



## **Cloiche Wind Farm EIA Report**

### **Chapter 9 Technical Appendix:**

#### **9.3 Details of Collision Risk Modelling**

**April 2020**

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## 1. INTRODUCTION

### 1.1 Purpose and Scope of this Document

- 1.1.1 This is a technical appendix to Chapter 9 (Ornithology) of the Cloiche wind farm Environmental Impact Assessment (EIA) Report. This appendix provides further background information on the bird collision risk model (CRM) that has been used to inform the impact assessment for the key ornithological receptors.
- 1.1.2 The CRM follows the method known as the Band (Band *et al.* 2007<sup>1</sup>) or SNH model (SNH 2000<sup>2</sup>). This method is based on the analysis of observational data collected from timed bird flight activity surveys at fixed vantage points overlooking the proposed wind farm development site. It provides an estimate of the number of birds that would collide with a proposed wind farm. Because birds may take action to avoid a wind farm, or to avoid collision with individual wind turbines, an avoidance rate is applied to the output from the CRM. Details of the methods, assumptions, parameters and avoidance rates used in this case are provided in this report.
- 1.1.3 Further details of the flight activity survey (FAS) methods, survey effort and results are provided in Technical Appendix 9.1. The FAS vantage points and estimated viewsheds are shown on Figures 9.3a & b to Chapter 9 (Ornithology).

### 1.2 The Proposed Wind Farm & Wind Turbine Model

- 1.2.1 Details of the proposed wind farm are provided in Chapter 3: Description of the Proposed Development. Table 9.3.1 provides the assumed wind farm / wind turbine parameters relevant to the CRM calculations.
- 1.2.2 For the purpose of the CRM turbine model Vestas V136-4.3 was selected from seven possible turbine options being considered for the Proposed Development. The seven potential turbine options are listed below with their minimum and maximum blade tip heights:
- Vestas V136-4.3 (14-149.9m);
  - Nordex N133/4.8 (11.4-144.6m);
  - Siemens Gamesa SG 5.0-132 (18-149.9m);
  - GE 3.8-130 (20-149.9m);
  - Enercon E-138 EP3 (12-149.9m);
  - Enercon E136 EP5 (14-149.9m); and
  - Enercon E126 EP3 (23-149m).
- 1.2.3 The rotor diameters ranged from 126m to 138m and there was a small variation in apparent collision risk (c. 5%) across all models when tested in the CRM. The Vestas V136-4.3 and the Enercon E-136 EP5 both had a similar highest apparent risk. In

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<sup>1</sup> Band, W, Madders, M, & Whitfield, D.P. (2007). Developing field and analytical methods to assess avian collision risk at wind farms. In: Janss, G, de Lucas, M & Ferrer, M (eds.) Birds and Wind Farms. Lynx edicions, Barcelona.

<sup>2</sup> SNH (2000). Wind Farms and Birds: Calculating a theoretical collision risk assuming no avoiding action. Guidance Note Series, Scottish Natural Heritage.

discussion with SSE it was agreed that V136-4.3 would be used, as a worst case scenario, in relation to the assessment of bird collision risk for the EIA.

**Table 9.3.1: Wind farm and wind turbine parameters**

Parameter	Value (where appropriate split by West / East <sup>i</sup> )
No. turbines (no. of blades per turbine)	Total 36 (3), West 28 (3), East 8 (3)
Wind farm area <sup>ii</sup>	Total 1837 ha, West 1364 ha, East 472 ha)
Blade length <sup>iii</sup>	68 m
Rotor diameter <sup>iii</sup>	136 m
Hub height <sup>iii</sup>	82 m
Max blade height <sup>iii</sup>	149.9 m
Min blade height <sup>iii</sup>	14 m
Max chord <sup>iv</sup>	4.1 m
Pitch <sup>v</sup>	5°
Rotation period (fastest) <sup>vi</sup>	3.4 secs
Turbine operation time <sup>vii</sup>	87%

1.2.4 The assumptions underlying the parameters listed in Table 9.3.1 are as follows:

- i. For the purposes of this CRM, the 'proposed development' has been split into two distinct geographical areas or clusters, 'West' and 'East', refer to Figures 9.2a & b.
- ii. The 'wind farm area' or 'flight risk area' is defined by a boundary around the outermost turbines plus a 500 m wide buffer (based on turbine Layout December 2019).
- iii. Hub height, blade length, rotor diameter and max/min blade tip height are based on turbine model Vestas V136-4.3<sup>3</sup> (turbine details provided by SSE, in November 2019). Note that although the maximum tip height is 149.9 m for the purposes of the CRM this was rounded up to 150 m.
- iv. Max chord assumed to be 4.1 m based on turbine model Vestas V136-4.3.
- v. Pitch is variable but was assumed to be 5 degrees.
- vi. Based on details provided for turbine model Vestas V136-4.3 the maximum rotational period was assumed to be 3.4 seconds (i.e. 12-17.5 revs min<sup>-1</sup> = rotation period 5.0-3.4 secs)
- vii. The turbine operation time was assumed to be 87%.

### 1.3 Key Species Considered

1.3.1 Table 9.3.2 lists the target bird species, which had activity recorded within the proposed wind farm area and at collision risk height, with the key species-specific metrics used in the CRM.

<sup>3</sup> <https://www.senvion.com/global/en/products-services/wind-turbines/4xm/42m140-ebc/>

**Table 9.3.2: Target Species for which CRM was applied and their key biometrics and avoidance rates**

Common name	Scientific name	Bird length (m) <sup>i</sup>	Wingspan (m) <sup>i</sup>	Bird speed (m/s) <sup>ii</sup>	Avoidance rate (%) <sup>iii</sup>
Red kite	<i>Milvus milvus</i>	0.60	1.80	10	99
White-tailed eagle	<i>Haliaeetus albicilla</i>	0.80	2.20	15	95
Golden eagle	<i>Aquila chrysaetos</i>	0.93	2.25	15	99
Osprey	<i>Pandion haliaetus</i>	0.58	1.70	12	98
Golden plover	<i>Pluvialis apricaria</i>	0.29	0.76	10	98
Merlin	<i>Falco columbarius</i>	0.30	0.62	10	98
Peregrine	<i>Falco peregrinus</i>	0.51	1.13	13	98

*i* - Bird length / wingspan, largest reported size is used, most values taken from Snow, D. W. & Perrins, C. M. (1998). *The Birds of the Western Palearctic Concise Edition*.

*ii* - Bird flight speed values primarily from Alerstam T., Rosén M., Bäckman J., Ericson P.G.P., Hellgren O. (2007). *Flight speeds among bird species: allometric and phylogenetic effects*. *PLoS Biol*, 5, 1656-1662.

*iii* - Assumed avoidance rates taken from current SNH Guidance (i.e. *Avoidance Rates for the onshore SNH Wind Farm Collision Risk Model*, July 2017).

## 2. METHODS

### 2.1 Introduction

2.1.1 Wind turbine collision risk for key species has been estimated following the method developed by SNH (2000) and Band *et al.* (2007), commonly referred to as the Band Model. Estimates of collision risk/mortality have been calculated for key receptors where there was sufficient data to carry out the analysis. Species that are not included in the collision risk analysis are either not of conservation concern or are at low collision risk due to their flight behaviour, and/or are species which are infrequently present within the study area.

2.1.2 In summary, the Band / SNH model involves three stages:

- Stage one is the estimation of the number of bird transits through the proposed rotor swept volume per year based on observed flight activity data and parameters of the wind farm and wind turbine design.
- Stage two involves the estimation of the predicted proportion of transits through the rotor swept volume that would result in a collision. All predicted collisions are assumed to be fatal. This provides an estimate of the number of fatalities per year for the wind farm but assumes that birds take no avoiding action to prevent a collision.
- Finally, an assumed rate for collision avoidance is applied to the estimate.

2.1.3 In order to provide a biologically realistic estimate of collision risk it is necessary to assume that birds take action to avoid collision. The species-specific avoidance rates assumed in this assessment are given in Table 9.3.2.

2.1.4 The following sections provide further information on the methods and assumptions applicable to each stage of the CRM process.

## 2.2 Data Processing

- 2.2.1 The mapped bird flight activity data was digitised using MapInfo (version 11.5.4) GIS software and the recorded parameters entered into a pre-formatted spreadsheet (MS Excel). The data is used to derive an estimate of the occupancy of the proposed wind farm flight risk volume and from this an estimate of the number of annual collisions based on data collected during different seasons.
- 2.2.2 The vantage point viewsheds were created using OS Land-Form Panorama ® DTM data and MapInfo's Vertical Mapper Viewshed Analysis tool (viewpoint height = 1.5 m; viewshed off-set for turbines = 10 m; viewing radius = 2000 m); the viewshed was then cut to a maximum of 180° field of view and to the wind farm area (i.e. the FRA, the 500 m wind turbine buffer). The observer locations varied on occasions for vantage points 2, 5 and 6 (locations were changed to improved viewpoint locations or to be more accessible locations during winter conditions). The slightly different viewshed areas between the variants have been accounted for in the collision risk modelling.

## 2.3 Directional or Non-directional Flight Activity

- 2.3.1 There are two approaches to CRM calculations the application of which depends on certain assumptions about the use of the flight risk volume by the species under consideration. The 'directional' flight CRM method is appropriate for species that regularly pass through a proposed wind farm area in a clear direction. A typical scenario where this method is appropriate are flights by geese or swans commuting across a site, moving regularly between habitually used night-time roosts and daytime feeding areas. The alternative method assumes that flight activity is non-directional (essentially random) within the flight risk volume. This method is generally applicable to species that are active across the site, such as raptors during the breeding season.
- 2.3.2 In this case, observations from the flight activity surveys indicated that the non-directional method was applicable for all species included in the CRM calculations.

## 2.4 The Flight Risk Volume

- 2.4.1 Target or secondary species recorded during the FAS were considered to be at potential risk of collision if they were active within the minimum and maximum proposed turbine blade tip heights and within or near to the proposed wind turbine locations. This is known as the 'flight risk volume' (FRV).
- 2.4.2 In this case, the FRV is defined as the space between 150 to 14 m above ground level (the minimum and maximum blade tip heights) and within 500 m of the proposed wind turbines.
- 2.4.3 Due to differences between the height bands adopted during the surveys (which were completed when different wind turbines were proposed for the site) and the actual dimensions of the proposed model of wind turbine some adjustment has to be made to the bird flights activity data. The risk heights assumed during the FAS were as follows:
- Very high > 250 m (above ground level)
  - High 180 - 250 m
  - Medium 30 - 180 m
  - Low 10 - 30 m
  - Very Low < 10 m

- 2.4.4 For the estimate of occupancy of the FRV, 83% of the medium height band flight activity data (representing 30-155m) was included and this was augmented by all of the low height band data (10-30m) to account for the difference between the height bands and the proposed wind turbine hub height and blade dimensions. A total of 17% of the medium band data was included in the high flight activity data (representing 155-180m). For the purpose of the Collision Risk Model, therefore, the Risk Height range is 10m-155m, giving a 4-5m error margin at end of the turbine blades.

## 2.5 Seasons and Active Hours

- 2.5.1 For each species, where there was sufficient data recorded, flight activity from various survey periods (seasons) was analysed separately in the CRM. These seasons and the assumed total hours of potential activity, extrapolated from data recorded in each period, for each species are detailed in Table 9.3.3 below.
- 2.5.2 The relevant periods / potential active hours for each species are based on the pattern of observed activity during the survey period (i.e. August 2018 to August 2019).

**Table 9.3.3: Survey Periods and Assumed Active Hours for each Species**

Species	Season	Potential Active Hours	Details
Red kite	Whole year	4380	Daylight hours whole year
White-tailed eagle	March - October	3306	Daylight hours March - October
Golden eagle	Breeding season	2916	Daylight hours February - August
	Non-breeding season	1467	Daylight hours September - January
Osprey	April – August	2616	Daylight hours (including dawn & dusk) April - August
Golden plover	March - October	3306	Daylight hours March - October
Merlin	March - October	3306	Daylight hours March - October
Peregrine	Whole year	4380	Daylight hours whole year

## 2.6 Calculating Total Transits

- 2.6.1 For non-directional flights (all species) the number of transits of the proposed wind turbines was calculated.
- 2.6.2 Total seconds of activity within the FRV ( $V_w$ ) was derived from the survey data, accounting for survey effort, overlaps between vantage point viewsheds and any simultaneous watches from overlapping viewsheds, expressed as hours per hectare. This is then extrapolated for the relevant season and number of potentially active hours (see Table 8.2.3).
- 2.6.3 The combined volume swept by the wind turbine blades ( $V_r$ ) is calculated as follows:

$$V_r = \text{no. turbines} \times \text{rotor swept area} (\pi R^2) \times (\text{depth of the blade} + \text{bird length})$$

- 2.6.4 The number of bird transits through the combined rotor swept volume is calculated from the ratio between  $V_r$  and  $V_w$  applied to the total seconds of activity within  $V_w$ .

## 2.7 Collision Probability

- 2.7.1 The probability that a transit through the rotors would result in a collision was calculated for each species using a spreadsheet provided by SNH. The spreadsheet models collision risk based on species specific biometrics (i.e. wingspan and bird length), assumed flight speed, whether the bird is gliding or using flapping flight, wind direction and various parameters associated with the design and operation of the proposed wind turbines. Where there was a range of potential values (e.g. for bird biometrics or wind turbine parameters) the value that results in an increased collision probability was used. For example, rotor speed is variable and has a strong influence on collision probability, in this case the maximum rotor speed was used based on the reported specifications of the model of wind turbine proposed (or most similar model where the required parameters were unavailable, see Table 9.3.1).
- 2.7.2 The predicted number of collisions per season (or year), assuming that birds take no avoiding action, is calculated by applying the collision probability to the number of estimated transits through the rotor swept volume ( $V_r$ ).

## 2.8 Assumed Avoidance Rates

- 2.8.1 The predicted number of collisions is then adjusted by an assumed avoidance rate, which is typically between 95 and >99%. The avoidance rates, based on current SNH guidance<sup>4</sup>, are species-specific where there is sufficient empirical data available from published wind farm monitoring studies or are generic, and precautionary, for other species. The avoidance rates assumed in this case are provided in Table 9.3.2.

## 3. RESULTS

### 3.1 Introduction

- 3.1.1 The tables presented in this appendix provide further detail on the methods and calculations, following the SNH / Band Model, used to determine estimates of annual collision risk for key bird species based on the observed flight activity recorded at the study area between August 2018 and August 2019.

### 3.2 Summary Calculations to Estimate Flight Risk

- 3.2.1 Tables 9.3.4a & b provides a summary of the flight activity data within the FRA for the species considered in the CRM analysis.
- 3.2.2 Tables 9.3.5a-e provide a summary of the background calculations to estimate mean flight time at all heights and at-risk height per hectare per hour within the wind farm area. This is based on 2 km radii cut-off for vantage point viewsheds, and data from August 2018 to August 2019.
- 3.2.3 Tables 9.3.6a & b provide the results of the calculations to determine the number of bird transits through the wind farm rotors per year or season.

### 3.3 Estimated Number of Collision per Year

- 3.3.1 Tables 9.3.7a-c give the estimated number of collisions per year for each relevant species, the estimated total number of collisions over an assumed 25-year and 50-year lifetime of the proposed development and the estimated rate of collision. This is

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<sup>4</sup> Scottish Natural Heritage (2018). Avoidance Rates for the onshore SNH Wind Farm Collision Risk Model. September 2018, version 2.



adjusted by an assumed avoidance rate (following current published guidance) for each species, as detailed in Table 9.3.2.

### **3.4 Band Model Outputs**

- 3.4.1 Tables 9.3.8 a-g provide the raw output from SNH Band model collision probability spreadsheet for each species considered in the CRM.

**Table 9.3.4a: Summary Flight Activity Data for all Species (except golden eagle, see below) considered in the CRM Analysis**

Species	Survey Period	Area	Total Flights (Birds) Recorded	Flights (Birds) within FRA	Duration at 'Low / V. Low' (secs) <sup>i,ii</sup>	Duration at 'Medium' (secs) <sup>i,ii</sup>	Duration at 'High / V. High' (secs) <sup>i,ii</sup>	Total Duration (secs) <sup>i</sup>	% Low/ V. Low	% Med.	% High/ V. High
Red Kite	Aug 2018 – Mar 2019	West	0	0	0	0	0	0	~	~	~
		East	4	4	0	161	33	194	0.00	83.00	17.00
	Apr. – Aug. 2019	West	4	1	0	129	26	155	0.00	83.00	17.00
		East	10	9	85	790	580	1455	5.81	54.29	39.90
	Totals	West	4	1	0	129	26	155	0.00	83.00	17.00
		East	14	13	85	951	614	1649	5.13	57.67	37.20
White-tailed Eagle	Aug 2018 – Mar 2019	West	2	2	0	12	183	195	0.00	6.34	93.66
		East	0	0	0	0	0	0	~	~	~
	Apr. – Aug. 2019	West	6	3	8	213	461	682	1.23	31.20	67.57
		East	6	1	0	40	77	117	0.00	34.09	65.91
	Mar - Oct	West	8	5	8	225	643	877	0.96	25.68	73.37
		East	6	1	0	40	77	117	0.00	34.09	65.91
	Totals	West	8	5	8	225	643	877	0.96	25.68	73.37
		East	6	1	0	40	77	117	0.00	34.09	65.91
Osprey	Aug 2018 – Mar 2019	West	0	0	0	0	0	0	~	~	~
		East	0	0	0	0	0	0	~	~	~
	Apr. – Aug. 2019	West	2	2	0	186	32	218	0.00	85.34	14.66
		East	1	1	15	21	4	40	37.50	51.88	10.63
	Totals	West	2	2	0	186	32	218	0.00	85.34	14.66
		East	1	1	15	21	4	40	37.50	51.88	10.63
Golden Plover	Aug 2018 – Mar 2019	West	8	8	73	74	0	147	49.47	50.53	0.00
		East	7	0	0	0	0	0	~	~	~

Species	Survey Period	Area	Total Flights (Birds) Recorded	Flights (Birds) within FRA	Duration at 'Low / V. Low' (secs) <sup>i, ii</sup>	Duration at 'Medium' (secs) <sup>i, ii</sup>	Duration at 'High / V. High' (secs) <sup>i, ii</sup>	Total Duration (secs) <sup>i</sup>	% Low/ V. Low	% Med.	% High/ V. High
	Apr. – Aug. 2019	West	4	3	60	0	24	84	71.43	0.00	28.57
		East	0	0	0	0	0	0	~	~	~
	Mar - Oct	West	11	10	118	74	24	216	54.51	34.36	11.13
		East	7	0	0	0	0	0	~	~	~
	Totals	West	12	11	133	74	24	231	57.47	32.12	10.41
		East	7	0	0	0	0	0	~	~	~
Merlin	Aug 2018 – Mar 2019	West	5	4	0	145	21	166	0.00	87.61	12.39
		East	0	0	0	0	0	0	~	~	~
	Apr. – Aug. 2019	West	0	0	0	0	0	0	~	~	~
		East	0	0	0	0	0	0	~	~	~
	Mar - Oct	West	5	4	0	145	21	166	0.00	87.61	12.39
		East	0	0	0	0	0	0	~	~	~
	Totals	West	5	4	0	145	21	166	0.00	87.61	12.39
		East	0	0	0	0	0	0	~	~	~
Peregrine	Aug 2018 – Mar 2019	West	1	0	0	0	0	0	~	~	~
		East	3	2	0	109	16	126	0.00	87.06	12.94
	Apr. – Aug. 2019	West	2	1	0	120	25	145	0.00	83.00	17.00
		East	1	0	0	0	0	0	~	~	~
	Totals	West	3	1	0	120	25	145	0.00	83.00	17.00
		East	4	2	0	109	16	126	0.00	87.06	12.94

i. Duration = recorded time x proportion of flightline within FRA x number of birds.

ii. Flight activity height bands have been adjusted to account for differences between the height band categories for the flight activity survey and the dimensions of the proposed wind turbine model. 'Low' just includes activity surveyed at 'V Low'. The 'medium' height includes all activity surveyed as 'low' plus 83% of activity surveyed as 'medium'. The 'high' height band includes 17% of the activity surveyed at 'medium'.

**Table 9.3.4b: Summary Flight Activity Data for all Golden Eagle considered in the CRM Analysis**

Species (Age)	Survey Period	Area	Total Flights (Birds) Recorded	Flights (Birds) within FRA	Duration at 'Low / V. Low' (secs) <sup>i, ii</sup>	Duration at 'Medium' (secs) <sup>i, ii</sup>	Duration at 'High / V. High' (secs) <sup>i, ii</sup>	Total Duration (secs) <sup>i</sup>	% Low/ V. Low	% Med.	% High/ V. High
Golden Eagle (All)	Aug 2018 – Jan 2019	West	11	6	15	181	271	467	3.21	38.73	58.05
		East	27	10	30	45	979	1054	2.85	4.26	92.89
	Feb – Aug 2019	West	30	12	1	413	536	950	0.10	43.44	56.45
		East	19	11	155	547	870	1572	9.85	34.78	55.38
	Totals	West	41	18	16	593	807	1417	1.13	41.89	56.98
		East	46	21	185	592	1850	2626	7.04	22.53	70.44
Golden Eagle (Juv. / Imm.)	Aug 2018 – Jan 2019	West	3	3	15	135	265	415	3.61	32.61	63.77
		East	11	1	30	0	0	30	100.00	0.00	0.00
	Feb – Aug 2019	West	6	4	1	277	55	333	0.29	83.24	16.47
		East	6	5	84	83	10	176	47.57	46.91	5.52
	Totals	West	9	7	16	413	320	748	2.13	55.16	42.71
		East	17	6	114	83	10	206	55.20	40.08	4.72
Golden eagle (Sub-ad. / Ad. / Unk.)	Aug 2018 – Jan 2019	West	8	3	0	45	6	52	0.00	87.94	12.06
		East	16	9	0	45	979	1024	0.00	4.39	95.61
	Feb – Aug 2019	West	24	8	0	135	481	617	0.00	21.94	78.06
		East	13	6	71	464	861	1396	5.09	33.25	61.67
	Totals	West	32	11	0	181	488	668	0.00	27.04	72.96
		East	29	15	71	509	1840	2420	2.93	21.03	76.04

i. Duration = recorded time x proportion of flightline within FRA x number of birds.

ii. Flight activity height bands have been adjusted to account for differences between the height band categories for the flight activity survey and the dimensions of the proposed wind turbine model. 'Low' just includes activity surveyed at 'V Low'. The 'medium' height includes all activity surveyed as 'low' plus 83% of activity surveyed as 'medium'. The 'high' height band includes 17% of the activity surveyed at 'medium'.

**Table 9.3.5a: Summary calculations to estimate flight activity at all heights and at risk height per hectare per hour within the wind farm area, based on all data recorded from August 2018 to August 2019.**

Species	Area	VP	Total VP observation time (hr)	Viewshed area x observation time (hahr)	Time species observed, all heights (secs)	Time species observed at risk height (secs)	Total time all heights (hr hahr <sup>-1</sup> )	Total time risk height (hr hahr <sup>-1</sup> )	Mean activity all heights (hr hr <sup>-1</sup> )	Mean activity at risk height (hr hr <sup>-1</sup> )	
Red Kite	West	1	90.00	32201.52	155.39	128.98	1.34044E-06	1.11257E-06			
		2	78.00	34239.08	0.00	0.00	0	0			
		3	78.00	27597.16	0.00	0.00	0	0			
		4	78.00	22613.99	0.00	0.00	0	0			
		Total	324.00	116651.76	155.39	128.98	1.34044E-06	1.11257E-06			
		Mean					3.35111E-07	2.78142E-07	0.000457209	0.000379484	
	East	5	78.00	18199.32	194.15	161.15	2.96335E-06	2.45958E-06			
		6	79.00	22018.35	1454.84	789.81	1.83539E-05	9.96398E-06			
Total		157.00	40217.68	1648.99	950.95	2.13173E-05	1.24236E-05				
Mean						1.06586E-05	6.21178E-06	0.005035752	0.002934801		
Peregrine	West	1	90.00	32201.52	0.00	0.00	0	0			
		2	78.00	34239.08	0.00	0.00	0	0			
		3	78.00	27597.16	0.00	0.00	0	0			
		4	78.00	22613.99	145.00	120.35	1.7811E-06	1.47831E-06			
		Total	324.00	116651.76	145.00	120.35	1.7811E-06	1.47831E-06			
		Mean					4.45275E-07	3.69578E-07	0.000607511	0.000504235	

Species	Area	VP	Total VP observation time (hr)	Viewshed area x observation time (hahr)	Time species observed, all heights (secs)	Time species observed at risk height (secs)	Total time all heights (hr hahr <sup>-1</sup> )	Total time risk height (hr hahr <sup>-1</sup> )	Mean activity all heights (hr hr <sup>-1</sup> )	Mean activity at risk height (hr hr <sup>-1</sup> )	
	East	5	78.00	18199.32	0.00	0.00	0	0			
		6	79.00	22018.35	125.65	109.39	1.58517E-06	1.38003E-06			
		Total	157.00	40217.68	125.65	109.39	1.58517E-06	1.38003E-06			
		Mean					7.92584E-07	6.90015E-07	0.000374462	0.000326003	

**Table 9.3.5b: Summary calculations to estimate flight activity at all heights and at risk height per hectare per hour within the wind farm area, based on data recorded between March and October (August – October 2018 and March – August 2019).**

Species	Area	VP	Total VP observation time (hr)	Viewshed area x observation time (hahr)	Time species observed, all heights (secs)	Time species observed at risk height (secs)	Total time all heights (hr hahr <sup>-1</sup> )	Total time risk height (hr hahr <sup>-1</sup> )	Mean activity all heights (hr hr <sup>-1</sup> )	Mean activity at risk height (hr hr <sup>-1</sup> )	
White-tailed Eagle	West	1	63.00	22541.06	450.27	225.11	5.54875E-06	2.77407E-06			
		2	54.00	25188.80	0.00	0.00	0	0			
		3	52.00	18398.11	0.00	0.00	0	0			
		4	53.50	15510.88	426.48	0.00	7.63768E-06	0			
		Total	222.50	81638.85	876.75	225.11	1.31864E-05	2.77407E-06			
		Mean					3.29661E-06	6.93519E-07	0.004497733	0.000946203	
	East	5	51.00	11856.57	116.65	39.77	2.73281E-06	9.31622E-07			
		6	53.50	15085.65	0.00	0.00	0	0			

Species	Area	VP	Total VP observation time (hr)	Viewshed area x observation time (hahr)	Time species observed, all heights (secs)	Time species observed at risk height (secs)	Total time all heights (hr hahr <sup>-1</sup> )	Total time risk height (hr hahr <sup>-1</sup> )	Mean activity all heights (hr hr <sup>-1</sup> )	Mean activity at risk height (hr hr <sup>-1</sup> )
		Total	104.50	26942.22	116.65	39.77	2.73281E-06	9.31622E-07		
		Mean					1.3664E-06	4.65811E-07	0.000645567	0.000220076
Golden Plover	West	1	63.00	22541.06	24.00	0.00	2.95757E-07	0		
		2	54.00	25188.80	90.00	0.00	9.92505E-07	0		
		3	52.00	18398.11	101.57	74.06	1.53349E-06	1.1182E-06		
		4	53.50	15510.88	0.00	0.00	0	0		
		Total	222.50	81638.85	215.57	74.06	2.82175E-06	1.1182E-06		
		Mean					7.05438E-07	2.79549E-07	0.000962465	0.000381404
	East	5	51.00	11856.57	0.00	0.00	0	0		
		6	53.50	15085.65	0.00	0.00	0	0		
		Total	104.50	26942.22	0.00	0.00	0	0		
		Mean					0	0	0	0
Merlin	West	1	63.00	22541.06	29.03	24.20	3.57771E-07	2.98189E-07		
		2	54.00	25188.80	0.00	0.00	0	0		
		3	52.00	18398.11	136.69	120.99	2.0638E-06	1.82671E-06		
		4	53.50	15510.88	0.00	0.00	0	0		

Species	Area	VP	Total VP observation time (hr)	Viewshed area x observation time (hahr)	Time species observed, all heights (secs)	Time species observed at risk height (secs)	Total time all heights (hr hahr <sup>-1</sup> )	Total time risk height (hr hahr <sup>-1</sup> )	Mean activity all heights (hr hr <sup>-1</sup> )	Mean activity at risk height (hr hr <sup>-1</sup> )
		Total	222.50	81638.85	165.72	145.19	2.42157E-06	2.1249E-06		
		Mean					6.05394E-07	5.31225E-07	0.00082597	0.000724778
	East	5	51.00	11856.57	0.00	0.00	0	0		
		6	53.50	15085.65	0.00	0.00	0	0		
		Total	104.50	26942.22	0.00	0.00	0	0		
		Mean					0	0	0	0

**Table 9.3.5c: Summary calculations to estimate flight activity at all heights and at risk height per hectare per hour within the wind farm area, based on data recorded between April and August 2019.**

Species	Area	VP	Total VP observation time (hr)	Viewshed area x observation time (hahr)	Time species observed, all heights (secs)	Time species observed at risk height (secs)	Total time all heights (hr hahr <sup>-1</sup> )	Total time risk height (hr hahr <sup>-1</sup> )	Mean activity all heights (hr hr <sup>-1</sup> )	Mean activity at risk height (hr hr <sup>-1</sup> )
Osprey	West	1	42.00	15027.37	167.60	144.20	3.09798E-06	2.6656E-06		
		2	30.00	14042.39	50.00	41.50	9.89069E-07	8.20927E-07		
		3	30.00	10614.29	0.00	0.00	0	0		
		4	30.00	8697.69	0.00	0.00	0	0		
		Total	132.00	48381.75	217.60	185.70	4.08705E-06	3.48652E-06		
		Mean					1.02176E-06	8.71631E-07	0.001394043	0.001189211



Species	Area	VP	Total VP observation time (hr)	Viewshed area x observation time (hahr)	Time species observed, all heights (secs)	Time species observed at risk height (secs)	Total time all heights (hr hahr <sup>-1</sup> )	Total time risk height (hr hahr <sup>-1</sup> )	Mean activity all heights (hr hr <sup>-1</sup> )	Mean activity at risk height (hr hr <sup>-1</sup> )	
	East	5	30.00	7047.50	40	20.75	1.5766E-06	8.17863E-07			
		6	30.00	8156.13	0.00	0.00	0	0			
		Total	60.00	15203.63	40.00	20.75	1.5766E-06	8.17863E-07			
		Mean					7.88301E-07	4.08931E-07	0.000372439	0.000193203	

**Table 9.3.5d: Summary calculations to estimate golden eagle flight activity at all heights and at risk height per hectare per hour within the wind farm area, based on all data recorded from 14 August 2018 to 31 January 2019 (non-breeding season).**

Species (Age)	Area	VP	Total VP observation time (hr)	Viewshed area x observation time (hahr)	Time species observed, all heights (secs)	Time species observed at risk height (secs)	Total time all heights (hr hahr <sup>-1</sup> )	Total time risk height (hr hahr <sup>-1</sup> )	Mean activity all heights (hr hr <sup>-1</sup> )	Mean activity at risk height (hr hr <sup>-1</sup> )	
Golden Eagle (All)	West	1	36.00	12880.61	371.19	98.99	8.00499E-06	2.13478E-06			
		2	39.00	15892.79	50.43	41.86	8.8139E-07	7.31554E-07			
		3	34.00	12029.53	0.00	0.00	0	0			
		4	36.50	10582.19	45.00	39.90	1.18123E-06	1.04736E-06			
		Total	145.5	51385.12	466.62	180.75	1.00676E-05	3.91369E-06			
	Mean					2.5169E-06	9.78422E-07	0.00343394	0.001334912		
	East	5	36.00	8332.82	945.00	37.35	3.15019E-05	1.24508E-06			
		6	33.00	9512.29	109.32	7.60	3.19241E-06	2.21916E-07			

Species (Age)	Area	VP	Total VP observation time (hr)	Viewshed area x observation time (hahr)	Time species observed, all heights (secs)	Time species observed at risk height (secs)	Total time all heights (hr hahr <sup>-1</sup> )	Total time risk height (hr hahr <sup>-1</sup> )	Mean activity all heights (hr hr <sup>-1</sup> )	Mean activity at risk height (hr hr <sup>-1</sup> )
		Total	69.00	17845.11	1054.32	44.95	3.46944E-05	1.46699E-06		
		Mean					1.73472E-05	7.33496E-07	0.008195846	0.000346548
Golden Eagle (Juv. / Imm.)	West	1	36.00	12880.61	371.19	98.99	8.00499E-06	2.13478E-06		
		2	39.00	15892.79	43.79	36.34	7.65307E-07	6.35205E-07		
		3	34.00	12029.53	0.00	0.00	0	0		
		4	36.50	10582.19	0.00	0.00	0	0		
		Total	145.5	51385.12	414.98	135.33	8.7703E-06	2.76998E-06		
		Mean					2.19257E-06	6.92496E-07	0.002991442	0.000944807
	East	5	36.00	8332.82	30.00	0.00	1.00006E-06	0		
		6	33.00	9512.29	0.00	0.00	0	0		
		Total	69.00	17845.11	30.00	0.00	1.00006E-06	0		
		Mean					5.00031E-07	0	0.000236245	0
Golden eagle (Sub-ad. / Ad. / Unk.)	West	1	36.00	12880.61	0.00	0.00	0	0		
		2	39.00	15892.79	6.64	5.51	1.16083E-07	9.63492E-08		
		3	34.00	12029.53	0.00	0.00	0	0		
		4	36.50	10582.19	45.00	39.90	1.18123E-06	1.04736E-06		
		Total	145.5	51385.12	51.64	45.41	1.29731E-06	1.14371E-06		

Species (Age)	Area	VP	Total VP observation time (hr)	Viewshed area x observation time (hahr)	Time species observed, all heights (secs)	Time species observed at risk height (secs)	Total time all heights (hr hahr <sup>-1</sup> )	Total time risk height (hr hahr <sup>-1</sup> )	Mean activity all heights (hr hr <sup>-1</sup> )	Mean activity at risk height (hr hr <sup>-1</sup> )
		Mean					3.24328E-07	2.85927E-07	0.000442498	0.000390104
	East	5	36.00	8332.82	915.00	37.35	3.05019E-05	1.24508E-06		
		6	33.00	9512.29	109.32	7.60	3.19241E-06	2.21916E-07		
		Total	69.00	17845.11	1024.32	44.95	3.36943E-05	1.46699E-06		
		Mean					1.68471E-05	7.33496E-07	0.007959602	0.000346548

**Table 9.3.5e: Summary calculations to estimate golden eagle flight activity at all heights and at risk height per hectare per hour within the wind farm area, based on all data recorded from 1 February 2019 to 14 August 2019 (breeding season).**

Species (Age)	Area	VP	Total VP observation time (hr)	Viewshed area x observation time (hahr)	Time species observed, all heights (secs)	Time species observed at risk height (secs)	Total time all heights (hr hahr <sup>-1</sup> )	Total time risk height (hr hahr <sup>-1</sup> )	Mean activity all heights (hr hr <sup>-1</sup> )	Mean activity at risk height (hr hr <sup>-1</sup> )
Golden Eagle (All)	West	1	54.00	19320.91	327.08	100.13	4.70251E-06	1.43959E-06		
		2	39.00	18346.29	19.16	18.46	2.9014E-07	2.79425E-07		
		3	44.00	15567.63	0.00	0.00	0	0		
		4	41.50	12031.80	603.66	294.10	1.39366E-05	6.7898E-06		
		Total	178.50	65266.64	949.90	412.68	1.89293E-05	8.50881E-06		
		Mean					4.73231E-06	2.1272E-06	0.006456539	0.002902253
	East	5	42.00	9866.50	340.93	222.23	9.59838E-06	6.25664E-06		

Species (Age)	Area	VP	Total VP observation time (hr)	Viewshed area x observation time (hahr)	Time species observed, all heights (secs)	Time species observed at risk height (secs)	Total time all heights (hr hahr <sup>-1</sup> )	Total time risk height (hr hahr <sup>-1</sup> )	Mean activity all heights (hr hr <sup>-1</sup> )	Mean activity at risk height (hr hr <sup>-1</sup> )
		6	46.00	12506.06	1230.72	324.33	2.73361E-05	7.2038E-06		
		Total	88.00	22372.56	1571.65	546.56	3.69344E-05	1.34604E-05		
		Mean					1.84672E-05	6.73022E-06	0.008725024	0.00317976
Golden Eagle (Juv. / Imm.)	West	1	54.00	19320.91	119.68	100.13	1.72058E-06	1.43959E-06		
		2	39.00	18346.29	0.00	0.00	0	0		
		3	44.00	15567.63	0.00	0.00	0	0		
		4	41.50	12031.80	213.56	177.25	4.93034E-06	4.09218E-06		
		Total	178.50	65266.64	333.23	277.38	6.65092E-06	5.53177E-06		
		Mean					1.66273E-06	1.38294E-06	0.002268548	0.00188682
	East	5	42.00	9866.50	176.13	82.62	4.95858E-06	2.32594E-06		
		6	46.00	12506.06	0.00	0.00	0	0		
		Total	88.00	22372.56	176.13	82.62	4.95858E-06	2.32594E-06		
		Mean					2.47929E-06	1.16297E-06	0.001171366	0.000549457
Golden eagle (Sub-ad. / Ad. / Unk.)	West	1	54.00	19320.91	207.41	0.00	2.98193E-06	0		
		2	39.00	18346.29	19.16	18.46	2.9014E-07	2.79425E-07		
		3	44.00	15567.63	0.00	0.00	0	0		
		4	41.50	12031.80	390.10	116.85	9.00626E-06	2.69762E-06		

Species (Age)	Area	VP	Total VP observation time (hr)	Viewshed area x observation time (hahr)	Time species observed, all heights (secs)	Time species observed at risk height (secs)	Total time all heights (hr hahr <sup>-1</sup> )	Total time risk height (hr hahr <sup>-1</sup> )	Mean activity all heights (hr hr <sup>-1</sup> )	Mean activity at risk height (hr hr <sup>-1</sup> )	
		Total	178.50	65266.64	616.67	135.30	1.22783E-05	2.97704E-06			
		Mean					3.06958E-06	7.4426E-07	0.004187991	0.001015432	
	East	5	42.00	9866.50	164.80	139.62	4.6398E-06	3.9307E-06			
		6	46.00	12506.06	1230.72	324.33	2.73361E-05	7.2038E-06			
		Total	88.00	22372.56	1395.52	463.94	3.19759E-05	1.11345E-05			
		Mean						1.59879E-05	5.56725E-06	0.007553659	0.002630304

**Table 9.3.6a: Results of calculations to determine the number of transits through the wind farm rotors for non-directional flights (excl. golden eagle)**

Data set	Species	Area	Combined volume swept by rotors ( $V_r$ ) ( $m^3$ ) <sup>i</sup>	Occupancy of the flight risk volume (hr) <sup>ii</sup>	Occupancy of rotor swept volume (secs) <sup>iii</sup>	Time taken to clear rotors (secs) <sup>iv</sup>	Number of transits through rotors <sup>v</sup>	Average collision risk <sup>vi</sup>
All data (14 Aug 2018 – 14 Aug 2019)	Red Kite	West	1911715.32	1.66	6.1649	0.4700	11.41	9.1
		East	546204.3772	12.85	39.3377	0.4700	72.82	9.1
	Peregrine	West	1875108.006	2.21	8.0347	0.3546	19.71	7.2
		East	535745.1445	1.43	4.2860	0.3546	10.52	7.2
March to October data	White-tailed Eagle	West	1993064.908	3.13	12.0961	0.3267	32.22	8.7
		East	569447.1167	0.73	2.3213	0.3267	6.18	8.7
	Golden Plover	West	1785623.459	1.26	4.3683	0.4390	8.66	6.3
		East	510178.1311	0.00	0.0000	0.4390	0.00	6.3
	Merlin	West	1789690.938	2.40	8.3200	0.4400	16.45	6.3
		East	511340.268	0.00	0.0000	0.4400	0.00	6.3
Apr 2019 – Aug 2019	Osprey	West	1903580.361	3.11	11.4896	0.3900	25.63	8.1
		East	543880.1033	0.51	1.5401	0.3900	3.44	8.1

*i* - Total rotor sweep area ( $m^2$ ) multiplied by ( $d+l$ ) i.e. the width of the rotor (max chord) and bird length, ( $m$ ).

*ii* - Occupancy of the flight risk volume in hours per year, derived from the mean risk-height flight time ( $hr\ hahr^{-1}$ ) multiplied by the flight risk area ( $ha$ ) multiplied by the potential active hours ( $hr$ ).

*iii* - Occupancy of rotor swept volume, derived from the occupancy of the flight risk volume (secs) divided by the flight risk volume ( $m^3$ ) multiplied by the combined rotor volume ( $V_r$ ) ( $m^3$ ).

*iv* - Time taken for the bird to clear the rotors (secs), derived from maximum rotor depth (max chord) and bird length ( $d+l$ ) ( $m$ ), divided by the assumed flight speed ( $m\ s^{-1}$ ).

*v* - Number of transits through the rotors is derived from the occupancy of the rotor swept volume divided by the time taken for the bird to clear the rotors, multiplied by operation time.

*vi* - Average collision risk derived from the SNH probability spreadsheet (see Tables 9.3.8 a-f below). The figure is based on an average between the upwind and downwind flight collision risk values. Flapping rather than gliding flight has been assumed in all cases.

**Table 9.3.6b: Results of calculations to determine the number of golden eagle transits through the wind farm rotors for non-directional flights.**

Data set	Species (Age)	Area	Combined volume swept by rotors ( $V_r$ ) ( $m^3$ ) <sup>i</sup>	Occupancy of the flight risk volume (hr) <sup>ii</sup>	Occupancy of rotor swept volume (secs) <sup>iii</sup>	Time taken to clear rotors (secs) <sup>iv</sup>	Number of transits through rotors <sup>v</sup>	Average collision risk <sup>vi</sup>
Non-breeding season (14 Aug 2018 – 31 Jan 2019)	Golden Eagle (All)	West	2045942.141	1.96	7.7734	0.3353	20.17	9.4
		East	584554.8973	0.51	1.6650	0.3353	4.32	9.4
	Golden Eagle (Juv. / Imm.)	West	2045942.141	1.39	5.5018	0.3353	14.27	9.4
		East	584554.8973	0.00	0.0000	0.3353	0.00	9.4
	Golden eagle (Sub-ad. / Ad. / Unk.)	West	2045942.141	0.57	2.2717	0.3353	5.89	9.4
		East	584554.8973	0.51	1.6650	0.3353	4.32	9.4
Breeding season (1 Feb 2019 – 14 Aug 2019)	Golden Eagle (All)	West	2045942.141	8.46	33.5934	0.3353	87.16	9.4
		East	584554.8973	9.27	30.3673	0.3353	78.79	9.4
	Golden Eagle (Juv. / Imm.)	West	2045942.141	5.50	21.8398	0.3353	56.66	9.4
		East	584554.8973	1.60	5.2474	0.3353	13.61	9.4
	Golden eagle (Sub-ad. / Ad. / Unk.)	West	2045942.141	2.96	11.7536	0.3353	30.49	9.4
		East	584554.8973	7.67	25.1199	0.3353	65.17	9.4

*i* - Total rotor sweep area ( $m^2$ ) multiplied by ( $d+l$ ) i.e. the width of the rotor (max chord) and bird length, ( $m$ ).

*ii* - Occupancy of the flight risk volume in hours per year, derived from the mean risk-height flight time ( $hr\ hahr^{-1}$ ) multiplied by the flight risk area ( $ha$ ) multiplied by the potential active hours ( $hr$ ).

*iii* - Occupancy of rotor swept volume, derived from the occupancy of the flight risk volume (secs) divided by the flight risk volume ( $m^3$ ) multiplied by the combined rotor volume ( $V_r$ ) ( $m^3$ ).

*iv* - Time taken for the bird to clear the rotors (secs), derived from maximum rotor depth (max chord) and bird length ( $d+l$ ) ( $m$ ), divided by the assumed flight speed ( $m\ s^{-1}$ ).

*v* - Number of transits through the rotors is derived from the occupancy of the rotor swept volume divided by the time taken for the bird to clear the rotors, multiplied by operation time.

*vi* - Average collision risk derived from the SNH probability spreadsheet (see Tables 9.3.8 a-f below). The figure is based on an average between the upwind and downwind flight collision risk values. Flapping rather than gliding flight has been assumed in all cases.

**Table 9.3.7a: Estimated collisions per year at the assumed collision avoidance rates for non-directional flights (excl. golden eagle).**

Data set	Species	Avoidance rate (%)	Area	No Avoidance collisions	Collisions per year	Total over 25 years	Total over 50 years	Years between collisions
All data (14 Aug 2018 – 14 Aug 2019)	Red Kite	99	West	1.04	0.01	0.26	0.52	96.30
			East	6.63	0.07	1.66	3.31	15.09
	Peregrine	98	West	1.42	0.03	0.71	1.42	35.23
			East	0.76	0.02	0.38	0.76	66.04
March to October data	White-tailed Eagle	95	West	2.80	0.14	3.50	7.01	7.14
			East	0.54	0.03	0.67	1.34	37.18
	Golden Plover	98	West	0.55	0.01	0.27	0.55	91.68
			East	0.00	~	~	~	~
	Merlin	98	West	1.04	0.02	0.52	1.04	48.24
			East	0.00	~	~	~	~
Apr 2019 – Aug 2019	Osprey	98	West	2.08	0.04	1.04	2.08	24.08
			East	0.28	0.01	0.14	0.28	179.67



**Table 9.3.7b: Estimated golden eagle collisions per season at the assumed collision avoidance rates for non-directional flights.**

Data set	Species (Age)	Avoidance rate (%)	Area	No Avoidance collisions	Collisions per season	Total over 25 seasons	Total over 50 seasons	Years between collisions
Non-breeding season (14 Aug 2018 – 31 Jan 2019)	Golden Eagle (All)	99	West	1.90	0.02	0.47	0.95	52.75
			East	0.41	0.00	0.10	0.20	246.27
	Golden Eagle (Juv. / Imm.)	99	West	1.34	0.01	0.34	0.67	74.53
			East	0.00	~	~	~	~
	Golden eagle (Sub-ad. / Ad. / Unk.)	99	West	0.55	0.01	0.14	0.28	180.50
			East	0.41	0.00	0.10	0.20	246.27
Breeding season (1 Feb 2019 – 14 Aug 2019)	Golden Eagle (All)	99	West	8.19	0.08	2.05	4.10	12.21
			East	7.41	0.07	1.85	3.70	13.50
	Golden Eagle (Juv. / Imm.)	99	West	5.33	0.05	1.33	2.66	18.78
			East	1.28	0.01	0.32	0.64	78.14
	Golden eagle (Sub-ad. / Ad. / Unk.)	99	West	2.87	0.03	0.72	1.43	34.89
			East	6.13	0.06	1.53	3.06	16.32

**Table 9.3.7c: Estimated golden eagle collisions per year at the assumed collision avoidance rates for non-directional flights (breeding season + non-breeding season collisions).**

Data set	Species (Age)	Avoidance rate (%)	Area	No Avoidance collisions	Collisions per year	Total over 25 years	Total over 50 years	Years between collisions
Breeding season + non breeding season (14 Aug 2018 – 31 Jan 2019, and 1 Feb 2019 – 14 Aug 2019)	Golden Eagle (All)	99	West	10.09	0.10	2.52	5.04	9.91
			East	7.81	0.08	1.95	3.91	12.80
	Golden Eagle (Juv. / Imm.)	99	West	6.67	0.07	1.67	3.33	15.00
			East	1.28	0.01	0.32	0.64	78.14
	Golden eagle (Sub-ad. / Ad. / Unk.)	99	West	3.42	0.03	0.86	1.71	29.24
			East	6.53	0.07	1.63	3.27	15.31

**Table 9.3.8a: Output from SNH Band model collision probability spreadsheet for red kite.**

K: [1D or [3D] (0 or 1)		Calculation of alpha and p(collision) as a function of radius										
NoBlades							Upwind:			Downwind:		
MaxChord		r/R	c/C	$\alpha$	collide	p(collision)		contribution	collide	p(collision)		
Pitch (degrees)		radius	chord	alpha	length			from radius r	length			
BirdLength	0.6	m	0.025	0.575	3.18	13.41	1.00	0.00125	13.00	1.00	0.00125	
Wingspan	1.8	m	0.075	0.575	1.06	4.61	0.41	0.00305	4.20	0.37	0.00278	
F: Flapping (0) or gliding (+1)	0		0.125	0.702	0.64	3.22	0.28	0.00355	2.72	0.24	0.00300	
			0.175	0.860	0.45	2.72	0.24	0.00421	2.11	0.19	0.00326	
Bird speed	10	m/sec	0.225	0.994	0.35	2.43	0.21	0.00482	1.72	0.15	0.00341	
RotorDiam	136	m	0.275	0.947	0.29	2.06	0.18	0.00499	1.38	0.12	0.00335	
RotationPeriod	3.40	sec	0.325	0.899	0.24	1.82	0.16	0.00522	1.18	0.10	0.00338	
			0.375	0.851	0.21	1.64	0.14	0.00543	1.03	0.09	0.00342	
			0.425	0.804	0.19	1.50	0.13	0.00563	0.93	0.08	0.00348	
			0.475	0.756	0.17	1.39	0.12	0.00581	0.85	0.07	0.00355	
			0.525	0.708	0.15	1.29	0.11	0.00598	0.79	0.07	0.00364	
			0.575	0.660	0.14	1.21	0.11	0.00614	0.74	0.07	0.00374	
			0.625	0.613	0.13	1.14	0.10	0.00627	0.70	0.06	0.00386	
			0.675	0.565	0.12	1.07	0.09	0.00640	0.67	0.06	0.00399	
			0.725	0.517	0.11	1.02	0.09	0.00650	0.65	0.06	0.00414	
			0.775	0.470	0.10	0.96	0.09	0.00660	0.63	0.06	0.00430	
	0.825	0.422	0.10	0.92	0.08	0.00668	0.62	0.05	0.00448			
	0.875	0.374	0.09	0.87	0.08	0.00674	0.61	0.05	0.00467			
	0.925	0.327	0.09	0.83	0.07	0.00679	0.60	0.05	0.00491			
	0.975	0.279	0.08	0.79	0.07	0.00682	0.61	0.05	0.00522			
Bird aspect ratio: $\beta$		0.33										
<b>Overall p(collision) =</b>						<b>Upwind</b>	<b>10.9%</b>	<b>Downwind</b>	<b>7.4%</b>			
						<b>Average</b>	<b>9.1%</b>					

**Table 9.3.8b: Output from SNH Band model collision probability spreadsheet for white-tailed eagle.**

K: [1D or [3D] (0 or 1)		Calculation of alpha and p(collision) as a function of radius										
NoBlades							Upwind:			Downwind:		
MaxChord		r/R	c/C	$\alpha$	collide	p(collision)		contribution	collide	p(collision)		
Pitch (degrees)		radius	chord	alpha	length			from radius r	length	from radius r		
BirdLength	0.8	m	0.025	0.575	4.77	21.92	1.00	0.00125	21.51	1.00	0.00125	
Wingspan	2.2	m	0.075	0.575	1.59	7.44	0.44	0.00328	7.03	0.41	0.00310	
F: Flapping (0) or gliding (+1)	0		0.125	0.702	0.95	5.09	0.30	0.00374	4.59	0.27	0.00337	
			0.175	0.860	0.68	4.20	0.25	0.00433	3.59	0.21	0.00370	
Bird speed	15	m/sec	0.225	0.994	0.53	3.68	0.22	0.00487	2.97	0.17	0.00393	
RotorDiam	136	m	0.275	0.947	0.43	2.97	0.17	0.00481	2.29	0.13	0.00371	
RotationPeriod	3.40	sec	0.325	0.899	0.37	2.48	0.15	0.00474	1.84	0.11	0.00351	
			0.375	0.851	0.32	2.21	0.13	0.00488	1.60	0.09	0.00353	
			0.425	0.804	0.28	2.01	0.12	0.00502	1.43	0.08	0.00359	
			0.475	0.756	0.25	1.85	0.11	0.00516	1.31	0.08	0.00365	
			0.525	0.708	0.23	1.71	0.10	0.00528	1.20	0.07	0.00372	
			0.575	0.660	0.21	1.60	0.09	0.00540	1.12	0.07	0.00380	
			0.625	0.613	0.19	1.50	0.09	0.00550	1.06	0.06	0.00389	
			0.675	0.565	0.18	1.41	0.08	0.00560	1.01	0.06	0.00400	
			0.725	0.517	0.16	1.33	0.08	0.00568	0.96	0.06	0.00411	
			0.775	0.470	0.15	1.26	0.07	0.00576	0.93	0.05	0.00423	
			0.825	0.422	0.14	1.20	0.07	0.00582	0.90	0.05	0.00436	
			0.875	0.374	0.14	1.14	0.07	0.00588	0.87	0.05	0.00450	
			0.925	0.327	0.13	1.09	0.06	0.00592	0.86	0.05	0.00465	
			0.975	0.279	0.12	1.04	0.06	0.00596	0.84	0.05	0.00482	
<b>Overall p(collision) =</b>						<b>Upwind</b>	<b>9.9%</b>	<b>Downwind</b>	<b>7.5%</b>			
						<b>Average</b>	<b>8.7%</b>					

**Table 9.3.8c: Output from SNH Band model collision probability spreadsheet for golden eagle.**

K: [1D or [3D] (0 or 1)		Calculation of alpha and p(collision) as a function of radius										
NoBlades	3						Upwind:			Downwind:		
MaxChord	4.1	m	r/R	c/C	$\alpha$	collide	contribution		collide	contribution		
Pitch (degrees)	5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r	
BirdLength	0.93	m	0.025	0.575	4.77	22.16	1.00	0.00125	21.75	1.00	0.00125	
Wingspan	2.25	m	0.075	0.575	1.59	7.52	0.44	0.00332	7.11	0.42	0.00314	
F: Flapping (0) or gliding (+1)	0		0.125	0.702	0.95	5.14	0.30	0.00378	4.63	0.27	0.00341	
			0.175	0.860	0.68	4.24	0.25	0.00436	3.62	0.21	0.00373	
Bird speed	15	m/sec	0.225	0.994	0.53	3.70	0.22	0.00490	2.99	0.18	0.00396	
RotorDiam	136	m	0.275	0.947	0.43	2.99	0.18	0.00484	2.32	0.14	0.00375	
RotationPeriod	3.40	sec	0.325	0.899	0.37	2.60	0.15	0.00497	1.96	0.12	0.00374	
			0.375	0.851	0.32	2.34	0.14	0.00516	1.73	0.10	0.00382	
			0.425	0.804	0.28	2.14	0.13	0.00535	1.56	0.09	0.00391	
			0.475	0.756	0.25	1.98	0.12	0.00552	1.44	0.08	0.00401	
			0.525	0.708	0.23	1.84	0.11	0.00568	1.33	0.08	0.00412	
			0.575	0.660	0.21	1.73	0.10	0.00584	1.25	0.07	0.00424	
			0.625	0.613	0.19	1.63	0.10	0.00598	1.19	0.07	0.00437	
			0.675	0.565	0.18	1.54	0.09	0.00611	1.14	0.07	0.00451	
			0.725	0.517	0.16	1.46	0.09	0.00624	1.09	0.06	0.00466	
			0.775	0.470	0.15	1.39	0.08	0.00635	1.06	0.06	0.00482	
0.825	0.422	0.14	1.33	0.08	0.00646	1.03	0.06	0.00499				
0.875	0.374	0.14	1.27	0.07	0.00655	1.00	0.06	0.00517				
0.925	0.327	0.13	1.22	0.07	0.00663	0.99	0.06	0.00536				
0.975	0.279	0.12	1.17	0.07	0.00671	0.97	0.06	0.00556				
<b>Overall p(collision) =</b>						<b>Upwind</b>	<b>10.6%</b>	<b>Downwind</b>	<b>8.3%</b>			
						<b>Average</b>	<b>9.4%</b>					

**Table 9.3.8d: Output from SNH Band model collision probability spreadsheet for osprey.**

K: [1D or [3D] (0 or 1)		Calculation of alpha and p(collision) as a function of radius										
NoBlades	3						Upwind:			Downwind:		
MaxChord	4.1	m	r/R	c/C	$\alpha$	collide	contribution		collide	contribution		
Pitch (degrees)	5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r	
BirdLength	0.58	m	0.025	0.575	3.82	15.67	1.00	0.00125	15.26	1.00	0.00125	
Wingspan	1.7	m	0.075	0.575	1.27	5.36	0.39	0.00296	4.95	0.36	0.00273	
F: Flapping (0) or gliding (+1)	0		0.125	0.702	0.76	3.74	0.27	0.00344	3.24	0.24	0.00298	
			0.175	0.860	0.55	3.15	0.23	0.00406	2.54	0.19	0.00326	
Bird speed	12	m/sec	0.225	0.994	0.42	2.80	0.21	0.00463	2.09	0.15	0.00346	
RotorDiam	136	m	0.275	0.947	0.35	2.27	0.17	0.00459	1.59	0.12	0.00322	
RotationPeriod	3.40	sec	0.325	0.899	0.29	1.98	0.15	0.00473	1.34	0.10	0.00320	
			0.375	0.851	0.25	1.77	0.13	0.00488	1.16	0.09	0.00320	
			0.425	0.804	0.22	1.60	0.12	0.00501	1.03	0.08	0.00322	
			0.475	0.756	0.20	1.47	0.11	0.00514	0.93	0.07	0.00325	
Bird aspect ratio: $\beta$	0.34		0.525	0.708	0.18	1.36	0.10	0.00525	0.85	0.06	0.00329	
			0.575	0.660	0.17	1.26	0.09	0.00534	0.79	0.06	0.00335	
			0.625	0.613	0.15	1.18	0.09	0.00543	0.74	0.05	0.00342	
			0.675	0.565	0.14	1.11	0.08	0.00550	0.70	0.05	0.00350	
			0.725	0.517	0.13	1.04	0.08	0.00556	0.67	0.05	0.00359	
			0.775	0.470	0.12	0.98	0.07	0.00561	0.65	0.05	0.00370	
			0.825	0.422	0.12	0.93	0.07	0.00564	0.63	0.05	0.00381	
			0.875	0.374	0.11	0.88	0.06	0.00567	0.61	0.05	0.00394	
			0.925	0.327	0.10	0.83	0.06	0.00568	0.60	0.04	0.00409	
			0.975	0.279	0.10	0.79	0.06	0.00567	0.59	0.04	0.00424	
<b>Overall p(collision) =</b>						<b>Upwind</b>	<b>9.6%</b>	<b>Downwind</b>	<b>6.7%</b>			
						<b>Average</b>	<b>8.1%</b>					

**Table 9.3.8e: Output from SNH Band model collision probability spreadsheet for golden plover.**

K: [1D or [3D] (0 or 1)		Calculation of alpha and p(collision) as a function of radius										
NoBlades	3						Upwind:			Downwind:		
MaxChord	4.1	m	r/R	c/C	$\alpha$	collide	contribution		collide	contribution		
Pitch (degrees)	5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r	
BirdLength	0.29	m	0.025	0.575	3.18	10.10	0.89	0.00111	9.69	0.85	0.00107	
Wingspan	0.76	m	0.075	0.575	1.06	3.50	0.31	0.00232	3.09	0.27	0.00205	
F: Flapping (0) or gliding (+1)	0		0.125	0.702	0.64	2.56	0.23	0.00282	2.06	0.18	0.00227	
			0.175	0.860	0.45	2.25	0.20	0.00347	1.64	0.14	0.00253	
Bird speed	10	m/sec	0.225	0.994	0.35	2.08	0.18	0.00413	1.37	0.12	0.00272	
RotorDiam	136	m	0.275	0.947	0.29	1.75	0.15	0.00424	1.07	0.09	0.00260	
RotationPeriod	3.40	sec	0.325	0.899	0.24	1.51	0.13	0.00433	0.87	0.08	0.00249	
			0.375	0.851	0.21	1.33	0.12	0.00441	0.72	0.06	0.00239	
			0.425	0.804	0.19	1.19	0.11	0.00447	0.62	0.05	0.00232	
			0.475	0.756	0.17	1.08	0.10	0.00452	0.54	0.05	0.00225	
Bird aspect ratio: $\beta$	0.38		0.525	0.708	0.15	0.98	0.09	0.00455	0.48	0.04	0.00220	
			0.575	0.660	0.14	0.90	0.08	0.00456	0.43	0.04	0.00217	
			0.625	0.613	0.13	0.83	0.07	0.00456	0.39	0.03	0.00215	
			0.675	0.565	0.12	0.76	0.07	0.00455	0.36	0.03	0.00215	
			0.725	0.517	0.11	0.71	0.06	0.00452	0.34	0.03	0.00216	
			0.775	0.470	0.10	0.65	0.06	0.00448	0.32	0.03	0.00218	
			0.825	0.422	0.10	0.61	0.05	0.00442	0.31	0.03	0.00222	
			0.875	0.374	0.09	0.56	0.05	0.00434	0.30	0.03	0.00228	
			0.925	0.327	0.09	0.52	0.05	0.00426	0.29	0.03	0.00238	
			0.975	0.279	0.08	0.48	0.04	0.00415	0.30	0.03	0.00255	
<b>Overall p(collision) =</b>						<b>Upwind</b>	<b>8.0%</b>	<b>Downwind</b>	<b>4.5%</b>			
						<b>Average</b>	<b>6.3%</b>					

**Table 9.3.8f: Output from SNH Band model collision probability spreadsheet for merlin.**

K: [1D or [3D] (0 or 1)		Calculation of alpha and p(collision) as a function of radius										
NoBlades		Upwind:						Downwind:				
MaxChord	4.1	m	r/R	c/C	$\alpha$	collide	contribution		collide	contribution		
Pitch (degrees)	5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r	
BirdLength	0.3	m	0.025	0.575	3.18	9.65	0.85	0.00106	9.24	0.82	0.00102	
Wingspan	0.62	m	0.075	0.575	1.06	3.36	0.30	0.00222	2.94	0.26	0.00195	
F: Flapping (0) or gliding (+1)	0		0.125	0.702	0.64	2.47	0.22	0.00272	1.97	0.17	0.00217	
			0.175	0.860	0.45	2.20	0.19	0.00340	1.59	0.14	0.00246	
Bird speed	10	m/sec	0.225	0.994	0.35	2.09	0.18	0.00415	1.38	0.12	0.00274	
RotorDiam	136	m	0.275	0.947	0.29	1.76	0.16	0.00426	1.08	0.10	0.00262	
RotationPeriod	3.40	sec	0.325	0.899	0.24	1.52	0.13	0.00436	0.88	0.08	0.00252	
			0.375	0.851	0.21	1.34	0.12	0.00444	0.73	0.06	0.00243	
			0.425	0.804	0.19	1.20	0.11	0.00451	0.63	0.06	0.00235	
			0.475	0.756	0.17	1.09	0.10	0.00456	0.55	0.05	0.00229	
			0.525	0.708	0.15	0.99	0.09	0.00459	0.49	0.04	0.00225	
			0.575	0.660	0.14	0.91	0.08	0.00461	0.44	0.04	0.00222	
			0.625	0.613	0.13	0.84	0.07	0.00462	0.40	0.04	0.00220	
			0.675	0.565	0.12	0.77	0.07	0.00461	0.37	0.03	0.00220	
			0.725	0.517	0.11	0.72	0.06	0.00459	0.35	0.03	0.00222	
			0.775	0.470	0.10	0.66	0.06	0.00455	0.33	0.03	0.00225	
			0.825	0.422	0.10	0.62	0.05	0.00449	0.32	0.03	0.00230	
0.875	0.374	0.09	0.57	0.05	0.00442	0.31	0.03	0.00236				
0.925	0.327	0.09	0.53	0.05	0.00434	0.30	0.03	0.00246				
0.975	0.279	0.08	0.49	0.04	0.00424	0.31	0.03	0.00264				
Overall p(collision) =						Upwind	8.1%	Downwind	4.6%			
						Average	6.3%					

**Table 9.3.8g: Output from SNH Band model collision probability spreadsheet for peregrine.**

K: [1D or [3D] (0 or 1)		Calculation of alpha and p(collision) as a function of radius										
NoBlades							Upwind:			Downwind:		
MaxChord		r/R	c/C	$\alpha$	collide	p(collision)		contribution	collide	p(collision)		contribution
Pitch (degrees)		radius	chord	alpha	length			from radius r	length			from radius r
BirdLength	0.51	m	0.025	0.575	4.14	14.60	0.99	0.00124	14.19	0.96	0.00120	
Wingspan	1.13	m	0.075	0.575	1.38	5.00	0.34	0.00255	4.59	0.31	0.00234	
F: Flapping (0) or gliding (+1)	0		0.125	0.702	0.83	3.56	0.24	0.00302	3.06	0.21	0.00259	
			0.175	0.860	0.59	3.05	0.21	0.00363	2.44	0.17	0.00290	
Bird speed	13	m/sec	0.225	0.994	0.46	2.74	0.19	0.00419	2.03	0.14	0.00310	
RotorDiam	136	m	0.275	0.947	0.38	2.30	0.16	0.00430	1.63	0.11	0.00304	
RotationPeriod	3.40	sec	0.325	0.899	0.32	2.00	0.14	0.00441	1.36	0.09	0.00299	
			0.375	0.851	0.28	1.77	0.12	0.00451	1.16	0.08	0.00297	
			0.425	0.804	0.24	1.60	0.11	0.00460	1.02	0.07	0.00295	
			0.475	0.756	0.22	1.45	0.10	0.00468	0.91	0.06	0.00294	
			0.525	0.708	0.20	1.33	0.09	0.00475	0.83	0.06	0.00295	
			0.575	0.660	0.18	1.23	0.08	0.00481	0.76	0.05	0.00296	
			0.625	0.613	0.17	1.14	0.08	0.00485	0.71	0.05	0.00299	
			0.675	0.565	0.15	1.07	0.07	0.00488	0.66	0.04	0.00303	
			0.725	0.517	0.14	1.00	0.07	0.00490	0.63	0.04	0.00308	
			0.775	0.470	0.13	0.93	0.06	0.00491	0.60	0.04	0.00315	
			0.825	0.422	0.13	0.88	0.06	0.00491	0.58	0.04	0.00322	
0.875	0.374	0.12	0.82	0.06	0.00490	0.56	0.04	0.00331				
0.925	0.327	0.11	0.78	0.05	0.00487	0.54	0.04	0.00341				
0.975	0.279	0.11	0.73	0.05	0.00483	0.53	0.04	0.00352				
<b>Overall p(collision) =</b>						<b>Upwind</b>	<b>8.6%</b>	<b>Downwind</b>	<b>5.9%</b>			
						<b>Average</b>	<b>7.2%</b>					