Technical Appendix 8.2: Collision Risk Model Analysis

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Contents

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Introduction

Overview

This Technical Appendix has been prepared to accompany **Chapter 8: Ornithology** of the Appin Wind Farm (hereafter the referred to as 'the Proposed Development') Environmental Impact Assessment (EIA) Report.

It presents the details and results of collision mortality risk calculations, completed to inform the assessment for the Proposed Development upon ornithological interests.

This Technical Appendix is supplementary to **Technical Appendix 8.1**, in **Volume 4** of the EIA Report, and which provides full details of baseline ornithological studies. Figures referenced within this Technical Appendix are presented in **Volume 2** of the EIA Report.

Methodology

Approach

Baseline ornithology surveys undertaken for the Proposed Development included VP flight activity surveys, which recorded flight activity of target species (see **Technical Appendix 8.1**) 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.

NatureScot advocates use of the model devised by Band *et al*. (2007) and which has recently been updated (Band, 2024). 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). 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) 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*". The results presented below are therefore considered robust for the purpose of assessment.

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.
- Stage 3: application of appropriate avoidance factors, whereby it is birds take action to avoid collision.

Wind Farm Parameters

The Proposed Development comprises nine turbines, with all turbines of 200 m maximum tip height. The assessment has been undertaken using a candidate turbine with a hub height of 119 m and rotor diameter of 162 m.

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 around turbine locations (area = 303.25 ha) and a height at least equal to the rotor diameter (162 m). This adopts a precautionary approach based on the candidate turbine rotor radius of 81 m.

The CRM for 'directional flights' (see below) uses the width of the wind farm to calculate the cross-sectional area through which the birds would pass. The value used for the width of the wind farm is taken to be the maximum width in any orientation, which for the Proposed Development is the distance between the north-westernmost and south-easternmost turbines (plus a 300 m buffer). This means that birds would actually only be exposed to the full 'risk window' if the directional flight is on a north-east/south-west axis.

Turbine parameters are summarised in **Table 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 'V162 – Vestas' but given the lack of available specification for all parameters for the turbine type, specification for a comparable candidate turbine (the 'Vestas V164-8.0') is used where parameters for the V162 are not available. Rotation period and downtime are representative values.

Table 1 – Turbine Parameters

Parameter	Value	Unit
Wind farm survey area (300 m turbine buffer)	303.25	ha
Width of wind farm (maximum) plus 300 m turbine buffer	4005.52	m
No. of rotors	9	-
No. of blades	3	-
Height to tip	200	metres
Hub height	119	metres
Rotor diameter	162	metres
Rotor radius	81	metres
Max chord	5.4	metres
Pitch	15	degrees
Rotation period	5.7	seconds
Downtime	15	%

Viewsheds

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).

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.

Table 2 presents the visible areas of each viewshed and that which falls within the survey area constructed using a 300 m buffer around the turbines for the purpose of CRM analysis.

Note, overlaps between VPs that were surveyed simultaneously (on occasion VPs 1 and 2) were minimal and thus overlaps were included in each VP viewshed, and VP viewsheds are provided in **Figure 8.2**.

Table 2 – VP Locations and Viewshed Visible Areas

VP	Grid Reference	Orientation	Visible Area (ha) – within 300 m turbine buffer
1	NX 71451 98775	South south-west	197.4
2	NX 74391 97573	West south-west	38.86
3	NX 72453 97455	North north-west	68.51

VP Flight Activity Survey Effort

Survey effort (hours) completed at each VP location between September 2020 and August 2021 is summarised in **Table 3**.

Table 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	6	6	6	6	6	6	6	9	9	6	12	9	87
2	6	6	6	6	6	6	6	9	9	9	9	9	87
3	6	6	6	6	6	6	6	9	9	9	9	9	87

Identification of 'At-risk' Flight Activity

Full details of all target species flights during the VP flight activity surveys are presented in **Technical Appendix 8.1** and are shown in **Figures 8.4a-b**. However, only those flights considered to be at-risk are included in the CRM analysis.

Some flights of red kite, goshawk, greylag goose, hen harrier and whooper swan were recorded as at-risk, identified as those flights recorded within 300 m of the turbines and flying at collision risk height (between 38 and 200 m). Bird flights at height bands 3 (25-150 m), 4 (150-180 m) and 5 (180-225 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, and height band 6 (>225 m) was above at-risk height. This is precautionary as some flights regarded as being at-risk may actually have been above collision risk height, with the upper limit of height band 5 (225 m) being above the maximum rotor sweep of the turbine (200 m tip height), or below collision risk height, with the lower limit of height band 3 (25 m) being below the lower rotor sweep of the turbine (38 m).

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

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 red kite (13 at-risk flights), goshawk (four at-risk flights) and whooper swan (one at-risk flight, but with 42 birds).

At-risk flight activity recorded during the survey period for red kite, goshawk and whooper swan, and which has been used in CRM calculations is summarised in **Table 4**. All at-risk flights were considered in the CRM calculations including those clearly identified as juvenile/immature birds (three such red kite flights, and one such goshawk flight).

Table 4 – 'At-risk' Flight Activity

Species	Total No. of Flights	Total No. of Birds	Total Flight Time (secs)	Total Time 'at-risk' Height (secs)
Red kite	13	16	2,622	1,652
Goshawk	4	4	932	767
Whooper swan	1	42	151	151

Target Species Parameters

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

Table 5 – Target Species Parameters

Species	Length (m)	Wingspan (m)	Flight Speed (m/s)	Collision Probability (%)	Avoidance Rates (%)	'Gliding' or 'Flapping' Flight
Red kite	0.63	1.85	12	7.3	99.0	Gliding
Goshawk	0.58	1.50	11.3*	7.6	98.0	Flapping
Whooper swan	1.50	2.29	17.3	8.9	99.5	Flapping

*Value not provided in Alerstam *et al*. (2007). Flight speed of a congener species (sparrowhawk) has been used as a proxy for goshawk.

Based on the flightlines recorded, red kite and goshawk were classified as having 'non-directional' (random) flights, while whooper swan was classified as having directional flights (commuting on a relatively straight path across the Site, south to north).

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). 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.

The seasons used in the calculations for each of the identified species are presented in **Table 6**. Note that for goshawk the breeding season is actually given as mid-March to mid-August, but complete calendar months have been used in the CRM analysis for ease.

Whooper swans are only recorded in Scotland during the non-breeding season, and for the CRM analysis, the non-breeding season has been taken to include the period between October and April (with the whooper swans recorded in April).

Table 6 – Species-specific Seasons Used in the CRM Analysis

Species	Breeding Season	Non-Breeding Season
Red kite	March to July	August to February
Goshawk	March to August	September to February
Whooper swan	-	October to April

For each identified species, the potential number of active hours within each season has been calculated following Forsythe *et al*. (1995), using a latitude of 55.259066 (the latitude of the central part of the Site). For each species, 'active hours' correspond with daylight hours. Although whooper swan may migrate at night, any such activity is assumed to happen above at-risk height.

Previous NatureScot guidance (based on Band *et al*., 2007), 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[1].

- Red kite – 7.3 %;
- Goshawk – 7.6 %; and

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

- Whooper swan – 8.9 %.

Collision Mortality Risks

Table 7 presents a summary of the annual collision mortality estimates calculated for the three at-risk species for which CRM analysis was undertaken.

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

In **Table 7**, seasons when a species is absent from Scotland are shaded out. Seasons when the species is present, but no at-risk flights were recorded have been given an estimate of 0.000.

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.

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.

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 7 – Collision Mortality Estimates

Species	Occupancy	Collision Mortality Estimate
Red kite	Breeding season	0.091
	Non-breeding season	0.036
	Annual estimate	**0.127**
Goshawk	Breeding season	0.000
	Non-breeding season	0.042
	Annual estimate	**0.042**
Whooper swan	Breeding season	
	Non-breeding season	0.157
	Annual estimate	**0.157**

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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. Birds	Start Time (24h)	Duration (s)	HT1 (s)	HT2 (s)	HT3 (s)	HT4 (s)	HT5 (s)	HT6 (s)
14/09/2020	3	Goshawk	1	12:21	148	0	58	90	0	0	0
14/09/2020	3	Red kite	1	14:05	35	5	15	15	0	0	0
14/09/2020	3	Red kite	1	12:40	314	15	30	179	90	0	0
18/10/2020	3	Red kite	1	14:30	20	0	0	20	0	0	0
06/02/2021	2	Goshawk	1	10:23	483	0	15	318	150	0	0
22/02/2021	1	Goshawk	1	10:42	92	0	17	45	30	0	0
22/02/2021	1	Goshawk	1	15:16	209	0	0	29	45	60	75
01/04/2021	3	Whooper swan	42	13:16	151	0	0	136	15	0	0
12/05/2021	1	Greylag goose	2	10:48	74	14	45	15	0	0	0
12/05/2021	1	Red kite	1	12:27	106	0	0	15	60	31	0
21/05/2021	3	Greylag goose	3	08:08	161	11	135	15	0	0	0
18/06/2021	1	Red kite	2	14:12	133	0	0	118	15	0	0
18/06/2021	1	Red kite	1	10:06	191	56	105	30	0	0	0
18/06/2021	1	Red kite	1	11:40	578	38	300	240	0	0	0
18/06/2021	1	Red kite	1	13:18	157	0	0	0	0	15	142
21/06/2021	3	Red kite	2	13:46	208	13	15	90	30	30	30
22/06/2021	2	Red kite	2	10:44	281	0	15	60	30	60	116
08/07/2021	3	Red kite	1	10:25	188	0	0	90	98	0	0
04/08/2021	1	Hen harrier	1	15:01	103	13	45	45	0	0	0
04/08/2021	1	Red kite	1	10:21	300	0	75	225	0	0	0
04/08/2021	1	Red kite	1	12:15	111	0	0	60	51	0	0
31/08/2021	3	Hen harrier	1	16:26	155	0	0	50	105	0	0

Annex 2 – Collision Probability Calculations

Red kite

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	**0.63**	m	0.025	0.575	5.38	23.26	1.00	0.00125	21.65	0.95	0.00119
Wingspan	**1.85**	m	0.075	0.575	1.79	8.29	0.36	0.00273	6.68	0.29	0.00220
F: Flapping (0) or gliding (+1)	**1**		0.125	0.702	1.08	6.18	0.27	0.00339	4.22	0.19	0.00231
			0.175	0.860	0.77	5.55	0.24	0.00426	3.15	0.14	0.00242
Bird speed	**12**	m/sec	0.225	0.994	0.60	5.19	0.23	0.00512	2.41	0.11	0.00238
Rotor Diam	**162**	m	0.275	0.947	0.49	4.31	0.19	0.00520	1.67	0.07	0.00201
Rotation Period	**5.70**	sec	0.325	0.899	0.41	3.68	0.16	0.00525	1.17	0.05	0.00167
			0.375	0.851	0.36	3.20	0.14	0.00527	0.82	0.04	0.00135
			0.425	0.804	0.32	3.08	0.14	0.00574	0.83	0.04	0.00155
			0.475	0.756	0.28	2.80	0.12	0.00584	0.69	0.03	0.00144
Bird aspect ratio: β	0.34		0.525	0.708	0.26	2.57	0.11	0.00591	0.67	0.03	0.00155
			0.575	0.660	0.23	2.36	0.10	0.00595	0.75	0.03	0.00189
			0.625	0.613	0.22	2.17	0.10	0.00596	0.80	0.04	0.00219
			0.675	0.565	0.20	2.01	0.09	0.00594	0.83	0.04	0.00247
			0.725	0.517	0.19	1.85	0.08	0.00589	0.85	0.04	0.00271
			0.775	0.470	0.17	1.71	0.08	0.00582	0.86	0.04	0.00293
			0.825	0.422	0.16	1.58	0.07	0.00571	0.86	0.04	0.00312
			0.875	0.374	0.15	1.45	0.06	0.00558	0.85	0.04	0.00327
			0.925	0.327	0.15	1.33	0.06	0.00541	0.84	0.04	0.00340
			0.975	0.279	0.14	1.22	0.05	0.00522	0.82	0.04	0.00350
				Overall p(collision) =			**Upwind**	**10.1%**		**Downwind**	**4.6%**
								Average	**7.3%**		

Goshawk

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	**0.58**	m	0.025	0.575	5.06	23.58	1.00	0.00125	21.97	1.00	0.00125
Wingspan	**1.5**	m	0.075	0.575	1.69	8.40	0.39	0.00293	6.79	0.32	0.00237
F: Flapping (0) or gliding (+1)	**0**		0.125	0.702	1.01	6.20	0.29	0.00361	4.24	0.20	0.00247
			0.175	0.860	0.72	5.53	0.26	0.00451	3.13	0.15	0.00255
Bird speed	**11.3**	m/sec	0.225	0.994	0.56	5.15	0.24	0.00540	2.37	0.11	0.00249
Rotor Diam	**162**	m	0.275	0.947	0.46	4.29	0.20	0.00549	1.64	0.08	0.00210
Rotation Period	**5.70**	sec	0.325	0.899	0.39	3.67	0.17	0.00555	1.15	0.05	0.00175
			0.375	0.851	0.34	3.27	0.15	0.00571	0.89	0.04	0.00155
			0.425	0.804	0.30	2.95	0.14	0.00584	0.71	0.03	0.00140
			0.475	0.756	0.27	2.69	0.13	0.00594	0.59	0.03	0.00130
Bird aspect ratio: β	0.39		0.525	0.708	0.24	2.46	0.11	0.00602	0.68	0.03	0.00166
			0.575	0.660	0.22	2.26	0.11	0.00606	0.74	0.03	0.00199
			0.625	0.613	0.20	2.08	0.10	0.00607	0.79	0.04	0.00230
			0.675	0.565	0.19	1.92	0.09	0.00604	0.82	0.04	0.00257
			0.725	0.517	0.17	1.77	0.08	0.00599	0.83	0.04	0.00281
			0.775	0.470	0.16	1.64	0.08	0.00591	0.84	0.04	0.00302
			0.825	0.422	0.15	1.51	0.07	0.00579	0.83	0.04	0.00320
			0.875	0.374	0.14	1.39	0.06	0.00565	0.82	0.04	0.00334
			0.925	0.327	0.14	1.27	0.06	0.00547	0.80	0.04	0.00346
			0.975	0.279	0.13	1.16	0.05	0.00526	0.78	0.04	0.00355
				Overall p(collision) =			**Upwind**	**10.4%**		**Downwind**	**4.7%**
								Average	**7.6%**		

Whooper swan

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	**1.5**	m	0.025	0.575	7.75	41.80	1.00	0.00125	40.19	1.00	0.00125
Wingspan	**2.29**	m	0.075	0.575	2.58	14.47	0.44	0.00330	12.86	0.39	0.00293
F: Flapping (0) or gliding (+1)	**0**		0.125	0.702	1.55	10.20	0.31	0.00388	8.24	0.25	0.00313
			0.175	0.860	1.11	8.70	0.26	0.00463	6.30	0.19	0.00335
Bird speed	**17.3**	m/sec	0.225	0.994	0.86	7.83	0.24	0.00536	5.05	0.15	0.00346
Rotor Diam	**162**	m	0.275	0.947	0.70	6.42	0.20	0.00537	3.77	0.11	0.00315
Rotation Period	**5.70**	sec	0.325	0.899	0.60	5.55	0.17	0.00549	3.04	0.09	0.00300
			0.375	0.851	0.52	4.98	0.15	0.00569	2.60	0.08	0.00297
			0.425	0.804	0.46	4.53	0.14	0.00586	2.29	0.07	0.00296
			0.475	0.756	0.41	4.16	0.13	0.00602	2.05	0.06	0.00297
Bird aspect ratio: β	0.66		0.525	0.708	0.37	3.85	0.12	0.00615	1.87	0.06	0.00299
			0.575	0.660	0.34	3.58	0.11	0.00627	1.74	0.05	0.00304
			0.625	0.613	0.31	3.35	0.10	0.00636	1.63	0.05	0.00311
			0.675	0.565	0.29	3.14	0.10	0.00644	1.56	0.05	0.00320
			0.725	0.517	0.27	2.94	0.09	0.00649	1.50	0.05	0.00331
			0.775	0.470	0.25	2.77	0.08	0.00653	1.54	0.05	0.00364
			0.825	0.422	0.23	2.61	0.08	0.00654	1.57	0.05	0.00395
			0.875	0.374	0.22	2.46	0.07	0.00654	1.59	0.05	0.00423
			0.925	0.327	0.21	2.31	0.07	0.00651	1.60	0.05	0.00450
			0.975	0.279	0.20	2.18	0.07	0.00646	1.60	0.05	0.00475
				Overall p(collision) =			**Upwind**	**11.1%**		**Downwind**	**6.6%**
								Average	**8.9%**		

Annex 3 – Collision Risk Mortality Model Calculations

Red kite (breeding season)

Per VP calculation based on a weighted per unit area per unit time

	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	197.4	42.0	8290.8	396	0.0000132669	0.647701545	0.000008593
2	38.9	42.0	1632.1	38	0.0000064002	0.127505988	0.000000816
3	68.5	42.0	2877.4	172	0.0000165616	0.224792466	0.000003723
Totals	304.8	126.0	12800.3	605	0.0000120762	1.000000000	0.000013132

Mean activity hr^-1 in wind farm		
Risk height	0.00398	0.3982%

WIND FARM DATA	
Wind farm area (ha)	303.25

Daylight hours	2249.9					
Downtime	15	0.85		D	162	
Flight risk volume Vw =	491265000			L + d	6.03	
Rotor swept volume Vr =	1118613	No.turbines	9	R	81	
Vr/Vw =	0.0022770					
Speed	12					
Vw Occupancy =	8.9597	32254.9				
Vr Occupancy =	0.0204	73.4				
Transit time =	0.5025					
Transits =	146.158					
Collision probability from SNH sheet	0.073					
Collisions with no avoidance	10.670					
				Collisions with 99% avoidance		0.107
				Collisions with 99% avoidance & downtime		**0.091**
				30 year mortality		3.201
				30 year mortality with 15% downtime etc		2.721
				Years for 1 death		11.03

Red kite (non-breeding season)

Per VP calculation based on a weighted per unit area per unit time

	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	197.4	45.0	8883.0	147	0.0000045927	0.647701545	0.000002975
2	38.9	45.0	1748.7	0	0.0000000000	0.127505988	0.000000000
3	68.5	45.0	3083.0	112	0.0000100758	0.224792466	0.000002265
Totals	304.8	135.0	13714.7	259	0.0000048895	1.000000000	0.000005240

Mean activity hr^-1 in wind farm		
Risk height	0.00159	0.1589%

WIND FARM DATA	
Wind farm area (ha)	303.25

Daylight hours	2222.5					
Downtime	15	0.85		D	162	
Flight risk volume Vw =	491265000			L + d	6.03	
Rotor swept volume Vr =	1118613	No.turbines	9	R	81	
Vr/Vw =	0.0022770					
Speed	12					
Vw Occupancy =	3.5314	12713.0				
Vr Occupancy =	0.0080	28.9				
Transit time =	0.5025					
Transits =	57.607					
Collision probability from SNH sheet	0.073					
Collisions with no avoidance	4.205					
				Collisions with 99% avoidance		0.042
				Collisions with 99% avoidance & downtime		**0.036**
				30 year mortality		1.262
				30 year mortality with 15% downtime etc		1.072
				Years for 1 death		27.98

Goshawk (breeding season)

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

Goshawk (non-breeding season)

Per VP calculation based on a weighted per unit area per unit time

VP	Watch data: Area (ha)	Watch data: Time (hrs)	Watch data: HaHr	Flying time (s): Risk height	Flying time hahr-1: Risk height	Weighted flying time ha hr^-1: Weighting	Weighted flying time ha hr^-1: Risk height
1	197.4	36.0	7106.4	76	0.0000029581	0.647701545	0.000001916
2	38.9	36.0	1399.0	3	0.0000005825	0.127505988	0.000000074
3	68.5	36.0	2466.4	76	0.0000086000	0.224792466	0.000001933
Totals	304.8	108.0	10971.7	155	0.0000040469	1.000000000	0.000003923

2020/21 non-breeding season presented

Mean activity hr^-1 in wind farm			
Risk height	0.00119	0.1190%	
Daylight hours	1771.3		
Downtime	15	0.85	
Flight risk volume: Vw =	491265000		
Rotor swept volume: Vr =	1109337	No.turbines	9
Vr/Vw =	0.0022581		
Speed	11.3		
Vw Occupancy =	2.1075	7586.9	
Vr Occupancy =	0.0048	17.1	
Transit time =	0.5292		
Transits =	32.374		
Collision probability from SNH sheet	0.076		
Collisions with no avoidance	2.460		
Collisions with 98% avoidance	0.049		
Collisions with 98% avoidance & downtime	**0.042**		
30 year mortality	1.476		
30 year mortality with 15% downtime etc	1.255		
Years for 1 death	23.91		

WIND FARM DATA	
Wind farm area (ha)	303.25
D	162
L + d	5.98
R	81

Whooper swan (non-breeding season) – VP1

Stage 1

Step 1

Identify a Risk window

Width of Windfarm	4,005.52	*Includes 300 m buffer*
Height of Rotor sweep	162	
Cross Sectional Area (W)	648894.24	

Step 2

Estimate number of birds flying through the Risk window

Potential Active Hours	2,177.50

Month	No. hours VP survey effort	No. of birds recorded	No. of birds per hr of observation
Oct-20	6	0	0
Nov-20	6	0	0
Dec-20	6	0	0
Jan-21	6	0	0
Feb-21	6	0	0
Mar-21	6	0	0
Apr-21	9	0	0
Total	45	**Activity pr Hour**	0.00

n	0.00

Step 3

Calculate proportion of area present by the wind farm rotors (A)

A	185531.96
Radius	81.00
Pi R2	20614.66
No. Rotors	9
Proportion A/W	0.29

Step 4

Calculate number of birds passing through rotors

N	0.00

Stage 2

Step 1

SNH Probability	8.90%	0.09	
Collisions no avoidance	0.00		

Stage 3

Step 1

Apply an avoidance factor

	Downtime %	15	0.85
Avoidance	**98%**	0.00	
	99%	0.00	
	99.50%	0.00	
	99.80%	0.00	
Avoidance with Downtime			
	98%	0.00	
	99%	0.00	
	99.50%	**0.00**	
	99.80%	0.00	

Whooper swan (non-breeding season) – VP2

Stage 1

Step 1

Identify a Risk window

Width of Windfarm	4,005.52	*Includes 300 m buffer*
Height of Rotor sweep	162	
Cross Sectional Area (W)	648894.24	

Step 2

Estimate number of birds flying through the Risk window

Potential Active Hours	2,177.50

Month	No. hours VP survey effort	No. of birds recorded	No. of birds per hr of observation
Oct-20	6	0	0
Nov-20	6	0	0
Dec-20	6	0	0
Jan-21	6	0	0
Feb-21	6	0	0
Mar-21	6	0	0
Apr-21	9	0	0
Total	45	**Activity pr Hour**	0.00

n	0.00

Step 3

Calculate proportion of area present by the wind farm rotors (A)

A	185531.96
Radius	81.00
Pi R2	20614.66
No. Rotors	9
Proportion A/W	0.29

Step 4

Calculate number of birds passing through rotors

N	0.00

Stage 2

Step 1

SNH Probability	8.90%	0.09	
Collisions no avoidance	0.00		

Stage 3

Step 1

Apply an avoidance factor

	Downtime %	15	0.85
Avoidance	**98%**	0.00	
	99%	0.00	
	99.50%	0.00	
	99.80%	0.00	
Avoidance with Downtime			
	98%	0.00	
	99%	0.00	
	99.50%	**0.00**	
	99.80%	0.00	

Whooper swan (non-breeding season) – VP3

Stage 1

Step 1

Identify a Risk window

Width of Windfarm	4,005.52	*Includes 300 m bufer*
Height of Rotor sweep	162	
Cross Sectional Area (W)	648894.24	

Step 2

Estimate number of birds flying through the Risk window

Potential Active Hours	2,177.50

Month	No. hours VP survey effort	No. of birds recorded	No. of birds per hr of observation
Oct-20	6	0	0
Nov-20	6	0	0
Dec-20	6	0	0
Jan-21	6	0	0
Feb-21	6	0	0
Mar-21	6	0	0
Apr-21	9	42	4.66666667
Total	45	**Activity pr Hour**	0.67

n	1451.67

Step 3

Calculate proportion of area present by the wind farm rotors (A)

A	185531.96
Radius	81.00
Pi R2	20614.66
No. Rotors	9
Proportion A/W	0.29

Step 4

Calculate number of birds passing through rotors

N	415.06

Stage 2

Step 1

SNH Probability	8.90%	0.09	
Collisions no avoidance	36.94		

Stage 3

Step 1

Apply an avoidance factor

	Downtime %	15	0.85
Avoidance	**98%**	0.74	
	99%	0.37	
	99.50%	0.18	
	99.80%	0.07	
Avoidance with Downtime			
	98%	0.63	
	99%	0.31	
	99.50%	**0.16**	
	99.80%	0.06	