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1.0 Introduction

This report updates the results of the Collision Risk Modelling (CRM) undertaken for white-tailed and golden eagle (previously reported in **EIA Technical Appendix 4.3**), following the removal of T1 from the Ben Sca Redesign Wind Farm Proposed Development[1]. It supplements **SEI Chapter 4: Ornithology** as a Technical Appendix (TA).

The revised modelling was based on the use of eight turbines with a rotor diameter of 138m, tip height of 150m and hub height of 82m.

The standard Band CRM (Band *et. al.* 2007[2]) was used to estimate collision risk following the same methods as in **TA4.3** of the **EIA Report.**[3]

1.1 Revised CRM

1.1.1 Survey Data

The number of birds that fly through the rotor swept area was estimated using flight data gathered during baseline surveys carried out during January to December 2023 (as described in **TA4.3** of the **EIA Report**). The number of white-tailed eagles and golden eagles flying through the risk area were re-calculated based on the revised risk area (**Table 1** and **Table 2**).

Table 1: White-tailed Eagle Flight Data used in CRM

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)				
					<20 m	20-150m	150-200m	>200 m	At risk
Jan-23 to Dec-23	VP1	8	10	1607	518	1089	0	0	1607
	VP2	17	31	3224	526	1936	526	236	2462
	VP3	4	5	643	98	396	63	86	494
Total		29	46	5474	1142	3421	589	322	4563

Table 2: Golden Eagle Flight Data used in CRM

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)				
					<20 m	20-150m	150-200m	>200 m	At risk
Jan-23 to Dec-23	VP1	2	2	286	126	160	0	0	286
	VP2	5	5	957	184	185	64	524	369
	VP3	1	1	135	90	45	0	0	135
Total		8	8	1378	400	390	64	524	790

[1] As eagles are the main species of concern these are the two species considered here.

[2] Band, W., Madders, M. and Whitfield, D.P. (2007) Developing Field and Analytical Methods to Assess Avian Collision Risk at Wind Farms. In: De Lucas, M., Janss, G. and Ferrer, M., Eds., Birds and Wind Power, Quercus Editions, Madrid, 259-275.

[3] This is for the purposes of direct comparison with the EIA Report. An updated collision risk model to assess bird collision risk at onshore wind farms was published by NatureScot in December 2024 but this has not been used in this case.

The number of golden plover flying through the risk area were also re-calculated based on the revised risk area. In total there 1,392 seconds of 'at-risk' occupancy for golden plover.

1.2 Risk Area and Viewshed Data

The CRM was based on the proportion of flights within 500m of the revised turbine layout, an area of 369.51ha.

The viewshed data were re-calculated based on the revised risk area using an offset of 20m. The respective areas of visibility of the 500m buffer of the revised turbine layout for VP1 and VP2 were:

- VP1: 206.02ha
- VP2: 56.70ha
- VP3: 127.66ha

1.3 Bird Biometrics and Avoidance Rates

Measurements and flight speeds of the species for which CRM was undertaken are consistent with **TA4.3** of the **EIA Report.**

1.4 Collision Risk Modelling Summary

The results of the removal of Turbine 1 from the Proposed Development are summarised in **Table 3**. Collision probability and model calculations for white-tailed eagle and golden eagle are provided in the following section.

Table 3: Collision Risk for Revised Turbine Layout

Species	Dataset/ period of analysis	Turbines covered	Modelled collisions per year
White-tailed eagle	Ben Sca Redesign (2023)	T1 – T9	3.473
	Ben Sca Redesign (2023)	T2 – T9	2.687
	Without T1, reduction of 0.786 collisions/year		-22.60%
Golden eagle	Ben Sca Redesign (2023)	T1 – T9	0.10
	Ben Sca Redesign (2023)	T2 – T9	0.0834
	Without T1, reduction of 0.017 collisions/year		-11.33%
Golden plover	Ben Sca Redesign (2023)	T1 – T9	0.3889
	Ben Sca Redesign (2023)	T2 – T9	0.3322
	Without T1, reduction of 0.0567 collisions/year		-14.6%

Collision Probability Calculations – White Tailed Eagle

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.1	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.8	m	0.025	0.575	5.15	19.52	1.00	0.00125	19.02	1.00	0.00125
Wingspan	2.2	m	0.075	0.575	1.72	6.67	0.36	0.00269	6.18	0.33	0.00249
F: Flapping (0) or gliding (-	1		0.125	0.702	1.03	4.69	0.25	0.00315	4.08	0.22	0.00275
			0.175	0.860	0.74	3.98	0.21	0.00374	3.24	0.17	0.00305
Bird speed	13	m/sec	0.225	0.994	0.57	3.54	0.19	0.00429	2.69	0.14	0.00326
RotorDiam	138	m	0.275	0.947	0.47	2.87	0.15	0.00424	2.06	0.11	0.00304
RotationPeriod	4.29	sec	0.325	0.899	0.40	2.39	0.13	0.00418	1.62	0.09	0.00283
			0.375	0.851	0.34	2.36	0.13	0.00475	1.63	0.09	0.00328
			0.425	0.804	0.30	2.14	0.11	0.00488	1.45	0.08	0.00331
			0.475	0.756	0.27	1.96	0.11	0.00500	1.31	0.07	0.00335
Bird aspect ratioo: β	0.36		0.525	0.708	0.25	1.81	0.10	0.00511	1.20	0.06	0.00340
			0.575	0.660	0.22	1.69	0.09	0.00521	1.12	0.06	0.00346
			0.625	0.613	0.21	1.58	0.08	0.00530	1.05	0.06	0.00354
			0.675	0.565	0.19	1.48	0.08	0.00538	1.00	0.05	0.00362
			0.725	0.517	0.18	1.40	0.08	0.00544	0.95	0.05	0.00372
			0.775	0.470	0.17	1.32	0.07	0.00550	0.92	0.05	0.00382
			0.825	0.422	0.16	1.25	0.07	0.00554	0.89	0.05	0.00394
			0.875	0.374	0.15	1.18	0.06	0.00558	0.86	0.05	0.00407
			0.925	0.327	0.14	1.13	0.06	0.00560	0.85	0.05	0.00421
			0.975	0.279	0.13	1.07	0.06	0.00561	0.83	0.04	0.00436
				Overall p(collision) =			**Upwind**	**9.2%**		**Downwind**	**6.7%**
								Average	**8.0%**		

Collision Probability Calculations – Golden Eagle

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**									
NoBlades	3					Upwind:			Downwind:			
MaxChord	4.1	m	r/R	c/C	α	collide		contribution	collide		contribution	
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r	
BirdLength	0.82	m	0.025	0.575	5.94	22.10	1.00	0.00125	21.61	1.00	0.00125	
Wingspan	2.1	m	0.075	0.575	1.98	7.53	0.35	0.00263	7.04	0.33	0.00246	
F: Flapping (0) or gliding (-	1		0.125	0.702	1.19	5.28	0.25	0.00308	4.68	0.22	0.00273	
			0.175	0.860	0.85	4.48	0.21	0.00365	3.74	0.17	0.00305	
Bird speed	15	m/sec	0.225	0.994	0.66	3.98	0.19	0.00418	3.13	0.15	0.00328	
RotorDiam	138	m	0.275	0.947	0.54	3.21	0.15	0.00412	2.40	0.11	0.00308	
RotationPeriod	4.29	sec	0.325	0.899	0.46	2.67	0.12	0.00405	1.90	0.09	0.00288	
			0.375	0.851	0.40	2.27	0.11	0.00396	1.54	0.07	0.00269	
			0.425	0.804	0.35	2.31	0.11	0.00457	1.62	0.08	0.00321	
			0.475	0.756	0.31	2.11	0.10	0.00467	1.46	0.07	0.00323	
Bird aspect ratioo: β	0.39		0.525	0.708	0.28	1.94	0.09	0.00475	1.33	0.06	0.00326	
			0.575	0.660	0.26	1.80	0.08	0.00482	1.23	0.06	0.00330	
			0.625	0.613	0.24	1.68	0.08	0.00488	1.15	0.05	0.00335	
			0.675	0.565	0.22	1.57	0.07	0.00494	1.08	0.05	0.00341	
			0.725	0.517	0.20	1.47	0.07	0.00498	1.03	0.05	0.00348	
			0.775	0.470	0.19	1.39	0.06	0.00502	0.99	0.05	0.00356	
			0.825	0.422	0.18	1.31	0.06	0.00504	0.95	0.04	0.00365	
			0.875	0.374	0.17	1.24	0.06	0.00506	0.92	0.04	0.00375	
			0.925	0.327	0.16	1.17	0.05	0.00506	0.89	0.04	0.00385	
			0.975	0.279	0.15	1.11	0.05	0.00506	0.87	0.04	0.00397	
				Overall p(collision) =			**Upwind**	**8.6%**		**Downwind**	**6.3%**	
								Average	**7.5%**			

Collision Probability Calculations – Golden Plover

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.1	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.28	m	0.025	0.575	7.12	20.13	0.78	0.00098	19.63	0.76	0.00095
Wingspan	0.7	m	0.075	0.575	2.37	6.87	0.27	0.00200	6.38	0.25	0.00186
F: Flapping (0) or gliding (-	1		0.125	0.702	1.42	5.01	0.19	0.00243	4.41	0.17	0.00214
			0.175	0.860	1.02	4.39	0.17	0.00299	3.65	0.14	0.00248
Bird speed	18	m/sec	0.225	0.994	0.79	3.99	0.15	0.00349	3.14	0.12	0.00274
RotorDiam	138	m	0.275	0.947	0.65	3.19	0.12	0.00341	2.38	0.09	0.00255
RotationPeriod	4.29	sec	0.325	0.899	0.55	2.64	0.10	0.00333	1.87	0.07	0.00236
			0.375	0.851	0.47	2.23	0.09	0.00324	1.50	0.06	0.00218
			0.425	0.804	0.42	1.90	0.07	0.00314	1.22	0.05	0.00201
			0.475	0.756	0.37	1.76	0.07	0.00325	1.11	0.04	0.00205
Bird aspect ratioo: β	0.40		0.525	0.708	0.34	1.56	0.06	0.00319	0.96	0.04	0.00195
			0.575	0.660	0.31	1.40	0.05	0.00312	0.83	0.03	0.00186
			0.625	0.613	0.28	1.25	0.05	0.00305	0.73	0.03	0.00177
			0.675	0.565	0.26	1.13	0.04	0.00296	0.65	0.03	0.00169
			0.725	0.517	0.25	1.02	0.04	0.00287	0.58	0.02	0.00162
			0.775	0.470	0.23	0.92	0.04	0.00277	0.52	0.02	0.00156
			0.825	0.422	0.22	0.83	0.03	0.00267	0.47	0.02	0.00151
			0.875	0.374	0.20	0.75	0.03	0.00255	0.43	0.02	0.00146
			0.925	0.327	0.19	0.68	0.03	0.00243	0.40	0.02	0.00142
			0.975	0.279	0.18	0.61	0.02	0.00230	0.37	0.01	0.00139
				Overall p(collision) =			**Upwind**	**5.6%**		**Downwind**	**3.8%**
								Average	**4.7%**		

CRM Calculations – White-tailed Eagle

	Viewsheds		
	1	2	3
STAGE 1: Estimation of rotor transits			
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	1607	2462	494
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)			
Hours of survey effort (e)	72	72	72
Windfarm area (ha) visible within viewshed (*v*)[1]	206.02	56.70	127.66
Observation effort (*e*v*)	14833.67	4082.23	9191.48
T_wV rate=$T_wV/e*v$	3.01E-05	1.68E-04	1.49E-05
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]			
Weight: proportion of total survey effort made at the VP	0.528	0.145	0.327
Weighted T_wV rate (T_wV rate * weight)	1.59E-05	2.43E-05	4.88E-06
Total weighted occupancy rate	0.000045	birds seconds per ha/hour	
Mean % activity hr^-1 in wind farm at risk height	1.666%		
Mean % activity hr^-1 in wind farm at rotor height (z)	1.533%		
Step 1.4: Total occupancy of risk volume during surveys (T_w)			
Hours potentially active: annual (a) (daylight hours)	4456	hours	
T_w=z*a	68.31	hours	
Step 1.6: Flight risk volume (V_w)			
Risk volume: $V_w=A*h$	509,921,267	m^3	
Step 1.7: Volume swept by windfarm rotors (V_r)			
Bird length (L)	0.8	m	
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$	610,250.60	m^3	
Step 1.8: Bird occupancy of rotor-swept volume (T_r)			
$T_r=T_w*(V_r/V_w)$	294.3201	seconds	
Step 1.9: Time taken to transit rotor *(t)*			
Flight speed *(s)*	13	m/sec	
$t=(d+L)/s$	0.39	seconds	
Step 1.10: Number of rotor transits (N)			
$N=T_r/t$	750	Rotor transits	
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet	0.080		
STAGE 3: Predicted mortality (birds per year)			
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	53.743	collisions	
Step 3.2: Adjusted using a range of avoidance rates:			
95.00%	**2.6872**	**Approx. one collision every 0.37 years**	

CRM Calculations – Golden Eagle

	Viewsheds		
	1	2	3
STAGE 1: Estimation of rotor transits			
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	286	369	135
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)			
Hours of survey effort (e)	72	72	72
Windfarm area (ha) visible within viewshed (*v*)[1]	206.02	56.70	127.66
Observation effort (*e*v*)	14833.67	4082.23	9191.48
T_wV rate=$T_wV/e*v$	5.36E-06	2.51E-05	4.08E-06
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]			
Weight: proportion of total survey effort made at the VP	0.528	0.145	0.327
Weighted T_wV rate (T_wV rate * weight)	2.83E-06	3.65E-06	1.33E-06
Total weighted occupancy rate	0.000006	birds seconds per ha/hour	
Mean % activity hr^-1 in wind farm at risk height	0.239%		
Mean % activity hr^-1 in wind farm at rotor height(z)	0.220%		
Step 1.4: Total occupancy of risk volume during surveys (T_w)			
Hours potentially active: annual (a) (daylight hours)	4456	hours	
T_w=z*a	9.81	hours	
Step 1.6: Flight risk volume (V_w)			
Risk volume: $V_w=A*h$	509,921,267	m^3	
Step 1.7: Volume swept by windfarm rotors (V_r)			
Bird length (L)	0.82	m	
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$	612,643.74	m^3	
Step 1.8: Bird occupancy of rotor-swept volume (Tr)			
$T_r=T_w*(V_r/V_w)$	42.4141	seconds	
Step 1.9: Time taken to transit rotor *(t)*			
Flight speed *(s)*	15	m/sec	
$t=(d+L)/s$	0.34	seconds	
Step 1.10: Number of rotor transits (N)			
$N=T_r/t$	124	Rotor transits	
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet	0.075		
STAGE 3: Predicted mortality (birds per year)			
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	8.343	collisions	
Step 3.2: Adjusted using a range of avoidance rates:			
99.00%	**0.0834**	**Approx. one collision every 11.99 years**	

CRM Calculations – Golden Plover

	Viewsheds		
	1	2	3
STAGE 1: Estimation of rotor transits			
Step 1.1: Seconds occupancy of the survey risk volume (T_w)[1] recorded within each viewshed (T_wV)	0	1,392	0
Step 1.2: Unweighted occupancy rate each viewshed ($T_wV$rate)			
Hours of survey effort (e)	72	72	72
Windfarm area (ha) visible within viewshed (*v*)[1]	206.02	56.70	127.66
Observation effort (*e*v*)	14833.67	4082.23	9191.48
T_wV rate=$T_wV/e*v$	5.36E-06	2.51E-05	4.08E-06
Step 1.3: Weighted occupancy rate *(weighted T_wV rate)*[1]			
Weight: proportion of total survey effort made at the VP	0.528	0.145	0.327
Weighted T_wV rate (T_wV rate * weight)	0.00E+00	9.47E-05	0.00E+00
Total weighted occupancy rate	0.000014	birds seconds per ha/hour	
Mean % activity hr^-1 in wind farm at risk height	0.508%		
Mean % activity hr^-1 in wind farm at rotor height(z)	0.468%		
Step 1.4: Total occupancy of risk volume during surveys (T_w)			
Hours potentially active: annual (a) (daylight hours)	5,537	hours	
T_w=z*a	25.90	hours	
Step 1.6: Flight risk volume (V_w)			
Risk volume: $V_w=A*h$	509,921,267	m^3	
Step 1.7: Volume swept by windfarm rotors (V_r)			
Bird length (L)	0.28	m	
Rotor-swept volume: $V_r=N*\pi*r^2*(d+L)$	548,028.97	m^3	
Step 1.8: Bird occupancy of rotor-swept volume (Tr)			
$T_r=T_w*(V_r/V_w)$	100.1919	seconds	
Step 1.9: Time taken to transit rotor *(t)*			
Flight speed *(s)*	18	m/sec	
$t=(d+L)/s$	0.25	seconds	
Step 1.10: Number of rotor transits (N)			
$N=T_r/t$	394	Rotor transits	
STAGE 2: Probability of Collision for a bird flying through rotors (*p*(collision)) from SNH spreadsheet	0.047		
STAGE 3: Predicted mortality (birds per year)			
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	16,612	collisions	
Step 3.2: Adjusted using a range of avoidance rates:			
98.00%	**0.3322**	**Approx. one collision every 3.01 years**	