



Annex 11.3D: Migratory Collision Risk Modelling

MachairWind Offshore Ornithology

ScottishPower Renewables (SPR)

320 St Vincent St Glasgow G2 5AD

Prepared by:

SLR Consulting Limited

St. Vincent Place, Glasgow, G1 2EU

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Table of Contents

1.0 Introduction	2
1.1 Project Summary.....	2
1.2 Purpose of this report.....	2
2.0 Methods	4
2.1 Overview of mCRM	4
2.2 Species assessed for migratory collision risk.....	4
2.3 Migratory collision risk modelling input parameters	7
2.3.1 Turbine parameters.....	7
2.3.2 Bird biometrics and migration seasons	9
3.0 Results	15
4.0 Discussion	19
5.0 References	21

Tables in Text

Table 1: Species selected for migratory collision risk modelling, UK population estimates and proportion of population potentially at risk of collision with the Project. Percentage of population potentially passing through the WDA obtained from mCRM.	4
Table 2: Offshore windfarm and turbine specifications used in the migratory collision risk modelling for the Most Likely Scenario (MLS) and the Worst Case Scenario (WCS).....	7
Table 3: Offshore windfarm maintenance downtime and operational wind availability by month.	8
Table 4: Input biometric and behavioural parameters (body length, wingspan, flight speed, avoidance rate and collision-risk height proportion) by species used in the mCRM. Values are derived from the mCRM tool.	10
Table 5: Species-specific migration periods applied in the mCRM assessment. Values are derived from the mCRM tool.	13
Table 6: Modelled collision mortality (mean \pm SD) by species and seasonal migration period, including cumulative total under the most likely design scenario.	15
Table 7: Modelled collision mortality (mean \pm SD) by species and seasonal migration period, including cumulative total under the worst case design scenario.....	17
Table 8: Predicted annual migratory collision mortality and proportion of UK population affected under the WCS.	19

Figures in Text

Figure 1: Location of the MachairWind Windfarm Development Area (WDA).....	3
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1.0 Introduction

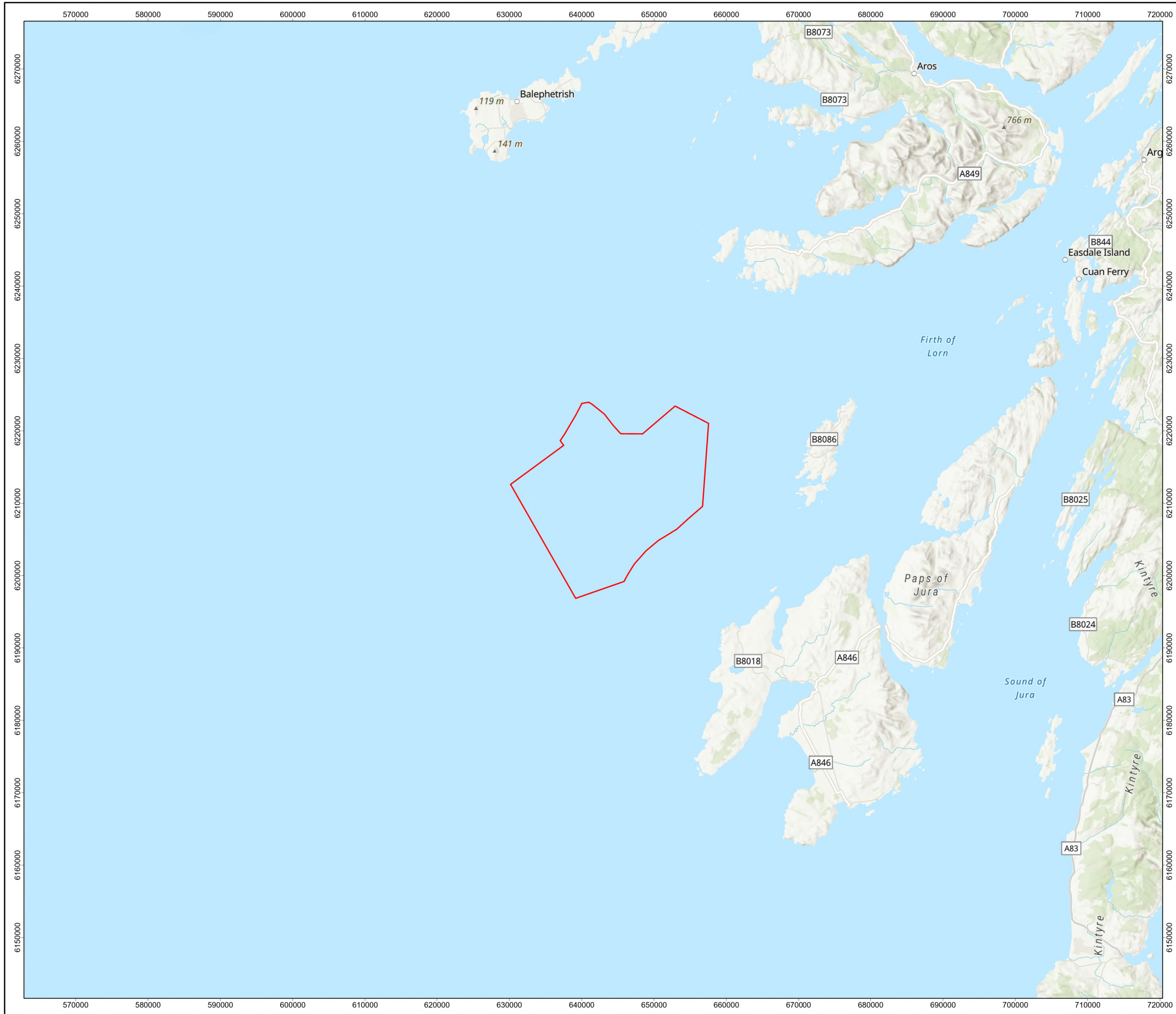
1.1 Project Summary

1. Machairwind Limited ('the Applicant') is proposing the development of the MachairWind Windfarm ('the Project'), an Offshore Windfarm (OWF), located on the west coast of Scotland approximately 15 kilometres (km) to the northwest of Islay and approximately 12.4 km west of Colonsay (**Figure 1**).
2. The Offshore Project will comprise up to 144 wind turbine generators (WTGs) with fixed-bottom foundations. The area within which the WTGs and associated infrastructure will be located is the Windfarm Development Area (WDA). The WDA covers an area of 448 km².

1.2 Purpose of this report

3. This **Annex 11.3D: Migratory Collision Risk Modelling** presents the outputs of migratory Collision Risk Modelling ('mCRM') undertaken to estimate potential collision mortality associated with migratory non-seabird species passing through the Windfarm Development Area (WDA) during the operational phase of the Project. The results of this annex are used to inform the impact assessments presented in Chapter 11 Offshore Ornithology of the Environmental Impact Assessment Report (EIAR) and the Report to Inform Appropriate Assessment (RIAA).
4. The potential seabird collision risks with turbines have been modelled using data collected by Digital Aerial Surveys (DAS; refer to **Technical Appendix 11.3: Collision Risk Modelling**). The baseline data on avian presence within the Project area should be interpreted in the context of survey design. DAS are primarily intended to characterise seabird distribution and abundance and are therefore optimised for species regularly present within the survey area. As a result, they are less well suited to detecting migratory species that may occur only intermittently or during relatively brief passage periods.
5. To provide an evaluation of potential migration-related collision risk for these species potentially under-recorded in DAS data, the Marine Scotland Avian Migration Collision Risk Model Shiny Application ('mCRM Shiny App' or 'mCRM tool'; HiDef Aerial Surveying Ltd., 2024) has been utilised. Following guidance presented in the Scottish Government's strategic review of birds on migration in Scottish waters (Woodward et al., 2023), seabird species were not included for analysis of migratory collision on the grounds that 1) distinguishing between migrant and resident seabirds is not possible, and 2) seabird exposure to offshore windfarms are adequately captured in the density estimates used as inputs in stochastic collision risk modelling (refer to **Technical Appendix 11.3: Collision Risk Modelling** for analysis of seabird species).





Windfarm Development Area (WDA)

N

0 5 10 20 Kilometres



1	21/04/2026	MMM	MMM	NG/SO	NG/SO
REV	DATE	GIS CREATOR	GIS REVIEWER	TECHNICAL CHECKER	TECHNICAL APPROVER

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Windfarm Development Area**

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2.0 Methods

2.1 Overview of mCRM

6. Migratory collision risk for non-seabird species was assessed using the mCRM tool, which combines spatial migration modelling with a stochastic implementation of the Band (2012) collision risk framework. The modelling was conducted within the R statistical environment (R Core Team, 2025). The mCRM framework uses simulated migration pathways (Woodward et al., 2023) to estimate the proportion of each species' population likely to traverse the WDA, and then applies species-specific biometric, behavioural as well as turbine parameters to quantify predicted collision mortality, with associated variability included through the use of appropriate probability distributions (e.g. for flight speed and wingspan, etc.).

2.2 Species assessed for migratory collision risk

7. Species selected for the migratory collision risk assessment were those with a route corridor that included the WDA, as defined by Woodward et al., (2023). The UK population for each selected species, and the percentage of the population predicted to cross the WDA, are presented in **Table 1**. The percentages at risk were obtained from the mCRM tool and represent the spatial overlap between simulated migration pathways and the WDA boundary.
8. Note that Greenland white-fronted goose were identified by NatureScot as of particular concern due to the sensitivity of the Islay wintering population and hence were assessed separately (**Annex 11.3C: Collision Risk Modelling of Greenland White-Fronted Goose**).

Table 1: Species selected for migratory collision risk modelling, UK population estimates and proportion of population potentially at risk of collision with the Project. Percentage of population potentially passing through the WDA obtained from mCRM.

Species	Total UK population (individuals)	Percentage of population potentially passing through WDA (%)	Number of individuals expected to pass through WDA
Bar-tailed godwit (<i>Limosa lapponica</i>)	680000	1.4	9585
Bittern (<i>Botaurus stellaris</i>)	714	0	0
Black-tailed godwit (<i>Limosa limosa</i>)	303000	0	0
Black-throated diver (<i>Gavia arctica</i>)	1180	1.5	19
Canadian light-bellied brent goose (<i>Branta hrota</i>)	40000	5.1	2059
Common scoter (<i>Melanitta nigra</i>)	135180	2.0	2738
Corncrake (<i>Crex crex</i>)	16960	1.99	328
Curlew (<i>Numenius arquata</i>)	141100	1.9	2631



Species	Total UK population (individuals)	Percentage of population potentially passing through WDA (%)	Number of individuals expected to pass through WDA
Dotterel (<i>Charadrius morinellus</i>)	390	0.9	4
Dunlin (<i>Calidris alpina</i>)	2021808	2.2	45300
Eider (<i>Somateria mollissima</i>)	106720	1.9	1983
Gadwall (<i>Mareca strepera</i>)	30940	0	0
Golden plover (<i>Pluvialis apricaria</i>)	3296500	2.0	67563
Goldeneye (<i>Bucephala clangula</i>)	37500	2.0	765
Goosander (<i>Mergus merganser</i>)	17420	0	0
Great crested grebe (<i>Podiceps cristatus</i>)	1380	0	0
Great northern diver (<i>Gavia immer</i>)	11000	2.5	280
Greenland barnacle goose (<i>Branta leucopsis</i>)	81000	7.1	5750
Greenshank (<i>Tringa nebularia</i>)	7200	2.0	141
Grey plover (<i>Pluvialis squatarola</i>)	124000	1.5	1890
Hen harrier (<i>Circus cyaneus</i>)	2176	1.5	32
Icelandic greylag goose (<i>Anser anser</i>)	68400	6.2	4232
Knot (<i>Calidris canutus</i>)	360000	2.5	9139
Lapwing (<i>Vanellus vanellus</i>)	3942500	1.8	70059
Long-tailed duck (<i>Clangula hyemalis</i>)	12800	2.1	264
Mallard (<i>Anas platyrhynchos</i>)	823600	1.5	12594
Marsh harrier (<i>Circus aeruginosus</i>)	2576	1.7	45
Merlin (<i>Falco columbarius</i>)	8256	2.7	227
Osprey (<i>Pandion haliaetus</i>)	665	1.4	10



Species	Total UK population (individuals)	Percentage of population potentially passing through WDA (%)	Number of individuals expected to pass through WDA
Oystercatcher (<i>Haematopus ostralegus</i>)	358900	2.4	8444
Pink-footed goose (<i>Anas acuta</i>)	500000	3.3	16265
Pintail (<i>Anas acuta</i>)	20942	2.3	474
Pochard (<i>Aythya ferina</i>)	28500	0	0
Purple sandpiper (<i>Calidris maritima</i>)	24400	2.6	627
Red-breasted merganser (<i>Mergus serrator</i>)	15840	2.4	375
Redshank (<i>Tringa totanus</i>)	420000	2.3	9631
Red-throated diver (<i>Gavia stellata</i>)	34000	1.8	624
Ringed plover (<i>Charadrius hiaticula</i>)	289520	2.3	6583
Ruff (<i>Calidris pugnax</i>)	31000	1.7	532
Sanderling (<i>Calidris alba</i>)	200000	1.8	3669
Scaup (<i>Aythya marila</i>)	7000	2.6	181
Shelduck (<i>Tadorna tadorna</i>)	62500	1.9	1207
Short-eared owl (<i>Asio flammeus</i>)	14880	1.8	269
Shoveler (<i>Spatula clypeata</i>)	22960	1.8	421
Slavonian grebe (<i>Podiceps auritus</i>)	989	2.0	20
Snipe (<i>Gallinago gallinago</i>)	6105001	2.2	135715
Spotted crake (<i>Porzana porzana</i>)	26	3.8	1
Teal (<i>Anas crecca</i>)	435500	0.9	4034
Tufted duck (<i>Aythya fuligula</i>)	155000	2.1	3267
Turnstone (<i>Arenaria interpres</i>)	347000	2.3	7829
Velvet scoter (<i>Melanitta fusca</i>)	3465	0	0
Whimbrel (<i>Numenius phaeopus</i>)	4680	2.5	116



Species	Total UK population (individuals)	Percentage of population potentially passing through WDA (%)	Number of individuals expected to pass through WDA
White-tailed eagle (<i>Haliaeetus albicilla</i>)	148	4.9	8
Whooper swan (<i>Cygnus cygnus</i>)	39990	1.9	746
Wigeon (<i>Mareca penelope</i>)	480000	2.2	10321

2.3 Migratory collision risk modelling input parameters

2.3.1 Turbine parameters

9. Wind turbine specifications used in the mCRM are provided in **Table 2**. The Project will comprise between 97 and 144 wind turbine generators (WTGs), for the most likely scenario and worst case scenario, respectively. In line with NatureScot Guidance Note 7 (NatureScot, 2025), both design scenarios have been modelled.
10. The predicted monthly time that turbines will be operational are presented in **Table 3**.
11. The mCRM additionally presents two parameter options: an option to apply large array correction (to account for behavioural avoidance at the offshore windfarm scale) and a user-defined value for the number of iterations of simulation for analysis. The large array correction was applied (although in practice this makes very little difference to the results obtained) and iterations were set to 1000.

Table 2: Offshore windfarm and turbine specifications used in the migratory collision risk modelling for the Most Likely Scenario (MLS) and the Worst Case Scenario (WCS).

Input parameter	MLS	WCS
Rotor speed (RPM)	7.43 (± 0.0001)	8.05 (± 0.0001)
Rotor radius (m)	138	118
Maximum blade width (m)	7.5	6.5
Mean blade pitch (°)	3.50	3.50
Number of rotor blades	3	3
Number of turbines	97	144
Mean windfarm width (km)	29 km	29 km
Latitude (°)	56.03°	56.03°
Large array correction (mCRM tool option)	Applied	Applied
Number of iterations (mCRM tool option)	1000	1000



Table 3: Offshore windfarm maintenance downtime and operational wind availability by month.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maintenance Downtime (%)	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
Maintenance Downtime (%) (SD)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Operational Wind Availability (%)	97.0%	96.1%	95.2%	92.4%	90.9%	90.3%	91.3%	92.1%	94.9%	96.5%	97.2%	96.6%



2.3.2 Bird biometrics and migration seasons

12. The mCRM tool provides recommended default biometric parameters and seasonal definition for each species and these were used without modification. Values implemented are presented in **Table 4** and **Table 5**.



Table 4: Input biometric and behavioural parameters (body length, wingspan, flight speed, avoidance rate and collision-risk height proportion) by species used in the mCRM. Values are derived from the mCRM tool.

Species	Flight type	Body Length (SD)	Mean wingspan (SD)	Flight speed (SD)	Avoidance rate (SD)	Proportion at collision risk height
Bar-tailed Godwit	Flapping	0.38 (0.02)	0.75 (0.02)	18.30 (2.10)	0.9990 (0.00000)	1.00
Bittern	Flapping	0.75 (0.02)	1.30 (0.02)	8.80 (2.00)	0.9950 (0.00001)	1.00
Black-tailed Godwit	Flapping	0.42 (0.02)	0.76 (0.02)	18.10 (6.00)	0.9990 (0.00000)	1.00
Black-throated Diver	Flapping	0.66 (0.02)	1.20 (0.02)	19.30 (2.10)	0.9950 (0.00001)	0.25
Canadian Light-bellied Brent Goose	Flapping	0.58 (0.02)	1.15 (0.02)	17.90 (6.10)	0.9990 (0.00010)	0.50
Common Scoter	Flapping	0.49 (0.03)	0.84 (0.03)	22.10 (4.00)	0.9850 (0.00080)	1.00
Corncrake	Flapping	0.28 (0.02)	0.50 (0.02)	13.00 (2.00)	0.9950 (0.00001)	1.00
Curlew	Flapping	0.55 (0.02)	0.90 (0.02)	15.40 (3.30)	0.9990 (0.00000)	1.00
Dotterel	Flapping	0.21 (0.01)	0.60 (0.01)	16.50 (1.80)	0.9990 (0.00000)	1.00
Dunlin	Flapping	0.18 (0.01)	0.40 (0.01)	15.30 (1.90)	0.9990 (0.00000)	1.00
Eider	Flapping	0.60 (0.03)	0.94 (0.03)	17.34 (2.40)	0.9850 (0.00080)	0.25
Gadwall	Flapping	0.51 (0.02)	0.90 (0.02)	19.60 (2.00)	0.9850 (0.00080)	1.00
Golden Plover	Flapping	0.28 (0.01)	0.72 (0.01)	16.50 (1.80)	0.9990 (0.00000)	1.00
Goldeneye	Flapping	0.46 (0.01)	0.72 (0.01)	20.30 (3.80)	0.9850 (0.00080)	1.00
Goosander	Flapping	0.62 (0.03)	0.90 (0.03)	19.70 (1.10)	0.9850 (0.00080)	1.00
Great Crested Grebe	Flapping	0.48 (0.02)	0.88 (0.02)	21.13 (1.55)	0.9950 (0.00001)	1.00
Great Northern Diver	Flapping	0.80 (0.02)	1.37 (0.02)	19.50 (1.60)	0.9950 (0.00001)	0.25
Greenland Barnacle Goose	Flapping	0.64 (0.04)	1.38 (0.04)	17.40 (1.08)	0.9990 (0.00010)	1.00
Greenshank	Flapping	0.32 (0.01)	0.69 (0.01)	12.30 (3.30)	0.9990 (0.00000)	1.00



Species	Flight type	Body Length (SD)	Mean wingspan (SD)	Flight speed (SD)	Avoidance rate (SD)	Proportion at collision risk height
Grey Plover	Flapping	0.28 (0.01)	0.77 (0.01)	16.50 (1.80)	0.9990 (0.00000)	1.00
Hen Harrier	Flapping	0.48 (0.02)	1.10 (0.02)	11.40 (1.10)	0.9950 (0.00010)	1.00
Icelandic Greylag Goose	Flapping	0.82 (0.03)	1.64 (0.03)	12.00 (4.90)	0.9996 (0.00000)	0.50
Knot	Flapping	0.24 (0.01)	0.59 (0.01)	24.60 (3.30)	0.9990 (0.00000)	1.00
Lapwing	Flapping	0.30 (0.01)	0.84 (0.01)	12.80 (1.30)	0.9990 (0.00000)	1.00
Long-tailed Duck	Flapping	0.44 (0.01)	0.76 (0.01)	19.70 (1.70)	0.9850 (0.00080)	1.00
Mallard	Flapping	0.58 (0.02)	0.90 (0.02)	15.86 (2.00)	0.9850 (0.00080)	1.00
Marsh Harrier	Flapping	0.52 (0.02)	1.22 (0.02)	13.20 (2.90)	0.9950 (0.00010)	0.50
Merlin	Flapping	0.28 (0.02)	0.56 (0.02)	12.70 (5.80)	0.9890 (0.00030)	1.00
Osprey	Flapping	0.56 (0.02)	1.58 (0.02)	10.60 (3.10)	0.9950 (0.00010)	0.50
Oystercatcher	Flapping	0.42 (0.02)	0.83 (0.02)	13.00 (2.50)	0.9990 (0.00000)	1.00
Pintail	Flapping	0.58 (0.02)	0.88 (0.02)	21.90 (2.00)	0.9850 (0.00080)	1.00
Pochard	Flapping	0.46 (0.01)	0.77 (0.01)	23.60 (2.00)	0.9850 (0.00080)	1.00
Purple Sandpiper	Flapping	0.21 (0.01)	0.44 (0.01)	15.30 (1.90)	0.9990 (0.00000)	1.00
Red-breasted Merganser	Flapping	0.55 (0.01)	0.78 (0.01)	22.00 (2.90)	0.9850 (0.00080)	1.00
Redshank	Flapping	0.28 (0.01)	0.62 (0.01)	15.30 (4.10)	0.9990 (0.00000)	1.00
Red-throated Diver	Flapping	0.61 (0.02)	1.11 (0.02)	18.60 (3.90)	0.9950 (0.00001)	0.25
Ringed Plover	Flapping	0.19 (0.01)	0.52 (0.01)	16.00 (1.10)	0.9990 (0.00000)	1.00
Ruff	Flapping	0.25 (0.01)	0.53 (0.01)	16.90 (1.81)	0.9990 (0.00000)	1.00
Sanderling	Flapping	0.20 (0.01)	0.42 (0.01)	21.40 (1.10)	0.9990 (0.00000)	1.00
Scaup	Flapping	0.46 (0.01)	0.78 (0.01)	21.10 (2.00)	0.9850 (0.00080)	1.00
Shelduck	Flapping	0.62 (0.02)	1.12 (0.02)	18.20 (4.30)	0.9850 (0.00080)	0.50



Species	Flight type	Body Length (SD)	Mean wingspan (SD)	Flight speed (SD)	Avoidance rate (SD)	Proportion at collision risk height
Short-eared Owl	Flapping	0.38 (0.02)	1.02 (0.02)	9.70 (2.00)	0.9950 (0.00010)	1.00
Shoveler	Flapping	0.48 (0.02)	0.77 (0.02)	18.30 (2.00)	0.9850 (0.00080)	1.00
Slavonian Grebe	Flapping	0.34 (0.02)	0.62 (0.02)	21.13 (1.55)	0.9950 (0.00001)	1.00
Snipe	Flapping	0.26 (0.01)	0.46 (0.01)	17.10 (2.70)	0.9990 (0.00000)	1.00
Spotted Crake	Flapping	0.23 (0.02)	0.40 (0.02)	13.00 (2.00)	0.9950 (0.00001)	1.00
Teal	Flapping	0.36 (0.015)	0.61 (0.015)	17.40 (1.60)	0.9850 (0.00080)	1.00
Tufted Duck	Flapping	0.44 (0.01)	0.70 (0.01)	21.10 (1.10)	0.9850 (0.00080)	1.00
Turnstone	Flapping	0.23 (0.01)	0.54 (0.01)	10.00 (3.30)	0.9990 (0.00000)	1.00
Velvet Scoter	Flapping	0.54 (0.03)	0.94 (0.03)	20.10 (4.70)	0.9850 (0.00080)	1.00
Whimbrel	Flapping	0.41 (0.02)	0.82 (0.02)	13.80 (0.40)	0.9990 (0.00000)	1.00
White-tailed Eagle	Flapping	0.80 (0.02)	2.20 (0.02)	14.40 (1.04)	0.9870 (0.00190)	1.00
Whooper Swan	Flapping	1.52 (0.04)	2.30 (0.04)	17.50 (4.20)	0.9880 (0.00090)	0.50
Wigeon	Flapping	0.48 (0.02)	0.80 (0.02)	18.50 (2.00)	0.9850 (0.00080)	1.00



Table 5: Species-specific migration periods applied in the mCRM assessment.
Values are derived from the mCRM tool.

Species	Pre-breeding migration	Post-breeding migration	Other
Bar-tailed godwit	March - April	July - October	NA
Bittern	January - May	June - October	NA
Black-tailed godwit	March - May	June - October	NA
Black-throated diver	March - May	August - November	NA
Canadian light-bellied brent Goose	March - May	August - October	NA
Common scoter	April - May	June - October	NA
Corncrake	April - May	July - August	NA
Curlew	March - May	June - October	NA
Dotterel	March - June	August - November	NA
Dunlin	March - May	June - October	NA
Eider	March - April	October - November	NA
Gadwall	March - July	July - November	NA
Golden plover	February - May	July - October	NA
Goldeneye	February - May	August - December	NA
Goosander	March - May	June - September	NA
Great crested grebe	March - June	July - November	February - March
Great northern diver	December - June	August - November	NA
Greenland barnacle goose	April - May	October - October	NA
Greenshank	March - June	August - November	NA
Grey plover	March - May	July - September	NA
Hen harrier	March - May	September - November	NA
Icelandic greylag goose	March - April	October - November	NA
Knot	February - May	June - October	NA
Lapwing	January - May	October - November	NA
Long-tailed duck	March - May	September - October	January - March
Mallard	April - June	September - October	January - March
Marsh harrier	March - May	August - November	NA
Merlin	March - May	August - November	NA
Osprey	March - April	August - October	NA
Oystercatcher	January - March	July - November	NA
Pintail	March - May	August - November	NA
Pochard	March - May	August - November	NA
Purple sandpiper	March - May	July - November	NA



Species	Pre-breeding migration	Post-breeding migration	Other
Red-breasted merganser	April - July	August - November	NA
Redshank	March - May	July - September	NA
Red-throated diver	February - June	July - September	NA
Ringed plover	March - May	August - October	NA
Ruff	March - May	July - November	NA
Sanderling	April - June	July - October	NA
Scaup	February - May	September - November	NA
Shelduck	January - February	June - July	August - December
Short-eared owl	March - May	July - October	NA
Shoveler	March - June	July - August	September - December
Slavonian grebe	February - April	August - October	NA
Snipe	March - May	August - October	October - December
Spotted crake	May - June	July - October	NA
Teal	February - May	July - December	NA
Tufted duck	April - June	September - October	NA
Turnstone	January - June	July - August	NA
Velvet scoter	March - May	June - September	NA
Whimbrel	April - June	June - October	NA
White-tailed eagle	April - May	August - October	NA
Whooper swan	February - April	September - November	NA
Wigeon	March - April	August - November	NA



3.0 Results

3.1 Collision risk modelling results for assessed migratory species under the most likely design scenario are presented in **Table 6**; results under the worst case design scenario are presented in **Table 7**.

Table 6: Modelled collision mortality (mean \pm SD) by species and seasonal migration period, including cumulative total under the most likely design scenario.

Species	Pre-breeding migration	Post-breeding migration	Other	Annual
Bar-tailed godwit	0.273 \pm 0.048	0.273 \pm 0.047	0 \pm 0	0.546 \pm 0.067
Bittern	0 \pm 0	0 \pm 0	0 \pm 0	0 \pm 0
Black-tailed godwit	0 \pm 0	0 \pm 0	0 \pm 0	0 \pm 0
Black-throated diver	0.001 \pm 0	0.001 \pm 0	0 \pm 0	0.002 \pm 0
Canadian light-bellied brent Goose	0.034 \pm 0.011	0.034 \pm 0.012	0 \pm 0	0.068 \pm 0.016
Common scoter	1.16 \pm 0.2	1.177 \pm 0.203	0 \pm 0	2.337 \pm 0.285
Corncrake	0.045 \pm 0.007	0.045 \pm 0.007	0 \pm 0	0.09 \pm 0.01
Curlew	0.085 \pm 0.016	0.085 \pm 0.016	0 \pm 0	0.17 \pm 0.023
Dotterel	0 \pm 0	0 \pm 0	0 \pm 0	0 \pm 0
Dunlin	1.163 \pm 0.168	1.165 \pm 0.169	0 \pm 0	2.328 \pm 0.238
Eider	0.237 \pm 0.04	0.245 \pm 0.041	0 \pm 0	0.482 \pm 0.057
Gadwall	0 \pm 0	0 \pm 0	0 \pm 0	0 \pm 0
Golden plover	1.861 \pm 0.309	1.862 \pm 0.309	0 \pm 0	3.723 \pm 0.437
Goldeneye	0.331 \pm 0.059	0.337 \pm 0.061	0 \pm 0	0.668 \pm 0.085
Goosander	0 \pm 0	0 \pm 0	0 \pm 0	0 \pm 0
Great crested grebe	0 \pm 0	0 \pm 0	0 \pm 0	0 \pm 0
Great northern diver	0.012 \pm 0.002	0.012 \pm 0.002	0 \pm 0	0.024 \pm 0.003
Greenland barnacle goose	0.185 \pm 0.025	0.195 \pm 0.026	0 \pm 0	0.38 \pm 0.036
Greenshank	0.004 \pm 0.001	0.004 \pm 0.001	0 \pm 0	0.008 \pm 0.001
Grey plover	0.052 \pm 0.01	0.052 \pm 0.01	0 \pm 0	0.104 \pm 0.014
Hen harrier	0.005 \pm 0.001	0.006 \pm 0.001	0 \pm 0	0.011 \pm 0.001
Icelandic greylag goose	0.041 \pm 0.034	0.042 \pm 0.035	0 \pm 0	0.083 \pm 0.049
Knot	0.236 \pm 0.034	0.235 \pm 0.033	0 \pm 0	0.471 \pm 0.047
Lapwing	2.057 \pm 0.313	2.112 \pm 0.321	0 \pm 0	4.169 \pm 0.448
Long-tailed duck	0.112 \pm 0.018	0.116 \pm 0.019	0 \pm 0	0.228 \pm 0.026
Mallard	5.917 \pm 1.174	6.209 \pm 1.232	6.235 \pm 1.238	18.361 \pm 2.104
Marsh harrier	0.004 \pm 0.001	0.004 \pm 0.001	0 \pm 0	0.008 \pm 0.001
Merlin	0.081 \pm 0.087	0.083 \pm 0.089	0 \pm 0	0.164 \pm 0.124



Species	Pre-breeding migration	Post-breeding migration	Other	Annual
Osprey	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Oystercatcher	0.273 ± 0.042	0.268 ± 0.041	0 ± 0	0.541 ± 0.059
Pink-footed goose	0.029 ± 0.055	0.029 ± 0.057	0 ± 0	0.058 ± 0.079
Pintail	0.21 ± 0.033	0.215 ± 0.034	0 ± 0	0.425 ± 0.047
Pochard	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Purple sandpiper	0.016 ± 0.002	0.017 ± 0.002	0 ± 0	0.033 ± 0.003
Red-breasted merganser	0.161 ± 0.028	0.168 ± 0.029	0 ± 0	0.329 ± 0.04
Redshank	0.268 ± 0.042	0.268 ± 0.042	0 ± 0	0.536 ± 0.059
Red-throated diver	0.025 ± 0.005	0.025 ± 0.005	0 ± 0	0.05 ± 0.007
Ringed plover	0.17 ± 0.026	0.173 ± 0.027	0 ± 0	0.343 ± 0.037
Ruff	0.014 ± 0.002	0.014 ± 0.002	0 ± 0	0.028 ± 0.003
Sanderling	0.091 ± 0.016	0.093 ± 0.016	0 ± 0	0.184 ± 0.023
Scaup	0.078 ± 0.011	0.08 ± 0.011	0 ± 0	0.158 ± 0.016
Shelduck	0.301 ± 0.053	0.283 ± 0.05	0.298 ± 0.053	0.882 ± 0.09
Short-eared owl	0.044 ± 0.007	0.045 ± 0.008	0 ± 0	0.089 ± 0.011
Shoveler	0.184 ± 0.036	0.183 ± 0.036	0.192 ± 0.038	0.559 ± 0.064
Slavonian grebe	0.003 ± 0	0.003 ± 0	0 ± 0	0.006 ± 0
Snipe	3.607 ± 0.542	3.672 ± 0.552	3.76 ± 0.565	11.039 ± 0.958
Spotted crake	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Teal	1.695 ± 0.377	1.715 ± 0.382	0 ± 0	3.41 ± 0.537
Tufted duck	1.345 ± 0.231	1.412 ± 0.243	0 ± 0	2.757 ± 0.335
Turnstone	0.233 ± 0.053	0.228 ± 0.052	0 ± 0	0.461 ± 0.074
Velvet scoter	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Whimbrel	0.003 ± 0	0.004 ± 0	0 ± 0	0.007 ± 0
White-tailed eagle	0.004 ± 0.001	0.004 ± 0.001	0 ± 0	0.008 ± 0.001
Whooper swan	0.211 ± 0.051	0.215 ± 0.051	0 ± 0	0.426 ± 0.072
Wigeon	4.583 ± 0.724	4.65 ± 0.734	0 ± 0	9.233 ± 1.031



Table 7: Modelled collision mortality (mean ± SD) by species and seasonal migration period, including cumulative total under the worst case design scenario.

Species	Pre-breeding migration	Post-breeding migration	Other	Total
Bar-tailed godwit	0.357 ± 0.055	0.356 ± 0.055	0 ± 0	0.713 ± 0.078
Bittern	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Black-tailed godwit	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Black-throated diver	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Canadian light-bellied brent Goose	0.044 ± 0.014	0.045 ± 0.014	0 ± 0	0.089 ± 0.02
Common scoter	1.507 ± 0.263	1.529 ± 0.267	0 ± 0	3.036 ± 0.375
Corncrake	0.062 ± 0.01	0.062 ± 0.01	0 ± 0	0.124 ± 0.014
Curlew	0.108 ± 0.021	0.108 ± 0.021	0 ± 0	0.216 ± 0.03
Dotterel	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Dunlin	1.441 ± 0.211	1.444 ± 0.211	0 ± 0	2.885 ± 0.298
Eider	0.317 ± 0.054	0.327 ± 0.056	0 ± 0	0.644 ± 0.078
Gadwall	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Golden plover	2.485 ± 0.381	2.487 ± 0.381	0 ± 0	4.972 ± 0.539
Goldeneye	0.444 ± 0.079	0.453 ± 0.081	0 ± 0	0.897 ± 0.113
Goosander	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Great crested grebe	0.016 ± 0.002	0.016 ± 0.002	0 ± 0	0.032 ± 0.003
Great northern diver	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Greenland barnacle goose	0.246 ± 0.03	0.259 ± 0.031	0 ± 0	0.505 ± 0.043
Greenshank	0.005 ± 0.001	0.005 ± 0.001	0 ± 0	0.01 ± 0.001
Grey plover	0.067 ± 0.011	0.067 ± 0.011	0 ± 0	0.134 ± 0.016
Hen harrier	0.007 ± 0.002	0.008 ± 0.002	0 ± 0	0.015 ± 0.003
Icelandic greylag goose	0.054 ± 0.046	0.056 ± 0.047	0 ± 0	0.11 ± 0.066
Knot	0.293 ± 0.044	0.291 ± 0.043	0 ± 0	0.584 ± 0.062
Lapwing	2.64 ± 0.441	2.711 ± 0.452	0 ± 0	5.351 ± 0.631
Long-tailed duck	0.148 ± 0.025	0.153 ± 0.025	0 ± 0	0.301 ± 0.035
Mallard	8.244 ± 1.555	8.651 ± 1.632	8.687 ± 1.639	25.582 ± 2.787
Marsh harrier	0.005 ± 0.001	0.005 ± 0.001	0 ± 0	0.01 ± 0.001
Merlin	0.102 ± 0.095	0.105 ± 0.098	0 ± 0	0.207 ± 0.136
Osprey	0.001 ± 0	0.001 ± 0	0 ± 0	0.002 ± 0
Oystercatcher	0.351 ± 0.054	0.345 ± 0.053	0 ± 0	0.696 ± 0.076
Pink-footed goose	0.039 ± 0.074	0.04 ± 0.076	0 ± 0	0.079 ± 0.106
Pintail	0.275 ± 0.041	0.282 ± 0.042	0 ± 0	0.557 ± 0.059



Species	Pre-breeding migration	Post-breeding migration	Other	Total
Pochard	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Purple sandpiper	0.021 ± 0.003	0.021 ± 0.003	0 ± 0	0.042 ± 0.004
Red-breasted merganser	0.216 ± 0.031	0.225 ± 0.032	0 ± 0	0.441 ± 0.045
Redshank	0.032 ± 0.005	0.032 ± 0.005	0 ± 0	0.064 ± 0.007
Red-throated diver	0.356 ± 0.054	0.356 ± 0.053	0 ± 0	0.712 ± 0.076
Ringed plover	0.216 ± 0.033	0.22 ± 0.033	0 ± 0	0.436 ± 0.047
Ruff	0.018 ± 0.003	0.018 ± 0.003	0 ± 0	0.036 ± 0.004
Sanderling	0.116 ± 0.018	0.119 ± 0.019	0 ± 0	0.235 ± 0.026
Scaup	0.105 ± 0.016	0.108 ± 0.016	0 ± 0	0.213 ± 0.023
Shelduck	0.394 ± 0.071	0.37 ± 0.067	0.389 ± 0.07	1.153 ± 0.12
Short-eared owl	0.06 ± 0.012	0.06 ± 0.012	0 ± 0	0.12 ± 0.017
Shoveler	0.238 ± 0.041	0.237 ± 0.041	0.249 ± 0.043	0.724 ± 0.072
Slavonian grebe	0.004 ± 0.001	0.004 ± 0.001	0 ± 0	0.008 ± 0.001
Snipe	4.8 ± 0.727	4.886 ± 0.74	5.004 ± 0.757	14.69 ± 1.284
Spotted crake	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Teal	2.317 ± 0.638	2.345 ± 0.646	0 ± 0	4.662 ± 0.908
Tufted duck	1.818 ± 0.262	1.907 ± 0.274	0 ± 0	3.725 ± 0.379
Turnstone	0.303 ± 0.073	0.297 ± 0.072	0 ± 0	0.6 ± 0.103
Velvet scoter	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Whimbrel	0.005 ± 0.001	0.005 ± 0.001	0 ± 0	0.01 ± 0.001
White-tailed eagle	0.005 ± 0.001	0.005 ± 0.001	0 ± 0	0.01 ± 0.001
Whooper swan	0.284 ± 0.06	0.289 ± 0.061	0 ± 0	0.573 ± 0.086
Wigeon	6.014 ± 0.933	6.102 ± 0.947	0 ± 0	12.116 ± 1.329



4.0 Discussion

4.1 **Table 8** summarises predicted annual collision mortality for the WCS and mortality as a percentage of total UK population by species. Predicted annual collision mortality for all migratory species is extremely low in both absolute and proportional terms. The highest mean annual mortality was predicted for mallard (25.6 individuals), yet this represents approximately 0.0031% of the UK population (823,600 individuals). Similarly, relatively higher absolute values for snipe (14.7 individuals) and wigeon (12.1 individuals) correspond to only ~0.0002% and ~0.0025% of their respective UK populations. The highest proportional impact was predicted for white-tailed eagle (0.0068%), but this equates to a mean of just 0.01 individuals per year. All other species are below ~0.003% of their UK populations. Accordingly, predicted collision risks for migratory species are negligible and would not be expected to result in detectable effects at the population level.

Table 8: Predicted annual migratory collision mortality and proportion of UK population affected under the WCS.

Species	Annual mortality (mean)	Annual mortality SD	Total population in the UK (individuals)	Mortality as a percentage of total UK population (%)
Bar-tailed godwit	0.713	0.078	680000	0.0001
Bittern	0	0	714	0.0000
Black-tailed godwit	0	0	303000	0.0000
Black-throated diver	0.002	0	1180	0.0002
Canadian light-bellied brent Goose	0.089	0.02	40000	0.0002
Common scoter	3.036	0.375	135180	0.0022
Corncrake	0.124	0.014	16960	0.0007
Curlew	0.216	0.03	141100	0.0002
Dotterel	0	0	390	0.0000
Dunlin	2.885	0.298	2021808	0.0001
Eider	0.644	0.078	106720	0.0006
Gadwall	0	0	30940	0.0000
Golden plover	4.972	0.539	3296500	0.0002
Goldeneye	0.897	0.113	37500	0.0024
Goosander	0	0	17420	0.0000
Great crested grebe	0	0	1380	0.0000
Great northern diver	0.032	0.003	11000	0.0003
Greenland barnacle goose	0.505	0.043	81000	0.0006
Greenshank	0.01	0.001	7200	0.0001
Grey plover	0.134	0.016	124000	0.0001
Hen harrier	0.015	0.003	2176	0.0007



Species	Annual mortality (mean)	Annual mortality SD	Total population in the UK (individuals)	Mortality as a percentage of total UK population (%)
Icelandic greylag goose	0.11	0.066	68400	0.0002
Knot	0.584	0.062	360000	0.0002
Lapwing	5.351	0.631	3942500	0.0001
Long-tailed duck	0.301	0.035	12800	0.0024
Mallard	25.582	2.787	823600	0.0031
Marsh harrier	0.01	0.001	2576	0.0004
Merlin	0.207	0.136	8256	0.0025
Osprey	0.002	0	665	0.0003
Oystercatcher	0.696	0.076	358900	0.0002
Pink-footed goose	0.079	0.106	500000	0.0000
Pintail	0.557	0.059	20942	0.0027
Pochard	0	0	28500	0.0000
Purple sandpiper	0.042	0.004	24400	0.0002
Red-breasted merganser	0.441	0.045	15840	0.0028
Redshank	0.712	0.076	420000	0.0002
Red-throated diver	0.064	0.007	34000	0.0002
Ringed plover	0.436	0.047	289520	0.0002
Ruff	0.036	0.004	31000	0.0001
Sanderling	0.235	0.026	200000	0.0001
Scaup	0.213	0.023	7000	0.0030
Shelduck	1.153	0.12	62500	0.0018
Short-eared owl	0.12	0.017	14880	0.0008
Shoveler	0.724	0.072	22960	0.0032
Slavonian grebe	0.008	0.001	989	0.0008
Snipe	14.69	1.284	6105001	0.0002
Spotted crake	0	0	26	0.0000
Teal	4.662	0.908	435500	0.0011
Tufted duck	3.725	0.379	155000	0.0024
Turnstone	0.6	0.103	347000	0.0002
Velvet scoter	0	0	3465	0.0000
Whimbrel	0.01	0.001	4680	0.0002
White-tailed eagle	0.01	0.001	148	0.0068
Whooper swan	0.573	0.086	39990	0.0014
Wigeon	12.116	1.329	480000	0.0025



5.0 References

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