technical report as part of the Environmental Statement.

1.2.2 Evidence Plan process

1.2.2.1 The purpose of the Evidence Plan process is to agree the information the Mona Offshore Wind Project needs to supply to the Secretary of State, as part of a DCO application for the Mona Offshore Wind Project. The Evidence Plan seeks to ensure compliance with EIA. The development and monitoring of the Evidence Plan and its subsequent progress is being undertaken by the Steering Group. The Steering Group will comprise of the Planning Inspectorate, the Applicant, NRW, Natural England, JNCC and the MMO as the key regulatory and SNCBs. To inform the EIA process during the pre-application stage of the Mona Offshore Wind Project, Expert Working Groups (EWGs) were also set up to discuss and agree topic specific issues with the relevant stakeholders. Consultation was undertaken via the Offshore Ornithology EWG, with meetings held in February 2022, July 2022, November 2022, February 2023, June 2023 and October 2023.

1.2.2.2 The responses provided and changes suggested by the stakeholders through the EWG are summarized in Table 1.1, together with changes implemented in the migratory bird collision risk technical report of the Environmental Statement.

1.2.3 Section 42 Consultation

1.2.3.1 A number of comments were received during the S42 consultation following submission of the PEIR chapter. All the responses provided, and changes suggested by the stakeholders are presented in the consultation report (Document reference E.3) together with changes implemented in the technical reports underpinning the Environmental Statement.

1.2.3.2 A summary of the key responses with changes implemented in the migratory bird collision risk technical report of the Environmental Statement are presented in Table 1.1.

Table 1.1: Summary of key topics and issues raised during consultation activities undertaken for the Mona Offshore Wind Project relevant to offshore ornithology migratory bird collision risk modelling technical report of the Environmental Statement.

Date	Consultee and type of response	Topics and issues raised	Response to issue raised and/or where considered in this chapter
May 2022	**Scoping Opinion** IOM Department of Infrastructure	The EWG recommended the inclusion of bird data from Manx Birdlife (and the inclusion of non-marine, migratory or nomadic species, in particular birds of prey, which are recognised as being vulnerable to OWF collisions). Manx Birdlife holds the national database for bird data.	Volume 6, Annex 5.4 Offshore ornithology migratory bird collision risk modelling technical report of the Environmental Statement considers the risk to migratory birds using the SOSS Migration Assessment Tool (Wright et al., 2012), which is comprehensive and adequate for assessing the impact of collision to migratory birds.
November 2022	**Offshore Ornithology Expert** **Working Group 3:** **Attended by:** Natural England, JNCC, NRW, TWT, IOM, Marine Management Organisation (MMO)	Agreed on the proposed methodology for assessing impacts on migratory seabirds	
June 2023	**S42 Consultation** NRW	The need for consideration of migrant seabird species (for example, skuas, terns) in collision risk assessments.	Migratory seabirds have been considered in the collision risk modelling for seabirds provided in Volume 6, Annex 5.4: Offshore ornithology migratory bird collision risk modelling technical report of the Environmental Statement.
		Seabird species that may pass through the Mona site on migration (for example, skuas, terns etc.) should not be excluded from assessments based on low numbers recorded during site-based surveys alone. It would not be appropriate to use the Strategic Ornithological Support Services Migration Assessment Tool (SOSSMAT) for these species as they often migrate following coastlines at a distance offshore, rather than straight lines between point of origin and destination, which is an assumption of SOSSMAT/Migropath. Therefore, alternative approaches are required. Consideration should also be given to the distribution of birds within the broad migratory front: birds	The approach to quantify migratory seabirds using the Marine Scotland project on strategic assessment of collision risk of OWFs to migrating birds (WWT Consulting and MacArthur Green, 2014) has been presented at the EWG05 and adopted in Volume 6, Annex 5.4: Offshore ornithology migratory birds collision risk modelling technical report of the Environmental Statement.

Date	Consultee and type of response	Topics and issues raised	Response to issue raised and/or where considered in this chapter
		could be distributed evenly, or they might have a skewed distribution; for example, if the species tends to avoid the coast on migration through the Irish Sea, then distribution could be biased towards the centre of the Irish Sea. This approach is broadly consistent with the approach taken in the report for the Marine Scotland project on strategic assessment of collision risk of OWFs to migrating birds.	
		With reference to Migratory non-seabird collision risk NRW (A) also advise that an example species Band (2012) input and output sheet are included.	An example species of the Band (2012) input and output is presented in Volume 6, Annex 5.4: Offshore ornithology migratory birds collision risk modelling technical report of the Environmental Statement.
June 2023	**S42 Consultation** Natural England	Natural England recognise that it may not be appropriate to use SOSSMAT for migratory species. An alternative approach is to consider a broad migratory front, and apportion impacts to the project area.	Migratory seabirds are considered in the collision risk modelling for seabirds provided in Volume 6, Annex 5.4: Offshore ornithology migratory bird collision risk modelling technical report of the Environmental Statement.
June 2023	**S42 Consultation** JNCC	1.10.4.8 & 1.10.4.10 Given the comments made regarding Volume 6: Annex 5.5 Offshore ornithology apportioning technical report of the Environmental Statement and Volume 6: Annex 5.3 Offshore ornithology collision risk technical report of the Environmental Statement, we cannot agree that all relevant SPAs and features have been included here.	All SPAs with seabird features within the mean-max foraging + 1 SD of the Mona Array Area have been considered in the assessment.
n.d.	**S42 Consultation** Orsted	Whooper Swan have so far been omitted in your offshore ornithology chapter.	Whopper swan have been included in migratory birds collision risk modelling presented in Volume 6, Annex 5.4: Offshore ornithology migratory bird collision risk modelling technical report of the Environmental Statement.
June 2023	**Offshore Ornithology Expert** **Working Group 5:** **Attend by:** JNCC, Natural England, NRW, IoM, MMO	Agreed on alternative approach to migratory collision	The agreed approach is in line with the approach outlined in previous advice.

1.3 Methodology

1.3.1.1 A combination of two approaches/ tools were followed to quantify the number of birds that may cross the Mona Array Area during migration periods:

- The SOSS Migration Assessment Tool (SOSSMAT) was used to assess the population size of migratory bird species designated as features of the UK Special Protection Area (SPA) network that may cross the Mona Array Area; instructions are given in Wright *et al*. (2012)
- An approach used in a *Strategic assessment of collision risk of Scottish offshore wind* (WWT Consulting and MacArthur Green, 2014) to estimate proportions of the seabird population likely to pass the Scottish offshore wind farm sites.

1.3.1.2 The resulting number of seabird and non-seabirds estimated to cross the Mona Array Area was inputted into the Band (2012) single transit Collision Risk Model (CRM).

1.3.2 Migratory non-seabird species

Selecting connectivity lines with Mona Array Area in SOSSMAT

1.3.2.1 First, the SOSSMAT Geographical Information System (GIS) tool was used to select crossing lines of migration (as identified by Wright *et al*., 2012) that intersected with the Mona Array Area. According to the sections of the coastline defined in the SOSSMAT tool (Figure 1.1) and the position of the Mona Array Area, a number of migration routes were selected that included a start or end point bordering the Irish Sea in England and Wales. The routes selected are shown in Table 1.2. These routes followed the broad migrating patterns known to occur across the British Isles and are described below:

- Birds from Iceland, Canada and Greenland moving through and overwintering in Ireland
- Birds from the Arctic and sub-Arctic (further to the east) moving through the British Isles and over-wintering in Ireland
- Birds from the Arctic and sub-Arctic moving through Ireland to winter further south (e.g. Spain).

Table 1.2: Migration routes selected and corresponding SOSSMAT code.

SOSSMAT code	Start migration	End migration
EWBEWI	England and Wales Bristol Channel	England and Wales Irish Sea
EWBNIC	England and Wales Bristol Channel	Northern Ireland Celtic Seas coast
EWBSCS	England and Wales Bristol Channel	Scottish mainland Celtic Seas coast
EWIEWI	England and Wales Irish Sea	England and Wales Irish Sea
EWINIC	England and Wales Irish Sea	Northern Ireland Celtic Seas coast
EWISCS	England and Wales Irish Sea	Scottish mainland Celtic Seas coast
RIEEWI	Republic of Ireland - Celtic Seas east coast	England and Wales Irish Sea
SPAEWI	Spanish north coast	England and Wales Irish Sea
SPASCS	Spanish north coast	Scottish mainland Celtic Seas coast

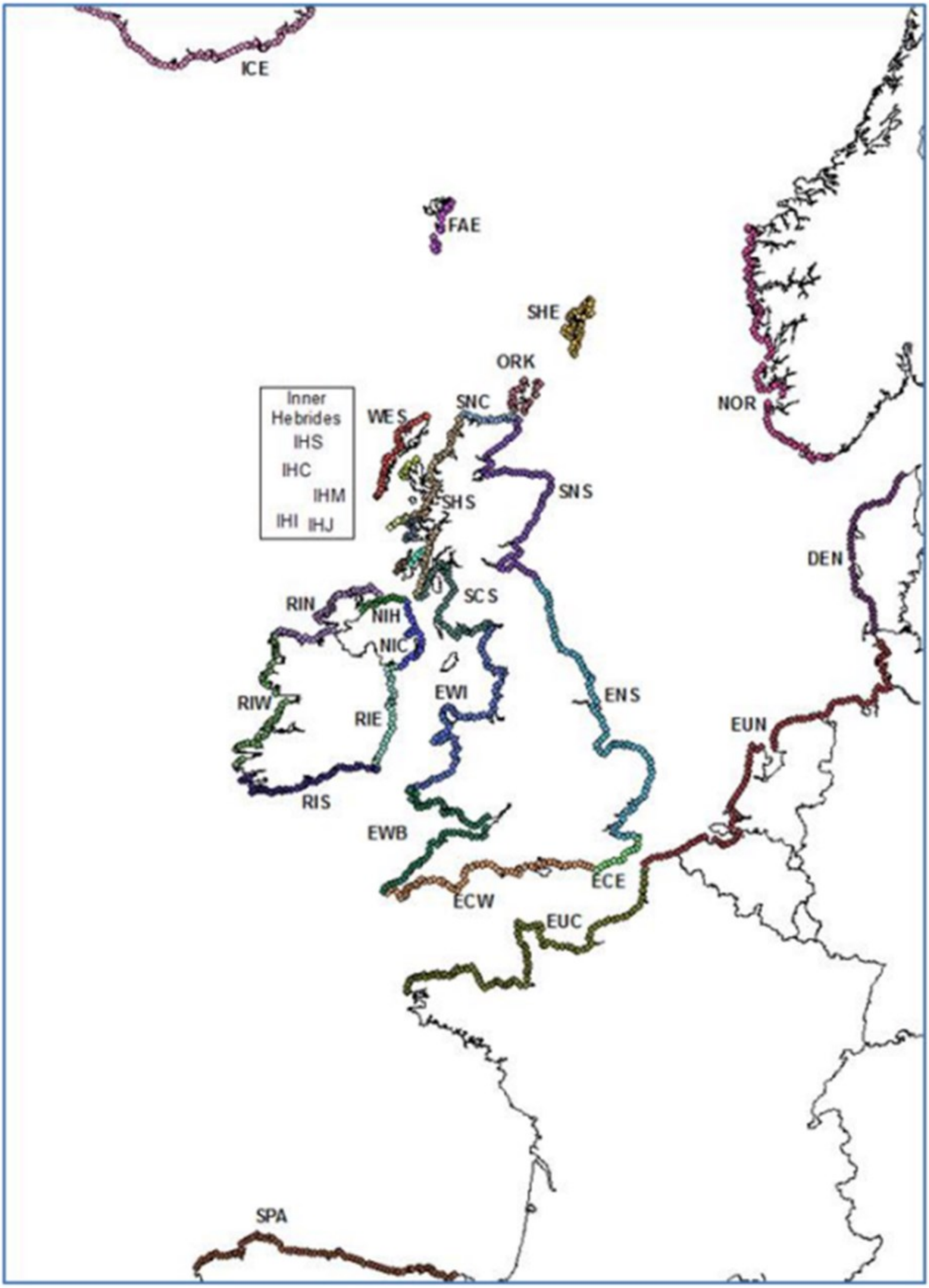


Figure 1.1: Coastal zones defined for the SOSSMAT. The thirty different coastal zones defined for the purpose of the migration assessment are labelled and shown in different colours in the figure above (Source: Wright *et al*., 2012).

Population size and population correction factor

1.3.2.2 The percentage of lines crossing the Mona Array Area was derived for each species known to migrate along the route selected in SOSSMAT. In the SOSSMAT worksheets, the number of birds crossing the Mona Array Area was calculated by adding parameters such as population size and population correction factor (% of the population using the relevant sea crossing). UK population size estimates were taken from Woodward *et al*. (2020) (Table 1.3).

1.3.2.3 The corrections factors (percent of population estimated to be using relevant sea-crossings) were estimated using the maps available in the SOSS guidance (*Wright et al.,* 2012) as there is little published evidence on the distribution of birds along migratory corridors.

Table 1.3: International name, scientific name, UK population size, population corrections factor (percent of population estimated to be using relevant sea-crossings).

International name	Scientific name	UK Population size	Population correction factor
Tundra swan (Bewick's swan)	*Cygnus columbianus bewickii*	4,350	9
Whooper swan	*Cygnus cygnus*	19,500	99
Greenland white-fronted goose	*Anser albifrons flavirostris*	14,000	100
Light-bellied brent goose (Canadian population)	*Branta bernicla hrota*	135,000	1
Common shelduck	*Tadorna tadorna*	51,000	100
Eurasian wigeon	*Mareca penelope*	450,000	100
Gadwall	*Mareca strepera*	31,000	100
Eurasian teal	*Anas crecca*	435,000	100
Mallard	*Anas platyrhynchos*	675,000	100
Northern pintail	*Anas acuta*	20,000	100
Northern shoveler	*Spatula clypeata*	19,500	100
Common pochard	*Aythya ferina*	29,000	100
Tufted duck	*Aythya fuligula*	140,000	100
Greater scaup	*Aythya marila*	6,400	100
Long-tailed duck	*Clangula hyemalis*	13,500	100
Common scoter	*Melanitta nigra*	135,000	100
Common goldeneye	*Bucephala clangula*	21,000	100
Red-breasted merganser	*Mergus serrator*	11,000	100
Eurasian bittern	*Botaurus stellaris*	795	100
Great crested grebe	*Podiceps cristatus*	18,000	100
Horned grebe (Slavonian grebe)	*Podiceps auritus*	995	100

International name	Scientific name	UK Population size	Population correction factor
Hen harrier	*Circus cyaneus*	545	100
Western osprey	*Pandion haliaetus*	240	100
Merlin	*Falco columbarius*	1,150	100
Corncrake	*Crex crex*	1,100	100
Eurasian oystercatcher (breeding)	*Haematopus ostralegus*	95,500	100
Eurasian oystercatcher (non-breeding)	*Haematopus ostralegus*	305,000	100
Common ringed plover (breeding)	*Charadrius hiaticula*	5,450	100
Common ringed plover (non-breeding)	*Charadrius hiaticula*	42,500	100
Eurasian dotterel	*Charadrius morinellus*	425	100
European golden plover (breeding)	*Pluvialis apricaria*	50,500	100
European golden plover (non-breeding)	*Pluvialis apricaria*	410,000	100
Grey plover	*Pluvialis squatarola*	33,500	100
Northern lapwing	*Vanellus vanellus*	635,000	100
Red knot	*Calidris canutus*	265,000	100
Sanderling	*Calidris alba*	20,500	100
Purple sandpiper	*Calidris maritima*	9,900	100
Dunlin (sub-species *schinzii* and *arctica*)	*Calidris alpina schinzii & C.a.arctica*	350,000	100
Dunlin (sub-species *alpina*)	*Calidris alpina alpina*	35,000	100
Ruff	*Philomachus pugnax*	820	100
Common snipe	*Gallinago gallinago*	1,100,000	100
Black-tailed godwit (Icelandic race)	*Limosa limosa islandica*	41,000	100
Bar-tailed godwit	*Limosa lapponica*	53,500	100
Whimbrel	*Numenius phaeopus*	310	100
Eurasian curlew (breeding)	*Numenius arquata*	58,500	100
Eurasian curlew (non-breeding)	*Numenius arquata*	125,000	100
Common greenshank	*Tringa nebularia*	290	100
Wood sandpiper	*Tringa glareola*	68	100
Common redshank (breeding)	*Tringa totanus britannica*	22,000	100
Common redshank (Icelandic race - non-breeding)	*Tringa totanus robusta*	100,000	100
Ruddy turnstone	*Arenaria interpres*	43,000	100
Short-eared owl	*Asio flammeus*	2,200	100

1.3.3 Migratory seabird species

1.3.3.1 Although the SOSSMAT tool provides a viable method for modelling species assumed to make direct flights across the open sea, it is not considered reliable for pelagic species or land-based seabirds that follow the coastline (but at some distance offshore) during migration such as petrels, skuas, gulls and terns. WWT Consulting and MacArthur Green developed an approach for the Scottish Government which assumed that seabirds followed broad migratory corridors that hugged the coastline. These corridors were categorised in different migratory distance bands from the coast: 0 to 10 km, 0 to 20 km, 0 to 40 km, 0 to 60 km and are shown in Figure 1.2.

1.3.3.2 As the Mona Array Area is 28.2 km from the Anglesey coastline species that travel in distance bands 0 to 10 km and 0 to 20 km were excluded. Furthermore, Manx shearwater, northern fulmar, northern gannet and black-legged kittiwake species were excluded from the assessment as they are already covered by the seabird collision risk modelling in Volume 6, Annex 5.3: Offshore ornithology collision risk modelling technical report of the Environmental Statement.

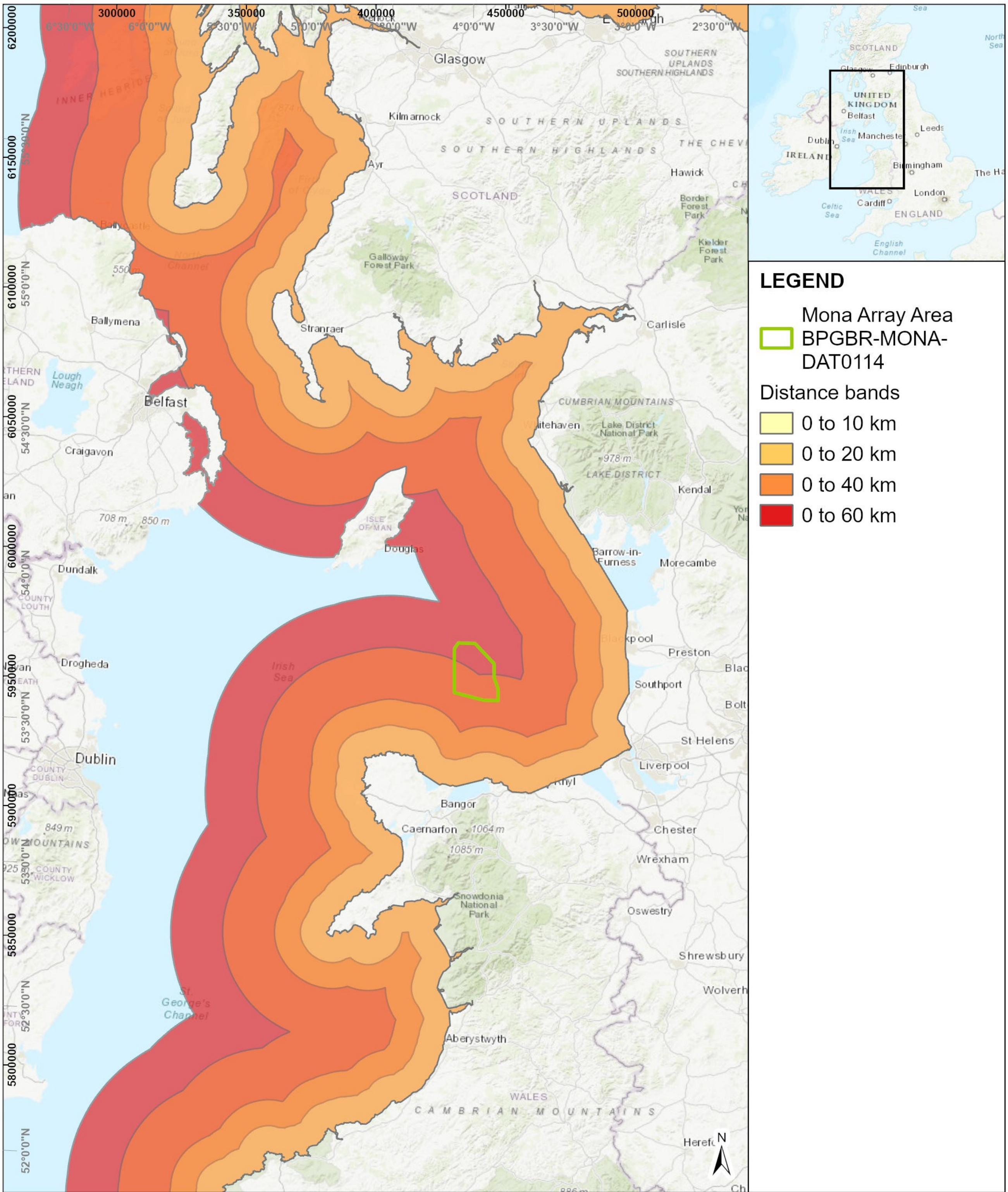
1.3.3.3 A total of seven seabird species were considered within the migratory collision risk modelling and are shown in Table 1.4 and Table 1.5.

Table 1.4: Identification of seabird species to be assessed for collision.

[1] Manx shearwater have been scoped out from the WWT Consulting and MacArthur Green approach (WWT Consulting and MacArthur Green, 2014) because they fly only at heights below collision risk height (Furness *et al*., 2013).

[2] Based on migratory bands defined by WWT Consulting and MacArthur Green (2014).

Species [1]	Migratory band (km) [2]	Overlap with Mona Array Area	Assessed in seabird CRM (Volume 6, Annex 5.3)	Assessed in migratory CRM
European storm-petrel	0 to 60	Yes	No	Yes
Leach's storm-petrel	0 to 60	Yes	No	Yes
Great skua	0 to 40	Yes	No	Yes
Pomarine skua	0 to 40	Yes	No	Yes
Long-tailed skua	0 to 60	Yes	No	Yes
Arctic skua	0 to 20	No	No	No
Little gull	0 to 20	No	No	No
Little tern	0 to 10	No	No	No
Sandwich tern	0 to 10	No	No	No
Common tern	0 to 10	No	No	No



Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS; World Topographic Map: Esri, HERE, Garmin, FAO, USGS, NGA	**Data Sources:** CLIENT
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Drawing Number: RPSE-MN-TEM-009-01

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01	17/08/23	First issue	AM	LM

Figure 1.2: Seabird migratory bands as defined by WWT Consulting and MacArthur Green (2014) in relation to the Mona Array Area.

Table 1.5: Parameters for numbers of seabirds migrating down the west and east coast of the UK, seasonality, distance from coastline and % at collision height (source: WWT Consulting and MacArthur Green, 2014).

Species	Passage population		Approximate proportion on each coast		Migratory band (km)	Percent estimated at collision height (Cook *et al.*, 2012)
	Spring	Autumn	West	East		
Great northern diver	3,000	3,000	0.6	0.4	0 to 40	2
Great skua	30,000	30,000	0.5	0.5	0 to 40	4.3
Pomarine skua	3,000	2,000	0.7	0.3	0 to 40	5
European storm-petrel	100,000	200,000	0.9	0.1	0 to 60	1
Leach's storm-petrel	200,000	500,000	0.9	0.1	0 to 60	1
Long-tailed skua	1,000	1,000	0.7	0.3	0 to 60	5
Black-headed gull	120,000	120,000	0.3	0.7	0 to 60	7.9

1.3.3.4 Using the parameters as set out by WWT Consulting and MacArthur Green (2014) (Table 1.5), and assuming as a worst-case scenario that all birds migrating down the west coast of Scotland enter the Irish Sea and hug the coastline of mainland Britain (in reality some birds will follow the west and east coasts of Ireland), the numbers of birds migrating through the Irish Sea and along the coast of mainland Britain was determined.

1.3.3.5 WWT Consulting and MacArthur Green (2014) used two patterns of distribution to determine the number of birds entering the offshore wind farm array areas. The first was to assume that birds were evenly distributed from the shoreline, and the second used negative binomial distribution which peaked at 25% from the coast. The latter method would cluster birds at 10 km from the coast for the 0 to 40 km migration band and 15 km for the 0 to 60 km band. As a precautionary measure the even distribution method was assumed to represent the worst-case scenario.

1.3.3.6 An east-west direction of travel for migratory birds was assumed as this provided the largest wind farm width perpendicular to the coastline. The maximum length of the Mona Array Area that overlapped with the migratory bands perpendicular to the coast was 15.57 km for the 0 to 40 km band, and 22.09 km for the 0 to 60 km band. The overlap was then used to calculate how many birds would be passing through the Mona Array Area assuming an even distribution of birds perpendicular to the coastline.

1.3.4 Collision risk modelling and avoidance rates

1.3.4.1 As recommended in the SOSSMAT guidance and WWT Consulting and MacArthur Green (2014), the Band (2012) single transit collision risk model was used. Input parameters for the wind turbine specifications used within the CRM are shown in Table 1.6. These values are based on the Maximum Design Scenario (MDS) parameter values for the worst-case collision risk. As recommended in the SOSSMAT guidance and WWT Consulting and MacArthur Green (2014), the Band (2012) single transit collision risk model was used. Input parameters for the wind turbine specifications used within the CRM are shown in Table 1.6. These values are based on the Maximum Design Scenario (MDS) parameter values for collision risk. The maximum design scenario taken forward to the assessment was the smallest, most numerous wind turbine option from the range of project parameters, as this option has the potential for the greatest level of effects.

1.3.4.2 Collision risk is an impact associated with the operation of wind turbines and their associated offshore structures. In the assessment of the collision risk to migratory bird species, the number of collisions is therefore predicted across the Mona Array Area only (Figure 1.3).

1.3.4.3 Species/populations input parameters are shown in Table 1.7. While species biometrics (length and wingspan) were taken from the British Trust for Ornithology (BTO) BirdFacts resource (Robinson, 2005), flight speeds were taken from Alerstam *et al*. (2007) for most species. For some species there were no estimations in Alerstam *et al*. (2007). As such, the same assumptions were followed as those used by WWT Consulting and MacArthur Green (2014) in their document *Strategic assessment of collision risk of Scottish offshore wind farms to migrating birds.* In this document, flight speed of species for which insufficient evidence existed were derived from species of similar genus and flight characteristics (e.g. European golden plover *Pluvialis apricaria* and American golden plover *Pluvialis dominica*).

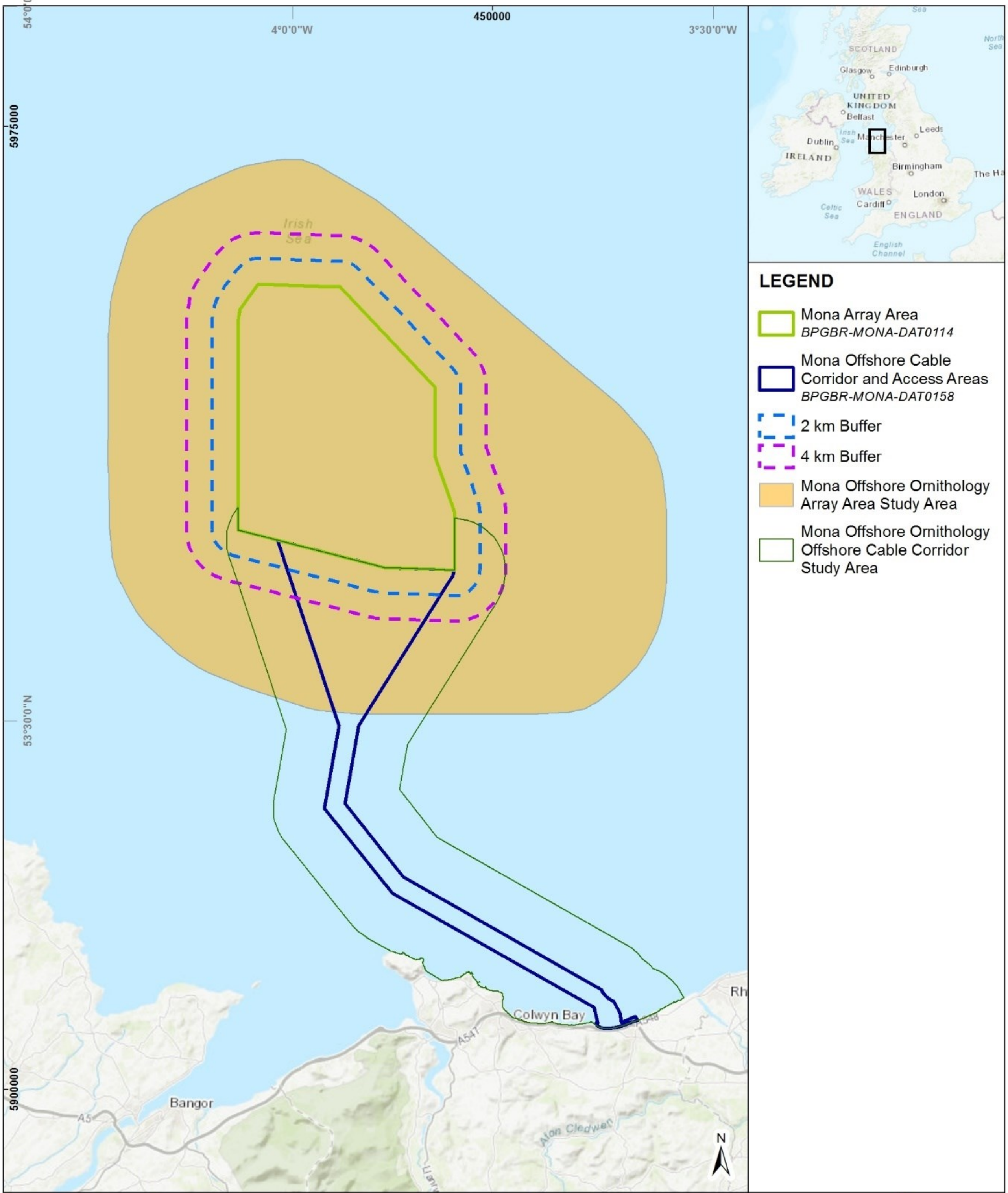
1.3.4.4 The CRMs used the proportion flying at rotor height given for species group (e.g. wildfowl, wader etc.) from Wright *et al.* (2012).

1.3.4.5 An example of the input and output of the Band (2012) single transit collision risk model is shown in Appendix A.

Table 1.6: The Mona Array Area configuration and wind turbines parameters

Parameter	Parameter value	Source/Reference
Max. number of wind turbines	96	Volume 1, chapter 3: Project description of the Environmental Statement
Number of rotor blades per wind turbine	3	Volume 1, chapter 3: Project description of the Environmental Statement
Max. chord width (m)	6.8	Volume 1, chapter 3: Project description of the Environmental Statement
Average blade pitch (degrees)	10	Provided by the Applicant
Max. rotor radius (m)	125	Volume 1, chapter 3: Project description of the Environmental Statement
Minimum Hub height above Lowest Astronomical Tide (LAT) (m)	159	Provided by the Applicant
Average rotation speed (rpm)	6.2	Volume 1, chapter 3: Project description of the Environmental Statement
Tidal offset Mean Sea Level (MSL) (m)	+/- 4	Volume 1, chapter 3: Project description of the Environmental Statement

Parameter	Parameter value	Source/Reference
Lower blade tip height above LAT (m)	34	Volume 1, chapter 3: Project description of the Environmental Statement
Air gap (MSL) (m)	30	Air gap relative to MSL allowing for -4 m tidal offset between LAT and MSL
Proportion of time operational	94%	Provided by the Applicant
Mona Array Area width (km)	27.0	Calculated in RStudio
Latitude	53.70	Calculated in RStudio
Large array correction	YES	Standard procedure



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Drawing Title: OFFSHORE ORNITHOLOGY STUDY AREA	**Geodetic Information:** Datum: ETRS 1989; Projection: ETRS 1989 UTM Zone 30N; Scale@160mmx220mm: 1:500,000	

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00	24/07/23	First Issue	MJ	AN
02	06/09/23	Revision	MJ	LM

Figure 1.3: Mona Offshore Ornithology Array Area study area, and Mona Array Area used for the migratory collision risk modelling and Mona Offshore Ornithology Offshore Cable Corridor Study Area.

Table 1.7: Waterbird species and population parameters used in the Band (2012) single transit collision risk model. Species are ranked according to their taxonomic order.

[1]In the absence of data in Alerstam *et al*. (2007), the flight speed was from a bird species of a similar genus/group and with similar biometrics (i.e. wingspan and length).

International name	Length (m)	Wingspan (m)	Flight speed (ms^{-1})[1]	Proportion at rotor height (%)	Number crossing the Mona Array Area per annum
Tundra swan (Bewick's swan)	1.21	1.96	18.50	50	43
Whooper swan	1.53	2.31	17.30	50	1,123
Greenland white-fronted goose	0.72	1.46	16.10	30	968
Light-bellied brent goose (Canadian population)	0.58	1.15	17.70	30	47
Common shelduck	0.67	1.33	15.40	15	3,038
Eurasian wigeon	0.48	0.80	20.60	15	26,808
Gadwall	0.51	0.90	18.50	15	2,024
Eurasian teal	0.36	0.61	19.70	15	25,914
Mallard	0.65	0.98	18.50	15	40,211
Northern pintail	0.58	0.88	20.60	15	1,191
Northern shoveler	0.48	0.77	18.50	15	1,218
Pochard	0.46	0.77	23.60	15	1,811
Tufted duck	0.44	0.70	21.10	15	8,340
Greater scaup	0.51	0.84	21.30	15	402
Long-tailed duck	0.44	0.76	20.30	15	804
Common scoter	0.49	0.84	22.10	1	8,042
Common goldeneye	0.46	0.72	20.30	15	1,251
Red-breasted merganser	0.55	0.78	19.70	15	661
Great northern diver	0.80	1.37	18.70	2	1,402
Eurasian bittern	0.75	1.30	8.80	50	94
Great crested grebe	0.48	0.88	18.60	10	1,296
Horned grebe (Slavonian grebe)	0.45	0.86	18.60	10	59
Hen harrier	0.48	1.10	9.10	50	36
Western osprey	0.56	1.58	13.30	50	24
Merlin	0.28	0.56	10.10	50	69
Corncrake	0.28	0.50	10.00	50	69

International name	Length (m)	Wingspan (m)	Flight speed (ms^{-1})[1]	Proportion at rotor height (%)	Number crossing the Mona Array Area per annum
Eurasian oystercatcher (breeding)	0.42	0.83	13.00	25	5,695
Eurasian oystercatcher (non-breeding)	0.42	0.83	13.00	25	18,170
Common ringed plover (breeding)	0.19	0.52	19.50	25	325
Common ringed plover (non-breeding)	0.19	0.52	19.50	25	2,532
Eurasian dotterel	0.21	0.60	13.70	25	42
European golden plover (breeding)	0.28	0.72	13.70	25	3,008
European golden plover (non-breeding)	0.28	0.72	13.70	25	24,425
Grey plover	0.28	0.77	17.90	25	1,996
Northern lapwing	0.30	0.84	11.90	25	37,828
Red knot	0.24	0.59	20.10	25	15,787
Sanderling	0.20	0.42	15.30	25	1,221
Purple sandpiper	0.21	0.44	15.30	25	600
Dunlin	0.18	0.40	15.30	25	20,850
Dunlin	0.18	0.40	15.30	25	2,793
Ruff	0.25	0.53	17.40	25	82
Common snipe	0.27	0.47	17.10	25	65,529
Black-tailed godwit (Icelandic race)	0.42	0.76	18.30	25	2,442
Bar-tailed godwit	0.38	0.75	18.30	25	3,898
Whimbrel	0.41	0.82	16.30	25	18
Eurasian curlew (breeding)	0.55	0.90	16.30	25	3,486
Eurasian curlew (non-breeding)	0.55	0.90	16.30	25	7,447
Common greenshank	0.32	0.69	12.30	25	18
Wood sandpiper	0.20	0.56	9.60	25	5
Common redshank (breeding)	0.28	0.62	12.30	25	1,311
Common redshank (Icelandic race - non-breeding)	0.28	0.62	12.30	25	5,957
Ruddy turnstone	0.23	0.54	14.90	25	2,562

International name	Length (m)	Wingspan (m)	Flight speed (ms^{-1})[1]	Proportion at rotor height (%)	Number crossing the Mona Array Area per annum
Short-eared owl	0.38	1.02	19.10	50	131

Table 1.8: Seabird species and population parameters used in the Band (2012) single transit collision risk model. Species are ranked according to their taxonomic order.

[1]In the absence of data in Alerstam *et al*. (2007), the flight speed was from a bird species of a similar genus/group and with similar biometrics (i.e. wingspan and length).

International name	Length (m)	Wingspan (m)	Flight speed (ms^{-1})[1]	Proportion at rotor height (%)	Number crossing the Mona Array Area per annum
European storm petrel	0.18	0.39	12.00	1	99,405
Leach's storm petrel	0.22	0.48	12.00	1	231,945
Great skua	0.58	1.50	14.90	4	11,680
Pomarine skua	0.51	1.38	15.20	5	1,363
Long-tailed skua	0.53	1.17	13.60	5	516
Black-headed gull	0.37	1.10	11.90	8	26,508

1.3.4.6 As birds may avoid the wind farm (through macro, meso or micro avoidance), an avoidance rate must be applied to the collision risk model theoretical predictions. As there is a paucity of species-specific avoidance rates, a range of avoidance rates (i.e. 95.00%, 98.00%, 99.00% and 99.50%) has been applied, as recommended by Band (2012).

1.4 Results

1.4.1 Migratory bird species

1.4.1.1 The species presented were considered in the Band (2012) single transit collision risk model. Wader species, which predominately breed in the Arctic and sub-Arctic regions, were estimated to move through the Mona Array Area in the highest numbers. Large numbers of seabirds were also expected to migrate through the Mona Array Area, in particular petrel species. Table 1.9 presents the number of birds crossing the site annually, considering the spring and autumn passage. For all species, it was assumed that there were two migration periods per year (i.e. spring and autumn) through the area.

Table 1.9: Number of each species and percentage (%) of the population crossing the Mona Array Area per annum. Species are ranked according to their taxonomic order.

International name	Proportion of population crossing the Mona Array Area per annum	No. crossing the Mona Array Area per annum
Tundra swan (Bewick's swan)	0.11	43
Whooper swan	0.06	1,123
Greenland white-fronted goose	0.07	968
Light-bellied brent goose (Canadian population)	0.07	47
Common shelduck	0.06	3,038
Eurasian wigeon	0.06	26,808
Gadwall	0.07	2,024
Eurasian teal	0.06	25,914
Mallard	0.06	40,211
Northern pintail	0.06	1,191
Northern shoveler	0.06	1,218
Pochard	0.06	1,811
Tufted duck	0.06	8,340
Greater scaup	0.06	402
Long-tailed duck	0.06	804
Common scoter	0.06	8,042
Common goldeneye	0.06	1,251
Red-breasted merganser	0.06	661
Great northern diver	0.70	1,402
European storm petrel	1.80	99,405
Leach's storm petrel	3.65	23,1945
Eurasian bittern	0.12	94
Great crested grebe	0.07	1,296
Horned grebe (Slavonian grebe)	0.06	59
Hen harrier	0.07	36
Western osprey	0.10	24
Merlin	0.06	69
Corncrake	0.06	69
Eurasian oystercatcher (breeding)	0.06	5,695
Eurasian oystercatcher (non-breeding)	0.06	18,170

International name	Proportion of population crossing the Mona Array Area per annum	No. crossing the Mona Array Area per annum
Common ringed plover (breeding)	0.06	325
Common ringed plover (non-breeding)	0.06	2,532
Eurasian dotterel	0.10	42
European golden plover (breeding)	0.06	3,008
European golden plover (non-breeding)	0.06	24,425
Grey plover	0.06	1,996
Northern lapwing	0.06	37,828
Red knot	0.06	15,787
Sanderling	0.06	1,221
Purple sandpiper	0.06	600
Dunlin (sub-species *schinzii* and *arctica*)	0.06	20,850
Dunlin (sub-species *alpina*)	0.08	2,793
Ruff	0.10	82
Common snipe	0.06	65,529
Black-tailed godwit (Icelandic race)	0.06	2,442
Bar-tailed godwit	0.07	3,898
Whimbrel	0.06	18
Eurasian curlew (breeding)	0.06	3,486
Eurasian curlew (non-breeding)	0.06	7,447
Common greenshank	0.06	18
Wood sandpiper	0.07	5
Common redshank (breeding)	0.06	1,311
Common redshank (Icelandic race - non-breeding)	0.06	5,957
Ruddy turnstone	0.06	2,562
Great skua	1.21	11,680
Pomarine skua	0.68	1,363
Long-tailed skua	0.52	516
Black-headed gull	0.10	26,508
Short-eared owl	0.06	131

1.4.2 Numbers of collisions predicted using a range of avoidance rates

1.4.2.1 Even assuming a highly precautionary avoidance rate of 95.00%, the numbers of collisions were low and predicted to be below one bird per annum for the majority of species considered (Table 1.10). The number of collisions however exceeded one bird per annum for whooper swan, Eurasian wigeon, Eurasian teal, mallard, tufted duck, Leach's storm petrel, Eurasian oystercatcher (breeding and non-breeding), European golden plover (non-breeding), Northern lapwing, red knot, dunlin, common snipe, Eurasian curlew (non-breeding), redshank (non-breeding Icelandic race) and black-headed gull.

Table 1.10: Migrant species annual collision risk for the Mona Array Area using a range of avoidance rates. Species are ranked according to their taxonomic order.

International name	No. of collision (no avoidance)	95.00%	98.00%	99.00%	99.50%
Bewick's swan	0.67	0.03	0.01	0.01	0.00
Whooper swan	20.12	1.01	0.40	0.20	0.10
Greenland white-fronted goose	7.42	0.37	0.15	0.07	0.04
Light-bellied brent goose (Canadian population)	0.34	0.02	0.01	0.00	0.00
Common shelduck	11.24	0.56	0.22	0.11	0.06
Eurasian wigeon	89.19	4.46	1.78	0.89	0.45
Gadwall	6.80	0.34	0.14	0.07	0.03
Eurasian teal	80.00	4.00	1.60	0.80	0.40
Mallard	144.50	7.22	2.89	1.44	0.72
Northern pintail	4.16	0.21	0.08	0.04	0.02
Northern shoveler	4.01	0.20	0.08	0.04	0.02
Pochard	6.07	0.30	0.12	0.06	0.03
Tufted duck	27.13	1.36	0.54	0.27	0.14
Greater scaup	1.36	0.07	0.03	0.01	0.01
Long-tailed duck	2.61	0.13	0.05	0.03	0.01
Common scoter	1.81	0.09	0.04	0.02	0.01
Goldeneye	4.09	0.20	0.08	0.04	0.02
Red-breasted merganser	2.24	0.11	0.04	0.02	0.01
Great northern diver	0.75	0.04	0.02	0.01	0.00
European storm petrel	15.20	0.76	0.30	0.15	0.08
Leach's storm petrel	37.30	1.86	0.75	0.37	0.19
Eurasian bittern	1.37	0.07	0.03	0.01	0.01
Great crested grebe	2.85	0.14	0.06	0.03	0.01
Slavonian grebe	0.12	0.01	0.00	0.00	0.00
Hen harrier	0.41	0.02	0.01	0.00	0.00

International name	No. of collision (no avoidance)	95.00%	98.00%	99.00%	99.50%
Western osprey	0.27	0.01	0.01	0.00	0.00
Merlin	0.58	0.03	0.01	0.01	0.00
Corncrake	0.58	0.03	0.01	0.01	0.00
Eurasian oystercatcher (breeding)	28.56	1.43	0.57	0.29	0.14
Eurasian oystercatcher (non-breeding)	91.12	4.56	1.82	0.91	0.46
Common ringed plover (breeding)	1.54	0.08	0.03	0.02	0.01
Common ringed plover (non-breeding)	11.98	0.60	0.24	0.12	0.06
Eurasian dotterel	0.17	0.01	0.00	0.00	0.00
European golden plover (breeding)	13.64	0.68	0.27	0.14	0.07
European golden plover (non-breeding)	110.77	5.54	2.22	1.11	0.55
Grey plover	9.90	0.50	0.20	0.10	0.05
Northern lapwing	169.87	8.49	3.40	1.70	0.85
Red knot	77.50	3.87	1.55	0.77	0.39
Sanderling	5.26	0.26	0.11	0.05	0.03
Purple sandpiper	2.62	0.13	0.05	0.03	0.01
Dunlin (sub-species *schinzii* and *arctica*)	88.45	4.42	1.77	0.88	0.44
Dunlin (sub-species *alpina*)	11.84	0.59	0.24	0.12	0.06
Ruff	0.38	0.02	0.01	0.00	0.00
Common snipe	307.81	15.39	6.16	3.08	1.54
Black-tailed godwit (Icelandic race)	12.93	0.65	0.26	0.13	0.06
Bar-tailed godwit	20.25	1.01	0.40	0.20	0.10
Whimbrel	0.09	0.00	0.00	0.00	0.00
Eurasian curlew (breeding)	19.64	2.83	1.13	0.57	0.28
Eurasian curlew (non-breeding)	28.90	1.44	0.58	0.29	0.14
Common greenshank	0.57	0.03	0.01	0.01	0.00
Wood sandpiper	0.01	0.00	0.00	0.00	0.00
Common redshank (breeding)	15.80	0.79	0.32	0.16	0.08
Common redshank (Icelandic race - non-breeding)	162.94	8.15	3.26	1.63	0.81
Ruddy turnstone	4.89	0.24	0.10	0.05	0.02
Great skua	11.19	0.56	0.22	0.11	0.06
Pomarine skua	1.58	0.08	0.03	0.02	0.01
Long-tailed skua	0.57	0.03	0.01	0.01	0.00
Black-headed gull		2.07	0.83	0.41	0.21
Short-eared owl	1.43	0.07	0.03	0.01	0.01

1.5 References

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Appendix A : Example collision risk calculation

A.1 Example of the input of the Band (2012) single transit Collision Risk Model (CRM) for Bewick's swan.

Table A. 1: Input parameters – Species.

Input	Data
Species name	Bewick's swan
Bird length	1.21 m
Wingspan	1.96 m
Flapping (0) or Gliding (+1)	0
Proportion of flights upwind	0 %
Bird speed	18.5 m/sec
Bird aspect ratio: β	0.62

Table A. 2: Input parameters – Windfarm data.

Input	Data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year Average
Number of turbines	96													
Rotor radius	125 m													
Minimum height of rotor	159 m													
Total rotor frontal area	4712389 sq.m													
Number of blades	3													
Max chord	6.80 m													
Pitch (degrees)	10													
Rotation speed	6.2 rpm													
Rotation period	9.68													
Integration interval	0.05													
Proportion of time operational	N/A	94%	94%	94%	94%	94%	94%	94%	94%	94%	94%	94%	94%	94%

Table A. 3: Calculation of alpha and p(collision) as a function of radius

			Upwind		Downwind	
Radius (r/R)	Chord (c/C)	Alpha (α)	Collide length	Collision (p)	Collide length	Collision (p)
0.00				1.000		1.000
0.05	0.73	4.56	32.08	0.538	30.36	0.509
0.10	0.79	2.28	17.46	0.293	15.59	0.261
0.15	0.88	1.52	12.97	0.217	10.90	0.183
0.20	0.96	1.14	10.69	0.179	8.43	0.141
0.25	1.00	0.91	9.07	0.152	6.71	0.112
0.30	0.98	0.76	7.63	0.128	5.32	0.089
0.35	0.92	0.65	6.38	0.107	4.20	0.070
0.40	0.85	0.57	5.46	0.091	3.45	0.058
0.45	0.80	0.51	4.87	0.082	2.98	0.050
0.50	0.75	0.46	4.39	0.073	2.61	0.044
0.55	0.70	0.41	3.98	0.067	2.33	0.039
0.60	0.64	0.38	3.59	0.060	2.08	0.035
0.65	0.58	0.35	3.26	0.055	1.89	0.032
0.70	0.52	0.33	2.96	0.050	1.73	0.029
0.75	0.47	0.30	2.72	0.046	1.61	0.027
0.80	0.41	0.28	2.48	0.041	1.51	0.025
0.85	0.37	0.27	2.31	0.039	1.44	0.024
0.90	0.30	0.25	2.07	0.035	1.36	0.023
0.95	0.24	0.24	1.88	0.031	1.31	0.022
1.00	0.00	0.23	1.21	0.020	1.21	0.020

Table A. 4: Overall collision (p) integrated over disk

Proportion		Upwind	Downwind	Average
Upwind	Downwind			
0%	100%	6.6%	4.5%	4.5%

A.2 Example of the output of the Band (2012) single transit Collision Risk Model (CRM) for Bewick's swan.

Table A. 5: Flight activity

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Per annum
Migration passages	0	0	0	0	0	0	0	0	43	0	0	0	43
Migrant flux density	0	0	0	0	0	0	0	0	1.59259	0	0	0	
Proportion at rotor height (birds/km) (%)	0	0	0	0	0	0	0	0	0	0	0	0	8%
Flux factor	0	0	0	0	0	0	0	0	30	0	0	0	