APPENDIX 7-5

COLLISION RISK ASSESSMENT

Appendix 7-5 – Collision Risk Assessment

Coole Wind Farm, Co. Westmeath

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1. INTRODUCTION

This document has been prepared by MKO to assess the collision risk for birds at the proposed Coole Wind Farm, Co. Westmeath. 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 October 2015 up to and including September 2017; and from April 2018 up to and including March 2020. This represents two 24-month survey periods, consisting of four breeding seasons and four non-breeding seasons, in full compliance with SNH (2017)[1]. Surveys were undertaken from three fixed Vantage Point (VP) Locations: VP3/VP4 between October 2015 to September 2017 and VP3/VP5 between April 2018 to 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 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 targeted studies 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 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 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 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 case of all species observed during surveys for the proposed Coole Wind Farm, 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 all species to calculate the predicted number of transits through the windfarm 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 Coole Wind Farm. These assumptions are tailored specifically to this site and are as follows:

- The worst-case scenario low swept height of the turbine blades is 20m. Bird flight activity information was collected in four height bands: 0-10m, 10-25m, 25-175m and +175m. Birds in flight within the study area at heights between 10m and 175m above ground level have been included in the analysis of collision risk. This approach avoids the need to split the 10-25m height band data.
- 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 Coole Wind Farm are presented in Table 2-1.

Table 2-1 Windfarm Parameters at Coole Wind Farm

Wind Farm Component	Scenario Modelled
Assumed turbine model	SG6.0 - 155
Number of turbines	15
Blades per turbine rotor (3d model used)	3
Rotor diameter (m)	155
Rotor radius (m)	77.5
Hub height (m)	97.5
Swept height (m)	20-175
Pitch of blade (degrees)	25
Maximum chord (m) (i.e. depth of blade)	4.5
Rotational period (s)	6
*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

Collison estimates were calculated using flight data recorded during vantage point watches at three vantage point locations within the study area: VP4 between October 2015 and September 2017; and VP3/VP5 between April 2018 and March 2020. The target species recorded within the potential collision risk zone included whooper swan, Greenland white-fronted goose, golden plover, merlin, peregrine falcon, osprey, red kite, teal, black-headed gull, lapwing, woodcock, 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 falcon populations is available in Appendix 1 below.

Table 3-1 Coole Wind Farm VP Survey Effort and Viewshed Coverage

Vantage Point	Visible Area at 20m (hectares)	Risk Area (hectares)	Turbines visible from VP	Total Survey Effort (hrs)
VP3	540	259	6	144
VP4	423	269	6	144
VP5	449	125	1	144

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 (10-175m)
Whooper Swan	1.52	2.3	17.3	3,500
Greenland White-fronted Goose	0.72	1.48	16.1	2,400
Golden Plover	0.28	0.72	17.9	344,399
Merlin	0.28	0.56	12.1	80
Peregrine Falcon	0.42	1.02	12.1	1,303
Osprey	0.56	1.58	13.3	110
Red Kite	0.63	1.85	13.3	10
Teal	0.36	0.61	19.7	105
Black-headed Gull	0.36	1.05	11.9	778
Lapwing	0.30	0.84	11.9	1,600
Woodcock	0.34	0.58	17.1	40
Buzzard	0.54	1.2	13.3	26,132

Species	Length (m)	Wingspan (m)	Ave. speed (m/s)	Seconds in flight at PCH (10-175m)
Sparrowhawk	0.33	0.62	10.0	1,327
Kestrel	0.34	0.76	10.1	5,292
Common Snipe	0.26	0.46	17.1	1,621

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 10-25m and 25-175m.

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

Species	VP3 (2015-2017)	VP3 (2018/2020)	VP4 (2015-2017)	VP5 (2018/2020)
*Whooper Swan (Winter)	0	69.88	19.22	0.88
*Greenland White-fronted Goose (Winter)	0	54.67	0	0
Golden Plover (Winter)	4,901.99	895.96	3,733.95	0
Merlin	0	0	1.72	0
Peregrine Falcon	5.03	5.69	11.34	2.79
Osprey (N/A)	0	0	3.19	0
Red Kite (Breeding)	0	0	0	0.27
Teal (Winter)	0	0	2.93	0
Black-headed Gull (Breeding)	0	0	0.76	17.89
Lapwing (Winter)	0	0	34.39	0
Woodcock (Breeding)	0	0	1.60	0
Buzzard	207.79	75.53	167.64	82.39
Sparrowhawk	12.65	3.20	1.70	1.52
Kestrel	20.69	15.46	37.39	10.66
*Common Snipe	0	0	0	54.22

***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 7-4 Above and adjusted for all 15 turbines)

Species	Average Transits	Transits Across Entire Site (All 15 Turbines) (Average Transits*15)
Whooper Swan	22.50	337.44
Greenland White-fronted Goose	13.67	205.01
Golden Plover	2,382.97	35,744.61
Merlin	0.43	6.44
Peregrine Falcon	6.21	93.17
Osprey	0.80	11.97
Red Kite	0.07	1.00
Teal	0.73	10.99

Species	Average Transits	Transits Across Entire Site (All 15 Turbines) (Average Transits*15)
Black-headed Gull	4.66	69.94
Lapwing	8.60	128.97
Woodcock	0.40	6.02
Buzzard	113.34	2000.08
Sparrowhawk	4.77	71.52
Kestrel	21.05	315.74
Common Snipe	13.55	203.31

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]
Whooper Swan	8.6%	8.3%	**8.5%**
Greenland White-fronted Goose	6.6%	6.3%	**6.5%**
Golden Plover	4.8%	N/A	**4.8%**
Merlin	6.1%	6.1%	**6.1%**
Peregrine Falcon	6.8%	6.7%	**6.8%**
Osprey	7%	6.7%	**6.9%**
Red Kite	7.4%	7%	**7.2%**
Teal	4.7%	N/A	**4.7%**
Black-headed Gull	6.7%	6.5%	**6.6%**
Lapwing	6.4%	N/A	**6.4%**
Woodcock	5%	N/A	5%
Buzzard	6.8%	6.6%	**6.7%**
Sparrowhawk	7.4%	7.3%	**7.4%**
Kestrel	7.4%	7.3%	**7.4%**
Common Snipe	4.7%	4.7%	**4.7%**

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

Species	Collision Risk	Transits Across Entire Site	Collisions/year (No Avoidance)
Whooper Swan	8.5%	337.44	**28.68**
Greenland White-fronted Goose	6.5%	205.01	**13.33**
Golden Plover	4.8%	35,744.61	**1715.74**
Merlin	6.1%	6.44	**0.39**
Peregrine Falcon	6.8%	93.17	**6.34**
Osprey	6.9%	11.97	**0.83**
Red Kite	7.2%	1.00	**0.07**
Teal	4.7%	10.99	**0.52**
Black-headed Gull	6.6%	69.94	**4.62**
Lapwing	6.4%	128.97	**8.25**
Woodcock	5.0%	6.02	**0.30**
Buzzard	6.7%	2000.08	**134.01**
Sparrowhawk	7.4%	71.52	**5.29**
Kestrel	7.4%	315.74	**23.36**
Common Snipe	4.7%	203.31	**9.56**

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
Whooper Swan	28.68	99.5%	**0.14**	**4.30**	Winter
Greenland White-fronted Goose	13.32	99.8%	**0.03**	**0.80**	Winter
Golden Plover	1715.74	98%	**34.31**	**1029.44**	Winter
Merlin	0.39	98%	**0.08**	**0.24**	All year
Peregrine Flacon	6.34	98%	**0.13**	**3.80**	All year
Osprey	0.83	98%	**0.02**	**0.50**	N/A
Red Kite	0.07	99%	**0.0007**	**0.02**	Breeding
Teal	0.52	98%	**0.01**	**0.31**	Winter
Black-headed Gull	4.62	98%	**0.09**	**2.77**	Breeding

Species	Collisions/year (no avoidance)	Avoidance factor (%)	Collisions /year	Collisions /30 Years	Note
Lapwing	8.25	98%	0.17	4.95	Winter
Woodcock	0.30	98%	0.006	0.18	Breeding
Buzzard	134.01	98%	2.68	80.40	All year
Sparrowhawk	5.29	98%	0.11	3.18	All year
Kestrel	23.36	95%	1.17	35.05	All year
Common Snipe	9.56	98%	0.19	5.73	All year

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

APPENDIX 1

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

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

Table 3-8 Standard Measurements (Specific to Peregrine Falcon, Windfarm Site, Turbines modelled & VP3)

Description	Value	Units
Survey area visible from VP (Hectares) [At 20m]	Avp	540
Survey Time at VP3 April 2018 – March 2020 (secs)	s	518.400
Bird observation time at >10m (secs)	PCH	338
Rotor Radius (metres)	r	77.5
Rotor Diameter (metres)	D	155
Max chord width of turbine blade (metres)	d	4.5
No. of turbines in viewshed of VP3	x	6
Bird length in metres (peregrine falcon) [Taken from BTO online)	l	0.42
Ave. Flight speed of peregrine falcon (m/s) [Allerstam et al. 2007]	v	12.1
500m buffer of turbines within viewshed, i.e. Area of Risk (Hectares)	Arisk	259
Availability of species activity during survey period (hours) [Daylight hours]	Ba	10,447.18

Table 3-9 CRM Stage 1 Calculations using Standard Measurements in Table 1

Description	Value	Formula	Units
Proportion of time in flight >10m	t1	PCH/s	0.00065201
Flight activity per visible unit of area	F	t1/Avp	1E-06
Proportion of time in risk area	Trisk	F*Arisk	0.0003
Bird occupancy of risk area	n	Trisk*Ba	3.26705758
Risk volume (Area of risk*Rotor Diameter)	Vw	(Arisk*D)*10,000	401450000
Actual volume of air swept by rotors	o	X*(Pi*r2(d+l))	557018.5
Bird occupancy of rotor swept area (seconds)	b	3600*(n*(o/Vw))	16.3191472
Time taken for bird to pass through rotors (seconds)	t2	(d+Bl)/v	0.4066
Number of bird passes through the rotor in the survey period	N	b/t2	40.1344879
Total transits adjusted for max annual Turbine Operation Time (85% in this case)	Tn	N*0.85	34.11

Description	Value	Formula	Units
Number of transits per turbine within viewshed of VP3 (2018-2020)	**TnT3**	**Tn/x**	**5.69**

Table 3-10 CRM Stage 1 Calculations – Number of transits through windfarm

Description	Value	Formula	Units
Number of transits per turbine with viewshed of VP3 (2018-2020)	**TnT3**	**Tn/x**	**5.69**
Number of transits per turbine with viewshed of VP3 (2015-2017)	TnT2	Tn/x	5.03
Number of transits per turbine with viewshed of VP4	TnT4	Tn/x	11.34
Number of transits per turbine with viewshed of VP5	TnT5	Tn/x	2.79
Average transits per turbine for all VPs	TnT	(TnT2+TnT3+TnT4+TnT5)/4	6.21
Predicted number of transits through windfarm site (All 15 turbines)	T	ATnT*15	93.17

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

93.17

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 falcon was taken to be 0.42 metre and the wingspan 1.02 metre. The flight velocity of the bird is assumed to be 12.1 metres per second. The maximum chord of the blades is taken to be 4.5 metres, variable pitch is assumed to be 25 degrees and the average rotation cycle is taken to be 6 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 3-7 above.

Collision Probability*

6.8%

*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

6.335

The annual theoretical collision rate assuming 98% avoidance (6.335*0.02)

0.127

Theoretical collision rate assuming 98% avoidance across the 30-year duration of the windfarm (0.127*30)

3.801