Technical Appendix 7.3: Collision Risk Modelling

Ravengill Energy Park

Collison Risk Modelling

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Ravengill Energy Park Ltd.

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Basis of Report

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1.0 Input Data

Delaunay Triangulation[1] from the proposed turbine locations was used to create a wind farm area[2] and from this the Collision Risk Analysis Area (CRAA) was created using a 500 metre (m) buffer (refer to **Figure 7.2, EIAR Volume 4**). Using the larger 500 m area around the turbines accounts for possible inaccuracies in the recording of flightlines and ensures the assessment is precautionary.

As recommended in NatureScot guidance (2025a[i]), the aim of baseline flight activity surveys should be to achieve maximum visual coverage of proposed turbines and associated CRAA from Vantage Point (VP) viewsheds using the minimum number of VPs. However, in practice complete (100%) coverage is often unachievable as a result of the topography of the site, presence of mature forestry and access permissions outwith site boundaries.

For the Proposed Development, although some small areas of the CRAA remain 'invisible' at 20 m above ground level (**Figure 7.2, EIAR Volume 4**), the habitats within these areas are however of sufficient similarity to that 'seen' within the VP viewsheds in the CRAA, such that the survey data collected over the course of flight activity surveys and subsequently assessed for potential collision mortality risks, is considered to be representative of the whole CRAA and therefore appropriate for the purposes of estimating collision mortality risks using the NatureScot Collision Risk Model (CRM) (Band et al. 2007[ii], Band 2024[iii]) .

In the use of the NatureScot CRM, flying time at risk height (secsHahr^{-1}) for each species is calculated as a single mean activity rate within the entirety of the CRAA.

Table 7-3-1, **Table 7-3-2** and **Table 7-3-3** present the parameters which apply to each Collision Risk Model (CRM).

Table 7-3-1: Wind farm parameters

Size of wind farm envelope	1261.34	hectares (ha)
Number of turbines	21	turbines
Rotor diameter	170	metres (m)
Hub height	135	m
Max. rotor depth	1.16	m (at 15° pitch angle)
Max. chord	4.5	m
Pitch	15	degrees (°)
Rotation period	6.51	seconds (secs)
Turbine operation time	0.85	percent (%)
Risk height: highest	220	m
Risk height: lowest	50	m
Flight risk volume	2144283295.26356	m^3

Table 7-3-2: CRM parameters per species

Species	Length (m)	Wingspan (m)	Assumed flight speed, v (ms^{-1})	Avoidance rate	Probability of collision	Bird transit time (secs)
Curlew	0.6	1	13	0.98	0.0562	0.1357
Golden eagle	0.815	2.12	15	0.99	0.0621	0.1320
Golden plover	0.28	0.72	17.9	0.98	0.0407	0.0807
Goshawk	0.62	1.65	9.7	0.98	0.0703	0.1840
Greylag goose	0.825	1.635	17.1	0.998	0.0569	0.1164
Hen harrier	0.48	1.1	12	0.99	0.0549	0.1371
Herring gull	0.64	1.5	12.8	0.98	0.0595	0.1410
Lapwing	0.31	0.87	11.9	0.98	0.0487	0.1239
Merlin	0.28	0.56	13	0.98	0.0446	0.1111
Peregrine falcon	0.48	1.1	12.1	0.98	0.0547	0.1359
Pink-footed goose	0.675	1.525	17.3	0.998	0.0530	0.1063
Red kite	0.66	1.95	12	0.99	0.0640	0.1521

Table 7-3-3: Visible area within the CRAA per vantage point

VP	Area (ha)
1	121.29
2	126.43
3	147.10
4	177.88
5	141.67
7	292.04
8	158.75
9	70.92
10	220.27

Birds are assumed to be active during all the daylight hours and this is estimated by calculating the number of hours per day between sunrise and sunset (adjusting for correct latitude) for the survey seasons as defined in **Table 7-3-4** below.

[1] Delaunay triangulation is a form of mathematical/computational geometry where a given set of points (in this case the turbine locations) are all joined to create discrete triangles. Further information is available here: https://uk.mathworks.com/help/matlab/math/delaunay-triangulation.html

[2] This was adjusted where appropriate depending on the spatial location of the turbines in relation to other turbines.

Table 7-3-4: Season definitions per species/species group

Species	Breeding season			Non-breeding season		
	Start date	End date	Hours presumed present	Start date	End date	Hours presumed present
Golden eagle	1st February	31st August	2,768	1st September	31st January	1,727
Golden plover	15th March	31st August	1,515	1st September	14th March	2,981
Geese and swans	15th May	31st August	1,792	1st September	14th May	2,704
Herring gull	15th March	31st August	2,644	1st September	14th March	1,851
Raptors	15th March	31st August	2,644	1st September	14th March	1,851
Waders	1st April	31st July	1.968	1st August	31st March	2,527

2.0 Output Summary

Only flightlines identified to be within the CRAA and recorded within the 2 km viewshed of the associated VP were considered to be 'at-risk' for the purposes of the collision risk modelling.

- 'At-risk' is defined as – a flight having at least part of its duration (i) at Potential Collision Height (PCH)[3]; (ii) within the CRAA; and (iii) recorded within the 2 km viewshed of the associated VP.
- PCH is defined as – the altitude between the minimum and maximum blade height[4] (taken to be from 50 m to 220 m for the Proposed Development).

Black grouse and whooper swan were recorded during flight activity surveys, but no flights were considered to be 'at-risk'[5]. Full survey results detailing the findings from each survey visit (including target species' flightlines considered not 'at-risk' and secondary species information) can be found within **Technical Appendix 7.1** (**EIAR Volume 4**). Only bird seconds for observations identified as 'at-risk' were then input into a Collision Risk Model (CRM) to calculate the predicted collision rates per season. **Table 7-3-5** and **Table 7-3-6** provide the estimated collision rates and number of seasons per collision for each species.

Table 7-3-5: Estimated collision rates

Species	2023/2024 non-breeding season	2024 breeding season	2024/2025 non-breeding season	2025 breeding season	Mean breeding	Mean non-breeding	Mean annual
Curlew	0	0.0144	0	0.0347	0.0245	0	0.0245
Golden eagle	0	0.0512	0.00008	0.0059	0.0285	0.00004	0.0286
Golden plover	2.4596	0	0.0276	0	0	1.2436	1.2436
Goshawk	0	0	0.0001	0	0	0.00005	0.00005
Greylag goose	0	0.0031	0.0006	0	0.0015	0.0003	0.0018
Hen harrier	0	0.0005	0.0040	0.0007	0.0006	0.0020	0.0026
Herring gull	0	0.1688	0	0.0255	0.0972	0	0.0972
Lapwing	0	0.0070	0.0016	0	0.0035	0.0008	0.0043
Merlin	0	0	0.0025	0.0008	0.0004	0.0012	0.0017
Peregrine falcon	0	0	0	0.0073	0.0037	0	0.0037
Pink-footed goose	0.0730	0	0	0	0	0.0365	0.0365
Red kite	0.0617	0.7704	0.2058	0.3718	0.5711	0.1338	0.7048

Table 7-3-6: Estimated number of seasons per collision

Species	2023/2024 non-breeding season	2024 breeding season	2024/2025 non-breeding season	2025 breeding season	Mean breeding	Mean non-breeding	Mean annual
Curlew	0	70	0	29	41	0	41
Golden eagle	0	19.5	12267	171	35	24534	35
Golden plover	0.41	0	36	0	0	0.80	0.80
Goshawk	0	0	9229	0	0	18458	18458
Greylag goose	0	327	1578	0	655	3155	542
Hen harrier	0	1896	250	1422	1625	499	382
Herring gull	0	5.92	0	39	10.3	0	10.3
Lapwing	0	142	607	0	284	1214	230
Merlin	0	0	401	1183	2366	802	599
Peregrine falcon	0	0	0	137	273	0	273

[3] In some cases, only part of a total flight duration was recorded at PCH, and it is assumed that this proportion is applicable for that part of the flight within the CRAA and 2 km viewshed area.

[4] Where the actual rotor blade altitude differs from the pre-defined survey height bands, the collision risk model accounts for this difference on the assumption of an even flight distribution within each particular survey height band, and an adjustment can be made to estimate total flight duration at actual rotor blade altitude.

[5] i.e. the flights were either not within the CRAA and associated viewshed or were only recorded flying outwith the PCH.

Species	2023/2024 non-breeding season	2024 breeding season	2024/2025 non-breeding season	2025 breeding season	Mean breeding	Mean non-breeding	Mean annual
Pink-footed goose	13.7	0	0	0	0	27	27
Red kite	16.2	1.30	4.86	2.69	1.75	7.48	1.42

Detailed outputs from the CRM for the following species scoped in to the assessment (**Chapter 7 EIAR Volume 2**) are presented in the following section below: golden plover, herring gull, and red kite.

3.0 Detailed Species Outputs

3.1 Golden plover

3.1.1 Non-Breeding Season 2023/2024

Table 7-3-7: Golden plover flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
2	2519.35	5752.78	1.03259E-05
10	13570.85	11343.97	5.56221E-05

Table 7-3-8: Golden plover mortality estimates

Mean activity in wind farm at rotor height	0.0832	hr^{-1}
Total Combined rotor swept volume	688621	m^3
Bird occupancy	247.9416	hrs/season
Bird occupancy of rotor swept volume	286.6488	bird-sec
No. of transits through rotors	3551.6474	per season
Estimated collisions	144.6806	per season
Estimated collisions after correction for operation	122.9785	per season
Estimated collisions after avoidance factor	2.4596	per season

3.1.2 Non-Breeding Season 2024/2025

Table 7-3-9: Golden plover flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
2	73.91	7522.87	2.44E-07
7	150	16938.15	4.96E-07

Table 7-3-10: Golden plover mortality estimates

Mean activity in wind farm at rotor height	0.0009	hr^{-1}
Total Combined rotor swept volume	688621	m^3
Bird occupancy	2.7832	hrs/season
Bird occupancy of rotor swept volume	3.2177	bird-sec
No. of transits through rotors	39.8675	per season
Estimated collisions	1.6241	per season
Estimated collisions after correction for operation	1.3804	per season
Estimated collisions after avoidance factor	0.0276	per season

3.2 Herring gull

3.2.1 Breeding Season 2024

Table 7-3-17: Herring gull flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
5	922.80	5100.25	4.89E-06

Table 7-3-18: Herring gull mortality estimates

Mean activity in wind farm at rotor height	0.0062	hr^{-1}
Total Combined rotor swept volume	860218	m^3
Bird occupancy	16.3062	hrs/season
Bird occupancy of rotor swept volume	23.5496	bird-sec
No. of transits through rotors	167.0288	per season
Estimated collisions	9.9312	per season
Estimated collisions after correction for operation	8.4415	per season
Estimated collisions after avoidance factor	0.1688	per season

3.2.2 Breeding Season 2025

Table 7-3-21: Herring gull flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
9	38.25	2553.16	2.03E-07
10	101.01	7929.76	5.35E-07

Table 7-3-22: Herring gull mortality estimates

Mean activity in wind farm at rotor height	0.0009	hr^{-1}
Total Combined rotor swept volume	860218	m^3
Bird occupancy	2.4608	hrs/season
Bird occupancy of rotor swept volume	3.5539	bird-sec
No. of transits through rotors	25.2063	per season
Estimated collisions	1.4987	per season
Estimated collisions after correction for operation	1.2739	per season
Estimated collisions after avoidance factor	0.0255	per season

3.3 Red kite

3.3.1 Non-Breeding Season 2023/2024

Table 7-3-23: Red kite flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	76.44	4366.37	4.04E-07
2	16.04	4551.65	8.49E-08
3	135.17	5295.65	7.15E-07
4	14.18	6403.57	7.5E-08
5	132.94	5100.24	7.03E-07
7	356.36	10586.34	1.89E-06
8	40.83	5715.15	2.16E-07
10	183.28	7929.76	9.7E-07

Table 7-3-24: Red kite mortality estimates

Mean activity in wind farm at rotor height	0.0064	hr^{-1}
Total Combined rotor swept volume	869751	m^3
Bird occupancy	11.8011	hrs/season
Bird occupancy of rotor swept volume	17.2321	bird-sec
No. of transits through rotors	113.3265	per season
Estimated collisions	7.2547	per season
Estimated collisions after correction for operation	6.1665	per season
Estimated collisions after avoidance factor	0.0617	per season

3.3.2 Breeding Season 2024

Table 7-3-25: Red kite flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	154.21	4366.37	8.17E-07
2	71.89	4551.65	3.81E-07
3	464.75	5295.65	2.46E-06
4	195.78	6403.57	1.04E-06
5	181.27	5100.24	9.6E-07
7	1401.67	10513.33	7.43E-06
8	2627.47	5715.15	1.39E-05
9	315.17	2553.16	1.67E-06
10	2931.82	7929.76	1.55E-05

Table 7-3-26: Red kite mortality estimates

Mean activity in wind farm at rotor height	0.0558	hr^{-1}
Total Combined rotor swept volume	869751	m^3
Bird occupancy	147.4423	hrs/season
Bird occupancy of rotor swept volume	215.2968	bird-sec
No. of transits through rotors	1415.8943	per season
Estimated collisions	90.6400	per season
Estimated collisions after correction for operation	77.0440	per season
Estimated collisions after avoidance factor	0.7704	per season

3.3.3 Non-Breeding Season 2024/2025

Table 7-3-27: Red kite flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	111.22	4366.37	5.89E-07
3	297.77	5295.65	1.58E-06
4	149.81	6403.57	7.94E-07
5	67.69	5100.24	3.59E-07
7	1691.65	10513.33	8.96E-06
8	166.78	5715.15	8.84E-07
9	237.29	2553.16	1.26E-06
10	461.94	7929.76	2.45E-06

Table 7-3-28: Red kite mortality estimates

Mean activity in wind farm at rotor height	0.0213	hr^{-1}
Total Combined rotor swept volume	869751	m^3
Bird occupancy	39.3916	hrs/season
Bird occupancy of rotor swept volume	57.5200	bird-sec
No. of transits through rotors	378.2786	per season
Estimated collisions	24.2159	per season
Estimated collisions after correction for operation	20.5835	per season
Estimated collisions after avoidance factor	0.2058	per season

3.3.4 Breeding Season 2025

Table 7-3-29: Red kite flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height ($secsHahr^{-1}$)
1	206.98	4366.37	1.1E-06
2	3.25	4551.65	1.72E-08
3	627.41	5295.65	3.32E-06
4	139.94	6403.57	7.41E-07
5	318.25	5100.24	1.69E-06
7	675.34	10513.33	3.58E-06
8	527.45	5715.15	2.79E-06
9	272.67	2553.16	1.44E-06
10	1254.89	7929.76	6.65E-06

Table 7-3-30: Red kite mortality estimates

Mean activity in wind farm at rotor height	0.0269	hr^{-1}
Total Combined rotor swept volume	869751	m^3
Bird occupancy	71.1445	hrs/season
Bird occupancy of rotor swept volume	103.8860	bird-sec
No. of transits through rotors	683.2035	per season
Estimated collisions	43.7360	per season
Estimated collisions after correction for operation	37.1756	per season
Estimated collisions after avoidance factor	0.3718	per season

[i] NatureScot (2025a) Recommended Bird Survey Methods to inform impact assessment of Onshore Windfarms. Available at: https://www.nature.scot/doc/recommended-bird-survey-methods-inform-impact-assessment-onshore-windfarms

[ii] 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.

[iii] Band, W. 2024. Using a collision risk model to assess bird collision risks for onshore wind farms. NatureScot Research Report 909. Available at: https://www.nature.scot/doc/naturescot-research-report-909-using-collision-risk-model-assess-bird-collision-risks-onshore-wind