Technical Appendix 9.4: Avian Collision Risk Assessment

Windburn Wind Farm

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Revision	Date	Prepared By	Checked By	Authorised By
01	2 June 2025	M. Austin	J. Wilson	A. Smith

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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
km / m	Kilometre / metre
MS	Microsoft
PCH	Potential Collision Height
SNH	Scottish Natural Heritage
SPA	Special Protection Area
VP	Vantage Point
V_w	Risk volume
WP	Windfarm polygon
WTG	Wind Turbine Generator

1.0 Executive Summary

Collision Risk Modelling (CRM) was undertaken for three bird species (red kite *Milvus milvus*, kestrel *Falco tinnunculus* and golden plover *Pluvialis apricaria*) to inform ornithological assessment studies at the proposed Windburn Wind Farm. Modelling was based on the use of the Enercon E138 which has a rotor diameter of 138m, tip height of 150m and hub height of 81m.

Where there was sufficient bird flight activity within the Windfarm Polygon 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:

- Red kite – annual rate of 0.265 (3.8 years per collision);
- Kestrel – annual rate of 0.670 (1.5 years per collision); and
- Golden plover – non-breeding season rate of 0.2205 (4.5 years per collision).

The conclusions from the CRM are used in the Ornithology assessment within the EIA Report for the proposed development.

2.0 Introduction

This report presents the results of CRM undertaken for three bird species to inform ornithological assessment studies at the proposed Windburn Wind Farm. From here on referred to as the 'proposed development'.

As advised by Wind2 Ltd., modelling was based on the use of a potential candidate turbine model, the Enercon E138 which has a rotor diameter of 138m, tip height of 150m and hub height of 81m.

Where there was sufficient bird flight activity within the CRZ (i.e. within the WP at PCH, 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 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 3.2 and copies of the modelling calculations for each species modelled are included in **Annex A**.

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).

The boundaries of two SPAs are located within 20km, which are potentially within the core foraging range of qualifying features which may occur on the site (e.g., as defined by SNH 2016). These are:

- South Tayside Goose Roosts SPA/ Ramsar (designated for migratory wildfowl including pink-footed goose *Anser brachyrhynchus* and greylag goose *Anser anser*); and
- Firth of Forth SPA/ Ramsar (designated for migratory wildfowl including pink-footed goose);

The only SPA species recorded during baseline surveys was pink-footed goose.

Other bird species of high conservation importance are those which are Annex I and Schedule 1 species and other species of high conservation importance which are considered to be vulnerable to impacts from wind farm developments.

The following species are therefore considered relevant as primary target species:

- Annex I and Schedule 1 raptor and owl species, plus kestrel;
- Breeding and migratory wildfowl; and
- Breeding and migratory waders.

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 2021 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 April 2021 to March 2023.

The surveys gathered data from a combination of three VPs (**Figure 9.4.1a** and **Figure 9.4.1b**), which were designed to cover the proposed turbines which are situated within Clackmannanshire plus a 500m buffer. Note that VP 2 on **Figure 9.4.1a** was re-located to VP 3 in October 2021 (**Figure 9.4.1b**) due to access restrictions. The additional benefit of this VP relocation was to provide additional coverage of the turbines located within Perth & Kinross, which weren't included in the original proposed development area.

The proposed additional five turbines located in Perth & Kinross are covered by a combination of these VPs as follows:

- VP1: covers T15, surveys undertaken April 2021 – March 2023.
- VP2: covers T11, T12 & T15, surveys undertaken April 2021 – September 2021.
- VP3: covers T11, T12, T13, T14 & T15, October 2021 – March 2023.

The total number of hours of survey undertaken are as shown in **Table 3-1**.

Table 3-1: VP Surveys undertaken at Windburn, April 2021 – March 2023

VP Number	Grid Coordinates (x,y)	Hours of Survey Completed (hrs:mins)			
		Apr – Sep 2021	Oct 2021 – Mar 2022	Apr – Aug 2022*	Sep 2022 – Mar 2023
VP1	289226, 701449	36:00	36:00	30:00	42:00
VP2	287465, 702953	36:00	00:00	00:00	00:00
VP3	287008, 701812	00:00	39:20	24:00	33:00
* Survey hours during this period are less than 36 hours due to prolonged periods of low cloud					

Furthermore, additional VPs commenced in April 2023 (to March 2024) to cover the addition of the turbines located on the Blackford estate into the proposed development, the viewsheds of which also cover the original Rhodders estate area of the proposed development, to which this report refers. CRM will be conducted on these data at a later date.

3.1.2 Viewshed Data

Viewshed data, i.e., from the area visible from each VP within the WP[1], are summarised in **Table 3-2**. The combined viewshed area (minus overlap) from VP1 + VP2 (5,476,259m²) represents 78.2% of the survey WP (7,001,886m²), and for VP1 + VP3 this is 5,521,498m² (78.9% of the survey WP. The VP1+VP3 combined viewshed covers all the proposed turbine locations, whereas the VP1+VP2 combined viewshed does not cover the two most northern turbine locations (WTG 12 & WTG 13) (**Figure 9.4.1a** and **Figure 9.4.1b**).

Table 3-2: Windburn Viewshed Data

VP/ Viewshed Number	Area of visibility (m²)*
April 2021 to September 2021	
VP 1 viewshed	4,409,899
VP 2 viewshed	3,906,375
VP 1+2 viewshed combined (minus overlap)	5,476,259
October 2021 to March 2023	
VP 1 viewshed	4,409,899
VP 3 viewshed	3,416,749
VP 1+3 viewshed combined (minus overlap)	5,521,498
* Area calculated in a GIS using offset of 20m above ground level	

3.1.3 Flight Selection for CRM

In order to select flights with 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 500m buffer around the proposed outermost turbine locations. The size of the buffer takes into account rotor blade length and potential spatial errors in flight recording. It is known that bird detection rates vary between species. To ensure the CRM used robust measures of flight activity, 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 NatureScot guidance).

Analysis in Microsoft Excel and GIS identified those flights that were at 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

Baseline VP surveys were initiated before the current candidate turbine details were known. The baseline surveys utilised the following height bands:

- 1 = <30m

[1] The WP includes the area within 500m of the outermost turbine blades.

- 2 = 30-150m
- 3 = >150m

As such, the height bands used to record flight activity do not correspond precisely to PCH for the proposed development (12-150m[2]), i.e., height band 1 overlaps with the lower limit of the actual PCH (12-30m of the 0-30m 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 all height bands, it is assumed that a proportion of the flights within height band 1 will be below risk height. Therefore, the model accounts for this by adjusting the proportion of flights included by rotor diameter/ survey risk height (138/150 (92.0%)).

3.1.5 Seasonal Definitions

CRMs were constructed using data based on the survey design (April 2021 to March 2023) and taking into account the relevant species breeding season periods, i.e., April – August 2021 (breeding season 2021), September 2021 – February 2022 (non-breeding season 2021/22); March – August 2022 (breeding season 2022) and September 2022 – March 2023 (non-breeding season 2022/23). These assumptions were complicated by the unavoidable relocation of VP2 due to access restrictions, in September 2021; this resulted in surveys commencing at VP3 in October 2021.

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 proposed development[3].

For waders (i.e., 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).

3.1.6 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 of 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 V_w (m^3) visible from each VP;
- An estimation of average daylight hours within the season of analysis;
- Species-specific bird parameters (**Table 3-3**); and
- Wind farm parameters (**Table 3-4**).

Maps showing VP locations and viewsheds along with the 500m buffer around the outermost turbine blades are provided (**Figure 9.4.1a** and **Figure 9.4.1b**).

[2] Using the turbine data in **Table 3-4**
[3] https://www.timeanddate.com [Accessed in September 2023].

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.

3.1.7 Bird Biometrics and Avoidance Rates

Table 3-3 lists the measurements and flight speeds of the species for which CRM was undertaken. These were derived from 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 NatureScot 2018[9].

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

Species name	Bird length (m)	Wingspan (m)	Flight speed (m/s)	Avoidance rate (%)
Red kite	0.63	1.85	11.0	99.0
Kestrel	0.34	0.8	12.7	95.0
Golden plover	0.28	0.72	17.5	98.0

3.1.8 Wind Farm and Turbine Parameters

The wind turbine parameters used in the CRM are detailed in **Table 3-4** and are based on the information provided by Wind2 Ltd for the purposes of assessment.

Table 3-4: Wind farm & turbine parameters

Parameter	Value
Size of survey wind farm polygon (WP)	700.2 ha
Number of turbines	13
Rotor radius/ diameter	69.0m/ 138.0m
Hub height	81.0m
Max. chord	4.3m
Pitch	6°
Rotation period	4.29s (max 13.9 rpm)

4 https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision [Accessed in September 2023].

5 https://www.bto.org/understanding-birds/birdfacts [Accessed in September 2023].

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 2023].

Parameter	Value
Assumed turbine operation time	90%

3.2 Windburn Flight Data

Table 3-5 summarises the primary target species flightline data from VP surveys conducted, presented for each season. **Table 3-6** to **Table 3-8** (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 3-5: Number of target species flights and individuals observed passing through the Windburn WP during VP surveys (Apr 2021 to Mar 2023)

Species name	Period of analysis	Total number of birds recorded in flight	Flights through WP		Flights through WP at PCH	
			No. of Flight Events	Cumulative no. of Birds	No. of Flight Events	Cumulative no. of Birds
Pink-footed goose	Apr-21 to Aug 21	0	0	0	0	0
	Sep-21 to Feb-22	60	0	0	0	0
	Mar-22 to Aug-22	0	0	0	0	0
	Sep-22 to Mar-23	97	4	97	0	0
Red kite	Apr-21 to Aug 21	16	13	15	13	15
	Sep-21 to Feb-22	12	12	12	12	12
	Mar-22 to Aug-22	13	12	12	12	12
	Sep-22 to Mar-23	16	13	16	11	14
Hen harrier	Apr-21 to Aug 21	2	2	2	2	2
	Sep-21 to Feb-22	1	1	1	1	1
	Mar-22 to Aug-22	0	0	0	0	0
	Sep-22 to Mar-23	1	1	1	1	1
Golden eagle	Apr-21 to Aug 21	0	0	0	0	0
	Sep-21 to Feb-22	0	0	0	0	0
	Mar-22 to Aug-22	0	0	0	0	0
	Sep-22 to Mar-23	1	1	1	1	1
Kestrel	Apr-21 to Aug 21	14	13	13	13	13
	Sep-21 to Feb-22	4	4	4	4	4
	Mar-22 to Aug-22	4	4	4	4	4
	Sep-22 to Mar-23	11	9	9	7	7
Merlin	Apr-21 to Aug 21	1	1	1	1	1
	Sep-21 to Feb-22	1	1	1	1	1
	Mar-22 to Aug-22	0	0	0	0	0
	Sep-22 to Mar-23	1	1	1	1	1
Golden plover	Apr-21 to Aug 21	0	0	0	0	0
	Sep-21 to Feb-22	0	0	0	0	0
	Mar-22 to Aug-22	0	0	0	0	0

Species name	Period of analysis	Total number of birds recorded in flight	Flights through WP		Flights through WP at PCH	
			No. of Flight Events	Cumulative no. of Birds	No. of Flight Events	Cumulative no. of Birds
	Sep-22 to Mar-23	51	5	51	4	48
Snipe	Apr-21 to Aug 21	1	1	1	1	1
	Sep-21 to Feb-22	0	0	0	0	0
	Mar-22 to Aug-22	4	4	4	4	4
	Sep-22 to Mar-23	0	0	0	0	0
Curlew	Apr-21 to Aug 21	0	0	0	0	0
	Sep-21 to Feb-22	0	0	0	0	0
	Mar-22 to Aug-22	0	0	0	0	0
	Sep-22 to Mar-23	1	1	1	1	1

Table 3-6: Details of Red Kite 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)			
					<30m	30-150m	>150m	At risk
Apr-21 to Aug-21	VP1	2	2	150	0	120	30	120
	VP2	11	13	2148	400	1403	345	1803
Sep-21 to Feb-22	VP1	8	8	1071	458	537	75	995
	VP2	1	1	300	285	15	0	300
	VP3	3	3	120	15	60	45	75
Mar-22 to Aug-22	VP1	3	3	211	68	85	59	153
	VP3	9	9	669	221	336	112	557
Sep-22 to Mar-23	VP1	8	9	1049	944	0	105	944
	VP3	5	7	683	214	349	119	563
Total		50	55	6401	2605	2905	890	5510

Table 3-7: Details of 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)			
					<30m	30-150m	>150m	At risk
Apr-21 to Aug-21	VP1	3	3	524	419	105	0	524
	VP2	10	10	1433	230	1011	192	1241
	VP1	2	2	240	15	225	0	240

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)			
					<30m	30-150m	>150m	At risk
Sep-21 to Feb-22	VP2	1	1	60	60	0	0	60
	VP3	1	1	28	28	0	0	28
Mar-22 to Aug-22	VP1	2	2	238	170	67	0	237
	VP3	0	0	0	0	0	0	0
Sep-22 to Mar-23	VP1	5	5	689	569	0	120	569
	VP3	4	4	486	400	86	0	486
Total		28	28	3698	1891	1494	312	3385

Table 3-8: Details of 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)			
					<30m	30-150m	>150m	At risk
Apr-21 to Aug-21	VP1	0	0	0	0	0	0	0
	VP2	0	0	0	0	0	0	0
Sep-21 to Feb-22	VP1	0	0	0	0	0	0	0
	VP2	0	0	0	0	0	0	0
	VP3	0	0	0	0	0	0	0
Mar-22 to Aug-22	VP1	0	0	0	0	0	0	0
	VP3	0	0	0	0	0	0	0
Sep-22 to Mar-23	VP1	1	3	90	0	0	90	0
	VP3	4	48	1172	1172	0	0	1172
Total		5	51	1262	1172	0	90	1172

4.0 Collision Risk Modelling Results

Table 4-1 summarises the predicted collision rates for the three species under consideration. Copies of the modelling calculations for each species are included in **Annex A** (note that those in **Annex A** are the annual models, which are those used for assessment).

Table 4-1: Summary of CRM Output

Species name	Period of analysis	Modelled collisions per Season/ Year	Years per collision
Red kite	Apr-21 to Aug-21	0.1899	5.27
	Sep-21 to Feb-22	0.0778	12.86
	Mar-22 to Aug-22	0.0770	12.99
	Sep-22 to Mar-23	0.1037	9.64
	Annual Yr1	0.2588	3.86
	Annual Yr2	0.1836	5.45
	Annual Yr1 + Yr2	**0.2666**	**3.75**
Kestrel	Apr-21 to Aug-21	0.7382	1.35
	Sep-21 to Feb-22	0.0789	12.68
	Mar-22 to Aug-22	0.1088	9.19
	Sep-22 to Mar-23	0.3075	3.25
	Annual Yr1	0.6753	1.48
	Annual Yr2	0.4822	2.07
	Annual Yr1 + Yr2	**0.6699**	**1.49**
Golden plover	Sep-22 to Mar-23	0.2205	4.54
	Annual Yr2	**0.2543**	**3.93**

4.1 Species Summary

4.1.1 Red Kite

Red kites use the study area primarily for foraging (n=28 flights) and commuting (n=12 flights). Other flight behaviours observed included random/ circling flights (n=12). No breeding activity was observed.

The peak in flight activity occurred during August 2021 (seven flights), which resulted in the highest predicted mortality throughout the two year survey period. The overall predicted mortality was 0.27 birds annually.

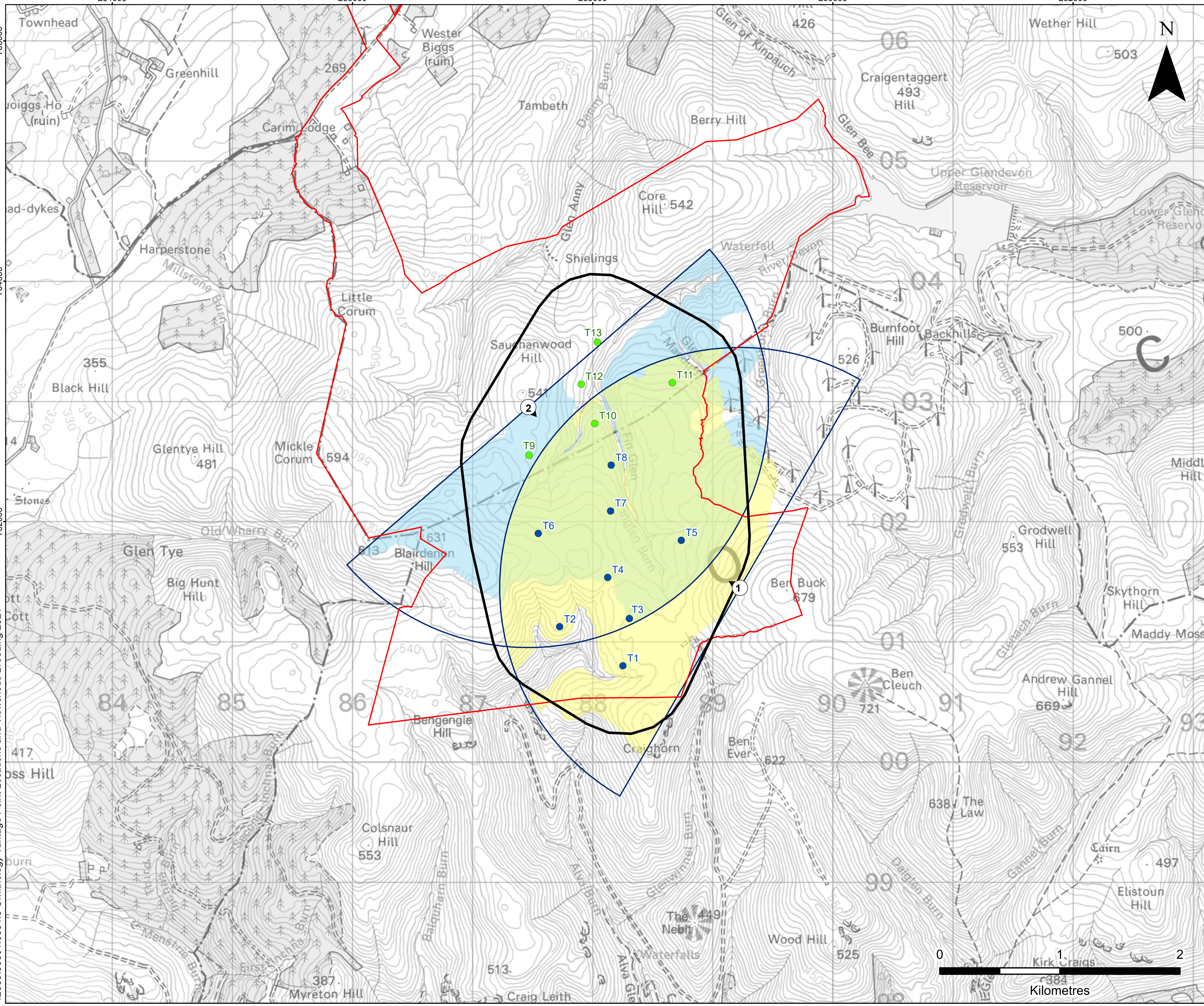
4.1.2 Kestrel

As for red kite, kestrel use the study area primarily for foraging (n=27 flights, out of a total of 31). No breeding activity was observed. The highest predicted mortality was during the year 1 breeding season, with an overall predicted mortality of 0.67 birds annually.

4.1.3 Golden Plover

Flight activity by golden plover was recorded on only two dates in September and November 2022, with all flights involving migrating or commuting birds. The resulting predicted mortality was zero birds based on Year 1 data and 0.25 birds based on Year 2 data.

Figures



LEGEND

- Application Boundary
- Rhodders Estate Proposed Turbine Location
- Blackford Estate Proposed Turbine Location
- Windfarm Polygon (WP)
- Vantage Point (VP)
- Vantage Point Viewing Arc
- Theoretical Visibility from VP2
- Theoretical Visibility from VP1
- Theoretical Visibility from VP1&2

NOTE:
This Zone of Theoretical Visibility (ZTV) has been generated using ESRI ArcGIS Special Analyst extension. The digital terrain model (DTM) has been derived from OS Terrain 50 dataset (+/-8m). Earth curvature has been included in the ZTV calculation and refraction of light has been applied using NatureScot guidance settings. The ZTV calculated with a surface offset of 20 m and a viewing height of 1.8 m. The use of ZTV mapping at this stage is limited and the following assumptions should be noted:

- The ZTV is generated from a bare earth terrain and does not account for the screening effect of features within the landscape such as settlements and woodland. It does not indicate potential visual effects or show the likely significance of effects. It shows potential theoretical visibility only. The ZTV has been produced for the purpose of informing 'on the ground' visual assessment.

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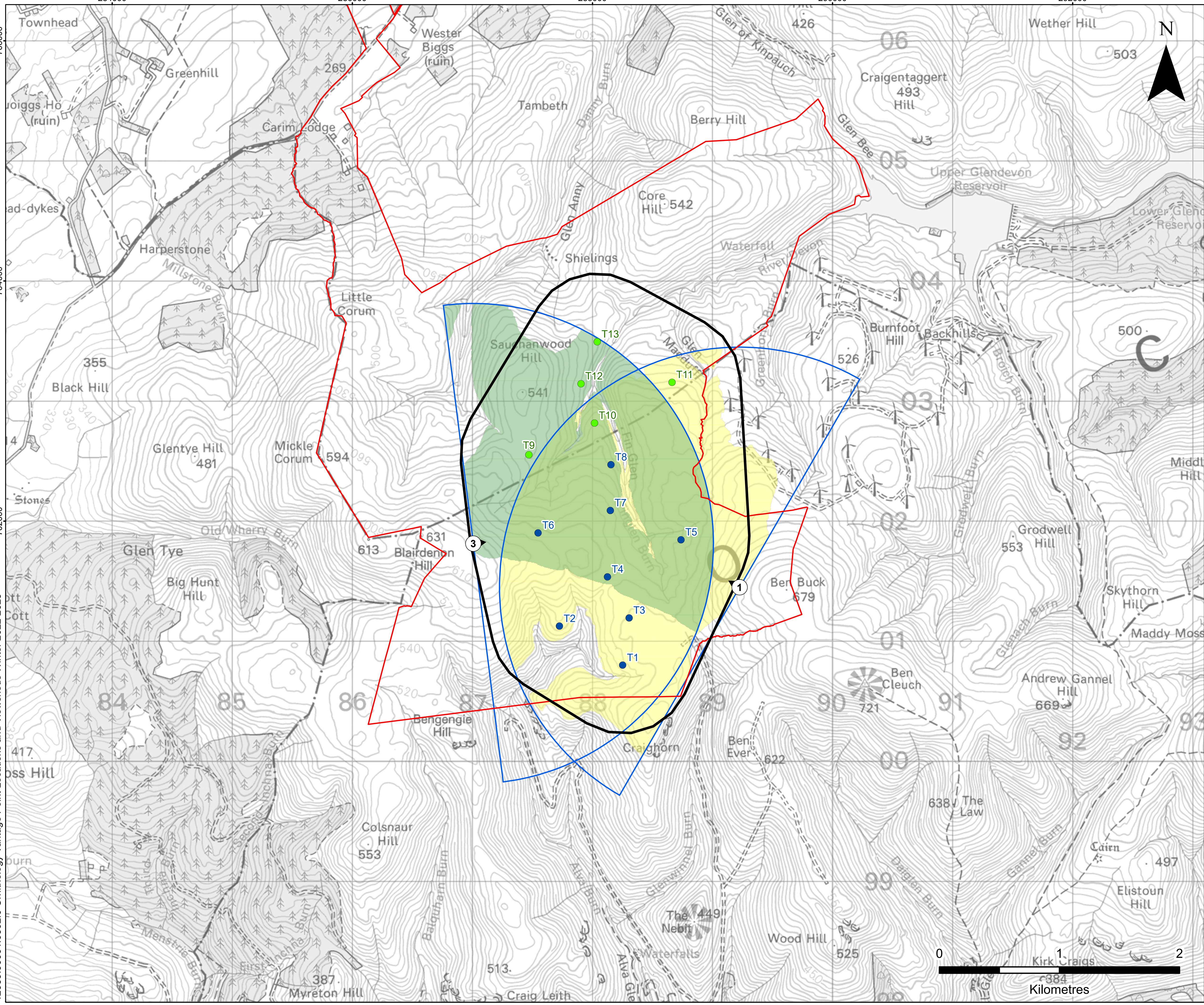
AVIAN COLLISION RISK ASSESSMENT

ORNITHOLOGY VANTAGE POINT LOCATIONS AND VIEWSHEDS APRIL 2021 TO SEPTEMBER 2021

FIGURE 9.4.1a

Scale	Date
1:30,000 @ A3	APRIL 2025

12959.00001.0301.0 Ornithology Vantage Point Locations and Viewsheds Breeding 2021



LEGEND

- Application Boundary
- Rhodders Estate Proposed Turbine Location
- Blackford Estate Proposed Turbine Location
- Windfarm Polygon (WP)
- Vantage Point (VP)
- Vantage Point Viewing Arc
- Theoretical Visibility from VP1
- Theoretical Visibility from VP3
- Theoretical Visibility from VP1&3

NOTE:
This Zone of Theoretical Visibility (ZTV) has been generated using ESRI ArcGIS Special Analyst extension. The digital terrain model (DTM) has been derived from OS Terrain 50 dataset (+/-8m). Earth curvature has been included in the ZTV calculation and refraction of light has been applied using NatureScot guidance settings. The ZTV calculated with a surface offset of 20 m and a viewing height of 1.8 m. The use of ZTV mapping at this stage is limited and the following assumptions should be noted:

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AVIAN COLLISION RISK ASSESSMENT

ORNITHOLOGY VANTAGE POINT LOCATIONS AND VIEWSHEDS OCTOBER 2021 TO MARCH 2023

FIGURE 9.4.1b

Scale	Date
1:30,000 @ A3	APRIL 2025

12959.00001.0302.0 Ornithology Vantage Point Locations and Viewsheds Winter 2022 2023

Annex A: CRM Calculations

Technical Appendix 9.4: Avian Collision Risk Assessment

Windburn Wind Farm

Windburn Wind Farm Limited

SLR Project No.: 428.V12959.00001

2 June 2025

Red Kite Probability of Collision

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	0.63	m	0.025	0.575	4.35	16.09	1.00	0.00125	15.58	0.99	0.00124
Wingspan	1.85	m	0.075	0.575	1.45	5.54	0.35	0.00264	5.02	0.32	0.00239
F: Flapping (0) or gliding (-	1		0.125	0.702	0.87	3.95	0.25	0.00314	3.32	0.21	0.00264
			0.175	0.860	0.62	3.41	0.22	0.00379	2.63	0.17	0.00293
Bird speed	11	m/sec	0.225	0.994	0.48	3.07	0.20	0.00440	2.18	0.14	0.00312
RotorDiam	138	m	0.275	0.947	0.40	2.49	0.16	0.00436	1.64	0.10	0.00287
RotationPeriod	4.29	sec	0.325	0.899	0.33	2.32	0.15	0.00480	1.51	0.10	0.00313
			0.375	0.851	0.29	2.07	0.13	0.00493	1.30	0.08	0.00311
			0.425	0.804	0.26	1.87	0.12	0.00506	1.15	0.07	0.00310
			0.475	0.756	0.23	1.71	0.11	0.00517	1.03	0.07	0.00311
Bird aspect ratioo: β	0.34		0.525	0.708	0.21	1.58	0.10	0.00526	0.94	0.06	0.00314
			0.575	0.660	0.19	1.46	0.09	0.00534	0.87	0.06	0.00317
			0.625	0.613	0.17	1.36	0.09	0.00541	0.81	0.05	0.00322
			0.675	0.565	0.16	1.27	0.08	0.00547	0.77	0.05	0.00329
			0.725	0.517	0.15	1.19	0.08	0.00551	0.73	0.05	0.00336
			0.775	0.470	0.14	1.12	0.07	0.00553	0.70	0.04	0.00345
			0.825	0.422	0.13	1.06	0.07	0.00555	0.68	0.04	0.00356
			0.875	0.374	0.12	1.00	0.06	0.00555	0.66	0.04	0.00368
			0.925	0.327	0.12	0.94	0.06	0.00553	0.65	0.04	0.00381
			0.975	0.279	0.11	0.89	0.06	0.00551	0.64	0.04	0.00395
				Overall p(collision) =			**Upwind**	**9.4%**		**Downwind**	**6.2%**
								Average	**7.8%**		

Red Kite CRM Annual Yr 1

	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)	1144	2,103	120	
Step 1.2: Unweighted occupancy rate within each viewshed ($T_wV$rate)				
Hours of survey effort (*e*)	72	36	39	
Windfarm area (ha) visible within viewshed (*v*)[1]	440.99	390.64	341.67	
Observation effort (*e**v*)	31751.27	14062.95	13439.21	
T_wV rate=$T_wV/e*v$	1.00E-05	4.15E-05	2.48E-06	
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]				
Weight: proportion of total survey effort made at the VP	0.536	0.237	0.227	
Weighted T_wV rate (T_wV rate * weight)	5.36E-06	9.86E-06	5.63E-07	
Total weighted occupancy rate	0.000016			birds seconds per ha/hour
Mean % activity hr^-1 in wind farm at risk height	1.105%			
Mean % activity hr^-1 in wind farm at rotor height (z)	1.017%			

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: annual (a) (footnote 2)	4,496	hours
Tw=z*a	45.72	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$ (footnote 3)	966,260,224	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.63	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$ footnote 4	958,601.99	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	163.2850	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	11	m/sec
$t=(d+L)/s$	0.45	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	364	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.078	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	25.651	collisions

Step 3.2: Adjusted using recommended avoidance rate:				
99.00%	**0.2565**	**approx. one collision every**	**3.90**	**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

[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=0.63m, wingspan 1.85m, flight speed= 11m/sec

Red Kite CRM Annual Yr 2

	Viewsheds		
	1	**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)	1038	1,045	
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)			
Hours of survey effort (*e*)	72	57	
Windfarm area (ha) visible within viewshed (*v*)[1]	440.99	341.67	
Observation effort (*e*v*)	31751.27	19475.47	
T_wV rate=$T_wV/e*v$	9.08E-06	1.49E-05	
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]			
Weight: proportion of total survey effort made at the VP	0.620	0.380	
Weighted T_wV rate (T_wV rate * weight)	5.63E-06	5.67E-06	
Total weighted occupancy rate	0.000011		birds seconds per ha/hour
Mean % activity hr^-1 in wind farm at risk height	0.791%		
Mean % activity hr^-1 in wind farm at rotor height (z)	0.728%		

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: annual (a) (footnote 2)	4,496	hours
Tw=z*a	32.72	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$ (footnote 3)	966,260,224	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.63	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$ footnote 4	958,601.99	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	116.8448	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	11	m/sec
$t=(d+L)/s$	0.45	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	261	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.078	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	18.355	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
99.00%	**0.1836**	**approx one collision every**	**5.45**	**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 during the period

[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=0.63m, wingspan 1.85m, flight speed= 11m/sec

Red Kite CRM Annual Yr 1 + 2

	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)	2,182	3,148	1,165	
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)				
Hours of survey effort (*e*)	144	36	96	
Windfarm area (ha) visible within viewshed (*v*)[1]	440.99	390.64	341.67	
Observation effort (*e*v*)	63502.55	14062.95	32914.68	
T_wV rate=$T_wV/e*v$	9.54E-06	6.22E-05	9.83E-06	
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]				
Weight: proportion of total survey effort made at the VP	0.575	0.127	0.298	
Weighted T_wV rate (T_wV rate * weight)	5.49E-06	7.91E-06	2.93E-06	
Total weighted occupancy rate	0.000016			birds seconds per ha/hour
Mean % activity hr^-1 in wind farm at risk height	1.143%			
Mean % activity hr^-1 in wind farm at rotor height (z)	1.052%			

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: annual (a) (footnote 2)	4,496	hours
Tw=z*a	47.30	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$ (footnote 3)	966,260,224	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.63	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$ footnote 4	958,601.99	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	168.9319	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	11	m/sec
$t=(d+L)/s$	0.45	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	377	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.078	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	26.538	collisions

Step 3.2: Adjusted using a range of avoidance rates:					
99.00%	**0.2654**	**approx one collision every**	**3.77**	**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

[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=0.63m, wingspan 1.85m, flight speed= 11m/sec

Kestrel: Probability of Collision

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	5.03	16.64	0.92	0.00115	16.12	0.89	0.00111
Wingspan	0.8	m	0.075	0.575	1.68	5.72	0.31	0.00236	5.20	0.29	0.00215
F: Flapping (0) or gliding (-	0		0.125	0.702	1.01	4.14	0.23	0.00285	3.50	0.19	0.00241
			0.175	0.860	0.72	3.60	0.20	0.00347	2.83	0.16	0.00273
Bird speed	12.7	m/sec	0.225	0.994	0.56	3.27	0.18	0.00405	2.37	0.13	0.00294
RotorDiam	138	m	0.275	0.947	0.46	2.64	0.15	0.00400	1.79	0.10	0.00271
RotationPeriod	4.29	sec	0.325	0.899	0.39	2.23	0.12	0.00399	1.42	0.08	0.00255
			0.375	0.851	0.34	1.94	0.11	0.00401	1.18	0.06	0.00243
			0.425	0.804	0.30	1.72	0.09	0.00402	0.99	0.05	0.00233
			0.475	0.756	0.26	1.53	0.08	0.00401	0.86	0.05	0.00224
Bird aspect ratioo: β	0.43		0.525	0.708	0.24	1.38	0.08	0.00400	0.75	0.04	0.00216
			0.575	0.660	0.22	1.25	0.07	0.00397	0.66	0.04	0.00209
			0.625	0.613	0.20	1.14	0.06	0.00393	0.59	0.03	0.00204
			0.675	0.565	0.19	1.04	0.06	0.00388	0.54	0.03	0.00199
			0.725	0.517	0.17	0.96	0.05	0.00382	0.49	0.03	0.00196
			0.775	0.470	0.16	0.88	0.05	0.00374	0.45	0.03	0.00194
			0.825	0.422	0.15	0.80	0.04	0.00365	0.43	0.02	0.00193
			0.875	0.374	0.14	0.74	0.04	0.00356	0.40	0.02	0.00194
			0.925	0.327	0.14	0.68	0.04	0.00345	0.38	0.02	0.00195
			0.975	0.279	0.13	0.62	0.03	0.00332	0.37	0.02	0.00198
				Overall p(collision) =			**Upwind**	**7.1%**		**Downwind**	**4.4%**
								Average	**5.7%**		

Kestrel CRM: Annual Yr 1

	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)	764	1,301	28	
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)				
Hours of survey effort (*e*)	72	36	39	
Windfarm area (ha) visible within viewshed (*v*)[1]	440.99	390.64	341.67	
Observation effort (*e*v*)	31751.27	14062.95	13439.21	
T_wV rate=$T_wV/e*v$	6.68E-06	2.57E-05	5.79E-07	
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]				
Weight: proportion of total survey effort made at the VP	0.536	0.237	0.227	
Weighted T_wV rate (T_wV rate * weight)	3.58E-06	6.10E-06	1.31E-07	
Total weighted occupancy rate	0.000010			birds seconds per ha/hour
Mean % activity hr^-1 in wind farm at risk height	0.687%			
Mean % activity hr^-1 in wind farm at rotor height (z)	0.632%			

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: annual (a) (footnote 2)	4,496	hours
Tw=z*a	28.42	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$ (footnote 3)	966,260,224	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.34	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$ footnote 4	902,213.64	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	95.5308	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	12.7	m/sec
$t=(d+L)/s$	0.37	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	261	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.057	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	13.507	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
95.00%	**0.6753**	**approx one collision every**	**1.48**	**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

[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=0.34m, wingspan 0.8m, flight speed= 12.7m/sec

Kestrel CRM: Annual Yr 2

	Viewsheds		
	1	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)	806	486	
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)			
Hours of survey effort (*e*)	72	57	
Windfarm area (ha) visible within viewshed (*v*)[1]	440.99	341.67	
Observation effort (*e*v*)	31751.27	19475.47	
T_wV rate=$T_wV/e*v$	7.05E-06	6.93E-06	
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]			
Weight: proportion of total survey effort made at the VP	0.620	0.380	
Weighted T_wV rate (T_wV rate * weight)	4.37E-06	2.64E-06	
Total weighted occupancy rate	0.000007		birds seconds per ha/hour
Mean % activity hr^-1 in wind farm at risk height	0.491%		
Mean % activity hr^-1 in wind farm at rotor height (z)	0.451%		

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: annual (a) (footnote 2)	4,496	hours
Tw=z*a	20.29	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$ (footnote 3)	966,260,224	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.34	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$ footnote 4	902,213.64	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	68.2109	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	12.7	m/sec
$t=(d+L)/s$	0.37	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	187	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.057	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	9.644	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
95.00%	0.4822	approx one collision every	2.07	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

[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=0.34m, wingspan 0.8m, flight speed= 12.7m/sec

Kestrel CRM: Annual Yr 1 + 2

	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)	1,570	1,787	514	
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)				
Hours of survey effort (*e*)	144	36	96	
Windfarm area (ha) visible within viewshed (*v*)[1]	440.99	390.64	341.67	
Observation effort (*e*v*)	63502.55	14062.95	32914.68	
T_wV rate=$T_wV/e*v$	6.87E-06	3.53E-05	4.34E-06	
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]				
Weight: proportion of total survey effort made at the VP	0.575	0.127	0.298	
Weighted T_wV rate (T_wV rate * weight)	3.95E-06	4.49E-06	1.29E-06	
Total weighted occupancy rate	0.000010			birds seconds per ha/hour
Mean % activity hr^-1 in wind farm at risk height	0.681%			
Mean % activity hr^-1 in wind farm at rotor height (z)	0.627%			

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: annual (a) (footnote 2)	4,496	hours
Tw=z*a	28.19	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$ (footnote 3)	966,260,224	m^3
Step 1.7: Volume swept by windfarm rotors (V_r)		
Bird length (L)	0.34	m
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$ footnote 4	902,213.64	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	94.7604	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	12.7	m/sec
$t=(d+L)/s$	0.37	seconds
Step 1.10: Number of rotor transits (N)		
$N=T_r/t$	259	rotor transits
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet[5]	0.057	
STAGE 3: Predicted mortality (birds per year)		
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	13.398	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
95.00%	**0.6699**	**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 daylight hours during the period

[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=0.34m, wingspan 0.8m, flight speed= 12.7m/sec

Golden Plover: Probability of Collision

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	6.93	20.47	0.82	0.00102	19.95	0.80	0.00100
Wingspan	0.72	m	0.075	0.575	2.31	6.99	0.28	0.00210	6.48	0.26	0.00194
F: Flapping (0) or gliding (-	1		0.125	0.702	1.39	5.11	0.20	0.00255	4.48	0.18	0.00224
			0.175	0.860	0.99	4.48	0.18	0.00313	3.71	0.15	0.00259
Bird speed	17.5	m/sec	0.225	0.994	0.77	4.07	0.16	0.00366	3.18	0.13	0.00286
RotorDiam	138	m	0.275	0.947	0.63	3.26	0.13	0.00359	2.41	0.10	0.00265
RotationPeriod	4.29	sec	0.325	0.899	0.53	2.70	0.11	0.00350	1.89	0.08	0.00245
			0.375	0.851	0.46	2.28	0.09	0.00341	1.51	0.06	0.00226
			0.425	0.804	0.41	1.95	0.08	0.00331	1.23	0.05	0.00208
			0.475	0.756	0.36	1.80	0.07	0.00341	1.12	0.04	0.00212
Bird aspect ratioo: β	0.39		0.525	0.708	0.33	1.60	0.06	0.00335	0.96	0.04	0.00202
			0.575	0.660	0.30	1.43	0.06	0.00328	0.83	0.03	0.00192
			0.625	0.613	0.28	1.28	0.05	0.00320	0.73	0.03	0.00182
			0.675	0.565	0.26	1.15	0.05	0.00311	0.65	0.03	0.00174
			0.725	0.517	0.24	1.04	0.04	0.00302	0.58	0.02	0.00167
			0.775	0.470	0.22	0.94	0.04	0.00291	0.52	0.02	0.00160
			0.825	0.422	0.21	0.85	0.03	0.00280	0.47	0.02	0.00155
			0.875	0.374	0.20	0.76	0.03	0.00267	0.43	0.02	0.00150
			0.925	0.327	0.19	0.69	0.03	0.00254	0.39	0.02	0.00146
			0.975	0.279	0.18	0.62	0.02	0.00240	0.37	0.01	0.00143
				Overall p(collision) =			**Upwind**	**5.9%**		**Downwind**	**3.9%**
								Average	**4.9%**		

Golden Plover CRM: Annual Yr 2

	Viewsheds		
	1	**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	1,172	
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)			
Hours of survey effort (*e*)	72	57	
Windfarm area (ha) visible within viewshed (*v*)[1]	440.99	341.67	
Observation effort (*e*v*)	31751.27	19475.47	
T_wV rate=$T_wV/e*v$	0.00E+00	1.67E-05	
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]			
Weight: proportion of total survey effort made at the VP	0.620	0.380	
Weighted T_wV rate (T_wV rate * weight)	0.00E+00	6.36E-06	
Total weighted occupancy rate	0.000006		birds seconds per ha/hour
Mean % activity hr^-1 in wind farm at risk height	0.445%		
Mean % activity hr^-1 in wind farm at rotor height (z)	0.409%		

Step 1.4: Total occupancy of risk volume during surveys (T_w)		
Hours potentially active: annual (a) (footnote 2)	5,564	hours
Tw=z*a	22.78	hours
Step 1.6: Flight risk volume (V_w)		
Risk volume: $V_w=A*h$ (footnote 3)	966,260,224	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	890,547.08	m^3
Step 1.8: Bird occupancy of rotor-swept volume (Tr)		
$T_r=T_w*(V_r/Vw)$	75.5737	seconds
Step 1.9: Time taken to transit rotor *(t)*		
Flight speed *(s)*	17.5	m/sec
$t=(d+L)/s$	0.26	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	12.717	collisions

Step 3.2: Adjusted using a range of avoidance rates:				
98.00%	**0.2543**	**approx one collision every**	**3.93**	**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

[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=0.48m, wingspan 1.1m, flight speed= 12m/sec

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