Appendix 7H

AVIAN COLLISION RISK MODELING

Appendix 7H: Avian Collision Risk Modelling report

Brittas Wind Farm, Co. Tipperary

Avian Collision Risk Modelling Report

Report prepared by APEM Group Woodrow on behalf of Ørsted Onshore Ireland Midco Limited

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7H.1 OVERVIEW

APEM Group Woodrow was commissioned by Brittas Wind Farm Limited, a subsidiary of Ørsted Onshore Ireland Midco Limited, to undertake Collision Risk Modelling (CRM) for a proposed wind farm development known as Brittas Wind Farm in Co. Tipperary, using baseline flight activity data, which included two years of data collected from October 2021 to September 2023. The proposed wind farm is for a 10-turbine site located within the townlands of Brittas, Brownstown, Clonbanna and Rossestown, approximately 3 km north of Thurles town centre.

The intention of this report is to display modelled data, based on observed bird usage of the area, to provide an indices of predicted collision risk imposed by the proposed wind farm on potentially sensitive avian populations.

The CRM employed is known as a 'Basic' Band Model (Band *et al.*, 2007), which for the target species and resultant flight behaviour recorded assumes a uniform distribution of birds across the study area. The proportion of birds at risk height is derived from vantage point (VP) watches conducted by appropriately experienced ornithological surveyors. Flight line data for selected target species was collected from four VPs. The survey period covered two breeding bird seasons and two non-breeding seasons (October 2021 to September 2023) and the minimum requirement of 36 hours of VP watches per VP per season was achieved, which over the two-year study amounted to a total of 589 hours of VP watch data. Note: A third year of VP watches conducted between October 2020 and August 2021 (see Appendix 7I) was not used in the modelling, as survey effort differed in terms of the number of VPs utilised.

The four VPs selected provide comprehensive coverage of the proposed Wind Farm Site and the VP locations are shown on Figure 7H.1, with the 2 km viewshed of each VP location shown in Figure 7H.2. It should be noted that the viewshed for VP4 overlaps significantly with viewsheds for VP2 and VP3. The CRM controls for this duplication in survey effort. Furthermore, the conducting of VP watches simultaneously by two or more surveyors was avoided to prevent surveyors from covering overlapping viewsheds at the same time and potentially recording flight activity in duplicate records. This approach also maximises the number of days when the site was visited over the study period. To limit observer fatigue, surveyors did not undertake VP watches of more than 3 hours without a break unless inclement periods of weather meant watches were paused for short durations until conditions improved.

The flight risk volume applied in this analysis is based on a buffer extending 500 m from the proposed turbine locations, which equates to an area of 490.53 ha. Three different turbine specifications were assessed, classified as Turbine - Type A, Turbine - Type B and Turbine - Type C, with specifications detailed in Table 7H.1. The flight heights within the collision risk zone (CRZ) were defined as those occurring between 25 m and 180 m above ground level, which is based on the minimum and maximum rotor swept heights of all turbine models, as derived from blade length and hub height, including:

- Turbine Type A - rotor swept dimensions: 30 m to 180 m (rotor diameter 150 m)
- Turbine Type B - rotor swept dimensions: 25 m to 180 m (rotor diameter 155 m)
- Turbine Type C - rotor swept dimensions: 31 m to 180 m (rotor diameter 149 m)

Although the extents and positions of rotor swept area relative to the ground varies between the three turbine types assessed, it was decided that initially all flight time recorded between 25 m and 180 m would be applied within the CRMs run for selected target species. This approach is precautionary for Turbine Type A and Type C, and was adopted as the minimum rotor swept height only varies by 1 to 6 m across the turbine types assessed, ranging from 25 to 31 m. In addition to not adjusting the flight times for the smaller CRZ, the initial CRMs also maintained consistent operational parameters, including pitch (6°) and rotational period (6.85 seconds). This approach identifies target species where collision risk presents the potential for likely significant effects, which as a guideline has been taken as a predicted collision risk of one or more collisions over 35 years. The approach also determines, independently of flight time and operational parameters, which turbine specifications present the greatest risk.

For target species where the initial CRMs identify predicted collision risk of more than one bird over 35 years, further analysis is undertaken including running CRMs using flight times for the slightly smaller CRZ (30 to 180 m), examining the effects of different operational parameters, in particular rational period of the turbines, investigating seasonal variation in collision risk, and reviewing the appropriateness of applying default avoidance rates.

Flight time applied in the CRMs used aggregated flight seconds recorded for target species, i.e. number birds x flight seconds for each observation, occurring at collision risk height (25-180 m) and within 500 m proposed turbine buffer. Collision risk modelling was undertaken for those target species with > 200 aggregated flight seconds occurring within the CRZ over the two years. For some target species only marginally exceeding this threshold it was decided not run CRMs, as the number of flight observations generating the flight time within the CRZ was notably low with only one or two observations recorded over the two year study period. Based on the observed aggregate flight times within the CRZ, collision risk models were run for 12 species, including:

Black-headed gull	1,035	flight seconds in CRZ
Buzzard	41,192	flight seconds in CRZ
Cormorant	989	flight seconds in CRZ
Golden plover	719,967	flight seconds in CRZ
Grey heron	1,306	flight seconds in CRZ
Kestrel	5,225	flight seconds in CRZ
Lapwing	531,730	flight seconds in CRZ
Lesser black-backed gull	52,161	flight seconds in CRZ
Little egret	721	flight seconds in CRZ
Peregrine	1,107	flight seconds in CRZ
Snipe	480	flight seconds in CRZ
Sparrowhawk	785	flight seconds in CRZ

Although recorded within the 500 m turbine buffer, CRMs were not run for the following target species: common gull, dunlin, green sandpiper, hen harrier, mallard, mute swan, swift, whimbrel, whooper swan and wigeon; as flight times and/or the number flight observations recorded within the CRZ for these species were too low to draw any significant conclusions in relation to predicted collision risk. Based on low recorded activity within the CRZ over the two-year study, there is not considered to be potential for significant effects due to collision mortality on these species, with the exception of swift. In spite of generating high flight times within the 500 m turbine buffer (325,615 secs), no CRM was run for swift as flights were not recorded systematically by surveyors over the two year study period.

Based on deteriorating conservation status swift were moved from the amber to red list in the most recently published BoCCI (Gilbert *et al.*, 2021). This species is emerging as being prone to turbine mediated mortality. Therefore, swifts were included as target species during VP surveys and flight line data was collected. However, as this was not implemented ubiquitously across the seasons by all surveyors, the flight times recorded are only indicative and do not represent a full breeding season. As such, a CRM was not run for swift and potential collision risk for this species is considered within the species account – see Appendix 7A, Section 7A.2.2.7.1.

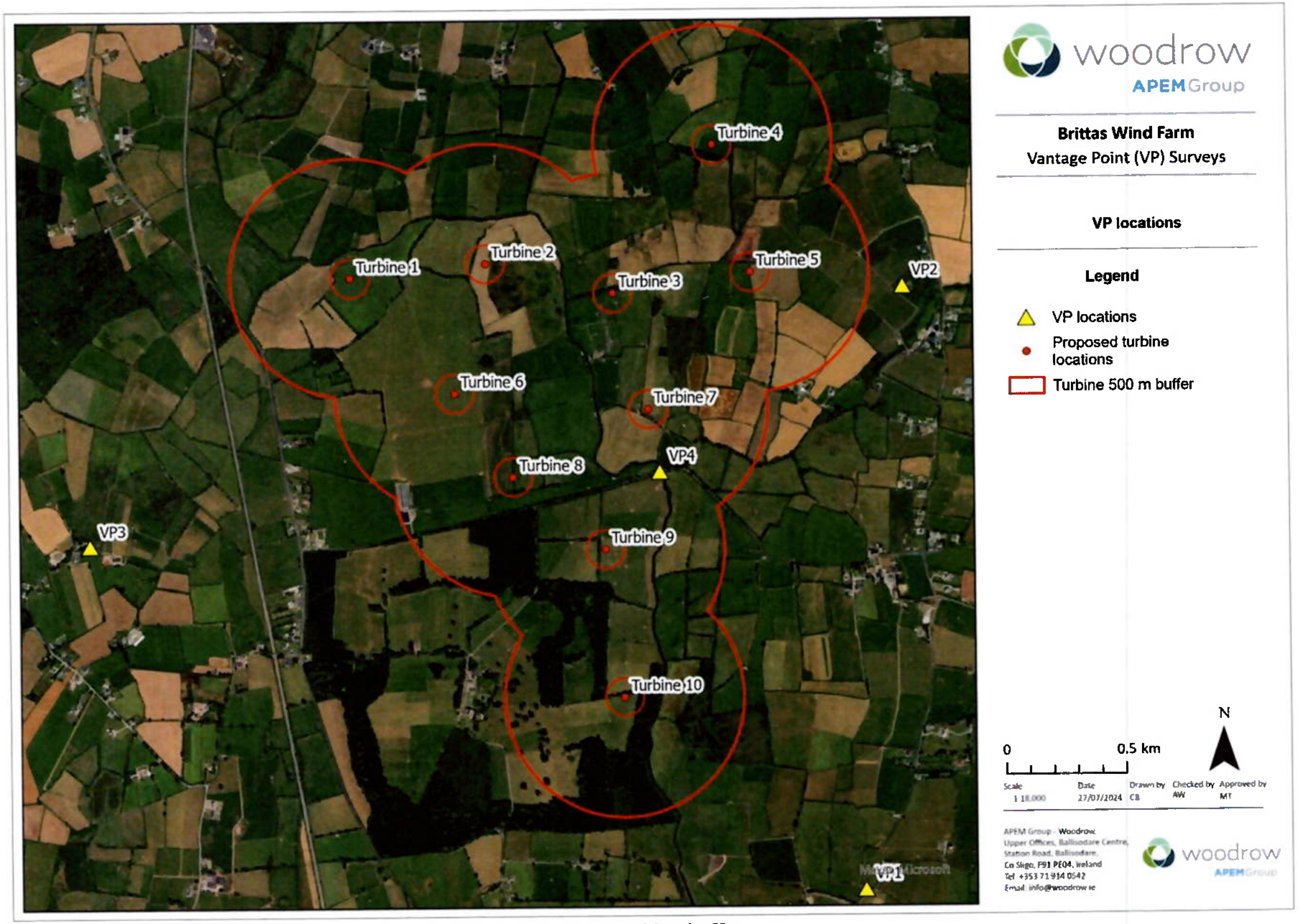

Figure 7H.1: VP locations in relation proposed turbines and 500 m turbine buffer

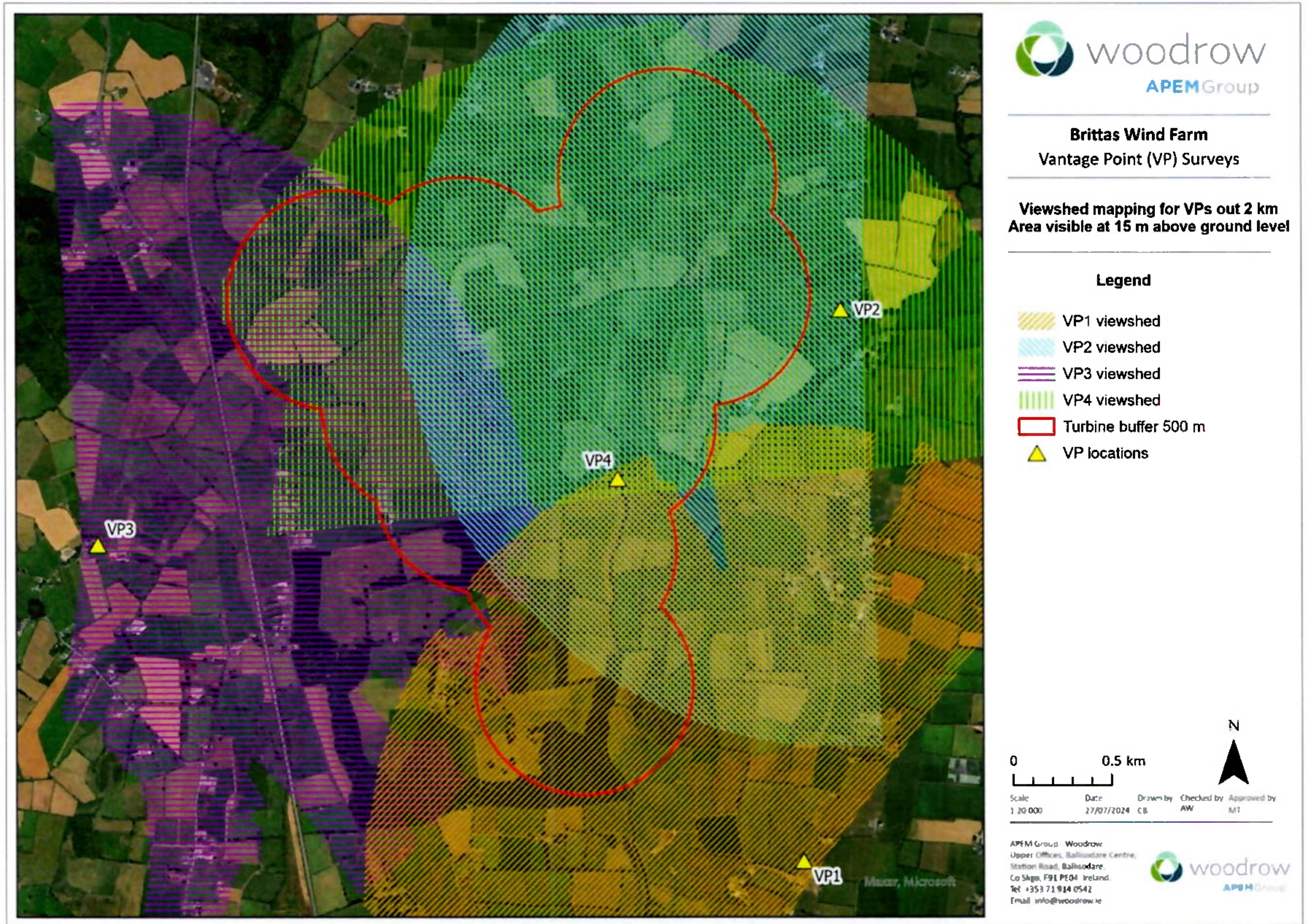

Figure 7H.2: Viewshed coverage out to 2 km from VP locations

7H.2 METHODOLOGY AND MODEL INPUTS

The collision risk modelling was undertaken using the Scottish Natural Heritage (SNH) model and guidelines, based on Band *et al.* (2007). The SNH or Band model uses two approaches for different situations (SNH, 2000). The first approach is for birds that take regular flights through a wind farm area and the second is for birds that may occupy an area, such as a wind farm, as a regular territory. The model approach used in this case is the second approach, relating to birds occupying a given area. The required stages, and tasks within them, are detailed the following sections.

7H.2.1 Stage 1 - Number of birds flying through rotors

This stage involved several sequential steps:

1. Identify a flight risk volume V_w which is the area of the windfarm multiplied by the rotor diameter, as shown in Equation 1.

$$V_w = Area_{windfarm} * rotor\ diameter \qquad \text{(Equation 1)}$$

2. Calculate the combined volume swept out by the windfarm rotors using Equation 2:

$$V_r = X\pi R^2(d + l) \qquad \text{(Equation 2)}$$

   where X is the number of wind turbines, d is the depth of the rotor back to front, and l is the length of the bird.

3. Estimate the bird occupancy n within the flight risk volume. This is the number of birds present, multiplied by the time spent flying in the flight risk volume, within the period (usually one or two years) for which the collision estimate is being made.

4. The bird occupancy, in bird-seconds, of the volume swept by the rotors b is then calculated using Equation 3.

$$b = n\left(\frac{V_r}{V_w}\right) \qquad \text{(Equation 3)}$$

5. Calculate the time taken for a bird to make a transit through the rotor and completely clear the rotor t, see Equation 4:

$$t = \frac{d + l}{v} \qquad \text{(Equation 4)}$$

   where v m/sec is the speed of the bird through the rotor.

6. To calculate the number of bird transits through the rotors N, divide the total occupancy of the volume swept by the rotors in bird-secs by the transit time t, as shown in Equation 5:

$$N = \frac{n\left(\frac{V_r}{V_w}\right)}{t} \qquad \text{(Equation 5)}$$

Note in this calculation that the factor $(d + l)$ cancels itself out, so only assumed values need be used - it is used above to help visualise the calculation.

Within this stage, a weighting system can be applied to the value for bird occupancy n, which is intended to take account of the fact that the observations arise from different VPs, that different VPs cover varying area extents, and that the combination of the areas seen from all VPs may not always equate to the entire site being assessed and notably acknowledging overlap between VP coverage. The weighting factor for each VP is worked out by the percentage cover of the viewshed of each VP (see viewshed maps in Figure 7H.2), as well as the combined percentage cover of all the VPs. This report includes calculations for both unweighted and weighted occupancy values.

7H.2.2 Stage 2 - Probability of bird being hit when flying through the rotors

This stage uses data relating to bird and rotor characteristics to compute the likelihood of a bird being hit when flying through the rotor. The turbine and operational model inputs have already been shown in Table 7H.1, and Table 7H.2 provides the model input for dimensions/attributes of target species. This, together with the output from Stage 1, allows for a model output of the predicted number of collisions per year. Data relating to the likelihood of a bird being hit when flying through the rotor is derived from a spreadsheet available from NatureScot (formerly Scottish Natural Heritage)[20]. The outputs from this spreadsheet are provided for each target species in Table 7H.3.

Following the above steps, the number of bird transits per year through the rotors can be combined with the probability of a bird being hit when flying through the rotor to give a value for predicted collision risk per year assuming no avoidance. This stage also considers the proportion of time that turbines are likely to be operational.

To attain the predicted collisions per annum with avoidance, avoidance rates are applied, as given in SNH (2018a) and Furness (2019). For species where specific avoidance rate are not available the SNH (2018a) guidelines suggest applying the default rate, which is 98% avoidance. However, for many species including gulls, wintering golden plover and lapwing the default avoidance rate is generally considered too low, and based on recent studies at operational wind farms, e.g. Goole Wind Farm - see Percival *et al.* (2018a, 2018b)[21], the application of higher avoidance rates (0.998) can be justified to generate modelled outputs more representative of actual avoidance rates likely to be exhibited by certain species. Applying higher avoidance rates for wintering waders would be in line with avoidance rates applied for wintering geese (SNH, 2013). Collision risk for wader species, including golden plovers are generally considered to be low due to manoeuvrability in flight (Mc Guinness *et al.*, 2015).

As the application is for a 35-year consent period, the predicted collision risk over the 35-year life span of the proposed wind farm is provided for further assessed in terms of potential population level effects.

[20] Available at: https://www.nature.scot/doc/wind-farm-impacts-birds-calculating-probability-collision (Accessed: November 2023)

[21] These post-construction monitoring reports compiled by Ecology Consulting can be accessed via index (ecologyconsult.co.uk)

Table 7H.1: Turbine specifications and operational inputs

Turbine Dimensions	Unit	Turbine – Type A	Turbine – Type B	Turbine – Type C
Number of blades		3	3	3
Hub height	m	105.0	102.5	105.0
Rotor diameter	m	150	155	149
Minimum swept height	m	30	25	31
Maximum swept height	m	180	180	180
Maximum rotor chord (*d*)	m	4.2	4.5	4.2
Blade pitch*	°	6	6	6
Speed – dynamic operating range	rpm	4.9 to 12.0	5.3 to 11.7	4.9 to 12.6
Rotational period applied**	s	6.85	6.85	6.85
Turbine operation time***	%	0.85	0.85	0.85

Notes on turbine specifications and operational parameters

*Pitch varies between -5° and 90° depending on windspeed. This CRM employs a conservative value of 6°, which is considered representative of typical operating conditions for large onshore turbines located at lower altitudes in the midlands of Ireland. This value can be difficult to obtain and is often derived from Band (2012), which states a mean pitch of 25° to 30° for large offshore turbines and this is not considered representative of onshore operating conditions.

**To control for the effects of variable operational parameters (rotational period and pitch), within the CRMs and on the three difference turbine specifications being assessed (rotor diameter and max chord), the values used for rotational period (6.85 sec) and pitch (6°) were kept consistent in the initial model. For target species where flight activity generated one or more collisions over 35 years, CRMs were re-run and additional higher (5.5 sec) and lower (8.0 sec) rotational periods were tested.

***An operational period of 85% is referenced from a report by the British Wind Energy Association (2007), which identifies the standard operational period of wind turbines in the UK to be 70-85% and therefore 85% is used on a precautionary basis.

Table 7H.2: Avian biometrics, flight speeds and avoidance rates used in the CRMs

Sources: Bird biometrics from Snow & Perrins (1998)
Flight speeds from Alerstam *et al.* (2007), Bruderer & Bolt (2001) and Provan & Whitfield (2006)
Avoidance rates form SNH (2018a), update rates for gulls based on Furness (2019)

Bird species	Length		Wingspan		Flight speed (m/s)	Avoidance rate
	Range (cm)	Average (m)	Range (cm)	Average (m)		
Black-headed gull	34-37	0.36	100–110	1.05	11.90	0.992
Buzzard*	51-57	0.54	113-128	1.21	11.60	0.98*
Cormorant*	80-100	0.90	130-160	1.45	16.94	0.98*
Golden plover*	26-29	0.28	67-76	0.72	17.90	0.98*
Grey heron*	90-98	0.94	175-195	1.85	12.50	0.98*
Kestrel	32-35	0.34	71-78	0.76	10.10	0.950
Lapwing*	28-31	0.30	82-87	0.84	12.80	0.98*
Lesser black-backed gull	52-64	0.58	135-150	1.43	13.40	0.995
Little egret*	55-65	0.60	88-106	0.97	25.00	0.98*
Peregrine*	36-48	0.42	95-110	1.03	12.01	0.98*
Snipe*	25-27	0.26	44-47	0.46	17.10	0.98*
Sparrowhawk*	28-38	0.33	55-70	0.62	10.00	0.98*

*Species for which there is no species specific avoidance rate available and default avoidance at 98% has been applied, as suggested by SNH (2018a). Higher avoidance rates are likely to be more appropriate for most species.

Table 7H.3: Averaged collision probability of bird passing through rotor swept area

Collision probability (%):	Turbine Type A			Turbine Type B			Turbine Type C		
Rotational period (sec)	8.00	6.85	5.50	8.00	6.85	5.50	8.00	6.85	5.50
Bird species									
Black-headed gull	4.85%	**4.98%**	5.24%	4.95%	**5.08%**	5.35%	4.88%	**5.01%**	5.27%
Buzzard	5.40%	**5.64%**	6.09%	5.50%	**5.75%**	6.20%	5.42%	**5.67%**	6.11%
Cormorant	5.73%	**6.00%**	6.50%	5.82%	**6.10%**	6.61%	5.75%	**6.03%**	6.52%
Golden plover	4.27%	**4.32%**	4.43%	4.38%	**4.43%**	4.54%	4.30%	**4.34%**	4.46%
Grey heron	6.59%	**7.00%**	6.59%	6.69%	**7.10%**	7.82%	6.62%	**7.03%**	7.75%
Kestrel	4.78%	**4.96%**	7.72%	4.89%	**5.08%**	5.41%	4.80%	**4.99%**	5.32%
Lapwing	4.53%	**4.63%**	4.83%	4.63%	**4.74%**	4.94%	4.56%	**4.66%**	4.85%
Lesser black-backed gull	5.44%	**5.64%**	6.02%	5.53%	**5.73%**	6.12%	5.47%	**5.66%**	6.04%
Little egret	4.65%	**4.74%**	4.92%	4.74%	**4.84%**	5.03%	4.67%	**4.76%**	4.95%
Peregrine	4.95%	**5.12%**	5.44%	5.06%	**5.23%**	5.55%	4.98%	**5.15%**	5.47%
Snipe	4.06%	**4.13%**	4.27%	4.17%	**4.25%**	4.39%	4.08%	**4.14%**	4.29%
Sparrowhawk	4.70%	**4.89%**	5.22%	4.81%	**5.00%**	5.34%	4.72%	**4.91%**	5.24%

Of the three turbine types assessed, Turbine Type B was found to present the highest level of collision probability for the target species assessed, with Turbine Type A presenting marginally lower levels of collision probability when compared with Turbine Type B and Type C.

7H.2.3 Viewshed spatial coverage

The locations of the VPs and respective viewsheds are shown in Figure 7H.2. The VP locations used were consistent throughout the two-year survey period (October 2021 to September 2023). The spatial coverage of viewsheds for each VP were calculated using ArcGIS Pro. The viewshed analysis was performed using a surface offset of 25 m to map the airspace visible to surveyors (height 1.75 m) above 25 m. Spatial coverage of the 500 m turbine buffer from these VPs, is given in Table 7H.4.

Table 7H.4: Spatial and temporal coverage of 500 m turbine buffer

Vantage Point	Area of CRZ visible within 500m turbine buffer (ha)	% Coverage	VP survey effort Breeding season (hours)	VP survey effort Non- breeding season (hours)	VP survey effort Total (hours)
VP1	122.0	24.87	72.0	72.5	144.5
VP2	339.5	69.20	75.0	72.0	147.0
VP3	165.9	33.83	75.0	75.0	150.0
VP4	361.3	73.66	75.0	72.5	147.5
Total for buffer	**490.5**	**100.00**	**297.0**	**292.0**	**589.0**

7H.2.4 Recorded flight activity

For the target species included in the CRMs, Table 7H.5 provides the total number of flight observations and aggregated flight seconds recorded at collision risk heights (25-180 m) within the 500 m turbine buffer over the two-year study period, along with aggregated flight seconds recorded at risk height for each VP. For observations where more than 1 bird was recorded, flight seconds are multiplied by the number of individuals recorded, i.e. aggregated flight seconds. Values in parenthesis in Table 7H.5 give total number of flight observations and aggregated flight seconds recorded within a slightly reduced and heightened rotor swept area of 30-180 m, and is representative of the time target species occurred within the CRZ for Turbine – Type A and Type C.

Table 7H.5: Aggregated flight seconds in 25-180 m CRZ for target species recorded from each VP

Note: Values in parenthesis give number of flights and total aggregated flight seconds for 30-180 m CRZ (Turbine – Type A & C)

Species	No. of flights	Analysis period	Aggregated flight seconds				
			VP1	VP2	VP3	VP4	Total
Black-headed gull	5 (4)	Year-round	-	585	450	-	**1,035** (915)
Buzzard	136 (128)	Year-round	3,141 (3,110)	20,346 (20,176)	5,162 (5,056)	12,544 (12,544)	**41,192** (40,885)
Cormorant	13 (10)	Year-round	38 (38)	326 (86)	35 (-)	590 (546)	**989** (670)
Golden plover	38 (34)	Wintering + passage	6,558 (6,558)	388,962 (388,362)	126,790 (125,974)	197,657 (197,657)	**719,967** (718,551)
Grey heron	12 (10)	Year-round	39 (39)	263 (233)	187 (187)	817 (786)	**1,306** (1,245)
Kestrel	42 (36)	Year-round	231 (84)	3,065 (3,024)	621 (621)	1,308 (1,054)	**5,225** (4,783)
Lapwing	98 (79)	Year-round	305 (305)	41,196 (27,307)	255,538 (238,442)	234,690 (217,100)	**531,730** (483,154)
Lesser black-backed gull	34 (28)	Year-round	2,829 (2,701)	8,339 (7,779)	2,964 (2,604)	38,028 (37,668)	**52,161** (50,752)
Little egret	10 (6)	Year-round	- (-)	394 (394)	- (-)	327 (194)	**721** (588)
Peregrine	6 (5)	Year-round	982	115	-	9	**1,107** (1,103)
Snipe	8 (7)	Wintering + passage (25% for night flights)	-	70	-	410	**480** (310)
Sparrowhawk	4 (4)	Year-round	-	351	194	240	**785** (758)

7H.3 COLLISION RISK ASSESSMENT

As detailed above, the collision risk assessment is undertaken in two stages, with Stage 1 being to ascertain the number of bird flights through the rotors and Stage 2 being to ascertain the probability of a bird being hit by the rotors as it passes through.

7H.3.1 Stage 1 - Number of birds flying through rotors

The first part of Stage 1 is defining the flight risk volume V_w and is calculated using Equation 1. Therefore, V_w is derived from the area of the 500 m turbine buffer (4,905,326 m^2) multiplied by the rotor diameter, which gives a flight risk volume V_w for each of the turbine model being assessed (Table 7H.6).

The rotor swept volume V_r is then worked out based on the rotor-swept area multiplied by the number of turbines, the depth of the rotor and the length of the bird. This is shown for the specified turbine types (A, B, C) in Table 7H.7 and calculated using Equation 2.

Table 7H.6: Flight Risk Volume V_w for each turbine model

Parameters	Turbine A	Turbine B	Turbine C
500 m turbine buffer area (m^2)	4,905,326	4,905,326	4,905,326
Rotor diameter (m)	150	155	149
V_w (m^3)	735,798,900	760,325,530	730,893,574

Table 7H.7: Risk Volume V_r and rotor transit time t for the turbine types (A, B, C)

	Vr (m^3)			t (s)		
Species name	Turbine A	Turbine B	Turbine C	Turbine A	Turbine B	Turbine C
Black-headed gull	805,819	917,043	795,110	0.38	0.41	0.38
Buzzard	837,627	951,007	826,496	0.41	0.43	0.41
Cormorant	901,244	1,018,936	889,268	0.30	0.32	0.30
Golden plover	791,681	901,947	781,161	0.25	0.27	0.25
Grey heron	908,313	1,026,484	896,243	0.41	0.44	0.41
Kestrel	802,284	913,269	791,623	0.45	0.48	0.45
Lapwing	795,216	905,721	784,648	0.35	0.38	0.35
Lesser black-backed gull	844,696	958,555	833,471	0.36	0.38	0.36
Little egret	848,230	962,329	836,958	0.19	0.20	0.19
Peregrine	816,421	928,364	805,572	0.38	0.41	0.38
Snipe	788,147	898,173	777,673	0.26	0.28	0.26
Sparrowhawk	800,517	911,382	789,879	0.45	0.48	0.45

The next stage of the calculations is to determine the bird occupancy n within the flight risk volume. This is worked out individually for each VP and then averaged to find the mean occupancy across the site. The observation effort (see Equation 6) of each VP (in hectare hours) is first calculated by multiplying the area viewed from the VP by the number of VP hours undertaken. Occupancy n is then calculated, using Equation 7, by dividing the flight time at risk height (in hours) by the observation effort and then multiplying that value by the area of the 500 m turbine buffer and the total hours the target species are active across the site (see Table 7H.8).

The time the birds are active is defined as the product of the number of days in the season/year and the mean day length. This is assumed to be an average of 12 hours of daylight for 365 days in the year for species that were present throughout the year (i.e. 4,380 hours). For wintering species, 1,704 hours was used and for species that were only present during the breeding season, 2,400 hours was applied. For golden plover 2,127 hours was applied, which considers the wintering season and passage season (April). Note: For lapwing, while modelled outputs presented in the following tables are for year-round activity, to investigate seasonal variation in predicted collision risk for lapwing the model was also run inputting lapwing occupancy for the breeding and non-breeding season separately – these results are present in the discussion.

The figures calculated for occupancy, in bird-seconds, are shown in Table 7H.8.

$$Observation\ effort = Area_{viewshed} * Survey\ effort \qquad \text{(Equation 6)}$$

$$n = \frac{Flight\ time\ at\ risk\ height\ (hrs)}{Observation\ effort} * Area_{500m\ turbine\ buffer} * Daylight\ hours \qquad \text{(Equation 7)}$$

Table 7H.8: Occupancy n (bird-secs) values calculated for each VP applying CRZ 25-180 m

Species name	Analysis period (hours)		Occupancy n (bird secs)			
			VP1	VP2	VP3	VP4
Black-headed gull	Year-round	4,380	-	6.99	10.79	-
Buzzard	Year-round	4,380	106.32	243.35	123.76	140.47
Cormorant	Year-round	4,380	1.29	3.90	0.84	6.61
Golden plover	Wintering + April	2,127	198.45	4,427.95	2,839.05	2,186.77
Grey heron	Year-round	4,380	1.32	3.15	4.48	9.14
Kestrel	Year-round	4,380	7.80	36.66	14.88	14.65
Lapwing	Year-round	4,380	10.34	492.73	6,127.07	2,628.08
Lesser black-backed gull	Year-round	4,380	95.76	99.74	71.07	425.84
Little egret	Year-round	4,380	-	4.72	-	3.66
Peregrine	Year-round	4,380	33.25	1.38	-	0.10
Snipe	Wintering + April	2,127	-	0.80	-	4.54
Sparrowhawk	Year-round	4,380	-	4.20	4.65	2.69

As previously described, a weighting factor was used to account for the varying extents of coverage from each VP, as well as the combined cover of each VP not accounting for the entire site (see Equation 8). Weighted values for n were calculated using the values for the percentage cover described in Table 7H.4. In this case, the combined VPs do provide 100% coverage of the entire 500 m turbine and there is significant overlap in the viewsheds. The following weighting was therefore applied:

$$n_{weighted} = \frac{(n_{vp1} * (0.249) + n_{vp2} * (0.692) + n_{vp3} * (0.338) + n_{vp4} * (0.737))}{1} \qquad \text{(Equation 8)}$$

Once a value for n and $n_{weighted}$ has been calculated for each VP, this is then used to generate the mean activity for the site as a percentage of time (i.e. a percentage occupancy) within the risk zone, n_{avg}. This is calculated by adding the values for n calculated for each VP then dividing by the number of VPs. In this case, both weighted and unweighted values for n_{avg} were obtained, as shown in Table 7H.9. These values are same for all three turbine types being assessed, as the aggregate flight seconds inputted for each target species was the same, which was precautionary for Turbine Type A and Turbine Type B.

Table 7H.9: Values obtained for n_{avg} and $n_{weightedavg}$ (bird-secs)

Species name	Turbine Type A, B & C CRZ 25-180 m		Turbine Type A & C CRZ 30-180 m (selected species)	
	n_{avg}	$n_{weightedavg}$	n_{avg}	$n_{weightedavg}$
Black-headed gull	4.45	2.12	na	na
Buzzard	153.47	85.04	152.07	84.41
Cormorant	3.16	2.04	2.11	1.38
Golden plover	2,413.05	1,421.19	2,406.78	1,418.46
Grey heron	4.52	2.69	4.35	2.56
Kestrel	18.50	10.78	16.42	9.87
Lapwing	2,314.55	1,088.03	2,121.30	988.35
Lesser black-backed gull	94.85	58.98	167.18	104.74
Little egret	2.09	1.49	1.72	1.22
Peregrine	8.68	2.32	na	na
Snipe	1.33	0.97	na	na
Sparrowhawk	2.88	1.62	na	na

The bird occupancy of the rotor-swept volume b is then worked out using Equation 3 by multiplying n_{avg} by $\frac{V_r}{V_w}$.

The bird occupancy of the swept volume b is used to ascertain the number of bird transits through the rotors N by dividing b by the rotor transit time t, see Equation 4 and Equation 5. The number of transits through the rotors N is then adjusted by a factor of 0.85[22] to obtain Tn, which considers likely wind turbine downtime. Calculations for the number of transits through the rotors are shown in Table 7H.10.

[22] This operational period of 85% is referenced from a report by the British Wind Energy Association (2007) which identifies the standard operational period of the wind turbines in the UK to be roughly 85%.

Table 7H.10: Values obtained for the number of transits through the rotors T_n

	Species name	Unweighted b	Unweighted N	Unweighted Tn	Weighted b	Weighted N	Weighted Tn
Turbine A CRZ 25-180 m	Black-headed gull	17.53	45.74	38.88	8.37	21.84	18.56
	Buzzard	628.96	1,539.22	1,308.34	348.53	852.94	725.00
	Cormorant	13.93	46.28	39.34	9.01	29.92	25.43
	Golden plover	9,346.75	37,345.27	31,743.48	5,504.84	21,994.79	18,695.57
	Grey heron	20.11	48.90	41.57	11.96	29.07	24.71
	Kestrel	72.61	161.54	137.31	42.33	94.17	80.05
	Lapwing	9,005.24	25,614.91	21,772.68	4,233.21	12,041.12	10,234.95
	Lesser black-backed gull	715.40	2,005.52	1,704.69	444.86	1,247.09	1,060.03
	Little egret	8.69	45.27	38.48	6.18	32.21	27.38
	Peregrine	34.68	90.83	77.20	9.29	24.32	20.67
	Snipe	5.14	19.71	16.75	3.75	14.39	12.23
	Sparrowhawk	11.30	24.94	21.20	6.33	13.96	11.87
Turbine A CRZ 30-180 m	**For selected species**	**b**	**N**	**Tn**	**b**	**N**	**Tn**
	Buzzard	623.21	1,525.15	1,296.37	345.94	846.61	719.62
	Cormorant	9.30	30.88	26.25	6.10	20.27	17.23
	Golden plover	9,322.44	37,248.14	31,660.92	5,494.28	21,952.58	18,659.70
	Grey heron	19.33	47.00	39.95	11.40	27.71	23.56
	Kestrel	64.47	143.41	121.90	38.73	86.15	73.23
	Lapwing	8,253.34	23,476.17	19,954.75	3,845.37	10,937.95	9,297.26
	Lesser black-backed gull	690.91	1,936.87	1,646.34	432.87	1,213.47	1,031.45
	Little egret	7.15	37.23	31.64	5.05	26.28	22.34
Turbine B CRZ 25-180 m	Black-headed gull	19.30	47.27	40.18	9.22	22.57	19.18
	Buzzard	691.06	1,590.53	1,351.95	382.94	881.37	749.17
	Cormorant	15.24	47.82	40.65	9.86	30.92	26.28
	Golden plover	10,305.07	38,590.11	32,801.60	6,069.25	22,727.95	19,318.76
	Grey heron	21.99	50.53	42.95	13.08	30.04	25.54
	Kestrel	79.99	166.93	141.89	46.63	97.31	82.72
	Lapwing	9,925.78	26,468.74	22,498.43	4,665.93	12,442.49	10,576.12
	Lesser black-backed gull	785.64	2,072.37	1,761.52	488.54	1,288.66	1,095.36
	Little egret	9.54	46.78	39.77	6.79	33.29	28.29
	Peregrine	38.16	93.85	79.78	10.22	25.13	21.36
	Snipe	5.67	20.37	17.31	4.14	14.87	12.64
	Sparrowhawk	12.45	25.77	21.91	6.97	14.43	12.26
Turbine C CRZ 25-180 m	Black-headed gull	17.41	45.44	38.62	8.31	21.69	18.44
	Buzzard	624.77	1,528.96	1,299.62	346.21	847.26	720.17
	Cormorant	13.84	45.97	39.07	8.95	29.72	25.26
	Golden plover	9,284.44	37,096.30	31,531.86	5,468.14	21,848.16	18,570.93
	Grey heron	19.97	48.58	41.29	11.88	28.88	24.55
	Kestrel	72.13	160.46	136.39	42.05	93.55	79.51
	Lapwing	8,945.21	25,444.15	21,627.53	4,204.98	11,960.85	10,166.72
	Lesser black-backed gull	710.63	1,992.15	1,693.33	441.89	1,238.78	1,052.96
	Little egret	8.63	44.97	38.23	6.14	32.00	27.20
	Peregrine	34.45	90.22	76.69	9.23	24.16	20.54
	Snipe	5.11	19.58	16.64	3.73	14.29	12.15
	Sparrowhawk	11.22	24.78	21.06	6.28	13.87	11.79
Turbine C CRZ 30-180 m	**For selected species**	**b**	**N**	**Tn**	**b**	**N**	**Tn**
	Buzzard	619.05	1,514.98	1,287.73	343.64	840.97	714.82
	Cormorant	9.23	30.67	26.07	6.06	20.14	17.12
	Golden plover	9,260.29	36,999.82	31,449.85	5,457.65	21,806.23	18,535.30
	Grey heron	19.20	46.68	39.68	11.32	27.53	23.40
	Kestrel	64.04	142.46	121.09	38.47	85.58	72.74
	Lapwing	8,198.32	23,319.66	19,821.72	3,819.74	10,865.04	9,235.28
	Lesser black-backed gull	686.31	1,923.95	1,635.36	429.98	1,205.38	1,024.58
	Little egret	7.10	36.98	31.43	5.01	26.11	22.19

7H.3.2 Stage 2 - Probability of bird being hit when flying through the rotors

Table 7H.3 provides the collision probability of the selected target species passing through the rotors, as calculated using the spreadsheet provided by NatureScot[23]. The average collision probability is applied within the CRM and is based the collision probability of birds travelling both upwind and downwind. All collision probability calculations were undertaken using the setting for birds flapping, as opposed to the setting for gliding birds. This is appropriate for birds, like golden plover and snipe that predominately employ a flapping mode of flight. The flapping setting generates higher values for collision probability in species that incorporate gliding in their flight behaviour, in particular larger raptors, like buzzards. The higher (flapping) value has been retained for these species and will generate a more precautionary estimate for collision risk.

[23] Available at: https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision (Accessed: November 2023)

Table 7H.11: Collision risk model results

Outputs from initial CRMs applying uniform flight times for CRZ 25-180 m and operational parameters (rotational period: 6.85 sec and pitch 6°)

The turbine models and specifications with the highest and lowest predicted collision risk are highlighted in red and green, respectively

	Species	Unweighted					Weighted				
		Collisions/year		Predicted risk stats			Collisions/year		Predicted risk stats		
		No avoid	Avoid	Per decade	Per 35 years	1 bird every x years	No avoid	Avoid	Per decade	Per 35 years	1 bird every x years
Turbine A	Black-headed gull	1.94	0.015	0.15	0.5	64.6	0.92	0.007	0.07	0.3	135.2
	Buzzard	73.79	1.476	14.76	51.7	0.7	40.89	0.818	8.18	28.6	1.2
	Cormorant	2.36	0.047	0.47	1.7	21.2	1.53	0.031	0.31	1.1	32.8
	Golden plover	1,371.32	27.426	274.26	959.9	0.04	807.65	16.153	161.53	565.4	0.1
	Grey heron	2.91	0.058	0.58	2.0	17.2	1.73	0.035	0.35	1.2	28.9
	Kestrel	6.81	0.341	3.41	11.9	2.9	3.97	0.199	1.99	6.9	5.0
	Lapwing	1,008.07	20.161	201.61	705.7	0.05	473.88	9.478	94.78	331.7	0.1
	Lesser black-backed gull	96.15	0.481	4.81	16.8	2.1	59.79	0.299	2.99	10.5	3.3
	Little egret	1.82	0.036	0.36	1.3	27.4	1.30	0.026	0.26	0.9	38.5
	Peregrine	3.95	0.079	0.79	2.8	12.6	1.06	0.021	0.21	0.7	47.2
	Snipe	0.69	0.014	0.14	0.5	72.3	0.51	0.010	0.10	0.4	99.0
	Sparrowhawk	1.04	0.021	0.21	0.7	48.2	0.58	0.012	0.12	0.4	86.1
Turbine B	Black-headed gull	2.04	0.016	0.16	0.6	61.2	0.98	0.008	0.08	0.3	128.2
	Buzzard	77.71	1.554	15.54	54.4	0.6	43.06	0.861	8.61	30.1	1.2
	Cormorant	2.48	0.050	0.50	1.7	20.2	1.60	0.032	0.32	1.1	31.2
	Golden plover	1,452.07	29.041	290.41	1,016.5	0.03	855.21	17.104	171.04	598.6	0.1
	Grey heron	3.05	0.061	0.61	2.1	16.4	1.81	0.036	0.36	1.3	27.6
	Kestrel	7.20	0.360	3.60	12.6	2.8	4.20	0.210	2.10	7.3	4.8
	Lapwing	1,066.02	21.320	213.20	746.2	0.05	501.12	10.022	100.22	350.8	0.1
	Lesser black-backed gull	101.02	0.505	5.05	17.7	2.0	62.81	0.314	3.14	11.0	3.2
	Little egret	1.92	0.038	0.38	1.3	26.0	1.37	0.027	0.27	1.0	36.5
	Peregrine	4.17	0.083	0.83	2.9	12.0	1.18	0.022	0.22	0.8	44.8
	Snipe	0.74	0.015	0.15	0.5	68.0	0.54	0.011	0.11	0.4	93.2
	Sparrowhawk	1.10	0.022	0.22	0.8	45.6	0.61	0.012	0.12	0.4	81.5
Turbine C	Black-headed gull	1.93	0.015	0.15	0.5	64.6	0.92	0.007	0.07	0.3	135.3
	Buzzard	73.69	1.474	14.74	51.6	0.7	40.83	0.817	8.17	28.6	1.2
	Cormorant	2.36	0.047	0.47	1.6	21.2	1.52	0.030	0.30	1.1	32.8
	Golden plover	1,368.48	27.370	273.70	957.9	0.0	805.98	16.120	161.20	564.2	0.1
	Grey heron	2.90	0.058	0.58	2.0	17.2	1.73	0.035	0.35	1.2	29.0
	Kestrel	6.81	0.340	3.40	11.9	2.9	3.97	0.198	1.98	6.9	5.0
	Lapwing	1,007.84	20.157	201.57	705.5	0.0	473.77	9.475	94.75	331.6	0.1
	Lesser black-backed gull	95.84	0.479	4.79	16.8	2.1	59.60	0.298	2.98	10.4	3.4
	Little egret	1.82	0.036	0.36	1.3	27.5	1.29	0.026	0.26	0.9	38.6
	Peregrine	3.95	0.079	0.79	2.8	12.7	1.06	0.021	0.21	0.7	47.3
	Snipe	0.69	0.014	0.14	0.5	72.6	0.50	0.010	0.10	0.4	99.4
	Sparrowhawk	1.03	0.021	0.21	0.7	48.4	0.58	0.012	0.12	0.4	86.4

7H.4 RESULTS

The output figures from stage 1 (bird transits through the rotors per year) and stage 2 (probability of a bird being hit while passing through the rotors) are multiplied to get an estimated collision/mortality rate per year in the absence of any avoidance. An avoidance rate is then applied to this value – see Table 7H.3. Unweighted and weighted results are detailed in Table 7H.11 for the three turbine models assessed (A, B, C). For clarity, Table 7H.12 shows the weighted results for CRM only (with avoidance).

For the dimensions and operational specifications inputted into the initial CRMs, the outputs for predicted collision risk are comparable for the three turbines assessed, with marginally higher values generated by Turbine Type B. The initial outputs from the CRMs predicated collisions risk of one or more collision over 35 years for eight species, and as listed in Table 7H.12 this included buzzard, cormorant, golden plover, grey heron, kestrel, lapwing, lesser black-backed gull and little egret (outputs shown for worst-case scenario - Turbine Type B).

- Buzzard 1 collision every 1.2 years (weighted, 98.0% avoidance)
- Cormorant 1 collision every 31.2 years (weighted, 98.0% avoidance)
- Golden plover 1 collision every 0.1 years (weighted, 98.0% avoidance)
- Grey heron 1 collision every 27.6 years (weighted, 98.0% avoidance)
- Kestrel 1 collision every 4.8 years (weighted, 95.0% avoidance)
- Lapwing 1 collision every 0.1 years (weighted, 98.0% avoidance)
- Lesser black-backed gull 1 collision every 3.2 years (weighted, 99.5% avoidance)
- Little egret 1 collision every 36.5 years (weighted, 98.0% avoidance)

For cormorant, grey heron and little egret modelled outputs predicted one or close to one collision over the 35 years, and this relatively low level of predicted collision risk is considered unlikely to have any significant population level effects. For the other five species, while these outputs are representative of high levels of flight activity within the CRZ, it is important to acknowledge that the application of a default avoidance rate (0.98), as suggested by SNH (2018a), is notably low for some species and leads to inflated estimates, in particular for wintering golden plover and lapwing. Application of higher avoidance rate, if it can be justified in certain cases, provides more realistic outputs for predicted collision risk. For these species further analysis is undertaken in the next section including investigating potential for population level effects to arise as a result of predicted collision risk and re-running CRMs to examine:

- the effect of using flight times for the slightly smaller CRZ (30 to 180 m);
- the effects of different operational parameters, in particular rational period of the turbines;
- seasonal variation in collision risk; and,
- the appropriateness of applying default avoidance rates.

For the target species listed in Table 7H.12, the CRMs generated notably low levels of theoretical collision risk for four of the target species analysed and outputs for the worst-case scenarios (Turbine B) predicted significantly less than one collision over the 35-year life span of the project for:

- Black-headed gull 1 collision every 128.2 years (weighted, 99.2% avoidance)
- Peregrine 1 collision every 44.8 years (weighted, 98.0% avoidance)
- Snipe 1 collision every 93.2 years (weighted, 98.0% avoidance)
- Sparrowhawk 1 collision every 81.5 years (weighted, 98.0% avoidance)

Table 7H.12: CRM weighted results (with avoidance) for three turbine types

CRM outputs inputting flight seconds recorded between 25 m and 180 m, a 6.85 second rotational period and pitch of 6 degrees
The turbine models/specifications with the highest and lowest predicted collision risk are highlighted in red and green, respectively
Species in listed **bold** exhibit predicted collision risk values of one or more collisions over the 35 years life span of the proposed Wind Farm site

	Collisions/year			Collisions per decade			Collisions per 35 years (WF life span)			Equivalent to 1 bird every x years		
	Turbine Type			Turbine Type			Turbine Type			Turbine Type		
Species	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Black-headed gull	0.007	0.008	0.007	0.07	0.08	0.07	0.3	0.3	0.3	135.20	128.20	135.30
Buzzard	0.818	0.861	0.817	8.18	8.61	8.17	28.6	**30.1**	28.6	1.2	1.2	1.2
Cormorant	0.031	0.032	0.030	0.31	0.32	0.30	1.1	**1.1**	1.1	32.8	31.2	32.8
Golden plover	16.153	17.104	16.120	161.53	171.04	161.20	565.4	**598.6**	564.2	0.1	0.1	0.1
Grey heron	0.035	0.036	0.035	0.35	0.36	0.35	1.2	**1.3**	1.2	28.9	27.6	29.0
Kestrel	0.199	0.21	0.198	1.99	2.1	1.98	6.9	**7.3**	6.9	5.0	4.8	5.0
Lapwing	9.478	10.022	9.475	94.78	100.22	94.75	331.7	**350.8**	331.6	0.1	0.1	0.1
Lesser black-backed gull	0.299	0.314	0.298	2.99	3.14	2.98	10.5	**11.0**	10.4	3.3	3.2	3.4
Little egret	0.026	0.027	0.026	0.26	0.27	0.26	0.9	**1.0**	0.9	38.5	36.5	38.6
Peregrine	0.021	0.022	0.021	0.21	0.22	0.21	0.7	0.8	0.7	47.2	44.8	47.3
Snipe	0.010	0.011	0.010	0.10	0.11	0.10	0.4	0.4	0.4	99.0	93.2	99.4
Sparrowhawk	0.012	0.012	0.012	0.12	0.12	0.12	0.4	0.4	0.4	86.1	81.5	86.4

7H.5 DISCUSSION

The CRM outputs present in Table 7H.12 are considered to represent theoretical collision risk at an elevated level for the target species recorded, as the parameters entered in the model are precautionary, including:

- Turbine dimensions, especially the maximum chord for the blades;
- Relatively high rotational period;
- Selecting flapping flight behaviour for each species; and,
- Application of the default avoidance (98%), which for some species is considered too low and higher levels of avoidance are more appropriate.

The following sections identify the species where the values for predicted collision risk indicate the potential for likely significant effects, which are identified as species with modelled outputs of one or more collisions over 35 years. For these species the robustness of the CRMs are tested by re-running the models to provides greater confidence in the outputs for predicted collisions risk. The potential for population level effects to arise as a result of turbine mediate mortality is then assessed.

7H.5.1 Predicted collision risk – potential for likely significant effects

For the target species listed in Table 7H.12, the CRMs generated low levels of theoretical collision risk (< 1 collision over 35 years) for four of the 12 target species analysed, including:

- Black-headed gull
- Peregrine
- Snipe
- Sparrowhawk

For these four species the levels of collision risk predicted is negligible and will not affect these species at the population level, i.e. collision-mediated mortality would not add significantly (>1%) to background levels of mortality. Nevertheless, it is important to stress that, as is always the case with a modelled approach, the CRM outputs are only considered to be indicative of the risk level for turbine mediate mortality. For instance, it is acknowledged that the application of CRMs to smaller, evasive species like sparrowhawk and snipe may not provide an accurate estimate of predicted collision risk, as these species can be difficult to detect over the full extent of the viewsheds for VPs, due to diminutive size, cryptic nature and/or flight behaviour. Furthermore, the modelled outputs do not consider the potential displacement of birds from the proposed Wind Farm site, which for species breeding within or directly adjacent to the site, like sparrowhawk or snipe has the potential for higher magnitude of effects than collision risk. This is examined further and taken into account when addressing potential for significant effects within the EIAR Chapter 7: Ornithology.

Likewise, for peregrine, while observed flight activity recorded within the CRZ was low over the two-year study, it is noted that there is a nest site within approximately 600 m of the closest turbine. Given the low level of flight activity observed through the 500 m turbine buffer and the separation distances between turbines and the nest, collision risk to adult peregrines is assessed as negligible. The EIAR Chapter 7: Ornithology addresses the potential effects that may be faced by recently fledged birds due to collision risk; as they are inexperienced at flying and likely to be naive to the hazard, which under certain weather conditions may pose a higher risk, e.g. under higher wind speeds if turbines were obscured by low cloud or fog.

For the proposed Wind Farm site the CRMs for buzzard, cormorant, golden plover, grey heron, kestrel, lapwing, lesser black-backed gull and little egret predicted one or more collisions per 35 years, which was reflective of higher levels of aggregate flight time in the collision risk zone recorded for these species and, with the exception of kestrel and both species of gull, these results are strongly influenced by application of a lower default avoidance rate. Based on predicted collision risk, as shown in Table 7H.12, potential for likely significant effects due to turbine mediated mortality were identified for these eight species, and further analysis is undertaken in the following sections to test the robustness of the modelled outputs.

The CRMs were re-run to investigate:

- the effects of different operational parameters, in particular rational period of the turbines;
- the effect of inputting lower flight times as occurring within the slightly smaller CRZ (30 to 180 m);
- the appropriateness of applying default avoidance rates; and
- seasonal variation in collision risk.

Following this analysis, which provides greater confidence in the outputs for predicted collisions risk, the potential for population level effects to arise as a result of turbine mediate mortality is then assessed.

Based on the initial CRM outputs, as summarised in Table 7H.12, it can be seen for three target species that only one or close to one collision is predicted over 35 years, including: cormorant, grey heron and little egret.

7H.5.2 Effects of operational period

Table 7H.3, shows the effect of slower (8.0 sec) and faster (5.5 sec) rotational periods on averaged collision probabilities for the three turbine types assessed. Turbine Type B has the highest averaged collision probabilities for target species passing the through the rotor swept area, which is to be expected given that Turbine Type B presents the highest flight risk volume (V_w), due having the the longest rotor diameter (155 m) and widest max chord (4.5 m). However, as shown by the final outputs in Table 7H.12, the differences for predicted collision risk across the three turbine types assessed was only marginal. For the operational specifications and flight times inputted into the CRM, Turbine Type B generated the outputs with slightly higher predicted collision risk than the other two turbine types. Turbine Type C, with the smallest flight risk volume (V_w), generated the lowest predicted collision risk, but this was only very marginal when compared to Turbine Type A.

In order to test the effect of rotational period, the CRMs were re-run for all three turbine types inputting rational periods of 5.50 seconds and 8.00 seconds. This was only undertaken for species were the CRM outputs predicted one or more collision over the 35 year life span of the proposed Wind Farm. The results for these modelled outputs are shown in Table 7H.14, along with the results from the initial CRMs applying a rational period of 6.85 seconds for comparison.

The effect of applying different rotational periods only has a minimal effect on the modelled outputs, especially for the smaller (shorter) and/or faster flying species like golden plover and lapwing, and predicted collision risk does not vary significantly over the range tested (5.5 to 8.0 seconds). Therefore, the outputs can be considered representative of a range operational conditions that may be encountered by birds flying through the proposed Wind Farm site.

7H.5.3 Effects of variation in the collision risk zone 25-180 m vs 30-180 m

In relation to target species occupancy within the collision risk zone, the same values for aggregated flight seconds were used initially to assess the three turbine types and captured all flights within the height range of 25 to 180 m. This was considered precautionary for Turbine Type A and Turbine Type C, as the lowest rotor swept heights for these two turbine types were 5-6 m higher than for Turbine Type B. As shown by the values in parenthesis in Table 7H.5, aggregated flight seconds recorded within the height range of 30 to 180 m are lower in some instances. In order to test the effect of lower flight time in the

CRZ, the CRMs were re-run for Turbine Type A and Type C, inputting aggregate flight seconds within the height range of 30-180 m and Table 7H.13 show occupancy (n) calculated for each VP. This was only undertaken for species were the CRM outputs predicted one or more collision over the 35 year life span of the proposed Wind Farm. The results for these modelled outputs are shown in Table 7H.15.

The effect of inputting lower flight time within the CRZ, representative of the 30 to 180 m height range, had minimal effects on most of the modelled outputs. Therefore, the outputs can be considered representative of typical levels of flight activity and behaviour for target species within the rotor swept area, especially within the lower height bands between 25 m and 30 m.

Table 7H.13: Occupancy n (bird-secs) values calculated for each VP applying CRZ 30-180 m

Species name	Analysis period (hours)		Occupancy n (bird secs)			
			VP1	VP2	VP3	VP4
Buzzard	Year-round	4,380	105.27	241.31	121.22	140.47
Cormorant	Year-round	4,380	1.29	1.03	-	6.11
Golden plover	Wintering + April	2,127	198.45	4421.12	2820.77	2186.77
Grey heron	Year-round	4,380	1.32	2.79	4.48	8.80
Kestrel	Year-round	4,380	2.84	36.17	14.88	11.80
Lapwing	Year-round	4,380	10.34	326.60	5717.15	2431.10
Lesser black-backed gull	Year-round	4,380	91.43	93.04	62.44	421.81
Little egret	Year-round	4,380	-	4.72	-	2.17

7H.5.4 Default avoidance rates

Based on SNH (2018a) guidelines, as there are no species specific avoidance rates officially recognised by NatureScot for buzzard, cormorant, golden plover, grey heron, lapwing and little egret, with the default avoidance rate (0.98) being applied in CRMs for these species. For buzzard, the while the default avoidance rate is considered too low it is not contested. Due to the favourable conservation status of buzzards, little research effort has been invested into investigating collision risk in buzzard and evidence to show that that the application of higher avoidance rates is appropriate for this species is limited. In addition, buzzards in similarity with kestrels may be somewhat prone to colliding with turbines. For cormorant, grey heron and little egret modelled outputs predicted one or close to one collision over the 35 years, which is very low and does warrant further investigation with regards to avoidance rates. Needless to say, application of higher avoidance rates would reduce predicted collision further for these species.

Several post-construction ornithological studies monitoring turbine mediated mortality have shown that avoidance rates for golden plover and lapwing are likely to be significantly higher than the default setting, especially for wintering populations (see review by Gittings, 2022). The relevance of studies are discussed further below and in view the findings, golden plover and lapwing CRMs were re-run, applying avoidance ranging from 98.5% to 99.9% for comparison against the default avoidance (98.0%), as applied in the initial CRMs. The specifications for Turbine Type B, as the marginally worst-case scenario, were inputted into the CRMs along with the operational parameters applied in the initial models (rotational period of 6.85 and pitch of 6°) and flight times for the maximum rotor swept area (25-180 m). The results for golden plover and lapwing are presented in Table 7H.16 and Table 7H.17, respectively.

The outputs for golden plover and lapwing show that avoidance rate strongly influences the levels of collision risk predicted and outputs range from:

- Golden plover — 599 collisions over 35 years at **98.0%** avoidance; 30 collisions over 35 years at **99.9%** avoidance
- Lapwing — 351 collisions over 35 years at **98.0%** avoidance

18 collisions over 35 years at **99.9%** avoidance

7H.5.5 Applying higher avoidance rate for golden plover and lapwing

Collision risk for wader species, including golden plovers and lapwing are generally considered to be low due to manoeuvrability in flight (Mc Guinness *et al.*, 2015). A review by Gittings (2022) of post-construction monitoring studies at three wind farm sites in the UK that support wintering golden plover, found that there is empirical evidence that higher avoidance rates should be applied for non-breeding golden plovers; and avoidance ranging from 99.6% to 99.8% would generate more realistic modelled outputs, which are in line with avoidances rates applied for wintering geese (SNH, 2013). Although not specifically reviewed by Gittings (2022), two of these wind farm sites also supported lapwing and based on these studies it is clear that both golden plover and lapwing exhibited very high degrees of turbine avoidance behaviour, well in excess of 99% – see post-construction monitoring reports for Blood Hill Wind Farm (Percival *et al.*, 2008) and Goole Fields Wind Farm (Percival *et al.*, 2018a, 2018b)[24]. Taking account of the findings from these studies, it is recommended that the impact assessment for golden plover and lapwing assess the effects of predicted collision risk by the applying higher, empirically derived avoidance rates suggested by these studies. Testing population level effects at 99.5% (precautionary) and 99.8% avoidance is considered appropriate, with reference to the default 98% avoidance included to remain in line with SNH (2018a) guidance on the application of default avoidance rates.

7H.5.6 Annual and seasonal variation in collision risk

Figure 7H.3, Figure 7H.4, Figure 7H.5, Figure 7H.6 and Figure 7H.7 illustrate how the flight times (aggregate seconds within the 500 m turbine buffer) recorded for buzzard, golden plover, kestrel, lapwing and lesser black-backed gull, respectively, were distributed over the two year study period. For lapwing and golden plover, the charts highlight the relatively sporadic nature of flights within the 500 m turbine buffer over the winter, and for lapwing the low level of time over the breeding season associated with attempts to breeding within the 500 m buffer.

In order to test for both annual and seasonal variation in collision risk for lapwing the CRM was re-run applying specifications for Turbine Type B, as the marginally worst-case scenario, along with the operational parameters applied in the initial model (rotational period of 6.85 and pitch of 6°) and flight times for the maximum rotor swept area (25-180 m), with adjustments made to the flight period and flight times based on the season being analysed (see Table 7H.18).

Table 7H.19 shows outputs for CRMs run to account for differences in lapwing flight time recorded in breeding seasons 2022 & 2023 combined and separately, and non-breeding seasons 2021/22 & 2022/23 combined and separately. In addition, outputs are shown for a range of avoidance rates and as outlined in the previous section, the default avoidance rate (0.98) is considered too low and will generate unrealistic outputs. Therefore testing population level effects for lapwing at 99.5% (precautionary) and 99.8% avoidance is considered appropriate.

The seasonal CRMs run for lapwing clearly show that predicted collision risk for lapwing is driven by the significantly higher levels of aggregate flight time recorded for wintering birds. Likewise, higher recorded aggregate flight times resulted in predicated collision risk being higher in the second non-breeding season (2022/23), with estimated collisions over 35 years for both non-breeding seasons ranging from:

- 116 to 425 collisions over 35 years with avoidance at 98.0%

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[24] These post-construction monitoring reports compiled by Ecology Consulting can be accessed via index (ecologyconsult.co.uk)

- 29 to 106 collisions over 35 years with avoidance at 99.5%
- 12 to 43 collisions over 35 years with avoidance at 99.8%

The outputs from the breeding season models run for lapwing (see Table 7H.19) show that collision risk becomes negligible for breeding birds once avoidance is set to 99.5%. Higher recorded aggregate flight times resulted in predicated collision risk being higher in the second breeding season (2023), with estimated collisions over 35 years for both breeding seasons ranging from:

- 0.7 to 4.3 collisions over 35 years with avoidance at 98.0%
- 0.2 to 1.1 collisions over 35 years with avoidance at 99.5%
- 0.1 to 0.4 collisions over 35 years with avoidance at 99.8%

In both breeding seasons (2022 & 2023), while a small number of pairs attempted to breed within the proposed Wind Farm site; these attempts failed entirely in 2022 and in 2023 only a single pair persisted, which contributed to low flight activity. In addition to the potential effects of collision risk, displacement effects of turbines on breeding lapwing, should be assessed further in the EIAR Chapter 7 Ornithology.

Examining the distribution of flight time for lesser black-back gull in Figure 7H.7, it can be seen that flight activity for lesser black-backed gull was almost entirely recorded within the first year. Re-running the CRM for lesser black-backed gull for year one only (Oct-2021 to Sept-2022), finds that predicted collision risk doubles from one collision every 3.2 years to one collision every 1.6 years. Adopting the high estimate is considered appropriate, rather than taking the average between a higher activity year and a lower activity year. This precautionary approach is supported by similar levels of activity being recorded over the preliminary study year, Oct-2020 to Aug-2021 (FTC, 2022).

Table 7H.14: Predicted collision risk for selected target species at different rotational periods

Turbine	Type A			Type B			Type C		
Rotational period (sec)	**5.50**	**6.85**	**8.00**	**5.50**	**6.85**	**8.00**	**5.50**	**6.85**	**8.00**
Predicted collisions per annum									
Buzzard	0.882	0.818	0.783	0.928	0.861	0.824	0.880	0.817	0.781
Cormorant	0.033	0.031	0.029	0.035	0.032	0.031	0.033	0.030	0.029
Golden plover	16.562	16.153	15.984	17.534	17.104	16.910	16.565	16.120	15.979
Grey heron	0.038	0.035	0.033	0.040	0.036	0.034	0.038	0.035	0.033
Kestrel	0.212	0.199	0.191	0.224	0.210	0.202	0.212	0.198	0.191
Lapwing	9.883	9.478	9.274	10.447	10.022	9.803	9.862	9.475	9.266
Lesser black-backed gull	0.319	0.299	0.288	0.335	0.314	0.303	0.318	0.298	0.288
Little egret	0.027	0.026	0.025	0.028	0.027	0.027	0.027	0.026	0.025
Predicted collisions per 35 years	**5.50**	**6.85**	**8.00**	**5.50**	**6.85**	**8.00**	**5.50**	**6.85**	**8.00**
Buzzard	30.9	28.6	27.4	32.5	30.1	28.8	30.8	28.6	27.34
Cormorant	1.2	1.1	1.0	1.2	1.1	1.1	1.2	1.1	1.02
Golden plover	579.7	565.4	559.4	613.7	598.6	591.8	579.8	564.2	559.25
Grey heron	1.3	1.2	1.1	1.4	1.3	1.2	1.3	1.2	1.14
Kestrel	7.4	6.9	6.7	7.8	7.3	7.1	7.4	6.9	6.68
Lapwing	345.9	331.7	324.6	365.6	350.8	343.1	345.2	331.6	324.32
Lesser black-backed gull	11.2	10.5	10.1	11.7	11.0	10.6	11.1	10.4	10.07
Little egret	0.9	0.9	0.9	1.0	1.0	0.9	0.9	0.9	0.89
Predicted number of years per collision	**5.50**	**6.85**	**8.00**	**5.50**	**6.85**	**8.00**	**5.50**	**6.85**	**8.00**
Buzzard	1.1	1.2	1.3	1.1	1.2	1.2	1.1	1.2	1.3
Cormorant	30.3	32.8	34.3	28.8	31.2	32.7	30.4	32.8	34.4
Golden plover	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Grey heron	26.2	28.9	30.7	25.0	27.6	29.3	26.3	29.0	30.8
Kestrel	4.7	5	5.2	4.5	4.8	4.9	4.7	5.0	5.2
Lapwing	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Lesser black-backed gull	3.1	3.3	3.5	3.0	3.2	3.3	3.1	3.4	3.5
Little egret	37.1	38.5	39.3	35.1	36.5	37.3	37.1	38.6	39.3

Table 7H.15: Predicted collision comparing flight times for CRZ 30-180 m and CRZ 25-180 m

Turbine	Type A		Type B	Type C	
Height band for CRZ	30-180	25-180	25-180	25-180	30-180
Predicted collisions per annum					
Buzzard	0.812	0.818	0.861	0.817	0.811
Cormorant	0.021	0.031	0.032	0.030	0.021
Golden plover	16.122	16.153	17.104	16.120	16.089
Grey heron	0.033	0.035	0.036	0.035	0.033
Kestrel	0.182	0.199	0.210	0.198	0.181
Lapwing	8.609	9.478	10.022	9.475	8.607
Lesser black-backed gull	0.291	0.299	0.314	0.298	0.290
Little egret	0.021	0.026	0.027	0.026	0.021
Predicted collisions per 35 years					
Buzzard	28.4	28.6	30.1	28.6	28.4
Cormorant	0.7	1.1	1.1	1.1	0.7
Golden plover	564.3	565.4	598.6	564.2	563.1
Grey heron	1.2	1.2	1.3	1.2	1.2
Kestrel	6.4	6.9	7.3	6.9	6.4
Lapwing	301.3	331.7	350.8	331.6	301.3
Lesser black-backed gull	10.2	10.5	11	10.4	10.1
Little egret	0.7	0.9	1.0	0.9	0.7
Predicted number of years per collision					
Buzzard	1.2	1.2	1.2	1.2	1.2
Cormorant	48.4	32.8	31.2	32.8	48.4
Golden plover	0.1	0.1	0.1	0.1	0.1
Grey heron	30.3	28.9	27.6	29	30.4
Kestrel	5.5	5.0	4.8	5	5.5
Lapwing	0.1	0.1	0.1	0.1	0.1
Lesser black-backed gull	3.4	3.3	3.2	3.4	3.4
Little egret	47.2	38.5	36.5	38.6	47.3

Table 7H.16: Predicted collision risk for golden plover applying different avoidance rates

CRM run for Turbine Type B (rotational period 6.85, pitch 6°) and flight time in CRZ 25-180m

Avoidance rate	Collisions			
	Per year	Per decade	Per 35 years	1 collision every x years
0.980	17.10	171.0	598.6	0.06
0.990	8.55	85.5	299.3	0.12
0.992	6.84	68.4	239.5	0.15
0.995	4.28	42.8	149.7	0.23
0.998	1.71	17.1	59.9	0.58
0.999	0.86	8.6	29.9	1.17

Table 7H.17: Predicted collision risk for lapwing applying different avoidance rates

CRM run for Turbine Type B (rotational period 6.85, pitch 6°) and flight time in CRZ 25-180m for two years

Avoidance rate	Collisions			
	Per year	Per decade	Per 35 years	1 collision every x years
0.980	10.02	100.2	350.8	0.10
0.990	5.01	50.1	175.4	0.20
0.992	4.01	40.1	140.3	0.25
0.995	2.51	25.1	87.7	0.40
0.998	1.00	10.0	35.1	1.00
0.999	0.50	5.0	17.5	2.00

Table 7H.18: Seasonal variation in flight times recorded for lapwing

Values used in the CRMs were aggregate flight time within the 500m buffer recorded at rotor swept heights 25-180m, with values in parenthesis showing aggregate flight time at and below the rotor swept heights within the 500m buffer

Season	Aggregate flight time (seconds)				
	VP1	VP2	VP3	VP4	Seasonal totals
Breeding 2022		0 (174)		480 (5,912)	**480** (6,086)
Breeding 2023		2,466 (2,466)		631 (646)	**3,097** (3,112)
Breeding season 2022 & 2023 combined		**2,466**		**1,111**	**3,577**
Non-breeding 2021-22	0 (810)	21,530 (21,76)5	64,953 (97,632)	23,275 (32,193)	**109,758** (152,401)
Non-breeding 2022-23	305 (305)	17,200 (17,200)	190,585 (190,585)	210,304 (212,299)	**418,394** (420,390)
Non-breeding season 2021-22 & 2022-23 combined	**305**	**38,730**	**255,538**	**233,579**	**528,153**
Overall total	**305**	**41,197**	**255,538**	**234690**	**531,730**

Table 7H.19: Seasonal CRM outputs for lapwing applying a range of avoidance rates

CRM run for Turbine Type B (rotational period 6.85, pitch 6°) and flight time in CRZ 25-180m – see Table 7H.11

Season(s) included in analysis	Avoidance rate	Collisions (weighted)			1 collision every x years
		Per year	Per decade	Per 35 years	
Breeding seasons combined 2022 & 2023	**0.980**	0.073	0.73	2.6	13.7
	0.990	0.037	0.37	1.3	27.3
	0.992	0.029	0.29	1.0	34.1
	0.995	0.018	0.18	0.6	54.6
	0.998	0.007	0.07	0.3	136.6
Breeding season 2022 only	**0.980**	0.020	0.20	0.7	48.9
	0.990	0.010	0.10	0.4	97.7
	0.992	0.008	0.08	0.3	122.1
	0.995	0.005	0.05	0.2	195.4
	0.998	0.002	0.02	0.1	488.5
Breeding season 2023 only	**0.980**	0.122	1.22	4.3	8.2
	0.990	0.061	0.61	2.1	16.4
	0.992	0.049	0.49	1.7	20.5
	0.995	0.030	0.30	1.1	32.8
	0.998	0.012	0.12	0.4	82.0
Non-breeding seasons combined 2021-22 & 2022-23	**0.980**	7.817	78.17	273.6	0.1
	0.990	3.908	39.08	136.8	0.3
	0.992	3.127	31.27	109.4	0.3
	0.995	1.954	19.54	68.4	0.5
	0.998	0.782	7.82	27.4	1.3
Non-breeding season 2021-22 ONLY	**0.980**	3.323	33.23	116.3	0.3
	0.990	1.662	16.62	58.2	0.6
	0.992	1.329	13.29	46.5	0.8
	0.995	0.831	8.31	29.1	1.2
	0.998	0.33	3.32	11.6	3.0
Non-breeding season 2022-23 ONLY	**0.980**	12.137	121.37	424.8	0.1
	0.990	6.069	60.69	212.4	0.2
	0.992	4.855	48.55	169.9	0.2
	0.995	3.034	30.34	106.2	0.3
	0.998	1.214	12.14	42.5	0.8

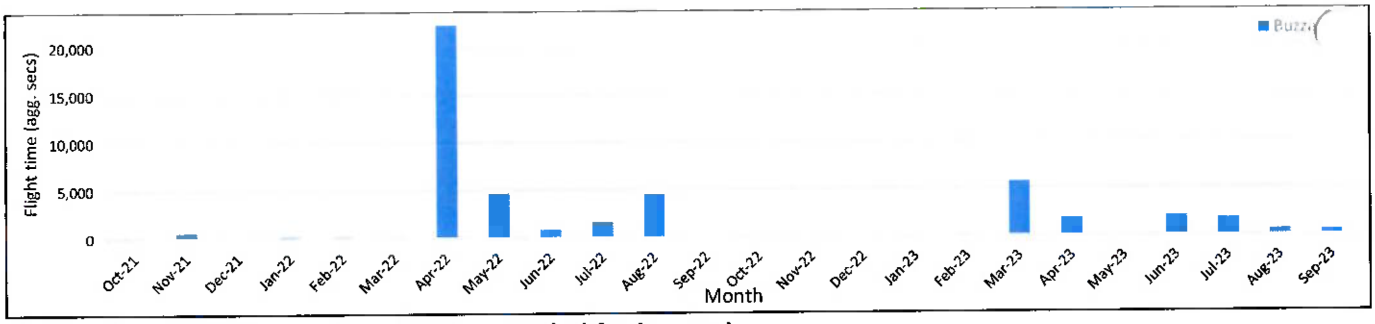

Figure 7H.3: Distribution of flight time recorded for buzzard

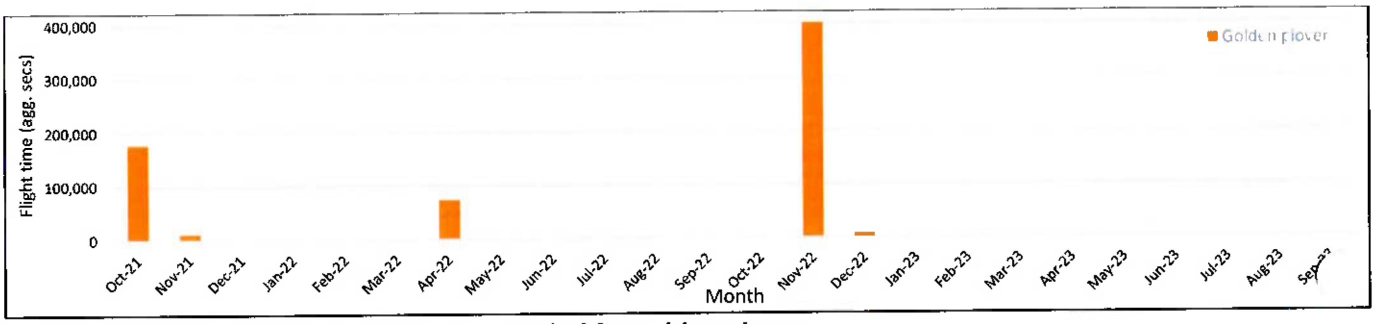

Figure 7H.4: Distribution of flight time recorded for golden plover

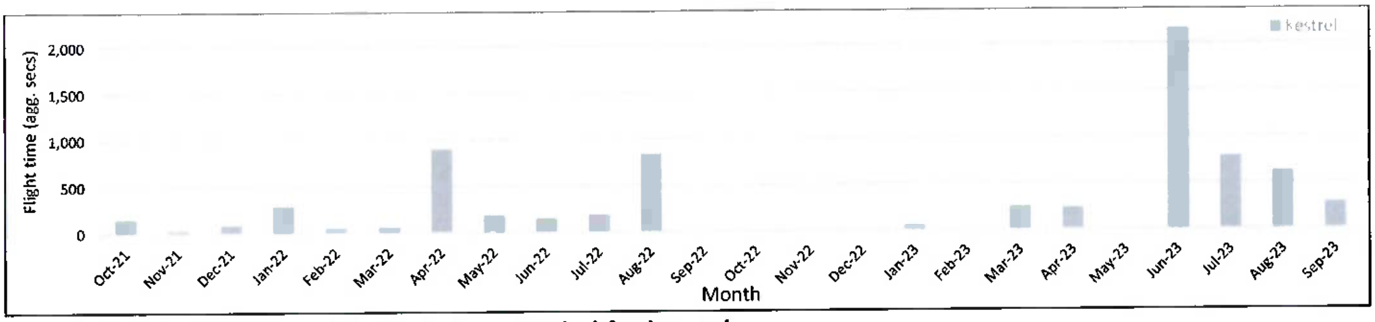

Figure 7H.5: Distribution of flight times recorded for kestrel

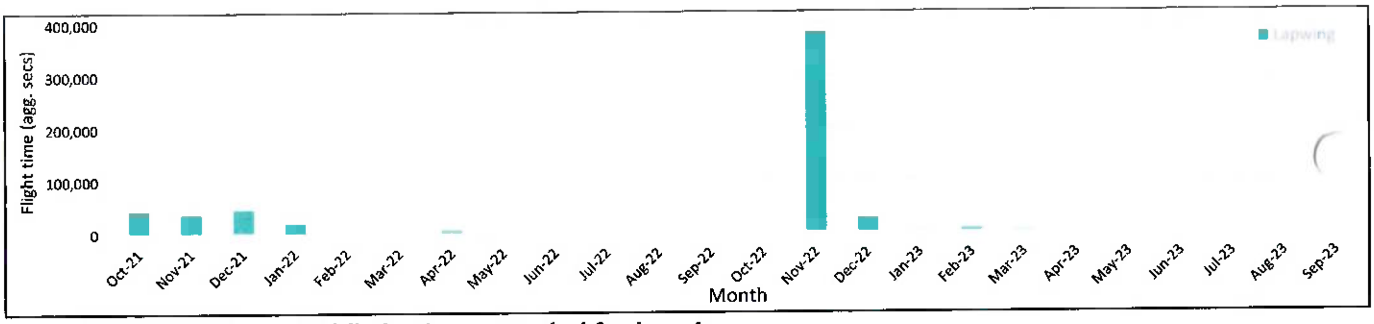

Figure 7H.6: Distribution of flight time recorded for lapwing

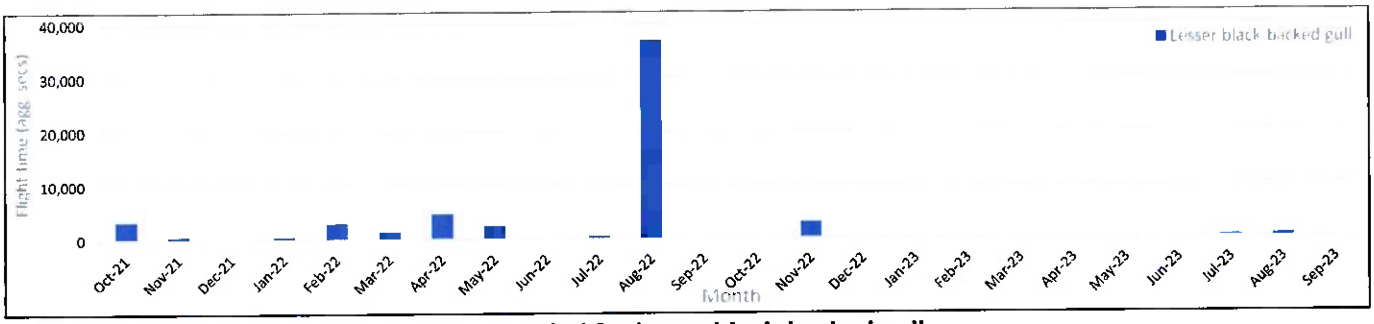

Figure 7H.7: Distribution of flight time recorded for lesser black-backed gull

7H.6 CONCLUSIONS

Collision risk models were run for 12 of the 22 target species recorded during VP watch and three turbine specification were tested.

For the target species listed in Table 7H.12, further investigation is warranted as part of the ornithological impact assessment where the predicted collision risk is more than one collision over 35 years and the ornithological impact assessment should attempt to describe any potential for significant effects at a population level, as well as any potential for significant effects on populations linked to SPAs. The factors that can influence collision risk for specific species, such as the displacement effects of wind turbines or even habituation over time, should be discussed in relation to modelled outputs to provide context to the predicted values for avian collision risk.

The CRMs identified eight species where observed flight activity generated predicted collision risk of one or more collision over 35 years, including buzzard, cormorant, golden plover, grey heron, kestrel, lapwing lesser black-backed gull and little egret. Predicted collision risk outputs for these species were analysed further, including investigating the effects of different operational parameters, the appropriateness of applying default avoidance rates and seasonality in collision risk.

The modelled values for predicted collision risk are provided for consideration within the ornithological impact assessment for the proposed Wind Farm, and this section concludes with an assessment of the population level effects that could be expected based on predicted collision risk – see Table 7H.20 (lapwing), Table 7H.21 (breeding lapwing), Table 7H.22 (golden plover), Table 7H.23 (lesser black-backed gull), Table 7H.24 (buzzard) and Table 7H.25 (kestrel). For cormorant, grey heron and little egret modelled outputs predicted one or close to one collision over the 35 years, and this relatively low level of predicted collision risk is considered unlikely to have any significant population level effects.

For the ornithological receptors identified the modelled outputs are applicable to the proposed turbine layout, proposed number of turbines and for turbine types within the dimensions specified. With the additional analysis conducted, including inputting of higher avoidance rates for golden plover and lapwing, it is considered that the modelled outputs for predicted collision risk while representative of typical operating conditions likely to be encountered by birds utilising the site, are still higher than anticipated for most target species, especially golden plover and lapwing where further assessment is required to account for high levels behavioural avoidance of turbines.

Table 7H.20: Lapwing collision risk – assessment of population level effects – all year

Lapwing	All-Ireland pop.			County pop. est.			Local pop. est.		
Population	84,690			2,000			260		
Annual survival rate (BTO BirdFacts)	0.71			0.71			0.71		
Annual background mortality	24,560			580			75		
Avoidance (%)	98.0%	99.5%	99.8%	98.0%	99.5%	99.8%	98.0%	99.5%	99.8%
Predicted annual collision mortality weighted, 98% | 99.5% | 99.8% avoidance	10.02	2.51	1.00	10.02	2.51	1.00	10.02	2.51	1.00
Increased annual mortality rate due to predicted collision risk (%)	0.04	0.01	0.00	1.73	0.43	0.17	13.29	3.33	1.33
No. of collisions per annum required for 1% increase in annual mortality	246			6			0.75		

Table 7H.21: Lapwing collision risk – assessment of population level effects – breeding population

Lapwing	All-Ireland pop. Low			All-Ireland pop. High			Local pop. est.		
Population (pairs converted to no. of birds)	952			1,240			12		
Annual survival rate (BTO BirdFacts)	0.71			0.71			0.71		
Annual background mortality	276			360			3		
Avoidance (%)	98.0%	99.5%	99.8%	98.0%	99.5%	99.8%	98.0%	99.5%	99.8%
Predicted annual collision mortality weighted, 98% | 99.5% | 99.8% avoidance	0.122	0.03	0.012	0.12	0.03	0.012	0.12	0.03	0.012
Increased annual mortality rate due to predicted collision risk (%)	0.04	0.01	0.00	0.03	0.01	0.00	3.51	0.86	0.34
No. of collisions per annum required for 1% increase in annual mortality	3			4			0.03		

Table 7H.22: Golden plover collision risk – assessment of population level effects

Golden plover	All-Ireland pop.			County pop. est. Low | High						Local pop. est. Low | High					
Population	92,060			3,000 | 5,000						200 | 700					
Annual survival rate (BTO BirdFacts)	0.73			0.73						0.73					
Annual background mortality	24,856			810 | 1,350						54 | 189					
Avoidance (%)	98.0%	99.5%	99.8%	98.0%		99.5%		99.8%		98.0%		99.5%		99.8%	
Predicted annual collision mortality weighted, 98% | 99.5% | 99.8% avoidance	17.10	4.28	1.71	17.10		4.28		1.71		17.10		4.28		1.71	
Increased annual mortality rate due to predicted collision risk (%)	0.07	0.02	0.01	2.1	1.3	0.5	0.3	0.2	0.1	31.7	9.1	7.9	2.3	3.2	0.9
No. of collisions per annum required for 1% increase in annual mortality	249			8 | 14						0.5 | 1.9					

Table 7H.23: Lesser black-backed gull collision risk – assessment of population level effects

Lesser black-backed gull	All-Ireland pop. Winter		All-Ireland pop. Breeding		County pop. est.		Local pop. est.	
Population	11,842		14,224		500		100	
Annual survival rate (BTO BirdFacts)	0.913				0.913		0.913	
Annual background mortality	1,030		1,237		44		9	
Predicted annual collision mortality weighted, 99.5% avoidance (low | high)	0.31	0.64	0.31	0.64	0.31	0.64	0.31	0.64
Increased annual mortality rate due to predicted collision risk (%)	0.03	0.06	0.03	0.05	0.71	1.47	3.56	7.36
No. of collisions per annum required for 1% increase in annual mortality	10		12		0.4		0.09	

Table 7H.24: Buzzard collision risk – assessment of population level effects

Buzzard	Irish pop. est.	County pop. est.	Local - adult pop.	Local - juv. pop. (up to 3 years)
Population	4,000	90	6	6
Annual survival rate (BTO BirdFacts)	0.90	0.90	0.90	0.63
Annual background mortality	350	9	1	2
Predicted annual collision mortality weighted, 98% avoidance	0.861	0.861	0.861	0.861
Increased annual mortality rate due to predicted collision risk (%)	0.2	9.6	143.5	38.8
No. of collisions per annum required for 1% increase in annual mortality	4	0.1	0.006	0.022

Table 7H.25: Kestrel collision risk – assessment of population level effects

Kestrel	Irish pop. est.		Local - adult pop.	Local - juv. pop. (up to 3 years)
	Low	High		
Population	9,918	17,393	6	4
Annual survival rate (BTO BirdFacts)	0.69	0.69	0.69	0.32
Annual background mortality	3,075	5,392	2	3
Predicted annual collision mortality weighted, 95% avoidance	0.21	0.21	0.21	0.21
Increased annual mortality rate due to predicted collision risk (%)	0.01	0.004	11.3	7.7
No. of collisions per annum required for 1% increase in annual mortality	31	54	0.02	0.03

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