APPENDIX 7-7

COLLISION RISK ASSESSMENT

Appendix 7-7 – Collision Risk Assessment

Glenard Wind Farm

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1. INTRODUCTION

This document has been prepared by McCarthy Keville O'Sullivan Ltd. (MKO) to assess the collision risk for birds at the proposed Glenard Wind Farm Site, Co. Donegal. The collision risk assessment, prepared by Mr Patrick Manley (BSc), is based on vantage point watch surveys undertaken at the development site from September 2016 to September 2019 and January to September 2021, and is supplemented by data collected between October 2019 and September 2020. This represents a 58-month survey period, consisting of four breeding seasons and three and a half non-breeding seasons, in full compliance with SNH (2017)[1]. Surveys were undertaken from six fixed Vantage Point (VP) Locations, (i.e. VP1a, VP2a, VP3, VP4, VP5a & VP6) between September 2016 and September 2019 and seven fixed Vantage Point (VP) locations, (i.e. VP1a, VP2a, VP3a, VP4, VP5a, VP6 & VP7) between January and September 2021. Note that VP3 was repositioned to VP3a in April 2021. Please refer to EIAR Figure 7.1 for location details. Supplementary data from two additional VP locations are also included in this assessment. These surveys were undertaken between October 2019 and September 2020 by Canavan Associates LTD. This data consists of one breeding and one non-breeding season. Details on the surveyor involved are provided in Section 7.1.3 of the EIAR.

Collision risk is calculated using a mathematical model to predict the numbers of individual birds, of a particular species, that may be killed by collision with moving wind turbine rotor blades. The modelling method used in this collision risk calculation follows Scottish Natural Heritage (SNH) guidance which is sometimes referred to as the Band Model (Band et al. 2007). The Band model has been the subject of academic assessment (e.g. Chamberlain et al., (2005 & 2006), Madders & Whitfield (2006), Drewitt & Langston (2006), Fernley, Lowther & Whitfield (2006)) and its results must be interpreted with a degree of caution.

Two stages are involved in the model:

- Stage 1: Estimation of the number of birds or flights passing through the air space swept by the rotor blades of the wind turbines. Transits are calculated using either the "**Regular** or **Random Flight**" model, depending on flight distribution and behaviour.
- Stage 2: Calculation of the probability of a bird strike occurring. Calculated using a statistical spreadsheet that considers avian biometrics and turbine parameters. This spreadsheet is publicly available on the SNH website. https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision

The product of Stage 1 and Stage 2 gives a theoretical annual collision mortality rate and is based on the assumption that birds do not attempt to avoid colliding with turbines.

An informal third stage is then applied to the generated outcome of Stage 1 and Stage 2. This third stage is to account for a "real life" scenario, i.e. to account for the avoidance measures taken by each bird species, worked out as a percentage applied to the product of stage 1 and 2. This third "informal" stage is often the most important factor of collision risk modelling. For several years, SNH advocated a highly precautionary approach, recommending a value of 95% as an avoidance rate (Band et al., (2007)). However, based on empirical evidence and literature reviews, precautionary rates have now been increased to 98-99% or higher in most cases and are regularly evolving with further examination of bird behaviour and mortality rates at wind farm sites. The most recently recommended species' avoidance rates can be found on the SNH website at https://www.nature.scot/wind-farm-impacts-birds-guidance-avoidance-rates-guidance.

[1] *SNH (2017). Recommended bird survey methods to inform impact assessment of onshore wind farms. Scottish Natural Heritage.*

2. METHODOLOGY

Two forms of collision risk modelling are considered when referencing the Band Model. These are often referred to as the **"Regular Flight Model"** and the **"Random Flight Model"**. The "Regular Flight Model" is generally applied to a suite of flightlines that form a regular pattern such as a commuting corridor between roosting and feeding grounds or migratory routes. As such the "Regular Flight Model" is typically relevant for waterbird species, particularly geese and swans. The "Random Flight Model" is relevant for scenarios whereby no discernible patterns or flight routes can be associated with a species within the study area. Random flights can occur for any species but are most prevalent when examining foraging or hunting flight behaviour.

- **"Random Flight Model"** examines the predicted number of transits through the windfarm by regarding all flights within the viewshed (i.e. a 2km arc of the vantage point) as randomly occurring. This model, therefore, assumes that any observed flight could just as easily occur within the wind farm site as outside it. Any flights recorded as flying within the rotor swept height inside the 2km arc of the vantage point is to be included in the model. This model has a number of key assumptions and limitations;

    1. *Bird activity is not spatially explicit, i.e. activity is equal throughout the viewshed area and this is equal to activity in the wind farm area.*
    2. *Habitat and bird activity will remain the same over time and be unchanged during the operational stage of the wind farm.*
    3. *All flight activity used in the model occurred within the viewshed area calculated at the lowest swept rotor height. (e.g. if the lowest swept height of the turbine blade is 26m, the viewshed coverage displaying the visibility of the area within the 2km arc at a height of 26m above ground level is used). All flights are assumed to have occurred within this visible area, although many are likely to have been above this. This is of note because the model translates flight activity into flight activity per unit area in calculating collision risk. As the observer looks up from the lowest swept height, the visible area will increase: for example as the vegetation of x-height is no longer obscuring the view shed. The visible area (AVP) calculation in the model is therefore highly precautionary as it is likely that the visible area is larger for the flight activity that occurred above 26m.*

  "Regular Flight Model" examines the predicted number of transits through a cross-sectional area of the windfarm which represents the width of the commuting corridor. A 2-dimensional line represents a "risk window" which is the width of the wind farm plus a 500m buffer of the turbines, multiplied by the rotor diameter. All commuting flights which pass through this risk window, within the swept height of the turbines, are included in collision risk modelling. Any regular flights more than 500m from the turbine layout can be excluded from analysis, as these flights are predicted to continue to occur outside of the risk window. This model has a number of key assumptions and limitations;

    1. *Firstly, that the turbine rotor swept area is 2-dimensional, i.e. there is a single row of turbines in the wind farm. This represents all turbines within the commuting corridor accounted for by a single straight-line.*
    2. *It is assumed that bird activity is spatially explicit.*
    3. *Birds in an observed flight only cross the turbine area once and do not pass through the cross-section a second time (or multiple times).*

More detail on both the Random and Regular Flight Model calculations are publicly available and can be found on the SNH website. https://www.nature.scot/wind-farm-impacts-birds-calculating-theoretical-collision-risk-assuming-no-avoiding-action.

In the present case, all species observed during surveys for the proposed Glenard wind farm were classified for the purpose of the analysis as randomly distributed flights that could occur anywhere within the given viewsheds[2]. Therefore the "Random Flight Model" was applied to these species to calculate the predicted number of transits through the wind farm site. An additional benefit of using the "Random Flight Model" is that this model can account for some gaps in the viewshed of the wind farm site.

While the majority of the wind farm site is visible, as provided in Figure 7.2, there is a gap in the viewshed. At the proposed wind farm site, it proved very difficult to achieve full visibility of the entire wind farm site (at the lowest swept height (26m)) given the topography and land use (commercial forestry) of the proposed wind farm site. For example, there is a small valley in a central section of the site surrounded by high ground covered in obscuring forestry. From the outside looking in, it is not possible to see into this valley.

To account for the gaps in the viewshed coverage replacement data was added to the collision risk analysis to act as a proxy for the flight activity that occurred within the viewshed gaps. The analysis was undertaken using all recorded flight activity, including flight activity recorded from vantage points that only overlooked areas where no turbines are proposed (i.e. VP4, VP6 and Canavan's VP2). It is noted that flight activity recorded within a viewshed that do not overlap with a proposed turbine location would not typically be subject to collision risk. The habitats within the viewshed of VP4, VP6 and Canavan's VP2 are not significantly different from the areas where gaps occur in the viewshed, as provided in Figure 7.2. Given this similarity, it is reasonable to use the flight activity recorded at VP4, VP6 and Canavan's VP2 as a proxy for the flight activity that occurred within the gaps in the viewshed. The analysis involved:

- Combined vantage point (VPs) Method – This method combines the data from all vantage point surveys, uses the sum of the flight activity across all vantage points and the sum of the viewshed areas. For this method, observations across all vantage point locations are used to calculate the transits across the wind farm site.

In addition, a second approach was taken, this second approach only includes flight activity that occurred within the viewsheds of vantage points that overlapped with turbine locations.

- VP Averaging Method – This method involves calculating the predicted transits per turbine separately for each vantage point location. The overall number of predicted transits across the entire wind farm site is calculated as the average number of transits multiplied by the total number of turbines for the wind farm site. This method can therefore only utilize data from VPs in which turbines are located within the viewshed (i.e. VP4, VP6 and Canavan VP2 are omitted from this calculation as no turbines are within the viewsheds of these VPs).

A comparison of the results derived from the combined versus averaging method is provided in Section 3.3 below.

The steps used to derive the collision mortality risk for each species observed at the proposed development according to the Band Model are outlined below:

1. Stage 1 (Band): the model uses observations of birds flying through the study area during vantage point surveys to calculate the number of birds estimated to fly through the proposed turbines blade swept areas.

2. Stage 2 (Band): the model calculates the collision risk for an individual bird flying through a rotating turbine blade. The collision risk depends on the species biometrics and flight behaviour. Bird biometrics are available from the British Trust of Ornithology (BTO) online bird collision risk guidance, while flight speeds have been referenced from Alerstam et al. (2007).

[2] It is noted that flight activity within a single species can be both random (unpredictable) and regular (predictable) where there is a ecological rationale for why some flight activity is predictably associated with a certain location.

3. The product of the number of birds calculated to fly through the turbines in a year multiplied by the collision risk (i.e. that a bird doing so will collide with the moving blades) gives the worst-case scenario for collision mortality. The worst-case scenario assumes that birds flying towards the turbines do not attempt to avoid them.

4. An avoidance factor is applied to the results to account for the avoidance of the turbines by birds in flight. This corrects for the ability of the birds to detect and manoeuvre around the turbines. Avoidance rates are available from SNH online bird collision risk guidance (SNH 2018).

This final output after all steps to the model is a real-world estimation of the number of collisions that may occur at the wind farm based on observed bird activity during the survey period.

The Band Method makes a number of assumptions on the biometrics of birds and the turbine design. These are:

- Birds are assumed to be of a simple cruciform shape.
- Turbine blades are assumed to have length, depth and pitch angle, but no thickness.
- Birds fly through turbines in straight lines.
- Bird flight is not affected by the slipstream of the turbine blade.
- As the model assumes that no action is taken by a bird to avoid a collision, it is recognised that the collision risk figures derived are purely theoretical and represent worst case estimates. Note: an avoidance factor is applied to the output of the model to account for the real-world ability of birds to avoid colliding with encountered objects.

Several assumptions were made in the calculation of collision risk for the proposed Glenard Windfarm. These assumptions are tailored specifically to Glenard and are as follows:

- Birds in flight within the study area at heights greater than 26m above ground level are assumed to be in danger of collision with the rotating turbine blades.
- Avoidance factors of individual species are those currently recommended by SNH (2018). An avoidance factor is applied to the results to account for the avoidance of the turbines by birds in flight. This corrects for the ability of the birds to detect and manoeuvre around the turbines.
- No preference was taken for birds using flapping or gliding flight through the study area for species that exhibit both behaviours. In the calculation of the percentage risk of collision for a bird flying through a rotating turbine, the mean of the worst-case scenario (i.e. a bird flying upwind through a turbine using flapping flight whilst the turbine is at its fastest rotation speed) and the best-case scenario (i.e. a bird flying downwind through a rotating turbine using a gliding flight whilst the turbine at its slowest rotation speed) has been used for species which exhibit both flapping and gliding flight. For species that do not glide, such as snipe; only the mean calculations for flapping flights were used.

The Collision Risk Assessment (CRA) also makes assumptions on the turbine specifications, such as rotor diameter and rotational speed. As the final choice of the turbine will not be known until a competitive tendering process is complete, the worst-case scenario is assumed. The worst-case scenario is a combination of the maximum collision risk area (i.e. swept area determined by hub height and rotor blade length), the maximum number of turbines proposed and turbine operational time. The turbine and wind farm characteristics for the purposes of this assessment at the proposed Glenard Windfarm Site are presented in Table 1.

Table 1 Windfarm Parameters at Glenard Wind Farm

Wind Farm Component	Scenario Modelled
Number of turbines	15
Blades per turbine rotor (3d model used)	3
Rotor diameter (m)	140
Rotor radius (m)	70
Hub height (m)	96
Swept height range(m) (i.e. above top of foundation)	26-166
Mean pitch of blade (degrees)	6
Maximum chord (m) (i.e. depth of blade)[3]	4
Max Tip Speed (m/s)	82
Circumference of Blade Tip (Pi*Rotor Diameter)	439.8
Rotational period (s) [439.8/82]	5.36
*Turbine operational time (%)	85%

***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%.**

It was necessary to run a second collision risk model to assess the largest swept path of the range of turbine dimensions (i.e. max. tip height 173m) considered in this application. The second model assesses the swept path between 41-173m. Appendix 1 shows the collision risk assessment based on the minimum rotor diameter and the maximum hub height. These two collision risk assessments allow for the full range of possible turbine dimensions to be assessed (26-173m). Taking a precautionary approach, the highest predicted collision risk for each species was then presented in Section 7.8.2 in Chapter 7 of the EIAR.

[3] The assumed turbine model was GE 137 Turbine for the following parameters: maximum chord and rotational period.

3. RESULTS

Collison estimates were calculated using flight data recorded during vantage point watches at six vantage point locations within the study area from September 2016 to September 2019 and seven vantage point locations within the study area from January to September 2021. Additionally, the data collected between October 2019 and August 2020 from two supplementary vantage points were included in the analysis. The target species recorded within the potential collision risk zone included golden eagle, golden plover, hen harrier, merlin, peregrine, whooper swan, black-headed gull, common gull, grey heron, greylag goose, mallard, buzzard, sparrowhawk, kestrel and snipe. It is acknowledged that the predicted number of transits, and hence predicted rate of collision for snipe may be underestimated, as flight activity for this species is largely crepuscular in nature (during twilight) while the VP survey sample predominantly consists of hours during daylight period when visibility is not an issue (Table 1.4, SNH (2017)).

The calculation parameters utilised in both calculation methods are outlined in Tables 2 – 4. A fully worked example of the calculation of collision risk for kestrel populations is available in Appendix 1.

Table 2 Glenard Windfarm VP Survey Effort and Viewshed Coverage

Vantage Point	Visible Area at 26m (hectares)	Risk Area (hectares)	Turbines visible from VP	Total Survey Effort (hrs)
VP1a	144.46	53.20	1	284.5
VP2a	451.43	261.75	6	279.5
VP3	366.03	183.99	4	246
VP3a	616.48	208.00	6	45.5
VP4	134.41	85.70	0	284.5
VP5a	334.04	159.93	4	284.5
VP6	363.38	19.51	0	285
VP7	523.32	248.98	5	58.5
Canavan's VP1	536.05	274.7	5	72
Canavan's VP2	462.71	45.56	1	72

Table 3 Bird Biometrics (Taken from BTO BirdFacts & Alerstam et al. (2007)) and duration at PCH during VP Surveys

Species	Length (m)	Wingspan (m)	Ave. speed (m/s)	Seconds in flight at PCH (25-175m) Averaging Method	Seconds in flight at PCH (25-175m) Combined Method
Golden Eagle	0.82	2.12	11.9	615	2,301
Golden Plover (Winter&Migration)	0.28	0.72	17.9	15,770	19,924
Hen Harrier	0.48	1.10	9.1	1,022	1,229
Merlin	0.28	0.56	11.3	58	163
Peregrine	0.42	1.02	12.1	185	402
Whooper Swan (Winter)	1.52	2.30	17.3	2,658	5,614
Black-headed Gull (Winter)	0.36	1.05	11.9	822	2,503
Common Gull	0.41	1.20	13.4	855	985
Grey Heron	0.94	1.85	11.2	815	961
Greylag Goose	0.82	1.64	17.1	10,390	10,390
Herring Gull (Breeding)	0.60	1.44	12.8	1,618	2,059
Curlew (Breeding)	0.55	0.90	16.3	180	180

Species	Length (m)	Wingspan (m)	Ave. speed (m/s)	Seconds in flight at PCH (25-175m) Averaging Method	Seconds in flight at PCH (25-175m) Combined Method
Kestrel	0.34	0.76	10.1	8,031	10,785
Snipe	0.26	0.46	17.1	358	1,445
Buzzard	0.54	1.20	13.3	28,215	36,236
Sparrowhawk	0.33	0.62	10	2,961	3,175

Seconds in flight at PCH is calculated by multiplying the number of birds observed per flight by the duration of the flight spent within the height bands 25-175m for VP1a to VP7. For Canavan Associates LTD's VP1 & VP2, height bands 20-100m, 100-130m and >130m were used.

Table 4 Collision Risk Workings (Both Flapping and Gliding Flights took the average Collision Risk Percentage between upwind and downwind)

Species	Flapping Flight	Gliding Flight	Collision Risk [(Flapping + Gliding)/2]
Golden Eagle	7.72%	7.40%	**7.56%**
Golden Plover (Winter&Migration)	4.55%	N/A	**4.55%**
Hen Harrier	6.53%	6.40%	**6.47%**
Merlin	4.76%	4.69%	**4.73%**
Peregrine	4.95%	4.66%	**4.80%**
Whooper Swan (Winter)	8.73%	N/A	**8.73%**
Black-headed Gull (Winter)	5.38%	5.19%	**5.28%**
Common Gull	5.48%	5.20%	**5.34%**
Grey Heron	8.38%	N/A	**8.38%**
Greylag Goose (Winter)	6.51%	N/A	**6.51%**
Herring Gull (Breeding)	6.36%	6.13%	**6.25%**
Curlew (Breeding)	5.48%	N/A	**5.48%**
Kestrel	5.42%	5.32%	**5.37%**
Snipe	4.37%	N/A	**4.37%**
Buzzard	5.95%	5.75%	**5.85%**
Sparrowhawk	5.34%	5.27%	**5.31%**

3.1 VP Averaging Method

The calculation parameters used in the vantage point averaging method for the collision risk model are outlined in Tables 5 – 7. Table 8 provides the results of the collision risk model using the averaging method. This calculation uses flight data from VP1a, VP2a, VP3/3a, VP5a, VP7 and Canavan's VP1 and VP2.

Table 5 Random CRM - Number of Transits per Turbine within the Viewshed of each VP

Species	VP1a	VP2a	VP3	VP3a	VP5a	VP7	CVP1	CVP2
Golden Eagle	1.38	9.15	1.70	0	0	0	0	0
Golden Plover (Winter&Migration)*	0	0	439.95	0	0	0	0	71.38
Hen Harrier	6.48	1.39	5.37	0	3.31	1.05	0.48	1.47
Merlin	1.75	0	0	0	0	0	0.41	0
Peregrine	6.70	0	1.00	0.85	2.03	0	0	0

Species	VP1a	VP2a	VP3	VP3a	VP5a	VP7	CVP1	CVP2
Whooper Swan (Winter)*	79.74	2.13	42.71	n/a	6.77	0	0	0
Black-headed Gull (Winter)*	17.63	3.24	0	n/a	7.34	0	0	0
Common Gull*	0	20.07	0	0	0	0	0	0
Grey Heron	13.21	3.66	3.25	0	4.03	0	0	0
Greylag Goose (Winter)*	25.80	54.67	243.02	n/a	0	0	0	0
Herring Gull (Breeding)*	93.08	0	12.95	0	0	0	0	0
Curlew (Breeding)*	0	0	0	0	0	4.67	0	0
Kestrel	102.67	28.27	4.23	0	5.50	5.56	10.20	29.55
Snipe*	0	1.23	0	0	12.61	0	0	0
Buzzard	292.18	145.30	62.28	8.10	45.93	27.54	118.15	36.48
Sparrowhawk	32.57	6.54	0.66	2.82	7.30	3.88	9.92	0

***Assumed to be active 25% of the night as well as daylight hours as per SNH guidance accounting for Swan/Goose, Gulls and Wader activity. This is calculated as a portion of the length of night for the survey period provided by www.timeanddate.com and is added to available hours for activity of the species per year.**

Table 6 Number of Transits across site per year (Averages calculated from Table 5 Above and adjusted for all 15 turbines)

Species	Average Transits	Transits Across Entire Site (All 15 Turbines) (Average Transits*15)
Golden Eagle	1.53	22.91
Golden Plover (Winter&Migration)	93.92	958.75
Hen Harrier	2.44	36.65
Merlin	0.27	4.05
Peregrine	1.32	19.84
Whooper Swan (Winter)	18.76	281.46
Black-headed Gull (Winter)	4.03	60.45
Common Gull	2.51	37.63
Grey Heron	3.02	45.31
Greylag Goose (Winter)	46.21	693.20
Herring Gull (Breeding)	13.25	198.80
Curlew (Breeding)	0.58	8.76
Kestrel	23.25	348.70
Snipe	1.73	25.94
Buzzard	92.00	1,379.93
Sparrowhawk	7.96	119.44

*Table 7 Collision Probability assuming no Avoidance (Transits*Collision Risk)*

Species	Collision Risk	Transits Across Entire Site	Collisions/year (No Avoidance)
Golden Eagle	7.56%	22.91	1.73
Golden Plover (Winter&Migration)	4.55%	958.75	43.60
Hen Harrier	6.47%	36.65	2.37
Merlin	4.73%	4.05	0.19
Peregrine	4.80%	19.84	0.95
Whooper Swan (Winter)	8.73%	281.46	24.57
Black-headed Gull (Winter)	5.28%	60.45	3.19

Species	Collision Risk	Transits Across Entire Site	Collisions/year (No Avoidance)
Common Gull	5.34%	37.63	2.01
Grey Heron	8.38%	45.31	3.80
Greylag Goose (Winter)	6.51%	693.20	45.10
Herring Gull (Breeding)	6.25%	198.80	12.42
Curlew (Breeding)	5.48%	8.76	0.48
Kestrel	5.37%	348.70	18.72
Snipe	4.37%	25.94	1.13
Buzzard	5.85%	1,379.93	80.74
Sparrowhawk	5.31%	119.44	6.34

Table 8 Collision Probability using Avoidance Rates outlined in SNH (September 2018 V2)

Species	Collisions/year (no avoidance)	Avoidance factor (%)	Collisions /year	Collisions /30 Years	Note
Golden Eagle	1.73	99%	0.02	0.52	All Year
Golden Plover (Winter&Migration)	43.60	98%	0.87	26.16	October to April
Hen Harrier	2.37	99%	0.02	0.71	All Year
Merlin	0.19	98%	0.004	0.11	All Year
Peregrine	0.95	98%	0.02	0.57	All Year
Whooper Swan (Winter)	24.57	99.5%	0.12	3.68	Winter Only
Black-headed Gull (Winter)	3.19	98%	0.06	1.92	Winter Only
Common Gull	2.01	98%	0.04	1.21	All Year
Grey Heron	3.80	98%	0.08	2.28	All Year
Greylag Goose (Winter)	45.10	99.8%	0.09	2.71	Winter Only
Herring Gull (Breeding)	12.42	98%	0.25	7.45	Breeding Only
Curlew (Breeding)	0.48	98%	0.01	0.29	Breeding Only
Kestrel	18.72	95%	0.94	28.08	All Year
Snipe	1.13	98%	0.02	0.68	All Year
Buzzard	80.74	98%	1.61	48.44	All Year
Sparrowhawk	6.34	98%	0.13	3.80	All Year

3.2 Combined VPs Method

The calculation parameters used in the combined vantage point method for the collision risk model are outlined in Tables 9 and 10. Table 11 shows the results of the collision risk model using the combined method. This calculation uses flight data from all vantage point locations (VP1a, VP2a, VP3/3a, VP4, VP5a, VP6, VP7, Canavan's VP1 and Canavan's VP2).

Table 9 Number of Transits across site per year (Averages calculated from Table 4 Above and adjusted for all 15 turbines)

Species	Transits per Turbine	Transits Across Entire Site (All 15 Turbines) (Average Transits*15)
Golden Eagle	4.63	69.39
Golden Plover (Winter&Migration)*	63.14	947.09
Hen Harrier	1.89	28.34
Merlin	0.35	5.20

Species	Transits per Turbine	Transits Across Entire Site (All 15 Turbines) (Average Transits*15)
Peregrine	1.41	21.09
Whooper Swan (Winter)*	16.30	244.52
Black-headed Gull (Winter)*	5.00	74.99
Common Gull*	2.56	38.47
Grey Heron	1.82	27.28
Greylag Goose (Winter)*	29.82	447.31
Herring Gull (Breeding)*	5.81	87.19
Curlew (Breeding)*	0.65	9.71
Kestrel	18.40	276.04
Snipe*	4.80	72.01
Buzzard	81.42	1,221.29
Sparrowhawk	5.36	80.46

***Assumed to be active 25% of the night as well as daylight hours as per SNH guidance accounting for Swan/Goose and Wader activity. This is calculated as a portion of the length of night for the survey period provided by www.timeanddate.com and is added to available hours for activity of the species per year.**

*Table 10 Collision Probability assuming no Avoidance (Transits*Collision Risk)*

Species	Collision Risk	Transits Across Entire Site	Collisions/year (No Avoidance)
Golden Eagle	7.56%	69.39	5.25
Golden Plover (Winter&Migration)	4.55%	947.09	43.07
Hen Harrier	6.47%	28.34	1.83
Merlin	4.73%	5.20	0.25
Peregrine	4.80%	21.09	1.01
Whooper Swan (Winter)	8.73%	244.52	21.34
Black-headed Gull (Winter)	5.28%	74.99	3.96
Common Gull	5.34%	38.47	2.05
Grey Heron	8.38%	27.28	2.28
Greylag Goose (Winter)	6.51%	447.31	29.10
Herring Gull (Breeding)	6.25%	87.19	5.44
Curlew (Breeding)	5.48%	9.71	0.53
Kestrel	5.37%	276.04	14.82
Snipe	4.37%	72.01	3.15
Buzzard	5.85%	1,221.29	71.46
Sparrowhawk	5.31%	80.46	4.27

Table 11 Collision Probability using Avoidance Rates outlined in SNH (September 2018 V2)

Species	Collisions/year (no avoidance)	Avoidance factor (%)	Collisions /year	Collisions /30 Years	Note
Golden Eagle	5.25	99%	0.05	1.27	All Year
Golden Plover (Winter&Migration)	43.07	98%	0.86	25.84	October to April
Hen Harrier	1.83	99%	0.02	0.55	All Year
Merlin	0.25	98%	0.005	0.15	All Year

Species	Collisions/year (no avoidance)	Avoidance factor (%)	Collisions /year	Collisions /30 Years	Note
Peregrine	1.01	98%	0.02	0.61	All Year
Whooper Swan (Winter)	21.34	99.5%	0.11	3.20	Winter Only
Black-headed Gull (Winter)	3.96	98%	0.08	2.38	Winter Only
Common Gull	2.05	98%	0.04	1.23	All Year
Grey Heron	2.28	98%	0.05	1.37	All Year
Greylag Goose (Winter)	29.10	99.8%	0.06	1.75	Winter Only
Herring Gull (Breeding)	5.44	98%	0.11	3.27	Breeding Only
Curlew (Breeding)	0.53	98%	0.01	0.32	Breeding Only
Kestrel	14.82	95%	0.74	22.23	All Year
Snipe	3.15	98%	0.06	1.89	All Year
Buzzard	71.46	98%	1.43	42.87	All Year
Sparrowhawk	4.27	98%	0.09	2.56	All Year

3.3 Comparison

A collision risk analysis was undertaken for key ornithological receptors that were recorded flying within the potential collision risk zone during vantage point (VP) surveys. A "Random" collision risk analysis (CRA) has been undertaken and as outlined in Section 2, two collision risk analysis methods were conducted, the VP averaging method and the combined VP method. The results of both methods are reported below. In the main, the results are very similar between the two methods. Where there are differences it is largely due to the inclusion of flight activity recorded at VP4 and VP6 in the combined VP method CRA. The VP4 and VP6 data is excluded from the VP averaging method CRA because no turbines are sited within its viewshed. This is a key difference between the two approaches, the combined VP method includes all flight activity in the analysis whereas, the VP averaging method only considers flight activity recorded at a vantage point with a viewshed that overlaps with a proposed turbine location to be at risk of a collision.

In the specific case of golden eagle the predicted rate of collisions is two to three times as high for the combined VP method as for the VP averaging method. The higher collision risk predicted from the combined collision risk analysis methodology is as a result of including the flight activity above Crockanure mountain which is approx. 1km from the nearest turbines. As provided in Figure 7.11 golden eagle flight activity is concentrated above a ridge where no turbines are proposed. Many large birds of prey, including golden eagle, make use of orographic lift/updraft winds associated with elevated ground that provide vertical lift allowing them to reach high altitude for soaring without expending much energy (Hedenström, 1993[4]). This is the likely explanation for the observed association of the majority of the golden eagle flight activity with Crockanure mountain rather than the lower elevation of the proposed wind farm site.

As this flight activity is predictably associated with a ridge some 1km from the nearest turbine, golden eagle soaring above Crockanure are not predicted to be at risk of collisions.

Table 12 Comparison of collisions per year for VP averaging method and the Combined VP Method

Species	Collisions per Year VP Averaging Method	Collisions per Year Combined VP Method
Golden Eagle	0.02	0.05

[4] *Hedenström, A. 1993. Migration by soaring or flapping flight in birds: the relative importance of energy cost and speed. Transactions of the Royal Society B: Biological Sciences 342: 353-361*

Species	Collisions per Year VP Averaging Method	Collisions per Year Combined VP Method
Golden Plover (Winter&Migration)	0.87	0.86
Hen Harrier	0.02	0.02
Merlin	0.004	0.005
Peregrine	0.02	0.02
Whooper Swan (Winter)	0.12	0.11
Black-headed Gull (Winter)	0.06	0.08
Common Gull	0.04	0.04
Grey Heron	0.08	0.05
Greylag Goose (Winter)	0.09	0.06
Herring Gull (Breeding)	0.25	0.11
Curlew (Breeding)	0.01	0.01
Kestrel	0.94	0.74
Snipe	0.02	0.06
Buzzard	1.61	1.43
Sparrowhawk	0.13	0.09

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https://www.timeanddate.com/sun/

APPENDIX 1

COLLISION RISK ASSESSMENT – MINIMUM BLADE DIAMETER AND MAXIMUM HUB HEIGHT

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Table 13 Windfarm Parameters at Glenard Wind Farm for minimum blade length and maximum hub height

Wind Farm Component	Scenario Modelled
Number of turbines	15
Blades per turbine rotor (3d model used)	3
Rotor diameter (m)	132
Rotor radius (m)	66
Hub height (m)	107
Swept height range(m) (i.e. above top of foundation)	41-173
Mean pitch of blade (degrees)	6
Maximum chord (m) (i.e. depth of blade)[5]	4
Max Tip Speed (m/s)	82
Circumference of Blade Tip (Pi*Rotor Diameter)	414.69
Rotational period (s) [414.69/82]	5.06
*Turbine operational time (%)	85%

***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%.**

[5] *The assumed turbine model was GE 137 Turbine for the following parameters: maximum chord and rotational period.*

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1. RESULTS

Collison estimates were calculated using flight data recorded during vantage point watches at six vantage point locations within the study area from September 2016 to September 2019 and seven vantage point locations within the study area from January to September 2021. Additionally, the data collected between October 2019 and August 2020 from two supplementary vantage points was included in the analysis. The target species recorded within the potential collision risk zone included golden eagle, golden plover, hen harrier, merlin, peregrine, whooper swan, black-headed gull, common gull, grey heron, greylag goose, mallard, buzzard, sparrowhawk, kestrel and snipe. It is acknowledged that the predicted number of transits, and hence predicted rate of collision for snipe may be underestimated, as flight activity for this species is largely crepuscular in nature (during twilight) while the VP survey sample predominantly consists of hours during daylight period when visibility is not an issue (Table 1.4, SNH (2017)).

The calculation parameters utilised in both calculation methods are outlined in Tables 2 – 4. A fully worked example of the calculation of collision risk for kestrel populations is available in Appendix 1.

Table 14 Glenard Windfarm VP Survey Effort and Viewshed Coverage

Vantage Point	Visible Area at 41m (hectares)	Risk Area (hectares)	Turbines visible from VP	Total Survey Effort (hrs)
VP1a	178.47	69.51	2	284.5
VP2a	538.09	305.98	7	279.5
VP3	439.62	223.75	6	246
VP3a	645.68	215.58	6	45.5
VP4	276.92	185.63	5	284.5
VP5a	408.27	223.07	5	284.5
VP6	379.77	31.06	0	285
VP7	581.32	249.68	5	58.5
Canavan's VP1	617.59	308.73	7	72
Canavan's VP2	513.48	45.17	1	72

Table 15 Bird Biometrics (Taken from BTO BirdFacts & Alerstam et al. (2007)) and duration at PCH during VP Surveys

Species	Length (m)	Wingspan (m)	Ave. speed (m/s)	Seconds in flight at PCH (25-175m) Averaging Method	Seconds in flight at PCH (25-175m) Combined Method
Golden Eagle	0.82	2.12	11.9	71	2,301
Golden Plover (Winter&Migration)	0.28	0.72	17.9	15,770	19,924
Hen Harrier	0.48	1.10	9.1	1,064	1,229
Merlin	0.28	0.56	11.3	135	163
Peregrine	0.42	1.02	12.1	402	402
Whooper Swan (Winter)	1.52	2.30	17.3	5,272	5,614
Black-headed Gull (Winter)	0.36	1.05	11.9	2,503	2,503
Common Gull	0.41	1.20	13.4	985	985
Grey Heron	0.94	1.85	11.2	928	961
Greylag Goose	0.82	1.64	17.1	10,390	10,390
Herring Gull (Breeding)	0.60	1.44	12.8	1,713	2,059
Curlew (Breeding)	0.55	0.90	16.3	180	180

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Species	Length (m)	Wingspan (m)	Ave. speed (m/s)	Seconds in flight at PCH (25-175m) Averaging Method	Seconds in flight at PCH (25-175m) Combined Method
Kestrel	0.34	0.76	10.1	8,921	10,785
Snipe	0.26	0.46	17.1	358	1,445
Buzzard	0.54	1.20	13.3	31,074	36,236
Sparrowhawk	0.33	0.62	10	2,961	3,175

Seconds in flight at PCH is calculated by multiplying the number of birds observed per flight by the duration of the flight spent within the height bands 25-175m for VP1a to VP7. For Canavan Associates LTD's VP1 & VP2, height bands 20-100m, 100-130m and >130m were used.

Table 16 Collision Risk Workings (Both Flapping and Gliding Flights took the average Collision Risk Percentage between upwind and downwind)

Species	Flapping Flight	Gliding Flight	Collision Risk [(Flapping + Gliding)/2]
Golden Eagle	8.18%	7.79%	7.98%
Golden Plover (Winter&Migration)	4.82%	N/A	4.82%
Hen Harrier	6.92%	6.79%	6.85%
Merlin	5.05%	4.97%	5.01%
Peregrine	5.25%	4.94%	5.09%
Whooper Swan (Winter)	9.24%	N/A	9.24%
Black-headed Gull (Winter)	5.71%	5.50%	5.60%
Common Gull	5.81%	5.51%	5.66%
Grey Heron	8.87%	N/A	8.87%
Greylag Goose (Winter)	6.89%	N/A	6.89%
Herring Gull (Breeding)	6.73%	6.50%	6.62%
Curlew (Breeding)	5.81%	N/A	5.81%
Kestrel	5.75%	5.64%	5.69%
Snipe	4.64%	N/A	4.64%
Buzzard	6.30%	6.10%	6.20%
Sparrowhawk	5.66%	5.59%	5.63%

1.1 VP Averaging Method

The calculation parameters used in the vantage point averaging method for the collision risk model are outlined in Tables 17 – 19. Table 20 provides the results of the collision risk model using the averaging method. This calculation uses flight data from VP1a, VP2a, VP3/3a, VP4, VP5a, VP7 Canavan's VP1 and Canavan's VP2.

Table 17 Random CRM - Number of Transits per Turbine within the Viewshed of each VP

Species	VP1a	VP2a	VP3	VP3a	VP4	VP5a	VP7	CVP1	CVP2
Golden Eagle	1.05	7.23	1.33	0.00	3.41	0.00	0.00	0.00	0.00
Golden Plover (Winter&Migration)*	0.00	0.00	345.38	0.00	0.00	0.00	0.00	0.00	60.65
Hen Harrier	4.95	1.10	4.21	0.00	3.46	2.56	0.89	0.39	1.25
Merlin	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00
Peregrine	5.12	0.00	0.78	0.77	2.73	1.57	0.00	0.00	0.00

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Species	VP1a	VP2a	VP3	VP3a	VP4	VP5a	VP7	CVP1	CVP2
Whooper Swan (Winter)*	60.85	1.68	33.53	n/a	101.71	5.23	0.00	0.00	0.00
Black-headed Gull (Winter)*	13.45	2.56	0.00	n/a	44.99	5.66	0.00	0.00	0.00
Common Gull*	0.00	15.87	0.00	0.00	4.61	0.00	0.00	0.00	0.00
Grey Heron	10.08	2.90	2.55	0.00	2.88	3.11	0.00	0.00	0.00
Greylag Goose (Winter)*	19.69	43.25	190.78	n/a	0.00	0.00	0.00	0.00	0.00
Herring Gull (Breeding)*	71.04	0.00	10.16	0.00	3.62	0.00	0.00	0.00	0.00
Curlew (Breeding)*	0.00	0.00	0.00	0.00	0.00	0.00	3.97	0.00	0.00
Kestrel	78.35	22.36	3.32	0.00	20.46	4.24	4.72	8.35	25.11
Snipe*	0.00	0.97	0.00	0.00	0.00	9.72	0.00	0.00	0.00
Buzzard	222.98	114.93	48.89	7.29	86.53	35.43	23.38	96.69	31.00
Sparrowhawk	24.86	5.17	0.52	2.54	0.00	5.63	3.30	8.12	0.00

***Assumed to be active 25% of the night as well as daylight hours as per SNH guidance accounting for Swan/Goose, Gulls and Wader activity. This is calculated as a portion of the length of night for the survey period provided by www.timeanddate.com and is added to available hours for activity of the species per year.**

Table 18 Number of Transits across site per year (Averages calculated from Table 5 Above and adjusted for all 15 turbines)

Species	Average Transits	Transits Across Entire Site (All 15 Turbines) (Average Transits*15)
Golden Eagle	1.63	24.43
Golden Plover (Winter&Migration)	43.17	647.58
Hen Harrier	2.09	31.33
Merlin	0.19	2.78
Peregrine	1.22	18.27
Whooper Swan (Winter)	25.37	380.62
Black-headed Gull (Winter)	8.33	125.01
Common Gull	2.28	34.14
Grey Heron	2.39	35.88
Greylag Goose (Winter)	31.71	475.71
Herring Gull (Breeding)	9.42	141.37
Curlew (Breeding)	0.44	6.61
Kestrel	18.55	278.18
Snipe	1.19	17.83
Buzzard	74.13	1,111.89
Sparrowhawk	5.57	83.56

*Table 19 Collision Probability assuming no Avoidance (Transits*Collision Risk)*

Species	Collision Risk	Transits Across Entire Site	Collisions/year (No Avoidance)
Golden Eagle	7.98%	24.43	1.73
Golden Plover (Winter&Migration)	4.82%	647.58	32.64
Hen Harrier	6.85%	31.33	2.15
Merlin	5.01%	2.78	0.14
Peregrine	5.09%	18.27	0.93

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Species	Collision Risk	Transits Across Entire Site	Collisions/year (No Avoidance)
Whooper Swan (Winter)	9.24%	380.62	35.18
Black-headed Gull (Winter)	5.60%	125.01	7.00
Common Gull	5.66%	34.14	1.93
Grey Heron	8.87%	35.88	3.18
Greylag Goose (Winter)	6.89%	475.71	32.78
Herring Gull (Breeding)	6.62%	141.37	9.35
Curlew (Breeding)	5.81%	6.61	0.38
Kestrel	5.69%	278.18	15.84
Snipe	4.64%	17.83	0.83
Buzzard	6.20%	1,111.89	68.96
Sparrowhawk	5.63%	83.56	4.70

Table 20 Collision Probability using Avoidance Rates outlined in SNH (September 2018 V2)

Species	Collisions/year (no avoidance)	Avoidance factor (%)	Collisions /year	Collisions /30 Years	Note
Golden Eagle	1.73	99%	0.02	0.52	All Year
Golden Plover (Winter&Migration)	32.64	98%	0.65	19.58	October to April
Hen Harrier	2.15	99%	0.02	0.64	All Year
Merlin	0.14	98%	0.003	0.08	All Year
Peregrine	0.93	98%	0.02	0.56	All Year
Whooper Swan (Winter)	35.18	99.5%	0.18	5.28	Winter Only
Black-headed Gull (Winter)	7.00	98%	0.14	4.20	Winter Only
Common Gull	1.93	98%	0.04	1.16	All Year
Grey Heron	3.18	98%	0.06	1.91	All Year
Greylag Goose (Winter)	32.78	99.8%	0.07	1.97	Winter Only
Herring Gull (Breeding)	9.35	98%	0.19	5.61	Breeding Only
Curlew (Breeding)	0.38	98%	0.008	0.23	Breeding Only
Kestrel	15.84	95%	0.79	23.75	All Year
Snipe	0.83	98%	0.02	0.50	All Year
Buzzard	68.96	98%	1.38	41.38	All Year
Sparrowhawk	4.70	98%	0.09	2.82	All Year

1.2 Combined VPs Method

The calculation parameters used in the combined vantage point method for the collision risk model are outlined in Tables 9 and 10. Table 11 shows the results of the collision risk model using the combined method. This calculation uses flight data from all vantage point locations (VP1a, VP2a, VP3/3a, VP4, VP5a, VP6, VP7, Canavan's VP1 and Canavan's VP2).

Table 21 Number of Transits across site per year (Averages calculated from Table 4 Above and adjusted for all 15 turbines)

Species	Transits per Turbine	Transits Across Entire Site (All 15 Turbines) (Average Transits*15)
Golden Eagle	3.75	56.18
Golden Plover (Winter&Migration)*	51.12	766.82

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Species	Transits per Turbine	Transits Across Entire Site (All 15 Turbines) (Average Transits*15)
Hen Harrier	1.53	22.95
Merlin	0.28	4.21
Peregrine	1.14	17.07
Whooper Swan (Winter)*	13.20	197.98
Black-headed Gull (Winter)*	4.05	60.72
Common Gull*	2.08	31.14
Grey Heron	1.47	22.08
Greylag Goose (Winter)*	24.14	362.17
Herring Gull (Breeding)*	4.71	70.59
Curlew (Breeding)*	0.52	7.86
Kestrel	14.90	223.50
Snipe*	3.89	58.30
Buzzard	65.92	988.83
Sparrowhawk	4.34	65.14

***Assumed to be active 25% of the night as well as daylight hours as per SNH guidance accounting for Swan/Goose and Wader activity. This is calculated as a portion of the length of night for the survey period provided by www.timeanddate.com and is added to available hours for activity of the species per year.**

*Table 22 Collision Probability assuming no Avoidance (Transits*Collision Risk)*

Species	Collision Risk	Transits Across Entire Site	Collisions/year (No Avoidance)
Golden Eagle	7.98%	56.18	4.48
Golden Plover (Winter&Migration)	4.82%	766.82	36.98
Hen Harrier	6.85%	22.95	1.57
Merlin	5.01%	4.21	0.21
Peregrine	5.09%	17.07	0.87
Whooper Swan (Winter)	9.24%	197.98	18.30
Black-headed Gull (Winter)	5.60%	60.72	3.40
Common Gull	5.66%	31.14	1.76
Grey Heron	8.87%	22.08	1.96
Greylag Goose (Winter)	6.89%	362.17	2.95
Herring Gull (Breeding)	6.62%	70.59	4.67
Curlew (Breeding)	5.81%	7.86	0.46
Kestrel	5.69%	223.50	12.72
Snipe	4.64%	58.30	2.70
Buzzard	6.20%	988.83	61.33
Sparrowhawk	5.63%	65.14	3.67

Table 23 Collision Probability using Avoidance Rates outlined in SNH (September 2018 V2)

Species	Collisions/year (no avoidance)	Avoidance factor (%)	Collisions /year	Collisions /30 Years	Note
Golden Eagle	4.48	99%	0.044	1.35	All Year

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Species	Collisions/year (no avoidance)	Avoidance factor (%)	Collisions /year	Collisions /30 Years	Note
Golden Plover (Winter&Migration)	36.98	98%	0.74	22.19	October to April
Hen Harrier	1.57	99%	0.02	0.47	All Year
Merlin	0.21	98%	0.004	0.13	All Year
Peregrine	0.87	98%	0.02	0.52	All Year
Whooper Swan (Winter)	18.30	99.5%	0.09	2.75	Winter Only
Black-headed Gull (Winter)	3.40	98%	0.07	2.04	Winter Only
Common Gull	1.76	98%	0.04	1.06	All Year
Grey Heron	1.96	98%	0.04	1.18	All Year
Greylag Goose (Winter)	2.95	99.8%	0.05	1.50	Winter Only
Herring Gull (Breeding)	4.67	98%	0.09	2.80	Breeding Only
Curlew (Breeding)	0.46	98%	0.009	0.27	Breeding Only
Kestrel	12.72	95%	0.64	19.08	All Year
Snipe	2.70	98%	0.05	1.62	All Year
Buzzard	61.33	98%	1.23	36.80	All Year
Sparrowhawk	3.67	98%	0.07	2.20	All Year

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1.3 Comparison

Table 24 Comparison of collisions per year for VP averaging method and the Combined VP Method

Species	Max Blade and Min Hub (26m minimum swept height)		Min Blade and Max Hub (41m minimum swept height)	
	Collisions per Year VP Averaging Method	Collisions per Year Combined VP Method	Collisions per Year VP Averaging Method	Collisions per Year Combined VP Method
Golden Eagle	0.02	0.05	0.02	0.044
Golden Plover (Winter&Migration)	0.87	0.86	0.65	0.74
Hen Harrier	0.02	0.02	0.02	0.02
Merlin	0.004	0.005	0.003	0.004
Peregrine	0.02	0.02	0.02	0.02
Whooper Swan (Winter)	0.12	0.11	0.18	0.09
Black-headed Gull (Winter)	0.06	0.08	0.14	0.07
Common Gull	0.04	0.04	0.04	0.04
Grey Heron	0.08	0.05	0.06	0.04
Greylag Goose (Winter)	0.09	0.06	0.07	0.05
Herring Gull (Breeding)	0.25	0.11	0.19	0.09
Curlew (Breeding)	0.01	0.01	0.008	0.009
Kestrel	0.94	0.74	0.79	0.64
Snipe	0.02	0.06	0.02	0.05
Buzzard	1.61	1.43	1.38	1.23
Sparrowhawk	0.13	0.09	0.09	0.07

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APPENDIX 2

WORKED EXAMPLE OF COLLISION RISK CALCULATION (RANDOM FLIGHT MODEL) – KESTREL

Stage 1 (Transits through rotors per year) [Using figures from VP1a Column]

Table 25 Standard Measurements (Specific to Kestrel, Windfarm Site, Turbines modelled & VP1a)

Description	Value	Units
Survey area visible from VP (Hectares) [At 26m]	Avp	144.46
Survey Time at VP1 (secs)	s	1,024,200
Bird observation time at >25m (secs)	PCH	2,197
Rotor Radius (metres)	r	70
Rotor Diameter (metres)	D	140
Max chord width of turbine blade (metres)	d	4
No. of turbines in viewshed of VP1a	x	1
Bird length in metres (kestrel) [Taken from BTO online)	l	0.34
Ave. Flight speed of kestrel (m/s) [Allerstam et al. 2007]	v	10.1
500m buffer of turbines within viewshed, i.e. Area of Risk (Hectares)	Arisk	53.2
Availability of species activity during survey period (hours) [Daylight hours]	Ba	20,345.77

Table 26 CRM Stage 1 Calculations using Standard Measurements in Table 9

Description	Value	Formula	Units
Proportion of time in flight >25m	t1	PCH/s	0.002145089
Flight activity per visible unit of area	F	t1/Avp	1.48E-05
Proportion of time in risk area	Trisk	F*Arisk	0.0007900
Bird occupancy of risk area	n	Trisk*Ba	16.07250013
Risk volume (Area of risk*Rotor Diameter)	Vw	(Arisk*D)*10,000	74480000
Actual volume of air swept by rotors	o	X*(Pi*r2(d+l))	66809.10937
Bird occupancy of rotor swept area (seconds)	b	3600*(n*(o/Vw))	51.9017442
Time taken for bird to pass through rotors (seconds)	t2	(d+Bl)/v	0.42970297
Number of bird passes through the rotor in the survey period	N	b/t2	120.7851651

Description	Value	Formula	Units
Total transits adjusted for max annual Turbine Operation Time (85% in this case)	Tn	N*0.85	102.67
Number of transits per turbine within viewshed of VP1a	**TnT1**	**Tn/x**	102.67

Table 27 CRM Stage 1 Calculations – Number of transits through windfarm

Description	Value	Formula	Units
Number of transits per turbine with viewshed of VP1a	TnT1	Tn/x	102.67
Number of transits per turbine with viewshed of VP2a	TnT2	Tn/x	28.27
Number of transits per turbine with viewshed of VP3	TnT3	Tn/x	4.23
Number of transits per turbine with viewshed of VP3a	TnT3a	Tn/x	0.00
Number of transits per turbine with viewshed of VP5a	TnT5	Tn/x	5.50
Number of transits per turbine with viewshed of VP7	TnT7	Tn/x	5.56
Number of transits per turbine with viewshed of Canavan's VP1	TnT8	Tn/x	10.20
Number of transits per turbine with viewshed of Canavan's VP2	TnT9	Tn/x	29.55
Average transits per turbine for all VPs	ATnT	(TnT1+TnT2........+TnT8) /8	23.25
Predicted number of transits through windfarm site (All 10 turbines)	T	ATnT*15	348.70

Transits through rotors for the species in a one-year period across the site

348.7016128

Stage 2 (Collision Probability)

Calculation of the probability of the birds colliding with the turbine rotors:

The probability of a bird colliding with the turbine blades when making a transit through a rotor depends on a number of estimated factors. These factors include the avoidance factor 95% – the ability of birds to take evasive action when coming close to wind turbine blades.

In the calculations, the length of a kestrel was taken to be 0.34 metres and the wingspan 0.76 metres. The flight velocity of the bird is assumed to be 10.1 metres per second. The maximum chord of the blades is taken to be 4 metres, variable pitch is assumed to be 6 degrees and the average rotation cycle is taken to be 5.36 seconds per rotation, depending on wind conditions. A probability, ρ (r, φ), of collision for a bird at radius r from the hub and at a position along a radial line that is at angle φ from the vertical is calculated. This probability is then integrated over the entire rotor disc, assuming that the bird transit may be anywhere at random within the area of the disc. Scottish Natural Heritage (SNH) have made available a spreadsheet to aid the calculation of these probabilities as referenced previously. For a full explanation of the calculation methods see Band et al. (2007). The results of these calculations for all species are shown in Table 8 above.

Collision Probability*

5.37%

*This is calculated using the SNH collision risk probability model at https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision

Collisions per year

The annual theoretical collision rate assuming no avoidance = Transits (T)*Collision probability

18.72

The annual theoretical collision rate assuming 95% avoidance (18.72*0.05)

0.94

Theoretical collision rate assuming 95% avoidance across the 30-year duration of the windfarm (0.94*30)

28.08