APPENDIX 8-6

COLLISION RISK ASSESSMENT

Appendix 8-6 – Collision Risk Assessment

Proposed Cahermurphy Two Windfarm

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Table of Contents

TABLE OF TABLES

1. INTRODUCTION

This document has been prepared by MKO to assess the collision risk for birds at the proposed Cahermurphy Two Wind Farm Site, Co. Clare. The collision risk assessment, prepared by Mr David Naughton (BSc), is based on vantage point watch surveys undertaken at the development site from April 2017 up to and including September 2019 covering a 30-month survey period, consisting of three breeding seasons and two non-breeding seasons, in full compliance with SNH (2017). Surveys were undertaken from three fixed Vantage Point (VP) Locations, (i.e. VP1, VP1 & VP3) between April 2017 and September 2019, while a forth Vantage Point (VP4), was added in April 2018 to cover an additional area of land to the west of the development site.

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 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 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 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 at https://www.nature.scot/wind-farm-impacts-birds-guidance-avoidance-rates-guidance.

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. within 2km 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 without. 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. *The area of the view shed used in the analysis is a worst-case scenario, given it is calculated based on the lowest swept height.*
    4. *All flight activity recorded at potential collision risk height within the view shed of relevant VPs are used in the model.*

- **"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-dimesional 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 at Cahermurphy Two, 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 steps used to derive the collision risk percentage 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 Cahermurphy Two Windfarm. These assumptions are tailored specifically to Cahermurphy Two and are as follows:

- Birds in flight within the study area at heights between 25m and 175m 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. Due to the nature of their flight activity, for species such as golden plover, snipe and common tern 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. 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 Cahermurphy Two Windfarm Site are presented in Table 1.

Table 1 Windfarm Parameters at Cahermurphy Wind Farm

Wind Farm Component	Scenario Modelled
Assumed turbine model	GE 3.6-137 Turbine
Number of turbines	10
Blades per turbine rotor (3d model used)	3
Rotor diameter (m)	140
Rotor radius (m)	70
Hub height (m)	100
Swept height (m)	30 - 170
*Mean pitch of blade (degrees)	25
Maximum chord (m) (i.e. depth of blade)	4.0
Max Tip Speed (M/S)	82
Circumference of Blade Tip (Pi*Rotor Diameter)	430.4
Rotational period (s) [430.4/82]	5.25
**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%.**

*Pitch of Blade used in the Analysis

It is acknowledged that pitch angle is determined by wind speeds which is something that is variable across seasons, and a range of geographical areas. The mean pitch of turbine blades has two referenced figures in Table 1 above. Wind speed versus the desired turbine rpm determines blade pitch. There is a specific pitch angle for any given wind speed to optimise output power. Typically speaking, the higher the wind speeds are, the higher the angle of the pitch.

This figure of 25 degrees is from Band (2012) where it is quoted that a standard figure for pitch for most large modern turbines would be between 25 – 30 degrees. This figure is considered highly precautionary however as the paper examines collision risk modelling for offshore windfarms, where windspeeds would be expected to be much higher than an on-shore windfarm site in County Clare.

3. RESULTS

Collison estimates were calculated using flight data recorded during vantage point watches at four vantage point locations (VP1, VP2, VP3 and VP4) within the study area between April 2017 and September 2019. The target species recorded within the potential collision risk zone included golden plover, hen harrier, common tern, peregrine, herring gull, buzzard, sparrowhawk, kestrel and snipe. It is acknowledged that the predicted number of transits, and hence predicted rate of collision for snipe may be largely underestimated, as flight activity for this species is largely crepuscular in nature while the VP survey sample consists of hours during daylight period for the most (Table 1.4, SNH (2017)).

The calculation parameters are outlined in Tables 2 – 8. A fully worked example of the calculation of collision risk for kestrel is available in Appendix 1.

Table 2 Cahermurphy Windfarm 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	573.5	202.6	4	180
VP2	619.7	313	7	180
VP3	569	332	9	180
VP4	284.8	143.9	2	109

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)
Golden Plover (Winter)	0.28	0.72	17.9	7,100
Hen Harrier	0.48	1.10	9.1	165
Common Tern	0.33	0.88	10.9	44
Peregrine	0.42	1.02	12.1	30
Herring Gull (Breeding)	0.60	1.44	12.8	43,354
Buzzard (Breeding)	0.54	1.20	13.3	1,669
Sparrowhawk	0.33	0.62	10.0	5
Kestrel	0.34	0.76	10.1	2,762
Snipe	0.26	0.46	17.1	538

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 band 25-175m.

Table 4 Random CRM - Number of Transits per Turbine within the Viewshed of each VP

Species	VP1	VP2	VP3	VP4
Golden Plover (Winter)	140.26	11.98	0	0
Hen Harrier	0	1.55	0.17	0
Common Tern	0	0	0.59	0
Peregrine	0	0.41	0	0
Herring Gull (Breeding)	229.78	417.73	48.32	37.08
Buzzard (Breeding)	4.66	0	17.43	18.90
Sparrowhawk	0	0.06	0	0
Kestrel	1.28	26.72	4.09	0
Snipe	4.65	0	8.44	0

Table 5 Number of Transits across site per year (Averages calculated from Table 3.3 Above and adjusted for all ten turbines)

Species	Average Transits	Transits Across Entire Site (All 10 Turbines) (Average Transits*10)
Golden Plover (Winter)	38.06	380.6
Hen Harrier	0.43	4.3
Common Tern	0.15	1.5
Peregrine	0.10	1.0
Herring Gull (Breeding)	183.23	1,832.3
Buzzard (Breeding)	10.25	102.5
Sparrowhawk	0.01	0.1
Kestrel	8.02	80.2
Snipe	3.27	32.7

Table 6 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 Plover	4.9%	N/A	**4.9%**
Hen Harrier	9.4%	9.3%	**9.3%**
Common Tern	7.3%	N/A	**7.3%**
Peregrine	7.1%	N/A	**7.1%**
Herring Gull	7.7%	7.5%	**7.6%**
Buzzard	7.2%	7.0%	**7.1%**
Sparrowhawk	7.7%	N/A	**7.7%**
Kestrel	7.7%	N/A	**7.7%**
Snipe	4.9%	N/A	**4.9%**

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

Species	Collision Risk	Transits Across Entire Site	Collisions/year (No Avoidance)
Golden Plover	4.9%	380.6	**18.78**
Hen Harrier	9.3%	4.3	**0.40**
Common Tern	7.3%	1.5	**0.11**
Peregrine	7.1%	1.0	**0.07**
Herring Gull	7.6%	1,832.3	**139.05**
Buzzard	7.1%	102.5	**7.23**
Sparrowhawk	7.7%	0.1	**0.76**
Kestrel	7.7%	80.2	**6.21**
Snipe	4.9%	32.7	**0.76**

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

Species	Collisions /year	Collisions /30 Years	Avoidance factor (%)	Note
*Golden Plover	0.376	11.27	98%	Winter/Passage (Oct-Mar)
Hen Harrier	0.004	0.12	99%	All year
Common Tern	0.002	0.07	98%	All year
Peregrine	0.001	0.04	98%	All year
Herring Gull	2.781	83.43	98%	Breeding (Feb – Sep)
Buzzard	0.145	4.34	98%	Breeding (Apr – Sep)
Sparrowhawk	0.015	0.46	98%	All year
Kestrel	0.310	9.31	95%	All year
*Snipe	0.015	0.46	98%	All year

***Assumed to be active 25% of the night as well as daylight hours per SNH guidance accounting for Swan/Geese 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.**

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

APPENDIX 1

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

Stage 1 (Transits through rotors per year) [Using figures from VP1 Column]

Table 9 Standard Measurements (Specific to Kestrel, Windfarm Site, Turbines modelled & VP1)

Description	Value	Units
Survey area visible from VP (Hectares) [At 30m]	Avp	573.5
Survey Time at VP1 April 2017 – September 2019 (secs)	s	648,00
Bird observation time at 25-175m (secs)	PCH	103
Rotor Radius (metres)	r	70
Rotor Diameter (metres)	D	140
Max chord width of turbine blade (metres)	d	4.0
No. of turbines in viewshed of VP1	x	4
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	202.6
Availability of species activity during survey period (hours) [Daylight hours]	Ba	13,544.05

Table 10 CRM Stage 1 Calculations using Standard Measurements in Table 1

Description	Value	Formula	Units
Proportion of time between 25-175m	t1	s/PCH	0.000158951
Flight activity per visible unit of area	F	t1/Avp	2.77E-07
Proportion of time in risk area	Trisk	F*Arisk	0.0000562
Bird occupancy of risk area	n	Trisk*Ba	0.760530764
Risk volume (Area of risk*Rotor Diameter)	Vw	(Arisk*D)*10,000	283640000
Actual volume of air swept by rotors	o	X*(Pi*r2(d+l))	267236.4375
Bird occupancy of rotor swept area (seconds)	b	3600*(n*(o/Vw))	2.579570987
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	6.00314907

Description	Value	Formula	Units
Total transits adjusted for max annual Turbine Operation Time (85% in this case)	Tn	N*0.85	5.10
Number of transits per turbine within viewshed of VP1	**TnT1**	**Tn/x**	**1.28**

Table 11 CRM Stage 1 Calculations – Number of transits through windfarm

Description	Value	Formula	Units
Number of transits per turbine with viewshed of VP1	**TnT1**	**Tn/x**	**1.28**
Number of transits per turbine with viewshed of VP2	TnT2	Tn/x	26.72
Number of transits per turbine with viewshed of VP3	TnT3	Tn/x	4.09
Number of transits per turbine with viewshed of VP4	TnT4	Tn/x	0
Average transits per turbine for all VPs	ATnT	(TnT1+TnT2+TnT3+TnT4) /4	8.02
Predicted number of transits through windfarm site (All ten turbines)	T	ATnT*10	80.2

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

80.2

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 4.0 metres, variable pitch is assumed to be 25 degrees and the average rotation cycle is taken to be 5.25 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. 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*

7.7%

*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

6.21

The annual theoretical collision rate assuming 95% avoidance (6.21*0.05)

0.31

Theoretical collision rate assuming 98% avoidance across the 30-year duration of the windfarm (0.31*30)

9.3