Morven North Offshore Wind Array Project

Environmental Impact Assessment Report

Volume 3, Annex 11.3: Offshore Ornithology Collision Risk Modelling Report: Migratory

MVCNS-J1201-RPS-10046
May 2026

B01

Document status

Version	Purpose of document	Authored by	Checker	Approved by	Date
FINAL	Application	TTRPSEL	TTRPSEL	MvOWL	May 2026

Prepared by:	Prepared for:
TTRPSEL	**Morven Offshore Wind Limited**

Table of contents

List of tables

List of figures

1 Introduction

1.1 Context

1.1.1.1 During the operations and maintenance (O&M) phase of the Morven North Offshore Wind Array Project (hereafter "Morven North"), the turning rotors of the wind turbines may present a risk of collision for birds. Stationary structures such as the tower, nacelle or when rotors are 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.

1.1.1.2 Whilst the presence of regularly occurring seabirds is effectively characterised through the use of digital aerial surveys (see Volume 3, Annex 11.1: Offshore Ornithology Baseline Characterisation Report), it is recognised that such surveys may inadequately capture migratory birds. Migratory birds often travel at night or in pulsed movements, which are unlikely to be captured in digital aerial surveys. Therefore, an alternative approach is required to estimate the passage of migratory birds through the windfarm, and subsequently the risk of collision to those birds.

1.2 Purpose and scope

1.2.1.1 This technical report covers the potential impacts as a result of collision risk from Morven North 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 United Kingdom (UK) Special Protection Areas (SPAs) and therefore primarily incorporates true waterbirds in addition to a small number of terrestrial birds. Migratory seabirds refers to species of tern, petrel, skua and little gull. Collision risk modelling for regularly occurring seabirds is presented in Volume 3, Annex 11.2: Offshore Ornithology Collision Risk Modelling Report. This report has been developed following guidance from NatureScot including published guidance (NatureScot, 2023) and project-specific guidance provided pre-application (Volume 1, Chapter 5: Consultation, and Volume 3, Annex 5.1: Consultation).

1.2.1.2 It is recommended that this report is read in-conjunction with Volume 2, Chapter 11: Offshore Ornithology.

2 Methodology

2.1 Migratory waterbirds

2.1.1 Introduction

2.1.1.1 The modelling undertaken for this report used the R code associated with the stochastic migration collision risk model (mCRM) shiny app developed by HiDef Aerial Surveying for Marine Scotland Science (HiDef, 2022). The use of the mCRM was agreed with NatureScot in pre-application consultation undertaken in January 2025 (see Section 1.4 of Volume 2, Chapter 11: Offshore Ornithology). The underlying functionality of the model is driven by the stochLAB package (Caneco *et al.,* 2022). The stochLAB package is a stochastic implementation of the collision risk modelling approach developed by Band (2012).

2.1.2 Wind turbine parameters

2.1.2.1 Wind turbine parameters used for collision risk modelling are provided in Table 2.1. These parameters represent the Maximum Design Scenario in relation to collision risk to migratory birds. Further details on the project design are given in Volume 1, Chapter 3: Project Description, but only the parameters given in Table 2.1 are relevant for mCRM. The wind farm width has been calculated across the east to west width of Morven North. This represents the shortest dimension of the wind farm and therefore a precautionary approach as this will provide the greatest risk of collision with birds modelled to be transiting the length of the wind farm, north to south, thereby subject to the greatest proportion of rotor swept area. As a result the modelling will over-estimate collision risk for species that fly across Morven North from east to west as these species would transit Morven North across a shorter flight path in reality and therefore be less likely to encounter a turbine. However, migratory waterbird flight behaviour is likely to be variable depending on migratory routes, and weather conditions.

Table 2.1: Wind turbine parameters used for collision risk modelling

Wind turbine parameter	Value
Latitude (°N)	56.74
Width (km)	15.69
Number of wind turbines	96
Number of blades	3
Rotor radius (m)	125
Maximum blade width (m)	6.8
Rotation speed (operational mean ± Standard Deviation (SD)) (rpm)	6.1 ± 1.42
Blade pitch (operational mean ± SD) (°)	5.5 ± 5.83
Wind availability (%)	99
Operational downtime (mean ± SD)	1± 2.11

2.1.3 Identification of species

2.1.3.1 The identification of migratory waterbird species for which collision risk modelling is required has utilised the migratory polygons associated with the mCRM. Where the species migratory polygon overlaps with Morven North, then collision risk modelling has been undertaken for that species. The species included in Table 2.2 are taken forward for mCRM.

Table 2.2: Migratory waterbird species included in migratory collision risk modelling

Species included in migratory collision risk modelling		
Brent goose (*Branta bernicla)* Barnacle goose (*Branta leucopsis)* Taiga Bean goose (*Anser fabalis)* Pink-footed goose (*Anser brachyrhynchus)* Whooper swan (*Cygnus cygnus)* Shelduck (*Tadorna tadorna)* Shoveler (*Spatula clypeata)* Wigeon (*Mareca Penelope)* Mallard (*Anas platyrhynchos)* Pintail (*Anas acuta)* Tufted duck (*Aythya fuligula)* Scaup (*Aythya marila)* Eider (*Somateria mollissima)* Velvet scoter (*Melanitta fusca)* Common scoter (*Melanitta nigra)* Long-tailed duck (*Clangula hyemalis)* Goldeneye (*Bucephala clangula)* Goosander (*Mergus merganser)* Red-breasted merganser (*Mergus serrator)* Nightjar (*Caprimulgus europaeus)* Corncrake (*Crex crex)* Spotted crake (*Porzana porzana)*	Great crested grebe (*Podiceps cristatus)* Slavonian grebe (*Podiceps auratus)* (breeding) Slavonian grebe *(Podiceps auratus)* (non-breeding) Oystercatcher (*Haematopus ostralegus)* (breeding) Oystercatcher (*Haematopus ostralegus)* (non-breeding) Lapwing (*Vanellus vanellus)* Golden plover (*Pluvialis apricaria)* Grey plover (*Pluvialis squatarola)* Ringed plover (*Charadrius hiaticula* (breeding) Ringed plover (*Charadrius hiaticula)* (passage) Dotterel (*Charadrius morinellus)* Whimbrel (*Numenius phaeopus)* Curlew (*Numenius Arquata)* Bar-tailed godwit (*Limosa lapponica)* (wintering) Bar-tailed godwit (*Limosa lapponica)* (passage) Turnstone (*Arenaria interpres)* Knot (*Calidris canutus)* Ruff (*Calidris pugnax)* Sanderling (*Calidris alba)* Dunlin (*Calidris alpina)*	Purple sandpiper (*Calidris maritima)* (N Europe) Purple sandpiper (*Calidris maritima)* (Canada) Snipe (*Gallinago gallinago)* (*faeroeensis*) Snipe (*Gallinago gallinago)* (*gallinago*) Redshank (*Tringa tetanus)* Wood sandpiper (*Tringa glareola)* Greenshank (*Tringa nebularia)* Red-throated diver (*Gavia stellata)* (wintering) Red-throated diver *(Gavia stellata)* (breeding) Black-throated diver (*Gavia arctica)* (wintering) Black-throated diver (*Gavia arctica)* (breeding) Great northern diver (*Gavia immer)* Bittern (*Botaurus stellaris)* Osprey (*Pandion haliaetus)* Marsh harrier (*Circus aeruginosus)* Hen harrier (*Circus cyaneus)* Short-eared owl (*Asio flammeus)* Merlin (*Falco columbarius)*

2.1.3.2 Whilst gannet is included in the mCRM, it has been excluded from modelling in this report as the species is incorporated into Volume 3, Annex 11.2: Offshore Ornithology Collision Risk Modelling Report.

2.1.4 Species parameters

2.1.4.1 The mCRM tool includes pre-populated inputs for all species identified in Table 2.2 using data supplied by the British Trust for Ornithology (HiDef, 2022). This includes:

- migratory pathways;
- biogeographic population size;
- proportion of biogeographic population migrating through UK waters;
- flight style (flapping/gliding);
- wingspan;
- flight speed;
- avoidance rate;
- proportion at Potential Collision Height (PCH);
- timing of migratory periods.

2.1.4.2 A number of the pre-populated values included in the mCRM do not match the values included in Woodward *et al.* (2023) and therefore these were updated to align with the values in Woodward *et al.* (2023). A full list of values for each species is presented in Appendix A.

2.1.5 Model parameters

2.1.5.1 The Morven North Boundary was uploaded as a shapefile. The model was run with the large array correction applied and 5,000 iterations.

2.2 Migratory seabirds

2.2.1 Identification of species

2.2.1.1 The identification of migratory seabird species for which collision risk modelling is required has utilised the migratory corridors defined in WWT Consulting and MacArthur Green (2014) (Figure 2.1). These corridors reflect that seabird species migrate at different distances from the UK coast, and can thus be assigned to one of four defined migration bands relevant to the species of interest in this report:

- 0 to 10km offshore;
- 0 to 20km offshore;
- 0 to 40km offshore;
- 0 to 60km offshore.

2.2.1.2 Where the species-specific migratory corridor overlaps with Morven North, then collision risk modelling has been undertaken for that species. This process is summarised in Table 2.3.

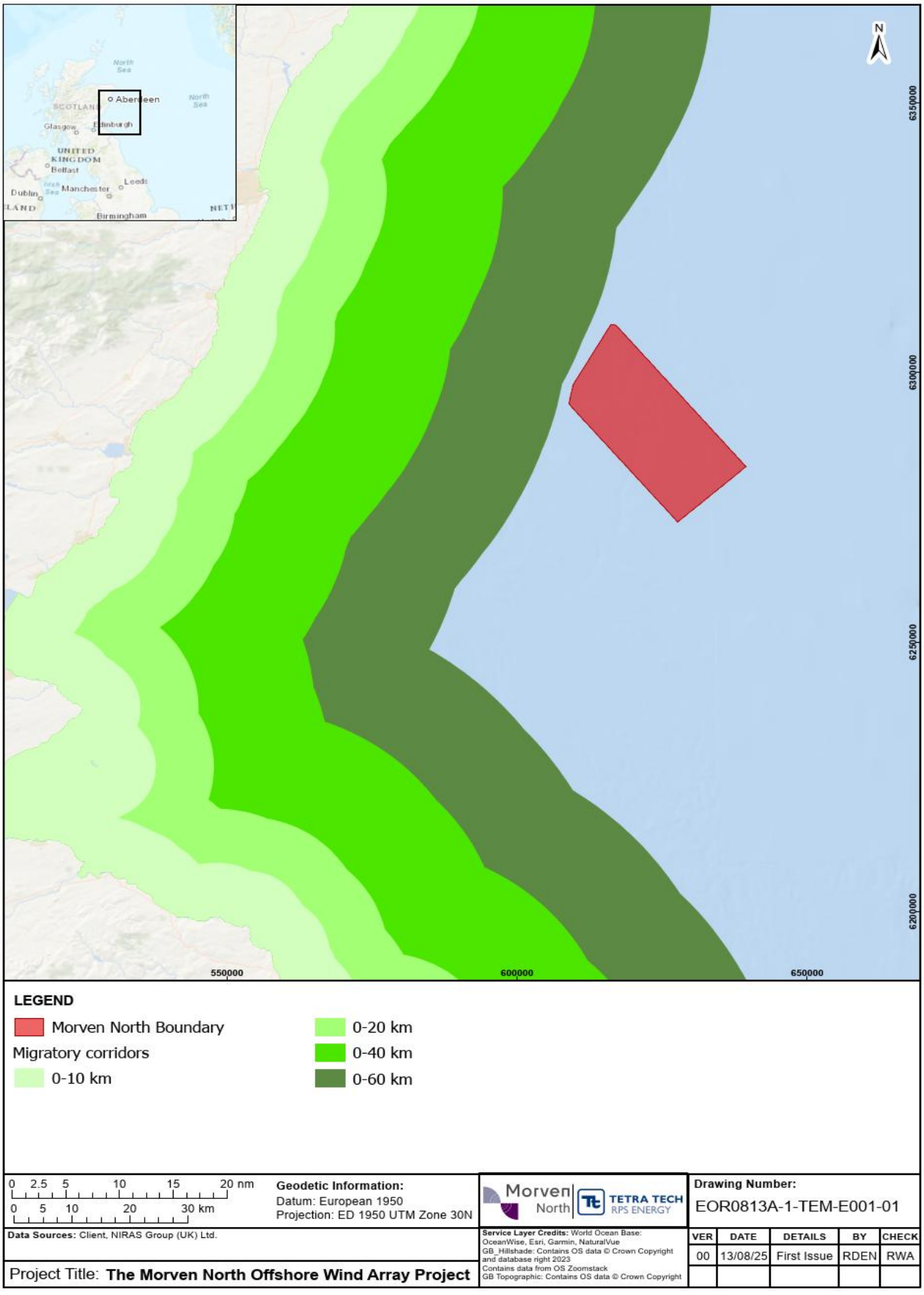

Figure 2.1: Migratory seabird migratory corridors

Table 2.3: Identification of migratory seabird species for which there is connectivity with Morven North

Species	Latin name	Width of migratory corridor out from shore (km)	Overlap with Morven North (Yes/No)
Little gull	*(Hydrocoloeus minutus)*	0 to 20	No
Sandwich tern	*(Thalasseus sandvicensis)*	0 to 10	No
Little tern	*(Sternula albifrons)*	0 to 10	No
Roseate tern	*(Sterna dougallii)*	0 to 10	No
Common tern	*(Sterna hirundo)*	0 to 10	No
Arctic tern	*(Sterna paradisaea)*	0 to 10	No
Great skua	*(Stercorarius skua)*	0 to 40	No
Arctic skua	*(Stercorarius parasiticus)*	0 to 20	No
European storm petrel	*(Hydrobates pelagicus)*	0 to 60	No
Leach's petrel	*(Oceanodroma leucorhoa)*	0 to 60	No

2.2.1.3 The migratory corridors associated with WWT Consulting and MacArthur Green (2014) suggest no connectivity between Morven North and any of the migratory seabirds considered in Table 2.3 with Morven North located more than 61km from the Scottish coast. However, although baseline surveys do not adequately capture migratory movements of migratory seabirds, the baseline surveys undertaken for Morven North have recorded a not insignificant number of Arctic tern within the Morven North Offshore Ornithology Baseline Characterisation Study Area during the August 2022 survey. A total of 293 individuals were recorded in August 2022, resulting in an abundance estimate of 3,691 individuals within the Morven North Baseline Characterisation Study Area. Smaller numbers were also recorded in two other months; July 2023 (population estimate of 41 birds) and August 2023 (population estimate of 67 birds). Arctic tern is therefore the only seabird species progressed for further consideration. All other species are therefore excluded from further consideration with any potential impacts considered to be indistinguishable from baseline mortality.

2.2.2 Methodology

2.2.2.1 Unlike the collision risk modelling approach applied for regularly occurring seabird species, density data collected during site specific surveys is deemed to be unsuitable to estimate the impact of collision for migratory seabird species. This is due to the snapshot nature of site specific surveys and consequential limitations in recording sporadic movements of migratory species. Therefore, the collision risk modelling approach used for migratory seabirds incorporates species-specific information relating to population estimates and migratory behaviour (WWT Consulting and MacArthur Green, 2014). A generic 'migratory front' is then defined which is then used to calculate the number of birds that have the potential to interact with Morven North during spring and autumn migration.

2.2.2.2 In order to identify the interacting population for use in collision risk modelling the following stages are applied:

1. Define relevant seasonal Biologically Defined Minimum Population Scales (BDMPS) populations for each species considered;
2. define a migratory front that incorporates the longest width of Morven North across which migration will occur;
3. calculate the proportion of the migratory front represented by Morven North;
4. calculate interacting populations for each species in each migratory season.

2.2.2.3 The interacting populations are then incorporated into collision risk modelling to provide a collision risk estimate for each species.

2.2.2.4 Collision risk modelling (CRM) has been undertaken using the Band (2012) CRM which allows for consideration of birds on migration.

2.2.3 Calculation of interacting populations

2.2.3.1 For Arctic tern the BDMPS population used as part of the modelling process is that defined in Furness (2015) covering the 'UK North Sea and Channel' (Table 2.4).

2.2.3.2 The proportion of this population that may interact with Morven North is calculated based on the proportion of the migratory front intersected by Morven North. The migratory front represents a hypothetical line across which the whole BDMPS population will cross, incorporating the greatest width of Morven North. It is assumed that birds are equally distributed across this front. This is a precautionary approach as the migratory movements of some seabird species tend to be biased towards inshore waters (Stienen et al., 2007).

2.2.3.3 Based on the migratory corridors defined in WWT Consulting and MacArthur Green (2014), Arctic terns are considered to migrate between 0 to 10km offshore. However, as a large number of Arctic terns recorded during the site specific surveys at Morven North, this corridor has been extended from the Scottish North Sea coast to the eastern edge of Morven North. This therefore represents a migratory front extending to 106.4km offshore from the Scottish North Sea coast, encompassing the widest part of Morven North. The populations of migratory seabird species considered to have potential to interact with Morven North are calculated using the following formula:

*Interacting population = Width of development area / width of migration route * species populations*

2.2.3.4 Morven North represents 20.3km of the migratory front, and therefore represents 19.1% of the total migratory front, with this proportion applied to the BDMPS populations in Table 2.4.

Table 2.4: Migratory seabird biologically defined minimum population scale populations and the proportion of these populations predicted to have potential to interact with Morven North

Species	Season	BDMPS population (no. of birds)	Interacting population (no. of birds)
Arctic tern	Autumn	163,930	31,276
	Spring	163,930	31,276

2.2.4 Peak migratory movements

2.2.4.1 To populate a collision risk model, single months are selected to represent autumn movements and spring movements respectively. In the Band (2012) CRM these months are populated with the populations in Table 2.4. The months selected for Arctic tern are May in the spring, which represents the peak spring migratory period in UK waters (Furness, 2015) and August in autumn, reflecting both the results of the Morven North site specific surveys and occurring within the autumn migratory period in Scottish waters (Furness, 2015).

2.2.5 Collision risk modelling

2.2.5.1 To quantify collision risk, collision risk modelling has been undertaken using the Band (2012) CRM. Band (2012) uses information derived from population estimation, bird behaviour, biological parameters and project specific wind turbine information to calculate monthly collision risk values.

2.2.5.2 The wind farm and wind turbine parameters used for migratory seabird collision risk modelling are the same as those used for migratory waterbirds (see Table 2.1). The width of migratory corridor is set to 106.4km.

2.2.5.3 The species-specific parameters used in the Band (2012) collision risk model for migratory seabirds are presented in Table 2.5.

Table 2.5: Species input parameters used in collision risk modelling for Arctic tern

Parameter	Source	Input value for Arctic tern
Bird length (m)	Robinson (2005)	0.34
Wingspan (m)	Robinson (2005)	0.8
Flight speed (m/s)	Alerstam (2007)	10.9
Flight type	-	Flapping

2.2.5.4 Generic flight height data from Johnston *et al*. (2014) has been used to inform Options 2 and 3 of the Band (2012) CRM for Arctic tern. Option 2 utilises the Basic model in the Band (2012) CRM and assumes a uniform distribution of flights across the rotor with a consistent risk of collision across the whole rotor swept area. Option 3 utilises the Extended model in the Band (2012) CRM and takes into account the distribution of birds in addition to the differential risk across the rotor swept area. It should be noted that the use of the basic model is precautionary as it does not take into account the variability in risk of collision that occurs across a rotor swept area, with the risk of collision decreasing as the distance from the hub of the wind turbine increases.

2.2.6 Avoidance rates

2.2.6.1 No species-specific avoidance rates are available for the migratory seabird species considered. JNCC *et al*. (2024) states that Statutory Nature Conservation Bodies (SNCBs) are likely to recommend the use of the 'all gulls and tern species' grouped rate from Ozsanlav-Harris *et al*. (2023) when using the Basic Band model. This rate, 99.02% along with a range of other avoidance rates no avoidance, 95%, 98%, and 99.5% are presented in Table 3.2.

3 Results

3.1 Migratory waterbirds

3.1.1.1 The results of the mCRM tool are provided in Table 3.1. The avoidance rates used for each species are provided in Appendix A. Of the 52 species considered, the majority had zero or negligible collision estimates. A total of 15 species/subspecies had an expected annual collision total exceeding one bird per year. These were: whooper swan, shelduck, wigeon, mallard, tufted duck, eider, common scoter, goldeneye, goosander, oystercatcher, lapwing, golden plover, bar-tailed godwit, dunlin and snipe.

Table 3.1: Results of mCRM. Species for which the annual collision estimate exceeds one bird (under any wind turbine option) are shown in bold. Species for which the annual collision estimate is zero are shown in italics

Species	Population using UK waters (Woodward *et al.*, 2023) **(no. of birds)**	**Population passing through Morven North per migration (mean ± SD) (no. of birds)**	**Annual collision estimate (mean ± SD) (no. of collisions)**
Svalbard light-bellied brent goose	13,400	385 ± 48	0.022 ± 0.006
Svalbard barnacle goose	43,500	2,589 ± 225	0.288 ± 0.030
Bean goose	970	46 ± 5	0.006 ± 0.000
Pink-footed goose	510,000	*0 ± 0*	*0.000 ± 0.000*
Whooper swan	**39,990**	**1,257 ± 153**	**1.154 ± 0.228**
Shelduck	**77,500**	**1,621 ± 248**	**1.995 ± 0.241**
Shoveler	22,960	411 ± 61	0.951 ± 0.088
Wigeon	**544,000**	**10,152 ± 1,715**	**15.302 ± 1.973**
Mallard	**823,600**	**17,951 ± 2,315**	**43.71 ± 3.959**
Pintail	20,942	434 ± 68	0.658 ± 0.079
Tufted duck	**155,000**	**2,804 ± 456**	**4.052 ± 0.496**
Scaup	7,000	146 ± 23	0.214 ± 0.025
Eider	**133,400**	**3,006 ± 495**	**1.208 ± 0.158**
Velvet scoter	4,510	123 ± 16	0.19 ± 0.023
Common scoter	**146,700**	**2,364 ± 408**	**3.504 ± 0.46**
Long-tailed duck	12,800	320 ± 47	0.47 ± 0.054
Goldeneye	**30,000**	**683 ± 96**	**1.008 ± 0.113**
Goosander	**17,420**	**770 ± 85**	**1.206 ± 0.113**
Red-breasted merganser	15,840	352 ± 54	0.526 ± 0.062
Nightjar	7,700	244 ± 33	0.138 ± 0.052
Corncrake	1,696	33 ± 5	0.016 ± 0.001
Spotted crake	251	8 ± 1	0.004 ± 0.000
Great crested grebe	1,380	4 ± 2	0.003 ± 0.000
Slavonian grebe	1,614	30 ± 5	0.014 ± 0.001

Species	Population using UK waters (Woodward *et al.*, 2023) **(no. of birds)**	**Population passing through Morven North per migration (mean ± SD) (no. of birds)**	**Annual collision estimate (mean ± SD) (no. of collisions)**
Oystercatcher	**620,389**	**12,471 ± 2,027**	**1.336 ± 0.182**
Lapwing	**3,942,500**	**78,229 ± 11,190**	**7.886 ± 0.874**
Golden plover	**3,267,600**	**51,008 ± 8,836**	**4.858 ± 0.614**
Grey plover	124,000	2,555 ± 370	0.244 ± 0.025
Ringed plover	241,920	3,071 ± 547	0.278 ± 0.035
Dotterel	*390*	*6 ± 1*	*0.000 ± 0.000*
Whimbrel	624,000	8,924 ± 1,709	0.926 ± 0.132
Curlew	141,100	3,161 ± 532	0.346 ± 0.049
Bar-tailed godwit	**680,000**	**13,142 ± 2,000**	**1.28 ± 0.144**
Turnstone	260,000	4,385 ± 615	0.474 ± 0.221
Knot	360,000	6,614 ± 1,105	0.596 ± 0.072
Ruff	3,100	70 ± 12	0.006 ± 0.001
Sanderling	200,000	3,789 ± 579	0.334 ± 0.037
Dunlin	**2,025,777**	**38,400 ± 5,847**	**3.446 ± 0.387**
Purple sandpiper	33,521	921 ± 119	0.084 ± 0.008
Snipe	**2,331,000**	**45,665 ± 6,222**	**6,309 ± 0.518**
Redshank	230,000	4,440 ± 831	0.432 ± 0.068
Wood sandpiper	*54*	*2 ± 1*	*0.000 ± 0.000*
Greenshank	1,080	25 ± 4	0.002 ± 0.000
Red-throated diver	40,697	1,079 ± 155	0.146 ± 0.017
Black-throated diver	1,883	50 ± 7	0.006 ± 0.001
Great northern diver	11,000	180 ± 28	0.026 ± 0.003
Bittern	714	14 ± 3	0.010 ± 0.003
Osprey	665	15 ± 3	0.004 ± 0.001
Marsh harrier	2,576	53 ± 8	0.016 ± 0.003
Hen harrier	2,176	46 ± 7	0.026 ± 0.003
Short-eared owl	14,880	314 ± 43	0.182 ± 0.03
Merlin	8,256	91 ± 18	0.118 ± 0.089

3.2 Migratory seabirds

3.2.1.1 Table 3.2 presents the collision risk estimates for Arctic tern for a range of avoidance rates. Annual collision risk estimates are zero individuals for all avoidance rates, with the exception of the no avoidance scenario under model Option 2 for which estimates annual collision risk is 3 individuals.

Table 3.2: Collision risk estimate for Arctic tern

Model option	Annual Collision Risk Estimates (Avoidance Rate (%)) (no. of collisions)				
	No avoidance	95	98	99.02	99.5
2	3	0	0	0	0
3	0	0	0	0	0

4 References

Alerstam, T., Rosén, M., Bäckman, J., Ericson, P.G.P., Hellgren, O. (2007). Flight speeds among bird species: allometric and phylogenetic effects. PLoS Biology 5(8): 1656-1662.

Band, W. (2012). Using a collision risk model to assess bird collision risks for offshore wind farms. Available at: https://www.bto.org/our-science/wetland-and-marine/soss/projects (Accessed: December 2024).

Caneco, B., Humphries, G., Cook, A., and Masden, E. (2022). Estimating bird collisions at offshore windfarms with stochLAB. Available at: https://hidef-aerial-surveying.github.io/stochLAB/ (Accessed: December 2024).

Furness, R.W. (2015). Non-breeding season populations of seabirds in UK waters. Available at: http://publications.naturalengland.org.uk/publication/6427568802627584 (Accessed: June 2025).

HiDef Aerial Surveying. (2022). Avian migration collision risk model (mCRM). Available at: https://hidef-aerial-surveying.github.io/mCRM/ (Accessed: December 2024).

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

JNCC (2024). Joint advice note from the Statutory Nature Conservation Bodies (SNCBs) regarding bird collision risk modelling for offshore wind developments. Available at: https://data.jncc.gov.uk/data/f7892820-0f84-4e96-9eff-168f93bd343d/joint-sncb-crm-advice-note.pdf (Accessed: October 2025).

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: March 2025).

Ozsanlav-Harris, L., Inger, R. and Sherley, R. (2023). Review of data used to calculate avoidance rates for collision risk modelling of seabirds. Available at: https://data.jncc.gov.uk/data/de5903fe-81c5-4a37-a5bc-387cf704924d/jncc-report-732.pdf (Accessed: June 2025).

Robinson, R.A. (2005). BirdFacts: profiles of birds occurring in Britain & Ireland (BTO Research Report 407). BTO, Thetford.

Stanbury, A. J., Burns, F., Aebischer, N. J., Baker, H., Balmer, D. E., Brown, A., ... & Quinn, L. (2024). The status of the UK's breeding seabirds: an. British Birds, 117, 471-487.

Stienen, E.W.M., Waeyenberge, V., Kuijken, E. and Seys, J. (2007). Trapped within the corridor of the southern North Sea: the potential impact of offshore wind farms on seabirds. Available at: http://www.vliz.be/imisdocs/publications/129847.pdf (Accessed: June 2025).

Woodward, I.D., Franks, S.E., Bowge, K., Davies, J.G., Green, R.M.W., Griffin, L.R., Mitchell, C., O'Hanlon, N., Pollock, C., Reex, E.C., Tremlett, C., Wright, L. and Cook, A.S.C.P. (2023). Strategic study of collision risk for birds on migration and further development of the stochastic collision risk modelling tool. Work Package 1: Strategic review of birds on migration in Scottish waters. Available at: https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2023/10/strategic-study-collision-risk-birds-migration-further-development-stochastic-collision-risk-

modelling-tool-work-package-1-strategic-review-birds-migration-scottish-waters/documents/strategic-study-collision-risk-birds-migration-further-development-stochastic-collision-risk-modelling-tool-work-package-1-strategic-review-birds-migration-scottish-waters/strategic-study-collision-risk-birds-migration-further-development-stochastic-collision-risk-modelling-tool-work-package-1-strategic-review-birds-migration-scottish-waters/govscot%3Adocument/strategic-study-collision-risk-birds-migration-further-development-stochastic-collision-risk-modelling-tool-work-package-1-strategic-review-birds-migration-scottish-waters.pdf (Accessed June 2025).

Woodward, I. D., Thaxter, C. B., Owen, E., Bolton, M., Ward, R. M., & Cook, A. S. (2024). The value of seabird foraging ranges as a tool to investigate potential interactions with offshore wind farms. Ocean & Coastal Management, 254, 107192.

WWT Consulting and MacArthur Green. (2014). Strategic assessment of collision risk of Scottish offshore wind farms to migrating birds. Available at: https://www.gov.scot/publications/scottish-marine-freshwater-science-volume-5-number-12-strategic-assessment/#:~:text=Overall%2C%20birds%20on%20migration%20through,gulls%2C%20cormorant%20and%20common%20tern. (Accessed: June 2025).

Appendix A Species-specific inputs for migratory waterbirds

Table A. 1: Species-specific inputs for migratory waterbirds (default parameters from HiDef (2022))

Species	Flight type	Body length (m) (mean ± SD)	Wingspan (m) (mean ± SD)	Flight speed (m/s) (mean ± SD)	Avoidance (mean ± SD)	Proportion at PCH	Biogeographic population (no. of birds)	Proportion in UK	Total population in UK (no. of birds)	Pre-breeding migration	Post-breeding migration	Other migration (NA = not applicable)
Svalbard light-bellied brent goose	Flapping	0.58 ± 0.02	1.15 ± 0.02	17.9 ± 6.1	0.999 ± 0.0001	50%	13,400	100.00%	13,400	Mar - Mar	Aug - Oct	NA
Svalbard barnacle goose	Flapping	0.64 ± 0.04	1.38 ± 0.04	17.4 ± 1.1	0.999 ± 0.0001	100%	43,500	100.00%	43,500	Mar - May	Sep - Oct	NA
Bean goose	Flapping	0.75 ± 0.06	1.58 ± 0.06	15.8 ± 1.3	0.999 ± 0.0001	100%	97,000	1.00%	970	Jan - Feb	Sep - Dec	NA
Pink-footed goose	Flapping	0.68 ± 0.06	1.52 ± 0.06	16.9 ± 0.2	1.000 ± 0.0002	50%	510,000	100.00%	510,000	Mar - Apr	Sep - Oct	NA
Whooper swan	Flapping	1.52 ± 0.04	2.30 ± 0.04	17.5 ± 4.2	0.988 ± 0.0009	50%	43,000	93.00%	39,990	Feb - Apr	Sep - Nov	NA
Shelduck	Flapping	0.62 ± 0.02	1.12 ± 0.02	18.2 ± 4.3	0.985 ± 0.0008	50%	310,000	25.00%	77,500	Jan - Feb	Jun - Jul	Aug - Dec
Shoveler	Flapping	0.48 ± 0.02	0.77 ± 0.02	18.3 ± 2.0	0.985 ± 0.0008	100%	80,000	28.70%	22,960	Mar - Jun	Jul - Aug	Sep - Dec
Wigeon	Flapping	0.48 ± 0.02	0.80 ± 0.02	18.5 ± 2.0	0.985 ± 0.0008	100%	1,600,000	34.00%	544,000	Mar - Apr	Aug - Nov	NA
Mallard	Flapping	0.58 ± 0.02	0.90 ± 0.02	15.9 ± 2.0	0.985 ± 0.0008	100%	7,100,000	11.60%	823,600	Apr - Jun	Sep - Oct	Jan - Mar
Pintail	Flapping	0.58 ± 0.02	0.88 ± 0.02	21.9 ± 2.0	0.985 ± 0.0008	100%	74,000	28.30%	20,942	Mar - May	Aug - Nov	NA

Species	Flight type	Body length (m) (mean ± SD)	Wingspan (m) (mean ± SD)	Flight speed (m/s) (mean ± SD)	Avoidance (mean ± SD)	Proportion at PCH	Biogeographic population (no. of birds)	Proportion in UK	Total population in UK (no. of birds)	Pre-breeding migration	Post-breeding migration	Other migration (NA = not applicable)
Tufted duck	Flapping	0.44 ± 0.01	0.70 ± 0.01	21.1 ± 1.1	0.985 ± 0.0008	100%	1,000,000	15.50%	155,000	Apr - Jun	Sep - Oct	NA
Scaup	Flapping	0.46 ± 0.01	0.78 ± 0.01	21.1 ± 2.0	0.985 ± 0.0008	100%	280,000	2.50%	7,000	Feb - May	Sep - Nov	NA
Eider	Flapping	0.60 ± 0.03	0.94 ± 0.03	17.3 ± 2.4	0.985 ± 0.0008	25%	920,000	14.50%	133,400	Mar - Apr	Oct - Nov	NA
Velvet scoter	Flapping	0.54 ± 0.03	0.94 ± 0.03	20.1 ± 4.7	0.985 ± 0.0008	100%	410,000	1.10%	4,510	Mar - May	Jun - Sep	NA
Common scoter	Flapping	0.49 ± 0.03	0.84 ± 0.03	22.1 ± 4.0	0.985 ± 0.0008	100%	815,000	18.00%	146,700	Apr - May	Jun - Oct	NA
Long-tailed duck	Flapping	0.44 ± 0.01	0.76 ± 0.01	19.7 ± 1.7	0.985 ± 0.0008	100%	1,600,000	0.80%	12,800	Mar - May	Sep - Oct	NA
Goldeneye	Flapping	0.46 ± 0.01	0.72 ± 0.01	20.3 ± 3.8	0.985 ± 0.0008	100%	1,500,000	2.00%	30,000	Feb - May	Aug - Dec	NA
Goosander	Flapping	0.62 ± 0.03	0.90 ± 0.03	19.7 ± 1.1	0.985 ± 0.0008	100%	260,000	6.70%	17,420	Mar - May	Jun - Sep	NA
Red-breasted merganser	Flapping	0.55 ± 0.01	0.78 ± 0.01	22.0 ± 2.9	0.985 ± 0.0008	100%	160,000	9.90%	15,840	Apr - Jul	Aug - Nov	NA
Nightjar	Flapping	0.27 ± 0.02	0.60 ± 0.02	9.7 ± 3.3	0.995 ± 0.0000	100%	1,100,000	0.70%	7,700	Apr - May	Aug - Sep	NA
Corncrake	Flapping	0.28 ± 0.02	0.50 ± 0.02	13.0 ± 2.0	0.995 ± 0.0000	100%	2,120,000	0.08%	1,696	Apr - May	Jul - Aug	NA
Spotted crake	Flapping	0.23 ± 0.02	0.40 ± 0.02	13.0 ± 2.0	0.995 ± 0.0000	100%	251,000	0.10%	251	May - Jun	Jul - Oct	NA

Species	Flight type	Body length (m) (mean ± SD)	Wingspan (m) (mean ± SD)	Flight speed (m/s) (mean ± SD)	Avoidance (mean ± SD)	Proportion at PCH	Biogeographic population (no. of birds)	Proportion in UK	Total population in UK (no. of birds)	Pre-breeding migration	Post-breeding migration	Other migration (NA = not applicable)
Great crested grebe	Flapping	0.48 ± 0.02	0.88 ± 0.02	21.1 ± 1.6	0.995 ± 0.0000	100%	690,000	0.20%	1,380	Mar - Jun	Jul - Nov	Feb - Mar
Slavonian grebe	Flapping	0.34 ± 0.02	0.62 ± 0.02	21.1 ± 1.6	0.995 ± 0.0000	100%	41,600	3.88%	1,614	Feb - Apr	Aug - Oct	NA
Oystercatcher	Flapping	0.42 ± 0.02	0.83 ± 0.02	13.0 ± 2.5	0.999 ± 0.0000	100%	1,813,512	34.21%	620,389	Jan - Mar	Jul - Nov	NA
Lapwing	Flapping	0.30 ± 0.01	0.84 ± 0.01	12.8 ± 1.3	0.999 ± 0.0000	100%	9,500,000	41.50%	3,942,500	Jan - May	Oct - Nov	NA
Golden plover	Flapping	0.28 ± 0.01	0.72 ± 0.01	16.5 ± 1.8	0.999 ± 0.0000	100%	3,470,000	94.17%	3,267,600	Feb - May	Jul - Oct	NA
Grey plover	Flapping	0.28 ± 0.01	0.77 ± 0.01	16.5 ± 1.8	0.999 ± 0.0000	100%	200,000	62.00%	124,000	Mar - May	Jul - Sep	NA
Ringed plover	Flapping	0.19 ± 0.01	0.52 ± 0.01	16.0 ± 1.1	0.999 ± 0.0000	100%	308,000	78.55%	241,920	Mar - May	Aug - Oct	NA
Dotterel	Flapping	0.21 ± 0.01	0.60 ± 0.01	16.5 ± 1.8	0.999 ± 0.0000	100%	65,000	0.60%	390	Mar - Jun	Aug - Nov	NA
Whimbrel	Flapping	0.41 ± 0.02	0.82 ± 0.02	13.8 ± 0.4	0.999 ± 0.0000	100%	780,000	80.00%	624,000	Apr - Jun	Jun - Oct	NA
Curlew	Flapping	0.55 ± 0.02	0.90 ± 0.02	15.4 ± 3.3	0.999 ± 0.0000	100%	830,000	17.00%	141,100	Mar - May	Jun - Oct	NA
Bar-tailed godwit	Flapping	0.38 ± 0.02	0.75 ± 0.02	18.3 ± 2.1	0.999 ± 0.0000	100%	680,000	100.00%	680,000	Mar - Apr	Jul - Oct	NA
Turnstone	Flapping	0.23 ± 0.01	0.54 ± 0.01	10.0 ± 3.3	0.999 ± 0.0000	100%	260,000	100.00%	260,000	Jan - Jun	Jul - Aug	NA

Species	Flight type	Body length (m) (mean ± SD)	Wingspan (m) (mean ± SD)	Flight speed (m/s) (mean ± SD)	Avoidance (mean ± SD)	Proportion at PCH	Biogeographic population (no. of birds)	Proportion in UK	Total population in UK (no. of birds)	Pre-breeding migration	Post-breeding migration	Other migration (NA = not applicable)
Knot	Flapping	0.24 ± 0.01	0.59 ± 0.01	24.6 ± 3.3	0.999 ± 0.0000	100%	360,000	100.00%	360,000	Feb - May	Jun - Oct	NA
Ruff	Flapping	0.25 ± 0.01	0.53 ± 0.01	16.9 ± 1.8	0.999 ± 0.0000	100%	6,200,000	0.05%	3,100	Mar - May	Jul - Nov	NA
Sanderling	Flapping	0.20 ± 0.01	0.42 ± 0.01	21.4 ± 1.1	0.999 ± 0.0000	100%	200,000	100.00%	200,000	Apr - Jun	Jul - Oct	NA
Dunlin	Flapping	0.18 ± 0.01	0.40 ± 0.01	15.3 ± 1.9	0.999 ± 0.0000	100%	2,308,000	87.77%	2,025,777	Mar - May	Jun - Oct	NA
Purple sandpiper	Flapping	0.21 ± 0.01	0.44 ± 0.01	15.3 ± 1.9	0.999 ± 0.0000	100%	122,000	27.48%	33,521	Mar - May	Jul - Nov	NA
Snipe	Flapping	0.26 ± 0.01	0.46 ± 0.01	17.1 ± 2.7	0.999 ± 0.0000	100%	11,100,000	21.0%	2,331,000	Mar - May	Aug - Oct	Oct - Dec
Redshank	Flapping	0.28 ± 0.01	0.62 ± 0.01	15.3 ± 4.1	0.999 ± 0.0000	100%	230,000	100.00%	230,000	Mar - May	Jul - Sep	NA
Wood sandpiper	Flapping	0.20 ± 0.01	0.56 ± 0.01	9.6 ± 1.7	0.999 ± 0.0000	100%	1,800,000	0.00%	54	Apr - May	Jul - Sep	NA
Greenshank	Flapping	0.32 ± 0.01	0.69 ± 0.01	12.3 ± 3.3	0.999 ± 0.0000	100%	360,000	0.3%	1,080	Mar - Jun	Aug - Nov	NA
Red-throated diver	Flapping	0.61 ± 0.02	1.11 ± 0.02	18.6 ± 3.9	0.995 ± 0.0000	25%	526,000	7.74%	40,697	Feb - Jun	Jul - Sep	NA
Black-throated diver	Flapping	0.66 ± 0.02	1.20 ± 0.02	19.3 ± 2.1	0.995 ± 0.0000	25%	765,600	0.25%	1,883	Mar - May	Aug - Nov	NA
Great northern diver	Flapping	0.80 ± 0.02	1.37 ± 0.02	19.5 ± 1.6	0.995 ± 0.0000	25%	11,000	100.0%	11,000	Dec - Jun	Aug - Nov	NA

Species	Flight type	Body length (m) (mean ± SD)	Wingspan (m) (mean ± SD)	Flight speed (m/s) (mean ± SD)	Avoidance (mean ± SD)	Proportion at PCH	Biogeographic population (no. of birds)	Proportion in UK	Total population in UK (no. of birds)	Pre-breeding migration	Post-breeding migration	Other migration (NA = not applicable)
Bittern	Flapping	0.75 ± 0.02	1.30 ± 0.02	8.8 ± 2.0	0.995 ± 0.0000	100%	8,200	8.7%	714	Jan - May	Jun - Oct	NA
Osprey	Flapping	0.56 ± 0.02	1.58 ± 0.02	10.6 ± 3.1	0.995 ± 0.0001	50%	24,600	2.7%	665	Mar - Apr	Aug - Oct	NA
Marsh harrier	Flapping	0.52 ± 0.02	1.22 ± 0.02	13.2 ± 2.9	0.995 ± 0.0001	50%	368,000	0.7%	2,576	Mar - May	Aug - Nov	NA
Hen harrier	Flapping	0.48 ± 0.02	1.10 ± 0.02	11.4 ± 1.1	0.995 ± 0.0001	100%	108,800	2.0%	2,176	Mar - May	Sep - Nov	NA
Short-eared owl	Flapping	0.38 ± 0.02	1.02 ± 0.02	9.7 ± 2.0	0.995 ± 0.0001	100%	372,000	4.0%	14,880	Mar - May	Jul - Oct	NA
Merlin	Flapping	0.28 ± 0.02	0.56 ± 0.02	12.7 ± 5.8	0.989 ± 0.0003	100%	103,200	8.0%	8,256	Mar - May	Aug - Nov	NA