TECHNICAL APPENDIX 9.3: AVIAN COLLISION RISK ASSESSMENT

Balmeanach Wind Farm

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TABLES

ANNEXES

1.0 Introduction

This report presents the results of Collision Risk Modelling (CRM) undertaken for four bird species to inform an assessment of potential ornithological impacts relating to the Proposed Development comprising ten turbines.

Modelling was based on the use of turbines with a rotor diameter of 138m, tip height of 149.9m (rounded up to 150m) and hub height of 80.9m (rounded up to 81m).

The CRM was undertaken in accordance with current NatureScot (NS) (formerly Scottish Natural Heritage (SNH)) guidance (SNH 2000[1]), which is recognised as standard best practice guidance through the UK and Ireland to inform impact assessment for onshore wind farms. Further details regarding the methodology used, including details of assumptions used and any corrections applied, are provided in Section 2. The monitoring results are presented in **Section 3** and copies of the modelling calculations for each species modelled are included in **Annexes 9.3A** and **9.3B**.

Species summary accounts are presented in **Section 3** of the report.

1.1 Primary Target Species

Target species for the surveys were defined by legal and/or conservation status and vulnerability to impacts caused by wind turbines, as defined in NS Guidance (SNH 2017[2]).

Bird species of high conservation importance are those which are Annex I and Schedule 1 species and other species of high conservation importance which are considered to be vulnerable to impacts from wind farm developments.

The following species are therefore considered relevant as primary target species:

- Annex I raptor and owl species*;*
- Breeding and migratory wildfowl; and
- Breeding and migratory waders.

[1] Scottish Natural Heritage (SNH) (2000). Windfarms and Birds: Calculating a theoretical collision risk assuming no avoiding action.
[2] SNH (2017). *Recommended Bird Survey Methods to Inform Impact Assessment of Onshore Wind Farms. Version 2.*

2.0 Methods

The standard Band CRM (Band *et. al.* 2007[3]) was used to estimate collision risk based on recorded target species activity levels and flight behaviour, proposed turbine numbers and specifications, and the relevant species biometrics and flight characteristics. Modelling collision risk under the Band CRM is a two-stage process. Stage 1 estimates the number of birds that fly through the rotor swept disc. Stage 2 predicts the proportion of these birds that have the potential to be hit by a rotor blade. Combining both stages produces an estimate of collision mortality in the absence of any avoidance action/behaviour by birds. Avoidance rates are then applied to generate predicted rates of collision mortality.

2.1 Prediction of Rotor Transits from Vantage Point Survey Data

2.1.1 Balmeanach Survey Data 2020 to 2022

The number of birds that fly through the rotor swept area was estimated using flight data gathered during baseline surveys carried out during February 2020 to March 2021, and October 2021 to September 2022.

The surveys gathered data from two vantage points (VPs) as shown on **Figure 9.1.2a**. The total number of hours are as shown in **Table 2-1**.

Table 2-1: VP Surveys undertaken at Balmeanach, May 2020 – Mar 2022

VP Number	Grid Coordinates (x,y)	Hours of Survey Completed (hrs:mins)				
		Feb 2020-Aug 2020	Sep 2020-Mar 2021	Oct 2021-Mar 2022	Apr 2022-Sep 2022	Total
1	132812, 846199	73:00	42:00	36.00	36:00	187:00
2	133650, 846913	69:00	42:00	36:00	36:00	183:00

2.1.2 Ben Sca Survey Data 2018 to 2019

Due to changes in the turbine layout extents through design evolution (see **Chapter 2: Site Selection and Design Evolution**), the viewsheds for Balmeanach surveys do not fully cover the northern part of the site, where proposed Turbines 1 and 2 would be located. Data are available from surveys undertaken for the adjacent consented Ben Sca Wind Farm from 2018 to 2019, the viewsheds of which cover the area in which proposed Turbines 1 & 2 would be located (**Figure 9.1.2b)**. A separate CRM for these two turbines has been undertaken (Section 3.2), for context. Note that the outputs from this separate CRM have not been added to the Balmeanach outputs, as the survey data used are from different years and are not directly comparable.

2.1.3 Viewshed Data

Viewshed data, i.e., the area visible from each VP within the wind farm polygon (WP)[4], are summarised in **Table 2-2**. The combined viewshed area (minus overlap) from VP1 & VP2 (3,485,957m²) represents 68.1% of the survey WP (5,122,253m²).

[3] Band, W., Madders, M. and Whitfield, D.P. (2007) Developing Field and Analytical Methods to Assess Avian Collision Risk at Wind Farms. In: De Lucas, M., Janss, G. and Ferrer, M., Eds., Birds and Wind Power, Quercus Editions, Madrid, 259-275.
[4] The survey wind farm polygon (WP) includes the area within 500m of the outermost turbine blades.

Table 2-2: Balmeanach VP Viewshed Data

VP/ Viewshed Number	Area of visibility (m²)*
VP 1 viewshed	1,839,264
VP 2 viewshed	2,693,820
VP 1+2 viewshed combined (minus overlap)	3,485,957
	* area calculated in GIS using offset of 15m above ground level

As noted above, the gap in the Balmeanach viewshed coverage around proposed Turbines 1 and 2 is covered by Ben Sca VPs viewsheds. A separate survey WP created for proposed Turbines 1 and 2 amounts to 1,467,113m², of which the Ben Sca viewsheds cover 1,182,234m² (80.5%).

2.1.4 Flight Selection for CRM

In order to select flights liable to incur a potential risk of collision, i.e., within the areas occupied by proposed turbines, the CRM used only observations collected within the WP – defined by a 500m buffer around the proposed outermost turbine locations. The size of buffer takes into account rotor blade length and potential spatial errors in flight recording accuracy. It is known that bird detection rates vary between species. To ensure the CRM used robust measures of flight activity, a 2km distance truncation was used in the viewshed from each VP, i.e., only flights within 2km of each VP were included (as per NS guidance).

Analysis in MS Excel and GIS identified those flights that were at Potential Collision Height (PCH) and within the WP. Flight times that were used in the CRM were derived from field data for each flight. Time spent at different flight heights was estimated in a database from interval data for flights that entered the WP. Flying time estimated to occur within the survey recording height bands (see Section 3.1.5) was used to determine the period that target species were at risk of collision with the rotors.

2.1.5 Correcting Survey PCH to Actual PCH

Baseline VP surveys were initiated before the current candidate turbine details were known. The baseline surveys utilised the following height bands:

- 1 = <30m
- 2 = 30-150m
- 3 = >150m

As such, the height bands used to record flight activity do not correspond precisely to PCH for the Proposed Development (12-150m[5]), i.e., height band 1 overlaps with the lower limit of the actual PCH (12-30m of the 0-30m band).

Because of this it was necessary to make assumptions about the distribution of some of the flight heights recorded. Assuming an equal distribution of heights within all height bands, it is assumed that a proportion of the flights within height band 1 will be below risk height. Therefore, the model accounts for this by adjusting the proportion of flights included by rotor diameter/ survey risk height (138/150 (92.0%)).

[5] Using the turbine data in Table 2-4: and rounded to nearest whole number

2.1.6 Seasonal Definitions

CRMs were constructed using data based on the survey design (February 2020 to March 2021 and October 2021 to September 2022) and taking into account the relevant species breeding season periods, i.e., February – August 2020 (breeding season 2020), September 2020 – March 2021 (non-breeding season 2020/21); October 2021 – March 2022 (non-breeding season 2021/22) and April – September 2022 (breeding season 2022).

The theoretical time that birds could be active with potential for turbine collisions was assumed to be the period between sunrise and sunset within each survey period using the latitude of the site[6].

For waders (i.e., golden plover), which could be active nocturnally, an additional 25% of nocturnal hours were added to the daylight hours to give a more accurate representation of the available hours for this species (as per Band *et al.*, 2007).

2.1.7 Undertaking CRM

Collision risk modelling employs an estimated three-dimensional risk volume, in keeping with the assumption that flight directions are random in space. For species with non-directional (e.g., random, circling and foraging) flights, the occupancy data are derived by multiplying the numbers of a particular species flying through the survey risk area by the total time spent.

The following parameters were entered into a bespoke modelling spreadsheet:-

- the total observation effort within the risk volume (V_w) visible from each VP;
- the occupancy total: the total time spent by a particular species flying within the risk volume (V_w) visible from each VP;
- the volume of Vw (m^3) visible from each VP (this is area covered by the outermost turbines without the 500m buffer);
- an estimation of average daylight hours within the season of analysis;
- species-specific bird parameters (**Table 2-3**:); and
- wind farm parameters (**Table 2-4**:).

The NS CRM spreadsheet[7] calculates the probability of collision for each particular species. The model then combines this probability of collision with the observed flight activity per unit area (hours per hectare) weighted for observation effort from each VP to produce an estimate of the number of transits through the rotor blades. Mortality estimates are then derived by applying species-specific avoidance rates.

2.1.8 Bird Biometrics and Avoidance Rates

Measurements and flight speeds of the species for which CRM was undertaken were derived from British Trust for Ornithology (BTO)[8], Provan & Whitfield (2007[9]), Bruderer & Boldt (2001[10]) and Alerstram *et al.* (2007[11]). The

[6] https://www.timeanddate.com [Accessed in September 2022].
[7] https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision [Accessed in September 2022].
[8] https://www.bto.org/understanding-birds/birdfacts [Accessed in September 2022].
[9] Provan, S. and Whitfield, D.P. (2007) Avian flight speeds and biometrics for use in collision risk modelling. Report to Scottish Natural Heritage.
[10] Bruderer, B. and Bolt, A. (2001) Flight characteristics of birds: 1. Radar measurements of speeds, *Ibis*, **143**. 178 – 204.
[11] Alerstam T, Rosén M, Bäckman J, Ericson PG, Hellgren O. (2007). Flight speeds among bird species: allometric and phylogenetic effects. PLoS Biol.

avoidance rates for these species are taken from NS (2018[12]). Although the default 95% avoidance rate is used here, further information on white-tailed eagle and avoidance rates is provided in **Technical Appendix 9.4**.

Table 2-3: Bird biometrics and avoidance rates used in CRM

Species name	Bird length (m)	Wingspan (m)	Flight speed (m/s)	Avoidance rate (%)
White-tailed eagle	0.8	2.2	13.0	95
Golden eagle	0.82	2.1	15.0	99
Hen harrier	0.48	1.1	12.0	99
Golden plover	0.28	0.72	17.5	98

2.1.9 Wind Farm and Turbine Parameters

The wind turbine parameters used in the CRM are detailed in **Table 2-4**: and are based on the information provided by the Applicant for the purposes of assessment (note: in terms of rotor diameter this is the maximum dimension and is worst case scenario).

Table 2-4: Wind Farm and Turbine Parameters

Parameter	Value
Size of survey wind farm polygon (WP)	512.2 ha
Number of turbines	10
Rotor radius/ diameter	69.0m/ 138.0m
Hub height	80.9m*
Max. chord	4.3m
Pitch	6°
Rotation period	4.29s (max 13.99rpm)
Turbine operation time	90%

* rounded up to 81m

2.2 Balmeanach Flightline Data

Table 2-5: summarises the primary target species flightline data from VP surveys conducted, presented for each season. **Table 2-6**: to **Table 2-9**: (inclusive) present the seasonal primary target species occupancy data within each height band, and the total at-risk occupancy data used in the CRM.

[12] SNH (2018) Avoidance rates for the onshore SNH wind farm collision risk model. https://www.nature.scot/doc/wind-farm-impacts-birds-use-avoidance-rates-naturescot-wind-farm-collision-risk-model#:~:text=2.%20Recommended%20avoidance%20rates%20%20%20Species%20,%20SNH%20%282013%29%20%207%20more%20rows%20. [Accessed in September 2022].

Table 2-5: Number of target species flights and individuals observed passing through the Balmeanach WP during VP surveys (2020 to 2022)

Species name	Period of analysis	Total number of birds recorded in flight	Flights through WP		Flights through WP at Potential Collision Height (PCH)	
			Flights	Individuals	Flights	Individuals
White-tailed eagle	Feb-20 to Aug-20	39	20	22	18	20
	Sep-20 to Mar-21	11	9	9	9	9
	Oct-21 to Mar-22	6	5	5	5	5
	Apr-22 to Sep-22	6	4	4	4	4
Golden eagle	Feb-20 to Aug-20	21	5	6	5	6
	Sep-20 to Mar-21	5	4	4	4	4
	Oct-21 to Mar-22	8	6	6	6	6
	Apr-22 to Sep-22	12	8	9	4	4
Hen harrier	Feb-20 to Aug-20	2	2	2	2	2
	Sep-20 to Mar-21	1	1	1	1	1
	Apr-22 to Sep-22	8	5	5	5	5
Golden plover	Feb-20 to Aug-20	64	6	64	6	64
	Sep-20 to Mar-21	20	5	20	5	20
	Oct-21 to Mar-22	74	4	74	4	74
	Apr-22 to Sep-22	3	3	3	3	3

Table 2-6: Details of White-tailed Eagle Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)			
					<30m	30-150m	>150m	At risk
Feb-20 to Aug-20	VP1	7	7	1543	401	488	654	889
	VP2	12	14	2153	670	495	988	1165
Sep-20 to Mar-21	VP1	8	8	2288	858	789	641	1647
	VP2	1	1	147	102	45	0	147
Oct-21 to Mar-22	VP1	1	1	128	0	128	0	128
	VP2	4	4	862	457	330	75	787

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)			
					<30m	30-150m	>150m	At risk
Apr-22 to Sep-22	VP1	0	0	0	0	0	0	0
	VP2	4	4	1200	137	688	375	825
Total		**37**	**39**	**8321**	**2625**	**2963**	**2733**	**5588**

Table 2-7: Details of Golden Eagle Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)			
					<30m	30-150m	>150m	At risk
Feb-20 to Aug-20	VP1	0	0	0	0	0	0	0
	VP2	5	6	475	285	90	100	375
Sep-20 to Mar-21	VP1	0	0	0	0	0	0	0
	VP2	4	4	837	402	360	75	762
Oct-21 to Mar-22	VP1	2	2	180	61	119	0	180
	VP2	4	4	336	129	207	0	336
Apr-22 to Sep-22	VP1	5	6	1522	256	378	888	634
	VP2	3	3	766	319	297	150	616
Total		**23**	**25**	**4116**	**1452**	**1451**	**1213**	**2903**

Table 2-8: Details of Hen Harrier Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)			
					<30m	30-150m	>150m	At risk
Feb-20 to Aug-20	VP1	1	1	119	119	0	0	119
	VP2	1	1	15	15	0	0	15
Sep-20 to Mar-21	VP1	1	1	51	51	0	0	51
	VP2	0	0	0	0	0	0	0
Oct-21 to Mar-22	VP1	0	0	0	0	0	0	0
	VP2	0	0	0	0	0	0	0
Apr-22 to Sep-22	VP1	5	5	777	777	0	0	777
	VP2	0	0	0	0	0	0	0
Total		**8**	**8**	**962**	**962**	**0**	**0**	**962**

Table 2-9: Details of Golden Plover Flights Recorded within 500m Buffer of Turbines

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)			
					<30m	30-150m	>150m	At risk
Feb-20 to Aug-20	VP1	0	0	0	0	0	0	0
	VP2	6	64	8659	200	2474	5985	2674
Sep-20 to Mar-21	VP1	2	8	120	120	0	0	120
	VP2	3	12	184	184	0	0	184
Oct-21 to Mar-22	VP1	0	0	0	0	0	0	0
	VP2	4	74	14407	8520	5887	0	14407
Apr-22 to Sep-22	VP1	1	3	78	48	30	0	78
	VP2	0	0	0	0	0	0	0
Total		**16**	**161**	**23448**	**9072**	**8391**	**5985**	**17463**

3.0 Collision Risk Modelling Results

Table 3-1: summarises the predicted collision rates for the four species under consideration. Copies of the modelling calculations for each species are included in **Annex 9.3A** and **Annex 9.3B**.

Table 3-1: Summary of CRM Output

Species name	Period of analysis	Modelled collisions per Season	Years per collision
White-tailed eagle	Feb-20 to Aug-20	0.9156	1.09
	Sep-20 to Mar-21	0.8798	1.14
	Annual Yr 1	1.5573	0.64
	Oct-21 to Mar-22	0.4242	2.36
	Apr-22 to Sep-22	0.6621	1.51
	Annual Yr 2	1.1015	0.91
	Annual Yr1 + Yr2	**1.3796**	**0.72**
Golden eagle	Feb-20 to Aug-20	0.0362	27.66
	Sep-20 to Mar-21	0.0808	12.37
	Annual Yr 1	0.0995	10.05
	Oct-21 to Mar-22	0.0517	19.32
	Apr-22 to Sep-22	0.2107	4.75
	Annual Yr 2	0.2418	4.14
	Annual Yr1 + Yr2	**0.1550**	**6.45**
Hen harrier	Feb-20 to Aug-20	0.0089	112.80
	Sep-20 to Mar-21	0.0037	269.40
	Annual Yr 1	0.0111	90.00
	Oct-21 to Mar-22	0	0
	Apr-22 to Sep-22	0.0899	11.13
	Annual Yr 2	0.0730	13.70
	Annual Yr1 + Yr2	**0.0352**	**28.37**
Golden plover	Feb-20 to Aug-20	0.4522	2.21
	Sep-20 to Mar-21	0.0673	14.86
	Annual Yr 1	0.4885	2.05
	Oct-21 to Mar-22	3.0940	0.32

Species name	Period of analysis	Modelled collisions per Season	Years per collision
	Apr-22 to Sep-22	0.0226	44.29
	Annual Yr 2	3.7166	0.27
	Annual Yr1 + Yr2	**1.7474**	**0.57**

3.1 Species Summary

3.1.1 White-tailed Eagle

White-tailed eagles use the area primarily for commuting (n=15 flights) but foraging was also recorded (n=12 flights). The species has been observed soaring to considerable altitude using thermals and updraughts and then gliding, often for long distances, at speed when having gained altitude. Other flight behaviours observed included display (n=6 flights), to/from roosts (n=4 flights) and random/ circling/ not recorded (n=15).

The peak in flight activity occurred during February – August 2020 when there was the most survey effort (142 hours of combined VP surveys, averaging approximately 10 hours per VP per month). Subsequently, there was 6 hours survey effort per VP per month.

There was an apparent reduction in observed flight activity in the second year of surveys. The surveyor commented that the 2021/2022 winter was particularly stormy which may have caused birds to temporarily move away from Skye. In addition, at this stage it is not known what impact avian flu has had on the white-tailed eagle population.

3.1.2 Golden Eagle

Observed flight behaviour by golden eagle was similar to white-tailed eagle and has been observed soaring/ circling using updraughts/ thermals to gain height. Foraging flights (n=15 flights) and commuting flights (n=11) predominated. There was n=1 display flight, n=3 flights to/ from roosts, and n=10 random/ circling flights; plus n=1 flight where behaviour was not recorded.

As with white-tailed eagle, the highest number of flights was recorded during February – August 2020 when there was the most survey effort. There was a less noticeable drop off in flight activity during year 2, in fact the predicted mortality was highest during April – September 2022.

3.1.3 Hen Harrier

Flight activity by hen harrier peaked in the year 2 breeding season, to the south of the proposed turbine array. Where behaviour was recorded, all flights were of foraging birds (n=9). The nearest confirmed breeding site lies >2km to the south-east.

The predicted mortality is low and not likely to be significant.

3.1.4 Golden Plover

Flight activity by golden plover within the WP was recorded throughout both years, and was focussed south of the Ben Sca ridge where there are breeding territories. The highest predicted collision risk is outside of the breeding season due to the presence of aggregations of up to 45 birds, which were commuting or on passage.

3.2 Standalone CRM Results for Turbines 1 & 2 using Ben Sca Flight Activity Data 2018-2019

As stated in **Section 2.1.2**, the viewsheds for Balmeanach surveys do not fully cover the northern part of the site, where proposed Turbines 1 and 2 would be located. In order to provide further context to the assessment, a separate CRM was conducted for proposed Turbines 1 and 2 using data gathered for the Ben Sca assessment in 2018-2019, as below.

3.2.1 White-tailed Eagle

Table 3-2: **and Figure 9.3.1** shows the white-tailed eagle flightline data from Ben Sca VP surveys conducted from 2018 to 2019 in relation to the Proposed Development layout, and **Table 3-3** presents the CRM results.

Table 3-2: Details of White-tailed Eagle Flights Recorded from VPs within 500m Buffer of Turbines, Jan 2018 to March 2019

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)			
					<30m	30-150m	>150m	At risk
Jan-18 to Aug-18	VP1	4	6	720	0	210	510	210
	VP2	5	5	540	90	195	255	285
Sep-18 to Mar-19	VP1	0	0	0	0	0	0	0
	VP2	0	0	0	0	0	0	0
Total		**9**	**11**	**1260**	**90**	**405**	**765**	**495**

Table 3-3: CRM Results for White-tailed Eagle

Period of analysis	Modelled collisions per Season	Years per collision
Jan-18 to Aug-18	0.2358	4.24
Sep-18 to Mar-19	0	n/a
Annual	**0.1907**	**5.24**

3.2.2 Golden Eagle

Table 3-4 details the Golden Eagle flightline data Ben Sca VP surveys conducted from 2018 to 2019, and **Table 3-5**: presents the CRM results.

Table 3-4: Details of Golden Eagle Flights Recorded from VPs within 500m Buffer of Turbines, Jan 2018 to March 2019

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)			
					<30m	30-150m	>150m	At risk
Jan-18 to Aug-18	VP1	1	1	105	0	30	75	30
	VP2	10	10	1125	0	705	420	705
Sep-18 to Mar-19	VP1	0	0	0	0	0	0	0
	VP2	4	4	105	105	0	0	105
Total		**15**	**15**	**1335**	**105**	**735**	**495**	**840**

Table 3-5: CRM Results for Golden Eagle

Period of analysis	Modelled collisions per Season	Years per collision
Jan-18 to Aug-18	0.0757	13.21
Sep-18 to Mar-19	0.0056	177.23
Annual	**0.0700**	**14.28**

3.2.3 Hen Harrier

Table 3-6: details the Hen Harrier flightline data Ben Sca VP surveys conducted from 2018 to 2019, and **Table 3-7**: presents the CRM results.

Table 3-6: Details of Hen Harrier Flights Recorded from VPs within 500m Buffer of Turbines, Jan 2018 to March 2019

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)			
					<30m	30-150m	>150m	At risk
Jan-18 to Aug-18	VP1	0	0	0	0	0	0	0
	VP2	5	5	330	285	45	0	330
Sep-18 to Mar-19	VP1	0	0	0	0	0	0	0
	VP2	3	3	495	360	135		495
Total		**8**	**8**	**825**	**645**	**180**	**0**	**825**

Table 3-7: CRM Results for Hen Harrier

Period of analysis	Modelled collisions per Season	Years per collision
Jan-18 to Aug-18	0.0255	39.28
Sep-18 to Mar-19	0.0259	38.57
Annual	**0.0542**	**18.45**

3.2.4 Golden Plover

Table 3-8: details the Hen Harrier flightline data Ben Sca VP surveys conducted from 2018 to 2019, and **Table 3-9**: presents the CRM results.

Table 3-8: Details of Golden Plover flights Recorded from VPs within 500m Buffer of Turbines, Jan 2018 to March 2019

Period	VP No.	No. of flights	No. of birds	Total flying time (s)	Time in height category (s)			
					<30m	30-150m	>150m	At risk
Jan-18 to Aug-18	VP1	0	0	0	0	0	0	0
	VP2	9	22	1425	795	630	0	1425
Sep-18 to Mar-19	VP1	0	0	0	0	0	0	0
	VP2	0	0	0	0	0	0	0
Total		**9**	**22**	**1425**	**195**	**630**	**0**	**1425**

Table 3-9: CRM results for Golden Plover

Period of analysis	Modelled collisions per Season	Years per collision
Jan-18 to Aug-18	0.2755	3.63
Sep-18 to Mar-19	0	n/a
Annual	**0.2781**	**3.60**

3.2.5 Conclusions for Turbines 1 & 2

Table 3-10 presents the results of the CRM for Balmeanach as a whole (using the Balmeanach 2020 – 2022 data) and the Ben Sca 2018 – 2019 data for proposed Turbines 1 and 2. Other than for hen harrier, the outputs are lower for proposed Turbines 1 and 2 alone, indicating a lower level of flight activity for white-tailed eagle, golden eagle and golden plover in this area, albeit from different years.

Table 3-10: CRM results for Balmeanach (all turbines 2020-2022) vs Turbines 1 & 2 (2018-2019)

Species	Dataset/ period of analysis	Modelled collisions per Year	Years per collision
White-tailed eagle	Balmeanach (2020-2022)	1.3796	0.72
	Ben Sca (2018-2019)	0.1907	5.24
Golden eagle	Balmeanach (2020-2022)	0.1550	6.45
	Ben Sca (2018-2019)	0.0700	14.28
Hen harrier	Balmeanach (2020-2022)	0.0352	28.37
	Ben Sca (2018-2019)	0.0542	18.45
Golden plover	Balmeanach (2020-2022)	1.7474	0.57
	Ben Sca (2018-2019)	0.2781	3.60

ANNEX 9.3A

CRM Probability Calculations

White-tailed Eagle

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**									
NoBlades	3					Upwind:			Downwind:			
MaxChord	4.1	m	r/R	c/C	α	collide		contribution	collide		contribution	
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r	
BirdLength	0.8	m	0.025	0.575	5.15	19.52	1.00	0.00125	19.02	1.00	0.00125	
Wingspan	2.2	m	0.075	0.575	1.72	6.67	0.36	0.00269	6.18	0.33	0.00249	
F: Flapping (0) or gliding (-	1		0.125	0.702	1.03	4.69	0.25	0.00315	4.08	0.22	0.00275	
			0.175	0.860	0.74	3.98	0.21	0.00374	3.24	0.17	0.00305	
Bird speed	13	m/sec	0.225	0.994	0.57	3.54	0.19	0.00429	2.69	0.14	0.00326	
RotorDiam	138	m	0.275	0.947	0.47	2.87	0.15	0.00424	2.06	0.11	0.00304	
RotationPeriod	4.29	sec	0.325	0.899	0.40	2.39	0.13	0.00418	1.62	0.09	0.00283	
			0.375	0.851	0.34	2.36	0.13	0.00475	1.63	0.09	0.00328	
			0.425	0.804	0.30	2.14	0.11	0.00488	1.45	0.08	0.00331	
			0.475	0.756	0.27	1.96	0.11	0.00500	1.31	0.07	0.00335	
Bird aspect ratioo: β	0.36		0.525	0.708	0.25	1.81	0.10	0.00511	1.20	0.06	0.00340	
			0.575	0.660	0.22	1.69	0.09	0.00521	1.12	0.06	0.00346	
			0.625	0.613	0.21	1.58	0.08	0.00530	1.05	0.06	0.00354	
			0.675	0.565	0.19	1.48	0.08	0.00538	1.00	0.05	0.00362	
			0.725	0.517	0.18	1.40	0.08	0.00544	0.95	0.05	0.00372	
			0.775	0.470	0.17	1.32	0.07	0.00550	0.92	0.05	0.00382	
			0.825	0.422	0.16	1.25	0.07	0.00554	0.89	0.05	0.00394	
			0.875	0.374	0.15	1.18	0.06	0.00558	0.86	0.05	0.00407	
			0.925	0.327	0.14	1.13	0.06	0.00560	0.85	0.05	0.00421	
			0.975	0.279	0.13	1.07	0.06	0.00561	0.83	0.04	0.00436	
				Overall p(collision) =			**Upwind**	**9.2%**		**Downwind**	**6.7%**	
								Average	**8.0%**			

Golden Eagle

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.1	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.82	m	0.025	0.575	5.94	22.10	1.00	0.00125	21.61	1.00	0.00125
Wingspan	2.1	m	0.075	0.575	1.98	7.53	0.35	0.00263	7.04	0.33	0.00246
F: Flapping (0) or gliding (-	1		0.125	0.702	1.19	5.28	0.25	0.00308	4.68	0.22	0.00273
			0.175	0.860	0.85	4.48	0.21	0.00365	3.74	0.17	0.00305
Bird speed	15	m/sec	0.225	0.994	0.66	3.98	0.19	0.00418	3.13	0.15	0.00328
RotorDiam	138	m	0.275	0.947	0.54	3.21	0.15	0.00412	2.40	0.11	0.00308
RotationPeriod	4.29	sec	0.325	0.899	0.46	2.67	0.12	0.00405	1.90	0.09	0.00288
			0.375	0.851	0.40	2.27	0.11	0.00396	1.54	0.07	0.00269
			0.425	0.804	0.35	2.31	0.11	0.00457	1.62	0.08	0.00321
			0.475	0.756	0.31	2.11	0.10	0.00467	1.46	0.07	0.00323
Bird aspect ratioo: β	0.39		0.525	0.708	0.28	1.94	0.09	0.00475	1.33	0.06	0.00326
			0.575	0.660	0.26	1.80	0.08	0.00482	1.23	0.06	0.00330
			0.625	0.613	0.24	1.68	0.08	0.00488	1.15	0.05	0.00335
			0.675	0.565	0.22	1.57	0.07	0.00494	1.08	0.05	0.00341
			0.725	0.517	0.20	1.47	0.07	0.00498	1.03	0.05	0.00348
			0.775	0.470	0.19	1.39	0.06	0.00502	0.99	0.05	0.00356
			0.825	0.422	0.18	1.31	0.06	0.00504	0.95	0.04	0.00365
			0.875	0.374	0.17	1.24	0.06	0.00506	0.92	0.04	0.00375
			0.925	0.327	0.16	1.17	0.05	0.00506	0.89	0.04	0.00385
			0.975	0.279	0.15	1.11	0.05	0.00506	0.87	0.04	0.00397
				Overall p(collision) =			**Upwind**	**8.6%**		**Downwind**	**6.3%**
								Average	**7.5%**		

Hen Harrier

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.1	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.48	m	0.025	0.575	4.75	14.71	0.86	0.00107	14.22	0.83	0.00104
Wingspan	1.1	m	0.075	0.575	1.58	5.07	0.30	0.00221	4.57	0.27	0.00200
F: Flapping (0) or gliding (-	1		0.125	0.702	0.95	3.68	0.21	0.00268	3.08	0.18	0.00224
			0.175	0.860	0.68	3.22	0.19	0.00329	2.49	0.14	0.00254
Bird speed	12	m/sec	0.225	0.994	0.53	2.94	0.17	0.00385	2.08	0.12	0.00273
RotorDiam	138	m	0.275	0.947	0.43	2.55	0.15	0.00409	1.74	0.10	0.00279
RotationPeriod	4.29	sec	0.325	0.899	0.37	2.20	0.13	0.00418	1.43	0.08	0.00272
			0.375	0.851	0.32	1.94	0.11	0.00425	1.21	0.07	0.00265
			0.425	0.804	0.28	1.74	0.10	0.00431	1.05	0.06	0.00260
			0.475	0.756	0.25	1.57	0.09	0.00436	0.93	0.05	0.00256
Bird aspect ratioo: β	0.44		0.525	0.708	0.23	1.44	0.08	0.00440	0.83	0.05	0.00254
			0.575	0.660	0.21	1.32	0.08	0.00442	0.75	0.04	0.00252
			0.625	0.613	0.19	1.22	0.07	0.00443	0.69	0.04	0.00252
			0.675	0.565	0.18	1.13	0.07	0.00443	0.64	0.04	0.00253
			0.725	0.517	0.16	1.05	0.06	0.00442	0.60	0.04	0.00255
			0.775	0.470	0.15	0.97	0.06	0.00440	0.57	0.03	0.00258
			0.825	0.422	0.14	0.91	0.05	0.00437	0.55	0.03	0.00263
			0.875	0.374	0.14	0.85	0.05	0.00432	0.53	0.03	0.00269
			0.925	0.327	0.13	0.79	0.05	0.00426	0.51	0.03	0.00275
			0.975	0.279	0.12	0.74	0.04	0.00419	0.50	0.03	0.00284
				Overall p(collision) =			**Upwind**	**7.8%**		**Downwind**	**5.0%**
								Average	**6.4%**		

Golden Plover

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3					Upwind:			Downwind:		
MaxChord	4.1	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.28	m	0.025	0.575	7.12	20.13	0.78	0.00098	19.63	0.76	0.00095
Wingspan	0.7	m	0.075	0.575	2.37	6.87	0.27	0.00200	6.38	0.25	0.00186
F: Flapping (0) or gliding (·	1		0.125	0.702	1.42	5.01	0.19	0.00243	4.41	0.17	0.00214
			0.175	0.860	1.02	4.39	0.17	0.00299	3.65	0.14	0.00248
Bird speed	18	m/sec	0.225	0.994	0.79	3.99	0.15	0.00349	3.14	0.12	0.00274
RotorDiam	138	m	0.275	0.947	0.65	3.19	0.12	0.00341	2.38	0.09	0.00255
RotationPeriod	4.29	sec	0.325	0.899	0.55	2.64	0.10	0.00333	1.87	0.07	0.00236
			0.375	0.851	0.47	2.23	0.09	0.00324	1.50	0.06	0.00218
			0.425	0.804	0.42	1.90	0.07	0.00314	1.22	0.05	0.00201
			0.475	0.756	0.37	1.76	0.07	0.00325	1.11	0.04	0.00205
Bird aspect ratioo: β	0.40		0.525	0.708	0.34	1.56	0.06	0.00319	0.96	0.04	0.00195
			0.575	0.660	0.31	1.40	0.05	0.00312	0.83	0.03	0.00186
			0.625	0.613	0.28	1.25	0.05	0.00305	0.73	0.03	0.00177
			0.675	0.565	0.26	1.13	0.04	0.00296	0.65	0.03	0.00169
			0.725	0.517	0.25	1.02	0.04	0.00287	0.58	0.02	0.00162
			0.775	0.470	0.23	0.92	0.04	0.00277	0.52	0.02	0.00156
			0.825	0.422	0.22	0.83	0.03	0.00267	0.47	0.02	0.00151
			0.875	0.374	0.20	0.75	0.03	0.00255	0.43	0.02	0.00146
			0.925	0.327	0.19	0.68	0.03	0.00243	0.40	0.02	0.00142
			0.975	0.279	0.18	0.61	0.02	0.00230	0.37	0.01	0.00139
				Overall p(collision) =			**Upwind**	**5.6%**		**Downwind**	**3.8%**
								Average	**4.7%**		

ANNEX 9.3B

CRM Calculations

White-tailed Eagle Feb. 2020 – Aug. 2020

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	889	1165			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	73	69			
Windfarm area (ha) visible within viewshed (v)1	184.5539	269.382			
Observation effort (e*v)	13472.43	18587.36			
TwV rate=TwV/e*v	1.83E-05	1.74E-05			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.420228	0.579772			
Weighted TwV rate (TwV rate * weight)	7.7E-06	1.01E-05			
Total weighted occupancy rate		1.78E-05	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.009116			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.008387			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: breeding season (a) (footnote 2)		3078.067	hours		
Tw=z*a		25.81452	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		

Step 1.7: Volume swept by windfarm rotors (Vr)					
Bird length (L)		0.8	m		
Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4		762813.3	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)		100.287	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)		13	m/sec		
t=(d+L)/s		0.392308	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t		255.6336	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5		0.079595			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90		18.31247	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.95		0.915623	approx one collision every	1.092152	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours during the period (Feb-Aug)					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.8m, wingspan 2.2m, flight speed= 13m/sec					

White-tailed Eagle Sep. 2020 – Mar 2021

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	1647	147			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	42	42			
Windfarm area (ha) visible within viewshed (v)1	184.5539	269.382			
Observation effort (e*v)	7751.263	11314.04			
TwV rate=TwV/e*v	5.9E-05	3.61E-06			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.406564	0.593436			
Weighted TwV rate (TwV rate * weight)	2.4E-05	2.14E-06			
Total weighted occupancy rate		2.61E-05	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.013389			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.012318			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: non-breeding season (a) (footnote 2)		2013.817	hours		
Tw=z*a		24.80533	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		

Step 1.7: Volume swept by windfarm rotors (Vr)					
Bird length (L)		0.8	m		
Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4		762813.3	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)		96.36638	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)		13	m/sec		
t=(d+L)/s		0.392308	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t		245.6398	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5		0.079595			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90		17.59656	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.95		0.879828	approx one collision every	1.136586	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours during the period (Sep-Mar)					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.8m, wingspan 2.2m, flight speed= 13m/sec					

White-tailed Eagle Annual Year 1

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	2536	1312			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	115	111			
Windfarm area (ha) visible within viewshed (v)1	184.5539	269.382			
Observation effort (e*v)	21223.7	29901.4			
TwV rate=TwV/e*v	3.32E-05	1.22E-05			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.415133	0.584867			
Weighted TwV rate (TwV rate * weight)	1.38E-05	7.13E-06			
Total weighted occupancy rate		2.09E-05	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.010709			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.009853			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: annual (a) (footnote 2)		4456.283	hours		
Tw=z*a		43.90561	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		
Step 1.7: Volume swept by windfarm rotors (Vr)					

Bird length (L)	0.8	m			
Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4	762813.3	m3			
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)	170.5692	seconds			
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)	13	m/sec			
t=(d+L)/s	0.392308	seconds			
Step 1.10: Number of rotor transits (N)					
N=Tr/t	434.7843	rotor transits			
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5	0.079595				
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	31.14604	collisions			
Step 3.2: Adjusted using a range of avoidance rates:					
0.95	1.557302	approx one collision every	0.642136	years	
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours during the period					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.8m, wingspan 2.2m, flight speed= 13m/sec					

White-tailed Eagle Oct 2021 – Mar 2022

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	128	787			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	36	36			
Windfarm area (ha) visible within viewshed (v)1	184.5539	269.382			
Observation effort (e*v)	6643.94	9697.752			
TwV rate=TwV/e*v	5.35E-06	2.25E-05			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.406564	0.593436			
Weighted TwV rate (TwV rate * weight)	2.18E-06	1.34E-05			
Total weighted occupancy rate		1.56E-05	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.007967			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.007329			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: non-breeding season (a) (footnote 2)		1631.817	hours		
Tw=z*a		11.96029	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		

Step 1.7: Volume swept by windfarm rotors (Vr)					
Bird length (L)		0.8	m		
Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4		762813.3	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)		46.46462	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)	13		m/sec		
t=(d+L)/s		0.392308	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t		118.4392	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5		0.079595			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90		8.484466	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.95		0.424223	approx one collision every	2.357249	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours during the period Oct - Mar					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.8m, wingspan 2.2m, flight speed= 13m/sec					

White-tailed Eagle Apr 2022 – Sep 2022

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	0	825			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	36	36			
Windfarm area (ha) visible within viewshed (v)1	184.5539	269.382			
Observation effort (e*v)	6643.94	9697.752			
TwV rate=TwV/e*v	0	2.36E-05			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.406564	0.593436			
Weighted TwV rate (TwV rate * weight)	0	1.4E-05			
Total weighted occupancy rate		1.4E-05	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.007183			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.006609			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: breeding season (a) (footnote 2)		2824.467	hours		
Tw=z*a		18.66551	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		

Step 1.7: Volume swept by windfarm rotors (Vr)					
Bird length (L)		0.8	m		
Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4		762813.3	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)		72.51375	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)		13	m/sec		
t=(d+L)/s		0.392308	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t		184.839	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5		0.079595			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90		13.24105	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.95		0.662053	approx one collision every	1.510454	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours during the period (Apr-Sep)					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.8m, wingspan 2.2m, flight speed= 13m/sec					

White-tailed Eagle Annual Year 2

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	128	1612			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	72	72			
Windfarm area (ha) visible within viewshed (v)1	184.5539	269.382			
Observation effort (e*v)	13287.88	19395.5			
TwV rate=TwV/e*v	2.68E-06	2.31E-05			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.406564	0.593436			
Weighted TwV rate (TwV rate * weight)	1.09E-06	1.37E-05			
Total weighted occupancy rate		1.48E-05	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.007575			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.006969			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: annual (a) (footnote 2)		4456.283	hours		
Tw=z*a		31.05571	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		

Step 1.7: Volume swept by windfarm rotors (Vr)					
Bird length (L)		0.8	m		
Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4		762813.3	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)		120.6485	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)		13	m/sec		
t=(d+L)/s		0.392308	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t		307.5355	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5		0.079595			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90		22.03049	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.95		1.101524	approx one collision every	0.907833	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours during the period					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.8m, wingspan 2.2m, flight speed= 13m/sec					

White-tailed Eagle Annual Year 1 + Year 2

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	2664	2924			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	187	183			
Windfarm area (ha) visible within viewshed (v)1	184.5539	269.382			
Observation effort (e*v)	34511.58	49296.91			
TwV rate=TwV/e*v	2.14E-05	1.65E-05			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.411791	0.588209			
Weighted TwV rate (TwV rate * weight)	8.83E-06	9.69E-06			
Total weighted occupancy rate		1.85E-05	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.009487			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.008728			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: annual (a) (footnote 2)		4456.283	hours		
Tw=z*a		38.89445	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		
Step 1.7: Volume swept by windfarm rotors (Vr)					

Bird length (L)		0.8	m		
Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4		762813.3	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)		151.1013	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)		13	m/sec		
t=(d+L)/s		0.392308	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t		385.1602	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5		0.079595			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90		27.59118	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.95	1.379559		approx one collision every	0.724869	years
0.98	0.551824		approx one collision every	1.812173	years
0.99	0.275912		approx one collision every	3.624346	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours during the period					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.8m, wingspan 2.2m, flight speed= 13m/sec					

Golden Eagle Feb. 2020 – Aug. 2020

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	0	375			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	73	69			
Windfarm area (ha) visible within viewshed (v)1	184.55	269.38			
Observation effort (e*v)	13472.15	18587.22			
TwV rate=TwV/e*v	0	5.6E-06			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.420225	0.579775			
Weighted TwV rate (TwV rate * weight)	0	3.25E-06			
Total weighted occupancy rate		3.25E-06	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.001664			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.001531			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: breeding season (a) (footnote 2)		3078.067	hours		
Tw=z*a		4.713035	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		
Step 1.7: Volume swept by windfarm rotors (Vr)					
Bird length (L)		0.82	m		

Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4		765804.7	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)		18.3815	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)		15	m/sec		
t=(d+L)/s		0.341333	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t		53.85207	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5		0.074606			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90		3.615897	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.99		0.036159	approx one collision every	27.65566	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours during the period (Feb-Aug)					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.82m, wingspan 2.1m, flight speed= 15m/sec					

Golden Eagle Sep. 2020 – Mar. 2021

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	0	762			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	42	42			
Windfarm area (ha) visible within viewshed (v)1	184.55	269.38			
Observation effort (e*v)	7751.1	11313.96			
TwV rate=TwV/e*v	0	1.87E-05			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.40656	0.59344			
Weighted TwV rate (TwV rate * weight)	0	1.11E-05			
Total weighted occupancy rate		1.11E-05	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.005687			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.005232			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: non-breeding season (a) (footnote 2)		2013.817	hours		
Tw=z*a		10.53618	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		
Step 1.7: Volume swept by windfarm rotors (Vr)					
Bird length (L)		0.82	m		

Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4		765804.7	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)		41.09259	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)		15	m/sec		
t=(d+L)/s		0.341333	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t		120.3884	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5		0.074606			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90		8.083482	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.99		0.080835	approx one collision every	12.37091	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours during the period (Sep-Mar)					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.82m, wingspan 2.1m, flight speed= 15m/sec					

Golden Eagle Annual Year 1

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	0	1137			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	115	111			
Windfarm area (ha) visible within viewshed (v)1	184.55	269.38			
Observation effort (e*v)	21223.25	29901.18			
TwV rate=TwV/e*v	0	1.06E-05			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.415129	0.584871			
Weighted TwV rate (TwV rate * weight)	0	6.18E-06			
Total weighted occupancy rate		6.18E-06	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.003164			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.002911			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: annual (a) (footnote 2)		4456.283	hours		
Tw=z*a		12.97332	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		
Step 1.7: Volume swept by windfarm rotors (Vr)					

Bird length (L)		0.82	m		
Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4		765804.7	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)		50.59779	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)		15	m/sec		
t=(d+L)/s		0.341333	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t		148.2357	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5		0.074606			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90		9.953287	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.99		0.099533	approx one collision every	10.04693	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours during the period					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.82m, wingspan 2.1m, flight speed= 15m/sec					

Golden Eagle Oct. 2021 – Mar. 2022

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	180	336			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	36	36			
Windfarm area (ha) visible within viewshed (v)1	184.55	269.38			
Observation effort (e*v)	6643.8	9697.68			
TwV rate=TwV/e*v	7.53E-06	9.62E-06			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.40656	0.59344			
Weighted TwV rate (TwV rate * weight)	3.06E-06	5.71E-06			
Total weighted occupancy rate		8.77E-06	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.004493			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.004133			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: non-breeding season (a) (footnote 2)		1631.817	hours		
Tw=z*a		6.744908	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		
Step 1.7: Volume swept by windfarm rotors (Vr)					
Bird length (L)		0.82	m		

Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4		765804.7	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)		26.3061	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)		15	m/sec		
t=(d+L)/s		0.341333	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t		77.06865	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5		0.074606			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90		5.174774	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.99		0.051748	approx one collision every	19.32451	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours during the period (Oct-Mar)					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.82m, wingspan 2.1m, flight speed= 15m/sec					

Golden Eagle Apr. 2022 – Sep. 2022

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	634	616			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	36	36			
Windfarm area (ha) visible within viewshed (v)1	184.55	269.38			
Observation effort (e*v)	6643.8	9697.68			
TwV rate=TwV/e*v	2.65E-05	1.76E-05			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.40656	0.59344			
Weighted TwV rate (TwV rate * weight)	1.08E-05	1.05E-05			
Total weighted occupancy rate		2.12E-05	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.010884			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.009868			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: breeding season (a) (footnote 2)		2824.467	hours		
Tw=z*a		27.87156	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		6.97E+08	m3		
Step 1.7: Volume swept by windfarm rotors (Vr)					
Bird length (L)		0.82	m		

Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4		743768.3	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)		107.1276	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)		15	m/sec		
t=(d+L)/s		0.341333	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t		313.8505	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5		0.074606			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90		21.07349	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.99		0.210735	approx one collision every	4.745298	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours during the period (Apr-Sep)					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.82m, wingspan 2.1m, flight speed= 15m/sec					

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	814	952			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	72	72			
Windfarm area (ha) visible within viewshed (v)1	184.55	269.38			
Observation effort (e*v)	13287.6	19395.36			
TwV rate=TwV/e*v	1.7E-05	1.36E-05			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.40656	0.59344			
Weighted TwV rate (TwV rate * weight)	6.92E-06	8.09E-06			
Total weighted occupancy rate		1.5E-05	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.007688			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.007073			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: annual (a) (footnote 2)		4456.283	hours		
Tw=z*a		31.52016	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		
Step 1.7: Volume swept by windfarm rotors (Vr)					
Bird length (L)		0.82	m		

Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4	765804.7		m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)	122.9331		seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)	15		m/sec		
t=(d+L)/s	0.341333		seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t	360.1556		rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5	0.074606				
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	24.18265		collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.99	0.241826		approx one collision every	4.135196	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours during the period					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.82m, wingspan 2.1m, flight speed= 15m/sec					

Golden Eagle Annual Year 1 + 2

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	814	2089			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	187	183			
Windfarm area (ha) visible within viewshed (v)1	184.55	269.38			
Observation effort (e*v)	34510.85	49296.54			
TwV rate=TwV/e*v	6.55E-06	1.18E-05			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.411788	0.588212			
Weighted TwV rate (TwV rate * weight)	2.7E-06	6.92E-06			
Total weighted occupancy rate		9.62E-06	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.004929			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.004534			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: annual (a) (footnote 2)		4456.283	hours		
Tw=z*a		20.20616	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		
Step 1.7: Volume swept by windfarm rotors (Vr)					

Bird length (L)		0.82	m		
Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4		765804.7	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)		78.80691	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)		15	m/sec		
t=(d+L)/s		0.341333	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t		230.8796	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5		0.074606			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90		15.50241	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.99		0.155024	approx one collision every	6.450609	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours during the period					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.82m, wingspan 2.1m, flight speed= 15m/sec					

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	947	15			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	187	183			
Windfarm area (ha) visible within viewshed (v)1	184.55	269.38			
Observation effort (e*v)	34510.85	49296.54			
TwV rate=TwV/e*v	7.62E-06	8.45E-08			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.411788	0.588212			
Weighted TwV rate (TwV rate * weight)	3.14E-06	4.97E-08			
Total weighted occupancy rate		3.19E-06	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.001633			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.001503			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: annual (a) (footnote 2)		4456.283	hours		
Tw=z*a		6.695945	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		
Step 1.7: Volume swept by windfarm rotors (Vr)					

Bird length (L)		0.48	m		
Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4		714950.5	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)		24.38093	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)		12	m/sec		
t=(d+L)/s		0.398333	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t		61.20735	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5		0.063984			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90		3.524635	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.99		0.035246	approx one collision every	28.37173	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours during the period					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
4Assumes bird length=0.48m, wingspan 1.1m, flight speed= 12.0m/sec					

Golden Plover Feb. 2020 – Aug. 2020

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	0	2674			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	73	69			
Windfarm area (ha) visible within viewshed (v)1	184.55	269.38			
Observation effort (e*v)	13472.15	18587.22			
TwV rate=TwV/e*v	0	4E-05			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.420225	0.579775			
Weighted TwV rate (TwV rate * weight)	0	2.32E-05			
Total weighted occupancy rate		2.32E-05	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.011868			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.010918			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: breeding season (a) (footnote 2)		3579.676	hours		
Tw=z*a		39.08377	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		
Step 1.7: Volume swept by windfarm rotors (Vr)					

Bird length (L)	0.28		m		
Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4	685036.2		m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)	136.3554		seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)	18		m/sec		
t=(d+L)/s	0.254444		seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t	535.8946		rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5	0.046875				
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	22.60828		collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.98	0.452166		approx one collision every	2.211579	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours + 25% nocturnal hours during the period (Feb-Aug)					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.28m, wingspan 0.7m, flight speed= 18m/sec					

Golden Plover Sep. 2020 – Mar. 2021

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	120	184			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	42	42			
Windfarm area (ha) visible within viewshed (v)1	184.55	269.38			
Observation effort (e*v)	7751.1	11313.96			
TwV rate=TwV/e*v	4.3E-06	4.52E-06			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.40656	0.59344			
Weighted TwV rate (TwV rate * weight)	1.75E-06	2.68E-06			
Total weighted occupancy rate		4.43E-06	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.002269			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.002087			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: non-breeding season (a) (footnote 2)		2787.491	hours		
Tw=z*a		5.818287	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		
Step 1.7: Volume swept by windfarm rotors (Vr)					
Bird length (L)		0.28	m		

Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4		685036.2	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)		20.29883	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)		18	m/sec		
t=(d+L)/s		0.254444	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t		79.77708	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5		0.046875			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90		3.365629	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.98		0.067313	approx one collision every	14.85606	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours + 25% nocturnal hours during the period (Sep-Mar)					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.28m, wingspan 0.7m, flight speed= 18m/sec					

Golden Plover Annual Year 1

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	120	2858			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	115	111			
Windfarm area (ha) visible within viewshed (v)1	184.55	269.38			
Observation effort (e*v)	21223.25	29901.18			
TwV rate=TwV/e*v	1.57E-06	2.66E-05			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.415129	0.584871			
Weighted TwV rate (TwV rate * weight)	6.52E-07	1.55E-05			
Total weighted occupancy rate		1.62E-05	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.008288			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.007625			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: annual (a) (footnote 2)		5537.341	hours		
Tw=z*a		42.22249	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		
Step 1.7: Volume swept by windfarm rotors (Vr)					

Bird length (L)		0.28	m		
Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4		685036.2	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)		147.3058	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)		18	m/sec		
t=(d+L)/s		0.254444	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t		578.9309	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5		0.046875			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90		24.42389	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.98		0.488478	approx one collision every	2.047176	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours + 25% nocturnal hours during the period					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.28m, wingspan 0.7m, flight speed= 18m/sec					

Golden Plover Oct. 2021 – Mar. 2022

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	0	14407			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	36	36			
Windfarm area (ha) visible within viewshed (v)1	184.55	269.38			
Observation effort (e*v)	6643.8	9697.68			
TwV rate=TwV/e*v	0	0.000413			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.40656	0.59344			
Weighted TwV rate (TwV rate * weight)	0	0.000245			
Total weighted occupancy rate		0.000245	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.125441			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.115406			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: non-breeding season (a) (footnote 2)		2317.363	hours		
Tw=z*a		267.4376	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		
Step 1.7: Volume swept by windfarm rotors (Vr)					
Bird length (L)		0.28	m		

Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4		685036.2	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)		933.036	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)		18	m/sec		
t=(d+L)/s		0.254444	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t		3666.954	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5		0.046875			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90		154.7012	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.98		3.094024	approx one collision every	0.323204	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours + 25% nocturnal hours during the period (Oct-Mar)					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.28m, wingspan 0.7m, flight speed= 18m/sec					

Golden Plover Apr. 2022 – Sep. 2022

	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	78	0			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	36	36			
Windfarm area (ha) visible within viewshed (v)1	184.55	269.38			
Observation effort (e*v)	6643.8	9697.68			
TwV rate=TwV/e*v	3.26E-06	0			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.40656	0.59344			
Weighted TwV rate (TwV rate * weight)	1.33E-06	0			
Total weighted occupancy rate		1.33E-06	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.000679			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.000616			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: breeding season (a) (footnote 2)		3216.35	hours		
Tw=z*a		1.98049	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		6.97E+08	m3		
Step 1.7: Volume swept by windfarm rotors (Vr)					
Bird length (L)		0.28	m		

Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4	665324	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)	6.809394	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)	18	m/sec		
t=(d+L)/s	0.254444	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t	26.76181	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5	0.046875			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	1.129025	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.98	0.022581	approx one collision every	44.28599	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours + 25% nocturnal hours during the period (Apr-Sep)					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.28m, wingspan 0.7m, flight speed= 18m/sec					

Golden Plover Annual Year 2

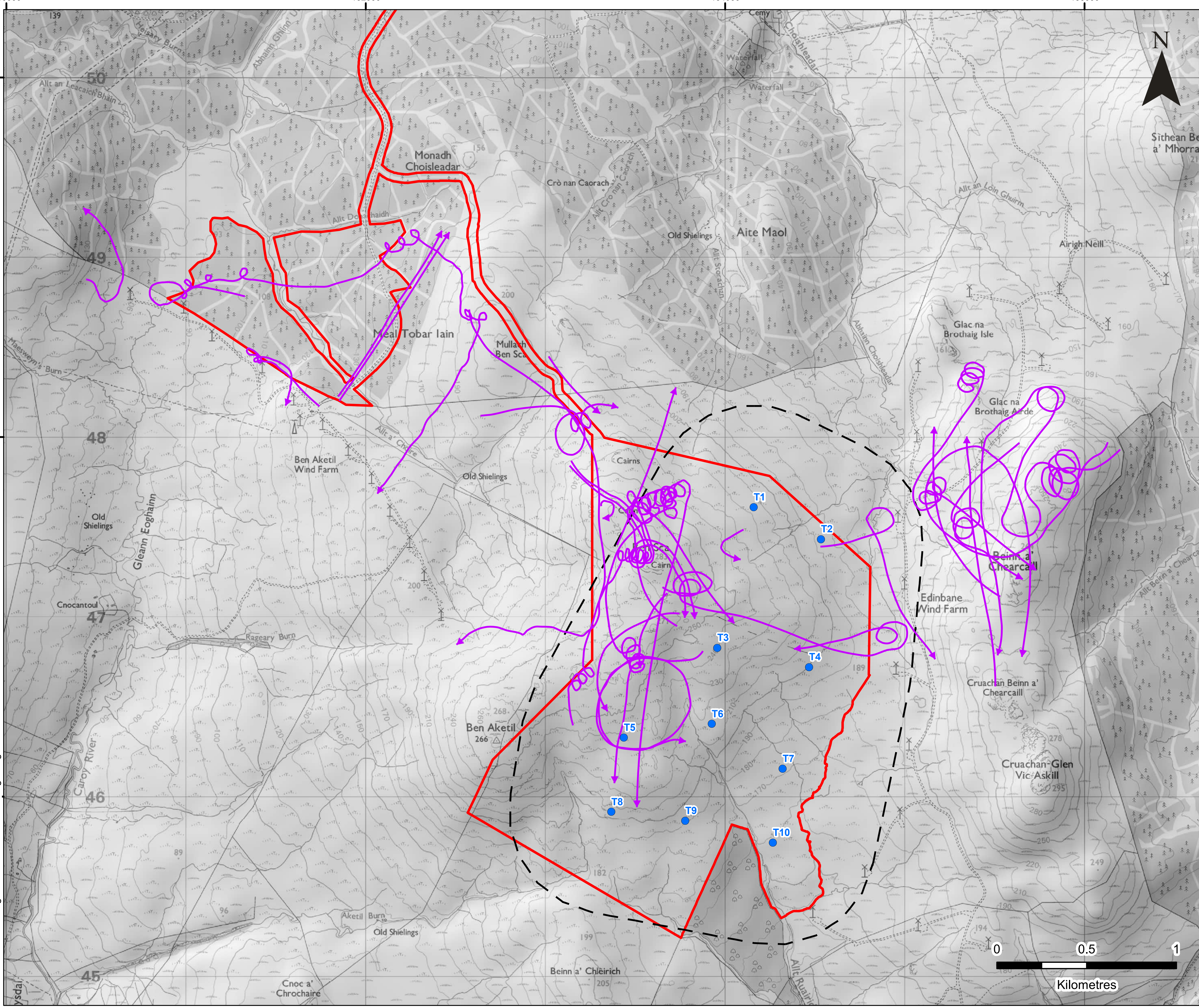
	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	78	14407			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	72	72			
Windfarm area (ha) visible within viewshed (v)1	184.55	269.38			
Observation effort (e*v)	13287.6	19395.36			
TwV rate=TwV/e*v	1.63E-06	0.000206			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.40656	0.59344			
Weighted TwV rate (TwV rate * weight)	6.63E-07	0.000122			
Total weighted occupancy rate		0.000123	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.06306			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.058015			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: annual (a) (footnote 2)		5537.341	hours		
Tw=z*a		321.2512	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		
Step 1.7: Volume swept by windfarm rotors (Vr)					
Bird length (L)		0.28	m		

Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4		685036.2	m3		
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)		1120.781	seconds		
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)		18	m/sec		
t=(d+L)/s		0.254444	seconds		
Step 1.10: Number of rotor transits (N)					
N=Tr/t		4404.815	rotor transits		
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5		0.046875			
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90		185.83	collisions		
Step 3.2: Adjusted using a range of avoidance rates:					
0.98		3.7166	approx one collision every	0.269063	years
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours + 25% nocturnal hours during the period					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.28m, wingspan 0.7m, flight speed= 18m/sec					

Golden Plover Annual Year 1 + Year 2

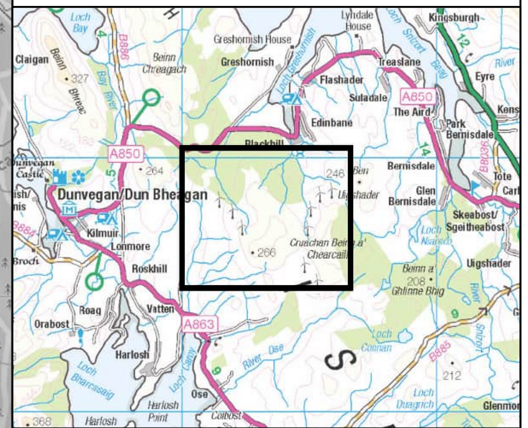
	Viewsheds				
	1	2			
STAGE 1: Estimation of rotor transits					
Step 1.1: Seconds occupancy of the survey risk volume (Tw)1 recorded within each viewshed (TwV)	198	17265			
Step 1.2: Unweighted occupancy rate each viewshed (TwVrate)					
Hours of survey effort (e)	187	183			
Windfarm area (ha) visible within viewshed (v)1	184.55	269.38			
Observation effort (e*v)	34510.85	49296.54			
TwV rate=TwV/e*v	1.59E-06	9.73E-05			
Step 1.3: Weighted occupancy rate (weighted TwV rate)1					
Weight: proportion of total survey effort made at the VP	0.411788	0.588212			
Weighted TwV rate (TwV rate * weight)	6.56E-07	5.72E-05			
Total weighted occupancy rate		5.79E-05	birds seconds per ha/hour		
Mean % activity hr^-1 in wind farm at risk height		0.029648			
Mean % activity hr^-1 in wind farm at rotor height (z)		0.027276			
Step 1.4: Total occupancy of risk volume during surveys (Tw)					
Hours potentially active: annual (a) (footnote 2)		5537.341	hours		
Tw=z*a		151.0373	hours		
Step 1.6: Flight risk volume (Vw)					
Risk volume: Vw=A*h (footnote 3)		7.07E+08	m3		
Step 1.7: Volume swept by windfarm rotors (Vr)					

Bird length (L)	0.28	m			
Rotor-swept volume: Vr=N*π*r2*(d+L) footnote 4	685036.2	m3			
Step 1.8: Bird occupancy of rotor-swept volume (Tr)					
Tr=Tw*(Vr/Vw)	526.9386	seconds			
Step 1.9: Time taken to transit rotor (t)					
Flight speed (s)	18	m/sec			
t=(d+L)/s	0.254444	seconds			
Step 1.10: Number of rotor transits (N)					
N=Tr/t	2070.938	rotor transits			
STAGE 2: Probability of Collision for a bird flying through rotors (p(collision)) from SNH spreadsheet5	0.046875				
STAGE 3: Predicted mortality (birds per year)					
Step 3.1: With no avoidance, turbines operational 90% of the time N*p(collision)*0.90	87.36857	collisions			
Step 3.2: Adjusted using a range of avoidance rates:					
0.98	1.747371	approx one collision every	0.572288	years	
1 The survey risk volume was derived from the windfarm polygon including a precautionary 500m buffer around the turbine rotors.					
2 The total number of daylight hours + 25% nocturnal hours during the period					
3 A= size of windfarm polygon(ha) h= rotor diameter (m)					
4 N= number of turbines, r= rotor radius (m), d= max depth of rotors (m)					
5Assumes bird length=0.28m, wingspan 0.7m, flight speed= 18m/sec					



LEGEND

- Application Site Boundary
- Proposed Turbine Location
- Proposed Turbine Location 569 m Buffer
- WE - White-Tailed Eagle



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BALMEANACH WIND FARM - EIA

TA 9.3

WHITE-TAILED EAGLE FLIGHT LINES (BEN SCA DATA 2018/19)

FIGURE 9.3.1

Scale	Date
1:20,000 @ A3	JULY 2023

11223.00001.0355.0 Figure 9.3.1 White-Tailed Eagle Flight Lines

130000 132000 134000 136000

850000 848000

LEGEND

- Application Site Boundary
- Proposed Turbine Location
- Proposed Turbine Location 569 m Buffer
- HH - Hen Harrier

N

T1 T2 T3 T4 T5 T6 T7 T8 T9 T10

0 0.5 1 Kilometres

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BALMEANACH WIND FARM - EIA

TA 9.3

HEN HARRIER FLIGHT LINES (BEN SCA DATA 2018/19)

FIGURE 9.3.2

Scale 1:20,000 @ A3

Date JULY 2023

11223.00001.0356.0 Figure 9.3.2 Hen Harrier Flight Lines

130000 132000 134000 136000

850000 848000

LEGEND

- Application Site Boundary
- Proposed Turbine Location
- Proposed Turbine Location 569 m Buffer
- EA - Golden Eagle

N

T1 T2 T3 T4 T5 T6 T7 T8 T9 T10

0 0.5 1 Kilometres

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TA 9.3

GOLDEN EAGLE FLIGHT LINES (BEN SCA DATA 2018/19)

FIGURE 9.3.3

Scale 1:20,000 @ A3

Date JULY 2023

11223.00001.0357.0 Figure 9.3.3 Golden Eagle Flight Lines

130000 132000 134000 136000

850000 848000

LEGEND

- Application Site Boundary
- Proposed Turbine Location
- Proposed Turbine Location 569 m Buffer
- GP - Golden Plover

N

T1 T2 T3 T4 T5 T6 T7 T8 T9 T10

0 0.5 1 Kilometres

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TA 9.3

GOLDEN PLOVER FLIGHT LINES (BEN SCA DATA 2018/19)

FIGURE 9.3.4

Scale 1:20,000 @ A3

Date JULY 2023

11223.00001.0358.0 Figure 9.3.4 Golden Plover Flight Lines

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