ScottishPower Renewables Ltd

HARESTANES WEST WINDFARM

Technical Appendix 9.3: Collision Risk Modelling Report

.

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ScottishPower Renewables Ltd

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1 INTRODUCTION

1.1.1. This Technical Appendix was commissioned by Scottish Power Renewables Ltd. (SPR) and has been prepared to accompany **Chapter 9: Ornithology** of the Harestanes West Windfarm (hereafter, the 'proposed Development') Environmental Impact Assessment (EIA) Report.

1.1.2. The proposed Development is located northwest of the village of Ae, approximately 1.3 kilometres (km) to the application boundary and 2.2 km to the nearest proposed turbine, and approximately 13 km north of Dumfries (The centre of the turbine area is at National Grid Reference (NGR) NX 95993 91814). The final design layout comprises a layout of 12 turbines, six with a maximum height of 220 m and six with a maximum height of 200 m (to vertical turbine blade tip), hard standings, 31.5 km of access track (10.5 km of which is new), and associated infrastructure.

1.1.3. This Technical Appendix documents the methodology and results of collision risk modelling based on flight activity data collected from Vantage Point (VP) surveys undertaken from September 2019 to August 2021. 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'.

1.1.4. The VP surveys commenced from eight VP locations relevant to the proposed Development (VPs 1 to 6, 8 and 15) in September 2019. The proposed Development was covered by VP surveys for six hours per month from each VP.

1.1.5. Goshawk (*Accipiter gentilis*) was the only species taken forward for assessment.

1.1.6. The Annex presents details of flight activity of the species included in the CRM. **Annex A** contains the flight data used in the CRM, whilst **Annex B** presents CRM calculations.

2 CRM METHODOLOGY

2.1 INTRODUCTION

2.1.1. The risk of birds colliding with the turbine rotors has been assessed using a model developed by Bill Band, which estimates the number of bird collisions with the turbine rotors during a specified time period (Band et al., 2007; NatureScot, 2000). The model requires input data based on species biometrics and flight characteristics, turbine specification and flights observed within the Study Area. The Study Area is the Collision Risk Zone (CRZ) as defined in Paragraph 2.4.1. The amount of time that a species may be active within the Study Area in any given season is also required for the model and must therefore be estimated.

2.1.2. 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 and the probability of a bird strike occurring is calculated at Stage 2. The product of Stage 1 and Stage 2 gives a theoretical annual collision mortality rate on the assumption that birds make no attempt to avoid collision.

2.1.3. However, it is widely accepted that many species are able to 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 or, at close proximity, birds may see an oncoming blade and emergency avoidance action can be taken (NatureScot, 2000). As such, avoidance rates specific to goshawk were applied to the model to estimate the collision risk (NatureScot, 2018).

2.1.4. The results of the modelling 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.

2.2 CHOICE OF RANDOM OR REGULAR MODEL

2.2.1. 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.

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

2.2.3. The modelling method for birds with irregular (or random) flight activity, such as raptors and waders, 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.

2.2.4. As goshawk, a raptor species, was the only species taken forward for assessment, the Random Model was used in this instance.

2.3 MODEL PARAMETERS

TURBINES

2.3.1. The turbine model for the proposed Development is the Vestas V162 6.8 MW, and its parameters are detailed in **Table 2-1**. Six Vestas V162 turbines are proposed at 139 m hub height alongside six with a 119 m hub height. The turbines will have a rotor diameter of 162 m. Those with a 119 m hub height will therefore have a potential collision risk height (PCH) of 38-200 m. Those with a hub height of 139 m will have a PCH of 58-220 m.

2.3.2. For the purposes of CRM, the lowest blade sweep height (38 m) and highest blade sweep height (220 m) from the two models have been used to calculate the PCH for the proposed Development (38-220 m).

2.3.3. It has been assumed that turbines will be non-operational for 15% of the time (e.g., during periods when wind speed is too low or too high to operate, or during maintenance).

Table 2-1 – Turbine Technical Parameters

Parameter	V162 Specification (119 m hub)	V162 Specification (139 m hub)
Number of turbines	6	6
Number of blades	3	3
Hub height (m)	119	139
Rotor diameter (m)	162	162
Maximum height to blade tip (m)	200	220
Minimum height to blade tip (m)	38	58
PCH (m)	38-200	58-220
Mean pitch (degrees)	45	45
Maximum chord (m)	4.3	4.3

2.3.4. Planning permission will be sought for the wind farm to operate in perpetuity. However, it will have an expected lifespan of 40 years before repowering is needed.

AVAILABLE ACTIVE HOURS PER SEASON, SURVEY EFFORT AND OBSERVATION TIME

2.3.5. Available active hours were defined as the number of hours that a bird species may be potentially active in any given season (NatureScot, 2017) (see **Table 2-2**). Available hours for flight activity for goshawk (the only species taken forward for assessment) were calculated to include daylight, one hour before sunrise and one hour after sunset[1].

Table 2-2 – Available Active Hours September 2019 – August 2021

Species	Season	Available Hours
Goshawk	Non-breeding (Sep 2019 – Feb 2020)	2,065:03
	Breeding (Mar – Aug 2020)	3,161:30
	Non-breeding (Sep 2020 – Feb 2021)	2,056:34

[1] Data taken from https://www.timeanddate.com/astronomy/@2656781 on 22 October 2024.

Species	Season	Available Hours
	Breeding (Mar – Aug 2021)	3,164:04

2.3.6. VP surveys commenced in September 2019 and continued through until the end of August 2021. A summary of survey effort is shown in **Table 2-3**. Seasons are defined using the baseline reports. Observation effort relates to the total number of survey hours undertaken at VP locations within the seasons in question (note that VPs 1, 8 and 15 were not analysed as they fell outside of the CRZ).

2.3.7. Guidance (NatureScot 2018) requires a minimum of 36 hours per season at each individual VP location. This was achieved at all VPs.

Table 2-3 – VP survey effort

Species	Season	Period	VP1	VP2	VP3	VP4	VP5	VP6	VP8	VP15
Goshawk	Non-breeding	Sep 2019 – Feb 2020	36	36	36	36	36	36	36	36
	Breeding	Mar – Aug 2020	36	36	36	36	36	36	36	36
	Non-breeding	Sep 2020 – Feb 2021	36	36	36	36	36	36	36	36
	Breeding	Mar – Aug 2021	36	36	36	36	36	36	36	36

2.4 RANDOM MODEL

DEFINITION OF TERMS

2.4.1. The **collision risk zone (CRZ)** is defined as the perimeter of the proposed Development plus a 500m buffer and the proposed rotor length of 81 m (therefore a 581 m buffer around the Proposed Development). NatureScot guidance currently recommends a 500 m buffer to allow for observer inaccuracies when mapping flights during surveys (NatureScot, 2018).

2.4.2. The **Vantage Point viewshed** is the survey area associated with each VP, calculated as a 180-degree arc of a 2 km radius applied from each VP location.

2.4.3. The **flight risk area (FRA)** is defined as the **area of visibility** of each viewshed at minimum collision risk height (CRH), in this instance 38 m, that falls within the CRZ. This was calculated using GIS.

2.4.4. **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 to four height bands that are not identical to the PCH of the final turbine dimensions. Therefore, the overall bird activity is weighted to reflect that the swept area will differ from what was initially predicted.

2.4.5. The 2019/20 non-breeding survey season used height bands of:

- <20 m;
- 20 – 40 m;

- 40 – 100 m;
- 100 – 150 m;
- 150 – 250 m; and
- >250 m.

2.4.6. Subsequent seasons (e.g. the 2020 and 2021 breeding season; and 2020/21 non-breeding season) used height bands of:

- <50 m;
- 50 – 250 m; and
- >250 m.

2.4.7. The adjustment was made by multiplying flight time for each relevant (split) height band by the proportion of it that fell within the CRH.

2.4.8. The **collision risk volume** is defined as the volume of the airspace between the minimum and maximum risk height (38 m – 220 m) and is used in random models (NatureScot, 2000).

2.4.9. The **rotor-swept volume** is defined as the volume of air that would be swept by all of the rotors in the wind farm. For an individual rotor this is determined by the area swept (πr^2) multiplied by the thickness of the rotor blades plus the length of the focal species (NatureScot, 2000).

SELECTION OF FLIGHTS

2.4.10. All flights observed at PCH falling within the CRZ are typically included in modelling. Due to the change in height bands after the surveys, flights at PCH are taken to mean flights in height bands A to B, or B to D (depending on the season) as adjusted by the FRAw calculation. 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 in the relevant height bands within CRZ was calculated as a proportion of the clipped flight length to the total flight length in that height band. 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.

2.4.11. As outlined earlier, data from VP1, VP8 and VP15 were not included in the analysis as their viewsheds did not fall within the CRZ.

2.4.12. Flights were apportioned to the breeding or non-breeding seasons identified in **Table 2-3**.

2.4.13. **Table 2-4** shows the total flight time for the species where flight data indicated that the random CRM approach should be used.

2.4.14. **Annex A** provides details of all flights included in the random CRM, including the length of clipped flights. All flight data can be found in of **Technical Appendix 9.1 – Annex 2**.

Table 2-4 – Random Model: Goshawk flight time in seconds (after clipping)

Species	Season	Year	Total Number of Flights	Total Seconds at PCH
Goshawk	Non-breeding	2019/20	16	672
	Breeding	2020	8	150
	Non-breeding	2020/21	3	347
	Breeding	2021	12	1494

* Due to overlap of flight bands with the final rotor heights, all flights in some band bands were counted as at PCH, and later adjusted using the FRAw calculation.

BIRD PARAMETERS

2.4.15. Biometric measurements for goshawk were taken from RSPB (n.d.). Flight speed was taken from Alerstam et al. (2007), using the closely-related sparrowhawk (*Accipiter nisus*) as a proxy owing to the absence of data for goshawk. Avoidance rate was taken from current guidance (NatureScot, 2018). These parameters are presented in **Table 2-5**.

Table 2-5 – Bird Parameters

Species	Avoidance Rate (%)	Length (m)	Wingspan (m)	Flight Speed (m/s)	Flight Style
Goshawk	98	0.55	1.1	11.3	Flapping

3 CRM RESULTS

3.1.1. A summary of the CRM results is shown in **Table 3-1**, whilst details of model calculations are presented in **Annex B**.

Table 3-1 – Bird Parameters

Season	Potential Collisions	No Avoidance	Avoidance (98%)
Non-breeding 2019/20	Per year 1 bird every X years Over 40 years	7.277 0.137 291.074	0.146 6.871 5.821
Breeding 2020	Per year 1 bird every X years Over 40 years	1.492 0.670 59.681	0.030 33.511 1.194
Non-breeding 2020/21	Per year 1 bird every X years Over 40 years	2.245 0.445 89.811	0.045 22.269 1.796
Breeding 2021	Per year 1 bird every X years Over 40 years	14.883 0.067 595.309	0.298 3.360 11.906

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Annex A

GOSHAWK FLIGHT DATA USED IN CRM

Table A-1 – Goshawk flight data used in CRM

VP	Date	Time	Total Flight Time (secs)	Secs Below PCH	Secs at PCH	Secs Above PCH	Original Length (m)	Clipped Length (m)	Clip Length %	Count	Clipped Flight Time at PCH (secs)
4	23/12/2019	10:21	240	210	30	0	893.07	892.71	99.96	2	30
5	03/01/2020	13:27	165	45	120	0	3135.25	342.02	10.91	2	13
5	03/01/2020	13:41	285	150	135	0	4470.73	1251.47	27.99	1	38
5	03/01/2020	13:43	210	90	120	0	2919.34	159.73	5.47	1	7
5	07/02/2020	10:43	195	60	135	0	2887.32	628.33	21.76	1	29
5	07/02/2020	12:07	150	15	135	0	2259.63	505.95	22.39	1	30
5	07/02/2020	14:52	285	30	255	0	4864.85	2712.47	55.76	1	142
5	07/02/2020	14:57	150	0	150	0	3738.11	1365.21	36.52	1	55
2	25/02/2020	11:49	285	0	285	0	1811.26	1437.33	79.36	1	226
2	25/02/2020	11:49	60	0	60	0	392.60	342.54	87.25	1	52
2	25/02/2020	11:54	30	30	0	0	208.16	208.06	99.95	1	0
4	25/02/2020	12:09	30	0	30	0	817.64	553.00	67.63	2	20
4	25/02/2020	13:15	30	0	30	0	625.05	624.75	99.95	1	30
5	16/03/2020	11:32	30	N/A	30	0	457.05	457.05	100.00	2	30
5	16/03/2020	12:20	15	N/A	15	0	276.48	276.48	100.00	1	15

VP	Date	Time	Total Flight Time (secs)	Secs Below PCH	Secs at PCH	Secs Above PCH	Original Length (m)	Clipped Length (m)	Clip Length %	Count	Clipped Flight Time at PCH (secs)
5	16/03/2020	12:42	15	N/A	15	0	313.77	313.77	100.00	1	15
4	19/03/2020	13:09	15	N/A	15	0	491.34	491.34	100.00	1	15
4	14/04/2020	10:31	45	N/A	45	0	1556.74	922.23	59.24	1	27
4	20/04/2020	11:20	75	N/A	45	30	2279.03	1335.97	58.62	1	26
5	19/05/2020	13:16	150	N/A	150	0	2546.59	372.64	14.63	1	22
2	16/09/2020	13:32	465	N/A	445	120	5333.07	3779.03	70.86	1	244
2	05/10/2020	14:20	130	N/A	130	0	1852.83	1039.14	56.08	1	73
4	22/11/2020	11:23	30	N/A	30	0	572.77	572.77	100.00	1	30
2	09/04/2021	10:48	135	N/A	135	0	1319.87	1319.87	100.00	1	135
2	09/04/2021	10:54	75	N/A	75	0	2970.24	2970.24	100.00	1	75
2	09/04/2021	10:54	105	N/A	105	0	1968.20	1968.20	100.00	2	105
3	04/05/2021	09:56	255	N/A	255	0	3236.67	1094.75	33.82	1	86
4	17/03/2021	12:30	195	N/A	195	0	2260.83	2260.83	100.00	1	195
4	29/04/2021	11:50	15	N/A	15	0	364.96	364.96	100.00	1	15
4	27/05/2021	11:45	345	N/A	285	60	2811.38	2260.36	80.40	1	229
4	27/05/2021	10:46	300	N/A	300	0	1993.02	674.44	33.84	1	102

VP	Date	Time	Total Flight Time (secs)	Secs Below PCH	Secs at PCH	Secs Above PCH	Original Length (m)	Clipped Length (m)	Clip Length %	Count	Clipped Flight Time at PCH (secs)
2	05/07/2021	13:07	75	N/A	75	0	1149.90	422.76	36.77	1	28
5	23/03/2021	10:26	270	N/A	270	0	868.90	868.90	100.00	1	270
5	23/03/2021	08:41	420	N/A	360	60	2703.27	1905.95	70.51	1	254

* “Seconds below PCH” are detailed as N/A due to the height bands used in these three recording seasons not covering the lower sweep height of 20 m. Therefore are precautionarily included in the PCH band.

Annex B

CRM CALCULATIONS

STAGE 1 CRM

Band Model - Random Flights Proposed Development Year 1

Species: Goshawk

Season: Non-breeding season 2020-21 (September-February)

Wind Farm Parameters		
WFP (ha)	865.587085	
Number turbines	12	
Rotor diameter	162	
Hub height (m)	129	mean
Max chord (m)	4.3	
Rotor depth	11.58	to 2 dp
Pitch (degrees)	45	mean
Rotation period (secs)	7.32	mean (to 2 dp)
Turbine operation time 85%	0.85	
Avoidance Rate 98%	0.02	
Rotor radius^2	6561.00	
Combined rotor swept area	247343.82	
Collision Risk volume 'Vw' (m^3)	1,402,251,078	
Rotor swept volume 'V_r' (m^3)	3,000,281	

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	2065.05
Maximum recording height (m)	150
Minimum recording height (m)	0

Survey Data					
VP	2	3	4	5	6
FRA (ha)	212	71	226	197	48
Observation Time (hours)	36	36	36	36	36
Time at height band A	30	0	210	85	0
Time at height band B	190	0	80	209	0
Time at height band C	36	0	0	105	0
Time at height band D	52	0	0	0	0
Total Time at PCH	278	0	80	314	0

	A	B	C	D
Band minimum	0	20	40	100
Band maximum	20	40	100	150
Band CRH minimum	-	38	40	100
Band CRH maximum	-	40	100	150
Band extent	20	20	60	50

No GI flights recorded in bands E and F

Flight activity per unit time and area		2	3	4	5	6	Total
Observation effort	Obsevation time (seconds) * hectare	27438084	9224538	29283319	25591310	6194867	97732118.1
Flying time at risk height	Effort at each VP / FRA	1.01E-05	0.00E+00	2.73E-06	1.23E-05	0.00E+00	2.51E-05
Weighted by observation effort							
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	2.81E-01	9.44E-02	3.00E-01	2.62E-01	6.34E-02	1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	2.84E-06	0.00E+00	8.19E-07	3.21E-06	0.00E+00	6.88E-06
Occupancy Rate							
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000006876					
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours active	12.29					
FRAw	Estimated bird time*(rotor diameter/recording height band)	13.27					
Rotor Transits							
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision risk volume)*	102.24					
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	1.07					
Number of transits 'ntr'	'n'/'t'	95.25					
E							
Probability of collision (Band model)		0.090					

Calculation of number collisions	No avoidance	Avoidance 98%
Collisions per year	7.277	0.146
Equivalent to 1 bird every *x* (years)	0.137	6.871
Over 40 years	291.074	5.821

Band Model - Random Flights Proposed Development Year 1

Species: Goshawk

Season: Breeding season 2021 (March-August)

Wind Farm Parameters		
WFP (ha)	865.587085	
Number turbines	12	
Rotor diameter	162	
Hub height (m)	129	mean
Max chord (m)	4.3	
Rotor depth	11.58	to 2 dp
Pitch (degrees)	45	mean
Rotation period (secs)	7.32	mean (to 2 dp)
Turbine operation time 85%	0.85	
Avoidance Rate 98%	0.02	
Rotor radius^2	6561.00	
Combined rotor swept area	247343.82	
Collision Risk volume 'Vw' (m^3)	1,402,251,078	
Rotor swept volume 'V_r' (m^3)	3,000,281	

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	3161.5
Maximum recording height (m)	250
Minimum recording height (m)	0

Survey Data					
VP	2	3	4	5	6
FRA (ha)	212	71	226	197	48
Observation Time (hours)	36	36	36	36	36
Time at height band A	0	0	18	69	0
Time at height band B	0	0	50	13	0
Time at height band C	0	0	14	0	0
Total Time at PCH	0	0	68	82	0

		A	B	C
Band minimum		0	40	250
Band maximum		40	250	-
Band CRH minimum		38	40	-
Band CRH maximum		40	220	-
Band extent		40	210	-

Flight activity per unit time and area		2	3	4	5	6	Total
Observation effort	Obsevation time (seconds) * hectare	27438084	9224538	29283319	25591310	6194867	97732118.1
Flying time at risk height	Effort at each VP / FRA	0.00E+00	0.00E+00	2.32E-06	3.20E-06	0.00E+00	5.53E-06
Weighted by observation effort							
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	2.81E-01	9.44E-02	3.00E-01	2.62E-01	6.34E-02	1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	0.00E+00	0.00E+00	6.96E-07	8.39E-07	0.00E+00	1.53E-06
Occupancy Rate							
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000001535					
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours active	4.20					
FRAw	Estimated bird time*(rotor diameter/recording height band)	2.72					
Rotor Transits							
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision risk volume)*	20.96					
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	1.07					
Number of transits 'ntr'	'n'/'t'	19.53					
E							
Probability of collision (Band model)		0.090					

Calculation of number collisions	No avoidance	Avoidance 98%
Collisions per year	1.492	0.030
Equivalent to 1 bird every *x* (years)	0.670	33.511
Over 40 years	59.681	1.194

Band Model - Random Flights Proposed Development Year 1

Species: Goshawk

Season: Non-breeding season 2020/21 (September-February)

Wind Farm Parameters		
WFP (ha)	865.587085	
Number turbines	12	
Rotor diameter	162	
Hub height (m)	129	mean
Max chord (m)	4.3	
Rotor depth	11.58	to 2 dp
Pitch (degrees)	45	mean
Rotation period (secs)	7.32	mean (to 2 dp)
Turbine operation time 85%	0.85	
Avoidance Rate 98%	0.02	
Rotor radius^2	6561.00	
Combined rotor swept area	247343.82	
Collision Risk volume 'Vw' (m^3)	1,402,251,078	
Rotor swept volume 'V_r' (m^3)	3,000,281	

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	2056.57
Maximum recording height (m)	250
Minimum recording height (m)	0

Survey Data					
VP	2	3	4	5	6
FRA (ha)	212	71	226	197	48
Observation Time (hours)	36	36	36	36	36
Time at height band A	159	0	30	0	0
Time at height band B	158	0	0	0	0
Time at height band C	414	0	0	0	0
Total Time at PCH	317	0	30	0	0

	A	B	C
Band minimum	0	40	250
Band maximum	40	250	-
Band CRH minimum	38	40	-
Band CRH maximum	40	220	-
Band extent	40	210	-

Flight activity per unit time and area		2	3	4	5	6	Total
Observation effort	Obsevation time (seconds) * hectare	27438084	9224538	29283319	25591310	6194867	97732118.1
Flying time at risk height	Effort at each VP / FRA	1.16E-05	0.00E+00	1.02E-06	0.00E+00	0.00E+00	1.26E-05
Weighted by observation effort							
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	2.81E-01	9.44E-02	3.00E-01	2.62E-01	6.34E-02	1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	3.24E-06	0.00E+00	3.07E-07	0.00E+00	0.00E+00	3.55E-06
Occupancy Rate							
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000003551					
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours active	6.32					
FRAw	Estimated bird time*(rotor diameter/recording height band)	4.10					
Rotor Transits							
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision risk volume)*	31.55					
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	1.07					
Number of transits 'ntr'	'n'/'t'	29.39					
E							
Probability of collision (Band model)		0.090					

Calculation of number collisions	No avoidance	Avoidance 98%
Collisions per year	2.245	0.045
Equivalent to 1 bird every *x* (years)	0.445	22.269
Over 40 years	89.811	1.796

Season: Breeding season 2021 (March-August)

Wind Farm Parameters		
WFP (ha)	865.587085	
Number turbines	12	
Rotor diameter	162	
Hub height (m)	129	mean
Max chord (m)	4.3	
Rotor depth	11.58	to 2 dp
Pitch (degrees)	45	mean
Rotation period (secs)	7.32	mean (to 2 dp)
Turbine operation time 85%	0.85	
Avoidance Rate 98%	0.02	
Rotor radius^2	6561.00	
Combined rotor swept area	247343.82	
Collision Risk volume 'Vw' (m^3)	1,402,251,078	
Rotor swept volume 'V_r' (m^3)	3,000,281	

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	3164.07
Maximum recording height (m)	250
Minimum recording height (m)	0

Survey Data					
VP	2	3	4	5	6
FRA (ha)	212	71	226	197	48
Observation Time (hours)	36	36	36	36	36
Time at height band A	178	41	119	96	0
Time at height band B	165	46	422	428	0
Time at height band C	0	0	48	42	0
Total Time at PCH	343	87	541	524	0

	A	B	C
Band minimum	0	40	250
Band maximum	40	250	-
Band CRH minimum	38	40	-
Band CRH maximum	40	220	-
Band extent	40	210	-

Flight activity per unit time and area		2	3	4	5	6	Total
Observation effort	Obsevation time (seconds) * hectare	27438084	9224538	29283319	25591310	6194867	97732118.1
Flying time at risk height	Effort at each VP / FRA	1.25E-05	9.43E-06	1.85E-05	2.05E-05	0.00E+00	6.09E-05
Weighted by observation effort							
Weighted obs effort	Effort at each VP / sum of all effort at all VP's	2.81E-01	9.44E-02	3.00E-01	2.62E-01	6.34E-02	1.0
Adjusted time at risk height	Weighted obs effort * flying time at risk height	3.51E-06	8.90E-07	5.54E-06	5.36E-06	0.00E+00	1.53E-05
Occupancy Rate							
Summed Occupancy rate	Sum of weighted average flight activity per visible ha	0.000015297					
Estimated bird time 'b' in risk area	Summed Occupancy rate*windfarm polygon*hours active	41.89					
FRAw	Estimated bird time*(rotor diameter/recording height band)	27.15					
Rotor Transits							
Bird occupancy of rotor swept volume ('b')	Estimated bird time * (rotor swept volume / collision risk volume)*	209.11					
Bird transit time (t)	(rotor depth+bird length)/flight speed(m/s)	1.07					
Number of transits 'ntr'	'n'/'t'	194.80					
E							
Probability of collision (Band model)		0.090					

Calculation of number collisions	No avoidance	Avoidance 98%
Collisions per year	14.883	0.298
Equivalent to 1 bird every *x* (years)	0.067	3.360
Over 40 years	595.309	11.906

STAGE 2 CRM

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA												
Only enter input parameters in green cells											04/11/2024	
K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**									
NoBlades	3						Upwind:			Downwind:		
MaxChord	4.3	m	r/R	c/C	α	collide		contribution	collide		contribution	
Pitch (degrees)	45		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r	
BirdLength	0.55	m	0.025	0.575	6.09	19.10	0.74	0.00092	15.61	0.60	0.00075	
Wingspan	1.1	m	0.075	0.575	2.03	7.53	0.29	0.00219	4.04	0.16	0.00117	
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.22	6.07	0.24	0.00294	1.81	0.07	0.00087	
			0.175	0.860	0.87	5.85	0.23	0.00396	1.30	0.05	0.00088	
Bird speed	11.3	m/sec	0.225	0.994	0.68	5.81	0.23	0.00506	1.72	0.07	0.00150	
RotorDiam	162	m	0.275	0.947	0.55	5.08	0.20	0.00541	1.89	0.07	0.00202	
RotationPeriod	6.86	sec	0.325	0.899	0.47	4.56	0.18	0.00574	2.00	0.08	0.00252	
			0.375	0.851	0.41	4.19	0.16	0.00608	2.09	0.08	0.00303	
			0.425	0.804	0.36	3.87	0.15	0.00636	2.12	0.08	0.00348	
			0.475	0.756	0.32	3.59	0.14	0.00659	2.11	0.08	0.00388	
Bird aspect ratioo: β	0.50		0.525	0.708	0.29	3.33	0.13	0.00676	2.08	0.08	0.00422	
			0.575	0.660	0.26	3.09	0.12	0.00688	2.03	0.08	0.00451	
			0.625	0.613	0.24	2.87	0.11	0.00694	1.96	0.08	0.00474	
			0.675	0.565	0.23	2.66	0.10	0.00694	1.88	0.07	0.00491	
			0.725	0.517	0.21	2.45	0.09	0.00688	1.79	0.07	0.00503	
			0.775	0.470	0.20	2.26	0.09	0.00677	1.70	0.07	0.00509	
			0.825	0.422	0.18	2.07	0.08	0.00661	1.60	0.06	0.00510	
			0.875	0.374	0.17	1.89	0.07	0.00639	1.49	0.06	0.00505	
			0.925	0.327	0.16	1.71	0.07	0.00611	1.38	0.05	0.00494	
			0.975	0.279	0.16	1.53	0.06	0.00577	1.27	0.05	0.00477	
				Overall p(collision) =			**Upwind**	**11.1%**		**Downwind**	**6.8%**	
								Average	**9.0%**			

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