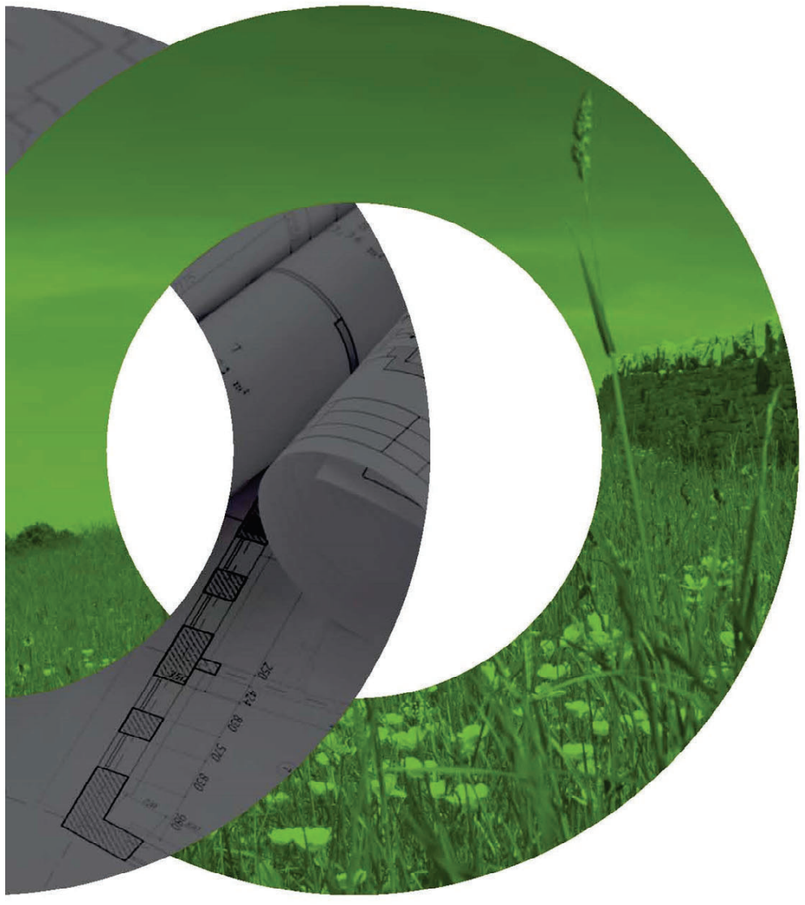
Appendix 9.2: Collision Mortality Risks

An Càrr Dubh Wind Farm

EIAR

Appendix 9.2: Collision Mortality Risks



avianecology

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1 INTRODUCTION

1.1.1 This Appendix has been prepared to accompany **Chapter 9: Ornithology** of the An Càrr Dubh Wind Farm (the Proposed Development) Environmental Impact Assessment Report (EIAR).

1.1.2 It presents the details and results of collision mortality risks calculations used to inform the design and assessment of the Proposed Development in relation to ornithological features.

2 METHODOLOGY

2.1 Background

2.1.1 The NatureScot Collision Risk Model (CRM) or the Band Model (Band *et al*., 2007[1]) has been used to estimate potential collision mortality risks to target bird species recorded during baseline Vantage Point (VP) flight activity, as a result of the Proposed Development.

2.1.2 The NatureScot CRM estimates collision mortality risks in three stages:

- Stage 1: the estimation of the number of birds passing through the rotor swept volume of the wind farm, based on observed flight activity data;
- Stage 2: the estimation of collision likelihood i.e. the probability of a bird flying through a rotor being hit, based on bird and wind farm parameters and whereby all collisions are assumed to be fatal. This provides an estimate of how many fatal collisions could occur, in theory, should birds take no avoiding action; and,
- After multiplying Stage 1 and Stage 2 an avoidance factor is then applied i.e. whereby it is assumed birds take action to avoid collision.

2.2 Wind Farm Parameters

2.2.1 The Proposed Development comprises up to 13 turbines with a 180 m maximum tip height and rotor diameter of 155 m.

2.2.2 For the purposes of analysis, the flight risk volume (Vw) is based on a buffer constructed around the outer turbine locations with a radius of 200 m (area = 449.58 ha) and a height at least equal to the rotor diameter (155 m).

2.2.3 Turbine parameters used in analysis are summarised in **Table 2.1** and are based on a Siemens Gamesa SG155 where these are publicly available, or a comparable alternative.

Table 2.1: Wind farm parameters.

Parameter	Value	Unit
Wind Farm Area (200m turbine buffer)	449.58	ha
No. of rotors	13	-
No. of blades	3	-

[1] Band, W., Madders, M., & Whitfield, D.P. (2007). Developing field and analytical methods to assess avian collision risk at wind farms. In: de Lucas, M., Janss, G.F.E. & Ferrer, M. (Eds.) *Birds and Wind Farms: Risk Assessment and Mitigation*, pp. 259- 275. Quercus, Madrid.

Parameter	Value	Unit
Tip height	180	meters
Hub height	102.5	meters
Rotor diameter	155	meters
Rotor radius	77.5	meters
Max chord	5.4	meters
Pitch	15	degrees
Rotation period	6.43[2]	seconds
Downtime	15%	%

2.3 Viewsheds

2.3.1 Target species flight activity data for use in collision mortality risk estimates has been obtained from baseline VP flight activity surveys between February 2019 and August 2021. Full details are presented in **Appendix 9.1: Ornithology** of the EIAR.

2.3.2 **Figure 9.3** of the EIAR illustrates visible areas for each VP location using a 2km viewshed radius (detection distance) and a 20m above the ground cut off.

2.3.3 Following the finalisation of turbine locations, only VPA and VPD provide visual coverage of the Proposed Development turbine locations and wind farm area (200m turbine buffer). As such only target species flight activity data derived from observations at VPA and VPD have been used for the purposes of collision mortality risk estimates for the Proposed Development.

2.3.4 As illustrated in **Figure 9.3** due to the topography of the Site and adopting a 2km viewshed radius, there are some limitations to visibility of the 200m turbine buffers. Extensive visual coverage of immediately adjacent and comparable moorland habitat has been provided and visibility was afforded in higher intervals above the ground, as evidence from flight activity recorded. This is not considered a limitation to the use of the NatureScot CRM.

2.3.5 Areas of viewshed visibility for VPs A and D within the wind farm area (200m turbine buffer), clipped to removed overlap for use in collision mortality risk estimates are summarised in **Table 2.2**.

Table 2.2: VP location and viewshed parameters.

VP	Grid Reference	Viewshed Radius (m)	Visible Area (ha) within wind farm area (200m turbine buffer)
VPA	NN 00794 11307	2,000	64.89
VPD	NN 03423 12908	2,000	356.6

2.4 VP Flight Activity Data

2.4.1 Survey effort (hours) completed at each VP between February 2019 and August 2021 are summarised in **Appendix 9.1**.

[2] Based on a possible maximum rotational speed of 11.20 revolutions per minute (r.p.m), with a conservative operating speed estimate derived as 20% of the maximum.

2.4.2 Full details of all target species flights during the VP flight activity surveys are presented in **Appendix 9.1** of the EIAR

2.5 'At Collision Risk' Flight Activity

2.5.1 'At collision risk' activity for the Proposed Development was defined as those target species flights recorded within the wind farm area (200m turbine buffer), with at least part of its flight 'at collision risk height' between 25m and 180 m above the ground.

2.5.2 'At collision risk' flight activity was recorded for the following species, with full details provided in **Annex 1** of this Appendix and illustrated in **Figures 9.6a-c** and **Figures 9.6d-f** of the EIAR:

- Red-throated diver;
- Golden eagle;
- Osprey;
- White-tailed eagle;
- Hen harrier;
- Snipe;
- Merlin;
- Peregrine; and,
- Red kite.

2.5.3 Collision mortality risk estimates have only been undertaken for golden eagle, hen harrier, red-throated diver and white-tailed eagle as no other target species recorded more than three 'at collision risk' flights during any survey year.

2.5.4 Collision mortality risks for all other target species can therefore be reasonably concluded to be very small (negligible) and not significant at any population level without the requirement for detailed analysis.

2.6 Target Species Parameters

2.6.1 Target species parameters used to calculate collision probabilities using the NatureScot CRM (SNH, 2000[3]) are presented in **Table 2.5**, with collision probability calculations presented in **Annex 2** of this Appendix.

[3] SNH (2000). Calculating a theoretical collision risk assuming no avoiding action. Scottish Natural Heritage (SNH), Guidance.

Table 2.5: Target species parameters.
Parameters are taken from Provan and Whitfield (2007[4]), with avoidance rates taken from NatureScot guidance (SNH, 2018[5]).

Species	Length (m)	Wingspan (m)	Flight Speed (m/s)	Collision Probability (Annex 1)	Avoidance Rate (%)	Occupancy
Golden eagle	0.82	2.12	15.0	7.3	99	All year
Hen harrier	0.42	1.1	12	6.3	99	All year
Red throated diver	0.61	1.11	15	6.3	99.5	Breeding *Apr to mid-September*
White-tailed eagle	0.8	2.2	12	8.0	95	All year

3 COLLISION MORTALITY RISKS

3.1.1 **Table 3.1** provides a summary of collision mortality risks estimated for golden eagle, hen harrier, red-throated diver and white-tailed eagle, with further details of analysis presented in **Annex 3** of this Appendix.

3.1.2 Potentially active hours for species occupancy periods listed in **Table 2.5,** have been calculated using a latitude of 56.252380 as per Forsythe *et al*. (1995[6]).

3.1.3 Calculations have also assumed a 15% operational downtime.

Table 2.5: Collision mortality estimates.

Species	Occupancy	Avoidance Rate (%)	Annual Collision Mortality Risk		
			2019/20 (Year 1)	2020/21 (Year 2)	2021 (Year 3 Breeding)
Golden eagle	All year	99	0.063	0.026	0.058
Hen harrier	All year	99	0.000[7]	0.025	0.000[7]
Red-throated diver	Breeding	99.5	0.000[7]	0.020	0.000[7]
White-tailed eagle	All year	95	1.228	1.140	0.604

[4] Provan, S. and Whitfield, D.P. (2007) Avian Flight Speeds and Biometrics for use in Collision Risk Modelling. Report to Scottish Natural Heritage (SNH), Natural Research (Projects) Ltd.
[5] SNH (2018). Avoidance Rates for the onshore SNH Wind Farm Collision Risk Model. September 2018 v2. Scottish Natural Heritage, Guidance.
[6] Forsythe, W.C., Rykiel, Jr., E.J., Stahl, R.S., Wu, H. and Schoolfield, R.M. (1995) A Model Comparison for Daylength as a Function of Latitude and Day of the Year. *Ecological modelling*, 80, 87-95.
[7] No "at collision risk" flight activity recorded.

ANNEX 1: "AT COLLISION RISK" FLIGHT ACTIVITY

"At collision risk" flights are identified as those within 200m of proposed turbine locations and with at least part of the flight occurring within:

- HT2 and HT3 (>21m) during surveys in February and March 2019;
- HT3 and HT4 (>25m) April 2019 onwards.

"At collision risk" flight activity for use in collision mortality risk calculations using the NatureScot CRM, is subsequently estimated on the basis of flight length, bird speed and the proportion of activity occurring at collision risk height.

The following British Trust for Ornithology (BTO) Species Codes are used to denote species: WE – White-tailed eagle, PE – Peregrine, EA – Golden eagle, ML – Merlin, HH – Hen harrier, RH – Red-throated diver, OP – Osprey, SN – Snipe and KT – Red kite

Table 1.1: "At Collision Risk" Flight Activity – Year 1.

Date	VP	Species	No. of Birds	Start Time	Duration (s)	HT1	HT2	HT3	HT4
05/03/2019	D	EA	1	16:26	75	15	60	0	0
25/03/2019	D	EA	1	11:16	480	0	235	45	0
28/03/2019	A	EA	7	09:32	630	0	630	0	0
25/04/2019	D	OP	1	12:10	300	50	0	250	0
17/05/2019	A	WE	1	09:59	720	0	0	45	675
17/05/2019	D	WE	1	14:22	243	0	60	165	18
17/05/2019	D	RH	1	11:02	45	0	30	24	0
29/05/2019	D	WE	3	15:55	630	0	0	0	630
29/05/2019	D	WE	1	15:40	240	0	30	45	165
29/05/2019	D	WE	1	15:50	240	0	0	0	240
26/06/2019	A	EA	1	16:49	135	0	0	135	0
27/06/2019	D	WE	1	17:52	345	15	15	45	270
17/07/2019	A	RH	1	08:22	75	0	0	75	0
26/07/2019	D	WE	2	15:03	582	0	30	270	282
19/08/2019	D	WE	1	14:18	441	6	30	330	75
23/08/2019	D	EA	1	13:32	187	37	15	60	75

Table 1.2: "At Collision Risk" Flight Activity – Year 2.

Date	VP	Species	No. of Birds	Start Time	Duration (s)	HT1	HT2	HT3	HT4
18/02/2020	A	WE	1	12:24	195	0	0	195	0
18/02/2020	D	WE	2	12:25	180	0	60	120	0
18/02/2020	D	WE	1	12:41	30	0	0	30	0
20/03/2020	A	RH	1	09:20	120	0	15	45	60
20/03/2020	D	EA	1	14:16	190	45	90	30	25

Date	VP	Species	No. of Birds	Start Time	Duration (s)	HT1	HT2	HT3	HT4
20/03/2020	D	WE	1	13:56	354	0	30	234	90
21/04/2020	A	WE	1	11:57	259	0	30	75	154
23/04/2020	D	WE	1	18:32	147	72	45	30	0
07/05/2020	D	WE	1	14:43	274	154	90	30	0
07/05/2020	D	HH	1	13:08	69	0	39	30	0
07/05/2020	D	EA	1	15:48	199	0	94	105	0
07/05/2020	D	WE	1	16:20	228	108	45	75	0
07/05/2020	D	RH	1	10:48	86	0	0	86	0
07/05/2020	D	RH	2	11:19	246	0	66	180	0
22/05/2020	A	OP	1	10:44	27	0	12	15	0
22/05/2020	D	SN	2	11:38	200	0	50	150	0
04/06/2020	A	WE	1	12:36	106	0	0	60	46
04/06/2020	A	WE	1	12:37	339	0	0	339	0
04/06/2020	D	OP	1	17:15	345	0	150	195	0
04/06/2020	D	WE	1	12:41	339	0	60	279	0
04/06/2020	D	WE	1	13:48	107	0	17	90	0
04/06/2020	D	WE	1	12:39	512	0	0	32	480
25/06/2020	D	WE	1	09:51	81	30	45	6	0
25/06/2020	D	WE	1	12:01	116	56	30	30	0
25/06/2020	D	WE	1	12:01	235	55	60	120	0
25/06/2020	D	WE	1	12:37	418	15	103	165	135
25/06/2020	D	WE	1	11:09	265	15	130	120	0
29/07/2020	D	EA	1	13:26	74	0	15	59	0
29/07/2020	D	RH	1	07:19	194	0	0	194	0
29/07/2020	D	RH	1	09:56	176	0	0	120	56
29/07/2020	D	RH	1	10:03	216	0	21	150	45
03/08/2020	D	EA	1	17:37	139	0	34	105	0
13/08/2020	D	HH	1	09:49	128	38	60	30	0
03/09/2020	D	WE	1	13:06	155	5	30	120	0
03/09/2020	D	ML	1	17:36	126	36	60	30	0
03/09/2020	D	PE	1	18:41	152	0	32	120	0
03/09/2020	D	HH	1	17:35	180	45	60	75	0
03/09/2020	D	HH	1	18:41	172	22	75	75	0
13/10/2020	D	WE	1	12:37	90	0	0	90	0
13/10/2020	D	KT	1	11:45	120	0	0	60	60

Table 1.3: "At Collision Risk" Flight Activity – Year 3.

Date	VP	Species	No. of Birds	Start Time	Duration (s)	HT1	HT2	HT3	HT4
16/02/2021	A	EA	1	10:50	45	0	0	45	0
16/02/2021	D	EA	1	10:51	210	0	0	180	30
24/02/2021	D	WE	1	12:59	51	0	6	45	0
11/03/2021	A	EA	1	13:43	353	45	143	165	0
16/03/2021	D	EA	1	10:14	173	0	38	135	0
21/03/2021	D	EA	1	12:48	177	0	27	150	0
21/03/2021	D	WE	1	13:27	205	0	85	120	0
06/04/2021	A	WE	2	11:02	244	0	0	180	64
06/04/2021	A	WE	1	16:14	285	0	15	105	165
06/04/2021	A	WE	1	14:09	316	0	15	45	256
06/04/2021	A	WE	1	13:57	96	0	61	45	0
07/07/2021	A	WE	1	13:30	960	0	0	240	720
07/07/2021	D	WE	1	12:43	45	15	0	30	0
07/07/2021	D	WE	1	12:45	56	11	30	15	0
07/07/2021	D	WE	3	12.59	900	90	90	270	450
07/07/2021	D	WE	1	14:05	147	0	0	57	90
09/08/2021	A	WE	1	16:34	741	0	0	621	120
09/08/2021	D	OP	1	13:26	522	45	132	345	0
09/08/2021	D	WE	1	14:28	141	6	45	90	0
09/08/2021	D	EA	1	18:12	79	4	60	15	0

ANNEX 2: COLLISION PROBABILITY CALCULATIONS

GOLDEN EAGLE

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

K: [1D or [3D	1		Calculation of alpha and p(collision) as a function of radius								
No. Blades	3					Upwind:			Downwind:		
Max Chord	5.4	m	r/R	c/C	α	collide		contribution from radius r	collide		contribution from radius r
Pitch (degree	15		radius	chord	alpha	length	p (collision)		length	p (collision)	
Bird Length	0.82	m	0.025	0.575	7.92	41.36	1.00	0.00125	39.75	1.00	0.00125
Wingspan	2.12	m	0.075	0.575	2.64	14.32	0.45	0.00334	12.72	0.40	0.00297
F: Flapping (I	0		0.125	0.702	1.58	10.14	0.32	0.00394	8.18	0.25	0.00318
			0.175	0.860	1.13	8.68	0.27	0.00472	6.28	0.20	0.00342
Bird speed	15	m/sec	0.225	0.994	0.88	7.82	0.24	0.00547	5.04	0.16	0.00353
Rotor Diam	155	m	0.275	0.947	0.72	6.41	0.20	0.00548	3.76	0.12	0.00322
Rotation Peri	6.43	sec	0.325	0.899	0.61	5.41	0.17	0.00546	2.89	0.09	0.00292
			0.375	0.851	0.53	4.65	0.14	0.00543	2.28	0.07	0.00265
			0.425	0.804	0.47	4.06	0.13	0.00537	1.82	0.06	0.00240
			0.475	0.756	0.42	3.58	0.11	0.00530	1.47	0.05	0.00217
Bird aspect r	0.39		0.525	0.708	0.38	3.20	0.10	0.00523	1.22	0.04	0.00200
			0.575	0.660	0.34	2.93	0.09	0.00524	1.08	0.03	0.00194
			0.625	0.613	0.32	2.69	0.08	0.00523	0.98	0.03	0.00190
			0.675	0.565	0.29	2.47	0.08	0.00520	0.90	0.03	0.00188
			0.725	0.517	0.27	2.28	0.07	0.00514	0.83	0.03	0.00188
			0.775	0.470	0.26	2.10	0.07	0.00507	0.85	0.03	0.00205
			0.825	0.422	0.24	1.94	0.06	0.00497	0.88	0.03	0.00226
			0.875	0.374	0.23	1.78	0.06	0.00486	0.90	0.03	0.00245
			0.925	0.327	0.21	1.64	0.05	0.00472	0.91	0.03	0.00262
			0.975	0.279	0.20	1.51	0.05	0.00456	0.91	0.03	0.00277
				Overall p(collision) =			Upwind	9.6%		Downwind	4.9%
								Average	7.3%		

HEN HARRIER

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

K: [1D or [3D	1		Calculation of alpha and p(collision) as a function of radius								
No. Blades	3					Upwind:			Downwind:		
Max Chord	5.4	m	r/R	c/C	α	collide		contribution from radius r	collide		contribution from radius r
Pitch (degree	15		radius	chord	alpha	length	p (collision)		length	p (collision)	
Bird Length	0.42	m	0.025	0.575	6.34	26.79	1.00	0.00125	25.18	0.98	0.00122
Wingspan	1.1	m	0.075	0.575	2.11	9.46	0.37	0.00276	7.86	0.31	0.00229
F: Flapping (I	0		0.125	0.702	1.27	7.01	0.27	0.00341	5.05	0.20	0.00246
			0.175	0.860	0.91	6.26	0.24	0.00426	3.86	0.15	0.00262
Bird speed	12	m/sec	0.225	0.994	0.70	5.82	0.23	0.00509	3.04	0.12	0.00266
Rotor Diam	155	m	0.275	0.947	0.58	4.80	0.19	0.00513	2.16	0.08	0.00231
Rotation Peri	6.43	sec	0.325	0.899	0.49	4.08	0.16	0.00515	1.57	0.06	0.00198
			0.375	0.851	0.42	3.53	0.14	0.00515	1.15	0.04	0.00168
			0.425	0.804	0.37	3.11	0.12	0.00513	0.86	0.03	0.00142
			0.475	0.756	0.33	2.79	0.11	0.00516	0.68	0.03	0.00125
Bird aspect r	0.38		0.525	0.708	0.30	2.52	0.10	0.00515	0.55	0.02	0.00111
			0.575	0.660	0.28	2.29	0.09	0.00512	0.45	0.02	0.00100
			0.625	0.613	0.25	2.09	0.08	0.00507	0.47	0.02	0.00113
			0.675	0.565	0.23	1.90	0.07	0.00499	0.52	0.02	0.00136
			0.725	0.517	0.22	1.73	0.07	0.00488	0.55	0.02	0.00156
			0.775	0.470	0.20	1.58	0.06	0.00475	0.58	0.02	0.00173
			0.825	0.422	0.19	1.43	0.06	0.00459	0.59	0.02	0.00188
			0.875	0.374	0.18	1.30	0.05	0.00441	0.59	0.02	0.00201
			0.925	0.327	0.17	1.17	0.05	0.00420	0.58	0.02	0.00210
			0.975	0.279	0.16	1.05	0.04	0.00397	0.57	0.02	0.00217
				Overall p(collision) =			Upwind	9.0%		Downwind	3.6%
								Average	6.3%		

RED-THROATED DIVER

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
K: [1D or [3D	1		Calculation of alpha and p(collision) as a function of radius								
No. Blades	3					Upwind:			Downwind:		
Max Chord	5.4	m	r/R	c/C	α	collide		contribution from radius r	collide		contribution from radius r
Pitch (degree	15		radius	chord	alpha	length	p (collision)		length	p (collision)	
Bird Length	0.61	m	0.025	0.575	7.92	33.36	1.00	0.00125	31.75	0.99	0.00123
Wingspan	1.11	m	0.075	0.575	2.64	11.66	0.36	0.00272	10.05	0.31	0.00234
F: Flapping (I	0		0.125	0.702	1.58	8.54	0.27	0.00332	6.58	0.20	0.00256
			0.175	0.860	1.13	7.54	0.23	0.00410	5.13	0.16	0.00279
Bird speed	15	m/sec	0.225	0.994	0.88	6.93	0.22	0.00485	4.15	0.13	0.00291
Rotor Diam	155	m	0.275	0.947	0.72	5.68	0.18	0.00486	3.03	0.09	0.00259
Rotation Peri	6.43	sec	0.325	0.899	0.61	4.79	0.15	0.00484	2.28	0.07	0.00230
			0.375	0.851	0.53	4.14	0.13	0.00483	1.77	0.05	0.00206
			0.425	0.804	0.47	3.69	0.11	0.00487	1.44	0.04	0.00190
			0.475	0.756	0.42	3.31	0.10	0.00489	1.20	0.04	0.00177
Bird aspect r	0.55		0.525	0.708	0.38	2.99	0.09	0.00489	1.01	0.03	0.00166
			0.575	0.660	0.34	2.72	0.08	0.00486	0.87	0.03	0.00156
			0.625	0.613	0.32	2.48	0.08	0.00482	0.77	0.02	0.00149
			0.675	0.565	0.29	2.26	0.07	0.00475	0.69	0.02	0.00144
			0.725	0.517	0.27	2.07	0.06	0.00467	0.62	0.02	0.00141
			0.775	0.470	0.26	1.89	0.06	0.00456	0.64	0.02	0.00154
			0.825	0.422	0.24	1.73	0.05	0.00443	0.67	0.02	0.00172
			0.875	0.374	0.23	1.57	0.05	0.00429	0.69	0.02	0.00188
			0.925	0.327	0.21	1.43	0.04	0.00412	0.70	0.02	0.00202
			0.975	0.279	0.20	1.30	0.04	0.00393	0.70	0.02	0.00214
				Overall p(collision) =			Upwind	8.6%		Downwind	3.9%
								Average	6.3%		

WHITE-TAILED EAGLE

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
K: [1D or [3D	1		Calculation of alpha and p(collision) as a function of radius								
No. Blades	3					Upwind:			Downwind:		
Max Chord	5.4	m	r/R	c/C	α	collide		contribution from radius r	collide		contribution from radius r
Pitch (degree	15		radius	chord	alpha	length	p (collision)		length	p (collision)	
Bird Length	0.8	m	0.025	0.575	6.34	33.76	1.00	0.00125	32.15	1.00	0.00125
Wingspan	2.2	m	0.075	0.575	2.11	11.79	0.46	0.00344	10.18	0.40	0.00297
F: Flapping (I	0		0.125	0.702	1.27	8.41	0.33	0.00409	6.45	0.25	0.00313
			0.175	0.860	0.91	7.26	0.28	0.00494	4.85	0.19	0.00330
Bird speed	12	m/sec	0.225	0.994	0.70	6.59	0.26	0.00577	3.81	0.15	0.00333
Rotor Diam	155	m	0.275	0.947	0.58	5.44	0.21	0.00581	2.79	0.11	0.00298
Rotation Peri	6.43	sec	0.325	0.899	0.49	4.62	0.18	0.00583	2.10	0.08	0.00266
			0.375	0.851	0.42	4.00	0.16	0.00583	1.62	0.06	0.00236
			0.425	0.804	0.37	3.51	0.14	0.00579	1.26	0.05	0.00208
			0.475	0.756	0.33	3.17	0.12	0.00586	1.06	0.04	0.00196
Bird aspect r	0.36		0.525	0.708	0.30	2.90	0.11	0.00593	0.93	0.04	0.00189
			0.575	0.660	0.28	2.67	0.10	0.00597	0.83	0.03	0.00185
			0.625	0.613	0.25	2.47	0.10	0.00599	0.85	0.03	0.00206
			0.675	0.565	0.23	2.28	0.09	0.00599	0.90	0.03	0.00236
			0.725	0.517	0.22	2.11	0.08	0.00596	0.93	0.04	0.00263
			0.775	0.470	0.20	1.96	0.08	0.00590	0.96	0.04	0.00288
			0.825	0.422	0.19	1.81	0.07	0.00581	0.97	0.04	0.00310
			0.875	0.374	0.18	1.68	0.07	0.00570	0.97	0.04	0.00330
			0.925	0.327	0.17	1.55	0.06	0.00557	0.96	0.04	0.00347
			0.975	0.279	0.16	1.43	0.06	0.00541	0.95	0.04	0.00361
				Overall p(collision) =			Upwind	10.7%		Downwind	5.3%
								Average	8.0%		

ANNEX 3: COLLISION MORTALITY RISK CALCULATIONS

Golden Eagle (Year 1)

VP			Watch data	Flying time (s)	Flying time hahr-1	Weighted flying time ha hr^-1	
	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height	Weighting	Risk height
A	64.89	93.0	6034.8	134.45	0.0000061887	0.162834711	0.000001008
D	356.6	87.0	31025.9	222.2775803	0.0000019901	0.837165289	0.000001666
Totals	421.5	180.0	37060.7	356.7	0.0	1.0	0.0

Mean activity hr^-1 in wind farm				WIND FARM DATA			
Risk height	0.00120	0.1202%		Wind farm area (ha)	449.58		
Daylight hours			4475				
Downtime			15			D	155
Vw =			696849000			L + d	6.22
Vr =			1525763	No. of turbines	13		
Vr/Vw =			0.0021895				
Speed			15				
Vw Occupancy =			5.3792				
Vr Occupancy =			0.0118				
Transit time =			0.4147				
Transits =			102.252				
Collision probability			0.073				
Annual Collisions with no avoidance			7.464				
Annual Collisions with 99% avoidance			0.075				
Annual Collisions with 99% avoidance & downtime			0.063				

Golden Eagle (Year 2)

VP			Watch data	Flying time (s)	Flying time hahr-1	Weighted flying time ha hr^-1	
	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height	Weighting	Risk height
A	64.89	90.0	5840.1	0	0.0000000000	0.141937826	0.000000000
D	356.6	99.0	35305.4	161.9044094	0.0000012738	0.858062174	0.000001093
Totals	421.5	189.0	41145.5	161.9	0.0	1.0	0.0
Mean activity hr^-1 in wind farm				WIND FARM DATA			
Risk height	0.00049	0.0491%		Wind farm area (ha)	449.58		

Daylight hours	4475			
Downtime	15		D	155
Vw =	696849000		L + d	6.22
Vr =	1525763	No. of turbines	13	
Vr/Vw =	0.0021895			
Speed	15			
Vw Occupancy =	2.1990			
Vr Occupancy =	0.0048			
Transit time =	0.4147			
Transits =	41.801			
Collision probability	0.073			
Annual Collisions with no avoidance	3.051			
Annual Collisions with 99% avoidance	0.031			
Annual Collisions with 99% avoidance & downtime	0.026			

Golden Eagle (Year 3 Breeding)

VP			Watch data	Flying time (s)	Flying time hahr-1	Weighted flying time ha hr^-1	
	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height	Weighting	Risk height
A	64.89	66.0	4282.7	94.73868178	0.0000061447	0.153946526	0.000000946
D	356.6	66.0	23536.9	269.6049005	0.0000031818	0.846053474	0.000002692
Totals	421.5	132.0	27819.7	364.3	0.0	1.0	0.0
Mean activity hr^-1 in wind farm				WIND FARM DATA			
Risk height	0.00164	0.1636%		Wind farm area (ha)	449.58		

Daylight hours	2993			
Downtime	15		D	155
Vw =	696849000		L + d	6.22
Vr =	1525763	No. of turbines	13	
Vr/Vw =	0.0021895			
Speed	15			
Vw Occupancy =	4.8952			
Vr Occupancy =	0.0107			
Transit time =	0.4147			
Transits =	93.051			
Collision probability	0.073			
Annual Collisions with no avoidance	6.793			
Annual Collisions with 99% avoidance	0.031			
Annual Collisions with 99% avoidance & downtime	0.026			

White-tailed Eagle (Year 1)

VP			Watch data	Flying time (s)	Flying time hahr-1	Weighted flying time ha hr^-1	
	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height	Weighting	Risk height
A	64.89	93.0	6034.8	95.77583333	0.0000044085	0.162834711	0.000000718
D	356.6	87.0	31025.9	1243.4173893	0.0000111324	0.837165289	0.000009320
Totals	421.5	180.0	37060.7	1339.2	0.0	1.0	0.0
Mean activity hr^-1 in wind farm				WIND FARM DATA			
Risk height	0.00451	0.4513%		Wind farm area (ha)	449.58		

Daylight hours	4475			
Downtime	15		D	155
Vw =	696849000		L + d	6.2
Vr =	1520857	No. of turbines	13	
Vr/Vw =	0.0021825			
Speed	12			
Vw Occupancy =	20.1942			
Vr Occupancy =	0.0441			
Transit time =	0.5167			
Transits =	307.092			
Collision probability	0.08			
Annual Collisions with no avoidance	24.567			
Annual Collisions with 95% avoidance	1.228			
Annual Collisions with 95% avoidance & downtime	1.044			

White-tailed Eagle (Year 2)

VP			Watch data	Flying time (s)	Flying time hahr-1	Weighted flying time ha hr^-1	
	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height	Weighting	Risk height
A	64.89	90.0	5840.1	166.2902593	0.0000079094	0.141937826	0.000001123
D	356.6	99.0	35305.4	1456.3425350	0.0000114583	0.858062174	0.000009832
Totals	421.5	189.0	41145.5	1622.6	0.0	1.0	0.0
Mean activity hr^-1 in wind farm				WIND FARM DATA			
Risk height	0.00492	0.4925%		Wind farm area (ha)	449.58		

Daylight hours	4475			
Downtime	15		D	155
Vw =	696849000		L + d	6.2
Vr =	1520857	No. of turbines	13	
Vr/Vw =	0.0021825			
Speed	12			
Vw Occupancy =	22.0392			
Vr Occupancy =	0.0481			
Transit time =	0.5167			
Transits =	335.149			
Collision probability	0.08			
Annual Collisions with no avoidance	26.812			
Annual Collisions with 95% avoidance	1.341			
Annual Collisions with 95% avoidance & downtime	1.140			

White-tailed Eagle (Year 3 Breeding)

VP			Watch data	Flying time (s)	Flying time hahr-1		Weighted flying time ha hr^-1	
	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height		Weighting	Risk height
A	64.89	66.0	4282.7	167.1348317	0.0000108403		0.153946526	0.000001669
D	356.6	66.0	23536.9	702.6232665	0.0000082922		0.846053474	0.000007016
Totals	421.5	132.0	27819.7	869.8	0.0		1.0	0.0
Mean activity hr^-1 in wind farm				WIND FARM DATA				
Risk height	0.00390	0.3904%		Wind farm area (ha)	449.58			
Daylight hours			2993					
Downtime			15			D	155	
Vw =			696849000			L + d	6.2	
Vr =			1520857	No. of turbines	13			
Vr/Vw =			0.0021825					
Speed			12					
Vw Occupancy =			11.6858					
Vr Occupancy =			0.0255					
Transit time =			0.5167					
Transits =			177.705					
Collision probability			0.08					
Annual Collisions with no avoidance			14.216					
Annual Collisions with 95% avoidance			0.711					
Annual Collisions with 95% avoidance & downtime			0.604					

Red-throated Diver (Year 1)
≤3 “at Collision Risk” flights.

Red-throated Diver (Year 2)
≤3 “at Collision Risk” flights.

VP			Watch data	Flying time (s)	Flying time hahr-1		Weighted flying time ha hr^-1	
	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height		Weighting	Risk height
A	64.89	90.0	5840.1	5.024139167	0.0000002390		0.141937826	0.000000034
D	356.6	99.0	35305.4	509.4540341	0.0000040083		0.858062174	0.000003439
Totals	421.5	189.0	41145.5	514.5	0.0		1.0	0.0
Mean activity hr^-1 in wind farm				WIND FARM DATA				
Risk height	0.00156	0.1562%		Wind farm area (ha)	449.58			
Daylight hours			2547					
Downtime			15			D	155	
Vw =			696849000			L + d	6.01	
Vr =			1474250	No. of turbines	13			
Vr/Vw =			0.0021156					
Speed			15					
Vw Occupancy =			3.9772					
Vr Occupancy =			0.0084					
Transit time =			0.4007					
Transits =			75.601					
Collision probability			0.063					
Annual Collisions with no avoidance			4.763					
Annual Collisions with 99% avoidance			0.048					
Annual Collisions with 99% avoidance & downtime			0.040					

Red-throated Diver (Year 3 Breeding)
≤3 “at Collision Risk” flights.

Hen Harrier (Year 1)
≤3 “at Collision Risk” flights.

Hen Harrier (Year 2)

VP			Watch data	Flying time (s)	Flying time hahr-1		Weighted flying time ha hr^-1
	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height	Weighting	Risk height
A	64.89	90.0	5840.1	0	0.0000000000	0.141937826	0.000000000
D	356.6	99.0	35305.4	228.0002395	0.0000017939	0.858062174	0.000001539
Totals	421.5	189.0	41145.5	228.0	0.0	1.0	0.0
Mean activity hr^-1 in wind farm				WIND FARM DATA			
Risk height	0.00069	0.0692%		Wind farm area (ha)	449.58		

Daylight hours	4475			
Downtime	696849000		D	155
Vw =	1427643		L + d	5.82
Vr =	0.0020487	No. of turbines	13	
Vr/Vw =	12			
Speed	696849000			
Vw Occupancy =	3.0968			
Vr Occupancy =	0.0063			
Transit time =	0.4850			
Transits =	47.093			
Collision probability	0.063			
Annual Collisions with no avoidance	2.967			
Annual Collisions with 99% avoidance	0.030			
Annual Collisions with 99% avoidance & downtime	0.025			

Hen Harrier (Year 3 Breeding)
≤3 “at Collision Risk” flights.