

Appendix 5C: Collision Calculations

Outline

Collision risk modelling (CRM) has been carried out for the revised Eredine Wind Farm (the Revised Development) following current NatureScot guidance¹. The modelling was completed by Dr A. Fielding BSc (Hons), MSc, PhD, FHEA, FLS, based on survey data collected by S. Smith, A. MacCormich and M. Marchant.

Results summary

Tables 1 – 4 show the annual collision rates (mean of two years) using turbine-weighted collision calculations, including lower and upper limits for the estimates based on a range of avoidance rates. Estimates using the avoidance rate suggested in current guidance² are highlighted in bold text. Figures in parentheses are those using survey-effort collision calculations.

Table 1 Golden Eagle annual collision estimates with error limits

Avoidance	Mean	Lower	Upper
95.0%	0.466	0.041	0.892
98.0%	0.187	0.016	0.357
99.0%	0.093 (0.075)	0.008 (0.001)	0.178 (0.148)
99.5%	0.047	0.004	0.089
99.9%	0.009	0.001	0.018

Table 2 Osprey annual collision estimates with error limits

Avoidance	Mean	Lower	Upper
95.0%	0.198	0.023	0.374
98.0%	0.079 (0.053)	0.009 (0.006)	0.149 (0.100)
99.0%	0.040	0.005	0.075
99.5%	0.020	0.002	0.037
99.9%	0.008	0.001	0.015

Table 3 Red-throated Diver annual collision estimates with error limits

Avoidance	Mean	Lower	Upper
95.0%	0.355	0.027	0.683
98.0%	0.142	0.011	0.273

¹ NatureScot (2024) Guidance on using an updated collision risk model to assess bird collision risk at onshore wind farms. Available online at: <https://www.nature.scot/doc/guidance-using-updated-collision-risk-model-assess-bird-collision-risk-onshore-wind-farms>

² NatureScot (2025) Wind farm impacts on birds - Use of Avoidance Rates in the NatureScot Wind Farm Collision Risk Model. Available online at: <https://www.nature.scot/doc/wind-farm-impacts-birds-use-avoidance-rates-naturescot-wind-farm-collision-risk-model>

Avoidance	Mean	Lower	Upper
99.0%	0.071	0.005	0.137
99.5%	0.036 (0.025)	0.003 (0.000)	0.068 (0.049)
99.9%	0.014	0.001	0.027

Table 4 White-tailed Eagle annual collision estimates with error limits

Avoidance	Mean	Lower	Upper
95.0%	0.111 (0.90)	0.065 (0.053)	0.156 (0.138)
98.0%	0.044	0.026	0.063
99.0%	0.022	0.013	0.031
99.5%	0.011	0.007	0.016
99.9%	0.002	0.001	0.003

CRM Method

All calculations were undertaken using the revised NatureScot (NS) guidance and collision calculation spreadsheet¹ (with additional weighted calculations). The NS spreadsheet summary pages are in Appendix A.

Data from eight Vantage Points (VPs) were used for the CRM. All VPs were surveyed for at least six hours each month of their survey period. Survey periods differed as three VPs (6, 7 & 8) were added later and there was additional survey effort from VP6 & 7 in 2020 to capture possible diver flights through the Proposed Development. VP 1 to 5 surveys were carried out between March 2019 and February 2021. VP6 was added in August 2019 and continued until July 2021. VP7 was added in May 2020 and continued until April 2022. VP8 did not begin until March 2021 and continued until April 2022. Full details of the VP survey timings and weather conditions are in Confidential Appendix 5D. Table 5 is a summary by month and year.

Table 5 Summary of monthly survey hours by VP and year.

Year	Month	VP							
		1	2	3	4	5	6	7	8
2019	Mar	6	6	6	6	6			
	Apr	6	6	6	6	6			
	May	6	6	6	6	6			
	Jun	6	6	6	6	6			
	Jul	6	6	6	6	6			
	Aug	6	6	6	6	6	6		
	Sep	6	6	6	6	6	6		
	Oct	6	6	6	6	6	6		
	Nov	6	6	6	6	6	6		
	Dec	6	6	6	6	7	6		
	Year	60	60	60	60	61	30		
	Mar-Sept	42	42	42	42	42	12		
2020	Jan	6	6	6	6	6	6		
	Feb	6	6	6	6	6	6		
	Mar	6	6	6	6	6	12		
	Apr	6	6	6	6	6	12		

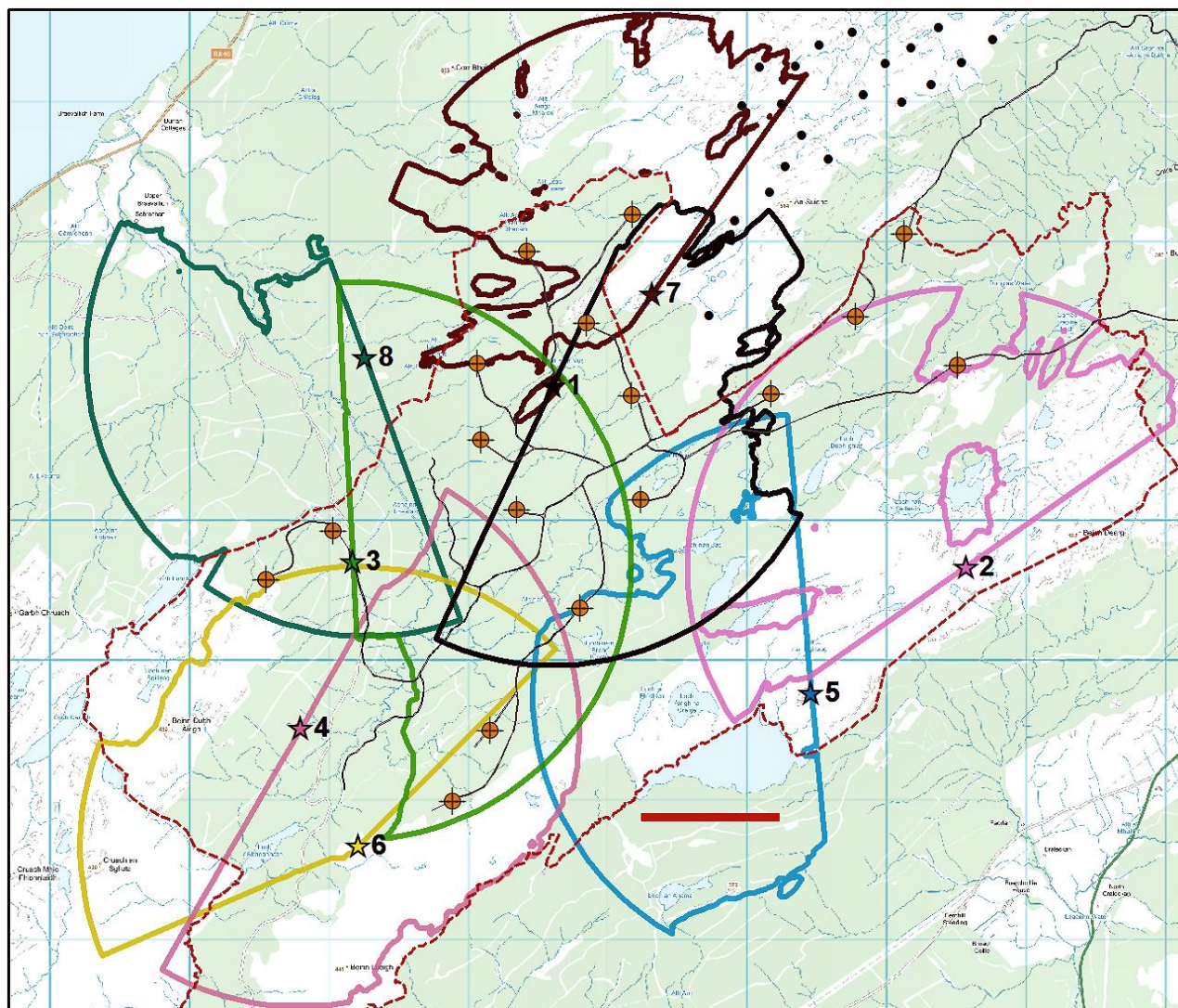
		VP							
Year	Month	1	2	3	4	5	6	7	8
	May	6	6	6	6	6	18	6	
	Jun	6	6	6	6	6	12	12	
	Jul	6	6	6	6	6	12	12	
	Aug	6	6	6	6	6	6	6	
	Sep	6	6	6	6	6	6	6	
	Oct	6	6	6	6	6	6	6	
	Nov	6	6	6	6	6	6	6	
	Dec	6	6	6	6	6	6	6	
	Year	72	72	72	72	72	108	60	
	Mar-Sept	42	42	42	42	42	78	42	
2021	Jan	6	6	6	9	6	6	6	
	Feb	6	6	6	6	6	6	6	
	Mar						6	6	6
	Apr						6	6	6
	May						6	6	6
	Jun						6	6	6
	Jul						6	6	6
	Aug							6	6
	Sep							6	6
	Oct							6	6
	Nov							6	6
	Dec							6	6
	Year	12	12	12	15	12	42	72	60
	Mar-Sept						30	42	42
2022	Jan							6	6
	Feb							6	6
	Mar							6	6
	Apr							6	6
	Year							24	24

View-sheds were clipped to a 500 m buffer around the turbine locations. The areas within each 500 m clipped view-shed are in Table along with the total and seasonal watch times.

Table 6 View-shed areas used in the collision calculations.

VP	Area (km ²)	Survey Time (hrs) All	Survey Time (hrs) Mar-Sept	Survey Time (hrs) Oct-Feb
1	3.27	156	84	72
2	1.38	156	84	72
3	3.85	156	84	72
4	1.70	159	84	75
5	1.01	157	84	73
6	0.85	192	120	72
7	1.82	168	96	72
8	1.15	96	54	42

Figure 1 View-shed survey coverage from eight VPs (coloured stars). Viewsheds are based on a 5m DEM. Also shown is the proposed infrastructure and the An Suidhe turbines (black circles). The horizontal red bar is 1km. Contains Ordnance Survey data © Crown copyright and database right 2020.



Duration of at-risk flight activity

Durations of flights at risk height were calculated from the flight activity data captured during VP surveys in four height bands at 15 second recording intervals. The flight height recording bands were: 1 <40 m; 2 40-140 m; 3 140-200 m; and 4 >200 m.

All flight sections in height bands 2 and 3 were assumed to be collision risk height. Flights in bands 1 and 4 were assumed to not to be risk of a collision (Turbine hub 122.5m, turbine radius 77.5m so lower sweep of turbines is 45m).

A proportional adjustment, based on all flights, was not used to estimate the duration of at-risk flights because flight height depends on topography, stage of flight and purpose of a flight. It cannot be assumed that flight height profiles are constant across a site or time of year.

Species selection

There were sufficient records to undertake CRM for four target species: Golden Eagle; Osprey; Red-throated Diver; and White-tailed Eagle.

No collision calculations were undertaken for Goosander (118 s of risk height flight by five individuals, in three flights, in March and October 2019); Golden Plover (336 s of risk height flight by a single flight of two individuals in August 2020); and Hen Harrier (18 s of risk height flight by three individuals in spring 2019 and 2020).

Ten more target species were recorded during VP surveys but none had flights at potential collision risk height within the Proposed Development.

Breeding and non-breeding seasons

The worked example in the Oct 2024 revised guidance (Annex 10)¹ notes that if the number of watch periods is too few to give reliable month-by-month times in flight, data should be aggregated into two periods: breeding and non-breeding. Data from two years are used to estimate the error in the estimated flight densities.

As the surveys from VPs 1 – 5 ran between March 2019 and February 2021 there were two full sequential breeding seasons recorded from these VPs.

VP6 started towards the end of the 2019 breeding season so 2020 is taken to be the first breeding season while the second uses August and September from 2019 plus March to July 2021. VP6 had two full sequential non-breeding seasons (2019-20 and 2020-21).

VP7 Surveys started in May 2020 and continued to April 2022. 2021 is taken to be the first breeding season while the second uses May to September from 2020 plus March and April 2022. VP7 had two full sequential non-breeding seasons (2020-21 and 2021-22).

VP8 surveys ran between March 2021 and April 2022 giving one full breeding and non-breeding season. These dates were used as Year 1 in the calculations.

Breeding seasons were obtained from a range of sources (Table 8), including the BTO bird facts webpages (<https://www.bto.org/learn/about-birds/birdfacts>), and all are compromises based as actual breeding seasons can vary between years. For these analyses breeding seasons are based on empirical regional field data with the exception of hen harrier which uses the dates suggested in the new collision guidance worked example¹.

Table 8 Breeding and non-breeding seasons for species included in the CRM

Species	Breeding Season	Non-Breeding Season
Golden Eagle	March to September	October to February
Osprey	April to August	Not on site
Red-throated Diver	March to August	Not on site
White-tailed Eagle	March to September	October to February

Values used for all species in the collision calculations

Table 9 includes the wind farm, environmental, and behavioural input variables used for the CRM. Flapping flight has been used in this collision risk modelling; it will give a slightly more precautionary estimate (higher collision estimate).

Table 9 Input variables for CRM

Variable	Input value
Number of Turbines	17
K: 1D or 3D	1
No. Blades	3
Max Chord Width (m)	4.2
Pitch (degrees)	15
Rotor Diameter (m)	155
RPM	9.5
Hub Height (m)	122.5
Array width (km)	5.4
Risk height range (m)	45-200
Flapping (0) or gliding (1)	0
Nocturnal activity (1-5)	1
% at risk	100.0%
% of flights upwind/downwind	50.0%
Latitude (decimal degrees)	56.184
Large Array Correction	No

Species-specific values used in the collision calculations

All biometrics are from Provan and Whitfield (2006)³.

Golden Eagle: 81.5 cm long, 212 cm wing width and a flight speed of 15 m/s.

Red Throated Diver: 61 cm long, 111 cm wing width and a flight speed of 17 m/s.

Osprey: 57 cm long, 157 cm wing width and flight speed of 14 m/s.

White-Tailed Eagle: 80 cm long, 220 cm wing width and flight speed of 12 m/s.

Operational time

The October 2024 revised collision guidance suggests that, if data are available, turbine operational time should be stated monthly to reflect the different proportions of non-operational time at different times of year, for example, reflecting differing wind conditions across the year and increased access for maintenance during the summer.

However, predicting monthly operational periods is an extremely unrealistic expectation. Turbine downtime is inherently unpredictable—both over a project's lifetime and on a month-to-month basis. As precise information

³ Provan, S. and Whitfield, D.P. 2006. Avian Flight Speeds and Biometrics for Use in Collision Risk Modelling. Unpublished Report to Scottish Natural Heritage.

regarding the proportion of time the turbines will be operational is not available; a precautionary proportion of 85 % has been used.

Weighted or unweighted view-shed contributions

The worked example in the revised collision calculation guidance (Annex 10) assumes no significant differences in habitat between vantage point view-sheds, and therefore the contributions from each view-shed are treated as equal, i.e. they are unweighted.

This is not true for this site so two weighted approaches were used: a survey-effort weighted (essentially the 'old' approach) and the new turbine-weighted approach described in the updated guidance. Bird density estimates were consistently greater using the turbine-weighted approach and these estimates were used in preference to the unweighted or survey-effort weighted approaches for all species.

Confidence interval calculations

The new guidance requires that the assessment should convey the uncertainty in the collision risk estimate by adding confidence limits to a 'best estimate'. It is unclear in the worked example how this is done but it can be replicated by back-tracking through the calculations.

A proportional error (0 – 1) is estimated for each of five contributing factors in the collision calculation to arrive at an estimate of the combined uncertainty (E) of the collision estimates. Only the uncertainty in bird density (e1) varies between species; the Golden Eagle uncertainty estimates are shown below as example (Table 10).

Table 10 Contributions to Collision risk uncertainty

Error No.	Source	Turbine Weighted	Survey Effort Weighted
e1	uncertainty in bird density	0.817	0.900
e2	uncertainty in level of nocturnal activity	0.025	0.025
e3	uncertainty in proportion flying at risk height	0.250	0.250
e4	uncertainty in operational time	0.250	0.250
e5	uncertainty due to simplifications in the model	0.200	0.200
E	combined uncertainty	0.913	0.988

- e1 - uncertainty in bird density (e1) is estimated empirically from survey data. A pooled standard deviation is calculated for the combined breeding and non-breeding season estimates (which can vary year-on-year and between seasons). This pooled standard deviation is converted into a confidence interval (CI) by multiplying the pooled standard deviation by 1.96 (as in the guidance notes).
A value similar to the coefficient of variation (CV) is calculated as the ratio of the CI to the pooled mean. The result is a dimensionless unit whose value increases as the magnitude of the CI increases relative to the value of pooled mean. When the CI > pooled mean the CV value is > 1.
However, in the suggested method for calculating the combined uncertainty (E) relative measures of variation (range 0 to 1) are used so the value of e1 is capped at 0.9. This way of estimating e1 has the effect of producing a larger value when there are large differences in bird density between survey years and seasons. A larger value of e1 contributes to a larger value for E and an increased uncertainty in the estimated collision estimate, which reflect in the variability in the use of the area.
- e2 - there is reasonable confidence in the amount of nocturnal activity so this is set at a low value of 0.025;

- e3 - there will always be considerable uncertainty in flight height recording so this is set at 0.25;
- e4 - similarly, there is considerable uncertainty in the operational time so this is also set at 0.25; and
- e5 - the NS worked example applies an uncertainty of 0.20 to simplifications in the model so this is retained.

The estimated mean annual collision rate is multiplied by E to produce an error bound. The lower collision estimate is the collision mean – the error bound whilst the upper collision estimate is the mean + the error bound. These results are shown at the start of this report (Tables 1 – 4).

Results

Table 11 shows the number of seconds of flight at risk height within the wind farm and the view-sheds corrected for the number of individuals in a flight record (i.e. the seconds at risk height multiplied by the number of birds).

Table 11 Total time (s) at risk height, by VP, year & month, for Golden Eagle (EA); Goosander (GD); Golden Plover (GP); Hen Harrier (HH); Osprey (OP), Red-throated Diver (RH); and White-tailed Eagle (WE).

Species	Year	Month	VP								Total
			1	2	3	4	5	6	7	8	
EA	2019	May	284		191	292					767
		Sep			34						34
		Oct		58							58
		Nov		77							77
		Dec					14				14
	2020	Sep				425					425
		Oct			54	347					401
	2021	Feb	19			168		47			234
		Mar								63	63
		Apr							133		133
		May						20			20
GD	2019	Mar	110	9							119
GP	2020	Aug			336						336
HH	2019	Mar				18					18
OP	2019	May				152					152
		Jun		25			7				32
		Aug	65								65
	2020	Jun			52			11			63
		Aug	131		331						462
RH	2019	Mar			79						79
		Apr		97							97
		May	339	7		234					580
		Jun		36							36
		Jul	26			12	26				64
		Aug					34				34
	2020	Mar		27				14			41
		Apr		1							1

			VP								
		May		218							218
		Jul						12			12
WE	2019	Apr				125					125
		May		25							25
	2020	Feb			160						160
		Apr					19				19
		Jun			24						24
		Sep				77					77
		Oct				125					125
	2021	Apr								73	73
		May						7			7

Example calculations using the Golden Eagle data from Table 11. The km² Hr values are calculated as the products of the VP hours and view-shed areas in Tables 12 & 13 use the turbine-weighted method. Tables 14 & 15 use the survey effort weighted method.

Turbine-weighted bird density calculations for Osprey, Red-throated Diver and White-tailed Eagle are in Appendix B.

Turbine-weighted density estimate

Table 12 Turbine-weighted breeding season bird density estimate

Breeding season						
VP	km ² Hr	Flying time (s)	Density (birds/km ²)	Turbines	Weight	Weighted Density
1	137.3	284	0.00057	5	0.294	0.00017
2	58.0	-	0.00000	3	0.176	0.00000
3	161.7	225	0.00039	6	0.353	0.00014
4	71.4	292	0.00114	2	0.118	0.00013
5	42.4	-	0.00000	2	0.118	0.00000
6	35.7	-	0.00000	1	0.059	0.00000
7	76.4	-	0.00000	4	0.235	0.00000
8	48.3	63	0.00036	2	0.118	0.00004
Sum						0.00048
1	137.3	-	0.0000	5	0.294	0.00000
2	58.0	-	0.0000	3	0.176	0.00000

Breeding season						
3	161.7	-	0.0000	6	0.353	0.00000
4	71.4	-	0.0000	2	0.118	0.00000
5	42.4	-	0.0000	2	0.118	0.00000
6	66.3	20	0.0001	1	0.059	<0.00001
7	76.4	133	0.0005	4	0.235	0.00011
8	0.0					
Sum						0.00012
Mean	631.3	1,017	0.0002			0.000300
SD			0.0003			0.000181

Table 13 Turbine-weighted non-breeding season bird density estimate

Non-Breeding season						
VP	km²Hr	Flying time (s)	Density (birds/km²)	Turbines	Weight	Weighted Density
1	98.1	-	0.0000	5	0.294	0.00000
2	41.4	135	0.0009	3	0.176	0.00016
3	113.6	-	0.0000	6	0.353	0.00000
4	51.0	-	0.0000	2	0.118	0.00000
5	30.8	14	0.0001	2	0.118	0.00001
6	25.1	-	0.0000	1	0.059	0.00000
7	54.6	-	0.0000	4	0.235	0.00000
8	34.5	-	0.0000	2	0.118	0.00000
Sum						0.00017
1	98.1	19	0.0001	5	0.294	0.00002
2	41.4	-	0.0000	3	0.176	0.00000
3	115.5	54	0.0001	6	0.353	0.00005
4	56.1	940	0.0047	2	0.118	0.00055
5	30.3	-	0.0000	2	0.118	0.00000
6	25.5	47	0.0005	1	0.059	0.00003
7	54.6	-	0.0000	4	0.235	0.00000
8	0.0					
Sum						0.00064
Mean		1,209	0.0004			0.00041
SD			0.0012			0.00023

Table 14 Survey-effort weighted breeding season bird density estimate

Breeding season						
VP	km ² Hr	Flying time(s)	Density (birds/km ²)	√km ² Hr	Weight	Weighted Density
1	137.3	284	0.0006	11.719	0.171	0.000098
2	58.0	-	0.0000	7.613	0.111	0.000000
3	161.7	225	0.0004	12.716	0.185	0.000072
4	71.4	292	0.0011	8.450	0.123	0.000140
5	42.4	-	0.0000	6.513	0.095	0.000000
6	35.7	-	0.0000	5.975	0.087	0.000000
7	76.4	-	0.0000	8.743	0.127	0.000000
8	48.3	63	0.0004	6.950	0.101	0.000037
Sum						0.000346
1	137.3	-	0.0000	11.719	0.183	0.000000
2	58.0	-	0.0000	7.613	0.119	0.000000
3	161.7	-	0.0000	12.716	0.199	0.000000
4	71.4	-	0.0000	8.450	0.132	0.000000
5	42.4	-	0.0000	6.513	0.102	0.000000
6	66.3	20	0.0001	8.142	0.127	0.000011
7	76.4	133	0.0005	8.743	0.137	0.000066
8	0.0					
Sum						0.000077
Mean	950.5	1,017	0.0002			0.000211
SD			0.0003			0.000190

Table 15 Survey effort weighted non-breeding season bird density estimate

Non-Breeding season						
VP	km ² Hr	Flying time(s)	Density (birds/km ²)	√km ² Hr	Weight	Weighted Density
1	98.1	-	0.0000	9.905	0.171	0.00000
2	41.4	135	0.0009	6.434	0.111	0.00010
3	113.6	-	0.0000	10.657	0.184	0.00000
4	51.0	-	0.0000	7.141	0.123	0.00000
5	30.8	14	0.0001	5.550	0.096	0.00001
6	25.1	-	0.0000	5.007	0.086	0.00000
7	54.6	-	0.0000	7.389	0.127	0.00000
8	34.5	-	0.0000	5.874	0.101	0.00000
Sum						0.00011
1	98.1	19	0.0001	9.905	0.171	0.00001
2	41.4	-	0.0000	6.434	0.111	0.00000
3	115.5	54	0.0001	10.747	0.185	0.00002
4	56.1	940	0.0047	7.490	0.129	0.00060
5	30.3	-	0.0000	5.505	0.095	0.00000
6	25.5	47	0.0005	5.050	0.087	0.00004
7	54.6	-	0.0000	7.389	0.127	0.00000
8	0.0					
Sum				52.519	0.9	0.00068
Mean		1,209	0.0004			0.000396
SD			0.0012			0.00040

APPENDIX A

NS COLLISION SPREADSHEET SUMMARIES

Golden Eagle

Bird data		Value	Units	Windfarm data		Value	Units	Turbine data		Value	Units						
Species name		Golden Eagle		Site name		Eredine		Model		Generic							
Bird Length		L	0.815 m	Latitude		56.184 degrees		Hub height		122.5	m						
Wingspan		W	2.12 m	No of turbines		17		Rotor radius		77.5	R	m					
Bird flight speed		v	15 m s ⁻¹	Width of windfarm		3 km		No of blades		3	b						
Flight type, flapping or gliding			0					Rotation speed		9.5	Ω	rpm					
% of flights upwind/downwind			50.0%	50.0%					Max blade width		4.2	C	m				
Nocturnal activity rank 1-5			1					Blade pitch		15	λ	degrees					
Nocturnal activity rank 1-6		f _{night}	0%					Risk height range		45 - 200		m					
Stage A					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Daytime bird density		D _A	birds/km ²		0.000407	0.000407	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.000407	0.000407	0.000407	
Proportion at rotor risk height		Q _{2R}	100.00%														
At latitude 56.184			Daylight hours per month		236.6	266.4	365.5	425.0	505.7	526.3	527.5	468.8	384.9	324.8	249.1	218.2	4498.7
			Nightime hours per month		507.4	405.6	378.5	295.0	238.3	193.7	216.5	275.2	335.1	419.2	470.9	525.8	4261.3
Stage B																	
No of Turbines		T	17														
Rotor radius		R	78 m														
			Total rotor frontal area m ²	320,776													
Nocturnal activity factor		f _{night}	0%														
Bird flight speed		v	15 m s ⁻¹		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year total
			Projected number of transits		10.8	12.1	12.3	14.3	17.0	17.7	17.7	15.7	12.9	14.8	11.3	9.9	166
Stage C																	
No of blades		b	3		Bird Length		L	0.815 m									
Rotation speed		Ω	9.5 rpm		Wingspan		W	2.12 m									
Rotor radius		R	77.5 m		Bird flight speed		v	15 m s ⁻¹									
Max blade width		C	4.2 m		Flight type			0									
Pitch		λ	15 degrees	% of flights upwind/downwind				50.0%	50.0%								
Blade profile			See Blade profile sheet														
			Single transit risk	upwind	8.4%												
				downwind	4.8%												
				weighted mean	6.6%												
Stage D					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year average
Prop time operating		Q _{op}			85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
					Collision rates before avoidance												Year total
					0.60	0.68	0.69	0.80	0.95	0.99	0.99	0.88	0.72	0.83	0.64	0.56	9.33
Stage E																	
Allow for Large array correction		0.9999	No														
Width of windfarm		w	3 km														
			large array correction		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Per Year
Avoidance rates modelled			95.0%	100.0%	0.030	0.034	0.034	0.040	0.048	0.049	0.050	0.044	0.036	0.041	0.032	0.028	0.466
			98.0%	100.0%	0.012	0.014	0.014	0.016	0.019	0.020	0.020	0.018	0.014	0.017	0.013	0.011	0.187
			99.0%	100.0%	0.006	0.007	0.007	0.008	0.010	0.010	0.010	0.009	0.007	0.008	0.006	0.006	0.093
			99.5%	100.0%	0.003	0.003	0.003	0.004	0.005	0.005	0.005	0.004	0.004	0.004	0.003	0.003	0.047
			99.9%	100.0%	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.009

Bird data			Value	Units	Windfarm data		Value	Units	
Species name			Golden Eagle		Site name		Eredine		
Bird Length	L		0.815 m		Latitude		56.184 degrees		
Wingspan	W		2.12 m		No of turbines		17		
Bird flight speed	v		15 m s ⁻¹		Width of windfarm		3 km		
Flight type, flapping or gliding			0						
% of flights upwind/downwind			50.0%	50.0%					
Nocturnal activity rank 1-5			1						
Nocturnal activity rank 1-6			f _{night}	0%					
Stage A					Jan	Feb	Mar	Apr	May
Daytime bird density	D _A		birds/km ²		0.000407	0.000407	0.0003	0.0003	0.0003
Proportion at rotor risk height	Q _{2R}		100.00%						
At latitude 56.184			Daylight hours per month		236.6	266.4	365.5	425.0	505.7
			Nighttime hours per month		507.4	405.6	378.5	295.0	238.3
Stage B									
No of Turbines	T		17						
Rotor radius	R		78 m						
			Total rotor frontal area m ²		320,776				
Nocturnal activity factor	f _{night}		0%						
Bird flight speed	v		15 m s ⁻¹		Jan	Feb	Mar	Apr	May
			Projected number of transits		10.8	12.1	12.3	14.3	17.0
Stage C									
No of blades	b		3		Bird Length		L	0.815 m	
Rotation speed	Ω		9.5 rpm		Wingspan		W	2.12 m	
Rotor radius	R		77.5 m		Bird flight speed		v	15 m s ⁻¹	
Max blade width	C		4.2 m		Flight type			0	
Pitch	λ		15 degrees		% of flights upwind/downwind			50.0%	50.0%
Blade profile			See Blade profile sheet						
			Single transit risk		upwind	8.4%			
					downwind	4.8%			
					weighted mean	6.6%			
Stage D					Jan	Feb	Mar	Apr	May
Prop time operating	Q _{op}				85.0%	85.0%	85.0%	85.0%	85.0%
					Collision rates before avoidance				
					0.60	0.68	0.69	0.80	0.95
Stage E									
Allow for Large array corrector	0.9999	No							
Width of windfarm	w		3 km						
			large array correction		Jan	Feb	Mar	Apr	May
					Collision rates allowing for avoidance				
Avoidance rates modelled			95.0%	100.0%	0.030	0.034	0.034	0.040	0.048
			98.0%	100.0%	0.012	0.014	0.014	0.016	0.019
			99.0%	100.0%	0.006	0.007	0.007	0.008	0.010
			99.5%	100.0%	0.003	0.003	0.003	0.004	0.005
			99.9%	100.0%	0.001	0.001	0.001	0.001	0.001

[illegible]

Osprey

Bird data		Value	Units	Windfarm data		Value	Units	Turbine data		Value	Units						
Species name		Osprey		Site name		Eredine		Model		Generic							
Bird Length	L	0.57	m	Latitude		56.184 degrees		Hub height		122.5	m						
Wingspan	W	1.58	m	No of turbines		17		Rotor radius		77.5	R	m					
Bird flight speed	v	14	m s ⁻¹	Width of windfarm		3 km		No of blades		3	b						
Flight type, flapping or gliding		0						Rotation speed		9.5	Ω	rpm					
% of flights upwind/downwind		50.0%	50.0%					Max blade width		4.2	C	m					
Nocturnal activity rank 1-5		1						Blade pitch		15	λ	degrees					
Nocturnal activity rank 1-6	f _{night}	0%						Risk height range		45 - 200		m					
Stage A				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Daytime bird density	D _A		birds/km ²	0	0	0	0.000314	0.000314	0.000314	0.000314	0.000314	0	0	0	0		
Proportion at rotor risk height	Q _{2R}	100.00%															
At latitude 56.184		Daylight hours per month		236.6	266.4	365.5	425.0	505.7	526.3	527.5	468.8	384.9	324.8	249.1	218.2	4498.7	
		Nighttime hours per month		507.4	405.6	378.5	295.0	238.3	193.7	216.5	275.2	335.1	419.2	470.9	525.8	4261.3	
Stage B																	
No of Turbines	T	17															
Rotor radius	R	78	m														
		Total rotor frontal area m ²	320,776														
Nocturnal activity factor	f _{night}	0%															
Bird flight speed	v	14	m s ⁻¹														
		Projected number of transits		-	-	-	13.9	16.6	17.3	17.3	15.4	-	-	-	-	80	
Stage C																	
No of blades	b	3															
Rotation speed	Ω	9.5	rpm														
Rotor radius	R	77.5	m														
Max blade width	C	4.2	m														
Pitch	λ	15	degrees														
Blade profile		See Blade profile sheet															
		Single transit risk		upwind	7.7%												
				downwind	3.9%												
		weighted mean			5.8%												
Stage D				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year average	
Prop time operating	Q _{op}			0.0%	0.0%	0.0%	85.0%	85.0%	85.0%	85.0%	85.0%	0.0%	0.0%	0.0%	0.0%	35.4%	
				Collision rates before avoidance												Year total	
				0.00	0.00	0.00	0.69	0.82	0.85	0.85	0.76	0.00	0.00	0.00	0.00	3.97	
Stage E																	
Allow for Large array correction?	1.0000	No															
Width of windfarm	w	3	km														
		large array correction		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Per Year	
				Collision rates allowing for avoidance													
Avoidance rates modelled		95.0%	100.0%	0.0000	0.0000	0.0000	0.0344	0.0409	0.0426	0.0426	0.0379	0.0000	0.0000	0.0000	0.0000	0.198	
		98.0%	100.0%	0.0000	0.0000	0.0000	0.0137	0.0164	0.0170	0.0171	0.0152	0.0000	0.0000	0.0000	0.0000	0.079	
		99.0%	100.0%	0.0000	0.0000	0.0000	0.0069	0.0082	0.0085	0.0085	0.0076	0.0000	0.0000	0.0000	0.0000	0.040	
		99.5%	100.0%	0.0000	0.0000	0.0000	0.0034	0.0041	0.0043	0.0043	0.0038	0.0000	0.0000	0.0000	0.0000	0.020	
		99.8%	100.0%	0.0000	0.0000	0.0000	0.0014	0.0016	0.0017	0.0017	0.0015	0.0000	0.0000	0.0000	0.0000	0.008	

Red-throated Diver

Bird data			Value	Units	Windfarm data			Value	Units	Turbine data				Value	Units				
	Species name		Red throated diver				Site name	Eredine			Model	Generic							
	Bird Length	L	0.61	m			Latitude	56.184	degrees		Hub height	122.5		m					
	Wingspan	W	1.1	m			No of turbines	17			Rotor radius	77.5		R	m				
	Bird flight speed	v	17	m s ⁻¹			Width of windfarm	3	km		No of blades	3		b					
	Flight type, flapping or gliding		0								Rotation speed	9.5		Ω	rpm				
	% of flights upwind/downwind		50.0%	50.0%							Max blade width	4.2		C	m				
	Nocturnal activity rank 1-5		1								Blade pitch	15		λ	degrees				
	Nocturnal activity rank 1-6	f _{night}	0%								Risk height range	45 - 200			m				
Stage A							Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	Daytime bird density	D _A		birds/km ²			0	0	0.000445	0.000445	0.000445	0.000445	0.000445	0.000445	0	0	0	0	
	Proportion at rotor risk height	Q _{2R}	100.00%																
	At latitude 56.184		Daylight hours per month				236.6	266.4	365.5	425.0	505.7	526.3	527.5	468.8	384.9	324.8	249.1	218.2	
			Nighttime hours per month				507.4	405.6	378.5	295.0	238.3	193.7	216.5	275.2	335.1	419.2	470.9	525.8	
Stage B																			
	No of Turbines	T	17																
	Rotor radius	R	78	m															
			Total rotor frontal area m ²		320,776														
	Nocturnal activity factor	f _{night}	0%																
	Bird flight speed	v	17	m s ⁻¹			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
			Projected number of transits				-	-	20.6	23.9	28.5	29.6	29.7	26.4	-	-	-	-	
																		Year total	
																		159	
Stage C																			
	No of blades	b	3						Bird Length	L	0.61	m							
	Rotation speed	Ω	9.5	rpm					Wingspan	W	1.1	m							
	Rotor radius	R	77.5	m					Bird flight speed	v	17	m s ⁻¹							
	Max blade width	C	4.2	m					Flight type		0								
	Pitch	λ	15	degrees					% of flights upwind/downwind		50.0%	50.0%							
	Blade profile		See Blade profile sheet																
			Single transit risk		upwind	6.9%													
					downwind	3.7%													
					weighted mean	5.3%													
Stage D							Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	Prop time operating	Q _{op}					0.0%	0.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	0.0%	0.0%	0.0%	0.0%	
							Collision rates before avoidance												Year total
							0.00	0.00	0.92	1.07	1.27	1.33	1.33	1.18	0.00	0.00	0.00	0.00	
																		7.11	
Stage E																			
	Allow for Large array correction:	1.0000	No																
	Width of windfarm	w	3	km															
			large array				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
			correction				Collision rates allowing for avoidance												Per Year
	Avoidance rates modelled		95.0%	100.0%			0.0000	0.0000	0.0461	0.0536	0.0637	0.0663	0.0665	0.0591	0.0000	0.0000	0.0000	0.0000	
			98.0%	100.0%			0.0000	0.0000	0.0184	0.0214	0.0255	0.0265	0.0266	0.0236	0.0000	0.0000	0.0000	0.0000	
			99.0%	100.0%			0.0000	0.0000	0.0092	0.0107	0.0127	0.0133	0.0133	0.0118	0.0000	0.0000	0.0000	0.0000	
			99.5%	100.0%			0.0000	0.0000	0.0046	0.0054	0.0064	0.0066	0.0066	0.0059	0.0000	0.0000	0.0000	0.0000	
			99.8%	100.0%			0.0000	0.0000	0.0018	0.0021	0.0025	0.0027	0.0027	0.0024	0.0000	0.0000	0.0000	0.0000	

White-tailed Eagle

Bird data			Value	Units	Windfarm data			Value	Units	Turbine data			Value	Units				
	Species name		White-tailed Eagle			Site name		Eredine		Model		Generic						
	Bird Length	L	0.8 m			Latitude		56.184 degrees		Hub height		122.5		m				
	Wingspan	W	2.2 m			No of turbines		17		Rotor radius		77.5	R	m				
	Bird flight speed	v	12 m s ⁻¹			Width of windfarm		3 km		No of blades		3	b					
	Flight type, flapping or gliding		0							Rotation speed		9.2	Ω	rpm				
	% of flights upwind/downwind		50.0%	50.0%						Max blade width		4.2	C	m				
	Nocturnal activity rank 1-5		1							Blade pitch		15	λ	degrees				
	Nocturnal activity rank 1-6	f _{night}	0%							Risk height range		45 - 200		m				
Stage A						Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	Daytime bird density	D _A		birds/km ²		0.000136	0.000136	0.000071	0.000071	0.000071	0.000071	0.000071	0.000071	0.000071	0.000136	0.000136	0.000136	
	Proportion at rotor risk height	Q _{2R}	100.00%															
	At latitude 56.184		Daylight hours per month			236.6	266.4	365.5	425.0	505.7	526.3	527.5	468.8	384.9	324.8	249.1	218.2	4498.7
			Nighttime hours per month			507.4	405.6	378.5	295.0	238.3	193.7	216.5	275.2	335.1	419.2	470.9	525.8	4261.3
Stage B																		
	No of Turbines	T	17															
	Rotor radius	R	78 m															
			Total rotor frontal area m ²		320,776													
	Nocturnal activity factor	f _{night}	0%															
	Bird flight speed	v	12 m s ⁻¹			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year total
			Projected number of transits			2.9	3.2	2.3	2.7	3.2	3.4	3.4	3.0	2.5	4.0	3.0	2.7	36
Stage C																		
	No of blades	b	3															
	Rotation speed	Ω	9.2 rpm															
	Rotor radius	R	77.5 m															
	Max blade width	C	4.2 m															
	Pitch	λ	15 degrees		% of flights upwind/downwind													
	Blade profile		See Blade profile sheet															
			Single transit risk		upwind	9.2%												
					downwind	5.1%												
					weighted mean	7.2%												
Stage D						Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year average
	Prop time operating	Q _{op}				85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
			Collision rates before avoidance															Year total
						0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	2.21
Stage E																		
	Allow for Large array correction?	0.9996	No															
	Width of windfarm	w	3 km															
			large array correction			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Per Year
	Avoidance rates modelled		95.0%	100.0%		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.111
			98.0%	100.0%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.044
			99.0%	100.0%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.022
			99.5%	100.0%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.011
			99.9%	100.0%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.002

APPENDIX B

TURBINE-WEIGHTED BIRD DENSITY CALCULATIONS

Table B.1 Osprey: turbine-weighted breeding season bird density estimate

Breeding season						
VP	km ² Hr	Flying time (s)	Density (birds/km ²)	Turbines	Weight	Weighted Density
1	98.1	65	0.00018	5	0.294	0.00005
2	41.4	25	0.00017	3	0.176	0.00003
3	115.5	-	0.00000	6	0.353	0.00000
4	51.0	152	0.00083	2	0.118	0.00010
5	30.3	7	0.00006	2	0.118	0.00001
6	51.0	-	0.00000	1	0.059	0.00000
7	76.4	-	0.00000	4	0.235	0.00000
8	34.5	-	0.00000	2	0.118	0.00000
Sum						0.00019
1	98.1	131	0.0004	5	0.294	0.00011
2	41.4	-	0.0000	3	0.176	0.00000
3	115.5	383	0.0009	6	0.353	0.00033
4	51.0	-	0.0000	2	0.118	0.00000
5	30.3	-	0.0000	2	0.118	0.00000
6	30.6	11	0.0001	1	0.059	0.00001
7	54.6	-	0.0000	4	0.235	0.00000
8		-				0.00000
Sum						0.00044
Mean	498.2	774	0.0002			0.000314
sd			0.0003			0.000126

Table B.2 Red-throated Diver: turbine-weighted breeding season bird density estimate

Breeding season						
VP	km ² Hr	Flying time (s)	Density (birds/km ²)	Turbines	Weight	Weighted Density
1	117.7	365	0.00086	5	0.294	0.00025
2	49.7	140	0.00078	3	0.176	0.00014
3	138.6	79	0.00016	6	0.353	0.00006
4	61.2	246	0.00112	2	0.118	0.00013
5	36.4	60	0.00046	2	0.118	0.00005
6	61.2	-	0.00000	1	0.059	0.00000
7	65.5	-	0.00000	4	0.235	0.00000
8	41.4	-	0.00000	2	0.118	0.00000
Sum						0.00063
1	117.7	-	0.0000	5	0.294	0.00000
2	49.7	246	0.0014	3	0.176	0.00024
3	138.6	-	0.0000	6	0.353	0.00000
4	61.2	-	0.0000	2	0.118	0.00000
5	36.4	-	0.0000	2	0.118	0.00000
6	30.6	26	0.0002	1	0.059	0.00001
7	87.4	-	0.0000	4	0.235	0.00000
8						
Sum						0.00026
Mean	571.7	1,162	0.0003			0.000445
sd			0.0005			0.000188

Table B.3 White-tailed Eagle: turbine-weighted breeding season bird density estimate

Breeding season						
VP	km ² Hr	Flying time (s)	Density (birds/km ²)	Turbines	Weight	Weighted Density
1	137.3	-	0.00000	5	0.294	0.00000
2	58.0	25	0.00012	3	0.176	0.00002
3	161.7	-	0.00000	6	0.353	0.00000
4	71.4	125	0.00049	2	0.118	0.00006
5	42.4	-	0.00000	2	0.118	0.00000
6	35.7	-	0.00000	1	0.059	0.00000
7	76.4	-	0.00000	4	0.235	0.00000
8	48.3	-	0.00000	2	0.118	0.00000
Sum						0.00008
1	137.3	-	0.0000	5	0.294	0.00000
2	58.0	-	0.0000	3	0.176	0.00000
3	161.7	24	0.0000	6	0.353	0.00001
4	71.4	77	0.0003	2	0.118	0.00004
5	42.4	19	0.0001	2	0.118	0.00001
6	66.3	-	0.0000	1	0.059	0.00000
7	76.4	-	0.0000	4	0.235	0.00000
8						
Sum						0.00006
Mean	631.3	270	0.0001			0.000071
sd			0.0001			0.000007

Table B.4 White-tailed Eagle: turbine-weighted non-breeding season bird density estimate

Non-Breeding season						
VP	km ² Hr	Flying time (s)	Density (birds/km ²)	Turbines	Weight	Weighted Density
1	98.1	-	0.0000	5	0.294	0.00000
2	41.4	-	0.0000	3	0.176	0.00000
3	113.6	160	0.0004	6	0.353	0.00014
4	51.0	-	0.0000	2	0.118	0.00000
5	30.8	-	0.0000	2	0.118	0.00000
6	25.1	-	0.0000	1	0.059	0.00000
7	54.6	-	0.0000	4	0.235	0.00000
8	34.5	-	0.0000	2	0.118	0.00000
Sum						0.000138
1	98.1	-	0.0000	5	0.294	0.00000
2	41.4	-	0.0000	3	0.176	0.00000
3	115.5	-	0.0000	6	0.353	0.00000
4	56.1	-	0.0000	2	0.118	0.00000
5	30.3	125	0.0011	2	0.118	0.00013
6	25.5	-	0.0000	1	0.059	0.00000
7	54.6	-	0.0000	4	0.235	0.00000
8						
Sum						0.0001
Mean	449.1	285	0.0001			0.000136
sd			0.0003			0.000002