APPENDIX 7-5

COLLISION RISK ASSESSMENT

Appendix 7-5 – Collision Risk Assessment

Curraglass Renewable Energy Development

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1. INTRODUCTION

This document has been prepared by MKO to assess the collision risk for birds at the proposed Curraglass Renewable Energy Development, Co. Cork. The collision risk assessment, prepared by Ms. Margaux Pierrel (BSc, MSc, Eng), is based on vantage point watch surveys undertaken at the development site from April 2018 up to and including March 2020. This represents a 24-month survey period, consisting of two breeding seasons and two non-breeding seasons, in full compliance with SNH (2017)[1]. Surveys were undertaken from three fixed Vantage Point (VP) locations, (i.e. VP1 – VP3) between April 2018 and March 2020.

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).

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 which 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 make no attempt to avoid colliding with turbines.

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.

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 percentage applied to the product of stages 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 continuous studies and literature, 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 windfarm 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 which 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 is 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 windfarm 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 windfarm area.*
  2. *Habitat and bird activity will remain the same over time and be unchanged during the operational stage of the windfarm.*
  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 25m, the viewshed coverage displaying the visibility of the area within the 2km arc at a height of 25m 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. The AVP calculation in the model is therefore highly precautionary as it is likely to have been a larger area of coverage for much of the flight activity.*

- **"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 windfarm 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.
  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 windfarm. 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 details 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 case of most species observed during surveys for the proposed Curraglass Renewable Energy Development, flights during the survey period could be classified as randomly distributed flights which could occur anywhere within the given viewsheds. Therefore the "Random Flight Model" was applied to these species to calculate the predicted number of transits through the windfarm site. The "Regular Flight Model" was applied to only one species (Herring Gull) in response of regular observations towards a north/north-east direction within, or partially within, the development site.

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).

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 make no attempt to avoid them.

4. An avoidance factor is applied to the results to account for 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).

5. 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.
- Because the model assumes that no action is taken by a bird to avoid collision, it is recognised that the collision risk figures derived are purely theoretical and represent worst-case estimates.

Several assumptions were made in the calculation of collision risk for the proposed Curraglass Renewable Energy Development. These assumptions are tailored specifically to this site and are as follows:

- Birds in flight within the study area at heights greater than 25m 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 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 which 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.

The Collision Risk Assessment (CRA) also makes assumptions on the turbine specifications, such as rotor diameter and rotational speed. Because the final choice of 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), maximum number of turbines proposed and turbine operational time. The turbine and wind farm characteristics for the purposes of this assessment at the proposed Curraglass Renewable Energy Development are presented in

.

Table 2-1 Windfarm Parameters at Curraglass Renewable Energy Development

Wind Farm Component	Scenario Modelled
Assumed turbine model	Vestas V150 Turbine
Number of turbines	7
Blades per turbine rotor (3d model used)	3
Rotor diameter (m)	150
Rotor radius (m)	75
Hub height (m)	103.5
Swept height (m)	28.5 – 178.5
Pitch of blade (degrees)	6
Maximum chord (m) (i.e. depth of blade)	4.2
Speed Dynamic Operation range (m/s)	4.9-12.0
Average Speed Dynamic (m/s)	8.5
Rotational period (s) [60/8.5]	7.1
*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%.**

3. RESULTS

3.1 Random Flight Model

Collision estimates were calculated using flight data recorded during vantage point watches at three vantage point locations (VP1, VP2 and VP3) within the study area between April 2018 and March 2020. The target species recorded within the potential collision risk zone included peregrine, white-tailed eagle, buzzard, sparrowhawk, kestrel and common snipe. It is acknowledged that the predicted number of transits, and hence predicted rate of collision for common snipe may be largely 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 are outlined in Tables 3-1 to 3-7. A fully worked example of the calculation of collision risk for peregrine populations is available in Appendix 1.

Table 3-1 Curraglass Renewable Energy Development VP Survey Effort and Viewshed Coverage

Vantage Point	Visible Area at 25m (hectares)	Risk Area (hectares)	Turbines visible from VP	Total Survey Effort (hrs)
VP1	382	246	6	145
VP2	513	300	6	148
VP3	163	76	2	145

Table 3-2 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 (>25m)
Peregrine	0.42	1.02	20.7	52
White-tailed Eagle	0.8	2.2	13.6	337
Buzzard	0.54	1.20	13.3	806
Sparrowhawk	0.33	0.62	10.0	516
Kestrel	0.34	0.76	10.1	228
Common Snipe	0.26	0.46	17.1	31

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 and >175m.

Table 3-3 Random CRM - Number of Transits per Turbine within the Viewshed of each VP

Species	VP1	VP2	VP3
Peregrine	0	0	4.76
White-tailed Eagle	7.95	0.51	0
Buzzard	6.02	0	33.28
Sparrowhawk	1.81	2.82	9.50
Kestrel	0.93	1.06	4.60
*Common Snipe	0	0	2.74

*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 3-4 Number of Transits across site per year (averages calculated from Table 3-3 above and adjusted for all 7 turbines)

Species	Average Transits	Transits Across Entire Site (All 7 Turbines) (Average Transits*7)
Peregrine	1.59	11.10
White-tailed Eagle	2.82	19.74
Buzzard	13.1	91.70
Sparrowhawk	4.71	32.99
Kestrel	2.20	15.37
Common Snipe	0.91	6.40

Table 3-5 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]
Peregrine	4.7%	N/A	**4.7%**
White-tailed Eagle	6.5%	6%	**6.3%**
Buzzard	5.4%	5.1%	**5.3%**
Sparrowhawk	4.8%	N/A	**4.8%**
Kestrel	4.9%	N/A	**4.9%**
Common Snipe	4.1%	N/A	**4.1%**

*Table 3-6 Collision Probability assuming no Avoidance (Transits *Collision Risk)*

Species	Collision Risk	Transits Across Entire Site	Collisions/year (No Avoidance)
Peregrine	4.7%	11.10	**0.52**
White-tailed Eagle	6.3%	19.74	**1.24**
Buzzard	5.3%	91.70	**4.86**
Sparrowhawk	4.8%	32.99	**1.58**
Kestrel	4.9%	15.37	**0.75**
Common Snipe	4.1%	6.40	**0.26**

Table 3-7 Collision Probability using Avoidance Rates outlined in SNH (September 2018 V2)

Species	Collisions/year (no avoidance)	Avoidance factor (%)	Collisions /year	Collisions /30 Years	Note
Peregrine	0.52	98%	**0.01**	**0.31**	All year

Species	Collisions/year (no avoidance)	Avoidance factor (%)	Collisions /year	Collisions /30 Years	Note
White-tailed Eagle	1.24	95%	**0.06**	**1.86**	All year
Buzzard	4.86	98%	**0.1**	**2.92**	All year
Sparrowhawk	1.58	98%	**0.032**	**0.95**	All year
Kestrel	0.75	95%	**0.04**	**1.13**	All year
Common Snipe	0.26	98%	**0.005**	**0.16**	All year

3.2 Regular Flight Model

A "Regular Flight model" was applied to one species (Herring Gull) due to a regular pattern of flights observed during the extensive vantage point surveys undertaken from April 2018 to March 2020. These flights follow a route which the species was regularly recorded flying along. As these flights followed a predictable route a "Regular Flight model" was used to estimate collision risk. The "Regular Flight Model" only includes flights passing within 500m of the turbines (as per Band et al. 2007). A number of flights were recorded in excess of 500m from the proposed turbine locations (to the east of the development site) and were therefore not included in the Regular CRM.

The calculation parameters are outlined in Tables 3-8 to 3-13.

Table 3-8 Development site parameters

Vantage Point	Width of windfarm as a line by which flights pass*	Area occupied by rotors (m2)	Total Survey Effort (hrs)
All VPs	1,516	52987.5	438

***Calculated using QGIS 3.4.15 software**

Table 3-9 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)	Bird Availability	Number of birds passing through PCH	Seconds in flight at PCH (>25m)
Herring Gull	0.6	1.4	12.8	12211.4	3	105

Table 3-10 Regular CRM – Number of transits through site

Species	Number of birds through rotors	Max operation	Number of transits with operation %
Herring Gull	19.48	85%	16.56

Table 3-11 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]
Herring Gull	5.7%	5.4%	**5.6%**

*Table 3-12 Collision Probability assuming no Avoidance (Transits *Collision Risk)*

Species	Collision Risk	Transits Across Entire Site	Collisions/year (No Avoidance)
Herring Gull	5.6%	16.56	0.92

Table 3-13 Collision Probability using Avoidance Rates outlined in SNH (September 2018 V2)

Species	Collisions/year (no avoidance)	Avoidance factor (%)	Collisions /year	Collisions /30 Years
Herring Gull	0.92	98%	0.018	0.56

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

APPENDIX 1

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

Stage 1 (Transits through rotors per year) [Using figures from VP3 Column]

Table 1 Standard Measurements (Specific to Peregrine, Windfarm Site, Turbines modelled & VP3)

Description	Value	Units
Survey area visible from VP (Hectares) [At 25m]	Avp	163
Survey Time at VP3 April 2018 – March 2020 (secs)	s	522,000
Bird observation time at >25m (secs)	PCH	52
Rotor Radius (metres)	r	75
Rotor Diameter (metres)	D	150
Max chord width of turbine blade (metres)	d	4.2
No. of turbines in viewshed of VP2	x	2
Bird length in metres (peregrine) [Taken from BTO online)	l	0.42
Ave. Flight speed of peregrine (m/s) [Alerstam et al. 2007]	v	20.7
500m buffer of turbines within viewshed, i.e. Area of Risk (Hectares)	Arisk	76
Availability of species activity during survey period (hours) [Daylight hours]	Ba	10,433.9

Table 2 CRM Stage 1 Calculations using Standard Measurements in Table 1

Description	Value	Formula	Units
Proportion of time in flight >25m	t1	PCH/s	9.96E-05
Flight activity per visible unit of area	F	t1/Avp	6.11E-07
Proportion of time in risk area	Trisk	F*Arisk	0.0000464
Bird occupancy of risk area	n	Trisk*Ba	0.484624648
Risk volume (Area of risk*Rotor Diameter)	Vw	(Arisk*D)*10,000	114000000
Actual volume of air swept by rotors	o	X*(Pi*r2(d+l))	163284.2782
Bird occupancy of rotor swept area (seconds)	b	3600*(n*(o/Vw))	2.498892184
Time taken for bird to pass through rotors (seconds)	t2	(d+Bl)/v	0.223188406
Number of bird passes through the rotor in the survey period	N	b/t2	11.19633511
Total transits adjusted for max annual Turbine Operation Time (85% in this case)	Tn	N*0.85	9.52
Number of transits per turbine within viewshed of VP3	**TnT1**	**Tn/x**	**4.76**

Table 3 CRM Stage 1 Calculations – Number of transits through windfarm

Description	Value	Formula	Units
Number of transits per turbine with viewshed of VP3	**TnT1**	**Tn/x**	**4.76**
Number of transits per turbine with viewshed of VP1	TnT2	Tn/x	0
Number of transits per turbine with viewshed of VP2	TnT3	Tn/x	0
Average transits per turbine for all VPs	TnT	(TnT1+TnT2+TnT3) /3	1.59
Predicted number of transits through windfarm site (All 7 turbines)	T	ATnT*7	11.10

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

11.10

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 98% – the ability of birds to take evasive action when coming close to wind turbine blades.

In the calculations, the length of a peregrine was taken to be 0.42 metre and the wingspan 1.02 metre. The flight velocity of the bird is assumed to be 20.7 metres per second. The maximum chord of the blades is taken to be 4.2 metres, variable pitch is assumed to be 6 degrees and the average rotation cycle is taken to be 7.1 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 **Error! Reference source not found.**3-7 above.

Collision Probability*

4.7%

*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

0.52

The annual theoretical collision rate assuming 98% avoidance (0.52*0.02)

0.01

Theoretical collision rate assuming 98% avoidance across the 30-year duration of the windfarm (0.01*30)

0.31