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1. INTRODUCTION

This document has been prepared by McCarthy Keville O'Sullivan Ltd. to assess the collision risk for birds at the proposed Lyrenacarriga Windfarm Site, Co. Waterford. The collision risk assessment, prepared by Mr Patrick Manley (BSc.), is based on vantage point watch surveys undertaken at the site of the development from September 2016, up to and including September 2018 covering two full years consisting of two breeding seasons and two non-breeding seasons. Vantage Point Surveys at the development site were undertaken from five fixed Vantage Point (VP) Locations (Site 2 & Site 3), which provided adequate coverage of the proposed turbine layout and 500m of the same (see Figure 8.2.2).

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. a 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 (classified as random) 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 20m, the viewshed coverage displaying the visibility of the area within the 2km arc at a height of 20m 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-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.

Flight data from Site 1, as well as Sites 4-7, was excluded from Collision Risk Modelling as none of these VPs provided coverage of the proposed turbine layout. While this data has been used in determining distribution and abundance of the species observed and contextualising the development site in comparison to habitat in the wider area, the flight data has not been considered for collision risk modelling.

In the case of all species, the majority of flights observed at Lyrenacarriga (Site 2 and Site 3) during the survey period could be classified as randomly distributed flights which could occur anywhere within the given viewsheds. The "Random Flight Model" was applied to each 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 Lyrenacarriga Windfarm Site. These assumptions are tailored specifically to Lyrenacarriga and are as follows:

- The turbine maximum tip height is 150m and lowest swept height is 17m. Therefore, birds in flight recorded during vantage point surveys in heights bands 0-20m, 20-140m and 140-175m are assumed (for the purposes of the analysis) to be in danger of collision with the rotating turbine blades. This includes flight data both above and below the potential swept heights as a range of turbine models were under assessment at the time of the survey design. Predicted collision rates are therefore likely to be an overestimate.

- 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. For species such as Swans and Geese only the mean calculations for flapping flights were used.
- The majority of the golden plover observed were recorded in foraging habitat (e.g. agricultural grassland offsite), as shown in Figure 8.1.2.1. This flight activity is not random but rather strongly associated with the foraging habitat available in the agricultural grassland. The flight activity associated with foraging habitat is therefore spatially explicit. Those flights recorded in excess of 500m from turbines and associated with grassland have been excluded from the analysis. Therefore, the collision risk assessment only utilises flight observations recorded within, or partially within, 500m of the proposed turbine layout.

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 Lyrenacarriga Windfarm Site are presented in Table 2-1.

Table 2-1 Turbine and wind farm characteristics

Wind Farm Component	Scenario Modelled
Assumed turbine model	Nordex N133
Number of turbines	17
Blades per turbine rotor (3d model used)	3
Rotor diameter (m)	133
Rotor radius (m)	66.5
Hub height (m)	83.5
Swept height (m)	17 - 150
Mean pitch of blade (degrees)	6
Maximum chord (m) (i.e. depth of blade)	4.0
Speed, Dynamic Operation Range (m/s)	6.9-13.9
Average Operating Range (m/s)	10.4
Rotational period (s) [60/11.95]	5.77

Wind Farm Component	Scenario Modelled
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

Collison estimates were calculated using flight data recorded during vantage point watches at five vantage point locations (Site 2 (VP1 & VP2) and Site 3 (VP1, VP2 & VP3)) within the study area between September 2016 and September 2018. The target species recorded within the potential collision risk zone included golden plover, hen harrier, peregrine, lesser black-backed gull, buzzard, sparrowhawk, kestrel and snipe. It is acknowledged that collision for snipe can be 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 part (Table 1.4, SNH (2017)). In the present case, significant numbers of snipe collisions are not predicted given the dominant habitat within the wind farm site (i.e. commercial forestry) is unlikely to attract significant numbers of snipe. Snipe favour open habitats for foraging and breeding.

The calculation parameters are outlined in Table 3-1– Table 3-7. A fully worked example of the calculation of collision risk for golden plover is available in Appendix 1 below.

Table 3-1 Lyrenacarriga Windfarm VP Survey Effort and Viewshed Coverage

Vantage Point	Visible Area above 30m (Hectares)	Risk Area (Hectares)	Turbines Visible from VP	Total Survey Effort (Hours)
Site 2 VP1	639.86	391.57	9	150
Site 2 VP2	586.5	294.26	8	150
Site 3 VP1	646.3	227.12	5	150
Site 3 VP2	650.35	199.29	4	150
Site 3 VP3	647.52	257.72	6	150

Table 3-2 Bird Biometrics (Taken from BTO BirdFacts & Alerstam et al. (2007)) and Recorded duration at PCH during VP Surveys

Species	Length (m)	Wingspan (m)	Ave. speed (m/s)	Seconds in flight at PCH (20 - 175 m)
Golden Plover (Wintering)	0.28	0.72	17.9	53,770
Hen Harrier (Wintering)	0.48	1.1	9.1	445
Peregrine (All Year)	0.42	1.02	12.1	500
Lesser Black-backed Gull (All Year)	0.58	1.42	11.9	86,743
Buzzard (All Year)	0.54	1.20	13.3	19,622
Sparrowhawk (All Year)	0.33	0.62	10.0	1,093
Kestrel (All Year)	0.34	0.76	10.1	6,283
Snipe (All Year)	0.26	0.46	17.1	6,046

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

Species	Site 2 VP1	Site 2 VP2	Site 3 VP1	Site 3 VP2	Site 3 VP3
Golden Plover (Wintering)	383.35	448.41	6.58	00	188.68
Hen Harrier (Wintering)	0.74	0	0.33	0.22	1.97
Peregrine (All Year)	2.19	0.16	0.18	0.1	3.42
Lesser Black-backed Gull (All Year)	15.55	587.13	199.59	106.25	421.31
Buzzard (All Year)	35.05	111.01	74.84	21.33	19.26
Sparrowhawk (All Year)	1.17	6.81	0.4	0.74	1.2
Kestrel (All Year)	3.15	6.24	16	4.29	30.31
Snipe (All Year)	0	1.32	2.98	1.32	113.2

Table 3-4 Number of Transits across site per year (Averages are calculated from Table 3-3 above and adjusted for all 17 turbines)

Species	Average Transits	Transits Across Entire Site (All 17 Turbines) (Average Transits*17)
Golden Plover (Wintering)	205.4	3491.85
Hen Harrier (Wintering)	0.65	11.09
Peregrine (All Year)	1.21	20.56
Lesser Black-backed Gull (All Year)	249.97	4249.43
Buzzard (All Year)	52.3	889.09
Sparrowhawk (All Year)	2.06	35.06
Kestrel (All Year)	12	203.97
Snipe (All Year)	23.76	404

Table 3-5 Collision Risk Workings using Band Model (2007) (Species which exhibit both Flapping and Gliding Flight Collision Risk took the average between upwind and downwind)

Species	Flapping Flight	Gliding Flight	Collision Risk [(Flapping + Gliding)/2]
Golden Plover (Wintering)	4.7%	N/A	4.7%
Hen Harrier (Wintering)	6.5%	6.4%	6.5%
Peregrine (All Year)	5.7%	5.5%	5.6%
Lesser Black-backed Gull (All Year)	6.5%	6.2%	6.4%

Species	Flapping Flight	Gliding Flight	Collision Risk [(Flapping + Gliding)/2]
Buzzard (All Year)	6.0%	5.8%	5.9%
Sparrowhawk (All Year)	5.4%	5.3%	5.4%
Kestrel (All Year)	5.5%	5.4%	5.4%
Snipe (All Year)	4.5%	N/A	4.5%

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

Species	Collision Risk	Transits/year Across Entire Site	Collisions/year (No Avoidance)
Golden Plover (Wintering)	4.7%	3491.85	164.73
Hen Harrier (Wintering)	6.5%	11.09	0.72
Peregrine (All Year)	5.6%	20.56	1.14
Lesser Black-backed Gull (All Year)	6.4%	4249.43	269.93
Buzzard (All Year)	5.9%	889.09	52.49
Sparrowhawk (All Year)	5.4%	35.06	1.88
Kestrel (All Year)	5.4%	203.97	11.1
Snipe (All Year)	4.5%	404	17.87

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

Species	Collisions /year	Collisions /30 Years	Avoidance factor (%)	Note
Golden Plover (Wintering)*	3.29	98.84	98%	Winter/Passage (Oct-Mar)
Hen Harrier (Wintering)	0.007	0.21	99%	Winter/Passage (Oct-Mar)
Peregrine (All Year)	0.02	0.69	98%	All year
Lesser Black-backed Gull (All Year)*	5.4	161.96	98%	All year
Buzzard (All Year)	1.05	31.49	98%	All year
Sparrowhawk (All Year)	0.04	1.13	98%	All year
Kestrel (All Year)	0.55	16.64	95%	All year

Species	Collisions /year	Collisions /30 Years	Avoidance factor (%)	Note
Snipe (All Year) *	0.36	10.72	98%	All year

***Assumed to be active 25% of the night as well as daylight hours per SNH guidance accounting for Swan/Geese/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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APPENDIX 1

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

Stage 1 (Transits through rotors per year) (Using figures from Site 2 VP1 Column)

Table 1: Standard Measurements (Specific to Golden Plover, Windfarm, Turbines modelled & Site 2 VP1)

Description	Value	Units
Survey area visible from VP (Hectares) [At 30m]	Avp	639.86
Survey Time at Site 2 VP1 both winter season (secs)	s	280,800
Bird observation time above 25m (secs)	PCH	20,780
Rotor Radius (metres)	r	66.5
Rotor Diameter (metres)	D	133
Max chord width of turbine blade (metres)	d	4.0
No. of turbines in viewshed of Site 2 VP1	x	9
Bird length in metres [Taken from BTO online)	l	0.28
Average Flight speed of Golden Plover (m/s)	v	17.9
500m buffer of turbines within viewshed, i.e. Area of Risk (Hectares)	Arisk	391.57
Availability of species activity during survey period (hours)	Ba	5,347.5

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

Description	Value	Formula	Units
Proportion of time between 0 -175m	t1	s/PCH	0.080169753
Flight activity per visible unit of area	F	t1/Avp	1.25E-04
Proportion of time in risk area	Trisk	F*Arisk	0.0490608
Bird occupancy of risk area	n	Trisk*Ba	262.3528514
Risk volume (Area of risk*Rotor Diameter)	Vw	(Arisk*D)*10,000	520788100
Actual volume of air swept by rotors	o	X*(Pi*r2(d+l))	535154.8205
Bird occupancy of rotor swept area (seconds)	b	3600*(n*(o/Vw))	970.5248931
Time taken for bird to pass through rotors (seconds)	t2	(d+Bl)/v	0.239106145
Number of bird passes through the rotor in the survey period	N	b/t2	4058.970932

Description	Value	Formula	Units
Total transits adjusted for max annual Turbine Operation Time (85% in this case)	Tn	N*0.85	3450.13
Number of transits per turbine within viewshed of Site 2 VP1	**TnT1**	**Tn/x**	**383.35**

Table 3: CRM Stage 1 Final Cumulative Calculations (All five VPs Golden Plover Transits):

Description	Value	Formula	Units
Number of transits per turbine with viewshed of Site 2 VP1	TnT1	Tn/x	383.35
Number of transits per turbine with viewshed of Site 2 VP2(a)	TnT2	Tn/x	448.41
Number of transits per turbine with viewshed of Site 3 VP1	TnT3	Tn/x	6.58
Number of transits per turbine with viewshed of Site 3 VP2	TnT4	Tn/x	0
Number of transits per turbine with viewshed of Site 3 VP3	TnT5	Tn/x	188.68
Average transits per turbine for all VPs	ATnT	(TnT1+TnT2+TnT3 +TnT4+TnT5) / 5	205.40
Predicted number of transits through windfarm site (All 18 turbines)	T	ATnT*17	3491.844492

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

3,491.84

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 golden plover to take evasive action when coming close to wind turbine blades.

In the calculations, the length of a golden plover was taken to be 0.28 metres and the wingspan 0.72 metres. The flight velocity of the bird is assumed to be 17.9 metres per second. The maximum chord of the blades is taken to be 4.0 metres and the average rotation cycle is taken to be 5.77 seconds per rotation, depending on wind conditions. The mean pitch for a Nordex N133 turbine is given as 6 degrees.

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 3-7.

Collision Probability*

4.72%

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

Collision per year

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

164.73

The annual theoretical collision rate assuming 98% avoidance (164.73*0.02)

3.29

Theoretical collision rate assuming 98% avoidance across the 30-year duration of the windfarm (3.29*30)

98.84