Coille Beith Wind Farm EIA Report

Technical Appendix 7.2: Collision Risk Model Analysis

June 2025

Contents

1. Introduction

1.1. Overview

1.1.1. This Technical Appendix has been prepared to accompany **Chapter 7** (EIA Report Volume 2) and presents the details and results of collision mortality risk calculations, completed to inform the assessment for the Proposed Development upon ornithological interests.

1.1.2. This Technical Appendix is supplementary to **Technical Appendix 7.1** (EIA Report Volume 4) which provides full details of baseline ornithological studies. Figures referenced within this Technical Appendix are presented in **Volume 3a** of the EIA Report.

2. Methodology

2.1. Approach

2.1.1. Baseline ornithology surveys undertaken for the Proposed Development included VP flight activity surveys, which recorded flight activity of target species (see **Technical Appendix 7.1 (**EIA Report Volume 4)) in the vicinity of proposed turbine locations. The results of the VP flight activity surveys have been used to estimate potential collision mortality risk using collision risk model (CRM) analysis.

2.1.2. NatureScot advocate use of the model devised by Band *et al*. (2007)[1] and which has recently been updated (Band, 2024)[2]. It should be noted that the CRM reported upon herein was started before the most recent CRM guidance was published and so does not fully follow the methodology set out in Band (2024)[2]. However, the main aim of the updated guidance is to standardise the approach to CRM and the previous approach is still considered valid. Band (2024)[2] states that the methods are 'mathematically equivalent' and that the estimates produced using the updated CRM 'should not differ substantially from those deriving from… earlier SNH [now NatureScot] guidance[1]'. The results herein are therefore considered robust for the purpose of assessment.

2.1.3. 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, using observed flight activity data, based on:
  - The amount of flight activity recorded in the vicinity of the wind farm;
  - The area watched (VP-specific viewsheds); and
  - The time spent watching the surveyed area (survey effort per VP per month);
- 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
- Stage 3: application of appropriate avoidance factors, whereby it is birds take action to avoid collision.

2.2. Wind Farm Parameters

2.2.1. The Proposed Development comprises 11 turbines, with all turbines of 200 m maximum tip height, 114 m hub height and maximum rotor diameter is 172 m.

2.2.2. For the purposes of analysis, the flight risk volume (Vw) is based on a buffer constructed around the turbine envelope with a radius of 300 m (area = 544.07 ha) and a height at least equal to the rotor diameter (172 m). This adopts a precautionary approach based on the candidate turbine rotor radius of 86 m.

2.2.3. Turbine parameters are summarised in **Table 2.1.** The final turbine model will be dependent on a procurement process and has not yet been confirmed. For the purposes of this assessment, the candidate turbine is the 'V172 – Vestas' but given the lack of available specification for all parameters for the turbine type, specification for comparable candidate turbines (the 'Vestas V164-8.0' and 'V162 – Vestas') is used where parameters for the V172 are not available. Rotation period and downtime are representative values.

[1] Band, W., Madders, M. and Whitfield, D.P. (2007). Developing field and analytical methods to assess avian collision risk at wind farms. In: Janss, G, de Lucas, M & Ferrer, M (eds.) Birds and Wind Farms. Quercus, Madrid. 259-275.
[2] Band, W. (2024). Using a collision risk model to assess bird collision risks for onshore wind farms. NatureScot Research Report 909.

Table 2.1 – Turbine Parameters

Parameter	Value	Unit
Wind farm survey area (300 m turbine buffer)	544.07	ha
No. of rotors	11	-
No. of blades	3	-
Height to tip	200	metres
Hub height	114	metres
Rotor diameter	172	metres
Rotor radius	86	metres
Max chord	5.4	metres
Pitch	15	degrees
Rotation period	5.7	seconds
Downtime	15	%

2.3. Viewsheds

2.3.1. Target species flight activity data for use in CRM calculations has been obtained from three Vantage Points (VPs) during VP flight activity surveys between September 2020 and August 2021 (VPs 1 - 3).

2.3.2. Visible areas for each VP location have been calculated using an observer height of 1.5 m and a 20 m vertical offset above the ground. The extent of the visible area that could be seen from each VP location was confirmed during a reconnaissance visit.

2.3.3. **Table 2.2** presents the visible areas of each viewshed and that which falls within the wind farm survey area constructed using a 300 m buffer around the turbines for the purpose of CRM analysis.

2.3.4. Note, VPs were not surveyed simultaneously, and thus overlaps were included in each VP viewshed, and VP viewsheds are provided in **Figure 7.2** (EIA Report Volume 3a).

Table 2.2 – VP Locations and Viewshed Visible Areas

VP	Grid Reference	Orientation	Visible Area (ha) – within 300 m turbine buffer
1	NH 40397 99102	South southeast	356.32
2	NH 41328 96885	North northeast	380.12
3	NH 43288 97640	North northwest	230.64

2.4. VP Flight Activity Survey Effort

2.4.1. Survey effort (hours) completed at each VP location between September 2020 and August 2021 is summarised in **Table 2.3**.

Table 2.3 – VP Flight Activity Survey Effort Summary (Hours)

VP	2020				2021								Total
	Non-breeding Season						Breeding Season						
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	
1	12	12	6	6	6	12	12	12	6	9	9	6	108
2	12	12	6	6	6	12	12	12	6	9	9	6	108
3	12	12	6	6	6	12	12	12	6	9	9	6	108

2.5. Identification of 'At-risk' Flight Activity

2.5.1. Full details of all target species flights during the VP flight activity surveys are presented in **Technical Appendix 7.1** (EIA Report Volume 4) and are shown in **Figures 7.4a-b** (EIA Report Volume 3a). However, only those flights considered to be at-risk are included in the CRM analysis.

2.5.2. Some flights of pink-footed goose, golden plover, golden eagle, white-tailed eagle, great skua, red kite, greenshank, merlin, marsh harrier, and goshawk were recorded as at-risk, identified as those flights recorded within 300 m of the turbines and flying at collision risk height (e.g. between 28 -200 m). Bird flights at height bands 3 (25-150 m), 4 (150-180 m) and 5 (>180 m), as utilised during survey recording, were regarded as at-risk from collision with turbines. Height band 1 (0-10 m) and height band 2 (10-25 m) were below at-risk height. This is precautionary as some flights regarded as being at-risk may actually have been above collision risk height, with tip height (200 m) being above the lower limit of height band 5 (180 m).

2.5.3. Details of at-risk flight activity of all target species is provided in **Annex 1**.

2.5.4. CRM calculations have only been undertaken for those target species with three, or more, at-risk flights, or greater than 10 birds if less than three flights, within the survey year, and this comprised golden eagle (three at-risk flights) and golden plover (four at-risk flights). Note, although five pink-footed goose at-risk flights were recorded, CRM analysis was not carried out on the species in accordance with NatureScot guidance (2024)[3]. This was given there are no international designated sites with pink-footed goose as a qualifying species within 20 km of the Site, and the high avoidance rate for the species (99.8 %).

2.5.5. At-risk flight activity recorded during the survey period for golden eagle and golden plover, and which has been used in CRM calculations is summarised in **Table 2.4**. As a precaution all at-risk flights were considered in the CRM calculations even where these were clearly identified as juvenile/immature birds (two of the three golden eagle flights).

Table 2.4 – 'At-risk' Flight Activity

Species	Total No. of Flights	Total No. of Birds	Total Flight Time (secs)	Total Time 'at-risk' Height (secs)
Golden eagle	3	3	1,437	1,020
Golden plover	4	12	269	144

2.6. Target Species Parameters

2.6.1. Target species parameters (taken from Snow and Perrins 1998[4], and/or Alerstam *et al.* 2007)[5] used to calculate collision probabilities are presented in **Table 2.5** together with calculated collision probabilities and recommended avoidance rates for the two target species in accordance with NatureScot guidance (SNH, 2018)[6]. The results of the collision probability calculations for all three species subject to CRM analysis are given in **Annex 2**.

Table 2.5 – Target Species Parameters

Species	Length (m)	Wingspan (m)	Flight Speed (m/s)	Collision Probability (%)	Avoidance Rates (%)	'Gliding' or 'Flapping' Flight
Golden eagle	0.82	2.12	11.9	8.1	99.0	Gliding
Golden plover	0.28	0.72	13	5.5	98.0	Flapping

2.6.2. Based on the flightlines recorded, golden eagle, and golden plover were classified as having 'non-directional' (random) flights.

2.6.3. The time period in which the ornithological features are likely to be present in the vicinity of the Proposed Development is considered in the CRM analysis, with mortality estimates presented for each season (breeding and non-breeding), where applicable. The time periods used are species-specific breeding seasons, taken from NatureScot guidance (SNH, 2014)[7]. These time periods differ from the more generic breeding and non-breeding seasons used to determine overall survey effort for the VP flight activity surveys.

2.6.4. The seasons used in the calculations for each of the identified species are presented in **Table 2.6**.

Table 2.6 – Species-specific Seasons Used in the CRM Analysis

Species	Breeding Season	Non-Breeding Season
Golden eagle	February to August	September to January
Golden plover	April to July	August to March

2.6.5. For each identified species, the potential number of active hours within each season has been calculated following Forsythe *et al*. (1995)[8], using a latitude of 57.952031 (the latitude of the central part of the Site). For each species, 'active hours' correspond with daylight hours.

[3] NatureScot (2024). Wind farm impacts on birds. Careful siting and design of wind farm developments can avoid significant impacts on birds. Available at: https://www.nature.scot/professional-advice/planning-and-development/planning-and-development-advice/renewable-energy/onshore-wind-energy/wind-farm-impacts-birds
[4] Snow, D. W. and Perrins, C. M. (1998). The Birds of the Western Palearctic. Concise Edition. Oxford University Press.
[5] Alerstam T., Rosén M., Bäckman J., Ericson P.G.P. and Hellgren O. (2007). Flight speeds among bird species: allometric and phylogenetic effects. PLoS Biol, 5, 1656-1662.
[6] SNH (2018). Avoidance Rates for the onshore SNH Wind Farm Collision Risk Model. September 2018 v2. NatureScot (formerly Scottish Natural Heritage), Inverness.
[7] SNH (2014). Breeding season dates for key breeding species in Scotland. Available at: https://www.nature.scot/professional-advice/planning-and-development/planning-and-development-advice/renewable-energy/onshore-wind-energy/wind-farm-impacts-birds
[8] 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.

2.6.6. Previous NatureScot guidance (based on Band *et al*., 2007)[1], used a 'collision probability' value for inclusion in the calculations and this is the approach that has been used in this analysis. These values have been calculated using the previously available NatureScot spreadsheet[9].

- Golden eagle – 8.1 %; and
- Golden plover - 5.5 %.

3. Results

3.1.1. **Table 3.1** presents a summary of the annual collision mortality estimates calculated for the two at-risk species for which CRM analysis was undertaken.

3.1.2. The collision mortality risk calculations for all three species subject to CRM analysis are provided in **Annex 3**.

3.1.3. In **Table 3.1**, seasons when the species is present, but no at-risk flights were recorded have been given an estimate of 0.000.

3.1.4. Where mortality risks were calculated for both the breeding and non-breeding seasons, both estimates are provided, and these are then summed to provide an annual estimate.

3.1.5. The mortality estimates are considered to be precautionary, based on the approach that has been used, and which is set out in this Technical Appendix.

3.1.6. The collision mortality risk estimates should also not be concluded as the number of bird deaths that will definitely occur as a result of the Proposed Development. The estimates are best treated as an indication as to the relative level of risk.

Table 3.1 – Collision Mortality Estimates

Species	Occupancy	Collision Mortality Estimate
Golden eagle	Breeding season	0.014
	Non-breeding season	0.000
	Annual estimate	**0.014**
Golden plover	Breeding season	0.008
	Non-breeding season	0.028
	Annual estimate	**0.036**

[9] Previously available from: https://www.nature.scot/doc/wind-farm-impacts-birds-calculating-probability-collision

Annex 1 – At-risk Flight Activity

Table A1.1 presents at-risk target species flight activity identified for the Proposed Development over the full baseline survey period.

The species, number of individuals, total flight duration (in seconds) and duration spent at each height band (recorded at 15 second intervals) is presented.

At-risk flight activity input into the CRM analysis is calculated as a proportional duration for each flight, based on flock size, flock length and duration at collision risk height.

Table A1.1 – 'At-risk' Flight Activity

Date	VP	Species	No. of Birds	Start Time (24h)	Duration (s)	HT1 (s)	HT2 (s)	HT3 (s)	HT4 (s)	HT5 (s)
23/09/2020	3	Pink-footed goose	90	11:28	60	0	0	0	0	60
23/09/2020	3	Pink-footed goose	35	11:06	45	0	0	0	0	45
23/09/2020	3	Pink-footed goose	9	15:09	30	0	0	0	0	30
24/02/2021	2	Golden plover	5	12:24	84	30	15	39	0	0
25/02/2021	1	Golden plover	1	12:25	38	0	8	30	0	0
24/03/2021	3	Golden plover	2	11:16	45	0	0	30	15	0
20/04/2021	2	Goshawk	1	15:19	50	0	5	45	0	0
20/04/2021	2	Golden plover	4	12:10	102	42	30	30	0	0
20/04/2021	2	Red kite	1	13:29	501	0	0	360	60	81
20/04/2021	2	White-tailed eagle	2	15:16	357	0	282	75	0	0
21/04/2021	3	Pink-footed goose	43	12:24	30	0	0	0	0	30
22/04/2021	3	Pink-footed goose	61	09:02	150	0	0	0	0	120
27/04/2021	2	Golden eagle	1	10:50	90	15	60	15	0	0
27/04/2021	2	Gret skua	2	15:41	120	0	0	0	30	90
21/06/2021	2	Greenshank	1	10:54	71	0	0	71	0	0
19/07/2021	2	Marsh harrier	1	20:51	90	0	15	75	0	0
23/08/2021	1	Golden eagle	1	16.51	278	0	188	90	0	0
24/08/2021	2	Golden eagle	1	14:31	1069	15	139	675	75	165
24/08/2021	2	Merlin	1	11.56	158	0	30	128	0	0

Annex 2 – Collision Probability Calculations

Golden Eagle

K: [1D or [3D] (0 or 1)	**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	collide		contribution	
Pitch (degrees)	**15**		radius	chord	alpha	length	p (collision)	from radius r	length	p (collision)	from radius r	
Bird Length	**0.82**	m	0.025	0.575	5.02	22.64	1.00	0.00125	21.03	0.93	0.00116	
Wingspan	**2.12**	m	0.075	0.575	1.67	8.08	0.36	0.00268	6.48	0.29	0.00215	
F: Flapping (0) or gliding (+1)	**1**		0.125	0.702	1.00	6.01	0.27	0.00332	4.05	0.18	0.00224	
			0.175	0.860	0.72	5.39	0.24	0.00417	2.98	0.13	0.00231	
Bird speed	**11.9**	m/sec	0.225	0.994	0.56	5.04	0.22	0.00501	2.26	0.10	0.00225	
Rotor Diam	**172**	m	0.275	0.947	0.46	4.19	0.19	0.00510	1.55	0.07	0.00188	
Rotation Period	**5.70**	sec	0.325	0.899	0.39	3.89	0.17	0.00559	1.37	0.06	0.00198	
			0.375	0.851	0.33	3.50	0.15	0.00580	1.12	0.05	0.00185	
			0.425	0.804	0.30	3.18	0.14	0.00598	0.93	0.04	0.00176	
			0.475	0.756	0.26	2.92	0.13	0.00613	0.83	0.04	0.00175	
Bird aspect ratio: β	0.39		0.525	0.708	0.24	2.69	0.12	0.00625	0.93	0.04	0.00215	
			0.575	0.660	0.22	2.50	0.11	0.00635	0.99	0.04	0.00252	
			0.625	0.613	0.20	2.32	0.10	0.00641	1.03	0.05	0.00286	
			0.675	0.565	0.19	2.16	0.10	0.00644	1.06	0.05	0.00317	
			0.725	0.517	0.17	2.01	0.09	0.00645	1.08	0.05	0.00345	
			0.775	0.470	0.16	1.87	0.08	0.00642	1.08	0.05	0.00370	
			0.825	0.422	0.15	1.74	0.08	0.00637	1.07	0.05	0.00392	
			0.875	0.374	0.14	1.62	0.07	0.00628	1.06	0.05	0.00411	
			0.925	0.327	0.14	1.51	0.07	0.00617	1.05	0.05	0.00428	
			0.975	0.279	0.13	1.40	0.06	0.00602	1.02	0.05	0.00441	
				Overall p(collision) =			**Upwind**	**10.8%**		**Downwind**	**5.4%**	
								Average	**8.1%**			

Golden plover

K: [1D or [3D] (0 or 1)	**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	collide		contribution
Pitch (degrees)	**15**		radius	chord	alpha	length	p (collision)	from radius r	length	p (collision)	from radius r
Bird Length	**0.28**	m	0.025	0.575	5.49	21.20	0.86	0.00107	19.60	0.79	0.00099
Wingspan	**0.72**	m	0.075	0.575	1.83	7.60	0.31	0.00231	6.00	0.24	0.00182
F: Flapping (0) or gliding (+1)	**0**		0.125	0.702	1.10	5.78	0.23	0.00293	3.82	0.15	0.00194
			0.175	0.860	0.78	5.28	0.21	0.00374	2.88	0.12	0.00204
Bird speed	**13**	m/sec	0.225	0.994	0.61	4.99	0.20	0.00455	2.21	0.09	0.00201
Rotor Diam	**172**	m	0.275	0.947	0.50	4.14	0.17	0.00461	1.50	0.06	0.00167
Rotation Period	**5.70**	sec	0.325	0.899	0.42	3.54	0.14	0.00466	1.03	0.04	0.00135
			0.375	0.851	0.37	3.09	0.13	0.00470	0.71	0.03	0.00108
			0.425	0.804	0.32	2.76	0.11	0.00474	0.51	0.02	0.00088
			0.475	0.756	0.29	2.47	0.10	0.00476	0.36	0.01	0.00070
Bird aspect ratio: β	0.39		0.525	0.708	0.26	2.23	0.09	0.00475	0.30	0.01	0.00065
			0.575	0.660	0.24	2.02	0.08	0.00471	0.38	0.02	0.00089
			0.625	0.613	0.22	1.84	0.07	0.00465	0.44	0.02	0.00110
			0.675	0.565	0.20	1.67	0.07	0.00456	0.47	0.02	0.00129
			0.725	0.517	0.19	1.51	0.06	0.00444	0.49	0.02	0.00145
			0.775	0.470	0.18	1.37	0.06	0.00430	0.50	0.02	0.00158
			0.825	0.422	0.17	1.24	0.05	0.00413	0.50	0.02	0.00168
			0.875	0.374	0.16	1.11	0.04	0.00393	0.50	0.02	0.00176
			0.925	0.327	0.15	0.99	0.04	0.00370	0.48	0.02	0.00181
			0.975	0.279	0.14	0.87	0.04	0.00345	0.47	0.02	0.00184
				Overall p(collision) =			**Upwind**	**8.1%**		**Downwind**	**2.9%**
								Average	**5.5%**		

Annex 3 – Collision Risk Mortality Model Calculations

Golden Eagle (Breeding Season)

		Watch data			Flying time (s)	Flying time hahr-1	Weighted flying time ha hr^-1	
	VP	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height	Weighting	Risk height
	1	356.3	66.0	23517.1	4	0.0000000477	0.368449353	0.000000018
	2	380.1	66.0	25087.9	244	0.0000027008	0.393059519	0.000001062
	3	230.6	66.0	15222.2	0	0.0000000000	0.238491128	0.000000000
	Totals	967.1	198.0	63827.3	248	0.0000009161	1.000000000	0.000001079

		Mean activity hr^-1 in wind farm				WIND FARM DATA		
		Risk height	0.00059	0.0587%		Wind farm area (ha)	544.07	
		Daylight hours	3020.7					
		Downtime	15	0.85		D	172	
	Flight risk volume	Vw =	935800400			L + d	6.22	
	Rotor swept volume	Vr =	1589754	No.turbines	11	R	86	
		Vr/Vw =	0.0016988					
		Speed	11.9					
		Vw Occupancy =	1.7735	6384.6				
		Vr Occupancy =	0.0030	10.8				
		Transit time =	0.5227					
		Transits =	20.751					
	Collision probability from SNH sheet		0.081					
	Collisions with no avoidance		1.681					
						Collisions with 99% avoidance		0.017
						Collisions with 99% avoidance & downtime		**0.014**
						30 year mortality		0.504
						30 year mortality with 15% downtime etc		0.429
						Years for 1 death		69.99

Golden Eagle (Non-Breeding Season)

No at-risk flights, so no CRM analysis undertaken, and the collision mortality estimate is considered as 0.000.

Golden plover (Breeding Season)

	Watch data			Flying time (s)	Flying time hahr-1	Weighted flying time ha hr^-1	
VP	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height	Weighting	Risk height
1	356.3	36.0	12827.5	0	0.0000000000	0.368449353	0.000000000
2	380.1	36.0	13684.3	77	0.0000015646	0.393059519	0.000000615
3	230.6	36.0	8303.0	0	0.0000000000	0.238491128	0.000000000
Totals	967.1	108.0	34814.9	77	0.0000005215	1.000000000	0.000000615

Mean activity hr^-1 in wind farm			WIND FARM DATA	
Risk height	0.00033	0.0335%	Wind farm area (ha)	544.07

Daylight hours	1922.3					
Downtime	15	0.85		D	172	
Flight risk volume	Vw =	935800400			L + d	5.68
Rotor swept volume	Vr =	1451736	No.turbines	11	R	86
	Vr/Vw =	0.0015513				
	Speed	13				
Vw Occupancy =		0.6432	2315.5			
Vr Occupancy =		0.0010	3.6			
Transit time =		0.4369				
Transits =		8.222				
Collision probability from SNH sheet		0.055				
Collisions with no avoidance		0.452				
Collisions with 98% avoidance		0.009				
Collisions with 98% avoidance & downtime		0.008				
30 year mortality		0.271				
30 year mortality with 15% downtime etc		0.231				
Years for 1 death		130.09				

Golden plover (Non-Breeding Season)

	Watch data			Flying time (s)	Flying time hahr-1	Weighted flying time ha hr^-1	
VP	Area (ha)	Time (hrs)	HaHr	Risk height	Risk height	Weighting	Risk height
1	356.3	72.0	25655.0	45	0.0000004909	0.368449353	0.000000181
2	380.1	72.0	27368.6	209	0.0000021244	0.393059519	0.000000835
3	230.6	72.0	16606.1	168	0.0000028081	0.238491128	0.000000670
Totals	967.1	216.0	69629.8	423	0.0000018078	1.000000000	0.000001686

Mean activity hr^-1 in wind farm			WIND FARM DATA	
Risk height	0.00092	0.0917%	Wind farm area (ha)	544.07

Daylight hours	2557.6					
Downtime	15	0.85		D	172	
Flight risk volume	Vw =	935800400			L + d	5.68
Rotor swept volume	Vr =	1451736	No.turbines	11	R	86
	Vr/Vw =	0.0015513				
	Speed	13				
Vw Occupancy =		2.3455	8443.8			
Vr Occupancy =		0.0036	13.1			
Transit time =		0.4369				
Transits =		29.980				
Collision probability from SNH sheet		0.055				
Collisions with no avoidance		1.649				
Collisions with 98% avoidance		0.033				
Collisions with 98% avoidance & downtime		**0.028**				
30 year mortality		0.989				
30 year mortality with 15% downtime etc		0.841				
Years for 1 death		35.67				