

Appendix 10.2

2018

Shepherd's Rig Wind Farm

Collision Risk Modelling Report

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Collision Risk Technical Report

Introduction

1. This report details the results of collision risk modelling for four species of raptor, goshawk (*Accipiter gentilis*), red kite (*Milvus milvus*), hen harrier (*Circus cyaneus*) and osprey (*Pandion haliaetus*), for a nineteen turbine layout at the proposed Shepherd's Rig wind farm ("the Proposed Development").

Collision Risk Modelling

2. The Band collision risk model (CRM) (Band *et al.*, 2007) was used to estimate the potential number of goshawk, red kite, hen harrier and osprey collisions likely to occur at the Proposed Development. The model requires input data based on species biometrics and flight characteristics, turbine specification and data on flights observed at the site.

3. SNH guidance on collision risk modelling was used. This is a three stage process, which involves:

- 1) An assessment of the probability of a collision, based on a bird flying through an operational turbine; and
- 2) An estimation of the number of birds passing through the swept zone of the turbine blades.

Multiplying stages 1 and 2 provides an estimate of collision risk with the turbines, assuming no avoidance action. After, the third stage is applied:

- 3) An avoidance rate is applied (where known) to account for the fact that many species will take avoidance action.
4. The result of the model provides an estimate of the number of collisions that can be expected over a year or for the lifetime of the wind farm.
5. For the turbines proposed, the probability of a goshawk, red kite, hen harrier or osprey being struck by a turbine blade when passing through the rotor swept volume has been estimated at 6.6%, 8.0%, 6.4% and 6.3% respectively, **assuming no avoidance** (see Appendix 1). However, it is widely accepted that raptors 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 (Macro avoidance). At close proximity, birds may see an oncoming blade and emergency avoidance action can be taken (Micro avoidance) (SNH, 2000). As such, an avoidance rate of 98%, 99%, 99% and 98% (SNH 2010) was applied to the model to estimate the collision risk for goshawk, red kite, hen harrier and osprey respectively.

Windfarm characteristics

6. The proposed scheme has nineteen turbines and the flight risk volume (Vw), in these analyses, is based on a buffer constructed with a radius of 500 m (area = 736 ha), centred on the turbine locations with a height that was equal to the diameter of the turbine blades (117 m). The turbines used for the collision risk modelling were based on a hub height of 91.5 m, giving an overall tip height of 150 m. Turbine specifications were obtained from the manufacturer¹ and are shown where relevant.

Viewsheds

7. Flight data were obtained from a total of five Vantage Points (VPs), however only four VPs were used in any one year, i.e. VPs 1, 2, 3 and 4 were used in Year 1 and VPs 2, 3, 4 and 6 were used in Year 2. Viewsheds were estimated using a Digital Elevation Model (DEM) and a 30 m vertical offset above the ground surface (lowest point of rotor sweep at 33 m). Other details of the viewshed calculation are given in Table 1. Details of at-risk flights are given in Tables 2. An 'at-risk' flight is one which passes into the 500 m turbine buffer with at least part of its flight at an altitude between 30 m and 150 m.
8. The total flight duration recorded during the vantage point watches was adjusted to give an estimate for the total expected over the period of occupancy by each species. The total potential flying time for each species was estimated from the sum of the day lengths of each day. Day length was estimated, for each day, using the method of Forsythe *et al.* (1995) at latitude 55.2117 ° N.

Species-specific information

9. Table 3 summarises the species-specific information used in the collision risk calculations. Collision probability was obtained using the SNH (2000) model and details, for each species, are available in Appendix 1. Species length and wing span have been derived using a mean of the figures presented within Snow & Perrins (1998) and flight speeds were derived using Alerstam *et al.* (2007) or Provan & Whitfield (2006)(SNH, 2014).

Tables

Table 1. Vantage point survey effort and visible areas within the 500 m buffer drawn around the turbines.		
VP	Visible area with 500m turbine buffer (ha)	Hours of observation (hrs)
1	207.4	75.00
2	391.1	148.67
3	197.1	149.75
4	264.3	147.50
6	267.3	73.58

¹<https://www.vestas.com/en/products/turbines>

Table 2. Flight durations recorded within VP viewsheds and clipped to 500 m survey buffer. Part, or all, of these flights at a height of 30 – 150 m agl places them at risk of a collision with the turbine blades (shaded columns).

Species	Season	VP	No. Flights	No. of Birds	Total fly time (s)	Time in height category (s)						
						<10m	10-30m	30-50m	50-100m	100-150m	>150m	
Goshawk	Apr-Aug	VP2	1	1	50		17	33				
			1	1	101					15	86	
			1	1	467				75	45	347	
			1	1	2	2						
		VP4	1	1	7		7					
			1	1	14		14					
		VP6	1	1	1	1						
			1	1	3	3						
	Total			8	8	644	6	38	33	75	60	433
	Sep-Mar	VP2	1	1	140		31	31	78			
		VP3	1	1	22	22						
Total			2	2	162	22	31	31	78			
Total			10	10	807	28	69	64	153	60	433	
Hen harrier	Apr-Aug	VP3	1	1	16				16			
	Total			1	1	16			16			
	Sep-Mar	VP4	1	1	41		16	25				
		VP6	1	1	16	16						
			1	1	198	183	15					
Total			3	3	255	199	31	25				
Total			4	4	271	199	31	25	16			
Red kite	Apr-Aug	VP2	1	1	88			88				
			1	1	186			30	140	16		
			1	1	123				123			
		VP3	1	1	30			15	15			
			1	1	230						230	
			1	1	185			31	108	46		
			1	1	141		30	48	63			
		VP6	1	1	45				45			
	Total			8	8	1028		30	212	494	62	230
	Sep-Mar	VP6	1	1	47		47					
			1	1	77		77					
1			1	47		47						
Total			3	3	171		171					
Total			11	11	1199		201	212	494	62	230	
Osprey	Apr-Aug	VP2	1	1	105			15	90			
			1	1	135			15	120			
		VP3	1	1	36	18	18					
			1	1	20		20					
			1	1	93		93					
			1	1	63			47	16			
	Total			6	6	452	18	131	77	226		
Total			6	6	452	18	131	77	226			

Table 3. Species-specific information used in the collision risk calculations.

Species	Bird length			Wingspan			Flight speed (ms ⁻¹)	Collision probability (%)	Total potential flying time (hrs)
	Min (cm)	Max (cm)	Average (m)	Min (cm)	Max (cm)	Average (m)			
Goshawk	48	62	0.55	135	165	1.5	14	6.6%	4,494
Red kite	60	66	0.63	175	195	1.85	11	8.0%	4,494
Hen harrier	44	52	0.48	100	120	1.1	13	6.4%	4,494
Osprey	55	58	0.565	145	170	1.575	16	6.3%	2,429

Results

Goshawk

WIND FARM PARAMETERS	
Size of windfarm envelope	736 ha
Number of turbines	19
Rotor diameter	117 m
Hub height	91.5 m
Max. rotor depth in metres	4.2 m
Max. chord	4.00 m
Pitch	15.0 degrees
Rotation period	5.00 s
Turbine operation time	87 %

BIRD PARAMETERS	
Length	0.55 m
Wingspan	1.50 m
Flapping (0) or gliding (+1)	1
Assumed flight speed	14 ms ⁻¹
Number of hours birds potentially present	4494 hrs
Assumed avoidance rate	98 %

BAND USED TO DEFINE 'RISK HEIGHT'	
Max height	150 m
Min height	30 m

VP	Watch Data		Bird Flight Data	
	Area (ha)	Time (hrs)	Total (s)	'Risk height' (s)
1	207.4	75.00	0.0	0.0
2	391.1	148.67	760.0	277.0
3	197.1	149.75	22.0	0.0
4	264.3	147.50	25.0	0.0
6	267.3	73.6	0.0	0.0
Totals	1327.2	594.5	807.0	277.0

Flight Activity Per Unit Time & Weighted By Observation Effort					
VP	Area		Flying time at 'risk height' (Hahr ⁻¹)	VP	Adjusted time at 'risk height' (Hahr ⁻¹)
	Observation effort (Hahr)	Weighting			
1	15555.00	0.0000000	0.0000000	1	0.096
2	58144.84	0.0000013	0.0000013	2	0.359
3	29515.73	0.0000000	0.0000000	3	0.182
4	38984.25	0.0000000	0.0000000	4	0.241
6	19667.93	0.0000000	0.0000000	6	0.122
Totals	161867.75	0.000000265	0.000000000	Totals	1.000
					Mean activity hr⁻¹ in wind farm
					Risk height 0.03499%
					Rotor height 0.03411%

MORTALITY ESTIMATE	
Flight risk volume (Vw)	861120000 m ³
Rotor radius ²	3422.25 m
Combined rotor swept area (Va)	204275 m ²
Vr = Va * (d + 1)	970306 m ³
Bird occupancy (n)	1.53 hrs / yr
Bird occupancy of rotor swept vol (b)	6.22 bird-secs
Bird transit time (t)	0.34 secs
No. of transits through rotors	18.33 per year
Estimated no. of collisions	1.05 per year
After allowing for avoidance	0.021 per year
	47.6 years

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Red kite

WIND FARM PARAMETERS	
Size of windfarm envelope	736 ha
Number of turbines	19
Rotor diameter	117 m
Hub height	91.5 m
Max. rotor depth in metres	4.2 m
Max. chord	4.00 m
Pitch	15.0 degrees
Rotation period	5.00 s
Turbine operation time	87 %

BIRD PARAMETERS	
Length	0.63 m
Wingspan	1.85 m
Flapping (0) or gliding (+1)	1
Assumed flight speed	11 ms ⁻¹
Number of hours birds potentially present	4494 hrs
Assumed avoidance rate	99 %

BAND USED TO DEFINE 'RISK HEIGHT'	
Max height	150 m
Min height	30 m

VP	Watch Data		Bird Flight Data	
	Area (ha)	Time (hrs)	Total (s)	'Risk height' (s)
1	207.4	75.00	0.0	0.0
2	391.1	148.67	397.0	397.0
3	197.1	149.75	586.0	326.0
4	264.3	147.50	47.0	0.0
6	267.3	73.6	169.0	45.0
Totals	1327.2	594.5	1199.0	768.0

VP	Area		Weighted By Observation Effort	
	Observation effort (HaHr)	Flying time at 'risk height' (Hahr ⁻¹)	VP	Adjusted time at 'risk height' (Hahr ⁻¹)
1	15555.00	0.0000000	1	0.0000000
2	58144.84	0.0000019	2	0.0000007
3	29515.73	0.0000031	3	0.0000006
4	38984.25	0.0000000	4	0.0000000
6	19667.93	0.0000006	6	0.0000001
Totals	161867.75	0.00000112	Totals	0.00000132

Mean activity hr ⁻¹ in wind farm	
Risk height	0.09700%
Rotor height	0.09458%

MORTALITY ESTIMATE	
Flight risk volume (Vw)	861120000 m ³
Rotor radius ²	3422.25 m
Combined rotor swept area (Va)	204275 m ²
Vr = Va * (d + 1)	986648 m ³
Bird occupancy (n)	4.25 hrs / yr
Bird occupancy of rotor swept vol (b)	17.53 bird-secs
Bird transit time (t)	0.44 secs
No. of transits through rotors	39.93 per year
Estimated no. of collisions	2.78 per year
After allowing for avoidance	0.028 per year
	<u>I.e. equivalent to one bird every 36.0 years</u>

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Hen harrier

WIND FARM PARAMETERS	
Size of windfarm envelope	736 ha
Number of turbines	19
Rotor diameter	117 m
Hub height	91.5 m
Max. rotor depth in metres	4.2 m
Max. chord	4.00 m
Pitch	15.0 degrees
Rotation period	5.00 s
Turbine operation time	87 %

BIRD PARAMETERS	
Length	0.48 m
Wingspan	1.10 m
Flapping (0) or gliding (+1)	1
Assumed flight speed	13 ms ⁻¹
Number of hours birds potentially present	4494 hrs
Assumed avoidance rate	99 %

BAND USED TO DEFINE 'RISK HEIGHT'	
Max height	150 m
Min height	30 m

VP	Watch Data		Bird Flight Data	
	Area (ha)	Time (hrs)	Total (s)	'Risk height' (s)
1	207.4	75.00	0.0	0.0
2	391.1	148.67	0.0	0.0
3	197.1	149.75	16.0	16.0
4	264.3	147.50	41.0	25.0
6	267.3	73.6	214.0	0.0
Totals	1327.2	594.5	271.0	41.0

Flight Activity Per Unit Time & Area				Weighted By Observation Effort	
VP	Observation effort (Hahr)	Flying time at 'risk height' (Hahr ⁻¹)	VP	Weighting	Adjusted time at 'risk height' (Hahr ⁻¹)
1	15555.00	0.0000000	1	0.096	0.0000000
2	58144.84	0.0000000	2	0.359	0.0000000
3	29515.73	0.0000002	3	0.182	0.0000000
4	38984.25	0.0000002	4	0.241	0.0000000
6	19667.93	0.0000000	6	0.122	0.0000000
Totals	161867.75	0.0000001	Totals	1.000	0.0000000704
				Mean activity hr ⁻¹ in wind farm	
				Risk height	0.00518%
				Rotor height	0.00505%

MORTALITY ESTIMATE	
Flight risk volume (Vw)	861120000 m ³
Rotor radius ²	3422.25 m
Combined rotor swept area (Va)	204275 m ²
Vr = Va * (d + 1)	956007 m ³
Bird occupancy (n)	0.23 hrs / yr
Bird occupancy of rotor swept vol (b)	0.91 bird-secs
Bird transit time (t)	0.36 secs
No. of transits through rotors	2.52 per year
Estimated no. of collisions	0.14 per year
After allowing for avoidance	0.001 per year
	i.e. equivalent to one bird every 707.9 years

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Osprey

WIND FARM PARAMETERS	
Size of windfarm envelope	736 ha
Number of turbines	19
Rotor diameter	117 m
Hub height	91.5 m
Max. rotor depth in metres	4.2 m
Max. chord	4.00 m
Pitch	15.0 degrees
Rotation period	5.00 s
Turbine operation time	87 %

BIRD PARAMETERS	
Length	0.57 m
Wingspan	1.58 m
Flapping (0) or gliding (+1)	1
Assumed flight speed	16 ms ⁻¹
Number of hours birds potentially present	2429 hrs
Assumed avoidance rate	98 %

BAND USED TO DEFINE 'RISK HEIGHT'	
Max height	150 m
Min height	30 m

VP	Watch Data		Bird Flight Data	
	Area (ha)	Time (hrs)	Total (s)	'Risk height' (s)
1	207.4	75.00	0.0	0.0
2	391.1	148.67	240.0	240.0
3	197.1	149.75	0.0	0.0
4	264.3	147.50	212.0	63.0
6	267.3	73.58	0.0	0.0
Totals	1327.2	594.5	452.0	303.0

VP	Flight Activity Per Unit Time & Area		Weighted By Observation Effort	
	Observation effort (hahr)	Flying time at 'risk height' (Hahr ⁻¹)	VP	Adjusted time at 'risk height' (Hahr ⁻¹)
1	15555.00	0.0000000	1	0.096
2	58144.84	0.0000011	2	0.359
3	29515.73	0.0000000	3	0.182
4	38984.25	0.0000004	4	0.241
6	19667.93	0.0000000	6	0.122
Totals	161867.75	0.00000319	Totals	1.000
				Mean activity hr ⁻¹ in wind farm
				Risk height 0.03827%
				Rotor height 0.03731%

MORTALITY ESTIMATE	
Flight risk volume (Vw)	861120000 m ³
Rotor radius ²	3422.25 m
Combined rotor swept area (Va)	204275 m ²
Vr = Va * (d + 1)	973370 m ³
Bird occupancy (n)	0.91 hrs / yr
Bird occupancy of rotor swept vol (b)	3.69 bird-secs
Bird transit time (t)	0.30 secs
No. of transits through rotors	12.38 per year
Estimated no. of collisions	0.68 per year
After allowing for avoidance	0.014 per year
	I.e. equivalent to one bird every 73.8 years

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Probability of collision; red kite

		Calculation of alpha and p(collision) as a function of radius									
K: [1D or [3D] (0 or 1)		Upw ind:					Dow nw ind:				
NoBlades		r/R	collide length	p(collision)	y(x)	collide length	p(collision)	y(x)			
MaxChord	4.00 m	0.05	10.77	0.59	0.059	9.58	0.52	0.052			
Pitch (degrees)	15.0	0.1	6.00	0.33	0.065	4.72	0.26	0.051			
BirdLength	0.63 m	0.15	4.99	0.27	0.082	3.38	0.18	0.055			
Wingspan	1.85 m	0.2	4.57	0.25	0.100	2.62	0.14	0.057			
F: Flapping (0) or gliding (+1)	1	0.25	3.95	0.22	0.108	1.94	0.11	0.053			
Bird speed	11 m/sec	0.3	3.32	0.18	0.109	1.41	0.08	0.046			
RotorDiam	117 m	0.35	2.85	0.16	0.109	1.04	0.06	0.040			
RotationPeriod	5.00 sec	0.4	2.49	0.14	0.109	0.78	0.04	0.034			
integration interval	0.05	0.45	2.44	0.13	0.120	0.82	0.04	0.040			
Bird aspect ratio: β	0.34	0.5	2.23	0.12	0.122	0.72	0.04	0.039			
		0.55	2.06	0.11	0.123	0.64	0.03	0.038			
		0.6	1.90	0.10	0.125	0.68	0.04	0.044			
		0.65	1.76	0.10	0.125	0.72	0.04	0.051			
		0.7	1.64	0.09	0.125	0.74	0.04	0.057			
		0.75	1.52	0.08	0.124	0.76	0.04	0.062			
		0.8	1.41	0.08	0.123	0.77	0.04	0.067			
		0.85	1.31	0.07	0.122	0.77	0.04	0.072			
		0.9	1.22	0.07	0.120	0.77	0.04	0.075			
		0.95	1.13	0.06	0.117	0.76	0.04	0.079			
		1	1.04	0.06	0.114	0.75	0.04	0.081			

Overall p(collision) = Upwind 10.7% Downwind 5.3% Average 8.0%

Probability of collision; hen harrier

K: [1D or [3D] (0 or 1)										
NoBlades	1	Calculation of alpha and p(collision) as a function of radius								
MaxChord	4.00 m	3	Upw ind:		Dow nw ind:					
Pitch (degrees)	15.0	r/R	c/C	α	collide length	p(collision)	y(x)	collide length	p(collision)	y(x)
BirdLength	0.48 m	0.05	0.575	3.54	10.93	0.50	0.000	9.74	0.45	0.000
Wingspan	1.1 m	0.1	0.622	1.77	6.13	0.28	0.050	4.85	0.22	0.045
F: Flapping (0) or gliding (+1)	1	0.15	0.781	1.18	5.19	0.24	0.072	3.57	0.16	0.049
Bird speed	13 m/sec	0.2	0.939	0.88	4.80	0.22	0.089	2.86	0.13	0.053
RotorDiam	117 m	0.25	0.971	0.71	4.15	0.19	0.096	2.14	0.10	0.049
RotationPeriod	5.00 sec	0.3	0.923	0.59	3.47	0.16	0.096	1.56	0.07	0.043
integration interval	0.05	0.35	0.875	0.51	2.97	0.14	0.096	1.16	0.05	0.037
Bird aspect ratio: β	0.44	0.4	0.827	0.44	2.58	0.12	0.095	0.87	0.04	0.032
		0.45	0.780	0.39	2.47	0.11	0.103	0.86	0.04	0.036
		0.5	0.732	0.35	2.24	0.10	0.103	0.72	0.03	0.033
		0.55	0.684	0.32	2.04	0.09	0.103	0.62	0.03	0.032
		0.6	0.637	0.29	1.86	0.09	0.103	0.55	0.03	0.030
		0.65	0.589	0.27	1.71	0.08	0.103	0.49	0.02	0.029
		0.7	0.541	0.25	1.57	0.07	0.101	0.51	0.02	0.033
		0.75	0.494	0.24	1.44	0.07	0.100	0.54	0.02	0.037
		0.8	0.446	0.22	1.32	0.06	0.098	0.56	0.03	0.041
		0.85	0.398	0.21	1.21	0.06	0.095	0.57	0.03	0.045
		0.9	0.350	0.20	1.11	0.05	0.092	0.58	0.03	0.048
		0.95	0.303	0.19	1.01	0.05	0.089	0.58	0.03	0.050
		1	0.255	0.18	0.92	0.04	0.085	0.57	0.03	0.053

Overall p(collision) =

Upwind

8.9%

Downwind

4.0%

Average

6.4%

Probability of collision; osprey

Calculation of alpha and p(collision) as a function of radius										
Upw ind:										
K: [1D or 3D] (0 or 1)	1									
NoBlades	3									
MaxChord	4.00 m	r/R	c/C	alpha	collide length	p(collision)	y(x)	collide length	p(collision)	y(x)
Pitch (degrees)	15.0	0								
BirdLength	0.57 m	0.05	0.575	4.35	14.63	0.55	0.000	13.44	1.00	0.000
Wingspan	1.575 m	0.1	0.622	2.18	8.06	0.30	0.055	6.77	0.50	0.050
F: Flapping (0) or gliding (+1)	1	0.15	0.781	1.45	6.64	0.25	0.060	5.02	0.25	0.051
		0.2	0.939	1.09	6.01	0.23	0.075	4.07	0.19	0.057
Bird speed	16 m/sec	0.25	0.971	0.87	5.14	0.19	0.090	3.13	0.15	0.061
RotorDiam	117 m	0.3	0.923	0.73	4.27	0.16	0.096	2.36	0.12	0.059
RotationPeriod	5.00 sec	0.35	0.875	0.62	3.63	0.14	0.095	1.82	0.09	0.053
		0.4	0.827	0.54	3.14	0.12	0.094	1.43	0.07	0.048
integration interval	0.05	0.45	0.780	0.48	2.75	0.10	0.093	1.13	0.05	0.043
		0.5	0.732	0.44	2.43	0.09	0.091	0.91	0.04	0.038
Bird aspect ratio: β	0.36	0.55	0.684	0.40	2.15	0.08	0.089	0.73	0.03	0.034
		0.6	0.637	0.36	1.91	0.07	0.086	0.60	0.03	0.030
		0.65	0.589	0.33	1.94	0.07	0.094	0.72	0.02	0.027
		0.7	0.541	0.31	1.78	0.07	0.093	0.65	0.03	0.035
		0.75	0.494	0.29	1.63	0.06	0.092	0.61	0.02	0.034
		0.8	0.446	0.27	1.50	0.06	0.090	0.57	0.02	0.034
		0.85	0.398	0.26	1.37	0.05	0.087	0.58	0.02	0.037
		0.9	0.350	0.24	1.26	0.05	0.085	0.60	0.02	0.041
		0.95	0.303	0.23	1.15	0.04	0.082	0.61	0.02	0.043
		1	0.255	0.22	1.04	0.04	0.078	0.61	0.02	0.046

Overall p(collision) = Upwind 8.4% Downwind 4.2%

Average 6.3%