Appendix 12J
Collision Risk Modelling Report

Introduction

This Appendix documents the methodology and results of collision risk modelling based on data collected from Vantage Point (VP) surveys undertaken from April 2018 to March 2020. This has been carried out in support of the Ornithological Impact Assessment for the Proposed Development.

Data obtained during VP surveys was used to determine the theoretical collision risk for a range of species by incorporation into a collision risk model (CRM) (Band *et al*, 2007), herein referred to as 'the Band model' after its creator. Goshawk, peregrine and red kite were the only species taken forward for assessment.

Appendices 12A-D and **Confidential Appendices 12E-H** present figures of flight activity of species included in the CRM. **Annex A** contains the flight data used in the CRM, whilst **Annex B** presents CRM calculations.

CRM Methodology

Introduction

The risk of birds colliding with the turbine rotors has been assessed using a model developed by Band, which estimates the number of bird collisions with the turbine rotors during a specified time period (NatureScot, 2000; NatureScot, 2018). The model requires input data based on species biometrics and flight characteristics, turbine specification and flights observed at the site. The amount of time that a species may be active within the survey area in any given season is also required for the model, and must therefore be estimated.

The Band model uses a two-stage approach, whereby the number of birds or flights passing through the air space swept by the rotors is determined at Stage 1. The probability of a bird strike occurring is then calculated during Stage 2. The product of Stage 1 and Stage 2 gives a theoretical annual collision mortality rate, based on the assumption that birds make no attempt to avoid collision.

However, it is widely accepted that many species can avoid turbine blades in a number of ways. Birds may exercise avoidance by detecting the wind farm or turbine and modifying their flight lines to avoid the structures. At close proximity, birds may see an oncoming blade and emergency avoidance action can be taken (NatureScot, 2020). As such, species specific avoidance rates were applied to the model to estimate the collision risk, as recommended by NatureScot (2018).

The results of the model provide an estimate of the number of collisions that can be expected over a specific season, year, or for the lifetime of the wind farm.

Choice of Random or Regular Model

The Stage 1 calculation varies depending on whether flight activity follows a regular predictable pattern or is random. The second stage is identical for both methods.

The modelling method for birds with predictable (regular) flight activity applies to birds such as geese following a regular migration route, or travelling from a winter roost to a regular feeding area.

The modelling method with irregular (or random) flight activity applies to birds such as raptors and waders. This requires the calculation of the amount of time birds were observed flying per unit of area surveyed. This level of flight activity is then applied to the Proposed Development in subsequent calculations of the collision risk.

As all three species taken forward for assessment are raptors, the Random Model was used in this instance.

Model Parameters

Turbines

The turbine parameters for the proposed for the Proposed Development are detailed in **Table 12J.1**. The turbines will have a hub height of up to 122.5 m and rotor diameter of up to 162 m. However, as the maximum tip height of the turbine will not exceed 200 m, a worst-case scenario is used in which the maximum diameter is attained, but the hub is situated lower than the maximum. This means the potential collision risk height (PCH) be from 38 m to 200 m above ground.

For the purposes of CRM, it has been assumed that turbines will be non-operational for 25 % of the time (e.g. during periods when wind speed is too low or too high to operate, or during maintenance).

Table 12J.1 – Turbine Technical Parameters

Parameter	Section 36 Application	Unit
Number of turbines	15	
Number of blades	3	
Approximate hub height	119	m
Approximate rotor diameter	162	m
Maximum height to blade tip	200	m
Minimum height to blade tip	38	
PCH	38 to 200	m
Pitch	-5 to 95	degrees
Rotor depth	4.1	m
Maximum chord	4.3	m
Rotation period	4.3 to 12.1	rpm

Survey Effort, Available Hours Per Season and Observation Time

VP surveys commenced in April 2018 and continued through until mid-March 2020 at four VP locations. A summary of survey effort is shown in **Table 12J.2.**

Table 12J.2 – VP survey effort (hours:minutes)

VP	Apr 18	May 18	Jun 18	Jul 18	Aug 18	Sep 18*	Oct 18	Nov 18	Dec 18	Jan 19*	Feb 19	Mar 19	Apr 19	May 19	Jun 19	Jul 19	Aug 19	Sep 19	Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20
6	9	9	9	9	6	-	6	12	6	6	-	12	9	9	9	9	6	6	6	4:30	5:30	-	-	20
7	8	10	9	9	6	2	1	9	7:30	3	6	14:30	9	9	9	11	4	6	6	6	-	3	6	15
8	8	10	9	9	6	2	1	9	6:30	3	6	14:30	9	9	9	12:05	3	6	6	6	-	3	6	15
9	9	9	9	9	6	-	6	12	6	6	-	9	9	9	9	9	6	6	6	5	5	-	-	20

* Solid lines show divisions between seasons.

Available active hours were defined as the number of hours that a bird species may be potentially active in any given season (NatureScot, 2018) (**Table 12J.3**). Available hours for flight activity were calculated to include daylight, one hour before sunrise and one hour after sunset for all three species taken forward for assessment. For goshawk, seasons are not defined using the baseline reports, but rather the breeding and non-breeding seasons in relation to goshawk as defined within Hardey *et al* (2013), and from experience of the area (breeding season March to August; non-breeding season September to February). The same approach is taken for peregrine and red kite (breeding season March to August; non-breeding season September to February).

Observation effort relates to the total number of survey hours undertaken at VP locations within the seasons in question.

Table 12I.3 – Available Hours and Observation Effort

Season	Available Time (hr:m)	Total Observation Effort (hr:m)
Breeding 2018 (Apr to Aug)	2,734:43	168 (42 hours at each VP). Surveys began in April 2018 and therefore missed the early part of the raptor breeding season (March).
Non-breeding 2018/19 (Sep 18 to Feb 19)	2,057:47	116 (30 hours at VP, 28 hours and 30 minutes at VP7, 27 hours and 30 minutes at VP8, 30 hours at VP9).
Breeding 2019 (Mar to Aug)	3,164:11	218.08 (54 hours at VP6, 56 hours and 30 minutes at VP7, 56 hours and 38 minutes at VP8 and 51 hours at VP9).
Non-breeding 2019/20 (Sep 19 to Feb 20)	2,071:14	98 (22 hours at VPs 6 and 9, 27 hours at VPs 7 and 8).
Breeding 2020 (Mar 20)	369:23	70 (20 hours at VPs 6 and 9, 15 hours at VPs 7 and 8). Ended in March and thus missed the later part (April to August) of the raptor breeding season.

Random Model

Definition of terms

The collision risk zone (CRZ) is defined as the wind farm polygon (WFP). This was calculated by creating a 581m buffer around each turbine location. NatureScot (2018) guidance currently recommends a 500 m buffer plus one rotor radius to allow for observer inaccuracies when mapping flights during surveys.

The Vantage Point view-shed is the survey area associated with each VP, calculated as a 180-degree arc of a 2 km radius applied around each VP location.

The flight risk area (FRA) is defined as the area of visibility of each viewshed at minimum collision-risk height (in this instance 38 m) that falls within the CRZ. This was calculated using GIS (**Figures 12J.1A-E, Annex A**).

FRAw is an adjustment calculation that accounts for the difference between the height bands used for recording collision risk height flights and the length of the turbine blades. The flight activity surveys were carried out prior to turbine model selection and used three height bands that are not

identical to the PCH of the final turbine dimensions. Therefore, overall bird activity is weighted to reflect that the swept area is larger than the recording area, increasing the overall bird activity. The 2018 season used the height bands 0-29 m, 30-150 m and >150 m, whereas the 2018/19 non-breeding used height bands of <15 m, 15-150 m and >150 m. The 2019 breeding season and 2019/20 non-breeding season used height bands of <15 m, 15-180 m and >180 m.

The collision risk volume is defined as the volume of the airspace between the minimum and maximum risk height band (38 m – 200 m) and is used in random models (NatureScot, 2000).

The rotor-swept volume is defined as the volume of air that would be swept by all the rotors in the wind farm. For an individual rotor, this is determined by the area swept ($\pi r2$) multiplied by the thickness of the rotor blades plus the length of the focal species (NatureScot, 2000).

Selection of flights

All flights that were observed at PCH falling within the CRZ were included. Those flights that extended beyond the CRZ were clipped to the CRZ boundary (i.e. only the time spent within the CRZ was included in the collision risk model). Where flights at PCH originated or ended outside of the CRZ, the amount of time for the clipped flight at PCH within CRZ was calculated as a proportion of the clipped flight length to the total flight length at PCH. Where a flight represented the activity of more than one bird, total flight time was calculated based on number of birds multiplied by the time at PCH within the CRZ.

Flights were apportioned to the breeding or non-breeding season identified in **Table 12J.3**. **Table 12J.4** shows the total flight times for each species where flight data indicated that the random CRM approach should be used. For each species, any season where no birds were recorded flying during VP surveys is excluded.

The clipped flights at PCH within the CRZ included in the modelling are shown in **Annex A, Figure 12J.2** (Confidential). **Annex A** provides details of all flights included in the random CRM. All flight data can be found in **Appendices 12A-B, 12D** and the **Confidential Appendices 12E-H**.

Table 12J.4 – Random Model: Clipped flight time in seconds prior to FRAw

Species	Season	Total Number Flights (Excluding Clipped Out)	Total Seconds Below PCH	Total Seconds at PCH	Total Seconds Above PCH
Goshawk	Breeding 2018 (Apr to Aug)	6	19	95.68	365.03
	Non-breeding 2018/19 (Sep to Feb)	1	0	28	0
	Breeding 2019 (March to Aug)	3	0	31.05	285
	Breeding 2020 (March)	1	0	46.76	0
Peregrine	Breeding 2018 (Apr to Aug)	2	15	13.15	0
	Breeding 2019 (Mar to Aug)	9	0	75.98	469.6

Species	Season	Total Number Flights (Excluding Clipped Out)	Total Seconds Below PCH	Total Seconds at PCH	Total Seconds Above PCH
	Breeding 2020 (March)	2	0	15	8.23
Red kite	Breeding 2018 (Apr to Aug)	26	480.27	709.77	49.09
	Breeding 2019 (Mar to Aug)	22	321.83	1,516.66	1,032.32
	Non-breeding 2019/20 (Sep to Feb)	8	1,017.14	940.15	0
	Breeding 2020 (March)	7	25	544.63	240

Bird Parameters

Biometric measurements for bird species were taken from the BTO (https://www.bto.org/about-birds/birdfacts) with flight speeds from Alerstam *et al* (2007) and are presented in **Table 12J.5**. Avoidance rates were taken from current guidance (NatureScot, 2000).

Table 12J.5 – Bird Species Biometric Parameters

Species	Avoidance Rate %	Length (m)	Wingspan (m)	Flight Speed (m/s)	Flight Style
Goshawk	98	0.55	1.10	11.3	Flapping
Peregrine	98	0.42	1.02	12.1	Flapping
Red kite	99	0.63	1.85	12.0	Gliding

Results

A summary of the CRM results is shown in **Table 12J.6**, whilst details of model calculations are presented in **Annex B**.

Table 12J.6 – Collision Rates

Species	Season	Potential Collisions	Without Avoidance	With Avoidance (see Table 12J.5)
Goshawk	Breeding 2018 (Apr to Aug)	Per year 1 bird every *X* years Over 30 years	2.18 0.46 65.4	0.044 22.9 1.31

Species	Season	Potential Collisions	Without Avoidance	With Avoidance (see Table 12J.5)
	Non-breeding 2018/19 (Sep to Feb)	Per year 1 bird every *X* years Over 30 years	0.54 1.86 16.1	0.011 93.2 0.32
	Breeding 2019 (Mar to Aug)	Per year 1 bird every *X* years Over 30 years	0.42 2.38 12.6	0.008 119.1 0.25
	Breeding 2020 (March)	Per year 1 bird every *X* years Over 30 years	0.2 5.09 5.9	0.004 254.5 0.12
Peregrine	Breeding 2018 (Apr to Aug)	Per year 1 bird every *X* years Over 30 years	0.29 3.48 8.6	0.006 174.1 0.17
	Breeding 2019 (Mar to Aug)	Per year 1 bird every *X* years Over 30 years	0.86 1.17 25.7	0.017 58.4 0.51
	Breeding 2020 (March)	Per year 1 bird every *X* years Over 30 years	0.06 16.6 1.8	0.001 828.3 0.04
Red kite	Breeding 2018 (Apr to Aug)	Per year 1 bird every *X* years Over 30 years	27.51 0.04 825.2	0.55 1.8 16.5
	Breeding 2019 (Mar to Aug)	Per year 1 bird every *X* years Over 30 years	17.46 0.06 523.8	0.175 5.7 5.24
	Non-breeding 2019/20 (Sep to Feb)	Per year 1 bird every *X* years Over 30 years	16.18 0.06 485.4	0.162 6.2 4.85
	Breeding 2020 (March)	Per year 1 bird every *X* years Over 30 years	2.36 0.42 70.8	0.024 42.4 0.71

References

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(8): e197. DOI:10.1371/journal.pbio.0050197.

Band, W., Madders, M. & Whitfield, D.P. 2007. Developing field and analytical methods to assess avian collision risk at wind farms. *Birds and Wind Farms: Risk Assessment and Mitigation*. de Lucas, M., Janss, G. & Ferrer, M. (eds). Lynx Edicions, Barcelona.

NatureScot. 2000. *Windfarms and Birds: Calculating a theoretical collision risk assuming no avoiding action*. SNH Guidance Note. Scottish Natural Heritage.

NatureScot. 2017. *Recommended bird survey methods to inform impact assessment of onshore wind farms*. Version 2. July 2017.

NatureScot. 2018. *Avoidance Rates for the onshore SNH Wind Farm Collision Risk Model*. Version 2. September 2018.

https://www.timeanddate.com/sun/@2653641 – Carsphairn: Sunrise, Sunset and Daylength. Accessed on 15 August 2022.

Annex A – Flight data used in CRM

Table 12J.7 – Goshawk flight data used in CRM (prior to FRAw)

Flight_Ref	VP	Date	Time	Individual Time in Height Band (s)	Original Length (m)	Clipped Length (m)	Clip Length %	Count	Height Band (A: below, B: within, C: above rotors)	Total Flight Time (s)
LWF_063_a	6	11/07/18	14:24	39	821.30	582.89	71	1	B	27.68
LWF_070_b	9	11/07/18	13:03	68	886.46	886.46	100	1	B	68
32964_VP_002	9	17/10/18	12:35	28	974.48	974.48	100	1	B	28
32964_VP_018	9	26/03/19	12:51	21	2,108.64	1,612	76.5	1	B	16.05
32964_VP_019_a	7	26/03/19	11:11	15	230.70	230.70	100	1	B	15
32964_VP_115	9	18/03/20	12:54	60	1,516.17	1,181.66	77.9	1	B	46.76

Table 12J.8 – Peregrine flight data used in CRM (prior to FRAw)

Flight_Ref	VP	Date	Time	Individual Time in Height Band (s)	Original Length (m)	Clipped Length (m)	Clip Length %	Count	Height Band	Total Flight Time (s)
LWF_029_a	6	18/05/18	13:47	14	1,024.19	962.33	94	1	B	13.15
32964_VP_026_a	7	26/03/19	13:09	30	1,900.47	1,373	72.2	1	B	21.67
32964_VP_043_b	6	13/05/19	17:38	5	152.36	152.36	100	1	B	5
32964_VP_050	9	24/07/19	14:00	115	866.36	107.81	12.4	1	B	14.31

Flight_Ref	VP	Date	Time	Individual Time in Height Band (s)	Original Length (m)	Clipped Length (m)	Clip Length %	Count	Height Band	Total Flight Time (s)
32964_VP_058	6	30/07/19	16:35	35	964.9	964.9	100	1	B	35
32964_VP_111_b	6	16/03/20	10:01	15	333.92	333.92	100	1	B	15

Table 12J.9 – Red kite flight data used in CRM (prior to FRAw)

Flight_Ref	VP	Date	Time	Individual Time in Height Band (s)	Original Length (m)	Clipped Length (m)	Clip Length %	Count	Height Band	Total Flight Time (s)
LWF_002	7	25/04/18	14:02	117	938	351.73	37.5	1	B	43.87
LWF_007	9	27/04/18	14:28	35	959	959	100	1	B	35
LWF_010	7	01/05/18	12:20	26	491	491	100	1	B	26
LWF_013_b	8	16/05/18	11:05	26	578.65	578.65	100	1	B	26
LWF_014	7	16/05/18	11:05	39	673.85	673.85	100	1	B	39
LWF_015_a	7	16/05/18	11:34	27	1,074.17	741.77	69.1	1	B	18.65
LWF_030_a	6	06/06/18	10:32	75	997.85	997.85	100	1	B	75
LWF_033	6	06/06/18	11:03	50	526.92	244.25	46.4	1	B	23.18
LWF_035_a	6	06/06/18	11:31	90	1,466.39	1,065.98	72.7	1	B	65.44

Flight_Ref	VP	Date	Time	Individual Time in Height Band (s)	Original Length (m)	Clipped Length (m)	Clip Length %	Count	Height Band	Total Flight Time (s)
LWF_038_c	6	06/06/18	14:44	30	400.91	104.89	26.2	1	B	7.85
LWF_040_a	6	06/06/18	15:59	180	1,307.01	1,307.01	100	1	B	180
LWF_072_a	7	25/07/18	15:00	43	869.21	256.35	29.5	1	B	12.68
LWF_073_a	7	25/07/18	17:43	90	1,003.48	919	91.6	1	B	82.42
LWF_073_c	7	25/07/18	17:43	153	694	89.27	12.9	1	B	19.68
LWF_084_a	6	15/08/18	12:37	55	661.87	661.87	100	1	B	55
32964_VP_020_a	7	26/03/19	11:55	30	371.51	371.51	100	1	B	30
32964_VP_024_a	6	26/03/19	11:55	30	741.88	741.88	100	1	B	30
32964_VP_024_c	6	26/03/19	11:55	20	459.95	53	11.5	1	B	2.3
32964_VP_028_b	7	11/04/19	15:12	20	1,011.85	302.30	29.9	1	B	5.98
32964_VP_031	6	01/05/19	15:53	40	549.40	420.78	76.6	1	B	30.64
32964_VP_036_b	7	15/05/19	11:28	60	2,836.98	306.16	10.8	2	B	12.95

Flight_Ref	VP	Date	Time	Individual Time in Height Band (s)	Original Length (m)	Clipped Length (m)	Clip Length %	Count	Height Band	Total Flight Time (s)
32964_VP_036_d	7	15/05/19	11:28	60	1,792.20	1,792.20	100	2	B	120
32964_VP_037_c	7	15/05/19	11:29	60	1,898.89	1,898.89	100	1	B	60
32964_VP_040	6	13/05/19	15:22	45	1,123.65	1,123.65	100	1	B	45
32964_VP_041	6	13/05/19	15:51	190	5,512.05	2,449.02	44.4	1	B	84.42
32964_VP_042_a	6	13/05/19	16:52	50	1,384.50	942.26	68.1	1	B	34.03
32964_VP_046_a	6	12/06/19	09:21	45	556.61	556.61	100	1	B	45
32964_VP_049	7	10/06/19	15:32	110	1,533.68	1,533.68	100	1	B	110
32964_VP_051	7	23/07/19	14:48	8	362.55	64.35	17.7	1	B	1.42
32964_VP_053	9	01/08/19	12:18	120	2,378.83	459.17	19.3	4	B	92.65
32964_VP_054	9	01/08/19	12:20	240	1,520.81	244.79	16.1	2	B	77.26
32964_VP_055_a	9	01/08/19	12:20	240	1,403.67	1,355.48	96.6	2	B	463.52

Flight_Ref	VP	Date	Time	Individual Time in Height Band (s)	Original Length (m)	Clipped Length (m)	Clip Length %	Count	Height Band	Total Flight Time (s)
32964_VP_059_d	6	30/07/19	16:46	50	1,278.72	1,278.72	100	1	B	50
32964_VP_060_a	6	01/08/19	11:19	80	2,540.09	1,989.69	78.3	1	B	62.67
32964_VP_062	6	01/08/19	16:01	160	4,944.90	2,505.76	50.7	1	B	81.08
32964_VP_063_a	6	01/08/19	16:08	80	2,790.95	2,712.66	97.2	1	B	77.76
32964_VP_073_b	6	02/10/19	13:14	20	597.69	335.01	56.1	1	B	11.21
32964_VP_074_a	6	02/10/19	14:02	30	486.78	486.78	100	1	B	30
32964_VP_074_c	6	02/10/19	14:02	30	2,410	2,410	100	1	B	30
32964_VP_074_e	6	02/10/19	14:02	45	808.98	808.98	100	1	B	45
32964_VP_075	6	02/10/19	14:02	20	794.84	778.96	98.0	1	B	19.6
32964_VP_076	6	02/10/19	14:25	420	11,074.97	10,530.89	95.1	1	B	399.37
32964_VP_077	6	02/10/19	14:52	10	682.85	611.15	89.5	1	B	8.95

Flight_Ref	VP	Date	Time	Individual Time in Height Band (s)	Original Length (m)	Clipped Length (m)	Clip Length %	Count	Height Band	Total Flight Time (s)
32964_VP_078_b	6	02/10/19	15:37	40	539.02	539.02	100	2	B	80
32964_VP_079	9	02/10/19	12:13	660	4,179.95	750.76	18.0	1	B	118.54
32964_VP_086	9	09/12/19	12:49	200	4,764.74	4,704.73	98.7	1	B	197.48
32964_VP_092_a	6	05/03/20	11:32	120	464.57	464.57	100	1	B	120
32964_VP_093	6	05/03/20	13:55	80	2,192.23	311.66	14.2	1	B	11.37
32964_VP_095_a	7	04/03/20	12:45	200	2,304.45	1,535.50	66.6	1	B	133.26
32964_VP_098	7	05/03/20	11:32	180	2,604.45	2,604.45	100	1	B	180
32964_VP_113_a	9	17/03/20	11:21	120	1,872.20	1,442.74	77.1	1	B	92.47
32964_VP_116	6	18/03/20	13:08	15	756.81	379.25	50.1	**1**	**B**	7.52

Annex B – CRM calculations

Band Model - Random Flights Proposed Development Year 1								
Species: Goshawk								
Season: Breeding season 2018 (April - August)								

Wind Farm Parameters			Bird Parameters	
WFP (ha)	904.35		length (m)	0.55
Number turbines	15		wingspan (m)	1.1
Rotor diameter	162		flapping (0)or gliding (1)	0
Hub height (m)	119		Assumed flight speed (m/s)	11.3
Max chord (m)	4.3		Number daylight hours available	2734.72
Rotor depth	4.1		Maximum recording height (m)	150
Pitch (degrees)	45		Minimum recording height (m)	30
Rotation period (secs)	8.2			
Turbine operation time 75%	0.75		**Survey Data**	
Avoidance Rate 98%	0.02			

Survey Data		6	7	8	9			
Rotor radius^2	6561.00	FRA (ha)	191.22	123.59	3.18	325.00		
Combined rotor swept area	309179.78	Observation Time (hours)	42	42	42	42		
Collision Risk volume 'Vw' (m^3)	1,465,044,732							
Rotor swept volume 'V$_r$' (m^3)	1,437,686	Time at height band B	27.68	0	0	68.00		
		Total Time at PCH (adjusted via FRAw)	37.37	0	0	91.80		

Flight activity per unit time and area		6	7	8	9					Total
Observation effort	Obsevation time (seconds) * hectare	28912464	18686808	481314	49140680					97221266.3
Flying time at risk height	Effort at each VP / FRA	1.29E-06	0.00E+00	0.00E+00	1.87E-06					3.16E-06
Weighted by observation effort		6	7	8	9					
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	2.97E-01	1.92E-01	4.95E-03	5.05E-01					1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	3.84E-07	0.00E+00	0.00E+00	9.44E-07					1.33E-06
Occupancy Rate										
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000001329								
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours active	3.29								
FRAw	Estimated bird time*(rotor diameter/recording height band)	4.44								
Rotor Transits										
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision risk volume)*3600	15.67								
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	0.41								
Number of transits 'ntr'	'n'/'t'	38.08								
E										
Probability of collision (Band model)		0.076								

Calculation of number collisions	No avoidance	Avoidance 98%
Collisions per year	2.18	0.044
Equivalent to 1 bird every *x* (years)	0.46	22.9
Over 30 years	65.4	1.31

Band Model - Random Flights Proposed Development Year 1

Species: Goshawk

Season: Non-breeding season 2018-19 (September - February)

Wind Farm Parameters	
WFP (ha)	587.9611
Number turbines	15
Rotor diameter	162
Hub height (m)	119
Max chord (m)	4.3
Rotor depth	4.1
Pitch (degrees)	45
Rotation period (secs)	8.2
Turbine operation time 75%	0.75
Avoidance Rate 98%	0.02
Rotor radius^2	6561.00
Combined rotor swept area	309179.78
Collision Risk volume 'Vw' (m^3)	952,496,982
Rotor swept volume 'V$_r$' (m^3)	1,437,686

Bird Parameters	
length (m)	0.55
wingspan (m)	1.1
flapping (0)or gliding (1)	0
Assumed flight speed (m/s)	11.3
Number daylight hours available	2057.78
Maximum recording height (m)	150
Minimum recording height (m)	15

Survey Data								
VP	6	7	8	9				
FRA (ha)	191.22	123.59	3.18	325.00				
Observation Time (hours)	30	28.5	27.5	30				
Time at height band B	0	0	0	28				
Total Time at PCH (adjusted via FRAw)	0	0	0	33.6				

Flight activity per unit time and area		6	7	8	9					Total
Observation effort	Obsevation time (seconds) * hectare	20651760	12680334	315146	35100486					68747726.0
Flying time at risk height	Effort at each VP / FRA	0.00E+00	0.00E+00	0.00E+00	9.57E-07					9.57E-07
Weighted by observation effort		6	7	8	9					
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	3.00E-01	1.84E-01	4.58E-03	5.11E-01					1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	0.00E+00	0.00E+00	0.00E+00	4.89E-07					4.89E-07
Occupancy Rate										
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000000489								
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours active	0.59								
FRAw	Estimated bird time*(rotor diameter/recording height band)	0.71								
Rotor Transits										
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision risk volume)*3600	3.86								
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	0.41								
Number of transits 'ntr'	'n'/'t'	9.37								
E										
Probability of collision (Band model		0.076								

Calculation of number collisions	No avoidance	Avoidance 98%
Collisions per year	0.54	0.011
Equivalent to 1 bird every x (years)	1.86	93.2
Over 30 years	16.1	0.32

Band Model - Random Flights Proposed Development Year 2

Species: Goshawk

Season: Breeding season 2019 (March - August)

Wind Farm Parameters	
WFP (ha)	587.9611
Number turbines	15
Rotor diameter	162
Hub height (m)	119
Max chord (m)	4.3
Rotor depth	4.1
Pitch (degrees)	45
Rotation period (secs)	8.2
Turbine operation time 75%	0.75
Avoidance Rate 98%	0.02
Rotor radius^2	6561.00
Combined rotor swept area	309179.78
Collision Risk volume 'Vw' (m^3)	952,496,982
Rotor swept volume 'V$_r$' (m^3)	1,437,686

Bird Parameters	
length (m)	0.55
wingspan (m)	1.1
flapping (0)or gliding (1)	0
Assumed flight speed (m/s)	11.3
Number daylight hours available	3164.18
Maximum recording height (m)	180
Minimum recording height (m)	15

Survey Data

VP	6	7	8	9				
FRA (ha)	191.22	123.59	3.18	325.00				
Observation Time (hours)	54	56.5	56.63333333	51				
Time at height band B	0	15	0	16.05				
Total Time at PCH (adjusted via FRAw)	0	18	0	19.26				

Flight activity per unit time and area		6	7	8	9					Total
Observation effort	Obsevation time (seconds) * hectare	37173168	25138206	649010	59670826					122631210.0
Flying time at risk height	Effort at each VP / FRA	0.00E+00	7.16E-07	0.00E+00	3.23E-07					1.04E-06
Weighted by observation effort		6	7	8	9					
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	3.03E-01	2.05E-01	5.29E-03	4.87E-01					1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	0.00E+00	1.47E-07	0.00E+00	1.57E-07					3.04E-07
Occupancy Rate										
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000000304								
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours active	0.57								
FRAw	Estimated bird time*(rotor diameter/recording height band)	0.56								
Rotor Transits										
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision risk volume)*3600	3.02								
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	0.41								
Number of transits 'ntr'	'n'/'t'	7.33								
E										
Probability of collision (Band model)		0.076								

Calculation of number collisions	No avoidance	Avoidance 98%
Collisions per year	0.42	0.008
Equivalent to 1 bird every *x* (years)	2.38	119.1
Over 30 years	12.6	0.25

Band Model - Random Flights Proposed Development Year 3

Species: Goshawk

Season: Breeding season 2020 (March)

Wind Farm Parameters	
WFP (ha)	587.9611
Number turbines	15
Rotor diameter	162
Hub height (m)	119
Max chord (m)	4.3
Rotor depth	4.1
Pitch (degrees)	45
Rotation period (secs)	8.2
Turbine operation time 75%	0.75
Avoidance Rate 98%	0.02
Rotor radius^2	6561.00
Combined rotor swept area	309179.78
Collision Risk volume 'Vw' (m^3)	952,496,982
Rotor swept volume 'V$_r$' (m^3)	1,437,686

Bird Parameters	
length (m)	0.55
wingspan (m)	1.1
flapping (0)or gliding (1)	0
Assumed flight speed (m/s)	11.3
Number daylight hours available	431.38
Maximum recording height (m)	180
Minimum recording height (m)	15

Survey Data								
VP	6	7	8	9				
FRA (ha)	191.22	123.59	3.18	325.00				
Observation Time (hours)	20	15	15	20				
Time at height band B	0	0	0	46.76				
Total Time at PCH (adjusted via FRAw)	0	0	0	45.91				

Flight activity per unit time and area		6	7	8	9					Total
Observation effort	Obsevation time (seconds) * hectare	13767840	6673860	171898	23400324					44013921.8
Flying time at risk height	Effort at each VP / FRA	0.00E+00	0.00E+00	0.00E+00	1.96E-06					1.96E-06
Weighted by observation effort		6	7	8	9					
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	3.13E-01	1.52E-01	3.91E-03	5.32E-01					1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	0.00E+00	0.00E+00	0.00E+00	1.04E-06					1.04E-06
Occupancy Rate										
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000001043								
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours active	0.26								
FRAw	Estimated bird time*(rotor diameter/recording height band)	0.26								
Rotor Transits										
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision risk volume)*3600	1.41								
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	0.41								
Number of transits 'ntr'	'n'/'t'	3.43								
E										
Probability of collision (Band model)		0.076								

Calculation of number collisions	No avoidance	Avoidance 98%
Collisions per year	0.20	0.004
Equivalent to 1 bird every x (years)	5.09	254.5
Over 30 years	5.9	0.12

Band Model - Random Flights Proposed Development Year 1

Species: Peregrine

Season: Breeding season 2018 (April - August)

Wind Farm Parameters	
WFP (ha)	904.35
Number turbines	15
Rotor diameter	162
Hub height (m)	119
Max chord (m)	4.3
Rotor depth	4.1
Pitch (degrees)	45
Rotation period (secs)	8.2
Turbine operation time 75%	0.75
Avoidance Rate 98%	0.02
Rotor radius^2	6561.00
Combined rotor swept area	309179.78
Collision Risk volume 'Vw' (m^3)	1,465,044,732
Rotor swept volume 'V$_r$' (m^3)	1,397,493

Bird Parameters	
length (m)	0.42
wingspan (m)	1.02
flapping (0)or gliding (1)	0
Assumed flight speed (m/s)	12.1
Number daylight hours available	2734.72
Maximum recording height (m)	150
Minimum recording height (m)	30

Survey Data								
VP	6	7	8	9				
FRA (ha)	191.22	123.59	3.18	325.00				
Observation Time (hours)	42	42	42	42				
Time at height band B	13.15	0	0	0				
Total Time at PCH (adjusted via FRAw)	17.76	0	0	0				

Flight activity per unit time and area		6	7	8	9					Total
Observation effort	Obsevation time (seconds) * hectare	28912464	18686808	481314	49140680					97221266.3
Flying time at risk height	Effort at each VP / FRA	6.14E-07	0.00E+00	0.00E+00	0.00E+00					6.14E-07
Weighted by observation effort		6	7	8	9					
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	2.97E-01	1.92E-01	4.95E-03	5.05E-01					1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	1.83E-07	0.00E+00	0.00E+00	0.00E+00					1.83E-07
Occupancy Rate										
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000000183								
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours active	0.45								
FRAw	Estimated bird time*(rotor diameter/recording height band)	0.61								
Rotor Transits										
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision risk volume)*3600	2.09								
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	0.37								
Number of transits 'ntr'	'n'/'t'	5.61								
E										
Probability of collision (Band model)		0.068								

Calculation of number collisions	No avoidance	Avoidance 98%
Collisions per year	0.29	0.006
Equivalent to 1 bird every x (years)	3.48	174.1
Over 30 years	8.6	0.17

Band Model - Random Flights Proposed Development Year 2

Species: Peregrine

Season: Breeding season 2019 (March - August)

Wind Farm Parameters	
WFP (ha)	587.9611
Number turbines	15
Rotor diameter	162
Hub height (m)	119
Max chord (m)	4.3
Rotor depth	4.1
Pitch (degrees)	45
Rotation period (secs)	8.2
Turbine operation time 75%	0.75
Avoidance Rate 98%	0.02
Rotor radius^2	6561.00
Combined rotor swept area	309179.78
Collision Risk volume 'Vw' (m^3)	952,496,982
Rotor swept volume 'V$_r$' (m^3)	1,397,493

Bird Parameters	
length (m)	0.42
wingspan (m)	1.02
flapping (0)or gliding (1)	0
Assumed flight speed (m/s)	12.1
Number daylight hours available	3164.18
Maximum recording height (m)	180
Minimum recording height (m)	15

Survey Data				
VP	6	7	8	9
FRA (ha)	191.22	123.59	3.18	325.00
Observation Time (hours)	54	56.5	56.63333333	51
Time at height band B	40	21.67	0	14.31
Total Time at PCH (adjusted via FRAw)	39.27	26.01	0	14.05

Flight activity per unit time and area		6	7	8	9				Total
Observation effort	Obsevation time (seconds) * hectare	37173168	25138206	649010	59670826				122631210.0
Flying time at risk height	Effort at each VP / FRA	1.06E-06	1.03E-06	0.00E+00	2.35E-07				2.33E-06
Weighted by observation effort		6	7	8	9				
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	3.03E-01	2.05E-01	5.29E-03	4.87E-01				1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	3.20E-07	2.12E-07	0.00E+00	1.15E-07				6.47E-07
Occupancy Rate									
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000000647							
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours active	1.20							
FRAw	Estimated bird time*(rotor diameter/recording height band)	1.18							
Rotor Transits									
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision risk volume)*3600	6.24							
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	0.37							
Number of transits 'ntr'	'n'/'t'	16.71							
E									
Probability of collision (Band model)		0.068							

Calculation of number collisions	No avoidance	Avoidance 98%
Collisions per year	0.86	0.017
Equivalent to 1 bird every x (years)	1.17	58.4
Over 30 years	25.7	0.51

Band Model - Random Flights Proposed Development Year 3

Species: Peregrine

Season: Breeding season 2020 (March)

Wind Farm Parameters	
WFP (ha)	587.9611
Number turbines	15
Rotor diameter	162
Hub height (m)	119
Max chord (m)	4.3
Rotor depth	4.1
Pitch (degrees)	45
Rotation period (secs)	8.2
Turbine operation time 75%	0.75
Avoidance Rate 98%	0.02
Rotor radius^2	6561.00
Combined rotor swept area	309179.78
Collision Risk volume 'Vw' (m^3)	952,496,982
Rotor swept volume 'V$_r$' (m^3)	1,397,493

Bird Parameters	
length (m)	0.42
wingspan (m)	1.02
flapping (0)or gliding (1)	0
Assumed flight speed (m/s)	12.1
Number daylight hours available	431.38
Maximum recording height (m)	180
Minimum recording height (m)	15

Survey Data								
VP	6	7	8	9				
FRA (ha)	191.22	123.59	3.18	325.00				
Observation Time (hours)	20	15	15	20				
Time at height band B	15	0	0	0				
Total Time at PCH (adjusted via FRAw)	14.73	0	0	0				

Flight activity per unit time and area		6	7	8	9					Total
Observation effort	Obsevation time (seconds) * hectare	13767840	6673860	171898	23400324					44013921.8
Flying time at risk height	Effort at each VP / FRA	1.07E-06	0.00E+00	0.00E+00	0.00E+00					1.07E-06
Weighted by observation effort		6	7	8	9					
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	3.13E-01	1.52E-01	3.91E-03	5.32E-01					1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	3.35E-07	0.00E+00	0.00E+00	0.00E+00					3.35E-07
Occupancy Rate										
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000000335								
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours active	0.08								
FRAw	Estimated bird time*(rotor diameter/recording height band)	0.08								
Rotor Transits										
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision risk volume)*3600	0.44								
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	0.37								
Number of transits 'ntr'	'n'/'t'	1.18								
E										
Probability of collision (Band model)		0.068								

Calculation of number collisions	No avoidance	Avoidance 98%
Collisions per year	0.06	0.001
Equivalent to 1 bird every *x* (years)	16.57	828.3
Over 30 years	1.8	0.04

Band Model - Random Flights Proposed Development Year 1

Species: Red kite

Season: Breeding season 2018 (April - August)

Wind Farm Parameters	
WFP (ha)	904.35
Number turbines	15
Rotor diameter	162
Hub height (m)	119
Max chord (m)	4.3
Rotor depth	4.1
Pitch (degrees)	45
Rotation period (secs)	8.2
Turbine operation time 75%	0.75
Avoidance Rate 98%	0.02
Rotor radius^2	6561.00
Combined rotor swept area	309179.78
Collision Risk volume 'Vw' (m^3)	1,465,044,732
Rotor swept volume 'V$_r$' (m^3)	1,462,420

Bird Parameters	
length (m)	0.63
wingspan (m)	1.85
flapping (0)or gliding (1)	1
Assumed flight speed (m/s)	12
Number daylight hours available	2734.72
Maximum recording height (m)	150
Minimum recording height (m)	30

Survey Data	6	7	8	9			
VP	6	7	8	9			
FRA (ha)	191.22	123.59	3.18	325.00			
Observation Time (hours)	42	42	42	42			
Time at height band B	406.47	242.31	26	35.00			
Total Time at PCH (adjusted via FRAw)	548.73	948.31	35.1	47.25			

Flight activity per unit time and area		6	7	8	9				Total
Observation effort	Obsevation time (seconds) * hectare	28912464	18686808	481314	49140680				97221266.3
Flying time at risk height	Effort at each VP / FRA	1.90E-05	5.07E-05	7.29E-05	9.62E-07				1.44E-04
Weighted by observation effort		6	7	8	9				
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	2.97E-01	1.92E-01	4.95E-03	5.05E-01				1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	5.64E-06	9.75E-06	3.61E-07	4.86E-07				1.62E-05
Occupancy Rate									
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000016245							
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours active	40.18							
FRAw	Estimated bird time*(rotor diameter/recording height band)	54.24							
Rotor Transits									
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision risk volume)*3600	194.91							
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	0.39							
Number of transits 'ntr'	'n'/'t'	494.49							
E									
Probability of collision (Band model		0.074							

Calculation of number collisions	No avoidance	Avoidance 98%
Collisions per year	27.51	0.550
Equivalent to 1 bird every *x* (years)	0.04	1.8
Over 30 years	825.2	16.50

Band Model - Random Flights Proposed Development Year 2

Species: Red kite

Season: Breeding season 2019 (March - August)

Wind Farm Parameters		Bird Parameters	
WFP (ha)	587.9611	length (m)	0.63
Number turbines	15	wingspan (m)	1.85
Rotor diameter	162	flapping (0)or gliding (1)	1
Hub height (m)	119	Assumed flight speed (m/s)	12
Max chord (m)	4.3	Number daylight hours available	3164.18
Rotor depth	4.1	Maximum recording height (m)	180
Pitch (degrees)	45	Minimum recording height (m)	15
Rotation period (secs)	8.2		
Turbine operation time 75%	0.75	**Survey Data**	
Avoidance Rate 99%	0.01		
Rotor radius^2	6561.00		
Combined rotor swept area	309179.78		
Collision Risk volume 'Vw' (m^3)	952,496,982		
Rotor swept volume 'V$_r$' (m^3)	1,462,420		

Survey Data

VP	6	7	8	9			
FRA (ha)	191.22	123.59	3.18	325			
Observation Time (hours)	54	56.5	56.63333333	51			
Time at height band B	542.89	340.35	0	633.43			
Total Time at PCH (adjusted via FRAw)	540.06	340.70	0	621.92			

Flight activity per unit time and area		6	7	8	9				Total
Observation effort	Obsevation time (seconds) * hectare	37173168	25138206	649010	59670826				122631210.0
Flying time at risk height	Effort at each VP / FRA	1.45E-05	1.36E-05	0.00E+00	1.04E-05				3.85E-05
Weighted by observation effort		6	7	8	9				
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	3.03E-01	2.05E-01	5.29E-03	4.87E-01				1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	4.40E-06	2.78E-06	0.00E+00	5.07E-06				1.23E-05
Occupancy Rate									
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000012254							
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours active	22.80							
FRAw	Estimated bird time*(rotor diameter/recording height band)	22.38							
Rotor Transits									
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision risk volume)*3600	123.71							
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	0.39							
Number of transits 'ntr'	'n'/'t'	313.86							
E									
Probability of collision (Band model)		0.074							

Calculation of number collisions	No avoidance	Avoidance 99%
Collisions per year	17.46	0.175
Equivalent to 1 bird every x (years)	0.06	5.7
Over 30 years	523.8	5.24

Band Model - Random Flights Proposed Development Year 2

Species: Red kite

Season: Non-breeding season 2019-20 (September - February)

Wind Farm Parameters	
WFP (ha)	587.9611
Number turbines	15
Rotor diameter	162
Hub height (m)	119
Max chord (m)	4.3
Rotor depth	4.1
Pitch (degrees)	45
Rotation period (secs)	8.2
Turbine operation time 75%	0.75
Avoidance Rate 99%	0.01
Rotor radius^2	6561.00
Combined rotor swept area	309179.78
Collision Risk volume 'Vw' (m^3)	952,496,982
Rotor swept volume 'V$_r$' (m^3)	1,462,420

Bird Parameters	
length (m)	0.63
wingspan (m)	1.85
flapping (0)or gliding (1)	1
Assumed flight speed (m/s)	12
Number daylight hours available	2071.23
Maximum recording height (m)	180
Minimum recording height (m)	15

Survey Data								
VP	6	7	8	9				
FRA (ha)	191.22	123.59	3.18	325.00				
Observation Time (hours)	22	27	27	22				
Time at height band B	624.13	0	0	316.02				
Total Time at PCH (adjusted via FRAw)	612.78	0	0	310.28				

Flight activity per unit time and area		6	7	8	9					Total
Observation effort	Obsevation time (seconds) * hectare	15144624	12012948	309416	25740356					53207344.5
Flying time at risk height	Effort at each VP / FRA	4.05E-05	0.00E+00	0.00E+00	1.21E-05					5.25E-05
Weighted by observation effort		6	7	8	9					
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	2.85E-01	2.26E-01	5.82E-03	4.84E-01					1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	1.15E-05	0.00E+00	0.00E+00	5.83E-06					1.73E-05
Occupancy Rate										
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000017348								
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours active	21.13								
FRAw	Estimated bird time*(rotor diameter/recording height band)	20.74								
Rotor Transits										
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision risk volume)*3600	114.65								
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	0.39								
Number of transits 'ntr'	'n'/'t'	290.87								
E										
Probability of collision (Band model)		0.074								

Calculation of number collisions	No avoidance	Avoidance 99%
Collisions per year	16.18	0.162
Equivalent to 1 bird every x (years)	0.06	6.2
Over 30 years	485.4	4.85

Band Model - Random Flights Proposed Development Year 3

Species: Red kite

Season: Breeding season 2020 (March)

Wind Farm Parameters	
WFP (ha)	587.9611
Number turbines	15
Rotor diameter	162
Hub height (m)	119
Max chord (m)	4.3
Rotor depth	4.1
Pitch (degrees)	45
Rotation period (secs)	8.2
Turbine operation time 75%	0.75
Avoidance Rate 99%	0.01
Rotor radius^2	6561.00
Combined rotor swept area	309179.78
Collision Risk volume 'Vw' (m^3)	952,496,982
Rotor swept volume 'V$_r$' (m^3)	1,462,420

Bird Parameters	
length (m)	0.63
wingspan (m)	1.85
flapping (0)or gliding (1)	1
Assumed flight speed (m/s)	12
Number daylight hours available	431.38
Maximum recording height (m)	180
Minimum recording height (m)	15

Survey Data								
VP	6	7	8	9				
FRA (ha)	191.22	123.59	3.18	325.00				
Observation Time (hours)	20	15	15	20				
Time at height band B	138.89	313.26	0	92.47				
Total Time at PCH (adjusted via FRAw)	136.36	307.57	0	91				

Flight activity per unit time and area		6	7	8	9				Total
Observation effort	Obsevation time (seconds) * hectare	13767840	6673860	171898	23400324				44013921.8
Flying time at risk height	Effort at each VP / FRA	9.90E-06	4.61E-05	0.00E+00	3.88E-06				5.99E-05
Weighted by observation effort		6	7	8	9				
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	3.13E-01	1.52E-01	3.91E-03	5.32E-01				1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	3.10E-06	6.99E-06	0.00E+00	2.06E-06				1.21E-05
Occupancy Rate									
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000012149							
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours active	3.08							
FRAw	Estimated bird time*(rotor diameter/recording height band)	3.03							
Rotor Transits									
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision risk volume)*3600	16.72							
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	0.39							
Number of transits 'ntr'	'n'/'t'	42.42							
E									
Probability of collision (Band model)		0.074							

Calculation of number collisions	No avoidance	Avoidance 99%
Collisions per year	2.36	0.024
Equivalent to 1 bird every *x* (years)	0.42	42.4
Over 30 years	70.8	0.71

Band Model - Random Flights Proposed Development Years 1-3

Species: Goshawk

Season: All seasons 2018-2020

Wind Farm Parameters		
WFP (ha)		904.35
Number turbines		15
Rotor diameter		162
Hub height (m)		119
Max chord (m)		4.3
Rotor depth		4.1
Pitch (degrees)		45
Rotation period (secs)		8.2
Turbine operation time 75%		0.75
Avoidance Rate 98%		0.02
Rotor radius^2		6561.00
Combined rotor swept area		309179.78
Collision Risk volume 'Vw' (m^3)		1,465,044,732
Rotor swept volume 'V$_r$' (m^3)		1,437,686

Bird Parameters	
length (m)	0.55
wingspan (m)	1.1
flapping (0)or gliding (1)	0
Assumed flight speed (m/s)	11.3
Number daylight hours available	10888.8
Maximum recording height (m)	200
Minimum recording height (m)	38

Survey Data								
VP	6	7	8	9				
FRA (ha)	191.22	123.59	3.18	325.00				
Observation Time (hours)	158	169	168.1333333	165				
Time at height band B	27.68	15	0	137.57				
Total Time at PCH (adjusted via FRAw)	37.37	18	0	145.54				

Flight activity per unit time and area		6	7	8	9				Total
Observation effort	Obsevation time (seconds) * hectare	108765936	75192156	1926784	193052673				378937548.6
Flying time at risk height	Effort at each VP / FRA	3.44E-07	2.39E-07	0.00E+00	7.54E-07				1.34E-06
Weighted by observation effort		6	7	8	9				
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	2.87E-01	1.98E-01	5.08E-03	5.09E-01				1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	9.86E-08	4.75E-08	0.00E+00	3.84E-07				5.30E-07
Occupancy Rate									
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000000530							
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours active	5.22							
FRAw	Estimated bird time*(rotor diameter/recording height band)	5.22							
Rotor Transits									
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision risk volume)*3600	18.44							
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	0.41							
Number of transits 'ntr' per calendar year	'n'/'t'/2	22.41							
E									
Probability of collision (Band model)		0.076							

Calculation of number collisions	No avoidance	Avoidance 98%
Collisions per year	1.28	0.026
Equivalent to 1 bird every *x* (years)	0.78	39.0
Over 30 years	38.5	0.77

Band Model - Random Flights Proposed Development Years 1-3

Species: Peregrine

Season: All seasons 2018-2020

Wind Farm Parameters		
WFP (ha)		904.35
Number turbines		15
Rotor diameter		162
Hub height (m)		119
Max chord (m)		4.3
Rotor depth		4.1
Pitch (degrees)		45
Rotation period (secs)		8.2
Turbine operation time 75%		0.75
Avoidance Rate 98%		0.02
Rotor radius^2		6561.00
Combined rotor swept area		309179.78
Collision Risk volume 'Vw' (m^3)		1,465,044,732
Rotor swept volume 'V$_r$' (m^3)		1,397,493

Bird Parameters		
length (m)		0.42
wingspan (m)		1.02
flapping (0)or gliding (1)		0
Assumed flight speed (m/s)		12.1
Number daylight hours available		10888.8
Maximum recording height (m)		200
Minimum recording height (m)		38

Survey Data	6	7	8	9			
VP	6	7	8	9			
FRA (ha)	191.22	123.59	3.18	325.00			
Observation Time (hours)	158	169	168.133333	165			
Time at height band B	68.15	21.67	0	14.31			
Total Time at PCH (adjusted via FRAw)	71.76	26.01	0	14.05			

Flight activity per unit time and area		6	7	8	9				Total
Observation effort	Obsevation time (seconds) * hectare	108765936	75192156	1926784	193052673				378937548.6
Flying time at risk height	Effort at each VP / FRA	6.60E-07	3.46E-07	0.00E+00	7.28E-08				1.08E-06
Weighted by observation effort		6	7	8	9				
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	2.87E-01	1.98E-01	5.08E-03	5.09E-01				1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	1.89E-07	6.86E-08	0.00E+00	3.71E-08				2.95E-07
Occupancy Rate									
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000000295							
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours active	2.91							
FRAw	Estimated bird time*(rotor diameter/recording height band	2.91							
Rotor Transits									
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision risk v	9.98							
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	0.37							
Number of transits 'ntr' per calendar year	'n'/'t'/2	13.36							
E									
Probability of collision (Band model)		0.068							

Calculation of number collisions	No avoidance	Avoidance 98%
Collisions per year	0.68	0.014
Equivalent to 1 bird every x (years)	1.46	73.1
Over 30 years	20.5	0.41

Band Model - Random Flights Proposed Development Years 1-3		
Species: Red kite		
Season: All seasons 2018-2020		

Wind Farm Parameters	
WFP (ha)	904.35
Number turbines	15
Rotor diameter	162
Hub height (m)	119
Max chord (m)	4.3
Rotor depth	4.1
Pitch (degrees)	45
Rotation period (secs)	8.2
Turbine operation time 75%	0.75
Avoidance Rate 99%	0.01
Rotor radius^2	6561.00
Combined rotor swept area	309179.78
Collision Risk volume 'Vw' (m^3)	1,465,044,732
Rotor swept volume 'V$_r$' (m^3)	1,462,420

Bird Parameters	
length (m)	0.63
wingspan (m)	1.85
flapping (0)or gliding (1)	1
Assumed flight speed (m/s)	12
Number daylight hours available	10888.8
Maximum recording height (m)	200
Minimum recording height (m)	38

Survey Data								
VP	6	7	8	9				
FRA (ha)	191.22	123.59	3.18	325.00				
Observation Time (hours)	158	169	168.1333333	165				
Time at height band B	1,712.37	895.91	26.0	1,076.93				
Total Time at PCH (adjusted via FRAw)	1,837.94	975.38	35.1	1,070.24				

Flight activity per unit time and area		6	7	8	9				Total
Observation effort	Obsevation time (seconds) * hectare	108765936	75192156	1926784	193052673				378937548.6
Flying time at risk height	Effort at each VP / FRA	1.69E-05	1.30E-05	1.82E-05	5.54E-06				5.36E-05
Weighted by observation effort		6	7	8	9				
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	2.87E-01	1.98E-01	5.08E-03	5.09E-01				1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	4.85E-06	2.57E-06	9.26E-08	2.82E-06				1.03E-05
Occupancy Rate									
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000010341							
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours acti	101.83							
FRAw	Estimated bird time*(rotor diameter/recording height b	101.83							
Rotor Transits									
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision ris	365.94							
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	0.39							
Number of transits 'ntr' per calendar year	'n'/'t'/2	464.19							
E									
Probability of collision (Band model)		0.074							

Calculation of number collisions	No avoidance	Avoidance 99%
Collisions per year	25.76	0.258
Equivalent to 1 bird every *x* (years)	0.04	3.9
Over 30 years	772.9	7.73