Cush Wind Farm

Environmental Impact Assessment Report

Annex 5.7: Avian Collision Risk Assessment

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CUSH WIND FARM

Avian Collision Risk Assessment

Cush Wind Farm Ltd

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APPENDICES

1.0 Introduction

This report presents the results of Collision Risk Modelling (CRM) undertaken for twelve bird species to inform an assessment of potential ornithological impacts relating to the proposed Cush Wind Farm, which has a layout comprising eight turbines.

As advised by Cush Wind Farm Ltd, modelling was based on the use of Vestas V172-7.2 MW turbines, each with a rotor diameter of 172m, tip height of 200m and hub height of 114m.

The CRM was undertaken in accordance with current NatureScot (NS) (formerly Scottish Natural Heritage (SNH)) guidance, which is recognised as standard best practice guidance through the UK and Ireland to inform impact assessment for onshore wind farms. Further details regarding the methodology used, including details of assumptions used and any corrections applied, are provided in Section 2. The monitoring results are presented in Section 3 and copies of the modelling calculations for each species modelled are included in Appendices 01-02.

1.1 Primary Target Species

Target species for the surveys were defined by legal and/ or conservation status and vulnerability to impacts caused by wind turbines, as defined in NS Guidance (SNH 2017[1]).

Bird species of high conservation importance in this case are those which are qualifying features of nearby Special Protection Areas (SPAs) which are potentially within core foraging range of the Site (e.g., as defined by SNH 2016[2]). Therefore, the following species are considered relevant as primary target species:

- Dovegrove Callows SPA (0 km from the Site):
  - Greenland white-fronted goose *Anser albifrons flavirostris*
- River Little Brosna Callows SPA (1.65 km from the Site);
  - Whooper swan *Cygnus cygnus*
  - Greenland white-fronted goose
  - Eurasian wigeon *Mareca penelope*
  - Eurasian teal *Anas crecca*
  - Northern pintail *Anas acuta*
  - Northern shoveler *Spatula clypeata*
  - European golden plover *Pluvialis apricaria*
  - Northern lapwing *Vanellus vanellus*
  - Black-tailed Godwit *Limosa limosa*
  - Black-headed gull *Chroicocephalus ridibundus*
- All Saints Bog (2.23 km from the Site)
  - Greenland white-fronted goose

[1] Scottish Natural Heritage (SNH) (2017). *Recommended Bird Survey Methods to Inform Impact Assessment of Onshore Wind Farms. Version 2*.

[2] Scottish Natural Heritage (SNH) (2016). *Assessing Connectivity with Special Protection Areas (SPAs). Version 3 – June 2016*. Scottish Natural Heritage, Inverness.

- Middle Shannon Callows SPA (6.24 km from the Site):
    - Whooper swan
    - Eurasian wigeon
    - Corncrake *Crex crex*
    - European golden plover
    - Northern lapwing
    - Black-tailed godwit
    - Black-headed gull
- Other Annex I species and other species of high conservation importance which are considered to be vulnerable to impacts from wind farm developments:
    - Great cormorant[3] *Phalacrocorax carbo*
    - Hen harrier *Circus cyaneus*
    - Kestrel *Falco tinnunculus*
    - Mallard *Anas platyrhynchos*
    - Peregrine *Falco peregrinus*
    - Snipe *Gallinago gallinago*

2.0 Methods

The standard Band CRM (Band *et. al.* 2007[4]) was used to estimate collision risk based on recorded target species activity levels and flight behaviour, proposed turbine numbers and specifications, and the relevant species biometrics and flight characteristics. Modelling collision risk under the Band CRM is a two-stage process. Stage 1 estimates the number of birds that fly through the rotor swept disc. Stage 2 predicts the proportion of these birds that have the potential to be hit by a rotor blade. Combining both stages produces an estimate of collision mortality in the absence of any avoidance action/behaviour by birds. Avoidance rates are then applied to generate predicted rates of collision mortality.

2.1 Prediction of Rotor Transits from Vantage Point Survey Data

2.1.1 Survey Data 2020 to 2023

The number of birds that fly through the rotor swept area was estimated using flight data gathered during baseline surveys carried out during May 2020 to March 2023, which equates to three breeding seasons and three non-breeding seasons.

[3] Note that cormorant was previously considered as a secondary target species prior to the Year 3 surveys

[4] Band, W., Madders, M. and Whitfield, D.P. (2007) Developing Field and Analytical Methods to Assess Avian Collision Risk at Wind Farms. In: De Lucas, M., Janss, G. and Ferrer, M., Eds., Birds and Wind Power, Quercus Editions, Madrid, 259-275.

The surveys gathered data from two[5] vantage points (VPs). The total number of hours are as shown in **Table 2-1**.

Table 2-1
VP Surveys undertaken at Cush, May 2020 – Mar 2022

VP Number	ITM Coordinates (x,y)	Hours of Survey Completed (hrs:mins)						
		May 2020-Aug 2020	Sep 2020-Mar 2021	Apr 2021-Sep 2021	Oct 2021-Mar 2022	May 2022-Aug 2022	Oct 2022-Mar 2023	Total
1	608740, 710139	27:00	42:30	36:00	36:00	36:00	36:00	213:30
2	605756, 709249	27:00	42:00	36:00	36:00	36:00	36:00	213:00

2.1.2 Viewshed Data

Viewshed data, i.e., the area visible from each VP within the wind farm polygon (WP)[6], are summarised in **Table 2-2**. The combined viewshed area (minus overlap) from VP1 & VP2 (5,060,775m²) represents 93.9% of the survey WP (5,389,116m²).

Table 2-2
Cush VP Viewshed Data

VP/ Viewshed Number	Area of visibility (m²)*
VP 1 viewshed	3,627,524
VP 2 viewshed	2,637,930
VP 1+2 viewshed combined (minus overlap)	5,060,775
	* area calculated in GIS using offset of 28 m above ground level

2.1.3 Flight Selection for CRM

In order to select flights liable to incur a potential risk of collision, i.e., within the areas occupied by proposed turbines, the CRM used only observations collected within the WP – defined by a 500 m buffer around the proposed outermost turbine locations. The size of buffer takes into account rotor blade length and potential

[5] Note that a third vantage point was added in Year 3 as a potential extension area was being considered. This has since been dropped and as the original two vantage points adequately covered the site, the viewshed and survey data from the third vantage point has not been included here. This is to avoid inflating the collision estimates artificially.
[6] The survey wind farm polygon (WP) includes the area within 500m of the outermost turbine blades.

spatial errors in flight recording accuracy. It is known that bird detection rates vary between species. To ensure the CRM used robust measures of flight activity, a 2 km distance truncation was used in the viewshed from each VP, i.e., only flights within 2 km of each VP were included (as per NS guidance).

Analysis in MS Excel and GIS identified those flights that were at Potential Collision Height (PCH) and within the WP. Flight times that were used in the CRM were derived from field data for each flight. Time spent at different flight heights was estimated in a database from interval data for flights that entered the WP. Flying time estimated to occur within the survey recording height bands (see following section) was used to determine the period that target species were at risk of collision with the rotors.

2.1.4 Correcting Survey PCH to Actual PCH

May 2020 to September 2021 Surveys

Baseline VP surveys were initiated before the current candidate turbine details were known. The baseline surveys during May 2020 to September 2021 utilised the following height bands:

- 1 = <25m
- 2 = 25-50m
- 3 = 50-150m
- 4 = >150m

As such, the height bands used to record flight activity do not correspond precisely to PCH for the proposed development (28-200m[7]), i.e., height band 2 overlaps with the lower limit of the actual PCH (28-50 m of the 25-50 m band) and height band 4 overlaps with the upper limit of the actual PCH (150-200 m of the >150 m band).

Because of this it was necessary to make assumptions about the distribution of some of the flight heights recorded. Assuming an equal distribution of heights within height band 2, it is assumed that a small proportion of flights will be below risk height. Therefore, as theoretically only a proportion of flights from 25-50 m are at risk, the proportion of flights included within the CRM in height band 2 was assumed to be 22/25 (88%).

For height band 4 (>150 m), it is not possible to make assumptions on the proportion of flights that were above risk height. Therefore, all flights in height band 4 were included in the CRM.

October 2021 to March 2023 Surveys

Following clarification re likely candidate turbine details, survey height bands were reviewed. Baseline surveys during October 2021 to March 2023 utilised the following height bands:

- 1 = <20m
- 2 = 20-150m
- 3 = 150-200m
- 4 = >200m

As such, height band 2 overlaps with the lower limit of PCH (28 m). It is therefore assumed that a small proportion of height band 2 flights will be below risk height. This is accounted for in the model using the method as described above.

[7] Using the turbine data in Table 2-4

2.1.5 Seasonal Definitions

CRMs were constructed using data based on the survey design which takes into account the relevant breeding and non-breeding season periods, defined as April – August (breeding season) and September – March (non-breeding season, as per SNH (2017)[8].

The theoretical time that birds could be active with potential for turbine collisions was assumed to be the period between sunrise and sunset within each survey period using the latitude of the Site[9].

For waders and wildfowl, which could be active nocturnally, an additional 25% of nocturnal hours were added to the daylight hours to give a more accurate representation of the available hours for these species (as per Band *et al.*, 2007).

2.1.6 Undertaking CRM

Collision risk modelling employs an estimated three-dimensional risk volume, in keeping with the assumption that flight directions are random in space. For species with non-directional (e.g., random, circling and foraging) flights, the occupancy data are derived by multiplying the numbers of a particular species flying through the survey risk area by the total time spent.

The following parameters were entered into a bespoke modelling spreadsheet:-

- The total observation effort within the risk volume (V_w) visible from each VP;
- The occupancy total: the total time spent by a particular species flying within the risk volume (V_w) visible from each VP;
- The volume of Vw (m^3) visible from each VP (this is area covered by the outermost turbines without the 500m buffer);
- An estimation of average daylight hours within the season of analysis;
- Species-specific bird parameters (Table 2-3); and
- Wind farm parameters (Table 2-4).

Maps showing VP locations and viewsheds along with the 500 m buffer around the outermost turbine blades can be seen in the baseline bird reports.

The NS CRM spreadsheet[10] calculates the probability of collision for each particular species. The model then combines this probability of collision with the observed flight activity per unit area (hours per hectare) weighted for observation effort from each VP to produce an estimate of the number of transits through the rotor blades. Mortality estimates are then derived by applying species-specific avoidance rates.

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[8] Scottish Natural Heritage (SNH) (2017). *Recommended Bird Survey Methods to Inform Impact Assessment of Onshore Wind Farms. Version 2*.
[9] https://www.timeanddate.com [Accessed in September 2022].
[10] https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision [Accessed in September 2022].

2.1.7 Bird Biometrics and Avoidance Rates

Measurements and flight speeds of the species for which CRM was undertaken were derived from British Trust for Ornithology (BTO)[11], Provan & Whitfield (2007[12]), Bruderer & Boldt (2001[13]) and Alerstram *et al.* (2007[14]). The avoidance rates for these species are taken from NS (2018[15]).

Table 2-3
Bird biometrics and avoidance rates used in CRM

Species name	Bird length (m)	Wingspan (m)	Flight speed (m/s)	Avoidance rate (%)
Whooper swan	1.52	2.3	17.3	99.5
Eurasian wigeon	0.48	0.8	10.3	98
Eurasian teal	0.39	0.55	19.7	98
Mallard	0.58	0.9	22.0	98
Great cormorant	1.0	1.6	16.7	98
Hen harrier	0.48	1.1	12.0	99
Common kestrel	0.34	0.8	12.7	95
Peregrine falcon	0.45	1.1	14.0	98
European golden plover	0.28	0.72	17.5	98
Northern lapwing	0.30	0.84	12.3	98
Common snipe	0.26	0.455	16.0	98
Black-headed gull	0.36	1.05	11.2	98

In addition to the NS 98% default avoidance rate, there has been recent research that shows that for European golden plover, an avoidance rate of 99.8% may be more appropriate. This is based on empirical evidence collected during post-construction monitoring surveys for operational wind farms in England[16]. Consequently,

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[11] https://www.bto.org/understanding-birds/birdfacts [Accessed in September 2022].
[12] Provan, S. and Whitfield, D.P. (2007) Avian flight speeds and biometrics for use in collision risk modelling. Report to Scottish Natural Heritage.
[13] Bruderer, B. and Bolt, A. (2001) Flight characteristics of birds: 1. Radar measurements of speeds, *Ibis*, **143**. 178 – 204.
[14] Alerstam T, Rosén M, Bäckman J, Ericson PG, Hellgren O. (2007). Flight speeds among bird species: allometric and phylogenetic effects. PLoS Biol.
[15] SNH (2018) Avoidance rates for the onshore SNH wind farm collision risk model. https://www.nature.scot/doc/wind-farm-impacts-birds-use-avoidance-rates-naturescot-wind-farm-collision-risk-model#:~:text=2.%20Recommended%20avoidance%20rates%20%20%20Species%20,%20SNH%20%282013%29%20%207%20more%20rows%20. [Accessed in September 2022].
[16] https://www.ballivorwindfarmplanning.ie/wp-content/uploads/sites/38/2023/04/Appendix_7-6_Collision_Risk_Assessment.pdf

we have presented the results using the two avoidance rates to show the range of possible collision estimates.

2.1.8 Wind Farm and Turbine Parameters

The wind turbine parameters used in the CRM are detailed in **Table 2-4** and are based on the use of Vestas V172-7.2 MW turbines, which are considered a reasonable representation of various turbines under consideration and were agreed with Galetech for the purposes of this CRM.

Table 2-4
Wind farm & turbine parameters

Parameter	Value
Size of survey wind farm polygon (WP)	538.9 ha
Number of turbines	8
Rotor radius/ diameter	86.0m/ 172.0m
Hub height	114.0m
Max. chord	4.3m
Pitch	6°
Rotation period	4.95s (max 12.12rpm)
Turbine operation time	97%

2.2 Cush Flightline Data

Table 2-5 summarises the primary target species flightline data from VP surveys conducted, presented for each season. **Table 2-6** to **Table 2-17** (inclusive) present the seasonal primary target species occupancy data within each height band, and the total at-risk occupancy data used in the CRM.

Table 2-5
Number of target species flights and individuals observed passing through the Cush WP during VP surveys (2021 to 2023)

Species name	Period of analysis	Total number of birds recorded in flight	Flights through WP		Flights through WP at Potential Collision Height (PCH)	
			Flights	Individuals	Flights	Individuals
Whooper swan	Non-breeding season 2020/21 (01 Sep-31 Mar)	20	0	0	0	0
	Non-breeding season 2021/22 (01 Sep-31 Mar)	16	2	16	2	16
	Non-breeding season 2022/23 (01 Oct-31 Mar)	18	3	18	3	18
Eurasian wigeon	Non-breeding season 2022/23 (01 Oct-31 Mar)	13	1	13	1	13
Eurasian teal	Non-breeding season 2022/23 (01 Oct-31 Mar)	42	1	42	1	42
Mallard	Non-breeding season 2021/22 (01 Sep-31 Mar)	26	12	26	4	10
	Non-breeding season 2022/23 (01 Oct-31 Mar)	9	3	7	3	7
Great cormorant	Non-breeding season 2022/23 (01 Oct-31 Mar)	9	9	9	9	9
Hen harrier	Non-breeding season 2020/21 (01 Sep-31 Mar)	2	2	2	2	2
	Non-breeding season 2021/22 (01 Sep-31 Mar)	2	2	2	2	2

Species name	Period of analysis	Total number of birds recorded in flight	Flights through WP		Flights through WP at Potential Collision Height (PCH)	
			Flights	Individuals	Flights	Individuals
	Non-breeding season 2022/23 (01 Oct-31 Mar)	3	3	3	3	3
Common kestrel	Breeding season 2021 (01 Apr-31 Aug)	5	5	5	4	4
	Non-breeding season 2021/22 (01 Sep-31 Mar)	25	22	22	19	19
	Breeding season 2022 (01 May-31 Aug)	34	20	20	20	20
	Non-breeding season 2022/23 (01 Oct-31 Mar)	27	19	19	19	19
Peregrine falcon	Non-breeding season 2021/22 (01 Sep-31 Mar)	8	6	6	4	4
	Breeding season 2022 (01 May-31 Aug)	1	1	1	0	0
	Non-breeding season 2022/23 (01 Oct-31 Mar)	4	4	4	1	1
European golden plover	Breeding season 2021 (01 Apr-31 Aug)	5	1	5	1	5
	Non-breeding season 2021/22 (01 Sep-31 Mar)	2,042	2	2,042	2	2,042
	Non-breeding season 2022/23 (01 Oct-31 Mar)	4,483	14	4,483	13	4,479
Northern lapwing	Breeding season 2020 (01 May-31 Aug)	2	2	2	2	2
	Non-breeding season 2020/21 (01 Sep-31 Mar)	13	1	13	1	13
	Breeding season 2021 (01 Apr-31 Aug)	36	23	36	14	26

Species name	Period of analysis	Total number of birds recorded in flight	Flights through WP		Flights through WP at Potential Collision Height (PCH)	
			Flights	Individuals	Flights	Individuals
	Non-breeding season 2021/22 (01 Sep-31 Mar)	28	2	28	2	28
	Breeding season 2022 (01 May-31 Aug)	70	33	65	10	36
	Non-breeding season 2022/23 (01 Oct-31 Mar)	653	29	653	24	635
Common snipe	Breeding season 2021 (01 Apr-31 Aug)	1	1	1	0	0
	Non-breeding season 2021/22 (01 Sep-31 Mar)	17	3	17	1	7
	Breeding season 2022 (01 May-31 Aug)	43	29	37	22	30
	Non-breeding season 2022/23 (01 Oct-31 Mar)	4	4	4	3	3
Black-headed gull	Breeding season 2021 (01 Apr-31 Aug)	81	41	80	21	36
	Non-breeding season 2021/22 (01 Sep-31 Mar)	78	4	56	4	56
	Breeding season 2022 (01 May-31 Aug)	240	103	189	73	134
	Non-breeding season 2022/23 (01 Oct-31 Mar)	37	4	34	3	32

Table 2-6
Details of Whooper Swan Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)				
					<20m	20-150m	150-200m	>200m	At risk
Sep-21 to Mar-22	VP1	0	0	0	0	0	0	0	0
	VP2	2	16	1020	0	1020	0	0	1020
Oct-22 to Mar-23	VP1	2	13	2250	0	2250	0	0	2250
	VP2	1	5	450	0	450	0	0	450
Total		5	34	3720	0	3720	0	0	3720

Table 2-7
Details of Eurasian Wigeon Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)				
					<20m	20-150m	150-200m	>200m	At risk
Oct-22 to Mar-23	VP1	1	13	585	390	195	0	0	195
	VP2	0	0	0	0	0	0	0	0
Total		1	13	585	390	195	0	0	195

Table 2-8
Details of Eurasian Teal Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)				
					<20m	20-150m	150-200m	>200m	At risk
Oct-22 to Mar-23	VP1	1	42	12600	3780	8820	0	0	8820
	VP2	0	0	0	0	0	0	0	0
Total		1	42	12600	3780	8820	0	0	8820

Table 2-9
Details of Mallard Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)				
					<20m	20-150m	150-200m	>200m	At risk
Sep-21 to Mar-22	VP1	11	24	765	345	420	0	0	420
	VP2	1	2	90	0	90	0	0	90
Oct-22 to Mar-23	VP1	2	4	180	90	90	0	0	90
	VP2	1	3	270	0	270	0	0	270
Total		15	33	1305	435	870	0	0	870

Table 2-10
Details of Great Cormorant Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)				
					<20m	20-150m	150-200m	>200m	At risk
Oct-22 to Mar-23	VP1	2	2	210	0	210	0	0	210
	VP2	7	7	465	120	345	0	0	345
Total		9	9	675	120	555	0	0	555

Table 2-11
Details of Hen Harrier Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)				
					<25m	25-50m	50-150m	>150m	At risk
Sep-20 to Mar-21	VP1	1	1	30	0	30	0	0	30
	VP2	1	1	30	0	30	0	0	30
					<20m	20-150m	150-200m	>200m	At risk
Sep-21 to Mar-22	VP1	1	1	120	0	120	0	0	120
	VP2	1	1	270	0	0	270	0	270
Oct-22 to Mar-23	VP1	1	1	60	15	45	0	0	45
	VP2	2	2	90	30	60	0	0	60
Total		7	7	600					555

Table 2-12
Details of Common Kestrel Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)				
					<25m	25-50m	50-150m	>150m	At risk
Apr-21 to Sep-21	VP1	1	1	105	15	90	0	0	0
	VP2	6	6	180	75	75	30	0	105
					<20m	20-150m	150-200m	>200m	At risk
Oct-21 to Mar-22	VP1	17	17	1500	390	765	270	75	1035
	VP2	4	4	240	90	150	0	0	150
May-22 to Aug-22	VP1	11	11	1530	375	1155	0	0	1155
	VP2	9	9	735	90	540	105	0	645
Oct-22 to Mar-23	VP1	15	15	1530	495	810	225	0	1035
	VP2	4	5	495	180	225	90	0	315
Total		67	68	4290					3150

Table 2-13
Details of Peregrine Falcon Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)				
					<20m	20-150m	150-200m	>200m	At risk
Oct-21 to Mar-22	VP1	3	3	405	45	360	0	0	360
	VP2	3	3	360	45	15	300	0	315
May-22 to Aug-22	VP1	1	1	15	15	0	0	0	0
	VP2	0	0	0	0	0	0	0	0
Oct-22 to Mar-23	VP1	4	4	165	105	60	0	0	60
	VP2	0	0	0	0	0	0	0	0
Total		11	11	945	210	435	300	0	735

Table 2-14
Details of European Golden Plover Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)				
					<25 m	25-50m	50-150m	>150 m	At risk
Apr-21 to Sep-21	VP1	1	5	300	0	300	0	0	300
	VP2	0	0	0	0	0	0	0	0
					<20 m	20-150m	150-200m	>200 m	At risk
Oct-21 to Mar-22	VP1	1	2000	600000	0	600000	0	0	600000
	VP2	1	42	1,890	0	1,890	0	0	1,890
Oct-22 to Mar-23	VP1	12	4305	958835	8745	303840	641250	0	945090
	VP2	2	178	34170	1080	9090	24000	0	33090
Total		17	6530	1595195					1580370

Table 2-15
Details of Northern Lapwing Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)				
					<25m	25-50m	50-150m	>150m	At risk
May-20 to Aug-20	VP1	2	2	105	0	105	0	0	105
	VP2	0	0	0	0	0	0	0	0
Sep-20 to Mar-21	VP1	0	0	0	0	0	0	0	0
	VP2	1	13	1170	0	780	390	0	1170
Apr-21 to Sep-21	VP1	17	30	1455	615	630	210	0	840
	VP2	7	7	225	150	60	15	0	75
					<20m	20-150m	150-200m	>200m	At risk
Oct-21 to Mar-22	VP1	1	27	6075	15	5268	810	0	6075
	VP2	0	0	0	0	0	0	0	0
May-22 to Aug-22	VP1	33	65	4890	1125	3765	0	0	3765
	VP2	0	0	0	0	0	0	0	0
Oct-22 to Mar-23	VP1	16	484	76830	8805	36915	31110	0	68025
	VP2	13	169	23025	435	4770	17820	0	22590
Total		90	797	113775					102645

Table 2-16
Details of Common Snipe Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)				
					<25m	25-50m	50-150m	>150m	At risk
Apr-21 to Sep-21	VP1	0	0	0	0	0	0	0	0
	VP2	1	1	15	15	0	0	0	0
					<20m	20-150m	150-200m	>200m	At risk
Oct-21 to Mar-22	VP1	3	17	465	150	315	0	0	315
	VP2	0	0	0	0	0	0	0	0
May-22 to Aug-22	VP1	25	33	4035	255	3780	0	0	3780
	VP2	0	0	0	0	0	0	0	0
Oct-22 to Mar-23	VP1	0	0	0	0	0	0	0	0
	VP2	4	4	210	75	135	0	0	135
Total		33	55	4725					4230

Table 2-17
Details of Black-headed Gull Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)				
					<25m	25-50m	50-150m	>150m	At risk
Apr-21 to Sep-21	VP1	19	49	2580	885	465	1095	135	1695
	VP2	22	31	1830	795	675	330	30	1035
					<20m	20-150m	150-200m	>200m	At risk
Oct-21 to Mar-22	VP1	1	2	90	0	90	0	0	90
	VP2	3	54	3165	0	3165	0	0	3165
May-22 to Aug-22	VP1	48	87	4485	1620	2775	90	0	2865
	VP2	55	102	6060	900	5040	105	15	5145
Oct-22 to Mar-23	VP1	4	34	6300	90	1380	4830	0	6210
	VP2	0	0	0	0	0	0	0	0
Total		197	495	32175					26190

3.0 Collision Risk Modelling Results

Table 3-1 summarises the predicted collision rates for the nine species under consideration. Copies of the modelling calculations for each species are included in Appendices 01-02.

Table 3-1
Summary of CRM Output

Species name	Period of analysis	Modelled collisions per Season	Years per collision
Whooper swan	Non-breeding season	0.0971	10.29
Eurasian wigeon	Non-breeding season	0.0250	40.02
Eurasian teal	Non-breeding season	1.5662	0.64
Mallard	Non-breeding season	0.0957	10.45
Great cormorant	Non-breeding season	0.0964	10.37
Hen harrier	Non-breeding season	0.0092	108.17
Common kestrel	Breeding season	0.2561	3.91
	Non-breeding season	0.2893	3.46
	Annual	0.6692	1.49
Peregrine falcon	Non-breeding season	0.0392	25.50
European golden plover	Non-breeding season (98% avoidance)	77.3575	0.01
	Non-breeding season (99.8% avoidance)	7.73575	0.10
Northern lapwing	Breeding season	0.1929	5.18
	Non-breeding season	3.9049	0.26
	Annual	4.9768	0.20
Common snipe	Breeding season	0.4782	2.09
	Non-breeding season	0.0307	32.54
	Annual	0.4485	2.23
Black-headed gull	Breeding season	0.5329	1.88
	Non-breeding season	0.4127	2.42
	Annual	1.1463	0.87

3.1 Species Summary

3.1.1 Whooper Swan

Flight activity by whooper swan was infrequent, with flights recorded only on six dates. Five flights entered the WP. There was a peak count of 12 birds. As a result, the predicted mortality was low (0.0971 per year).

3.1.2 Eurasian Wigeon

Flight activity by wigeon was low, with a single flight of 13 birds recorded. The predicted mortality of 0.0250 is consequently very low.

3.1.3 Eurasian Teal

Flight activity by teal was low, with a single long flight of 42 birds recorded. The predicted mortality of 1.5662 is considered to be an over-estimate, given the low level of observed flight activity over three years of survey.

3.1.4 Mallard

Flight activity by mallard was generally random in nature within the centre of the WP. There was a peak count of just five birds. The predicted mortality of 0.0957 is low. For reference the background mortality is given as 37.3% for adults and 48.2% for first years**Error! Bookmark not defined.**.

3.1.5 Great Cormorant

Flight activity by cormorant involved birds commuting to/ from waterbodies off site. While this species was not treated as a primary target for the first two years of surveys, qualitative estimates of collision are likely low due to low numbers of observations. The predicted mortality of 0.0964 is low.

3.1.6 Hen Harrier

Flight activity by hen harrier was restricted to the non-breeding season. All four flights involved single birds. The predicted mortality of 0.0092 is very low. For reference the background mortality is given as 19% for adults and 78% for birds to age two years**Error! Bookmark not defined.**.

3.1.7 Common Kestrel

Flight activity by kestrel was recorded throughout the year. All but one of the flights involved single birds, and where recorded, the majority involved foraging behaviour. The predicted annual mortality of 0.6692 is low. For reference the background mortality is given as 31% for adults and 68% for first year birds **Error! Bookmark not defined.**.

3.1.8 Peregrine Falcon

All flight activity by peregrine was in the non-breeding season. All flights involved single birds, and six flights involved foraging behaviour. The predicted annual mortality of 0.0392 is low. For reference the background mortality is given as 19% for adults and 40% for first year birds **Error! Bookmark not defined.**.

3.1.9 European Golden Plover

Flight activity by golden plover within the WP was actually quite low, with only three flights recorded in the first two years of surveys. There was a peak of activity in October and November 2022 (11 flights). The peak numbers recorded were 1) at least 2,000 birds on 18/01/2022 and 2) approximately 3,500 birds on 29/11/2022. These counts skewed the predicted mortality to produce a very high result (77.4 birds per year). It is considered that this is an over-estimate as this activity is not considered typical for the site.

3.1.10 Northern Lapwing

Flight activity by lapwing was predominantly within the viewshed of VP1 (on the eastern side of the WP), with most flights in the breeding season, but higher numbers were in the winter with a peak count of 250. The predicted mortality was 4.9768 per year.

3.1.11 Common Snipe

Flight activity by common snipe peaked in Year 3 breeding season. The peak count was of seven birds. The predicted annual mortality of 0.4485 is low. For reference the background mortality is given as 52% for both adult and juvenile birds **Error! Bookmark not defined.**.

3.1.12 Black-headed Gull

Flight activity by black-headed gull was randomly distributed through the site throughout the year. Generally low numbers were recorded, with peak counts of 14 in July 2021 (during the post-breeding dispersal period) and of 46 in December 2021 (non-breeding season). The predicted mortality was 1.1463 per year.

APPENDIX 01

CRM Probability Calculations

Whooper Swan

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	1.52	m	0.025	0.575	6.34	30.43	1.00	0.00125	29.91	1.00	0.00125
Wingspan	2.3	m	0.075	0.575	2.11	10.31	0.36	0.00271	9.80	0.34	0.00257
F: Flapping (0) or gliding (-	0		0.125	0.702	1.27	7.03	0.25	0.00308	6.40	0.22	0.00280
			0.175	0.860	0.91	5.80	0.20	0.00356	5.03	0.18	0.00308
Bird speed	17.3	m/sec	0.225	0.994	0.70	5.06	0.18	0.00399	4.17	0.15	0.00329
RotorDiam	172	m	0.275	0.947	0.58	4.28	0.15	0.00412	3.43	0.12	0.00330
RotationPeriod	4.95	sec	0.325	0.899	0.49	3.80	0.13	0.00432	2.99	0.10	0.00340
			0.375	0.851	0.42	3.44	0.12	0.00452	2.68	0.09	0.00352
			0.425	0.804	0.37	3.16	0.11	0.00471	2.44	0.09	0.00363
			0.475	0.756	0.33	2.94	0.10	0.00489	2.26	0.08	0.00376
Bird aspect ratioo: β	0.66		0.525	0.708	0.30	2.75	0.10	0.00506	2.12	0.07	0.00389
			0.575	0.660	0.28	2.60	0.09	0.00523	2.00	0.07	0.00403
			0.625	0.613	0.25	2.46	0.09	0.00539	1.91	0.07	0.00418
			0.675	0.565	0.23	2.34	0.08	0.00554	1.83	0.06	0.00434
			0.725	0.517	0.22	2.24	0.08	0.00568	1.77	0.06	0.00450
			0.775	0.470	0.20	2.14	0.08	0.00582	1.72	0.06	0.00467
			0.825	0.422	0.19	2.06	0.07	0.00594	1.68	0.06	0.00485
			0.875	0.374	0.18	1.98	0.07	0.00606	1.64	0.06	0.00503
			0.925	0.327	0.17	1.91	0.07	0.00618	1.61	0.06	0.00523
			0.975	0.279	0.16	1.84	0.06	0.00628	1.59	0.06	0.00543
				Overall p(collision) =			**Upwind**	**9.4%**		**Downwind**	**7.7%**
								Average	**8.6%**		

Eurasian Wigeon

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.48	m	0.025	0.575	3.77	12.56	0.74	0.00092	12.04	0.71	0.00089
Wingspan	0.8	m	0.075	0.575	1.26	4.36	0.26	0.00192	3.84	0.23	0.00170
F: Flapping (0) or gliding (-	0		0.125	0.702	0.75	3.18	0.19	0.00234	2.55	0.15	0.00188
			0.175	0.860	0.54	2.85	0.17	0.00293	2.08	0.12	0.00214
Bird speed	10.3	m/sec	0.225	0.994	0.42	2.71	0.16	0.00359	1.82	0.11	0.00240
RotorDiam	172	m	0.275	0.947	0.34	2.29	0.14	0.00371	1.44	0.08	0.00234
RotationPeriod	4.95	sec	0.325	0.899	0.29	2.00	0.12	0.00382	1.19	0.07	0.00228
			0.375	0.851	0.25	1.78	0.10	0.00392	1.01	0.06	0.00224
			0.425	0.804	0.22	1.60	0.09	0.00401	0.88	0.05	0.00220
			0.475	0.756	0.20	1.46	0.09	0.00409	0.78	0.05	0.00219
Bird aspect ratioo: β	0.60		0.525	0.708	0.18	1.34	0.08	0.00415	0.71	0.04	0.00218
			0.575	0.660	0.16	1.24	0.07	0.00420	0.65	0.04	0.00219
			0.625	0.613	0.15	1.15	0.07	0.00423	0.60	0.04	0.00221
			0.675	0.565	0.14	1.07	0.06	0.00426	0.56	0.03	0.00224
			0.725	0.517	0.13	1.00	0.06	0.00427	0.54	0.03	0.00228
			0.775	0.470	0.12	0.94	0.06	0.00427	0.51	0.03	0.00234
			0.825	0.422	0.11	0.88	0.05	0.00425	0.50	0.03	0.00241
			0.875	0.374	0.11	0.82	0.05	0.00423	0.48	0.03	0.00249
			0.925	0.327	0.10	0.77	0.05	0.00419	0.48	0.03	0.00264
			0.975	0.279	0.10	0.72	0.04	0.00413	0.49	0.03	0.00281
				Overall p(collision) =			**Upwind**	**7.3%**		**Downwind**	**4.4%**
								Average	**5.9%**		

Eurasian Teal

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.39	m	0.025	0.575	7.22	21.98	0.68	0.00085	21.46	0.66	0.00083
Wingspan	0.55	m	0.075	0.575	2.41	7.50	0.23	0.00173	6.98	0.21	0.00161
F: Flapping (0) or gliding (-	0		0.125	0.702	1.44	5.44	0.17	0.00209	4.81	0.15	0.00185
			0.175	0.860	1.03	4.75	0.15	0.00256	3.97	0.12	0.00214
Bird speed	19.7	m/sec	0.225	0.994	0.80	4.30	0.13	0.00298	3.40	0.10	0.00236
RotorDiam	172	m	0.275	0.947	0.66	3.47	0.11	0.00294	2.62	0.08	0.00222
RotationPeriod	4.95	sec	0.325	0.899	0.56	2.93	0.09	0.00293	2.12	0.07	0.00212
			0.375	0.851	0.48	2.52	0.08	0.00291	1.76	0.05	0.00203
			0.425	0.804	0.42	2.21	0.07	0.00289	1.49	0.05	0.00195
			0.475	0.756	0.38	1.96	0.06	0.00286	1.28	0.04	0.00187
Bird aspect ratioo: β	0.71		0.525	0.708	0.34	1.75	0.05	0.00283	1.11	0.03	0.00180
			0.575	0.660	0.31	1.57	0.05	0.00278	0.98	0.03	0.00173
			0.625	0.613	0.29	1.42	0.04	0.00273	0.87	0.03	0.00168
			0.675	0.565	0.27	1.29	0.04	0.00268	0.78	0.02	0.00162
			0.725	0.517	0.25	1.17	0.04	0.00262	0.71	0.02	0.00158
			0.775	0.470	0.23	1.07	0.03	0.00255	0.65	0.02	0.00154
			0.825	0.422	0.22	0.97	0.03	0.00247	0.60	0.02	0.00151
			0.875	0.374	0.21	0.89	0.03	0.00239	0.55	0.02	0.00149
			0.925	0.327	0.20	0.81	0.02	0.00230	0.52	0.02	0.00147
			0.975	0.279	0.19	0.74	0.02	0.00221	0.49	0.01	0.00146
				Overall p(collision) =			**Upwind**	**5.0%**		**Downwind**	**3.5%**
								Average	**4.3%**		

Mallard

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.58	m	0.025	0.575	8.06	27.34	0.75	0.00094	26.82	0.74	0.00092
Wingspan	0.9	m	0.075	0.575	2.69	9.28	0.26	0.00192	8.77	0.24	0.00181
F: Flapping (0) or gliding (-	0		0.125	0.702	1.61	6.60	0.18	0.00227	5.97	0.16	0.00206
			0.175	0.860	1.15	5.66	0.16	0.00273	4.89	0.13	0.00236
Bird speed	22	m/sec	0.225	0.994	0.90	5.06	0.14	0.00314	4.17	0.11	0.00258
RotorDiam	172	m	0.275	0.947	0.73	4.05	0.11	0.00307	3.20	0.09	0.00242
RotationPeriod	4.95	sec	0.325	0.899	0.62	3.37	0.09	0.00302	2.56	0.07	0.00229
			0.375	0.851	0.54	2.92	0.08	0.00302	2.15	0.06	0.00222
			0.425	0.804	0.47	2.57	0.07	0.00301	1.85	0.05	0.00216
			0.475	0.756	0.42	2.29	0.06	0.00300	1.61	0.04	0.00211
Bird aspect ratioo: β	0.64		0.525	0.708	0.38	2.06	0.06	0.00298	1.42	0.04	0.00206
			0.575	0.660	0.35	1.87	0.05	0.00296	1.27	0.04	0.00202
			0.625	0.613	0.32	1.70	0.05	0.00293	1.15	0.03	0.00198
			0.675	0.565	0.30	1.56	0.04	0.00289	1.05	0.03	0.00195
			0.725	0.517	0.28	1.43	0.04	0.00285	0.96	0.03	0.00192
			0.775	0.470	0.26	1.31	0.04	0.00280	0.89	0.02	0.00190
			0.825	0.422	0.24	1.21	0.03	0.00275	0.83	0.02	0.00189
			0.875	0.374	0.23	1.12	0.03	0.00269	0.78	0.02	0.00188
			0.925	0.327	0.22	1.03	0.03	0.00263	0.74	0.02	0.00188
			0.975	0.279	0.21	0.95	0.03	0.00256	0.70	0.02	0.00188
				Overall p(collision) =			**Upwind**	**5.4%**		**Downwind**	**4.0%**
								Average	**4.7%**		

Great Cormorant

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	1	m	0.025	0.575	6.12	25.10	0.91	0.00114	24.58	0.89	0.00112
Wingspan	1.6	m	0.075	0.575	2.04	8.54	0.31	0.00232	8.02	0.29	0.00218
F: Flapping (0) or gliding (-	0		0.125	0.702	1.22	5.94	0.22	0.00270	5.31	0.19	0.00241
			0.175	0.860	0.87	5.00	0.18	0.00318	4.23	0.15	0.00268
Bird speed	16.7	m/sec	0.225	0.994	0.68	4.43	0.16	0.00361	3.53	0.13	0.00288
RotorDiam	172	m	0.275	0.947	0.56	3.68	0.13	0.00367	2.83	0.10	0.00282
RotationPeriod	4.95	sec	0.325	0.899	0.47	3.21	0.12	0.00379	2.41	0.09	0.00284
			0.375	0.851	0.41	2.87	0.10	0.00390	2.10	0.08	0.00286
			0.425	0.804	0.36	2.60	0.09	0.00401	1.88	0.07	0.00289
			0.475	0.756	0.32	2.38	0.09	0.00410	1.70	0.06	0.00293
Bird aspect ratioo: β	0.63		0.525	0.708	0.29	2.20	0.08	0.00419	1.56	0.06	0.00298
			0.575	0.660	0.27	2.05	0.07	0.00427	1.45	0.05	0.00304
			0.625	0.613	0.24	1.92	0.07	0.00435	1.37	0.05	0.00310
			0.675	0.565	0.23	1.80	0.07	0.00441	1.29	0.05	0.00317
			0.725	0.517	0.21	1.70	0.06	0.00447	1.23	0.04	0.00325
			0.775	0.470	0.20	1.61	0.06	0.00452	1.19	0.04	0.00333
			0.825	0.422	0.19	1.52	0.06	0.00456	1.14	0.04	0.00343
			0.875	0.374	0.17	1.45	0.05	0.00460	1.11	0.04	0.00353
			0.925	0.327	0.17	1.38	0.05	0.00462	1.08	0.04	0.00364
			0.975	0.279	0.16	1.31	0.05	0.00464	1.06	0.04	0.00376
				Overall p(collision) =			**Upwind**	**7.7%**		**Downwind**	**5.9%**
								Average	**6.8%**		

Hen Harrier

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.48	m	0.025	0.575	4.40	14.15	0.71	0.00089	13.63	0.69	0.00086
Wingspan	1.1	m	0.075	0.575	1.47	4.89	0.25	0.00185	4.37	0.22	0.00166
F: Flapping (0) or gliding (-	1		0.125	0.702	0.88	3.57	0.18	0.00225	2.94	0.15	0.00186
			0.175	0.860	0.63	3.14	0.16	0.00277	2.36	0.12	0.00209
Bird speed	12	m/sec	0.225	0.994	0.49	2.87	0.14	0.00326	1.97	0.10	0.00224
RotorDiam	172	m	0.275	0.947	0.40	2.52	0.13	0.00351	1.67	0.08	0.00232
RotationPeriod	4.95	sec	0.325	0.899	0.34	2.18	0.11	0.00359	1.38	0.07	0.00226
			0.375	0.851	0.29	1.93	0.10	0.00365	1.16	0.06	0.00221
			0.425	0.804	0.26	1.73	0.09	0.00371	1.01	0.05	0.00216
			0.475	0.756	0.23	1.57	0.08	0.00376	0.89	0.04	0.00213
Bird aspect ratioo: β	0.44		0.525	0.708	0.21	1.43	0.07	0.00380	0.80	0.04	0.00211
			0.575	0.660	0.19	1.32	0.07	0.00382	0.72	0.04	0.00210
			0.625	0.613	0.18	1.22	0.06	0.00384	0.67	0.03	0.00210
			0.675	0.565	0.16	1.13	0.06	0.00384	0.62	0.03	0.00211
			0.725	0.517	0.15	1.05	0.05	0.00384	0.58	0.03	0.00213
			0.775	0.470	0.14	0.98	0.05	0.00382	0.55	0.03	0.00217
			0.825	0.422	0.13	0.91	0.05	0.00379	0.53	0.03	0.00221
			0.875	0.374	0.13	0.85	0.04	0.00375	0.51	0.03	0.00227
			0.925	0.327	0.12	0.79	0.04	0.00370	0.50	0.03	0.00233
			0.975	0.279	0.11	0.74	0.04	0.00364	0.49	0.02	0.00241
				Overall p(collision) =			**Upwind**	**6.7%**		**Downwind**	**4.2%**
								Average	**5.4%**		

Common Kestrel

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.34	m	0.025	0.575	4.65	14.07	0.67	0.00084	13.55	0.65	0.00081
Wingspan	0.8	m	0.075	0.575	1.55	4.86	0.23	0.00174	4.35	0.21	0.00156
F: Flapping (0) or gliding (-	1		0.125	0.702	0.93	3.58	0.17	0.00214	2.95	0.14	0.00176
			0.175	0.860	0.66	3.17	0.15	0.00265	2.40	0.11	0.00200
Bird speed	12.7	m/sec	0.225	0.994	0.52	2.91	0.14	0.00312	2.02	0.10	0.00216
RotorDiam	172	m	0.275	0.947	0.42	2.48	0.12	0.00325	1.63	0.08	0.00214
RotationPeriod	4.95	sec	0.325	0.899	0.36	2.12	0.10	0.00329	1.31	0.06	0.00203
			0.375	0.851	0.31	1.85	0.09	0.00331	1.09	0.05	0.00194
			0.425	0.804	0.27	1.64	0.08	0.00333	0.92	0.04	0.00186
			0.475	0.756	0.24	1.47	0.07	0.00334	0.79	0.04	0.00180
Bird aspect ratioo: β	0.43		0.525	0.708	0.22	1.33	0.06	0.00333	0.69	0.03	0.00174
			0.575	0.660	0.20	1.21	0.06	0.00332	0.61	0.03	0.00169
			0.625	0.613	0.19	1.10	0.05	0.00329	0.55	0.03	0.00165
			0.675	0.565	0.17	1.01	0.05	0.00325	0.50	0.02	0.00162
			0.725	0.517	0.16	0.93	0.04	0.00321	0.46	0.02	0.00160
			0.775	0.470	0.15	0.85	0.04	0.00315	0.43	0.02	0.00159
			0.825	0.422	0.14	0.78	0.04	0.00309	0.40	0.02	0.00159
			0.875	0.374	0.13	0.72	0.03	0.00301	0.38	0.02	0.00161
			0.925	0.327	0.13	0.66	0.03	0.00292	0.37	0.02	0.00163
			0.975	0.279	0.12	0.61	0.03	0.00283	0.36	0.02	0.00166
				Overall p(collision) =			**Upwind**	**5.8%**		**Downwind**	**3.4%**
								Average	**4.6%**		

Peregrine Falcon

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.45	m	0.025	0.575	5.13	16.47	0.71	0.00089	15.95	0.69	0.00086
Wingspan	1.1	m	0.075	0.575	1.71	5.66	0.25	0.00184	5.14	0.22	0.00167
F: Flapping (0) or gliding (-	1		0.125	0.702	1.03	4.11	0.18	0.00222	3.48	0.15	0.00188
			0.175	0.860	0.73	3.60	0.16	0.00272	2.82	0.12	0.00214
Bird speed	14	m/sec	0.225	0.994	0.57	3.27	0.14	0.00318	2.38	0.10	0.00231
RotorDiam	172	m	0.275	0.947	0.47	2.64	0.11	0.00314	1.79	0.08	0.00213
RotationPeriod	4.95	sec	0.325	0.899	0.39	2.37	0.10	0.00334	1.56	0.07	0.00220
			0.375	0.851	0.34	2.08	0.09	0.00337	1.31	0.06	0.00213
			0.425	0.804	0.30	1.85	0.08	0.00340	1.13	0.05	0.00207
			0.475	0.756	0.27	1.66	0.07	0.00342	0.98	0.04	0.00202
Bird aspect ratioo: β	0.41		0.525	0.708	0.24	1.51	0.07	0.00343	0.87	0.04	0.00198
			0.575	0.660	0.22	1.38	0.06	0.00343	0.78	0.03	0.00195
			0.625	0.613	0.21	1.26	0.05	0.00342	0.71	0.03	0.00193
			0.675	0.565	0.19	1.16	0.05	0.00340	0.66	0.03	0.00191
			0.725	0.517	0.18	1.07	0.05	0.00337	0.61	0.03	0.00191
			0.775	0.470	0.17	0.99	0.04	0.00333	0.57	0.02	0.00192
			0.825	0.422	0.16	0.92	0.04	0.00329	0.54	0.02	0.00193
			0.875	0.374	0.15	0.85	0.04	0.00323	0.52	0.02	0.00196
			0.925	0.327	0.14	0.79	0.03	0.00316	0.50	0.02	0.00199
			0.975	0.279	0.13	0.73	0.03	0.00309	0.48	0.02	0.00203
				Overall p(collision) =			**Upwind**	**6.1%**		**Downwind**	**3.9%**
								Average	**5.0%**		

European Golden Plover

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.28	m	0.025	0.575	6.60	21.09	0.71	0.00089	20.58	0.69	0.00087
Wingspan	0.7	m	0.075	0.575	2.20	7.20	0.24	0.00182	6.69	0.23	0.00169
F: Flapping (0) or gliding (-	0		0.125	0.702	1.32	5.20	0.17	0.00219	4.57	0.15	0.00192
			0.175	0.860	0.94	4.51	0.15	0.00266	3.74	0.13	0.00220
Bird speed	18	m/sec	0.225	0.994	0.73	4.08	0.14	0.00309	3.18	0.11	0.00241
RotorDiam	172	m	0.275	0.947	0.60	3.27	0.11	0.00303	2.42	0.08	0.00224
RotationPeriod	4.95	sec	0.325	0.899	0.51	2.71	0.09	0.00297	1.90	0.06	0.00208
			0.375	0.851	0.44	2.29	0.08	0.00289	1.53	0.05	0.00193
			0.425	0.804	0.39	1.97	0.07	0.00283	1.25	0.04	0.00179
			0.475	0.756	0.35	1.74	0.06	0.00279	1.06	0.04	0.00170
Bird aspect ratioo: β	0.40		0.525	0.708	0.31	1.55	0.05	0.00274	0.91	0.03	0.00161
			0.575	0.660	0.29	1.39	0.05	0.00268	0.79	0.03	0.00154
			0.625	0.613	0.26	1.25	0.04	0.00262	0.70	0.02	0.00146
			0.675	0.565	0.24	1.12	0.04	0.00256	0.62	0.02	0.00140
			0.725	0.517	0.23	1.02	0.03	0.00248	0.55	0.02	0.00134
			0.775	0.470	0.21	0.92	0.03	0.00240	0.50	0.02	0.00129
			0.825	0.422	0.20	0.83	0.03	0.00231	0.45	0.02	0.00125
			0.875	0.374	0.19	0.75	0.03	0.00221	0.41	0.01	0.00122
			0.925	0.327	0.18	0.68	0.02	0.00210	0.38	0.01	0.00119
			0.975	0.279	0.17	0.61	0.02	0.00199	0.36	0.01	0.00117
				Overall p(collision) =			**Upwind**	**4.9%**		**Downwind**	**3.2%**
								Average	**4.1%**		

Northern Lapwing

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.2	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.3	m	0.025	0.575	4.97	16.36	0.84	0.00105	15.86	0.81	0.00102
Wingspan	0.84	m	0.075	0.575	1.66	5.62	0.29	0.00216	5.12	0.26	0.00197
F: Flapping (0) or gliding (+1)	0		0.125	0.702	0.99	4.06	0.21	0.00260	3.44	0.18	0.00220
			0.175	0.860	0.71	3.52	0.18	0.00316	2.77	0.14	0.00248
Bird speed	12.3	m/sec	0.225	0.994	0.55	3.19	0.16	0.00368	2.32	0.12	0.00268
RotorDiam	150	m	0.275	0.947	0.45	2.58	0.13	0.00364	1.75	0.09	0.00247
RotationPeriod	4.76	sec	0.325	0.899	0.38	2.15	0.11	0.00358	1.36	0.07	0.00227
			0.375	0.851	0.33	1.85	0.09	0.00356	1.10	0.06	0.00212
			0.425	0.804	0.29	1.63	0.08	0.00356	0.93	0.05	0.00202
			0.475	0.756	0.26	1.46	0.07	0.00355	0.79	0.04	0.00193
Bird aspect ratioo: β	0.36		0.525	0.708	0.24	1.31	0.07	0.00353	0.69	0.04	0.00185
			0.575	0.660	0.22	1.19	0.06	0.00349	0.61	0.03	0.00179
			0.625	0.613	0.20	1.08	0.06	0.00345	0.54	0.03	0.00173
			0.675	0.565	0.18	0.98	0.05	0.00340	0.49	0.02	0.00168
			0.725	0.517	0.17	0.90	0.05	0.00333	0.44	0.02	0.00165
			0.775	0.470	0.16	0.82	0.04	0.00326	0.41	0.02	0.00162
			0.825	0.422	0.15	0.75	0.04	0.00317	0.38	0.02	0.00161
			0.875	0.374	0.14	0.69	0.04	0.00308	0.36	0.02	0.00160
			0.925	0.327	0.13	0.63	0.03	0.00297	0.34	0.02	0.00161
			0.975	0.279	0.13	0.57	0.03	0.00285	0.33	0.02	0.00163
				Overall p(collision) =			**Upwind**	**6.3%**		**Downwind**	**3.8%**
								Average	**5.0%**		

Common Snipe

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.26	m	0.025	0.575	5.86	17.34	0.66	0.00082	16.83	0.64	0.00080
Wingspan	0.455	m	0.075	0.575	1.95	5.95	0.23	0.00169	5.44	0.21	0.00154
F: Flapping (0) or gliding (-	0		0.125	0.702	1.17	4.37	0.17	0.00207	3.74	0.14	0.00177
			0.175	0.860	0.84	3.85	0.15	0.00255	3.08	0.12	0.00204
Bird speed	16	m/sec	0.225	0.994	0.65	3.51	0.13	0.00299	2.62	0.10	0.00223
RotorDiam	172	m	0.275	0.947	0.53	2.84	0.11	0.00296	1.99	0.08	0.00208
RotationPeriod	4.95	sec	0.325	0.899	0.45	2.40	0.09	0.00295	1.59	0.06	0.00196
			0.375	0.851	0.39	2.07	0.08	0.00293	1.30	0.05	0.00185
			0.425	0.804	0.34	1.81	0.07	0.00291	1.08	0.04	0.00174
			0.475	0.756	0.31	1.60	0.06	0.00287	0.92	0.03	0.00165
Bird aspect ratioo: β	0.57		0.525	0.708	0.28	1.42	0.05	0.00283	0.79	0.03	0.00157
			0.575	0.660	0.25	1.28	0.05	0.00278	0.68	0.03	0.00149
			0.625	0.613	0.23	1.15	0.04	0.00272	0.60	0.02	0.00142
			0.675	0.565	0.22	1.04	0.04	0.00266	0.53	0.02	0.00136
			0.725	0.517	0.20	0.94	0.04	0.00258	0.47	0.02	0.00130
			0.775	0.470	0.19	0.85	0.03	0.00250	0.43	0.02	0.00126
			0.825	0.422	0.18	0.77	0.03	0.00241	0.39	0.01	0.00122
			0.875	0.374	0.17	0.70	0.03	0.00231	0.36	0.01	0.00119
			0.925	0.327	0.16	0.63	0.02	0.00220	0.33	0.01	0.00117
			0.975	0.279	0.15	0.56	0.02	0.00209	0.31	0.01	0.00116
				Overall p(collision) =			**Upwind**	**5.0%**		**Downwind**	**3.1%**
								Average	**4.0%**		

Black-headed Gull

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.36	m	0.025	0.575	4.10	14.66	0.79	0.00099	14.14	0.77	0.00096
Wingspan	1.05	m	0.075	0.575	1.37	5.06	0.27	0.00205	4.54	0.25	0.00184
F: Flapping (0) or gliding (-	0		0.125	0.702	0.82	3.64	0.20	0.00246	3.01	0.16	0.00204
			0.175	0.860	0.59	3.16	0.17	0.00299	2.39	0.13	0.00226
Bird speed	11.2	m/sec	0.225	0.994	0.46	2.86	0.16	0.00349	1.97	0.11	0.00240
RotorDiam	172	m	0.275	0.947	0.37	2.33	0.13	0.00346	1.48	0.08	0.00220
RotationPeriod	4.95	sec	0.325	0.899	0.32	1.98	0.11	0.00348	1.17	0.06	0.00206
			0.375	0.851	0.27	1.74	0.09	0.00353	0.97	0.05	0.00198
			0.425	0.804	0.24	1.55	0.08	0.00357	0.83	0.04	0.00191
			0.475	0.756	0.22	1.40	0.08	0.00359	0.72	0.04	0.00185
Bird aspect ratioo: β	0.34		0.525	0.708	0.20	1.27	0.07	0.00361	0.63	0.03	0.00180
			0.575	0.660	0.18	1.16	0.06	0.00361	0.57	0.03	0.00176
			0.625	0.613	0.16	1.07	0.06	0.00360	0.51	0.03	0.00174
			0.675	0.565	0.15	0.98	0.05	0.00358	0.47	0.03	0.00173
			0.725	0.517	0.14	0.91	0.05	0.00355	0.44	0.02	0.00173
			0.775	0.470	0.13	0.84	0.05	0.00351	0.41	0.02	0.00174
			0.825	0.422	0.12	0.77	0.04	0.00346	0.39	0.02	0.00176
			0.875	0.374	0.12	0.72	0.04	0.00339	0.38	0.02	0.00180
			0.925	0.327	0.11	0.66	0.04	0.00331	0.37	0.02	0.00184
			0.975	0.279	0.11	0.61	0.03	0.00322	0.36	0.02	0.00190
				Overall p(collision) =			**Upwind**	**6.4%**		**Downwind**	**3.7%**
								Average	**5.1%**		

APPENDIX 02

CRM Calculations

Whooper Swan Non-Breeding Season

	Viewsheds								
	1	2							
STAGE 1: Estimation of rotor transits									
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	2250	1,470							
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	108	108							
Windfarm area (ha) visible within viewshed (*v*)	362.75	263.79							
Observation effort (HaHr)	39177.26	28489.65							
T_wV rate=$T_wV/HaHr$	1.60E-05	1.43E-05							
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total effort made at the VP	0.579	0.421							
Weighted T_wV rate (T_wV rate * weight)	9.24E-06	6.03E-06							
Total weighted occupancy rate	0.000015					birds seconds per ha/hour			
Mean activity hr^-1 in wind farm at risk height	0.823%								
Mean activity hr^-1 in wind farm at rotor height (z)	0.786%								

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: annual (a)[2]	2,384	hours
Tw=z*a	18.75	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$	926,927,884	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	1.52	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$	1,081,831.81	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	78.7831	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	17.3	m/sec
$t_r=(d+L)/s$	0.34	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	234	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.086	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 97% of the time N*p(collision)*0.97	19.430	collisions

SLR

Step 3.2: Adjusted using a range of avoidance rates:							
99.50%	**0.0971**			**approx one collision every**		**10.29**	**years**
[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.							
[2] The total number of daytime hours during the period +25% to account for nocturnal activity.							
[4]Assumes bird length=1.52m, wingspan 2.35m, flight speed= 17.5m/sec							

Eurasian Wigeon Non-Breeding Season

	Viewsheds								
	1	**2**							
STAGE 1: Estimation of rotor transits									
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	195	0							
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	36	36							
Windfarm area (ha) visible within viewshed (*v*)	362.75	263.79							
Observation effort (HaHr)	13059.09	9496.55							
T_wV rate=$T_wV/HaHr$	4.15E-06	0.00E+00							
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total effort made at the VP	0.579	0.421							
Weighted T_wV rate (T_wV rate * weight)	2.40E-06	0.00E+00							
Total weighted occupancy rate	0.000002				birds seconds per ha/hour				
Mean activity hr^-1 in wind farm at risk height	0.129%								
Mean activity hr^-1 in wind farm at rotor height (z)	0.124%								

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: breeding season (a)[2]	2,384	hours
Tw=z*a	2.95	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w = A*h$	926,927,884	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.48	m
Rotor-swept volume: $V_r = N*\pi*r^2*(d+L)$	888,514.78	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r = T_w*(V_r/Vw)$	10.1754	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	10.3	m/sec
$t_r = (d+L)/s$	0.46	seconds
Step 1.10: Number of rotor transits (N)		
$N = T_r/t$	22	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.059	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 97% of the time N*p(collision)*0.97	1.249	collisions

Step 3.2: Adjusted using a range of avoidance rates:									
98.00%	**0.0250**					**approx one collision every**		**40.02**	**years**
[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.									
[2] The total number of daylight hours during the period + 25% nocturnal hours during the period									
[4]Assumes bird length=0.48m, wingspan 0.8m, flight speed= 10.3m/sec									

Eurasian Teal

	Viewsheds								
	1	2							
STAGE 1: Estimation of rotor transits									
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	8820	0							
Step 1.2: Unweighted occupancy rate each viewshed (T_wVrate)									
Hours of survey effort (*e*)	36	36							
Windfarm area (ha) visible within viewshed (*v*)	362.75	263.79							
Observation effort (HaHr)	13059.09	9496.55							
T_wV rate=$T_wV/HaHr$	1.88E-04	0.00E+00							
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total effort made at the VP	0.579	0.421							
Weighted T_wV rate (T_wV rate * weight)	1.09E-04	0.00E+00							
Total weighted occupancy rate	0.000109				birds seconds per ha/hour				
Mean activity hr^-1 in wind farm at risk height	5.854%								
Mean activity hr^-1 in wind farm at rotor height (z)	5.594%								

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: breeding season (a)[2]	2,384	hours
Tw=z*a	133.37	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w = A*h$	926,927,884	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.39	m
Rotor-swept volume: $V_r = N*\pi*r^2*(d+L)$	871,785.43	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r = T_w*(V_r/Vw)$	451.5749	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	19.7	m/sec
$t_r = (d+L)/s$	0.24	seconds
Step 1.10: Number of rotor transits (N)		
$N = T_r/t$	1,897	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.043	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 97% of the time N*p(collision)*0.97	78.308	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
98.00%	**1.5662**	**approx one collision every**	**0.64**	**years**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daylight hours during the period + 25% nocturnal hours during the period

[4]Assumes bird length=0.39m, wingspan 0.55m, flight speed= 19.7m/sec

Mallard Non-Breeding Season

	Viewsheds								
	1	**2**							
STAGE 1: Estimation of rotor transits									
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	510	360							
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	72	72							
Windfarm area (ha) visible within viewshed (*v*)	362.75	263.79							
Observation effort (HaHr)	26118.17	18993.10							
T_wV rate=$T_wV/HaHr$	5.42E-06	5.27E-06							
Step 1.3: Weighted occupancy rate (*weighted T_wV rate*)[1]									
Weight: proportion of total effort made at the VP	0.579	0.421							
Weighted T_wV rate (T_wV rate * weight)	3.14E-06	2.22E-06							
Total weighted occupancy rate	0.000005					birds seconds per ha/hour			
Mean activity hr^-1 in wind farm at risk height	0.289%								
Mean activity hr^-1 in wind farm at rotor height (z)	0.276%								

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: annual (a)[2]	2,384	hours
Tw=z*a	6.58	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w = A*h$	926,927,884	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.58	m
Rotor-swept volume: $V_r = N*\pi*r^2*(d+L)$	907,102.96	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r = T_w*(V_r/Vw)$	23.1738	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	22	m/sec
$t_r = (d+L)/s$	0.22	seconds
Step 1.10: Number of rotor transits (N)		
$N = T_r/t$	104	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.047	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 97% of the time N*p(collision)*0.97	4.786	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
98.00%	**0.0957**	**approx one collision every**	**10.45**	**years**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daylight hours + 25% nocturnal hours during the period

[4]Assumes bird length=0.58m, wingspan 0.9m, flight speed= 22.0m/sec

Great Cormorant

	Viewsheds								
	1	2							
STAGE 1: Estimation of rotor transits									
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	210	345							
Step 1.2: Unweighted occupancy rate each viewshed (T_wVrate)									
Hours of survey effort (*e*)	36	36							
Windfarm area (ha) visible within viewshed (*v*)	362.75	263.79							
Observation effort (HaHr)	13059.09	9496.55							
T_wV rate=$T_wV/HaHr$	4.47E-06	1.01E-05							
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total effort made at the VP	0.579	0.421							
Weighted T_wV rate (T_wV rate * weight)	2.59E-06	4.25E-06							
Total weighted occupancy rate	0.000007				birds seconds per ha/hour				
Mean activity hr^-1 in wind farm at risk height	0.368%								
Mean activity hr^-1 in wind farm at rotor height (z)	0.352%								

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: non-breeding season (a)[2]	1,723	hours
Tw=z*a	6.07	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$	926,927,884	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	1	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$	985,173.30	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	23.21	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	16.7	m/sec
t=(d+L)/s	0.32	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	73	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.068	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	4.820	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
98.00%	**0.0964**	**approx one collision every**	**10.37**	**years**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daylight hours during the period

[4]Assumes bird length=1.0m, wingspan 1.6m, flight speed= 16.7m/sec

Hen Harrier Non-Breeding Season

	Viewsheds								
	1	2							
STAGE 1: Estimation of rotor transits									
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	195	360							
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	108	108							
Windfarm area (ha) visible within viewshed (*v*)	362.75	263.79							
Observation effort (HaHr)	39177.26	28489.65							
T_wV rate=$T_wV/HaHr$	1.38E-06	3.51E-06							
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total effort made at the VP	0.579	0.421							
Weighted T_wV rate (T_wV rate * weight)	8.00E-07	1.48E-06							
Total weighted occupancy rate	0.000002				birds seconds per ha/hour				
Mean activity hr^-1 in wind farm at risk height	0.123%								
Mean activity hr^-1 in wind farm at rotor height (z)	0.117%								

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: breeding season (a)[2]	1,723	hours
Tw=z*a	2.02	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$	926,927,884	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.48	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$	888,514.78	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	6.9766	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	12	m/sec
$t_r=(d+L)/s$	0.40	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	18	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.054	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 97% of the time N*p(collision)*0.97	0.924	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
99.00%	**0.0092**	**approx one collision every**	**108.17**	**years**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daylight hours during the period

[4]Assumes bird length=0.48m, wingspan 1.1m, flight speed= 12.0m/sec

	Viewsheds								
	1	2							
STAGE 1: Estimation of rotor transits									
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	3390	1,170							
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	144	144							
Windfarm area (ha) visible within viewshed (*v*)	362.75	263.79							
Observation effort (HaHr)	52236.34	37986.19							
T_wV rate=$T_wV/HaHr$	1.80E-05	8.56E-06							
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total effort made at the VP	0.579	0.421							
Weighted T_wV rate (T_wV rate * weight)	1.04E-05	3.60E-06							
Total weighted occupancy rate	0.000014				birds seconds per ha/hour				
Mean activity hr^-1 in wind farm at risk height	0.757%								
Mean activity hr^-1 in wind farm at rotor height (z)	0.723%								

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: annual (a)[2]	4,484	hours
Tw=z*a	32.42	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w = A*h$	926,927,884	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.34	m
Rotor-swept volume: $V_r = N*\pi*r^2*(d+L)$	862,491.34	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r = T_w*(V_r/Vw)$	108.5944	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	12.7	m/sec
$t_r = (d+L)/s$	0.37	seconds
Step 1.10: Number of rotor transits (N)		
$N = T_r/t$	297	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.046	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 97% of the time N*p(collision)*0.97	13.384	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
95.00%	**0.6692**	**approx one collision every**	**1.49**	**years**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime hours during the period.

[4]Assumes bird length=0.34m, wingspan 0.8m, flight speed= 12.7m/sec

Peregrine Falcon Non-Breeding Season

	Viewsheds								
	1	**2**							
STAGE 1: Estimation of rotor transits									
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	420	315							
Step 1.2: Unweighted occupancy rate each viewshed (T_wVrate)									
Hours of survey effort (*e*)	72	72							
Windfarm area (ha) visible within viewshed (*v*)	362.75	263.79							
Observation effort (HaHr)	26118.17	18993.10							
T_wV rate=$T_wV/HaHr$	4.47E-06	4.61E-06							
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total effort made at the VP	0.579	0.421							
Weighted T_wV rate (T_wV rate * weight)	2.59E-06	1.94E-06							
Total weighted occupancy rate	0.000005					birds seconds per ha/hour			
Mean activity hr^-1 in wind farm at risk height	0.244%								
Mean activity hr^-1 in wind farm at rotor height (z)	0.233%								

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: breeding season (a)[2]	1,723	hours
Tw=z*a	4.02	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$	926,927,884	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.45	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$	882,938.33	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	13.7720	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	14	m/sec
$t_r=(d+L)/s$	0.34	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	41	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.050	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 97% of the time N*p(collision)*0.97	1.961	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
98.00%	**0.0392**	**approx one collision every**	**25.50**	**years**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daylight hours during the period

[4]Assumes bird length=0.45m, wingspan 1.1m, flight speed= 14.0m/sec

European Golden Plover Non-Breeding

	Viewsheds								
	1	2							
STAGE 1: Estimation of rotor transits									
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	1545090	34980							
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	115	114							
Windfarm area (ha) visible within viewshed (*v*)	362.75	263.79							
Observation effort (HaHr)	41535.15	30072.40							
T_wV rate=$T_wV/HaHr$	1.03E-02	3.23E-04							
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total effort made at the VP	0.580	0.420							
Weighted T_wV rate (T_wV rate * weight)	5.99E-03	1.36E-04							
Total weighted occupancy rate	0.006129				birds seconds per ha/hour				
Mean activity hr^-1 in wind farm at risk height	330.318%								
Mean activity hr^-1 in wind farm at rotor height (z)	315.637%								

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: breeding season (a)[2]	2,384	hours
Tw=z*a	7,526.06	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$	926,927,884	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.28	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$	851,338.43	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	24884.3532	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	18	m/sec
$t_r=(d+L)/s$	0.25	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	97,799	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.041	
STAGE 3: Predicted mortality (birds per year)		

Step 3.1: With no avoidance, turbines operational 97% of the time N*p(collision)*0.97	3867.873	collisions		
Step 3.2: Adjusted using a range of avoidance rates:				
98.00%	**77.3575**	**approx one collision every**	**0.01**	**years**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daylight hours during the period + 25% nocturnal hours during the period.

[4]Assumes bird length=0.28m, wingspan 0.72m, flight speed= 17.5m/sec

Northern Lapwing Annual

	Viewsheds								
	1	2							
STAGE 1: Estimation of rotor transits									
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	78810	23,835							
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	207	207							
Windfarm area (ha) visible within viewshed (*v*)	362.75	263.79							
Observation effort (HaHr)	75089.74	54605.15							
T_wV rate=$T_wV/HaHr$	2.92E-04	1.21E-04							
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total effort made at the VP	0.579	0.421							
Weighted T_wV rate (T_wV rate * weight)	1.69E-04	5.10E-05							
Total weighted occupancy rate	0.000220				birds seconds per ha/hour				
Mean activity hr^-1 in wind farm at risk height	11.848%								
Mean activity hr^-1 in wind farm at rotor height (z)	11.321%								

SLR

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: annual (a)[2]	5,553	hours
Tw=z*a	628.67	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$	926,927,884	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.3	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$	855,056.07	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	2087.7118	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	12.3	m/sec
$t_r=(d+L)/s$	0.37	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	5,582	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.046	
STAGE 3: Predicted mortality (birds per year)		

Step 3.1: With no avoidance, turbines operational 97% of the time N*p(collision)*0.97	248.842	collisions			
Step 3.2: Adjusted using a range of avoidance rates:					
98.00%	**4.9768**	**approx one collision every**	**0.20**	**years**	

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime hours during the period.

[4]Assumes bird length=0.3m, wingspan 0.84m, flight speed= 12.3m/sec

	Viewsheds								
	1	2							
STAGE 1: Estimation of rotor transits									
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	4095	135							
Step 1.2: Unweighted occupancy rate each viewshed (T_wVrate)									
Hours of survey effort (*e*)	108	108							
Windfarm area (ha) visible within viewshed (*v*)	362.75	263.79							
Observation effort (HaHr)	39177.26	28489.65							
T_wV rate=$T_wV/HaHr$	2.90E-05	1.32E-06							
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total effort made at the VP	0.579	0.421							
Weighted T_wV rate (T_wV rate * weight)	1.68E-05	5.54E-07							
Total weighted occupancy rate	0.000017					birds seconds per ha/hour			
Mean activity hr^-1 in wind farm at risk height	0.936%								
Mean activity hr^-1 in wind farm at rotor height (z)	0.894%								

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: annual (a)[2]	5,553	hours
Tw=z*a	49.66	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$	926,927,884	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.26	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$	847,620.80	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	163.4657	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	16	m/sec
$t_r=(d+L)/s$	0.29	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	574	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.040	
STAGE 3: Predicted mortality (birds per year)		
#REF!	22.426	collisions
Step 3.2: Adjusted using a range of avoidance rates:		

98.00%	**0.4485**	**approx one collision every**	**2.23**	**years**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime hours during the period + 25% nocturnal hours during the period

[4]Assumes bird length=0.26m, wingspan 0.455m, flight speed= 16.0m/sec

Black-headed Gull Annual

	Viewsheds								
	1	**2**							
STAGE 1: Estimation of rotor transits									
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	10860	9,345							
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	144	144							
Windfarm area (ha) visible within viewshed (*v*)	362.75	263.79							
Observation effort (HaHr)	52236.34	37986.19							
T_wV rate=$T_wV/HaHr$	5.78E-05	6.83E-05							
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total effort made at the VP	0.579	0.421							
Weighted T_wV rate (T_wV rate * weight)	3.34E-05	2.88E-05							
Total weighted occupancy rate	0.000062					birds seconds per ha/hour			
Mean activity hr^-1 in wind farm at risk height	3.352%								
Mean activity hr^-1 in wind farm at rotor height (z)	3.203%								

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: annual (a)[2]	4,484	hours
Tw=z*a	143.64	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$	926,927,884	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.36	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$	866,208.97	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	483.2471	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	11.2	m/sec
$t_r=(d+L)/s$	0.42	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	1,161	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[4]	0.051	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 97% of the time N*p(collision)*0.97	57.313	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
98.00%	**1.1463**	**approx one collision every**	**0.87**	**years**

[1] The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.

[2] The total number of daytime hours during the period.

[4]Assumes bird length=0.36m, wingspan 1.05m, flight speed= 11.2m/sec

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