Bracklyn Wind Farm

Annex 5.7:
Avian Collision Risk Modelling

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List of Tables

Statement of Authority

This report has been written by **Aoife Moroney** (BSc., MSc.) with guidance and input from **Will Woodrow** (MSc., MSc. (Arch), CIEEM, CEcol) throughout the analysis and assessment.

Will is a Director and Principal Ecologist at Woodrow Sustainable Solutions Ltd (Woodrow). He has been studying and working in ecology, including avian ecology, since 1985 and has worked as an ecological consultant since 2004. Will has worked on numerous wind farm projects, including over 20 impact assessments and has undertaken collision risk modelling on over nine wind farm proposals to date.

Aoife is a Graduate Ecologist with Woodrow. She has completed a B.Sc. in Engineering at University College Dublin and M.Sc. in Environmental Engineering (specialising in Environmental Management) at the Technical University of Denmark and the Royal Institute of Technology, Sweden. She is currently undertaking a Post-graduate Certificate in Ecological Survey Techniques at the University of Oxford. Aoife is highly proficient in data analysis and management. She regularly assists in the compilation of environmental reports (including for Appropriate Assessment and Ecological Impact Assessment) as part of larger and smaller scale infrastructure projects.

1.0 Overview

The Application is for a nine-turbine wind farm development proposed for Bracklyn, Co. Westmeath.

As shown in **Figures A5.2.1** to **A5.2.4** in **Annex 5.2**, flight data for selected target species was collected from four vantage points (VPs) over two years. **Annex 5.2** also provides details of timings for VP watches and demonstrates that the minimum requirement of 36 hours per VP per season was achieved across the two year, amounting to a total of 578.25 hours of VP watch data. As listed by the survey effort **Tables A5.2.2** to **A5.2.5** in **Annex 5.2**, conducting of VP watches simultaneous by two surveyors was largely avoided over the two-year study. Simultaneous VP watches were only undertaken on nine out of 96 survey days. When simultaneous VP watches did occur, care was taken to ensure that the viewsheds of the VPs did not overlap, i.e. watches from VP1 and VP3 were not undertaken at the same time to avoid overlap. Therefore, no correction factor to account for simultaneous observer effort was required.

The flight risk volume applied in this analysis is based on a buffer extending 500 m from turbine towers (as shown on the flight line maps in **Annex 5.4**), which equates to area of 450.43 ha. The Collision Risk Modelling (CRM) applies a worst-case scenario with a rotor swept area spanning from 20 to 185 m, which accounts for the proposed hub height of 104 m and a blade diameter of 162 m of the Vestas V162 specified.

CRM was undertaken for those target species with > 200 flight seconds occurring with the potential collision risk zone (CRZ) over the two years (i.e. at collision risk height and within the turbine envelope = 500 m turbine buffer). CRMs were run for nine species, including:

- Greenland white-fronted goose 18,900 flight seconds in CRZ
- Mallard 1,843 flight seconds in CRZ
- Sparrowhawk 2,480 flight seconds in CRZ
- Buzzard 53,033 flight seconds in CRZ
- Kestrel 15,751 flight seconds in CRZ
- Lapwing 9,642 flight seconds in CRZ
- Golden plover 1,341,077 flight seconds in CRZ
- Snipe 1,689 flight seconds in CRZ
- Lesser black-backed gull 6,100 flight seconds in CRZ

2.0 Collision Risk Model – Approach

The collision risk analysis was undertaken using the Scottish Natural Heritage (SNH) model and guidelines[1][2][3], based on Band *et al*. (2007)[4].. The SNH model uses two approaches for different situations. 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, including 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.

[1] SNH (2000). Windfarms and birds: Calculating a theoretical collision risk assuming no avoiding action. Guidance Note Series. Scottish Natural Heritage.

[2] SNH (2018). Avoidance Rates for the onshore SNH Wind Farm Collision Model v2. Scottish Natural Heritage

[3] SNH (2014) Flight Speeds and Biometrics for Collision Risk Modelling. Scottish Natural Heritage October 2014.

[4] Band, W., Madders, M., & Whitfield, DP., (2007). Developing Field and Analytical Methods to Assess Avian Collision Risk at Wind Farm Sites. In: de Lucas, M., Janss, G. & Ferrer, M. (Eds) 2007. Birds and Wind Farms – Risk Assessment and Mitigation. Quercus Editions, Madrid, 259-279

2.1 Stage 1 - Number of birds flying through rotors

This stage involved a number of sequential steps:-

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

$$V_w = Area_{windfarm} * rotor\ diameter \tag{1}$$

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

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

   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 year) 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.

$$b = n\left(\frac{V_r}{V_w}\right) \tag{3}$$

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

$$t = \frac{d + l}{v} \tag{4}$$

   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:

$$N = \frac{n\left(\frac{V_r}{V_w}\right)}{t} = \frac{b}{t} \tag{5}$$

Note in this calculation that the factor $(d + l)$ actually 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 is also applied to the value for bird occupancy n, which is intended to take account of the fact that the observations arise from different Vantage Points (VPs), that different vantage points cover varying area extents (in terms of total hectarage), and that the combination of the areas seen from all VPs may not always incorporate the entire site being assessed. The weighting factor for each VP is worked out by the percentage cover of the 20 m viewshed, as well as the combined percentage cover of all the VPs

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

This stage uses data relating to bird and rotor characteristics in order to compute the likelihood of a bird being hit when flying through the rotor. The turbine and operational model inputs are shown in **Table A5.7.1** and **Table A5.7.2** 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 likely 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)[5]. The outputs from this spreadsheet are provided for each target species in**Table A5.7.2: Avian biometrics and flight speeds model inputs**

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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 likely collision risk per year (assuming no avoidance). An avoidance figure is then applied in order to get a predicted likely collision rate, and thus a likely mortality rate. This stage also takes into account the proportion of time that turbines are likely to be operational.

Avoidance rate are given in SNH (2016, 2018)[6, 7] and Furness (2019)[8], which are used to provide estimates of the number of collisions per annum and for the life of the project (30 years).

Turbine parameter*	Input data used in CRM
No. of turbines proposed	9
No. of blades per rotor	3 blades
Hub height	104 m
Rotor diameter	162 m
Max. chord of blade	4.5 m
Circumference of rotor swept area	508.9 m
Rotor swept area	20,612 m^2
Extent of rotor swept area	23 to 185 m
Pitch of blade[9]	25°
Rotational period	6.5[10]
Cut-in wind speed	3 m/s
Cut-out wind speed	25 m/s
Restart wind speed	24 m/s
Turbine operational time	85%

*Based on turbine specifications of Vestas V162-6.0MW with a hub height of 104 m rotor diameter of 162 m

[5] Available at - https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision (Accessed March 2021)

[6] Scottish Natural Heritage (2016). Avoidance rates for the onshore SNH wind farm collision risk model. SNH.

[7] Scottish Natural Heritage (2018). Avoidance rates for the onshore SNH wind farm collision risk model. SNH.

[8] Furness, R.W. (2019). Avoidance rates of herring gull, great black-backed gull and common gull for use in the assessment of terrestrial wind farms in Scotland. Scottish Natural Heritage Research Report No. 1019.

[9] This estimate is based on Band (2012) where it is stated that 25-30 degrees is reasonable for typical large turbines. It should be noted, however, that this is in relation to large off-shore turbines which will experience larger pitch angles than onshore due to higher wind speeds. It is therefore considered that this is a conservative estimate.

[10] This is a precautionary value chosen based on turbines of a similar dimension.

Table A5.7.1: Turbine and operational inputs – worst case scenario

Species	Length (cm)	Average (cm)	Wing-span (cm)	Average (cm)	Mean equivalent airspeed (m/s)
Greenland white-fronted goose[11]	64-78	71	-	1.45	16
Mallard	-	58	-	90	18.5
Sparrowhawk	28-38	33	55-70	63	10.0
Buzzard	51-57	54	113-128	121	11.6
Kestrel	32-35	34	71-80	76	10.1
Golden plover	-	28	-	72	17.9
Lapwing	-	30	-	84	12.8
Snipe	25-27	26	44-47	46	17.1
Lesser black-backed gull	52-64	58	135-150	143	11.9

Table A5.7.2: Avian biometrics[12] and flight speeds[13] [14] [15] model inputs

Species	Average	Upwind	Downwind	Avoidance rate
Buzzard	6.1%	8.3%	3.9%	98.0%[16]
Golden plover	4.3%	6.0%	2.6%	98.0%[16]
Greenland white-fronted goose	6.0%	7.9%	4.2%	99.8%[17]
Kestrel	5.8%	8.2%	3.4%	95.0%[17]
Lesser black-backed gull	6.2%	8.3%	4.0%	99.5%[18]
Mallard	5.1%	6.8%	3.5%	98.0%[16]
Snipe	4.2%	6.0%	2.4%	98.0%[16]
Sparrowhawk	5.4%	7.6%	3.1%	98.0%[16]
Lapwing	5.0%	7.1%	2.8%	98.0%[16]

Table A5.7.3: Average collision probability as calculated by Band (2007)

[11] Sugimoto, H. & Matsuda, H. (2011). Collision risk of White-fronted Geese with wind turbines. *Ornithological Science* 10(1), pp 61-71.

[12] Snow, D. & Perrins, C.M. 1998. The Birds of the Western Palearctic: 2 Volume Set: Volume 1, Non-passerines; Volume 2, Passerines.

[13] Alerstam, T., Rosen M., Backman J., G P., Ericson P & Hellgren O. 2007. Flight Speeds among Bird Species: Allometric and Phylogenetic Effects. *PLoS Biol*, 5, 1656-1662.

[14] Bruderer, B & Boldt, A. (2001). Flight characteristics of birds: I. radar measurements of speeds. *Ibis* 143, pp 178-204.

[15] Provan, S. & Whitfield, D. P. (2006). *Avian flight speeds and biometrics for use in collision risk modelling*. Report from Natural Research to Scottish Natural Heritage. Natural Research Ltd, Banchory

[16] For species where there is no avoidance rate SNH (2018) recommend applying a rate of 98%

[17] SNH (2018) Avoidance Rates for the onshore SNH Wind Farm Collision Model v2. Scottish Natural Heritage

[18] Furness, R.W. (2019). Avoidance rates of herring gull, great black-backed gull and common gull for use in the assessment of terrestrial wind farms in Scotland. Scottish Natural Heritage Research Report No. 1019.

3.0 Viewshed Spatial Coverage

Vantage point (VP) locations used were the same during all survey periods. Viewshed spatial coverages for each VP were calculated using ArcGIS Pro. Spatial coverage of these VPs, both in relation to the spatial area of the viewshed (at 20 m) within the study area and proportion of the study area, is given in **Total area** = 450.43 ha

Table A5.7.4. The locations of these vantage points in relation to the site and study area (500m buffer from the turbines) and the spatial coverage of each viewshed are mapped in **Figures A5.7.1-A5.7.4.**

Vantage Point (VP)	Area of CRZ visible within 500m turbine buffer	% Coverage	VP survey effort		
			Breeding season (hours)	**Non-breeding season** (hours)	**Total effort** (hours)
VP1	204.18 ha	45%	72.00	72.00	144.00
VP2	206.44 ha	46%	72.00	72.00	144.00
VP3	289.43 ha	64%	72.25	72.00	144.25
VP4	270.75 ha	60%	73.00	72.00	145.00

Total area = 450.43 ha

Table A5.7.4: Spatial visual coverage of 500 m buffer and collision risk zone (CRZ)

Figure A5.7.1: Viewshed analysis at Vantage Point 1

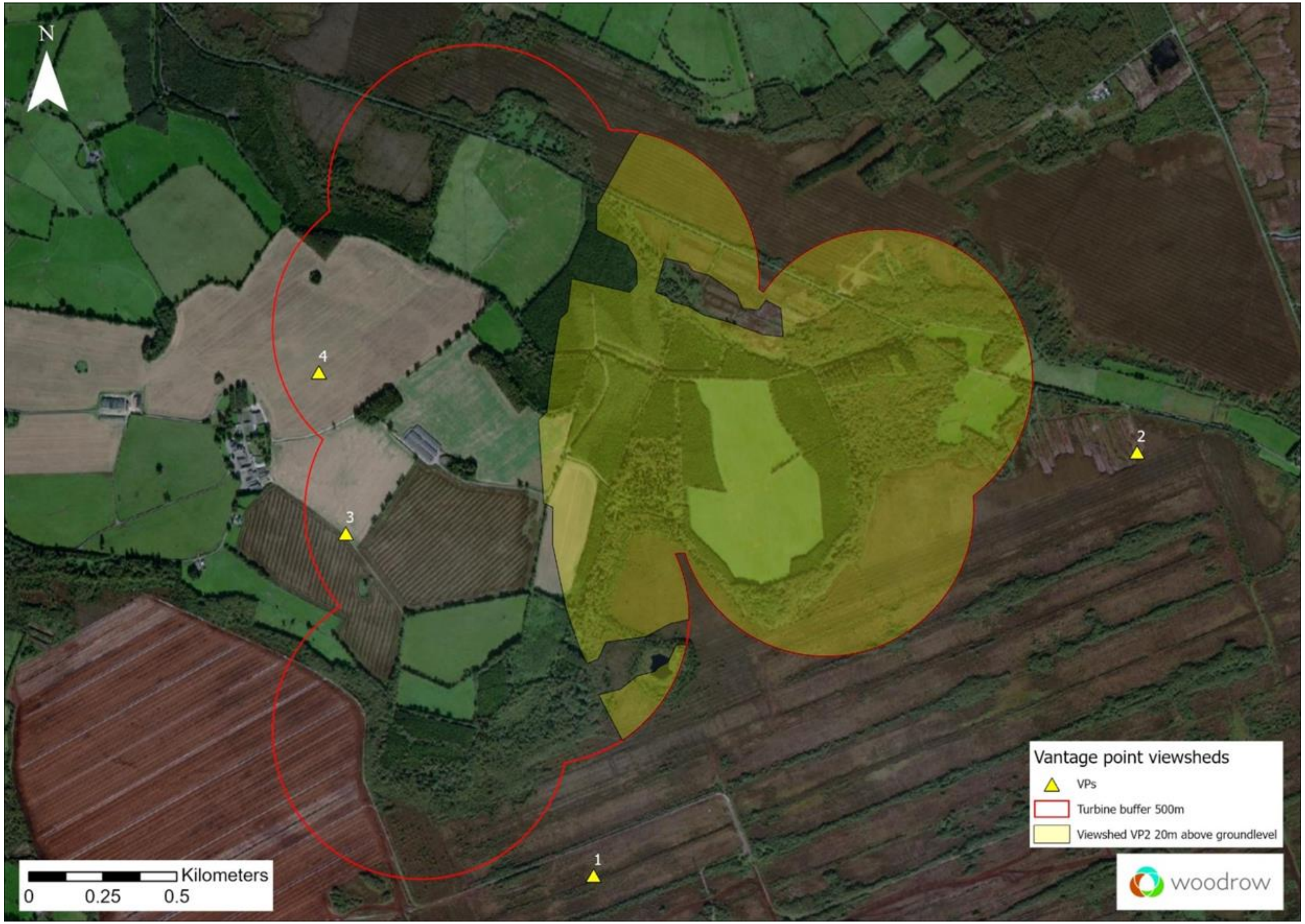

Figure A5.7.2: Viewshed analysis at Vantage Point 2

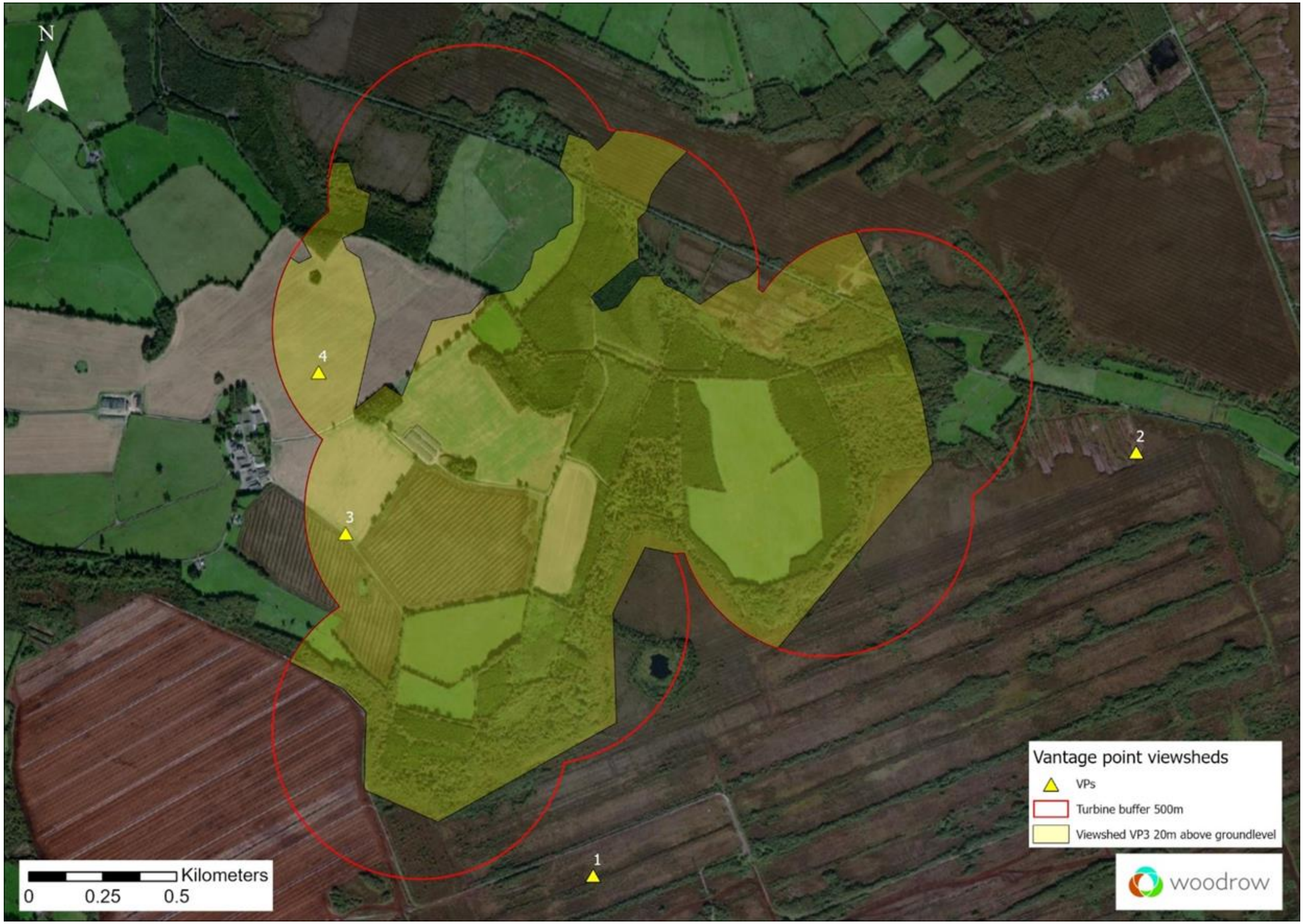

Figure A5.7.3: Viewshed analysis at Vantage Point 3

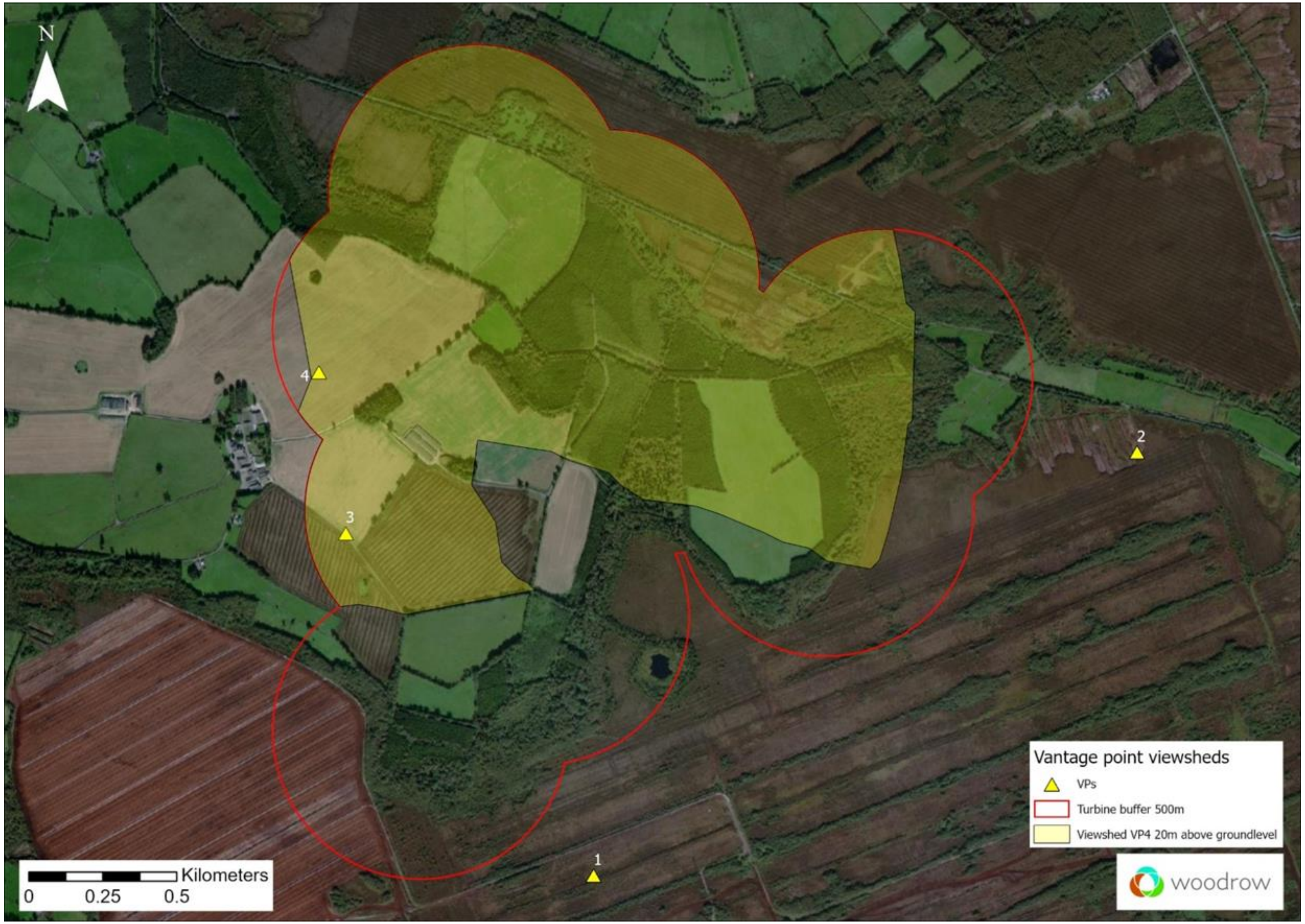

Figure A5.7.4: Viewshed analysis at Vantage Point 4

4.0 Recorded Flight Activity

Surveys were undertaken for four seasons between October 2018 and August 2020. Flight times within the study area and at risk height are provided in **Table A5.7.5** for the 9 target species included in the model.

Species		VP1	VP2	VP3	VP4	Total (flight seconds)
Greenland white-fronted goose				18,900		18,900
Mallard		329	1,028	486		1,843
Sparrowhawk		265	449	658	1,108	2,480
Buzzard		6,372	4,761	21,619	20,281	53,033
Kestrel		2,280	2,923	7,625	2,923	15,751
Golden plover		34,950	62,530	1,131,637	111,960	1,341,077
Snipe		794	685		210	1,689
Lesser black-backed gull			4,470	1,280	230	6,100
Lapwing	Year-round			3,200	6,442	9,642
	Breeding			3200	10	3210
	Wintering				6432	6432

Table A5.7.5: Flight seconds in CRZ for target species from each VP

Oct-2018 to Aug-2020

5.0 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.

The model inputs for both turbine and bird parameters, as well as the basis of weighting for observational effort are provided in **Table A5.7.1** to **Table A5.7.5**.

5.1 Stage 1 - Number of birds flying through rotors

As detailed in the preceding section, the first part of Stage 1 is defining the 'flight risk volume' V_w. This is derived from the wind farm area (4,504,300 m^2) multiplied by the rotor diameter (rotor swept area). This is shown below as 729,696,600 m^3, and calculated using Equation 1. The 'rotor swept volume' V_r is then worked out on the basis of 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 each bird in **Table A5.7.6** and calculated using Equation 2.

$$V_w = Area_{windfarm} * rotor\ diameter = 4504300 * 162 = 729696600m^3$$

$$V_r = X\pi R^2(d+l) = 9\pi\left(\frac{162}{2}\right)^2(4.5+l)$$

Species	V_r (m³)	t (s)
Buzzard	934959.839	0.40482
Golden plover	886727.784	0.26704
Greenland white-fronted goose	966496.183	0.32563
Kestrel	897858.258	0.47921
Lesser black-backed gull	942380.155	0.38779
Mallard	942380.155	0.27459
Snipe	883017.626	0.27836
Sparrowhawk	896003.179	0.42743
Lapwing	890437.942	0.37500

Table A5.7.6: Risk Volume V_r and rotor transit time t for each species

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 (see **Total area** = 450.43 ha

Table A5.7.4**Error! Reference source not found.**) by the number of VP hours undertaken (see **Total area** = 450.43 ha

Table A5.7.4). 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 study area (500m turbine buffer) and the total hours the birds are active across the site. 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. The figures calculated for occupancy, in bird-seconds, are shown in **Table A5.7.7**.

$$Observation\ effort = Area_{viewshed} * Survey\ effort \quad (6)$$

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

Species		VP1	VP2	VP3	VP4
Buzzard		29.5764	21.8569	70.7906	70.9911
Golden plover		78.6679	139.2061	1796.914	190.0457
Greenland white-fronted goose		0.0000	0.0000	24.0767	0.0000
Kestrel		10.5829	13.4189	24.9678	10.2316
Lesser black-backed gull		0.0000	11.2443	2.5119	0.4411
Mallard		1.5271	4.7194	1.5914	0.0000
Snipe		4.6068	3.9309	0.0000	0.9188
Sparrowhawk		1.2300	2.0613	2.1546	3.8784
Lapwing	Year-round	0.0000	0.0000	10.4783	22.5494

	Breeding	0.0000	0.0000	11.5279	0.0385
	Wintering	0.0000	0.0000	0.0000	17.4502

Table A5.7.7: Occupancy n (bird-secs) values calculated for each Vantage Point

As previously described, a weighting factor was used to account for the varying extents of cover of each VP as well as the combined cover of each VP not accounting for the entire site. Weighted values for n were calculated using the values for percentage cover described in **Total area** = 450.43 ha

Table A5.7.4. In this case, the combined VPs cover the entirety of the site and therefore the total cover is 1.

$$n_{weighted} = \frac{n_{VP1}(0.45) + n_{VP2}(0.46) + n_{VP3}(0.64) + n_{VP4}(0.60)}{1}$$

Once a value for n 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 and dividing by the number of VPs, in this case, four. The value for $n_{weighted}$ is also averaged. Both weighted and unweighted values for n_{avg} are shown in **Table A5.7.8.**

Species		n_{avg}	$n_{weightedavg}$
Buzzard		48.3037	27.8960
Golden plover		551.2084	342.0819
Greenland white-fronted goose		6.0192	3.8677
Kestrel		14.8003	8.2852
Lesser black-backed gull		3.5494	1.7582
Mallard		1.9595	0.9694
Snipe		2.3641	1.1105
Sparrowhawk		2.3311	1.3045
Lapwing	Year-round	8.2569	5.0718
	Breeding	2.8916	1.8576
	Wintering	4.3625	2.6223

Table A5.7.8: Values obtained for n_{avg} and $n_{weightedavg}$ (bird-secs)

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 4-5.**Table A5.7.6** The number of transits through the rotors N is then adjusted by a factor of 0.85[19] to obtain Tn, which takes into account likely wind turbine down time. Calculations for the number of transits through the rotors are shown in **Table A5.7.9.**

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

		Unweighted				Weighted			
		n_{avg}	b	N	T_n	n_{avg}	b	N	T_n
Buzzard		48.3037	222.8096	550.3928	467.8339	27.8960	128.6753	317.8587	270.1799
Golden plover		551.2084	2411.384	9030.077	7675.566	342.0819	1496.513	5604.098	4763.483
Greenland white-fronted goose		6.0192	28.7010	88.1413	74.9201	3.8677	18.4422	56.6364	48.1410
Kestrel		14.8003	65.5599	136.8090	116.2876	8.2852	36.7005	76.5858	65.0979
Lesser black-backed gull		3.5494	16.5019	42.5542	36.1711	1.7582	8.1743	21.0793	17.9174
Mallard		1.9595	9.1101	33.1765	28.2000	0.9694	4.5072	16.4140	13.9519
Snipe		2.3641	10.2992	36.9991	31.4492	1.1105	4.8380	17.3802	14.7732
Sparrowhawk		2.3311	10.3045	24.1078	20.4917	1.3045	5.7666	13.4911	11.4675
Lapwing	Year-round	8.2569	36.2729	96.7277	82.2186	5.0718	22.2806	59.4149	50.5027
	Breeding	2.8916	12.7029	33.8743	28.7932	1.8576	8.1607	21.7618	18.4975
	Wintering	4.3625	19.1648	51.1061	43.4401	2.6223	11.5198	30.7195	26.1115

Table A5.7.9: Values obtained for number of transits through the rotors T_n

5.2 Stage 2 - Probability of bird being hit when flying through the rotors

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. These results are detailed in **Table A5.7.10Table A5.7.2: Avian biometrics and flight speeds model inputs**

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Table A5.7.3 provides the collision probability of the selected target species passing through the rotors. The average collision probability is applied within the CRM and is based the collision probability of a bird travelling upwind and travelling 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.

The model was also run for different rotation periods and pitch angles to examine the relationship between these variables and collision risk, see **Table A5.7.11** and **Table A5.7.12Table A5.7.11.** In terms of rotation period, a range of 5-12s was examined, based on turbines of a similar dimension. A high pitch angle of 30 degrees along with a lower pitch angle of 13 degrees was also compared.

		Unweighted					*Weighted*				
		Collisions/year		Stats			Collisions/year		Stats		
		No avoid	Avoid	Per 10 years	Per 30 years	1 bird every x years	No avoid	Avoid	Per 10 years	Per 30 years	1 bird every x years
Buzzard		31.221	0.624	6.244	18.733	1.601	18.030	0.361	3.606	10.818	2.773
Golden plover		346.447	6.929	69.289	207.868	0.144	215.006	4.300	43.001	129.004	0.233
Greenland white-fronted goose		4.603	0.009	0.092	0.276	108.618	2.958	0.006	0.059	0.177	169.039
Kestrel		8.018	0.401	4.009	12.028	2.494	4.489	0.224	2.244	6.733	4.456
Lesser black-backed gull		2.403	0.012	0.120	0.360	83.230	1.190	0.006	0.060	0.179	168.021
Mallard		1.444	0.029	0.289	0.867	0.000	0.715	0.014	0.143	0.429	69.963
Snipe		1.395	0.028	0.279	0.837	35.831	0.656	0.013	0.131	0.393	76.278
Sparrowhawk		1.274	0.025	0.255	0.765	39.237	0.713	0.014	0.143	0.428	70.114
Lapwing	Year-round	4.647	0.093	0.929	2.788	10.761	2.854	0.057	0.571	1.713	17.51
	Breeding	1.627	0.033	0.325	0.976	30.727	1.045	0.021	0.209	0.627	47.829
	Wintering	2.455	0.049	0.491	1.473	20.366	1.476	0.030	0.295	0.885	33.882

Table A5.7.10: Collision risk model results

		High rotation period (5s)					Low rotation period (12s)				
		Collisions/year		Stats			Collisions/year		Stats		
		No avoid	Avoid	Per 10 years	Per 30 years	1 bird every x years	No avoid	Avoid	Per 10 years	Per 30 years	1 bird every x years
Buzzard		22.247	0.445	4.449	13.348	2.247	12.808	0.256	2.562	7.685	3.904
Golden plover		250.558	5.011	50.112	150.335	0.200	184.154	3.683	36.831	110.492	0.272
Greenland white-fronted goose		3.555	0.007	0.071	0.213	140.638	2.306	0.005	0.046	0.138	216.808
Kestrel		5.642	0.282	2.821	8.463	3.545	2.963	0.148	1.482	4.445	6.749
Lesser black-backed gull		1.456	0.007	0.073	0.218	137.398	0.875	0.004	0.044	0.131	228.560
Mallard		0.847	0.017	0.169	0.508	59.066	0.579	0.012	0.116	0.347	86.351
Snipe		0.777	0.016	0.155	0.466	64.318	0.532	0.011	0.106	0.319	93.949
Sparrowhawk		0.890	0.018	0.178	0.534	56.200	0.485	0.010	0.097	0.291	103.123
Lapwing	Year-round	3.486	0.070	0.697	2.092	14.342	2.112	0.042	0.422	1.267	23.678
	Breeding	1.277	0.026	0.255	0.766	39.156	0.773	0.015	0.155	0.464	64.647
	Wintering	1.803	0.036	0.361	1.082	27.738	1.092	0.022	0.218	0.655	45.796

Table A5.7.11: Weighted collision risk values for low and high rotation periods

		High pitch angle (30°)					Low pitch angle (13°)				
		Collisions/year		Stats			Collisions/year		Stats		
		No avoid	Avoid	Per 10 years	Per 30 years	1 bird every x years	No avoid	Avoid	Per 10 years	Per 30 years	1 bird every x years
Buzzard		19.557	0.391	3.911	11.734	2.557	15.147	0.303	3.029	9.088	3.301
Golden plover		228.384	4.568	45.677	137.030	0.219	200.506	4.010	40.101	120.304	0.249
Greenland white-fronted goose		3.133	0.006	0.063	0.188	159.613	2.711	0.005	0.054	0.163	184.425
Kestrel		4.991	0.250	2.496	7.487	4.007	3.435	0.172	1.717	5.152	5.823
Lesser black-backed gull		1.284	0.006	0.064	0.193	155.740	1.021	0.005	0.051	0.153	195.918
Mallard		0.751	0.015	0.150	0.450	66.615	0.680	0.014	0.136	0.408	73.533
Snipe		0.702	0.014	0.140	0.421	71.267	0.599	0.012	0.120	0.359	83.528
Sparrowhawk		0.789	0.016	0.158	0.473	63.385	0.562	0.011	0.112	0.337	88.916
Lapwing	Year-round	3.128	0.063	0.626	1.877	15.984	2.349	0.047	0.470	1.409	21.286
	Breeding	1.146	0.023	0.229	0.687	43.641	0.860	0.017	0.172	0.516	58.116
	Wintering	1.617	0.032	0.323	0.970	30.916	1.214	0.024	0.243	0.729	41.170

Table A5.7.12: Weighted collision risk values for low and high pitch angles

6.0 Results & Observations

The results generated by running this version of the CRM are considered to represent relatively high levels of theoretical collision risk posed to the target species recorded within the turbine envelope based on the flight data collected from October 2018 to August 2020, due to the parameters entered into the model being notably precautionary, including turbine dimensions (especially the maxchord for the blades and pitch), relatively high rotational period and selecting flapping flight behaviour for each species. It is also important to note that, as is always the case with a modelled approach, the collision risk model outputs are only considered to be indicative of the level of risk of fatalities resulting from the proposed wind farm site, and should be considered in conjunction with other discussions within the Avi-fauna section in the Biodiversity Chapter of the EIS. For instance, the outputs from the model do not take account of potential displacement of birds from the wind farm envelope, which for species breeding within or directly adjacent to the site may be more of a cause for concern, e.g. lapwing. It is also acknowledged that the application of CRMs to smaller, evasive species like sparrowhawk and snipe may not provide an accurate estimate of collision risk, as these species can be difficult to detect over the full extent of the viewsheds for VPs, due diminutive size, cryptic nature and/or flight behaviour.

The CRMs generated notably low levels of theoretical collision risk for eight of the target species recorded and less than 1 collisions (weighted) were predicted over the 30-year life span of the project for Greenland white-fronted goose, lesser black-backed gull, mallard, snipe and sparrowhawk.

- Buzzard 10.818 collisions per 30 years (weighted)
- Golden plover 129.004 collisions per 30 years (weighted)
- Greenland white-fronted goose 0.177 collisions per 30 years (weighted)
- Kestrel 6.733 collisions per 30 years (weighted)
- Lapwing (year-round) 1.713 collisions per 30 years (weighted)
- Lesser black-backed gull 0.179 collisions per 30 years (weighted)
- Mallard 0.429 collisions per 30 years (weighted)
- Snipe 0.393 collisions per 30 years (weighted)
- Sparrowhawk 0.428 collisions per 30 years (weighted)

The highest calculated collision risk was for golden plover, at approximately 4 collisions per annum. It is important to note, however, that robust studies on avoidance rates for golden plover have not been carried out and the generic avoidance rate of 98% as per SNH guidance was therefore applied. It should be acknowledged that avoidance rates for this species are likely to be considerably higher.

Weighted collision risk values for low and high dynamic operation speeds and pitch angles were also calculated to examine the impact of these variables on collision risk. These results emphasise how collision risk will vary with wind speed over time at Bracklyn Wind Farm.

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