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Avian Collision Risk Assessment

Drumnahough Wind Farm

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1 INTRODUCTION

1.1 BACKGROUND

Collision with the turbine rotors of onshore wind farms is a potential source of avian mortality. This document has been prepared to assess that risk by using a Collision Risk Model (CRM) for specific target bird species at the proposed Drumnahough Wind Farm site in central County Donegal.

In line with Scottish Natural Heritage (SNH, 2000) guidance, the Band Collision Risk Model (Band *et al*., 2007) was used in this assessment. This model estimates the risk of collision based on a target species' activity levels, flight details, biometrics and behaviour, along with the number, layout and specifications of the proposed turbines. The data for this assessment was obtained from vantage point (VP) surveys carried out on site at the Drumnahough wind farm site from April 2018 to March 2020 inclusive at four fixed vantage point locations.

1.2 BAND MODELLING METHOD

The Band modelling method involves two stages:

- Stage 1: Establishing the number of birds or flights that pass through the air space swept by the turbine rotors. These transits are determined by using either the "Regular or Random flight" model depending on flight activity and behaviour.

- Stage 2: Calculating the probability of a bird being struck when making a transit through a rotor.

The figures obtained in both stages are then multiplied together to give a theoretical annual collision mortality rate based on the supposition that birds make no attempt to avoid collision. However in "real-life" circumstances, birds demonstrate high rates of avoidance - usually 98% to 99% according to SNH (2018). To account for these evasion measures, known avoidance rates are applied as a percentage to the theoretical collision value as a final step.

Band Model values are solely speculative and representative of worst-case estimates, only drawing conclusions by assuming likely levels of active avoidance by specific species. Accordingly, results obtained are dependent on the quality of field observation data and accuracy of the avoidance rates used, and must therefore be interpreted with a certain degree of caution.

2 METHODOLOGY

2.1 FLIGHT DATA

Flight data was recorded from four vantage point (VP) locations from April 2018 to March 2020 (inclusive). A potential collision height (PCH) of between 20m and 180m above ground was established based on the Drumnahough Wind Farm turbines having a maximum blade tip height of 167.5m, and a rotor diameter of 145m (see **Table 5**). This ensured that the PCH was easily within the rotor sweep of the turbine. VP watches were carried out at each VP location for 6 hours per month over a two-year period between April 2018 and March 2020 based on recent SNH guidance (2017).

The VP Arc for each VP is a 180° arc with a radius of 2km from the vantage point location, which represents the theoretical maximum coverage. In the case of VP2, the radius was 2.5km. The viewshed represents the actual area visible to the surveyor at a specified height above ground level from the vantage point location within each VP Arc. GIS computer software was used to generate the viewsheds for each VP. Flight data from the viewshed-mapping for each VP was used to inform the CRM.

Table 1 below presents the details on the viewshed area for each VP while **Figure 1** and

Figure 2 below illustrate the viewshed areas within each VP Arc.

Table 1: Viewshed and vantage point details

Vantage Point	VP Arc (ha)	Viewshed area within VP Arc (ha)	Viewshed coverage within VP Arc (%)	Turbine Buffer Area within Viewshed (ha)	No. of turbines within viewshed	Total survey effort (hrs)
VP1	628	530	84.39	189	4	144
VP2	981	776	79.10	302	8	144
VP3	628	525	83.60	224	3	144
VP4	628	423	67.36	53	1	144

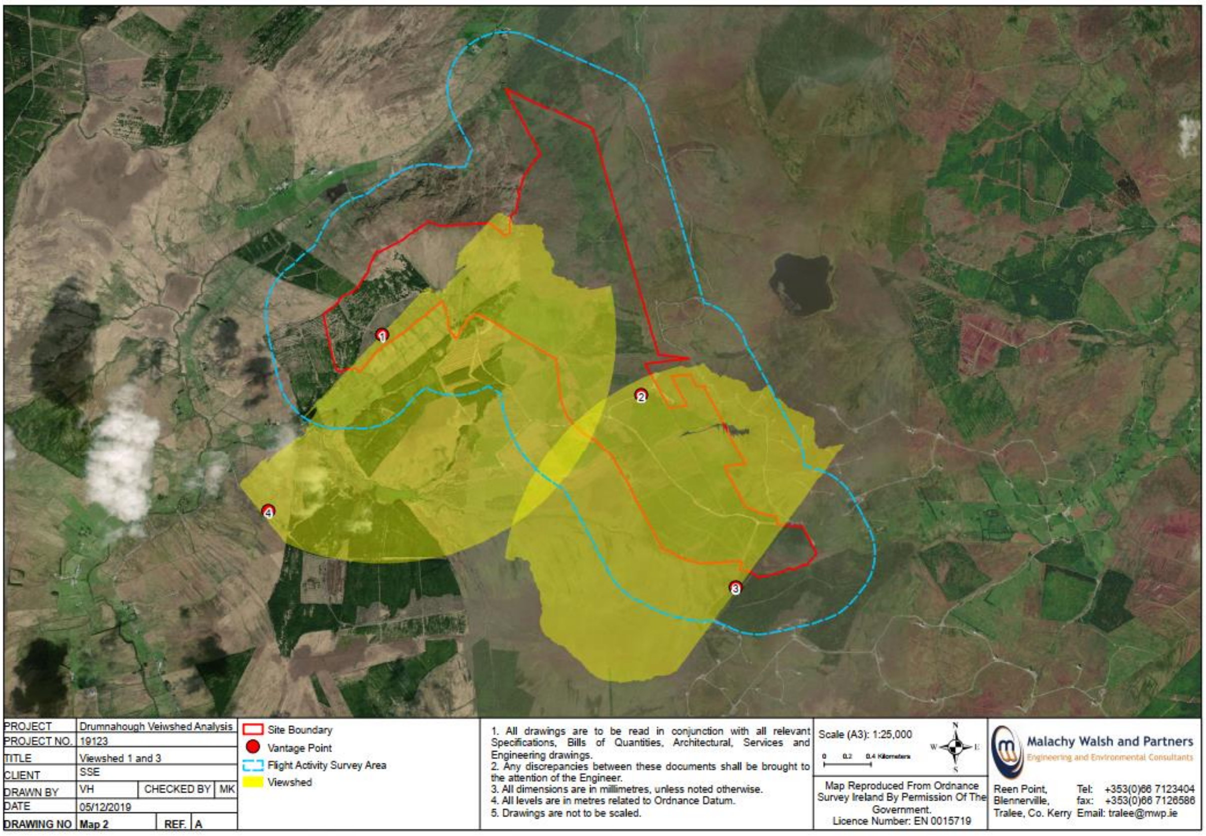

Figure 1: Viewshed maps for VP1 and VP3

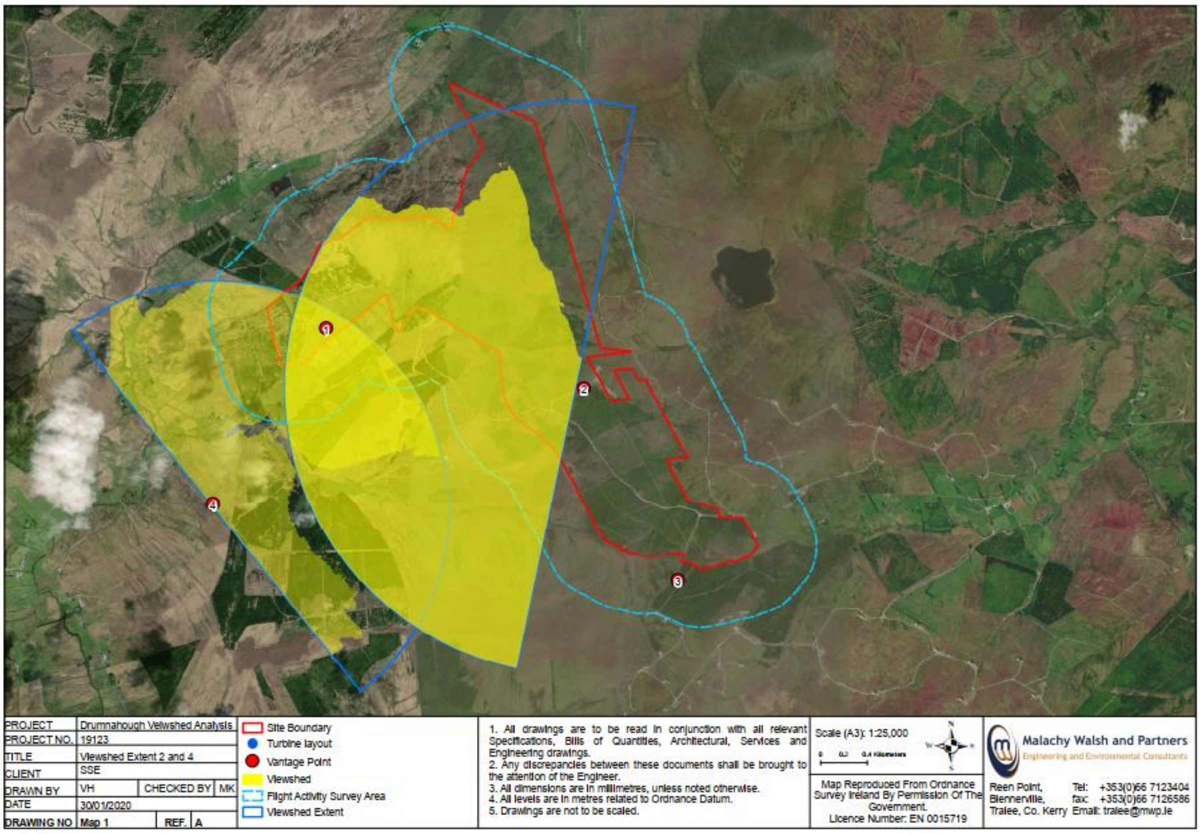

Figure 2: Viewshed maps for VP2 and VP4

The 24 months of data used in the CRM was collected from April 2018 to March 2020 inclusive, thereby providing data on two breeding season cycles and two winter cycles for each species. However, as detailed in **Table 6** below, there are several species whose breeding seasons start before April, thereby resulting in an unavailability of data from the beginning of their respective 2018/19 breeding seasons at Drumnahough. Thus, the final winter cycles of these species also concluded earlier than April yet data was still collected until the end of March 2020 (as described in **Section 2.1**). Therefore, the issue of unavailable data from the beginning of the 2018 breeding season was rectified using the "extra" data created after the final winter cycle in 2020 (refer to **Table 2** below for specifics on the distribution of monthly data for each affected species).

Table 2: Details of monthly breeding season data for species whose breeding seasons begins prior to April

Species	Breeding Season Cycle	Months of Data Used for each Breeding Season
Golden Eagle	1st	April, May, June, July, August (2018) plus February, March (2020)
	2nd	February, March, April, May, June, July, August (2019)
Grey Heron	1st	April, May, June, July, August (2018) plus March (2020)
	2nd	March, April, May, June, July, August (2019)
Hen Harrier	1st	April, May, June, July, August (2018) plus March (2020)
	2nd	March, April, May, June, July, August (2019)
Peregrine	1st	April, May, June, July, August (2018) plus March (2020)
	2nd	March, April, May, June, July, August (2019)

2.2 BIRD BIOMETRICS AND FLIGHT DURATION AT PCH

The amount of time a species was observed flying at heights of between 20 and 180 metres, i.e. within the PCH, is presented in **Table 3**. Flights where the flight height was simply recorded as '>150m' were also included in calculations (i.e. they were deemed to be within the PCH). Species-specific morphometric measurements and flight speeds are also shown in **Table 3** below. Total monthly values of bird-seconds at PCH within all viewsheds are set out in **Table 4.**

Table 3: Bird biometrics, and bird-seconds of species at Potential Collision Height (20-180m)

Species (BTO Code)	Species Length (m)	Species Wingspan (m)	Species mean flight speed (m/s)	Bird-seconds in flight at PCH (20-180m)						Total bird-secs at PCH over 24 Months
				2018/2019			2019/2020			
				Breeding	Winter	12-Month Total	Breeding	Winter	12-Month Total	
Buzzard (BZ)	0.54	1.2	13.3	970	636	1606	527	3171	878	3698
Golden Eagle (EA)	0.82	2.12	11.9	0	0	0	120	1061	1181	1181
Golden Plover (GP)	0.275	0.715	17.9	0	4680	4680	0	0	0	4680
Goosander (GD)	0.62	0.93	19.7	0	300	300	0	0	0	300
Great Black-backed Gull (GB)	0.71	1.67	13.7	330	0	330	195	120	405	735
Grey Heron (H.)	0.94	1.85	12.5	0	0	0	206	0	206	206
Hen Harrier (HH)	0.48	1.1	12	0	0	0	0	180	180	180
Kestrel (K.)	0.34	0.76	10.1	641	120	761	460	1980	2440	3201
Lesser Black-backed Gull (LB)	0.58	1.42	13.1	1599	100	1699	0	0	0	1699
Merlin (ML)	0.28	0.6	11.3	64	0	64	29	0	29	93
Peregrine (PE)	0.42	1.02	12.1	0	0	0	0	15	15	15
Sparrowhawk (SH)	0.33	0.67	10	25	0	25	0	15	15	40

Table 4: Monthly values of bird-seconds spent at PCH (20-180m)

Species	Year	Monthly values of bird-seconds spent at PCH within viewsheds											
		April	May	June	July	August	September	October	November	December	January	February	March
Buzzard	2018/19	600	0	60	12	298	420	0	20	0	0	0	196
	2019/20	3	0	240	0	1274	111	0	45	0	195	0	2820
Golden Eagle	2018/19	0	0	0	0	0	0	0	0	0	0	0	0
	2019/20	120	0	0	0	0	161	0	0	0	900	0	0
Golden Plover	2018/19	0	0	0	0	0	0	0	0	0	0	0	4680
	2019/20	0	0	0	0	0	0	0	0	0	0	0	0
Goosander	2018/19	0	0	0	0	0	0	0	0	0	300	0	0
	2019/20	0	0	0	0	0	0	0	0	0	0	0	0
Great Black-backed Gull	2018/19	0	0	0	90	240	0	0	0	0	0	0	0
	2019/20	195	0	0	0	0	0	0	0	0	0	90	30
Grey Heron	2018/19	0	0	0	0	0	0	0	0	0	0	0	0
	2019/20	206	0	0	0	0	0	0	0	0	0	0	0
Hen Harrier	2018/19	0	0	0	0	0	0	0	0	0	0	0	0
	2019/20	0	0	0	0	0	180	0	0	0	0	0	0
Kestrel	2018/19	0	0	360	0	281	60	60	0	0	0	0	0
	2019/20	0	0	420	40	0	70	1010	705	0	0	195	15
Lesser Black-backed Gull	2018/19	0	1359	240	0	0	0	0	0	0	0	0	100
	2019/20	0	0	0	0	0	0	0	0	0	0	0	0
Merlin	2018/19	0	0	0	64	0	0	0	0	0	0	0	0
	2019/20	12	0	17	0	0	0	0	0	0	0	0	0
Peregrine	2018/19	0	0	0	0	0	0	0	0	0	0	0	0
	2019/20	0	0	0	0	0	0	0	15	0	0	0	0
Sparrowhawk	2018/19	0	0	0	25	0	0	0	0	0	0	0	0
	2019/20	0	0	0	0	0	0	0	0	0	15	0	0

2.3 BAND COLLISION RISK MODELLING

2.3.1 Regular and Random Flight Models – Stage 1

The Stage 1 calculations uses the VP survey data for each of the target species to calculate the number of predicted bird transits to fly through the turbine blade swept areas. Appendix 1 presents the Stage 1 calculations for each of the target species. Stage 1 calculations are carried out using one of two methods based on whether flight activity follows a regular pattern or is random – the "Regular Flight Model" or the "Random Flight Model", respectively.

For predictable flightlines, like those created by geese following a migratory route or those produced by the regular travel of divers to the coast from nest sites, the "Regular Flight Model" is used. This model involves calculating the number of birds flying through the rotor swept area each year.

The "Random Flight Model" is used in cases of irregular flight activity such as that displayed by raptors occupying a recognized territory, or by waders. This model requires calculation of the proportion of time birds were observed flying per unit of survey area.

More information on both Regular and Random Flight Model calculations have been made freely available by the SNH (2000) at: https://www.nature.scot/wind-farm-impacts-birds-calculating-theoretical-collision-risk-assuming-no-avoiding-action.

The recorded flights for target species from the four vantage points (VP1, VP2, VP3, VP4) at the Drumnahough Wind Farm were deemed to be randomly distributed – that is, with a potential to occur anywhere within a viewshed, or with no regular patterns observed. Consequently, the "Random Flight Model" was used for each target species to determine the predicted number of transits through the site.

The proportion of flight time between 20m and 180m for a bird species for each of the 4 VPs was calculated. If multiple birds were observed in one flight, the seconds spent at PCH were calculated by multiplying the number of birds observed per flight by the duration of the flight at PCH (in line with SNH, 2000).

The hours that a species may potentially be active in either a breeding or a non-breeding season was calculated to include hours of daylight, one hour before sunrise, and one hour after sunset (dusk) for all species with the exception of goosander and golden plover (*Pluvialis apricaria*). For these two species it was calculated as hours of daylight, one hour before sunrise, one hour after sunset (dusk) and 25% of the night (SHN, 2017). All calculations of the hours available for potential activity were carried out using values based on data obtained from timeanddate.com (2020) and Wilson *et al.* (2015).

This flight activity was used to calculate the number of bird passes through the rotor for each VP in turn and per turbine within each viewshed before being calculated for the entire 12-turbine wind farm. The Stage 1 calculation was carried out for each season - breeding and wintering - and for each species.

2.3.2 Probability of Collision – Stage 2

Stage 2 calculates the probability of a bird flying through the rotor being struck, and is determined using the same method for both regular and random flightlines using a publicly available SNH collision risk probability model spreadsheet available at: https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision.

The spreadsheet provides for a scenario in which the bird is either flapping or gliding, and where the transit is either upwind or downwind. For collision risk assessment, the mean probability of both flapping and gliding behaviour was used, with the exception of goosander (*Mergus merganser*) where only flapping behaviour was considered (see **Table 9** below). For a detailed explanation of Stage 2 calculations see Band *et al*. (2007). A completed spreadsheet of Stage 2 calculations for buzzard (*Buteo buteo*) is included in **Appendix 1** as an example.

For Stage 2 the probability of collision depends on the size of the bird (length and wingspan), the breadth and pitch of the turbine blades, the rotation speed of the turbine, and the flight speed of the bird (Band *et al*., 2007). **Table 5** below lists the wind farm and turbine characteristics used in this analysis. Values for the mean pitch of a turbine blade (degrees), the maximum chord (metres), and the rotational speed (rotations per minute) were obtained from a senior wind farm engineer with Malachy Walsh and Partners based on knowledge and specifications of the proposed turbine dimensions.

Table 5. Turbine technical parameters

Parameter	Specification
Proposed number of turbines	12
Number of blades per turbine rotor	3
Rotor diameter (metres)	145
Rotor radius (metres)	72.5
Hub height (metres)	95
Maximum height to blade tip (metres)	167.5
Minimum height to blade tip (metres)	22.5
Swept area per turbine (metres^2)	14527
Mean pitch of blade (degrees)	5
Maximum chord (metres)	4.1
Rotational speed (rotations per minute)	5.6 - 14.0
Mean rotational speed (rotation per minute)	9.8
Mean rotational period (seconds)	6.12
Turbine operational time (%)	85

Bird biometric parameters (**Table 3**, above) were obtained from Wilson *et al*. (2015), Alerstam *et al*. (2007), and the British Trust for Ornithology (BTO) (2000).

2.3.3 Calculating Collision Risk

For each target species included in the CRM, collision risk predictions were calculated for both relevant seasonal periods within each 12-month cycle (see **Table 6** for the seasonal divisions for each species). The sum of these separate summer and winter CRM results were taken as the predicted annual collision risk rather than using results from a single all-year CRM. This was to ensure that any potential underestimation or overestimation for a species risk of collision was minimised as much as possible i.e. to increase the precision of the CRM. For example, all sightings of buzzard are likely to be of resident birds from the same population. However, during winter some birds may disperse from the area meaning that a single 12-month CRM would likely underestimate the risk of collision. Conversely, local golden plover are part of a wintering population so producing a single all-year CRM would likely overestimate collision risk of this species.

Table 6: Seasonal divisions for species (British Trust for Ornithology (BTO) (2000), SNH (2017) and Wilson *et al*. (2015))

Species	Breeding Season	Winter Season
Buzzard	April to August	September to March
Golden Eagle	February to August	September to January
Golden Plover	April to August	September to March
Goosander	April to August	September to March
Great Black-backed Gull	April to August	September to March
Grey Heron	March to August	September to February
Hen Harrier	March to August	September to February
Kestrel	April to August	September to March
Lesser Black-backed Gull	April to August	September to March
Merlin	April to July	August to March
Peregrine	March to August	September to February
Sparrowhawk	April to August	September to February

Collision data derived from Stage 1 and Stage 2 were multiplied together to calculate the risk of collision for the target bird species per season. Multiplying Stage 1 by Stage 2 produces a predicted collision mortality rate that assumes birds take no action to avoid collision. In practice however, birds probably show a very high degree of collision avoidance which dramatically lowers predicted mortality (Band *et al*., 2007). An avoidance rate was applied to the collision risk, which considerably reduces the predicted risk. The collision risk was then multiplied by 30 years to calculate the risk over the lifetime of the wind farm for each season. Following this, the winter and breeding results were added to estimate the risk per year.

3 RESULTS

The following target species were observed flying at the potential collision risk height at Drumnahough over the two year survey period:

- Buzzard (*Buteo buteo*)
- Golden Eagle (*Aquila chrysaetos*)
- Golden Plover (*Pluvialis apricaria*)
- Goosander (*Mergus merganser*)
- Great Black-backed Gull (*Larus marinus*)
- Hen Harrier (*Circus cyaneus*)
- Kestrel (*Falco tinnunculus*)
- Grey Heron (*Ardea cinerea*)
- Lesser Black-backed Gull (*Larus fuscus*)
- Merlin (*Falco columbarius*)
- Peregrine (*Falco peregrinus*)
- Sparrowhawk (*Accipiter nisus*)

Grey heron is a green-listed species in Ireland and is classed as least conservation concern but was also included in this collision risk assessment as it is considered to be a wind farm-sensitive species.

3.1 STAGE 1 CALCULATIONS RESULTS

Table 7 and **Table 8** below show the results of Stage 1 calculations – the number of birds estimated to fly through the blades of the proposed turbines at the Drumnahough Wind Farm. **Table 7** presents the number of annual transits predicted to occur within the viewshed of each VP during each breeding season and winter season. **Table 8** gives further details on the mean predicted transits through each turbine per season, and mean predicted transits per season through all turbines across the proposed 12-turbine site.

Table 7: Predicted transits per turbine within the viewshed of each VP for the 2016/17 and 2017/18 breeding seasons and the 2016/17 and 2017/18 winter seasons.

Species	Year	VP1			VP2			VP3			VP4			Total over 12 Months
		Breeding	Winter	Total	Breeding	Winter	Total	Breeding	Winter	Total	Breeding	Winter	Total	
Buzzard	2018/2019	0	2.51	2.51	1.64	0	1.64	0.23	0	0.23	20.24	7.07	27.31	31.69
	2019/2020	0.06	38.15	38.21	0	0	0	0	0	0	12.71	3.13	15.84	54.05
Golden Eagle	2018/2019	0	0	0	0	0	0	0	0	0	0	0	0	0
	2019/2020	0	11.76	11.76	1.49	1.33	2.82	0	0	0	0	0	0	14.58
Golden Plover	2018/2019	0	67.71	67.71	0	0	0	0	0	0	0	0	0	67.71
	2019/2020	0	0	0	0	0	0	0	0	0	0	0	0	0
Goosander	2018/2019	0	0	0	0	0	0	0	0	0	0	5.60	5.60	5.60
	2019/2020	0	0	0	0	0	0	0	0	0	0	0	0	0
Great Black-backed Gull	2018/2019	4.79	0	4.79	0	0	0	0	0	0	2.25	0	2.25	7.04
	2019/2020	0	0	0	0	0.27	0.27	3.93	0	3.93	0	1.49	1.49	5.69
Grey Heron	2018/2019	0	0	0	0	0	0	0	0	0	0	0	0	0
	2019/2020	3.62	0	3.62	0	0	0	0	0	0	0	0	0	3.62
Hen Harrier	2018/2019	0	0	0	0	0	0	0	0	0	0	0	0	0
	2019/2020	0	2.10	2.10	0	0	0	0	0	0	0	0	0	2.10
Kestrel	2018/2019	2.60	0	2.60	0	0.40	0.40	2.54	0	2.54	8.21	0.73	8.94	14.48
	2019/2020	6.76	13.2	19.96	0	0.07	0.07	0	4.13	4.13	0	2.56	2.56	26.72
Lesser Black-backed Gull	2018/2019	0	0	0	3.13	0.86	3.99	0	0	0	32.48	0	32.48	36.47
	2019/2020	0	0	0	0	0	0	0	0	0	0	0	0	0
Merlin	2018/2019	0	0	0	0.73	0	0.73	0	0	0	0	0	0	0.73
	2019/2020	0	0	0	0.33	0	0.33	0	0	0	0	0	0	0.33
Peregrine	2018/2019	0	0	0	0	0	0	0	0	0	0	0	0	0
	2019/2020	0	0	0	0	0	0	0	0.17	0.17	0	0	0	0.17
Sparrowhawk	2018/2019	0	0	0	0	0	0	0.37	0	0.37	0	0	0	0.37
	2019/2020	0	0	0	0	0.10	0.10	0	0	0	0	0	0	0.10

Table 8: Mean number of predicted transits per turbine per season, and mean number of predicted transits across the entire wind farm site per season.

Species	Year	Mean transits predicted per turbine per season			Mean transits predicted across entire proposed wind farm site per season		
		Breeding	Winter	Entire Year	Breeding	Winter	Entire Year
Buzzard	2018/2019	5.53	4.28	9.81	66.33	51.36	117.69
	2019/2020	3.19	38.94	42.13	38.32	467.24	505.56
Golden Eagle	2018/2019	0	0	0	0	0	0
	2019/2020	0.37	3.27	3.64	4.48	39.27	43.75
Golden Plover	2018/2019	0	16.93	16.93	0	203.13	203.13
	2019/2020	0	0	0	0	0	0
Goosander	2018/2019	0	1.40	1.40	0	16.81	16.81
	2019/2020	0	0	0	0	0	0
Great Black-backed Gull	2018/2019	1.76	0	1.76	21.11	0	21.11
	2019/2020	0.98	0.44	1.42	11.78	5.28	17.06
Grey Heron	2018/2019	0	0	0	0	0	0
	2019/2020	0.90	0	0.90	10.85	0	10.85
Hen Harrier	2018/2019	0	0	0	0	0	0
	2019/2020	0	0.52	0.52	0	6.29	6.29
Kestrel	2018/2019	3.34	0.28	3.62	40.04	3.39	43.43
	2019/2020	1.69	4.99	6.68	20.29	59.84	80.13
Lesser Black-backed Gull	2018/2019	8.90	0.22	9.12	106.82	2.59	109.41
	2019/2020	0	0	0	0	0	0
Merlin	2018/2019	0.18	0	0.18	2.18	0	2.18
	2019/2020	0.08	0	0.08	0.99	0	0.99
Peregrine	2018/2019	0	0	0	0	0	0
	2019/2020	0	0.04	0.04	0	0.51	0.51
Sparrowhawk	2018/2019	0.09	0	0.09	1.10	0	1.10
	2019/2020	0	0.02	0.02	0	0.30	0.30

3.2 STAGE 2 CALCULATIONS RESULTS

The second stage of calculations determines the percentage risk of collision of a bird flying through a rotating turbine, the results of which are presented in **Table 9** below.

The highest values or "worst-case scenario" collision percentages occur when the bird flies upwind using flapping behaviour whilst the turbine is rotating at its fastest speed. Conversely, "best-case scenario" or lowest collision percentage values occur when a bird flies downwind using a gliding flight whilst the turbine is rotating at its slowest speed. The Collision Risk Assessment in this case used the mean of these two scenarios for each species, the values of which can be found in the final column of **Table 9** below.

Table 9: Probability of collision – Stage 2 calculation outputs

Species	Flapping bird		Gliding bird		Mean probability of collision
	upwind	downwind	upwind	downwind	
Buzzard	6.4%	4.9%	6.2%	4.7%	5.55%
Golden Eagle	8.1%	6.4%	7.7%	6.1%	7.10%
Golden Plover	5.0%	3.9%	4.7%	3.7%	4.30%
Goosander	5.6%	4.7%	-	-	5.10%
Great Black-backed Gull	7.1%	5.6%	6.7%	5.3%	6.15%
Grey Heron	8.2%	6.6%	7.9%	6.3%	7.25%
Hen Harrier	6.4%	4.8%	6.2%	4.6%	5.50%
Kestrel	6.1%	4.1%	6.0%	4.1%	5.10%
Lesser Black-backed Gull	6.7%	5.2%	6.4%	4.9%	6.80%
Merlin	5.6%	3.8%	5.5%	3.8%	4.65%
Peregrine	6.1%	4.5%	6.0%	4.3%	5.20%
Sparrowhawk	6.1%	4.1%	6.0%	4.1%	5.08%

3.3 COLLISION RATES

The theoretical collision rates for each species per season, based on the assumption that the bird makes no attempt to avoid the moving rotors, are presented in **Table 10** below. Rates were calculated using the data collected from two consecutive years of bird surveys at the Drumnahough Wind Farm from 2018 to 2020.

Table 10: Predicted collision rates per season assuming no avoidance measures taken by bird

Species	Collision probability	Year	Predicted collisions per season with no avoidance measures applied		
			Breeding	Winter	Entire Year
Buzzard	5.55%	**2018/2019**	3.68	2.85	6.53
		2019/2020	2.22	25.93	28.15
Golden Eagle	7.10%	**2018/2019**	0	0	0
		2019/2020	0.32	2.79	3.11
Golden Plover	4.30%	**2018/2019**	0	8.73	8.73
		2019/2020	0	0	0
Goosander	5.10%	**2018/2019**	0	0.86	0.86
		2019/2020	0	0	0
Great Black-backed Gull	6.15%	**2018/2019**	1.30	0	1.30
		2019/2020	0.72	0.32	1.04
Grey Heron	7.25%	**2018/2019**	0	0	0
		2019/2020	0.77	0	0.77
Hen Harrier	5.50%	**2018/2019**	0	0	0
		2019/2020	0	0.35	0.35
Kestrel	5.10%	**2018/2019**	2.04	0.17	2.21
		2019/2020	1.04	3.05	4.09
Lesser Black-backed Gull	5.80%	**2018/2019**	6.20	0.15	6.35
		2019/2020	0	0	0
Merlin	4.65%	**2018/2019**	0.10	0	0.10
		2019/2020	0.05	0	0.05
Peregrine	5.20%	**2018/2019**	0	0	0
		2019/2020	0	0.03	0.03
Sparrowhawk	5.08%	**2018/2019**	0.06	0	0.06
		2019/2020	0	0.02	0.02

3.3.1 Collision Rates with Application of Specific Avoidance Rates

The final phase of the collision risk assessment is to apply avoidance rates to the predicted collision rates from **Table 10**, above, to correct for a bird's ability to identify and move around turbines. The avoidance rates used were those recommended by SNH (2018).

The seasonal values for each species for each year were added together to give the predicted number of annual collisions for both the 12-month datasets. Finally, the number of collisions predicted to occur over the life-span of the wind farm (30 years) was calculated (refer to **Table 11**, below).

Table 11: Number of collisions predicted with the application of avoidance rates as specified by SNH (2018).

Species	Avoidance Rate	Year	Predicted collisions per season			Predicted collisions over 30-year lifetime of proposed wind farm		
			Breeding	Winter	Entire Year	Breeding	Winter	Entire Year
Buzzard	98%	2018/2019	0.074	0.057	0.131	2.219	1.710	3.929
		2019/2020	0.044	0.519	0.563	1.333	15.559	16.892
Golden Eagle	99%	2018/2019	0	0	0	0	0	0
		2019/2020	0.003	0.024	0.027	0.083	0.727	0.813
Golden Plover	98%	2018/2019	0	0.175	0.175	0	5.241	5.241
		2019/2020	0	0	0	0	0	0
Goosander	98%	2018/2019	0	0.017	0.017	0	0.514	0.514
		2019/2020	0	0	0	0	0	0
Great Black-backed Gull	98%	2018/2019	0.026	0	0.026	0.780	0	0.780
		2019/2020	0.014	0.006	0.020	0.435	0.195	0.630
Grey Heron	98%	2018/2019	0	0	0	0	0	0
		2019/2020	0.016	0	0.016	0.472	0	0.472
Hen Harrier	99%	2018/2019	0	0	0	0	0	0
		2019/2020	0	0.003	0.003	0	0.104	0.104
Kestrel	95%	2018/2019	0.102	0.009	0.111	3.063	0.260	3.323
		2019/2020	0.052	0.153	0.205	1.553	4.578	6.131
Lesser Black-backed Gull	98%	2018/2019	0.124	0.003	0.127	3.717	0.090	3.807
		2019/2020	0	0	0	0	0	0
Merlin	98%	2018/2019	0.002	0	0.002	0.061	0	0.061
		2019/2020	0.001	0	0.001	0.028	0	0.028
Peregrine	98%	2018/2019	0	0	0	0	0	0
		2019/2020	0	0.001	0.001	0	0.016	0.016
Sparrowhawk	98%	2018/2019	0.001	0	0.001	0.034	0	0.034
		2019/2020	0	0.0003	0.0003	0	0.009	0.009

Table 12 below presents the final collision risk modelling results for each species. For all species, the annual number of collisions predicted to occur is less than one bird – that is to say, it is predicted that less than one bird a year will die due to turbine collision. The amount of predicted collisions per 30 years is also relatively low for most species. There are, however, two species with comparatively high rates of predicted collisions over 30 years, namely buzzard and kestrel.

Table 12: Mean number of predicted collisions per year and per 30 years, using 24 months of data and the application of avoidance rates specified by SNH (2018).

Species	Mean no. of predicted collisions per year	Mean no. of predicted collisions per 30 years	Equivalent to 1 bird every x (years)
Buzzard	0.347	10.411	2.88
Golden Eagle	0.014	0.495	60.61
Golden Plover	0.088	2.621	11.45
Goosander	0.009	0.257	116.73
Great Black-backed Gull	0.023	0.705	42.55
Grey Heron	0.008	0.236	127.11
Hen Harrier	0.002	0.052	576.92
Kestrel	0.158	4.727	6.35
Lesser Black-backed Gull	0.064	1.904	57.12
Merlin	0.002	0.045	666.67
Peregrine	0.001	0.008	3750
Sparrowhawk	0.001	0.005	6000

4 CONCLUSION

A CRM has been completed for the proposed Drumnahough Wind Farm development. The Band method for collision risk modelling operates using many assumptions, particularly regarding bird behaviour and characteristics, and relies on accurate information regarding species avoidance rates, turbine specifications, and the recording of data.

Kestrel, a year-round resident of the area, has a seemingly high prediction of 4.727 collisions every 30 years. This value, however, is liable to be rather tenuous as a large percentage of recorded kestrel flight activity is likely to have involved hovering birds, and the CRM operates on the assumption that all birds are constantly moving. Therefore, the mean flight speed of kestrel used in the CRM may not be indicative of mean flight speed of the kestrels observed during the surveys. Kestrels fly relatively quickly between hovering spots which can lead to an underestimation of their speed resulting in a greater predicted risk of collision than would likely occur in "real-life" scenarios.

With more than 10 collisions predicted every thirty years, buzzard is by far the species with the highest predicted collision risk and it is clear from the VP surveys that there is a considerable amount of buzzard activity in the area with much of it seemingly at PCH. However, as discussed above, collision risk modelling is dependent on many assumptions and can be prone to biases.

In view of the assumptions and limitations presented by collision risk modelling, the resulting predicted collisions should only be considered indicative and never definitive, and ought to be used solely as a comparative tool rather than an accurate indicator of mortality risk. Therefore, it is perhaps safest to interpret the results of CRM analyses as indicating only the order of magnitude of predicted collision risk.

5 REFERENCES

Alerstam, T., Rosén, M., Bäckman, J., Ericson, P.G. & Hellgren, O.(2007). Flight speeds among bird species: allometric and phylogenetic effects. *PLoS biology*, *5*(8), p.e197.

Band, W., Madders, M. & Whitfield, D.P. (2007) "Developing field and analytical methods to assess avian collision risk at wind farms", In De Lucas, M. Et al. (eds.) *Birds and wind farms: Risk assessment and mitigation*. Madrid: Quercus/Libreria Linneo, pp.259-275.

British Trust for Ornithology (2018). *Welcome to BirdFacts*. Available at: https://www.bto.org/understanding-birds/birdfacts.

Masden, E. A., & Cook, A. S. C. P. (2016). Avian collision risk models for wind energy impact assessments. *Environmental Impact Assessment Review*, 56, 43-49.

Scottish Natural Heritage (2000). *Windfarms and Birds - Calculating a theoretical collision risk assuming no avoiding action. SNH Guidance Note*. Available at http://www.snh.gov.uk/docs/C205425.pdf

Scottish Natural Heritage (2017). Recommended Bird Survey Methods to Inform Impact Assessment on Onshore Wind Farms. Version 2. Available at: https://www.nature.scot/recommended-bird-survey-methods-inform-impact-assessment-onshore-windfarms

Scottish Natural Heritage (2018). *Use of avoidance rates in the SNH wind farm Collision Risk Model*. Available at: https://www.nature.scot/wind-farm-impacts-birds-use-avoidance-rates-snh-wind-farm-collision-risk-model.

timeanddate.com (2020). *Letterkenny, Ireland – Sunrise, Sunset, and Daylength*. Available at: https://www.timeanddate.com/sun/ireland/letterkenny

Wilson, M., Fernández-Bellon, D., Irwin, S. & O'Halloran, J. (2015). *The interactions between Hen Harriers and wind turbines: WINDHARRIER - Final Project Report*. School of Biological Earth & Environmental Sciences at University College Cork (BEES). Available at: https://www.ucc.ie/en/media/research/planforbio/forestecology/WINDHARRIERFinalProjectReport.pdf

Appendix 1: Calculation Spreadsheets

Buzzard, Breeding VP Surveys: April 2018 - Aug 2018						
Measurements	Code	Value				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Buzzard length (metres)	l	0.54				
Average flight speed of Buzzard (m/s)	v	13.3				
Wingspan (m)		1.2				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 5 months (secs)	s		108000	108000	108000	108000
Total flight-time between 20 - 180m (bird-secs)	PCH		0	124	12	834
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2720	2720	2720	2720
Stage 1 Calculations						
Measurements	Code	Calculation				
Proportion of flight-time betwen 20 - 180m	t1	PCH/s	0.0000	0.0011	0.0001	0.0077
Flight activity per visible unit of area	F	t1/Avp	0	1.4796E-06	2.1164E-07	1.8256E-05
Proportion of time in risk area	Trisk	F*Arisk	0	0.00044683	4.7407E-05	0.00096756
Bird occupancy of risk area	n	Trisk*Ba	0	1.21537992	0.12894815	2.63176254
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	x*(Pi*r^2(d+l))	269479.3216	538958.643	202109.491	67369.8304
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	0	5.38511587	0.28886059	8.30559566
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.34887218	0.34887218	0.34887218	0.34887218
Number of bird passes through the rotor during survey period	N	b/t2	0	15.4357847	0.82798403	23.8069875
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	0	13.120417	0.70378642	20.2359394
Number of transits per turbine within viewshed	TnT	Tn/x	0	1.64005212	0.23459547	20.2359394
Average TnT of all VP's	ATnT	(TnT_1+TnT_2+TnT_3+.....)/4	5.527646754			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	66.33176104			
		Collision Probability (Stage 2)	**5.55%**			
		Collisions during study period	T*Collision Probability	3.68141274		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.07362825		
		Over 30-year duration of windfarm	*30	**2.20884764**		

Buzzard, Winter VP Surveys: Sep 2018 - March 2019						
Measurements	Code	Value				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Buzzard length (metres)	l	0.54				
Average flight speed of Buzzard (m/s)	v	13.3				
Wingspan (m)		1.2				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 7 months (secs)	s		151200	151200	151200	151200
Total flight-time between 20 - 180m (bird-secs)	PCH		196	0	0	440
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2521	2521	2521	2521
Stage 1 Calculations						
Measurements	Code	Calculation				
Proportion of flight-time betwen 20 - 180m	t1	PCH/s	0.0013	0.0000	0.0000	0.0029
Flight activity per visible unit of area	F	t1/Avp	2.44584E-06	0	0	6.88E-06
Proportion of time in risk area	Trisk	F*Arisk	0.000462264	0	0	0.0003646
Bird occupancy of risk area	n	Trisk*Ba	1.165367925	0	0	0.9191983
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	269479.3216	538958.64	202109.49	67369.83
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	4.125353796	0	0	2.9009037
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.34887218	0.3488722	0.3488722	0.3488722
Number of bird passes through the rotor during survey period	N	b/t2	11.82482877	0	0	8.3150904
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	10.05110445	0	0	7.0678269
Number of transits per turbine within viewshed	TnT	Tn/x	2.512776113	0	0	7.0678269
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	4.279732829			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	51.35679395			
		Collision Probability (Stage 2)	**5.55%**			
		Collisions during study period	T*Collision Probability	2.8503021		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.057006		
		Over 30-year duration of windfarm	*30	**1.7101812**		

Buzzard, Breeding VP Surveys: April 2019 - Aug 2019						
Measurements	**Code**	**Value**				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Buzzard length (metres)	l	0.54				
Average flight speed of Buzzard (m/s)	v	13.3				
Wingspan (m)		1.2				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	**2**	**3**	**4**
Survey time over 5 months (secs)	s		108000	108000	108000	108000
Total flight-time between 20 - 180m (bird-secs)	PCH		3	0	0	524
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2720	2720	2720	2720
Stage 1 Calculations						
Measurements	**Code**	**Calculation**				
Proportion of flight-time betwen 20 - 180m	t1	PCH/s	0.0000	0.0000	0.0000	0.0049
Flight activity per visible unit of area	F	t1/Avp	5.24109E-08	0	0	1.147E-05
Proportion of time in risk area	Trisk	F*Arisk	9.90566E-06	0	0	0.00060792
Bird occupancy of risk area	n	Trisk*Ba	0.026943396	0	0	1.65352946
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	269479.3216	538958.643	202109.491	67369.8304
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	0.095378498	0	0	5.21838384
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.34887218	0.34887218	0.34887218	0.34887218
Number of bird passes through the rotor during survey period	N	b/t2	0.273390952	0	0	14.9578675
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	0.23238231	0	0	12.7141874
Number of transits per turbine within viewshed	TnT	Tn/x	0.058095577	0	0	12.7141874
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	3.193070733			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	38.3168488			
		Collision Probability (Stage 2)	**5.80%**			
		Collisions during study period	T*Collision Probability	2.22237723		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.04444754		
		Over 30-year duration of windfarm	*30	**<u>1.33342634</u>**		

Buzzard, Winter VP Surveys: Sep 2019 - March 2020

Measurements	Code	Value				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Buzzard length (metres)	l	0.54				
Average flight speed of Buzzard (m/s)	v	13.3				
Wingspan (m)		1.2				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 7 months (secs)	s		151200	151200	151200	151200
Total flight-time between 20 - 180m (bird-secs)	PCH		2976	0	0	195
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2521	2521	2521	2521
Stage 1 Calculations						
Measurements	Code	Calculation				
Proportion of flight-time betwen 20 - 180m	t1	PCH/s	0.0197	0.0000	0.0000	0.0013
Flight activity per visible unit of area	F	t1/Avp	3.71369E-05	0	0	3.049E-06
Proportion of time in risk area	Trisk	F*Arisk	0.007018868	0	0	0.0001616
Bird occupancy of risk area	n	Trisk*Ba	17.69456604	0	0	0.407372
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	269479.3216	538958.64	202109.49	67369.83
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	62.63802498	0	0	1.2856278
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.34887218	0.3488722	0.3488722	0.3488722
Number of bird passes through the rotor during survey period	N	b/t2	179.5443389	0	0	3.6850969
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	152.612688	0	0	3.1323324
Number of transits per turbine within viewshed	TnT	Tn/x	38.15317201	0	0	3.1323324
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	38.9362551			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	467.2350612			
		Collision Probability (Stage 2)	**5.55%**			
		Collisions during study period	T*Collision Probability	25.931546		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.5186309		
		Over 30-year duration of windfarm	*30	**15.558928**		

Golden Eagle, Breeding VP Surveys: Feb 2019 - Aug 2019						
Measurements	**Code**	**Value**				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Golden Eagle length (metres)	l	0.82				
Average flight speed of Golden Eagle (m/s)	v	11.9				
Wingspan (m)		2.12				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 7 months (secs)	s		151200	151200	151200	151200
Total flight-time between 20 - 180m (bird-secs)	PCH		0	120	0	0
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		3478	3478	3478	3478
Stage 1 Calculations						
Measurements	**Code**	**Calculation**				
Proportion of flight-time betwen 20 - 180m	t1	PCH/s	0.0000	0.0008	0.0000	0.0000
Flight activity per visible unit of area	F	t1/Avp	0	1.0227E-06	0	0
Proportion of time in risk area	Trisk	F*Arisk	0	0.00030887	0	0
Bird occupancy of risk area	n	Trisk*Ba	0	1.07424726	0	0
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	285741.0048	571482.01	214305.754	71435.2512
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	0	5.04701242	0	0
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.413445378	0.41344538	0.41344538	0.41344538
Number of bird passes through the rotor during survey period	N	b/t2	0	12.2072048	0	0
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	0	10.3761241	0	0
Number of transits per turbine within viewshed	TnT	Tn/x	0	1.29701551	0	0
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	0.324253878			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	3.891046538			
		Collision Probability (Stage 2)	**7.10%**			
		Collisions during study period	T*Collision Probability	0.2762643		
		Collisions during study period with 99% Avoidance Rate	*0.01	0.00276264		
		Over 30-year duration of windfarm	*30	**0.08287929**		

Golden Eagle, Winter VP Surveys: Sep 2019 - Jan 2020

Measurements	Code	Value				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Golden Eagle length (metres)	l	0.82				
Average flight speed of Golden Eagle (m/s)	v	11.9				
Wingspan (m)		2.12				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 5 months (secs)	s		108000	108000	108000	108000
Total flight-time between 20 - 180m (bird-secs)	PCH		910	151	0	0
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		1762	1762	1762	1762

Stage 1 Calculations

Measurements	Code	Calculation				
Proportion of flight-time betwen 20 - 180m	t1	PCH/s	0.0084	0.0014	0.0000	0.0000
Flight activity per visible unit of area	F	t1/Avp	1.5898E-05	1.8017E-06	0	0
Proportion of time in risk area	Trisk	F*Arisk	0.003004717	0.00054412	0	0
Bird occupancy of risk area	n	Trisk*Ba	5.294311321	0.95874766	0	0
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	285741.0048	571482.01	214305.754	71435.2512
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	19.87260212	4.50437393	0	0
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.413445378	0.41344538	0.41344538	0.41344538
Number of bird passes through the rotor during survey period	N	b/t2	48.0658466	10.8947256	0	0
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	40.85596961	9.26051673	0	0
Number of transits per turbine within viewshed	TnT	Tn/x	10.2139924	1.15756459	0	0
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	2.842889248			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	34.11467098			
		Collision Probability (Stage 2)	**7.10%**			
		Collisions during study period	T*Collision Probability	2.42214164		
		Collisions during study period with 99% Avoidance Rate	*0.01	0.02422142		
		Over 30-year duration of windfarm	*30	**0.72664249**		

Golden Plover, Winter VP Surveys: Sep 2018 - March 2019						
Measurements	**Code**	**Value**				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Golden Plover length (metres)	l	0.54				
Average flight speed of Golden Plover (m/s)	v	13.3				
Wingspan (m)		1.2				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	**2**	**3**	**4**
Survey time over 7 months (secs)	s		151200	151200	151200	151200
Total flight-time between 20 - 180m (bird-secs)	PCH		4680	0	0	0
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2845	2845	2845	2845
Stage 1 Calculations						
Measurements	**Code**	**Calculation**				
Proportion of flight-time betwen 20 - 180m	t1	PCH/s	0.0310	0.0000	0.0000	0.0000
Flight activity per visible unit of area	F	t1/Avp	5.84007E-05	0	0	0
Proportion of time in risk area	Trisk	F*Arisk	0.011037736	0	0	0
Bird occupancy of risk area	n	Trisk*Ba	31.40235849	0	0	0
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	x*(Pi*r^2(d+l))	269479.3216	538958.643	202109.491	67369.8304
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	111.1630379	0	0	0
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.34887218	0.34887218	0.34887218	0.34887218
Number of bird passes through the rotor during survey period	N	b/t2	318.635432	0	0	0
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	270.8401172	0	0	0
Number of transits per turbine within viewshed	TnT	Tn/x	67.7100293	0	0	0
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	16.92750733			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	203.1300879			
		Collision Probability (Stage 2)	**4.30%**			
		Collisions during study period	T*Collision Probability	8.73459378		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.17469188		
		Over 30-year duration of windfarm	*30	**5.24075627**		

Goosander, Winter VP Surveys: Sep 2018 - March 2019

Measurements	Code	Value				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Goosander length (metres)	l	0.71				
Average flight speed of Goosander (m/s)	v	13.7				
Wingspan (m)		1.67				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 7 months (secs)	s		151200	151200	151200	151200
Total flight-time between 20 - 180m (bird-secs)	PCH		0	0	0	300
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2845	2845	2845	2845

Stage 1 Calculations

Measurements	Code	Calculation				
Proportion of flight-time between 20 - 180m	t1	PCH/s	0.0000	0.0000	0.0000	0.0020
Flight activity per visible unit of area	F	t1/Avp	0	0	0	4.6906E-06
Proportion of time in risk area	Trisk	F*Arisk	0	0	0	0.0002486
Bird occupancy of risk area	n	Trisk*Ba	0	0	0	0.70727326
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	x*(Pi*r^2(d+l))	279352.4864	558704.973	209514.365	69838.1216
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	0	0	0	2.31386712
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.351094891	0.35109489	0.35109489	0.35109489
Number of bird passes through the rotor during survey period	N	b/t2	0	0	0	6.59043235
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	0	0	0	5.60186749
Number of transits per turbine within viewshed	TnT	Tn/x	0	0	0	5.60186749
Average TnT of all VP's	ATnT	(TnT$_1$+TnT$_2$+TnT$_3$+.....)/4	1.400466873			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	16.80560248			
		Collision Probability (Stage 2)	**5.10%**			
		Collisions during study period	T*Collision Probability	0.85708573		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.01714171		
		Over 30-year duration of windfarm	*30	**0.51425144**		

Great Black-backed Gull, Breeding VP Surveys: April 2018 - Aug 2018						
Measurements	**Code**	**Value**				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Great Black-backed Gull length (metres)	l	0.71				
Average flight speed of Great Black-backed Gull (m/s)	v	13.7				
Wingspan (m)		1.67				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 5 months (secs)	s		108000	108000	108000	108000
Total flight-time between 20 - 180m (bird-secs)	PCH		240	0	0	90
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2720	2720	2720	2720
Stage 1 Calculations						
Measurements	**Code**	**Calculation**				
Proportion of flight-time between 20 - 180m	t1	PCH/s	0.0022	0.0000	0.0000	0.0008
Flight activity per visible unit of area	F	t1/Avp	4.19287E-06	0	0	1.9701E-06
Proportion of time in risk area	Trisk	F*Arisk	0.000792453	0	0	0.00010441
Bird occupancy of risk area	n	Trisk*Ba	2.155471698	0	0	0.28400315
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	x*(Pi*r^2(d+l))	279352.4864	558704.973	209514.365	69838.1216
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	7.909837481	0	0	0.92912541
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.351094891	0.35109489	0.35109489	0.35109489
Number of bird passes through the rotor during survey period	N	b/t2	22.52905894	0	0	2.64636552
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	19.1497001	0	0	2.24941069
Number of transits per turbine within viewshed	TnT	Tn/x	4.787425024	0	0	2.24941069
Average TnT of all VP's	ATnT	(TnT_1+TnT_2+TnT_3+.....)/4	1.75920893			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	21.11050715			
		Collision Probability (Stage 2)	**6.15%**			
		Collisions during study period	T*Collision Probability	1.29829619		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.02596592		
		Over 30-year duration of windfarm	*30	**0.77897771**		

Great Black-backed Gull, Breeding VP Surveys: April 2019 - Aug 2019						
Measurements	**Code**	**Value**				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Great Black-backed Gull length (metres)	l	0.71				
Average flight speed of Great Black-backed Gull (m/s)	v	13.7				
Wingspan (m)		1.67				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 5 months (secs)	s		108000	108000	108000	108000
Total flight-time between 20 - 180m (bird-secs)	PCH		0	0	195	0
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2720	2720	2720	2720
Stage 1 Calculations						
Measurements	**Code**	**Calculation**				
Proportion of flight-time between 20 - 180m	t1	PCH/s	0.0000	0.0000	0.0018	0.0000
Flight activity per visible unit of area	F	t1/Avp	0	0	3.4392E-06	0
Proportion of time in risk area	Trisk	F*Arisk	0	0	0.00077037	0
Bird occupancy of risk area	n	Trisk*Ba	0	0	2.09540741	0
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	x*(Pi*r^2(d+l))	279352.4864	558704.973	209514.365	69838.1216
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	0	0	4.86596252	0
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.351094891	0.35109489	0.35109489	0.35109489
Number of bird passes through the rotor during survey period	N	b/t2	0	0	13.8593943	0
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	0	0	11.7804851	0
Number of transits per turbine within viewshed	TnT	Tn/x	0	0	3.92682838	0
Average TnT of all VP's	ATnT	($TnT_1+TnT_2+TnT_3+.....$)/4	0.981707096			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	11.78048515			
		Collision Probability (Stage 2)	**6.15%**			
		Collisions during study period	T*Collision Probability	0.72449984		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.01449		
		Over 30-year duration of windfarm	*30	**0.4346999**		

Great Black-backed Gull, Winter VP Surveys: Sep 2019 - March 2020						
Measurements	**Code**	**Value**				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Great Black-backed Gull length (metres)	l	0.71				
Average flight speed of Great Black-backed Gull (m/s)	v	13.7				
Wingspan (m)		1.67				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 7 months (secs)	s		151200	151200	151200	151200
Total flight-time between 20 - 180m (bird-secs)	PCH		0	30	0	90
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2521	2521	2521	2521
Stage 1 Calculations						
Measurements	**Code**	**Calculation**				
Proportion of flight-time between 20 - 180m	t1	PCH/s	0.0000	0.0002	0.0000	0.0006
Flight activity per visible unit of area	F	t1/Avp	0	2.5569E-07	0	1.4072E-06
Proportion of time in risk area	Trisk	F*Arisk	0	7.7217E-05	0	7.4581E-05
Bird occupancy of risk area	n	Trisk*Ba	0	0.19466485	0	0.18801784
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	279352.4864	558704.973	209514.365	69838.1216
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	0	0.89412373	0	0.6151064
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.351094891	0.35109489	0.35109489	0.35109489
Number of bird passes through the rotor during survey period	N	b/t2	0	2.54667259	0	1.75196625
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	0	2.1646717	0	1.48917131
Number of transits per turbine within viewshed	TnT	Tn/x	0	0.27058396	0	1.48917131
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	0.439938819			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	5.279265827			
		Collision Probability (Stage 2)	**6.15%**			
		Collisions during study period	T*Collision Probability	0.32467485		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.0064935		
		Over 30-year duration of windfarm	*30	**0.19480491**		

Grey Heron, Breeding VP Surveys: March 2019 - Aug 2019

Measurements	Code	Value				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Grey Heron length (metres)	l	0.94				
Average flight speed of Grey Heron (m/s)	v	12.5				
Wingspan (m)		1.85				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 6 months (secs)	s		129600	129600	129600	129600
Total flight-time between 20 - 180m (bird-secs)	PCH		206	0	0	0
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		3150	3150	3150	3150
Stage 1 Calculations						
Measurements	**Code**	**Calculation**				
Proportion of flight-time between 20 - 180m	t1	PCH/s	0.0016	0.0000	0.0000	0.0000
Flight activity per visible unit of area	F	t1/Avp	2.99907E-06	0	0	0
Proportion of time in risk area	Trisk	F*Arisk	0.000566824	0	0	0
Bird occupancy of risk area	n	Trisk*Ba	1.785495283	0	0	0
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	292710.2976	585420.595	219532.723	73177.5744
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	6.865456232	0	0	0
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.4032	0.4032	0.4032	0.4032
Number of bird passes through the rotor during survey period	N	b/t2	17.02742121	0	0	0
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	14.47330803	0	0	0
Number of transits per turbine within viewshed	TnT	Tn/x	3.618327007	0	0	0
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	0.904581752			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	10.85498102			
		Collision Probability (Stage 2)	**7.25%**			
		Collisions during study period	T*Collision Probability	0.78698612		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.01573972		
		Over 30-year duration of windfarm	*30	**0.47219167**		

Hen Harrier, Winter VP Survey: Sep 2019 - February 2020						
Measurements	**Code**	**Value**				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Hen Harrier length (metres)	l	0.94				
Average flight speed of Hen Harrier (m/s)	v	12.5				
Wingspan (m)		1.85				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 7 months (secs)	s		129600	129600	129600	129600
Total flight-time between 20 - 180m (bird-secs)	PCH		180	0	0	0
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2090	2090	2090	2090
Stage 1 Calculations						
Measurements	**Code**	**Calculation**				
Proportion of flight-time between 20 - 180m	t1	PCH/s	0.0014	0.0000	0.0000	0.0000
Flight activity per visible unit of area	F	t1/Avp	2.62055E-06	0	0	0
Proportion of time in risk area	Trisk	F*Arisk	0.000495283	0	0	0
Bird occupancy of risk area	n	Trisk*Ba	1.035141509	0	0	0
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	292710.2976	585420.595	219532.723	73177.5744
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	3.980250631	0	0	0
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.4032	0.4032	0.4032	0.4032
Number of bird passes through the rotor during survey period	N	b/t2	9.871653351	0	0	0
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	8.390905348	0	0	0
Number of transits per turbine within viewshed	TnT	Tn/x	2.097726337	0	0	0
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	0.524431584			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	6.293179011			
		Collision Probability (Stage 2)	**5.50%**			
		Collisions during study period	T*Collision Probability	0.34612485		
		Collisions during study period with 99% Avoidance Rate	*0.01	0.00346125		
		Over 30-year duration of windfarm	*30	**0.10383745**		

Kestrel, Breeding VP Survey: April 2018 - Aug 2018						
Measurements	Code	Value				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Kestrel length (metres)	l	0.94				
Average flight speed of Kestrel (m/s)	v	12.5				
Wingspan (m)		1.85				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 5 months (secs)	s		108000	108000	108000	108000
Total flight-time between 20 - 180m (bird-secs)	PCH		143	0	138	360
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2720	2720	2720	2720
Stage 1 Calculations						
Measurements	Code	Calculation				
Proportion of flight-time between 20 - 180m	t1	PCH/s	0.0013	0.0000	0.0013	0.0033
Flight activity per visible unit of area	F	t1/Avp	2.49825E-06	0	2.4339E-06	7.8802E-06
Proportion of time in risk area	Trisk	F*Arisk	0.00047217	0	0.00054519	0.00041765
Bird occupancy of risk area	n	Trisk*Ba	1.284301887	0	1.4829037	1.13601261
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	292710.2976	585420.595	219532.723	73177.5744
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	4.938303941	0	3.60826724	3.89421379
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.4032	0.4032	0.4032	0.4032
Number of bird passes through the rotor during survey period	N	b/t2	12.24777763	0	8.94907548	9.65826833
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	10.41061099	0	7.60671416	8.20952808
Number of transits per turbine within viewshed	TnT	Tn/x	2.602652747	0	2.53557139	8.20952808
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	3.336938053			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	40.04325664			
		Collision Probability (Stage 2)	**5.10%**			
		Collisions during study period	T*Collision Probability	2.04220609		
		Collisions during study period with 95% Avoidance Rate	*0.05	0.1021103		
		Over 30-year duration of windfarm	*30	**3.06330913**		

Kestrel, Winter VP Survey: Sep 2018 - March 2019						
Measurements	**Code**	**Value**				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Kestrel length (metres)	l	0.34				
Average flight speed of Kestrel (m/s)	v	10.1				
Wingspan (m)		0.76				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 7 months (secs)	s		151200	151200	151200	151200
Total flight-time between 20 - 180m (bird-secs)	PCH		0	60	0	60
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2521	2521	2521	2521
Stage 1 Calculations						
Measurements	**Code**	**Calculation**				
Proportion of flight-time between 20 - 180m	t1	PCH/s	0.0000	0.0004	0.0000	0.0004
Flight activity per visible unit of area	F	t1/Avp	0	5.1137E-07	0	9.3812E-07
Proportion of time in risk area	Trisk	F*Arisk	0	0.00015443	0	4.972E-05
Bird occupancy of risk area	n	Trisk*Ba	0	0.38932969	0	0.12534523
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	257863.8336	515727.667	193397.875	64465.9584
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	0	1.65068997	0	0.37852701
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.43960396	0.43960396	0.43960396	0.43960396
Number of bird passes through the rotor during survey period	N	b/t2	0	3.75494791	0	0.8610637
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	0	3.19170572	0	0.73190415
Number of transits per turbine within viewshed	TnT	Tn/x	0	0.39896322	0	0.73190415
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	0.282716841			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	3.392602092			
		Collision Probability (Stage 2)	**5.10%**			
		Collisions during study period	T*Collision Probability	0.17302271		
		Collisions during study period with 95% Avoidance Rate	*0.05	0.00865114		
		Over 30-year duration of windfarm	*30	**0.25953406**		

Kestrel, Breeding VP Survey: April 2019 - Aug 2019

Measurements	Code	Value				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Kestrel length (metres)	l	0.34				
Average flight speed of Kestrel (m/s)	v	10.1				
Wingspan (m)		0.76				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 5 months (secs)	s		108000	108000	108000	108000
Total flight-time between 20 - 180m (bird-secs)	PCH		460	0	0	0
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2720	2720	2720	2720
Stage 1 Calculations						
Measurements	Code	Calculation				
Proportion of flight-time between 20 - 180m	t1	PCH/s	0.0043	0.0000	0.0000	0.0000
Flight activity per visible unit of area	F	t1/Avp	8.03634E-06	0	0	0
Proportion of time in risk area	Trisk	F*Arisk	0.001518868	0	0	0
Bird occupancy of risk area	n	Trisk*Ba	4.131320755	0	0	0
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	257863.8336	515727.667	193397.875	64465.9584
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	13.99432785	0	0	0
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.43960396	0.43960396	0.43960396	0.43960396
Number of bird passes through the rotor during survey period	N	b/t2	31.83394398	0	0	0
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	27.05885239	0	0	0
Number of transits per turbine within viewshed	TnT	Tn/x	6.764713097	0	0	0
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	1.691178274			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	20.29413929			
		Collision Probability (Stage 2)	**5.10%**			
		Collisions during study period	T*Collision Probability	1.0350011		
		Collisions during study period with 95% Avoidance Rate	*0.05	0.05175006		
		Over 30-year duration of windfarm	*30	**1.55250166**		

Kestrel, Winter VP Survey: Sep 2019 - March 2020						
Measurements	Code	Value				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Kestrel length (metres)	l	0.34				
Average flight speed of Kestrel (m/s)	v	10.1				
Wingspan (m)		0.76				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 7 months (secs)	s		151200	151200	151200	151200
Total flight-time between 20 - 180m (bird-secs)	PCH		1355	10	420	210
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2521	2521	2521	2521
Stage 1 Calculations						
Measurements	Code	Calculation				
Proportion of flight-time between 20 - 180m	t1	PCH/s	0.0090	0.0001	0.0028	0.0014
Flight activity per visible unit of area	F	t1/Avp	1.69088E-05	8.5229E-08	5.291E-06	3.2834E-06
Proportion of time in risk area	Trisk	F*Arisk	0.003195755	2.5739E-05	0.00118519	0.00017402
Bird occupancy of risk area	n	Trisk*Ba	8.056497642	0.06488828	2.98785185	0.4387083
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	257863.8336	515727.667	193397.875	64465.9584
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	27.29036936	0.275115	6.40467709	1.32484455
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.43960396	0.43960396	0.43960396	0.43960396
Number of bird passes through the rotor during survey period	N	b/t2	62.07944381	0.62582465	14.5691979	3.01372297
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	52.76752723	0.53195095	12.3838182	2.56166452
Number of transits per turbine within viewshed	TnT	Tn/x	13.19188181	0.06649387	4.1279394	2.56166452
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	4.9869949			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	59.8439388			
		Collision Probability (Stage 2)	**5.10%**			
		Collisions during study period	T*Collision Probability	3.05204088		
		Collisions during study period with 95% Avoidance Rate	*0.05	0.15260204		
		Over 30-year duration of windfarm	*30	**4.57806132**		

Lesser Black-back Gull, Breeding VP Survey: April 2018 - Aug 2018

Measurements	Code	Value				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Lesser Black-backed Gull length (metres)	l	0.58				
Average flight speed of Lesser Black-backed Gull (m/s)	v	13.1				
Wingspan (m)		1.42				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 5 months (secs)	s		108000	108000	108000	108000
Total flight-time between 20 - 180m (bird-secs)	PCH		0	240	0	1359
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2720	2720	2720	2720

Stage 1 Calculations

Measurements	Code	Calculation				
Proportion of flight-time between 20 - 180m	t1	PCH/s	0.0000	0.0022	0.0000	0.0126
Flight activity per visible unit of area	F	t1/Avp	0	2.8637E-06	0	2.9748E-05
Proportion of time in risk area	Trisk	F*Arisk	0	0.00086483	0	0.00157664
Bird occupancy of risk area	n	Trisk*Ba	0	2.35234822	0	4.2884476
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	271802.4192	543604.838	203851.814	67950.6048
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	0	10.5126567	0	13.6506101
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.357251908	0.35725191	0.35725191	0.35725191
Number of bird passes through the rotor during survey period	N	b/t2	0	29.4264535	0	38.2100412
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	0	25.0124855	0	32.478535
Number of transits per turbine within viewshed	TnT	Tn/x	0	3.12656068	0	32.478535
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	8.901273919			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	106.815287			
		Collision Probability (Stage 2)	**5.80%**			
		Collisions during study period	T*Collision Probability	6.19528665		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.12390573		
		Over 30-year duration of windfarm	*30	**3.71717199**		

Lesser Black-back Gull, Winter VP Survey: Sep 2018 - March 2019						
Measurements	**Code**	**Value**				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Lesser Black-backed Gull length (metres)	l	0.58				
Average flight speed of Lesser Black-backed Gull (m/s)	v	13.1				
Wingspan (m)		1.42				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 7 months (secs)	s		151200	151200	151200	151200
Total flight-time between 20 - 180m (bird-secs)	PCH		0	100	0	0
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2521	2521	2521	2521
Stage 1 Calculations						
Measurements	**Code**	**Calculation**				
Proportion of flight-time between 20 - 180m	t1	PCH/s	0.0000	0.0007	0.0000	0.0000
Flight activity per visible unit of area	F	t1/Avp	0	8.5229E-07	0	0
Proportion of time in risk area	Trisk	F*Arisk	0	0.00025739	0	0
Bird occupancy of risk area	n	Trisk*Ba	0	0.64888282	0	0
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	271802.4192	543604.838	203851.814	67950.6048
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	0	2.89986076	0	0
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.357251908	0.35725191	0.35725191	0.35725191
Number of bird passes through the rotor during survey period	N	b/t2	0	8.11713162	0	0
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	0	6.89956187	0	0
Number of transits per turbine within viewshed	TnT	Tn/x	0	0.86244523	0	0
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	0.215611309			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	2.587335703			
		Collision Probability (Stage 2)	**5.80%**			
		Collisions during study period	T*Collision Probability	0.15006547		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.00300131		
		Over 30-year duration of windfarm	*30	**0.09003928**		

Merlin, Breeding VP Survey: April 2018 - July 2018						
Measurements	Code	Value				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Merlin length (metres)	l	0.28				
Average flight speed of Merlin (m/s)	v	11.3				
Wingspan (m)		0.6				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 4 months (secs)	s		86400	86400	86400	86400
Total flight-time between 20 - 180m (bird-secs)	PCH		0	64	0	0
No. of turbines in viewshed	x		5	8	4	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2197	2197	2197	2197
Stage 1 Calculations						
Measurements	Code	Calculation				
Proportion of flight-time between 20 - 180m	t1	PCH/s	0.0000	0.0007	0.0000	0.0000
Flight activity per visible unit of area	F	t1/Avp	0	9.5456E-07	0	0
Proportion of time in risk area	Trisk	F*Arisk	0	0.00028828	0	0
Bird occupancy of risk area	n	Trisk*Ba	0	0.6333467	0	0
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	317973.984	508758.374	254379.187	63594.7968
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	0	2.64899194	0	0
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.387610619	0.38761062	0.38761062	0.38761062
Number of bird passes through the rotor during survey period	N	b/t2	0	6.83415728	0	0
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	0	5.80903369	0	0
Number of transits per turbine within viewshed	TnT	Tn/x	0	0.72612921	0	0
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	0.181532303			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	2.178387635			
		Collision Probability (Stage 2)	**4.65%**			
		Collisions during study period	T*Collision Probability	0.10129503		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.0020259		
		Over 30-year duration of windfarm	*30	**0.06077702**		

Merlin, Breeding VP Survey: April 2019 - July 2019

Measurements	Code	Value				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Merlin length (metres)	l	0.28				
Average flight speed of Merlin (m/s)	v	11.3				
Wingspan (m)		0.6				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 4 months (secs)	s		86400	86400	86400	86400
Total flight-time between 20 - 180m (bird-secs)	PCH		0	29	0	0
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2197	2197	2197	2197

Stage 1 Calculations

Measurements	Code	Calculation				
Proportion of flight-time between 20 - 180m	t1	PCH/s	0.0000	0.0003	0.0000	0.0000
Flight activity per visible unit of area	F	t1/Avp	0	4.3254E-07	0	0
Proportion of time in risk area	Trisk	F*Arisk	0	0.00013063	0	0
Bird occupancy of risk area	n	Trisk*Ba	0	0.28698522	0	0
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	x*(Pi*r^2(d+l))	254379.1872	508758.374	190784.39	63594.7968
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	0	1.20032447	0	0
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.387610619	0.38761062	0.38761062	0.38761062
Number of bird passes through the rotor during survey period	N	b/t2	0	3.09672752	0	0
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	0	2.63221839	0	0
Number of transits per turbine within viewshed	TnT	Tn/x	0	0.3290273	0	0
Average TnT of all VP's	ATnT	(TnT$_1$+TnT$_2$+TnT$_3$+.....)/4	0.082256825			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	0.987081897			
		Collision Probability (Stage 2)	**4.65%**			
		Collisions during study period	T*Collision Probability	0.04589931		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.00091799		
		Over 30-year duration of windfarm	*30	**0.02753958**		

Peregrine, Winter VP Survey: Sep 2019 - Feb 2020						
Measurements	**Code**	**Value**				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Peregrine length (metres)	l	0.42				
Average flight speed of Peregrine (m/s)	v	12.1				
Wingspan (m)		1.02				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 6 months (secs)	s		129600	129600	129600	129600
Total flight-time between 20 - 180m (bird-secs)	PCH		0	0	15	0
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2090	2090	2090	2090
Stage 1 Calculations						
Measurements	**Code**	**Calculation**				
Proportion of flight-time between 20 - 180m	t1	PCH/s	0.0000	0.0000	0.0001	0.0000
Flight activity per visible unit of area	F	t1/Avp	0	0	2.2046E-07	0
Proportion of time in risk area	Trisk	F*Arisk	0	0	4.9383E-05	0
Bird occupancy of risk area	n	Trisk*Ba	0	0	0.10320988	0
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	262510.0288	525020.058	196882.522	65627.5072
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	0	0	0.22522412	0
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.373553719	0.37355372	0.37355372	0.37355372
Number of bird passes through the rotor during survey period	N	b/t2	0	0	0.60292298	0
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	0	0	0.51248453	0
Number of transits per turbine within viewshed	TnT	Tn/x	0	0	0.17082818	0
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	0.042707044			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	0.512484533			
		Collision Probability (Stage 2)	**5.20%**			
		Collisions during study period	T*Collision Probability	0.0266492		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.00053298		
		Over 30-year duration of windfarm	*30	**0.01598952**		

Sparrowhawk, Breeding VP Survey: April 2018 - Aug 2018						
Measurements	**Code**	**Value**				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Sparrowhawk length (metres)	l	0.33				
Average flight speed of Sparrowhawk (m/s)	v	10				
Wingspan (m)		0.67				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 5 months (secs)	s		108000	108000	108000	108000
Total flight-time between 20 - 180m (bird-secs)	PCH		0	0	25	0
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2720	2720	2720	2720
Stage 1 Calculations						
Measurements	**Code**	**Calculation**				
Proportion of flight-time between 20 - 180m	t1	PCH/s	0.0000	0.0000	0.0002	0.0000
Flight activity per visible unit of area	F	t1/Avp	0	0	4.4092E-07	0
Proportion of time in risk area	Trisk	F*Arisk	0	0	9.8765E-05	0
Bird occupancy of risk area	n	Trisk*Ba	0	0	0.26864198	0
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	257283.0592	514566.118	192962.294	64320.7648
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	0	0	0.57455659	0
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.443	0.443	0.443	0.443
Number of bird passes through the rotor during survey period	N	b/t2	0	0	1.29696746	0
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	0	0	1.10242234	0
Number of transits per turbine within viewshed	TnT	Tn/x	0	0	0.36747411	0
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	0.091868529			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	1.102422342			
		Collision Probability (Stage 2)	**5.08%**			
		Collisions during study period	T*Collision Probability	0.05600305		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.00112006		
		Over 30-year duration of windfarm	*30	**0.03360183**		

Sparrowhawk, Winter VP Survey: Sep 2019 - March 2019						
Measurements	**Code**	**Value**				
Rotor radius (metres)	r	72.5				
Rotor diameter (metres)	D	145				
Max chord width of turbine blades (metres)	d	4.1				
Sparrowhawk length (metres)	l	0.33				
Average flight speed of Sparrowhawk (m/s)	v	10				
Wingspan (m)		0.67				
Mean pitch of blade (degrees)		5				
Rotors per turbine		3				
Rotational period (seconds)		6.12				
Turbine operational time (%)		85				
			Vantage Point			
			1	2	3	4
Survey time over 7 months (secs)	s		151200	151200	151200	151200
Total flight-time between 20 - 180m (bird-secs)	PCH		0	15	0	0
No. of turbines in viewshed	x		4	8	3	1
Survey area visible from VP (hectares)	Avp		530	776	525	423
Area of risk, i.e. 500m buffer of turbines within viewshed (hectares)	Arisk		189	302	224	53
Availability of species activity during survey period (hours)	Ba		2521	2521	2521	2521
Stage 1 Calculations						
Measurements	**Code**	**Calculation**				
Proportion of flight-time between 20 - 180m	t1	PCH/s	0.0000	0.0001	0.0000	0.0000
Flight activity per visible unit of area	F	t1/Avp	0	1.2784E-07	0	0
Proportion of time in risk area	Trisk	F*Arisk	0	3.8609E-05	0	0
Bird occupancy of risk area	n	Trisk*Ba	0	0.09733242	0	0
Risk volume	Vw	(Arisk*D)*10000	274050000	437900000	324800000	76850000
Actual volume of air swept by rotors	o	$x*(Pi*r^2(d+l))$	257283.0592	514566.118	192962.294	64320.7648
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	0	0.41174305	0	0
Time taken for bird to pass through rotors (secs)	t2	(d+l)/v	0.443	0.443	0.443	0.443
Number of bird passes through the rotor during survey period	N	b/t2	0	0.92944255	0	0
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	0	0.79002617	0	0
Number of transits per turbine within viewshed	TnT	Tn/x	0	0.09875327	0	0
Average TnT of all VP's	ATnT	$(TnT_1+TnT_2+TnT_3+.....)/4$	0.024688318			
Number of transits across windfarm	T	ATnT*(Total no. turbines)	0.296259813			
		Collision Probability (Stage 2)	**5.08%**			
		Collisions during study period	T*Collision Probability	0.01505		
		Collisions during study period with 98% Avoidance Rate	*0.02	0.000301		
		Over 30-year duration of windfarm	*30	**0.00903**		

CALCULATION OF COLLISION RISK FOR BUZZARD PASSING THROUGH ROTOR AREA											
										W Band	#########
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)	5		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.54	m	0.025	0.575	7.15	25.57	0.94	0.00118	25.16	0.93	0.00116
Wingspan	1.2	m	0.075	0.575	2.38	8.66	0.32	0.00239	8.25	0.30	0.00228
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.43	6.06	0.22	0.00279	5.56	0.20	0.00256
			0.175	0.860	1.02	5.12	0.19	0.00330	4.50	0.17	0.00291
Bird speed	13.3	m/sec	0.225	0.994	0.79	4.53	0.17	0.00376	3.82	0.14	0.00317
RotorDiam	145	m	0.275	0.947	0.65	3.63	0.13	0.00368	2.95	0.11	0.00299
RotationPeriod	6.12	sec	0.325	0.899	0.55	3.00	0.11	0.00359	2.36	0.09	0.00282
			0.375	0.851	0.48	2.53	0.09	0.00350	1.92	0.07	0.00266
			0.425	0.804	0.42	2.21	0.08	0.00346	1.63	0.06	0.00256
			0.475	0.756	0.38	1.97	0.07	0.00345	1.43	0.05	0.00251
Bird aspect ratio: β	0.45		0.525	0.708	0.34	1.78	0.07	0.00344	1.27	0.05	0.00246
			0.575	0.660	0.31	1.61	0.06	0.00342	1.14	0.04	0.00242
			0.625	0.613	0.29	1.47	0.05	0.00340	1.04	0.04	0.00239
			0.675	0.565	0.26	1.35	0.05	0.00337	0.95	0.03	0.00236
			0.725	0.517	0.25	1.25	0.05	0.00333	0.88	0.03	0.00234
			0.775	0.470	0.23	1.15	0.04	0.00329	0.81	0.03	0.00233
			0.825	0.422	0.22	1.06	0.04	0.00324	0.76	0.03	0.00232
			0.875	0.374	0.20	0.99	0.04	0.00318	0.72	0.03	0.00232
			0.925	0.327	0.19	0.91	0.03	0.00312	0.68	0.03	0.00232
			0.975	0.279	0.18	0.85	0.03	0.00305	0.65	0.02	0.00233
				Overall p(collision) =			**Upwind**	**6.4%**		**Downwind**	**4.9%**
								Average	**5.7%**		