TA4.3: Avian Collision Risk Assessment

Ben Sca Redesign Wind Farm

Ben Sca Wind Farm Limited

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Making Sustainability Happen

Basis of Report

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Acronyms and Abbreviations

BTO	British Trust for Ornithology
CRM	Collision Risk Modelling
CRZ	Collision Risk Zone
EIAR	Environmental Impact Assessment Report
GIS	Geographic Information System
PCH	Potential Collision Height
SNH	Scottish Natural Heritage
SPA	Special Protection Area
VP	Vantage Point
WP	Wind Farm Polygon

1.0 Executive Summary

Collision Risk Modelling (CRM) was undertaken for three bird species (white-tailed eagle *Haliaeetus albicilla,* golden eagle *Aquilia chrysaetos*, and golden plover *Pluvialis apricaria*) to inform an update of the ornithology assessment of the proposed Ben Sca Wind Farm Redesign. Modelling was based on the use of turbines with a rotor diameter of 138m, tip height of 149.9m and hub height of 80.9m.

Where there was sufficient bird flight activity within the Collision Risk Zone at Potential Collision Height, collision risk modelling was used to predict the number of individuals per target species that might collide with the wind turbine rotors.

The standard Band CRM (Band *et. al.* 2007) 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.

The results of the CRM were as follows:

- White-tailed eagle – annual rate of 3.47 (0.29 years per collision);
- Golden eagle – annual rate of 0.10 (9.9 years per collision); and
- Golden plover – annual rate of 0.39 (2.57 years per collision).

The conclusions from the CRM are used in **Chapter 4: Ornithology** of the EIA Report for the Proposed Development.

2.0 Introduction

This report presents the results of Collision Risk Modelling (CRM) undertaken for three bird species to inform ornithological assessment studies at the site of the Ben Sca Redesign Wind Farm. From here on referred to as the 'Proposed Development'.

Modelling was based on the use of turbines with a rotor diameter of 138m, tip height of 149.9m and hub height of 80.9m.

Where there was sufficient bird flight activity within the Collision Risk Zone (CRZ) (i.e. within the Wind Farm Polygon (WP)) at Potential Collision Height (PCH), collision risk modelling (CRM) was used to predict the number of individuals per target species that might collide with the wind turbine rotors.

The CRM was undertaken in accordance with current NatureScot (formerly Scottish Natural Heritage (SNH)) guidance, which is recognised as standard best practice guidance through the United Kingdom 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 3. The monitoring results are presented in Section 3.4 and copies of the modelling calculations for each species modelled are included in **Annex 4.3A**.

2.1 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 NatureScot Guidance (SNH 2017), as described in **Chapter 4**.

3.0 Methods

The standard Band CRM (Band *et. al.* 2007) 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.

3.1 Prediction of Rotor Transits from Vantage Point Survey Data

3.1.1 Survey Data 2023

The number of birds that fly through the rotor swept area was estimated using flight data gathered during baseline surveys carried out during January to December 2023 inclusive.

The surveys gathered data from three vantage points (VPs):

VP1: 132120, 847660

VP2: 133930, 848270

VP3: 130883, 850414

The total number of hours of survey undertaken were six hours per month per VP; i.e., 72 hours per VP throughout the year.

3.1.2 Viewshed Data

Viewshed data, i.e., the area visible from each VP within the wind farm polygon (WP)[1], are summarised in **Table 1 and Figure 4.1**. The combined viewshed area (minus overlap) from all three VPs (3,364,933m²) represents 82.8% of the survey WP (4,063,879 m²).

Table 1: Ben Sca Viewshed Data

VP/ Viewshed Number	Area of visibility (m²)*
VP 1 viewshed	2,276,324
VP 2 viewshed	770,861
VP 3 viewshed	1,279,458
All VPs viewshed combined (minus overlap)	3,364,933
	* area calculated in GIS using offset of 20 m above ground level

3.1.3 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 spatial errors in flight recording

[1] The survey wind farm polygon (WP) includes the area within 500m of the outermost turbine blades.

accuracy. It is known that bird detection rates vary between species. To ensure the CRM used robust measures of flight activity data, a 2km distance truncation was used in the viewshed from each VP, i.e., only flights within 2km 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.

3.1.4 Correcting Survey PCH to Actual PCH

The baseline surveys utilised the following four height bands:

1 = 0-20m

2 = 20-150m

3 = 150-200m

4 = >200m

The PCH for the turbines is 12-150m[2] As such, all flights within a survey PCH of 0-150 m were included for CRM. To account for a rotor height of 138m, the model adjusted the occupancy by rotor diameter/ survey risk height (i.e., 138/150 (92.0%)).

3.1.5 Adjusting Occupancy Rates

Considering the total flying time for long flights which moved inside and outside each WP, including the time spent outside the at-risk areas was considered over-precautionary and likely to produce substantial over-estimates of collision risk. Further adjustments were made by calculating the proportion of each clipped flightline and factoring this into the occupancy calculations (e.g., a flightline with a proportion of 0.5 outside of the WP used 0.5 of the flying time within the model). By necessity, this assumes a constant flying speed.

3.1.6 Seasonal Definitions

CRMs were constructed using data from the periods used in the survey design (see Section 3.1.1). All target species encountered are present year-round and therefore annual rates are produced rather than separate rates for the breeding and non-breeding seasons.

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[3].

For golden plover, 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 this species (as per Band *et al.*, 2007).

3.1.7 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

[2] Numbers are rounded up from 11.9m to 12m and 149.9m to 150m for the purposes of this report.

[3] https://www.timeanddate.com [Accessed in September 2023].

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**); and
- wind farm parameters (**Table 3**).

The NatureScot CRM spreadsheet[4] 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.

3.1.8 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)[5], Provan & Whitfield (2007[6]), Bruderer & Boldt (2001[7]) and Alerstram *et al.* (2007[8]). The avoidance rates for these species are taken from NS (2018[9]) (**Table 2**).

Table 2: Bird biometrics and avoidance rates used in CRM

Species name	Bird length (m)	Wingspan (m)	Flight speed (m/s)	Avoidance rate (%)
White-tailed eagle	0.8	2.2	13.0	95 & 98
Golden eagle	0.82	2.1	15.0	99
Golden plover	0.28	0.72	17.5	98

For white-tailed eagle, the specific avoidance rate as currently recommended by NatureScot, is 95%. However, there is a body of evidence based on empirical data suggesting that an avoidance rate of 98% is more realistic for this species. A detailed review of the white-tailed eagle collision mortality and a discourse on the validity of the 95% avoidance rate being used as a standard for white-tailed eagle in the NatureScot collision risk model was

4 https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision [Accessed in September 2022].

5 https://www.bto.org/understanding-birds/birdfacts [Accessed in September 2022].

6 Provan, S. and Whitfield, D.P. (2007) Avian flight speeds and biometrics for use in collision risk modelling. Report to Scottish Natural Heritage.

7 Bruderer, B. and Bolt, A. (2001) Flight characteristics of birds: 1. Radar measurements of speeds, *Ibis*, **143**. 178 – 204.

8 Alerstam T, Rosén M, Bäckman J, Ericson PG, Hellgren O. (2007). Flight speeds among bird species: allometric and phylogenetic effects. PLoS Biol.

9 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].

undertaken for the adjacent Balmeanach Wind Farm EIA Report (Technical Appendix 9.4: Avoidance Rate Review (Confidential) (August 2023)). Therefore, results for white-tailed eagle are presented for both 95% and 98% avoidance rates.

3.1.9 Wind Farm and Turbine Parameters

The wind turbine parameters used in the CRM are detailed in Error! Reference source not found. and are based on the information provided by the Applicant for the purposes of assessment.

Table 3: Wind farm & turbine parameters

Parameter	Value
Size of survey wind farm polygon (WP)	406.4ha
Number of turbines	9
Rotor radius/ diameter	69.0m/ 138.0m
Hub height	80.9m
Max. chord	4.3m
Pitch	6°
Rotation period	4.29s (max 13.99rpm)
Turbine operation time	90%

3.2 Ben Sca Occupancy Data 2023

Using the 2023 survey data (**Technical Appendix 4.1**) the occupancy of species with sufficient data to be taken forward to CRM[10] are presented below. The results are presented in the following tables which detail the target species flights within 500m, the target species occupancy data within each height band, and the total at-risk occupancy data used in the CRM.

In order to compare the difference between the consented development and the Proposed Development, the CRM was run twice against the 2023 survey data, once using the consented development layout and turbine parameters and once using the Proposed Development layout and turbine parameters. Note the following tables present the data for the Proposed Development layout only, as the data for the consented development are broadly similar.

Table 4: Details of White-tailed Eagle Flights Recorded within 500m Buffer of Turbines (2023 Data)

Date	VP No.	No. of birds	Total flight length (m)	Flight length (m) within 500m	Proportion within 500m
26/01/2023	2	1	849.9	338.4	0.40
26/01/2023	2	1	847.1	654.7	0.77

[10] Sufficient flight activity was defined as a minimum total of five flights or minimum ten individuals of each primary target species recorded in the WP during each season of analysis. Numbers below these thresholds are likely to result in negligible predicted mortality.

Date	VP No.	No. of birds	Total flight length (m)	Flight length (m) within 500m	Proportion within 500m
26/01/2023	2	1	173.3	173.3	1.00
26/01/2023	2	1	288.7	288.7	1.00
09/02/2023	1	2	2808.8	1986.4	0.71
09/02/2023	1	1	5104.4	5049.6	0.99
25/02/2023	2	1	2014.7	779.0	0.39
25/02/2023	2	2	2391.3	327.0	0.14
04/03/2023	1	1	3992.5	816.7	0.20
06/03/2023	3	2	11968.8	2858.3	0.24
24/04/2023	1	1	1614.6	835.8	0.52
14/05/2023	1	1	3664.7	2179.0	0.59
15/05/2023	3	1	4832.8	4430.5	0.92
31/08/2023	2	2	6675.9	5576.3	0.84
31/08/2023	2	2	2985.4	2761.5	0.92
31/08/2023	2	2	1414.4	1414.0	1.00
31/08/2023	2	2	946.9	946.9	1.00
31/08/2023	2	1	1035.3	1035.3	1.00
31/08/2023	2	5	1139.3	429.1	0.38
31/08/2023	2	1	523.1	523.1	1.00
31/08/2023	2	1	877.7	816.6	0.93
31/08/2023	2	2	1471.7	1471.1	1.00
31/08/2023	2	6	7358.4	5066.1	0.69
19/09/2023	1	2	3743.3	3742.3	1.00
19/09/2023	1	1	1315.0	824.2	0.63
19/09/2023	1	1	704.9	283.1	0.40
27/09/2023	3	1	124.3	124.3	1.00
27/09/2023	3	1	86.5	86.5	1.00
30/10/2023	2	1	2354.4	1707.4	0.73
30/10/2023	2	1	6585.3	5902.2	0.90
19/12/2023	1	1	4564.2	1565.2	0.34

Table 5: Summary of White-tailed Eagle Occupancy within 500m of Turbines (2023 Data)

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
1	9	11	1898	597	1301	0	0	1898
2	18	33	4998	629	2790	937	643	3419
3	4	5	642	99	394	63	86	493
Total	31	49	7538	1325	4485	1000	729	5810

Table 6: Details of Golden Eagle Flights within 500m of Turbines (2023 Data)

Date	VP No.	No. of birds	Total flight length (m)	Flight length (m) within 500m	Proportion within 500m
26/01/2023	2	1	391.5	85.8	0.22
05/02/2023	3	1	1232.2	1232.2	1.00
25/02/2023	2	1	1480.3	1379.0	0.93
25/02/2023	2	1	436.2	436.2	1.00
20/04/2023	1	1	1380.9	776.3	0.56
26/04/2023	2	1	1240.1	772.4	0.62
26/04/2023	2	1	4738.8	4088.2	0.86
14/05/2023	1	1	4071.1	3297.8	0.81
16/10/2023	1	1	1621.6	452.4	0.28

Table 7: Summary of Golden Eagle Occupancy within 500m of Turbines (2023 Data)

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
1	3	2	376	171	206	0	0	377
2	5	5	1002	208	198	65	531	406
3	1	1	135	90	45	0	0	135
Total	9	9	1513	469	449	65	531	918

Table 8: Details of Golden Plover Flights Recorded within 500m Buffer of Turbines (2023 Data)

Date	VP No.	No. of birds	Total flight length (m)	Flight length (m) within 500m	Proportion within 500m
19/03/2023	2	3	1012.2	389.3	0.38
19/03/2023	2	13	2394.2	2383.5	0.99

Table 9: Summary of Golden Plover Occupancy within 500m of Turbines (2023 Data)

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
1	0	0	0	0	0	0	0	0
2	2	16	1605	406	1199	0	0	1605
3	0	0	0	0	0	0	0	0
Total	2	16	1605	406	1199	0	0	1605

4.0 Collision Risk Modelling Results for the Consented and Proposed Developments

Using the 2023 data, the predicted collision risk for the Consented and Proposed Development undertaken for white-tailed eagle, golden eagle, and golden plover are displayed in **Table 10.**

Table 10: Comparison of CRM results between the Consented and Proposed Development using the 2023 Data (Modelled Collisions per year)

Species	Avoidance Rate	Modelled Collisions per Year		Years per Collision	
		Consented Development	Proposed Development	Consented Development	Proposed Development
White-tailed eagle	95%	2.03	3.47	0.49	0.29
	98%	0.81	1.39	1.23	0.72
Golden eagle	99%	0.04	0.10	23.03	9.88
Golden plover	98%	0.25	0.39	3.96	2.57

The differences in collision risk between the two schemes are likely caused by the following factors:

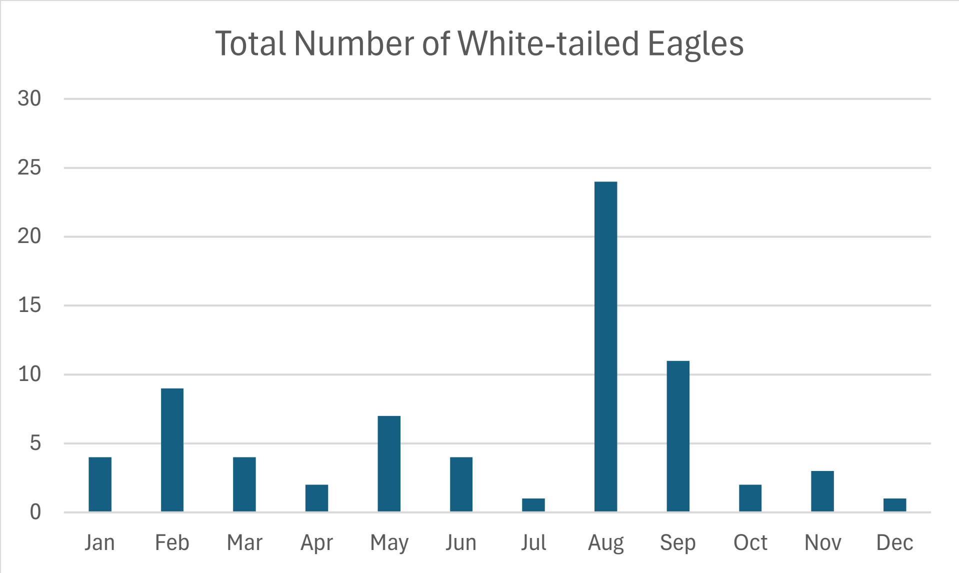
- The main difference is the distribution of survey data in relation to the PCH, with survey height bands <20m; 20-150m; 150-200m; >200m.
    - For the consented development, PCH is 20-135m, therefore the CRM only includes data from the 20-150m height band. The model then adjusts the occupancy by height of rotors/height of survey height band (i.e., 115/130, 88.5%).
    - For the Proposed Development, PCH is 12-150m, therefore the CRM includes data from 0-150m. The model then adjusts the occupancy by 138/150, (92%). Therefore, the occupancy is higher for the Proposed Development.
- The shape of the risk area is slightly smaller for the consented development, therefore the flight lengths within this area are also slightly smaller than for the Proposed Development.
- Blade parameters – the proposed turbines have a bigger chord length, and slightly slower rotation speed than the consented turbines, which both marginally increase the probability of collision.

4.1 Species Summary

4.1.1 White-tailed Eagle

Flight activity by white-tailed eagle peaked in the post-breeding period (August and September 2023) with 10 flights (involving up to 11 different birds) on one date, i.e., 31st August (19.6% of the total number of flights throughout the year). Other than on this date, the number of eagles recorded ranged between one to three, with 75% of records involving single birds. The cumulative number of birds recorded per month is shown in **Figure 1**.

Figure 1: Cumulative Number of White-tailed Eagles per Month



A hotspot of activity in 2023 was around the summit of Ben Sca, to the south of proposed Turbine 1 (**Figure 4.3.2**), with birds circling around using the thermals and updraughts generated by the higher ground. Flight behaviour recorded involved foraging (n=15/51), commuting (n=10/51), display (n=5/51) and flying to/ from a roost (n=7/51). Roosting birds were recorded >500m to the west of proposed turbine BS-08 in September 2023.

4.1.2 Golden Eagle

Flight activity by golden eagle was less regular then for white-tailed, with records in six out of the twelve months (January to May (inclusive) and October). The majority of flights involved sub-adult birds, with only three flights involving adults (a male and female in October). A juvenile female was also recorded in October.

Flight behaviour recorded involved foraging (n=11/14) and commuting (n=3/14). There was no particular pattern in the distribution of flights, other than these being mostly on the Ben Aketil side of the site (**Figure 4.3.1**).

4.1.3 Golden Plover

Flight activity by golden plover was recorded on three dates (in February, March and June). Only two of these flights were within 500m, to the north or east of Ben Sca summit (**Figure 4.3.3**).

Annex 4.3A

Collision Risk Modelling Results

Golden Eagle Probability of Collision: Proposed Development

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.1	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	0.82	m	0.025	0.575	5.94	22.10	1.00	0.00125	21.61	1.00	0.00125
Wingspan	2.1	m	0.075	0.575	1.98	7.53	0.35	0.00263	7.04	0.33	0.00246
F: Flapping (0) or gliding (	1		0.125	0.702	1.19	5.28	0.25	0.00308	4.68	0.22	0.00273
			0.175	0.860	0.85	4.48	0.21	0.00365	3.74	0.17	0.00305
Bird speed	15	m/sec	0.225	0.994	0.66	3.98	0.19	0.00418	3.13	0.15	0.00328
RotorDiam	138	m	0.275	0.947	0.54	3.21	0.15	0.00412	2.40	0.11	0.00308
RotationPeriod	4.29	sec	0.325	0.899	0.46	2.67	0.12	0.00405	1.90	0.09	0.00288
			0.375	0.851	0.40	2.27	0.11	0.00396	1.54	0.07	0.00269
			0.425	0.804	0.35	2.31	0.11	0.00457	1.62	0.08	0.00321
			0.475	0.756	0.31	2.11	0.10	0.00467	1.46	0.07	0.00323
Bird aspect ratioo: β	0.39		0.525	0.708	0.28	1.94	0.09	0.00475	1.33	0.06	0.00326
			0.575	0.660	0.26	1.80	0.08	0.00482	1.23	0.06	0.00330
			0.625	0.613	0.24	1.68	0.08	0.00488	1.15	0.05	0.00335
			0.675	0.565	0.22	1.57	0.07	0.00494	1.08	0.05	0.00341
			0.725	0.517	0.20	1.47	0.07	0.00498	1.03	0.05	0.00348
			0.775	0.470	0.19	1.39	0.06	0.00502	0.99	0.05	0.00356
			0.825	0.422	0.18	1.31	0.06	0.00504	0.95	0.04	0.00365
			0.875	0.374	0.17	1.24	0.06	0.00506	0.92	0.04	0.00375
			0.925	0.327	0.16	1.17	0.05	0.00506	0.89	0.04	0.00385
			0.975	0.279	0.15	1.11	0.05	0.00506	0.87	0.04	0.00397
				Overall p(collision) =			**Upwind**	**8.6%**		**Downwind**	**6.3%**
								Average	**7.5%**		

Golden Eagle CRM: Proposed Development 500m WP

	Viewsheds								
	1	2	3						
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)	377	406	135						
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	72	72	72						
Windfarm area (ha) visible within viewshed (*v*)[1]	227.63	77.09	127.94584						
Observation effort (*e*v*)	16389.54	5550.20	9212.10						
T_wV rate=$T_wV/e*v$	6.39E-06	2.03E-05	4.07E-06						
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total survey effort made at the VP	0.526	0.178	0.296						
Weighted T_wV rate (T_wV rate * weight)	3.36E-06	3.62E-06	1.20E-06						
Total weighted occupancy rate	0.000007					birds seconds per ha/hour			
Mean % activity hr^-1 in wind farm at risk height	0.284%								
Mean % activity hr^-1 in wind farm at rotor height (z)	0.261%								

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: Jan-Sep (a) (footnote 2)	4,456	hours
Tw=z*a	11.63	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$ (footnote 3)	560,815,235	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.82	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$ footnote 4	689,224.21	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	51.4660	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	15	m/sec
$t=(d+L)/s$	0.34	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	151	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.075	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	10.124	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
99.00%	**0.1012**	**approx one collision every**	**9.88**	**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 (Feb-Aug)

[3] A= size of windfarm polygon(ha) h= rotor diameter (m)

[4] N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)

[5]Assumes bird length=0.82m, wingspan 2.1m, flight speed= 15m/sec

Golden Eagle Probability of Collision: Consented Development

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	3.6	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	0.82	m	0.025	0.575	7.56	25.87	1.00	0.00125	25.44	1.00	0.00125
Wingspan	2.1	m	0.075	0.575	2.52	8.77	0.39	0.00289	8.34	0.37	0.00275
F: Flapping (0) or gliding (	1		0.125	0.702	1.51	6.08	0.27	0.00334	5.55	0.24	0.00305
			0.175	0.860	1.08	5.09	0.22	0.00392	4.44	0.20	0.00342
Bird speed	15	m/sec	0.225	0.994	0.84	4.49	0.20	0.00444	3.74	0.16	0.00370
RotorDiam	115	m	0.275	0.947	0.69	3.60	0.16	0.00436	2.89	0.13	0.00349
RotationPeriod	4.55	sec	0.325	0.899	0.58	2.99	0.13	0.00427	2.31	0.10	0.00330
			0.375	0.851	0.50	2.53	0.11	0.00417	1.89	0.08	0.00311
			0.425	0.804	0.44	2.18	0.10	0.00406	1.57	0.07	0.00293
			0.475	0.756	0.40	1.89	0.08	0.00395	1.32	0.06	0.00276
Bird aspect ratioo: β	0.39		0.525	0.708	0.36	2.00	0.09	0.00461	1.47	0.06	0.00338
			0.575	0.660	0.33	1.85	0.08	0.00466	1.35	0.06	0.00341
			0.625	0.613	0.30	1.71	0.08	0.00471	1.25	0.06	0.00344
			0.675	0.565	0.28	1.60	0.07	0.00474	1.17	0.05	0.00348
			0.725	0.517	0.26	1.50	0.07	0.00477	1.11	0.05	0.00353
			0.775	0.470	0.24	1.41	0.06	0.00479	1.05	0.05	0.00359
			0.825	0.422	0.23	1.32	0.06	0.00480	1.01	0.04	0.00365
			0.875	0.374	0.22	1.25	0.05	0.00481	0.97	0.04	0.00372
			0.925	0.327	0.20	1.18	0.05	0.00480	0.94	0.04	0.00381
			0.975	0.279	0.19	1.12	0.05	0.00479	0.91	0.04	0.00389
				Overall p(collision) =			**Upwind**	**8.4%**		**Downwind**	**6.6%**
								Average	**7.5%**		

Golden Eagle CRM: Consented Development 500m WP

	Viewsheds								
	1	**2**	**3**						
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)	200	196	45						
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	72	72	72						
Windfarm area (ha) visible within viewshed (*v*)[1]	213.47	74.55	122.46						
Observation effort (*e*v*)	15370.13	5367.50	8816.84						
T_wV rate=$T_wV/e*v$	3.61E-06	1.01E-05	1.42E-06						
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total survey effort made at the VP	0.520	0.182	0.298						
Weighted T_wV rate (T_wV rate * weight)	1.88E-06	1.84E-06	4.23E-07						
Total weighted occupancy rate	0.000004						birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height	0.141%								
Mean % activity hr^-1 in wind farm at rotor height (z)	0.125%								

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: Jan-Sep (a) (footnote 2)	4,456	hours
Tw=z*a	5.57	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$ (footnote 3)	436,805,776	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.82	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$ footnote 4	413,190.51	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	18.9781	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	15	m/sec
$t=(d+L)/s$	0.29	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	64	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.075	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	4.342	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
99.00%	**0.0434**	**approx one collision every**	**23.03**	**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 (Feb-Aug)

[3] A= size of windfarm polygon(ha) h= rotor diameter (m)

[4] N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)

[5]Assumes bird length=0.82m, wingspan 2.1m, flight speed= 15m/sec

White-tailed Eagle Probability of Collision: Proposed Development

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.1	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	0.8	m	0.025	0.575	5.15	19.52	1.00	0.00125	19.02	1.00	0.00125
Wingspan	2.2	m	0.075	0.575	1.72	6.67	0.36	0.00269	6.18	0.33	0.00249
F: Flapping (0) or gliding (·	1		0.125	0.702	1.03	4.69	0.25	0.00315	4.08	0.22	0.00275
			0.175	0.860	0.74	3.98	0.21	0.00374	3.24	0.17	0.00305
Bird speed	13	m/sec	0.225	0.994	0.57	3.54	0.19	0.00429	2.69	0.14	0.00326
RotorDiam	138	m	0.275	0.947	0.47	2.87	0.15	0.00424	2.06	0.11	0.00304
RotationPeriod	4.29	sec	0.325	0.899	0.40	2.39	0.13	0.00418	1.62	0.09	0.00283
			0.375	0.851	0.34	2.36	0.13	0.00475	1.63	0.09	0.00328
			0.425	0.804	0.30	2.14	0.11	0.00488	1.45	0.08	0.00331
			0.475	0.756	0.27	1.96	0.11	0.00500	1.31	0.07	0.00335
Bird aspect ratioo: β	0.36		0.525	0.708	0.25	1.81	0.10	0.00511	1.20	0.06	0.00340
			0.575	0.660	0.22	1.69	0.09	0.00521	1.12	0.06	0.00346
			0.625	0.613	0.21	1.58	0.08	0.00530	1.05	0.06	0.00354
			0.675	0.565	0.19	1.48	0.08	0.00538	1.00	0.05	0.00362
			0.725	0.517	0.18	1.40	0.08	0.00544	0.95	0.05	0.00372
			0.775	0.470	0.17	1.32	0.07	0.00550	0.92	0.05	0.00382
			0.825	0.422	0.16	1.25	0.07	0.00554	0.89	0.05	0.00394
			0.875	0.374	0.15	1.18	0.06	0.00558	0.86	0.05	0.00407
			0.925	0.327	0.14	1.13	0.06	0.00560	0.85	0.05	0.00421
			0.975	0.279	0.13	1.07	0.06	0.00561	0.83	0.04	0.00436
				Overall p(collision) =			**Upwind**	**9.2%**		**Downwind**	**6.7%**
								Average	**8.0%**		

White-tailed Eagle: Proposed Development 500m WP

	Viewsheds								
	1	2	3						
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)	1898	3,419	493						
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	72	72	72						
Windfarm area (ha) visible within viewshed (*v*)[1]	227.63	77.09	127.95						
Observation effort (*e*v*)	16389.54	5550.20	9212.10						
T_wV rate=$T_wV/e*v$	3.22E-05	1.71E-04	1.49E-05						
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total survey effort made at the VP	0.526	0.178	0.296						
Weighted T_wV rate (T_wV rate * weight)	1.69E-05	3.05E-05	4.40E-06						
Total weighted occupancy rate	0.000052				birds seconds per ha/hour				
Mean % activity hr^-1 in wind farm at risk height	2.105%								
Mean % activity hr^-1 in wind farm at rotor height (z)	1.937%								

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: Jan-Sep (a) (footnote 2)	4,456	hours
Tw=z*a	86.32	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$ (footnote 3)	560,815,235	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.8	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$ footnote 4	686,531.93	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	380.3950	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	13	m/sec
$t=(d+L)/s$	0.39	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	970	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.080	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	69.460	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
95.00%	**3.4730**	**approx one collision every**	**0.29**	**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 daylight hours during the period (Feb-Aug)

[3] A= size of windfarm polygon(ha) h= rotor diameter (m)

[4] N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)

[5]Assumes bird length=0.8m, wingspan 2.2m, flight speed= 13m/sec

White-tailed Eagle Probability of Collision: Consented Development

K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3					Upwind:			Downwind:		
MaxChord	3.6	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	0.8	m	0.025	0.575	6.55	22.87	1.00	0.00125	22.44	1.00	0.00125
Wingspan	2.2	m	0.075	0.575	2.18	7.77	0.39	0.00295	7.33	0.37	0.00279
F: Flapping (0) or gliding (·	1		0.125	0.702	1.31	5.39	0.27	0.00342	4.86	0.25	0.00308
			0.175	0.860	0.94	4.51	0.23	0.00401	3.87	0.20	0.00343
Bird speed	13	m/sec	0.225	0.994	0.73	3.98	0.20	0.00455	3.24	0.16	0.00369
RotorDiam	115	m	0.275	0.947	0.60	3.21	0.16	0.00447	2.50	0.13	0.00348
RotationPeriod	4.55	sec	0.325	0.899	0.50	2.67	0.14	0.00439	1.99	0.10	0.00328
			0.375	0.851	0.44	2.26	0.11	0.00430	1.62	0.08	0.00308
			0.425	0.804	0.39	1.95	0.10	0.00420	1.35	0.07	0.00290
			0.475	0.756	0.34	2.02	0.10	0.00486	1.45	0.07	0.00349
Bird aspect ratioo: β	0.36		0.525	0.708	0.31	1.86	0.09	0.00495	1.32	0.07	0.00353
			0.575	0.660	0.28	1.72	0.09	0.00502	1.22	0.06	0.00357
			0.625	0.613	0.26	1.61	0.08	0.00509	1.14	0.06	0.00363
			0.675	0.565	0.24	1.50	0.08	0.00515	1.08	0.05	0.00369
			0.725	0.517	0.23	1.41	0.07	0.00520	1.02	0.05	0.00376
			0.775	0.470	0.21	1.33	0.07	0.00524	0.98	0.05	0.00385
			0.825	0.422	0.20	1.26	0.06	0.00527	0.94	0.05	0.00394
			0.875	0.374	0.19	1.19	0.06	0.00529	0.91	0.05	0.00404
			0.925	0.327	0.18	1.13	0.06	0.00530	0.88	0.04	0.00415
			0.975	0.279	0.17	1.07	0.05	0.00530	0.86	0.04	0.00427
				Overall p(collision) =			**Upwind**	**9.0%**		**Downwind**	**6.9%**
								Average	**8.0%**		

White-tailed Eagle: Consented Development 500m WP

	Viewsheds								
	1	**2**	**3**						
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)	1225	2,419	379						
Step 1.2: Unweighted occupancy rate each viewshed (T_wVrate)									
Hours of survey effort (*e*)	72	72	72						
Windfarm area (ha) visible within viewshed (*v*)[1]	213.47	74.55	122.46						
Observation effort (*e*v*)	15370.13	5367.50	8816.84						
T_wV rate=$T_wV/e*v$	2.21E-05	1.25E-04	1.19E-05						
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total survey effort made at the VP	0.520	0.182	0.298						
Weighted T_wV rate (T_wV rate * weight)	1.15E-05	2.27E-05	3.56E-06						
Total weighted occupancy rate	0.000038					birds seconds per ha/hour			
Mean % activity hr^-1 in wind farm at risk height	1.436%								
Mean % activity hr^-1 in wind farm at rotor height (z)	1.270%								

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: Jan-Sep (a) (footnote 2)	4,456	hours
Tw=z*a	56.62	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$ (footnote 3)	436,805,776	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.8	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$ footnote 4	411,320.87	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	191.9274	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	13	m/sec
$t=(d+L)/s$	0.34	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	567	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.080	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	40.596	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
95.00%	**2.0298**	**approx one collision every**	**0.49**	**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 daylight hours during the period (Feb-Aug)

[3] A= size of windfarm polygon(ha) h= rotor diameter (m)

[4] N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)

[5]Assumes bird length=0.8m, wingspan 2.2m, flight speed= 13m/sec

Golden Plover Probability of Collision: Proposed Development

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.1	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	7.12	20.13	0.78	0.00098	19.63	0.76	0.00095
Wingspan	0.7	m	0.075	0.575	2.37	6.87	0.27	0.00200	6.38	0.25	0.00186
F: Flapping (0) or gliding (	1		0.125	0.702	1.42	5.01	0.19	0.00243	4.41	0.17	0.00214
			0.175	0.860	1.02	4.39	0.17	0.00299	3.65	0.14	0.00248
Bird speed	18	m/sec	0.225	0.994	0.79	3.99	0.15	0.00349	3.14	0.12	0.00274
RotorDiam	138	m	0.275	0.947	0.65	3.19	0.12	0.00341	2.38	0.09	0.00255
RotationPeriod	4.29	sec	0.325	0.899	0.55	2.64	0.10	0.00333	1.87	0.07	0.00236
			0.375	0.851	0.47	2.23	0.09	0.00324	1.50	0.06	0.00218
			0.425	0.804	0.42	1.90	0.07	0.00314	1.22	0.05	0.00201
			0.475	0.756	0.37	1.76	0.07	0.00325	1.11	0.04	0.00205
Bird aspect ratioo: β	0.40		0.525	0.708	0.34	1.56	0.06	0.00319	0.96	0.04	0.00195
			0.575	0.660	0.31	1.40	0.05	0.00312	0.83	0.03	0.00186
			0.625	0.613	0.28	1.25	0.05	0.00305	0.73	0.03	0.00177
			0.675	0.565	0.26	1.13	0.04	0.00296	0.65	0.03	0.00169
			0.725	0.517	0.25	1.02	0.04	0.00287	0.58	0.02	0.00162
			0.775	0.470	0.23	0.92	0.04	0.00277	0.52	0.02	0.00156
			0.825	0.422	0.22	0.83	0.03	0.00267	0.47	0.02	0.00151
			0.875	0.374	0.20	0.75	0.03	0.00255	0.43	0.02	0.00146
			0.925	0.327	0.19	0.68	0.03	0.00243	0.40	0.02	0.00142
			0.975	0.279	0.18	0.61	0.02	0.00230	0.37	0.01	0.00139
				Overall p(collision) =			**Upwind**	**5.6%**		**Downwind**	**3.8%**
								Average	**4.7%**		

Golden Plover: Proposed Development 500m WP

	Viewsheds								
	1	2	3						
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)	0	1,605	0						
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)									
Hours of survey effort (*e*)	72	72	72						
Windfarm area (ha) visible within viewshed (*v*)[1]	227.63	77.09	127.94584						
Observation effort (*e*v*)	16389.54	5550.20	9212.10						
T_wV rate=$T_wV/e*v$	0.00E+00	8.03E-05	0.00E+00						
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]									
Weight: proportion of total survey effort made at the VP	0.526	0.178	0.296						
Weighted T_wV rate (T_wV rate * weight)	0.00E+00	1.43E-05	0.00E+00						
Total weighted occupancy rate	0.000014					birds seconds per ha/hour			
Mean % activity hr^-1 in wind farm at risk height	0.582%								
Mean % activity hr^-1 in wind farm at rotor height (z)	0.535%								

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: Jan-Sep 2023 (a) (footnote 2)	5,537	hours
Tw=z*a	29.63	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$ (footnote 3)	560,815,235	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.28	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$ footnote 4	616,532.59	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	117.2620	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	18	m/sec
$t=(d+L)/s$	0.25	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	461	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.047	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	19.443	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
98.00%	**0.3889**	**approx one collision every**	**2.57**	**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 (Feb-Aug)

[3] A= size of windfarm polygon(ha) h= rotor diameter (m)

[4] N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)

[5]Assumes bird length=0.28m, wingspan 0.7m, flight speed= 18m/sec

Golden Plover Probability of Collision: Consented Development

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	3.6	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	9.07	22.92	0.84	0.00105	22.49	0.82	0.00103
Wingspan	0.7	m	0.075	0.575	3.02	7.79	0.29	0.00214	7.35	0.27	0.00202
F: Flapping (0) or gliding (·	1		0.125	0.702	1.81	5.63	0.21	0.00258	5.10	0.19	0.00233
			0.175	0.860	1.30	4.89	0.18	0.00313	4.24	0.16	0.00272
Bird speed	18	m/sec	0.225	0.994	1.01	4.41	0.16	0.00363	3.66	0.13	0.00302
RotorDiam	115	m	0.275	0.947	0.82	3.52	0.13	0.00354	2.81	0.10	0.00283
RotationPeriod	4.55	sec	0.325	0.899	0.70	2.89	0.11	0.00345	2.22	0.08	0.00264
			0.375	0.851	0.60	2.43	0.09	0.00334	1.79	0.07	0.00246
			0.425	0.804	0.53	2.07	0.08	0.00323	1.47	0.05	0.00229
			0.475	0.756	0.48	1.79	0.07	0.00311	1.22	0.04	0.00212
Bird aspect ratioo: β	0.40		0.525	0.708	0.43	1.55	0.06	0.00299	1.02	0.04	0.00196
			0.575	0.660	0.39	1.46	0.05	0.00308	0.96	0.04	0.00203
			0.625	0.613	0.36	1.31	0.05	0.00299	0.85	0.03	0.00193
			0.675	0.565	0.34	1.17	0.04	0.00290	0.75	0.03	0.00185
			0.725	0.517	0.31	1.05	0.04	0.00280	0.66	0.02	0.00176
			0.775	0.470	0.29	0.95	0.03	0.00269	0.60	0.02	0.00169
			0.825	0.422	0.27	0.85	0.03	0.00258	0.54	0.02	0.00162
			0.875	0.374	0.26	0.77	0.03	0.00246	0.49	0.02	0.00156
			0.925	0.327	0.25	0.69	0.03	0.00234	0.44	0.02	0.00150
			0.975	0.279	0.23	0.62	0.02	0.00220	0.41	0.01	0.00145
				Overall p(collision) =			**Upwind**	**5.6%**		**Downwind**	**4.1%**
								Average	**4.9%**		

Golden Plover: Consented Development 500m WP

	Viewsheds									
	1	**2**	**3**							
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)	0	1,192	0							
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)										
Hours of survey effort (*e*)	72	72	72							
Windfarm area (ha) visible within viewshed (*v*)[1]	213.47	74.55	122.46							
Observation effort (*e*v*)	15370.13	5367.50	8816.84							
T_wV rate=$T_wV/e*v$	0.00E+00	6.17E-05	0.00E+00							
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]										
Weight: proportion of total survey effort made at the VP	0.520	0.182	0.298							
Weighted T_wV rate (T_wV rate * weight)	0.00E+00	1.12E-05	0.00E+00							
Total weighted occupancy rate	0.000011					birds seconds per ha/hour				
Mean % activity hr^-1 in wind farm at risk height	0.426%									
Mean % activity hr^-1 in wind farm at rotor height (z)	0.376%									

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: Jan-Sep 2023 (a) (footnote 2)	5,537	hours
Tw=z*a	20.84	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$ (footnote 3)	436,805,776	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.28	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$ footnote 4	362,710.22	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	62.3119	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	18	m/sec
t=(d+L)/s	0.22	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	289	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.049	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	12.625	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
98.00%	**0.2525**	**approx one collision every**	**3.96**	**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 (Feb-Aug)

[3] A= size of windfarm polygon(ha) h= rotor diameter (m)

[4] N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)

[5]Assumes bird length=0.28m, wingspan 0.7m, flight speed= 18m/sec

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