Foel Fach Wind Farm Limited.

Foel Fach Wind Farm – Environmental Statement Volume III

Appendix 6.2: Collision Risk Model Analysis

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Energy for generations

Coriolis Energy

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Foel Fach Wind Farm

on behalf of Foel Fach Wind Farm Limited

Environmental Statement

Appendix 6.2: Collision Risk Model Analysis

avian ecology

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EXECUTIVE SUMMARY

Collision risk modelling has been undertaken following the approach set out in this Technical Appendix. Collision mortality estimates were calculated for three species: red kite, golden plover and kestrel. This produced mean annual estimates as follows: red kite – 0.441 birds per year, golden plover – 9.293 birds per year, and kestrel – 1.485 birds per year.

1 INTRODUCTION

1.1.1 This Technical Appendix has been prepared to accompany **Environmental Statement (ES) Volume II, Chapter 6: Ornithology**, for the Proposed Development.

1.1.2 It presents the details and results of Collision Risk Model (CRM) calculations, completed to inform the assessment for the Proposed Development upon ornithological interests.

1.1.3 In the absence of Welsh-specific guidance, the approach to CRM has been taken in reference to the approach advocated by NatureScot.

1.1.4 This Technical Appendix should be read in conjunction with **ES Volume III, Appendix 6.1: Ornithology**, and which provides full details of the ornithological field surveys, including identification of 'target species', undertaken to inform the CRM analysis.

2 METHODOLOGY

2.1 Background

2.1.1 Baseline ornithology surveys undertaken for the Proposed Development included Vantage Point (VP) flight activity surveys, which recorded flight activity of target species (**Appendix 6.1**) 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 CRM analysis.

2.1.2 NatureScot advocate 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 follows the Band *et al.* (2007) approach. The main aim of the updated 2024 guidance is to standardise the approach to CRM and the previous 2007 approach is still considered valid and robust. 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 herein are therefore considered robust for the purpose of assessment and determining collision mortality risk, albeit that the outputs of CRM will always only ever provide a relative estimate of risk.

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 would comprise ten wind turbines (indicative model is the Enercon 175 (7 MW)), with six turbines with a maximum tip height of 220 m, hub height of 132.46 m and rotor diameter of 175 m (rotor sweep height of 45 m to 220 m); and four turbines with a maximum tip height of 200 m, hub height 114.45 m and rotor diameter of 171.1 m (rotor sweep height of 29 m to 200 m).

2.2.2 Turbine parameters used in the CRM analysis are summarised in **Table 2.1**. Where certain details were not available, a representative value has been used.

Table 2.1: Wind farm and turbine parameters used in the CRM.

Parameter	200 m Tip	220 Tip	Used in CRM	Unit
Size of Wind Farm			**373.82**	ha
No. of rotors (turbines)	4	6	**10**	-
No. of blades (per turbine)			**3**	-
Hub height	114.45	132.46	**-**	metres
Rotor diameter	171.1	175	**175**	metres
Rotor radius	85.6	87.5	**87.5**	metres
Maximum rotor height	200	220	**220**	metres
Minimum rotor height	29	45	**29**	metres
Max chord*			**5.4**	metres
Pitch*			**15**	degrees
Rotation period*			**6.0**	seconds
Downtime*			**15**	%

* Representative values

2.2.3 The 'size of wind farm' parameter has been calculated as the area of the individual turbine locations plus an appropriate surrounding buffer. A combination of professional judgment and experience within the industry means that, for this analysis, the area has been calculated as the full turbine envelope (i.e. one continuous area) incorporating a 300 m buffer around turbines. A buffer of 300 m is precautionary given this equates to rotor radius plus an additional 212.5 m. The buffer allows for small spatial errors made when mapping flights. It also allows for the micrositing of turbines without re-running the CRM analysis. The spatial area used to determine at risk from collision flights is referred to in this assessment as the Collision Risk Zone (CRZ).

2.2.4 **Table 2.1** shows the dimensions of the proposed turbines as well as the values used in the CRM analysis. Potential Collision Height (PCH) has been taken as the above ground height range between the minimum rotor swept height and the maximum rotor swept height for the two turbine models (29 m and 220 m respectively), with any flights within this range considered as being at risk from collision.

Thus, the precautionary principal has also been applied to the approach for determining at risk from collision flights.

2.3 Viewsheds

2.3.1 Flight activity data of target species, for use in the CRM analysis, have been obtained using baseline surveys from two VP locations (**Appendix 6.1**).

2.3.2 **ES Volume IV, Figure 6.2: Vantage Point Flight Activity Survey Plan** illustrates the visible study area from the two VP locations adopted during baseline surveys, using a 2 km radius (detection distance) and a 20 m above the ground cut-off.

2.3.3 Surveys at the two VPs were not undertaken simultaneously.

2.3.4 The areas of viewshed visibility within the CRZ, for use in the CRM analysis, are summarised in **Table 2.2**.

2.3.5 Table 2.2: VP locations and viewshed visible areas.

VP	Grid Reference	Orientation	Visible Area (ha)
1	SH 92894 41045	South south-east	79.1
2	SH 93878 42179	South south-east	290.6

2.4 Vantage Point Survey Effort

2.4.1 Two years of baseline VP flight activity surveys were completed, in accordance with NatureScot guidance (2025a), with this undertaken over two 12-month periods between September 2021 and August 2022 ('Year 1') and between September 2022 and August 2023 ('Year 2'). Further details of the surveys completed are presented in **Appendix 6.1.**

2.4.2 Survey effort (hours) achieved at each VP location is summarised in **Table 2.3**.

Table 2.3: Summary of VP flight activity survey effort (hours).

VP	2021				2022								Total (Year 1)
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	
1	6	6	6	6	6	6	6	9	9	9	9	9	87
2	6	6	6	6	6	6	6	9	9	9	9	9	87
VP	**2022**				**2023**								**Total (Year 2)**
	Sep	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	
1	6	3	9	9	3	6	6	9	9	9	9	6	84
2	6	3	9	3	9	6	6	9	9	6	12	6	84

2.4.3 Annual survey effort exceeded 72 hours at each VP, with at least 36 hours per VP in each broad survey season, regarded as being March to August (breeding season) and September to February (non-breeding season), in accordance with NatureScot guidance (2025a).

2.4.4 Note, that when undertaking the CRM analysis, species-specific breeding seasons have been used (see **Table 2.5**).

2.4.5 NatureScot (2024) pre-application guidance states that baseline ornithology data should have been collected within the last five years. At the time of writing this assessment, both years of survey are within the five-year period, and thus are considered valid and robust for assessment.

2.5 Identification of At Risk from Collision Flight Activity

2.5.1 'At risk from collision' flight activity has been defined as those target species flights for which part of their flightline was recorded within the CRZ and with at least part of the flight at PCH (29 m to 220 m).

2.5.2 During the baseline surveys, flight activity was recorded into seven height bands: Height Band 1 = <20 m, Height Band 2 = 20 – 50 m, Height Band 3 = 50 – 150 m, Height Band 4 = 150 – 180 m, Height Band 5 = 180 – 200 m, Height Band 6 = 200 – 250 m, and Height Band 7 = >250 m.

2.5.3 Flights in height bands 2 to 6 (20 m to 250 m) were treated as being at risk from collision. This is precautionary given that six turbines have maximum tip height of 220 m and four maximum tip height of 200 m, and thus some flights in height band 6 would likely be above collision risk height, and some flights in height band 2 may be below collision risk height.

2.5.4 Details of all at risk from collision flight activity recorded in Years 1 and 2 are provided in **Annex 1**.

2.6 Species Progressed for Analysis

2.6.1 Collision mortality risk estimates have only been calculated for species for which there is a potential for a significant effect.

2.6.2 For the purposes of the analysis, a target species qualified for CRM if it met the criteria of three or more at risk from collision flights (or ten or more individuals) during a survey year.

2.6.3 For species with a low level of at collision risk flight activity, especially those with a favourable conservation status, it can reasonably be predicted that the impact of collision mortality would be inconsequential at any population level and no significant effect be concluded for these ornithological receptors without the requirement for undertaking a detailed assessment.

2.6.4 **Table 2.4** lists the target species recorded during surveys (across both survey years) that had at risk from collision flights and, using the criteria set out above, sets out which target species was subject to CRM analysis (shown in **bold**). Note that kestrel was only recorded as a target species in Year 2.

Table 2.4: Identification of target species for CRM analysis.

Species	Total No. of Flights	Total No. of Birds	Flight Time At-Risk Height (seconds)
Red kite	63	69	12,023
Golden plover	11	333	1,985
Kestrel	3	5	220
Hen harrier	2	2	155
Peregrine	2	2	200

Species	Total No. of Flights	Total No. of Birds	Flight Time At-Risk Height (seconds)
Snipe	1	1	10

2.6.5 Based on the survey results and the above stated threshold in terms of criteria for CRM analysis, red kite was subject to CRM in the breeding and non-breeding seasons in both Years 1 and 2, golden plover was subject to CRM in the breeding season in Year 1, and non-breeding season in Year 2, and kestrel was subject to CRM in the breeding season in Year 2.

2.7 Target Species Parameters

2.7.1 The CRM analysis uses parameters for each species to calculate collision risk. The parameters used are presented in **Table 2.5**. Parameters are primarily taken from Snow and Perrins (1998) (biometrics), and Alerstam *et al*. (2007) and Bruderer and Bolt (2001) (flight speed), with avoidance rates taken from NatureScot (2025b). Kestrel parameters are taken from the website of the Hawk and Owl Trust (2025). Biometrics (bird length and wingspan) are average measurements.

Table 2.5: Target species parameters.

Species	Length (m)	Wingspan (m)	Flight Speed (m/s)	Avoidance Rate (%)	Occupancy on-site
Red kite	0.63	1.85	12.0	99	Breeding: Mar to Jul Non-breeding: Aug to Feb
Golden plover	0.28	0.72	17.9	98	Breeding: Apr to Jul Non-breeding: Aug to Mar
Kestrel	0.34	0.76	12.7	95	Breeding: Mar to Aug

2.7.2 Based on the flightlines recorded, all target species were classified as having 'non-directional' (random) flights, as opposed to directional flights which refer to birds regularly commuting on a straight path. Based on the flightlines and behaviour recorded, golden plover and kestrel were regarded as having 'flapping' flight action, whilst red kite was classed as having a 'gliding' flight.

2.7.3 The collision probability calculations produced for each target species in accordance with NatureScot guidance (SNH, 2000) produced the following outputs for use in the CRM analysis:

- Red kite – 6.9 %
- Golden plover – 4.6 %
- Kestrel – 5.6 %

2.7.4 Collision probability calculations for red kite, golden plover and kestrel are provided in **Annex 2.**

2.7.5 The potential number of active hours for the occupancy periods listed in **Table 2.5** has been calculated using a latitude of 52.95242, as per Forsythe *et al*. (1995). For red kite and kestrel activity is considered to correspond with daylight hours. For golden plover, which may be active outside daylight hours, an additional 25 % of time was added to daylight hours to account for low level activity between sunset and sunrise.

3 COLLISION RISK ANALYSIS

3.1.1 **Table 3.1** provides a summary of the collision mortality risks estimated for red kite, golden plover and kestrel. Note, kestrel was treated as a target species in Year 2, so CRM analysis was only carried out on Year 2 survey results (when three at risk from collision flights were recorded).

3.1.2 Example collision mortality risk calculations are provided in **Annex 3**. All species calculations can be provided on request.

Table 3.1: Collision mortality estimates.

Species	Avoidance Rate	Occupancy	Collision Mortality Estimate		
			Year 1	Year 2	Average
Red kite	99.0 %	Breeding season	0.427	0.127	0.277
		Non-breeding season	0.248	0.080	0.164
		Annual	0.675	0.207	**0.441**
Golden plover	98.0 %	Breeding season	1.796	0	0.898
		Non-breeding season	0	16.490	8.245
		Annual	1.796	16.490	**9.293**
Kestrel	95.0 %	Breeding season		1.485	1.485
		Non-breeding season		0	0
		Annual		1.485	**1.485**

3.1.3 On the basis of the approach to identifying at collision risk flight activity, as set out above, the mortality estimates are considered to be precautionary.

3.1.4 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 level of risk.

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ANNEX 1: AT RISK FROM COLLISION FLIGHT ACTIVITY

Table A1-1 presents at risk from collision flight activity for all target species recorded during the two-year survey period (September 2021 – August 2023). CRM analysis was carried out for red kite, golden plover and kestrel. The duration and the time at each height band (HT1 to HT7) is presented in seconds.

Table A1-1: Target species at risk from collision flight activity (within CRZ and PCH)
The following British Trust for Ornithology (BTO) species codes are used to denote species: KT – red kite, GP – golden plover, PE – peregrine, HH – hen harrier, K. – kestrel and SN - snipe.

Date	VP	Species	Number	Start Time	Duration	HT1	HT2	HT3	HT4	HT5	HT6	HT7
15/09/2021	1	KT	1	12:12	130	0	30	100	0	0	0	0
15/09/2021	1	KT	2	12:18	175	0	0	160	15	0	0	0
15/09/2021	1	KT	1	14:29	32	0	0	32	0	0	0	0
15/09/2021	1	KT	1	12:21	137	0	0	30	15	15	77	0
15/09/2021	2	KT	1	16:12	14	0	14	0	0	0	0	0
15/09/2021	2	KT	1	16:08	40	0	40	0	0	0	0	0
13/10/2021	1	KT	1	12:38	60	0	0	60	0	0	0	0
13/10/2021	1	KT	1	12:04	120	30	45	45	0	0	0	0
13/10/2021	1	KT	1	13:52	27	0	0	27	0	0	0	0
19/11/2021	1	KT	1	13:34	89	0	0	89	0	0	0	0
19/11/2021	1	KT	1	11:25	174	75	75	24	0	0	0	0
26/01/2022	2	KT	1	12:24	154	0	124	30	0	0	0	0
26/01/2022	2	KT	1	11:46	963	150	450	288	75	0	0	0
28/02/2022	1	KT	1	10:41	134	0	0	0	0	134	0	0
15/03/2022	1	KT	1	11:02	452	0	135	120	197	0	0	0
15/03/2022	2	KT	1	11:51	28	0	28	0	0	0	0	0
15/03/2022	2	KT	1	12:53	399	0	0	45	105	174	75	0
21/04/2022	2	GP	3	08:37	43	0	43	0	0	0	0	0
21/04/2022	2	GP	35	10:28	130	0	0	0	130	0	0	0
21/04/2022	2	GP	15	09:22	221	26	0	30	60	105	0	0
21/04/2022	2	KT	1	12:49	194	0	30	15	60	44	45	0
21/04/2022	2	KT	1	10:13	232	0	0	90	97	45	0	0
21/04/2022	2	KT	2	11:11	147	0	0	15	30	102	0	0
28/04/2022	1	KT	1	11:48	180	0	0	0	0	0	180	0
28/04/2022	2	KT	1	10:30	130	0	0	0	130	0	0	0
28/04/2022	2	KT	1	11:27	54	0	0	0	54	0	0	0
05/05/2022	1	KT	1	07:11	222	0	0	0	222	0	0	0
05/05/2022	1	KT	2	12:32	583	0	0	30	240	313	0	0
05/05/2022	1	KT	1	11:59	138	0	0	0	138	0	0	0
05/05/2022	1	KT	1	13:03	232	0	0	30	45	157	0	0
12/05/2022	2	GP	1	10:12	49	0	0	0	0	0	49	0
12/05/2022	2	KT	1	12:01	78	0	0	48	30	0	0	0
12/05/2022	2	KT	1	09:15	470	60	0	30	380	0	0	0
27/05/2022	2	KT	1	13:33	70	0	15	30	0	15	0	0
01/06/2022	1	KT	1	08:02	168	0	0	0	0	168	0	0
08/06/2022	2	KT	1	10:22	137	0	0	0	107	30	0	0
08/06/2022	2	KT	1	10:46	64	0	0	0	64	0	0	0

Date	VP	Species	Number	Start Time	Duration	HT1	HT2	HT3	HT4	HT5	HT6	HT7
08/06/2022	2	KT	2	10:01	288	0	0	0	45	243	0	0
08/06/2022	2	KT	2	13:37	406	0	0	0	90	241	75	0
22/06/2022	1	KT	1	11:37	347	0	0	0	0	45	302	0
07/07/2022	1	KT	1	13:39	125	0	0	30	95	0	0	0
15/07/2022	2	KT	1	11:37	120	0	0	0	120	0	0	0
15/07/2022	2	KT	1	09:46	174	0	0	75	99	0	0	0
03/08/2022	2	KT	1	11:49	418	0	0	60	253	105	0	0
03/08/2022	2	KT	1	12:32	186	0	0	0	156	30	0	0
25/08/2022	1	KT	1	15:16	419	0	359	60	0	0	0	0
30/08/2022	2	KT	1	11:49	418	0	0	60	253	105	0	0
30/08/2022	2	KT	1	12:32	186	0	0	0	156	30	0	0
09/09/2022	1	SN	1	14:22	10	0	10	0	0	0	0	0
13/10/2022	1	HH	1	11:47	140	30	110	0	0	0	0	0
03/11/2022	1	KT	1	12:21	110	0	60	30	20	0	0	0
03/11/2022	2	GP	5	09:57	20	0	0	0	20	0	0	0
03/11/2022	2	KT	1	09:16	130	75	55	0	0	0	0	0
15/11/2022	2	KT	1	13:01	160	0	100	60	0	0	0	0
30/11/2022	1	GP	80	10:22	340	15	15	55	15	240	0	0
30/11/2022	1	HH	1	09:41	143	98	45	0	0	0	0	0
30/11/2022	2	GP	80	12:14	720	0	0	0	0	435	135	150
30/11/2022	2	GP	80	12:01	300	0	0	0	30	270	0	0
06/12/2022	1	KT	1	09:33	148	0	0	0	0	148	0	0
06/12/2022	2	GP	5	13:23	48	0	0	48	0	0	0	0
06/12/2022	2	GP	11	13:44	45	0	0	45	0	0	0	0
16/12/2022	1	KT	1	15:09	225	0	60	105	60	0	0	0
31/01/2023	2	KT	1	12:50	130	0	45	85	0	0	0	0
31/01/2023	2	KT	1	12:32	80	0	0	20	30	30	0	0
09/02/2023	1	GP	18	13:04	320	60	230	30	0	0	0	0
09/02/2023	1	KT	1	11:51	160	0	0	40	30	90	0	0
09/02/2023	1	PE	1	13:27	165	0	0	45	120	0	0	0
23/02/2023	1	KT	2	09:53	225	0	0	15	45	15	45	105
23/02/2023	1	PE	1	10:47	35	0	0	20	15	0	0	0
27/03/2023	2	K.	2	13:13	115	0	15	100	0	0	0	0
27/03/2023	2	KT	1	10:02	210	30	105	75	0	0	0	0
27/03/2023	2	KT	1	11:07	195	0	60	135	0	0	0	0
25/04/2023	1	KT	1	12:23	90	0	0	90	0	0	0	0
25/04/2023	2	KT	1	17:23	58	0	0	30	28	0	0	0
25/04/2023	2	KT	1	15:14	67	0	0	0	0	0	30	37
25/05/2023	2	KT	1	12:53	472	97	45	45	90	60	105	30
29/06/2023	2	K.	1	12:42	111	36	75	0	0	0	0	0
17/07/2023	1	KT	1	10:24	259	139	120	0	0	0	0	0
18/07/2023	2	K.	2	13:02	145	115	30	0	0	0	0	0
18/07/2023	2	KT	1	14:21	292	37	45	90	120	0	0	0
19/07/2023	1	KT	1	14:28	408	0	33	105	270	0	0	0
22/08/2023	1	KT	1	14:29	223	58	165	0	0	0	0	0

ANNEX 2 – COLLISION PROBABILITY CALCULATIONS

Red kite

K: [1D or [3D] (0 or 1)	**1**	
No. Blades	**3**	
Max Chord	**5.4**	m
Pitch (degrees)	**15**	
Bird Length	**0.63**	m
Wingspan	**1.85**	m
F: Flapping (0) or gliding (+1)	**1**	
Bird speed	**12**	m/sec
Rotor Diam	**175**	m
Rotation Period	**6.00**	sec
Bird aspect ratio: β	0.34	

Calculation of alpha and p(collision) as a function of radius

			Upwind:			Downwind:		
r/R	c/C	α	collide	p	contribution	collide	p	contribution
radius	chord	alpha	length	(collision)	from radius r	length	(collision)	from radius r
0.025	0.575	5.24	22.68	0.95	0.00118	21.08	0.88	0.00110
0.075	0.575	1.75	8.10	0.34	0.00253	6.49	0.27	0.00203
0.125	0.702	1.05	6.05	0.25	0.00315	4.09	0.17	0.00213
0.175	0.860	0.75	5.44	0.23	0.00397	3.04	0.13	0.00221
0.225	0.994	0.58	5.09	0.21	0.00478	2.31	0.10	0.00217
0.275	0.947	0.48	4.24	0.18	0.00485	1.59	0.07	0.00182
0.325	0.899	0.40	3.62	0.15	0.00490	1.11	0.05	0.00150
0.375	0.851	0.35	3.15	0.13	0.00492	0.77	0.03	0.00121
0.425	0.804	0.31	3.04	0.13	0.00539	0.80	0.03	0.00141
0.475	0.756	0.28	2.77	0.12	0.00549	0.66	0.03	0.00131
0.525	0.708	0.25	2.54	0.11	0.00556	0.70	0.03	0.00153
0.575	0.660	0.23	2.34	0.10	0.00560	0.77	0.03	0.00184
0.625	0.613	0.21	2.16	0.09	0.00561	0.82	0.03	0.00213
0.675	0.565	0.19	1.99	0.08	0.00560	0.85	0.04	0.00238
0.725	0.517	0.18	1.84	0.08	0.00556	0.87	0.04	0.00261
0.775	0.470	0.17	1.70	0.07	0.00549	0.87	0.04	0.00282
0.825	0.422	0.16	1.57	0.07	0.00539	0.87	0.04	0.00299
0.875	0.374	0.15	1.45	0.06	0.00527	0.86	0.04	0.00314
0.925	0.327	0.14	1.33	0.06	0.00512	0.85	0.04	0.00326
0.975	0.279	0.13	1.22	0.05	0.00494	0.82	0.03	0.00335

Overall p(collision) = **Upwind** **9.5 %** **Downwind** **4.3 %**

Average **6.9 %**

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	p	contribution from radius r	collide	p	contribution from radius r
Pitch (degrees)	**15**		radius	chord	alpha	length	(collision)		length	(collision)	
Bird Length	**0.28**	m	0.025	0.575	7.81	29.87	0.83	0.00104	28.26	0.79	0.00099
Wingspan	**0.72**	m	0.075	0.575	2.60	10.49	0.29	0.00220	8.88	0.25	0.00186
F: Flapping (0) or gliding (+1)	**0**		0.125	0.702	1.56	7.82	0.22	0.00273	5.86	0.16	0.00205
			0.175	0.860	1.12	7.01	0.20	0.00343	4.61	0.13	0.00225
Bird speed	**17.9**	m/sec	0.225	0.994	0.87	6.52	0.18	0.00410	3.74	0.10	0.00235
Rotor Diam	**175**	m	0.275	0.947	0.71	5.34	0.15	0.00410	2.70	0.08	0.00207
Rotation Period	**6.00**	sec	0.325	0.899	0.60	4.51	0.13	0.00409	1.99	0.06	0.00181
			0.375	0.851	0.52	3.88	0.11	0.00406	1.50	0.04	0.00157
			0.425	0.804	0.46	3.38	0.09	0.00401	1.13	0.03	0.00135
			0.475	0.756	0.41	2.97	0.08	0.00395	0.86	0.02	0.00114
Bird aspect ratio: β	0.39		0.525	0.708	0.37	2.64	0.07	0.00388	0.66	0.02	0.00097
			0.575	0.660	0.34	2.37	0.07	0.00381	0.53	0.01	0.00085
			0.625	0.613	0.31	2.14	0.06	0.00373	0.42	0.01	0.00074
			0.675	0.565	0.29	1.92	0.05	0.00363	0.34	0.01	0.00065
			0.725	0.517	0.27	1.73	0.05	0.00350	0.28	0.01	0.00058
			0.775	0.470	0.25	1.55	0.04	0.00336	0.32	0.01	0.00069
			0.825	0.422	0.24	1.39	0.04	0.00321	0.35	0.01	0.00080
			0.875	0.374	0.22	1.24	0.03	0.00303	0.37	0.01	0.00090
			0.925	0.327	0.21	1.10	0.03	0.00283	0.38	0.01	0.00097
			0.975	0.279	0.20	0.96	0.03	0.00262	0.38	0.01	0.00103
				Overall p(collision) =			**Upwind**	**6.7 %**		**Downwind**	**2.6 %**
								Average	**4.6 %**		

Kestrel

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	p	contribution from radius r	collide	p	contribution from radius r
Pitch (degrees)	**15**		radius	chord	alpha	length	(collision)		length	(collision)	
Bird Length	**0.34**	m	0.025	0.575	5.54	21.64	0.85	0.00107	20.04	0.79	0.00099
Wingspan	**0.76**	m	0.075	0.575	1.85	7.75	0.31	0.00229	6.14	0.24	0.00181
F: Flapping (0) or gliding (+1)	**0**		0.125	0.702	1.11	5.88	0.23	0.00289	3.92	0.15	0.00193
			0.175	0.860	0.79	5.36	0.21	0.00369	2.95	0.12	0.00203
Bird speed	**12.7**	m/sec	0.225	0.994	0.62	5.05	0.20	0.00448	2.27	0.09	0.00201
Rotor Diam	**175**	m	0.275	0.947	0.50	4.19	0.17	0.00454	1.55	0.06	0.00168
Rotation Period	**6.00**	sec	0.325	0.899	0.43	3.60	0.14	0.00460	1.08	0.04	0.00139
			0.375	0.851	0.37	3.17	0.12	0.00468	0.79	0.03	0.00117
			0.425	0.804	0.33	2.83	0.11	0.00474	0.58	0.02	0.00098
			0.475	0.756	0.29	2.55	0.10	0.00476	0.43	0.02	0.00081
Bird aspect ratio: β	0.45		0.525	0.708	0.26	2.30	0.09	0.00476	0.35	0.01	0.00073
			0.575	0.660	0.24	2.09	0.08	0.00474	0.43	0.02	0.00098
			0.625	0.613	0.22	1.91	0.08	0.00469	0.49	0.02	0.00120
			0.675	0.565	0.21	1.73	0.07	0.00461	0.52	0.02	0.00139
			0.725	0.517	0.19	1.58	0.06	0.00451	0.55	0.02	0.00156
			0.775	0.470	0.18	1.43	0.06	0.00438	0.56	0.02	0.00170
			0.825	0.422	0.17	1.30	0.05	0.00422	0.56	0.02	0.00182
			0.875	0.374	0.16	1.17	0.05	0.00404	0.55	0.02	0.00191
			0.925	0.327	0.15	1.05	0.04	0.00383	0.54	0.02	0.00197
			0.975	0.279	0.14	0.94	0.04	0.00359	0.52	0.02	0.00201
				Overall p(collision) =			**Upwind**	**8.1 %**		**Downwind**	**3.0 %**
								Average	**5.6 %**		

ANNEX 3 – COLLISION RISK MODEL CALCULATION (EXAMPLES)

Red kite – breeding season (2022)

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	**79.1**	**42.0**	3322.2	**907**	0.0000758444	0.213980414	0.000016229
2	**290.6**	**42.0**	12203.5	**2181**	0.0000496521	0.786019586	0.000039028
Totals	369.7	84.0	15525.7	3088	0.0000627482	1.000000000	0.000055257

	Mean activity hr^-1 in wind farm				**WIND FARM DATA**		
	Risk height	0.02066	2.0656%		Wind farm area (ha)	**373.82**	
	Daylight hours	2219.2					
	Downtime	**15**	0.85		**D**	**175**	
Flight risk volume	Vw =	654185000			**L + d**	**6.03**	
Rotor swept volume	Vr =	1450385	No.turbines	**10**	**R**	**87.5**	
	Vr/Vw =	0.0022171					
	Speed	**12**					
	Vw Occupancy =	45.8399	165023.8				
	Vr Occupancy =	0.1016	365.9				
	Transit time =	0.5025					
	Transits =	728.104					
Collision probability from SNH sheet		**0.069**					
Collisions with no avoidance		50.239					
Collisions with 98% avoidance		1.005			**Collisions with 99% avoidance**		0.502
Collisions with 98% avoidance & downtime		0.854			**Collisions with 99% avoidance & downtime**		0.427
30 year mortality		30.143			**30 year mortality**		15.072
30 year mortality with 15% downtime etc		**25.622**			**30 year mortality with 15% downtime etc**		**12.811**
Years for 1 death		1.17			**Years for 1 death**		2.34

Red kite – non-breeding season (2021/22)

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	**79.1**	**45.0**	3559.5	**1115**	0.0000869848	0.213980414	0.000018613
2	**290.6**	**45.0**	13075.2	**782**	0.0000166235	0.786019586	0.000013066
Totals	369.7	90.0	16634.7	1897	0.0000518041	1.000000000	0.000031679

	Mean activity hr^-1 in wind farm				**WIND FARM DATA**		
	Risk height	0.01184	1.1842%		Wind farm area (ha)	**373.82**	*This is the area c*
	Daylight hours	2247.7		*If only part of the year is being assessed, e.g. for a RTD, this needs to redu*			
	Downtime	**15**	0.85		**D**	**175**	
Flight risk volume	Vw =	654185000			**L + d**	**6.03**	*add the turbine l*
Rotor swept volume	Vr =	1450385	No.turbines	**10**	**R**	**87.5**	
	Vr/Vw =	0.0022171					
	Speed	**12**	*This is the same speed as in cell B4 on the SNH GE sheet*				
	Vw Occupancy =	26.6182	95825.5	*Column C is hours D is seconds*			
	Vr Occupancy =	0.0590	212.5	*Column C is hours D is seconds*			
	Transit time =	0.5025					
	Transits =	422.793					
Collision probability from SNH sheet		**0.069**	*From the SNH GE sheet / 100)*				
Collisions with no avoidance		29.173					
Collisions with 98% avoidance		0.583			**Collisions with 99% avoidance**		0.292
Collisions with 98% avoidance & downtime		0.496			**Collisions with 99% avoidance & downtime**		0.248
30 year mortality		17.504			**30 year mortality**		8.752
30 year mortality with 15% downtime etc		**14.878**			**30 year mortality with 15% downtime etc**		**7.439**
Years for 1 death		2.02			**Years for 1 death**		4.03

Golden plover – breeding season (2022)

	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	**79.1**	**36.0**	2847.6	**0**	0.0000000000	0.213980414	0.000000000
	2	**290.6**	**36.0**	10460.2	**5372**	0.0001426449	0.786019586	0.000112122
	Totals	369.7	72.0	13307.8	5372	0.0000713225	1.000000000	0.000112122
		Mean activity hr^-1 in wind farm				**WIND FARM DATA**		
		Risk height	0.04191	4.1913%		Wind farm area (ha)	**373.82**	
		Daylight hours	2312.8					
		Downtime	**15**	0.85		**D**	**175**	
	Flight risk volume	Vw =	654185000			**L + d**	**5.68**	
	Rotor swept volume	Vr =	1366200	No.turbines	**10**	**R**	**87.5**	
		Vr/Vw =	0.0020884					
		Speed	**17.9**					
		Vw Occupancy =	96.9372	348973.8				
		Vr Occupancy =	0.2024	728.8				
		Transit time =	0.3173					
		Transits =	2296.737					
	Collision probability from SNH sheet		**0.046**					
	Collisions with no avoidance		105.650					
	Collisions with 98% avoidance		2.113			**Collisions with 99% avoidance**		1.056
	Collisions with 98% avoidance & downtime		1.796			**Collisions with 99% avoidance & downtime**		0.898
	30 year mortality		63.390			**30 year mortality**		31.695
	30 year mortality with 15% downtime etc		**53.881**			**30 year mortality with 15% downtime etc**		**26.941**
	Years for 1 death		0.56			**Years for 1 death**		1.11