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APPENDIX 7-6

COLLISION RISK ASSESSMENT

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1. INTRODUCTION

This document outlines the methodology used to assess the predicted rate of collisions for birds at the Proposed Wind Farm. The collision risk assessment is based on vantage point surveys undertaken at the Proposed Wind Farm site from September 2020 to March 2023. This represents a 33-month survey period, consisting of two breeding seasons and three winter seasons, which is in full compliance with Scottish Natural Heritage guidance (SNH, 2017). Surveys were undertaken from five fixed vantage points, four of which were used in the collision risk model. VP3 and VP5 no longer contain turbines and therefore were not included in the assessment. Surveys at VP1 and VP5 were discontinued in October 2021 due to sufficient coverage from the remaining vantage points. VP3 and VP4 were relocated to VP3a and VP4a in October 2021.

Collision risk is calculated using a mathematical model to predict the number of birds that may be killed by collision with moving wind turbine rotor blades. The modelling method used in this collision risk calculation is known as the Band Model (Band *et al.,* 2007) and has been used in a number of studies on bird collision with wind turbines (e.g. Chamberlain *et al.,* 2006; Drewitt and Langston, 2006; Fernley *et al.,* 2006; Madders and Whitfield, 2006). Note that these are theoretical predictions, therefore results must be interpreted with a degree of caution.

Two stages are involved in the Band Model. First, the number of bird transits through the air space swept by the rotor blades of the wind turbines per year is estimated. Then the collision risk for a bird passing through the rotor blades is calculated using a mathematical formula. The product of these provides a theoretical annual collision mortality rate. Finally, a bird avoidance rate is applied to the collision mortality rate to account for birds attempting to avoid collision. This final collision mortality rate informs the assessment of impacts of the wind turbine on birds.

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2. METHODOLOGY

2.1 The Band Model

The Band Model is used to predict the number of bird collisions that might be caused by a wind turbine. It uses species-specific information on bird biometrics, flight characteristics and the expected amount of flight activity, along with turbine-specific information on hub height, rotor diameter, pitch and rotational speed. The proposed turbines will be between 102.5m and 105m at hub height, with 3 blades of a diameter between 149m and 155m, giving a maximum rotor height of between 179.5m and 180m and a minimum rotor height of between 25m and 30.5m. The model makes a number of assumptions on the turbine design and on biometrics of birds:

- 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 of collision. The final step in the analysis accounts for the ability of birds to avoid a collision.

Two forms of collision risk modelling are outlined by Band *et al.* (2007): a **"Regular Flight Model"** and the **"Random Flight Model"**. A Regular Flight Model is generally applied to situations where flightlines form a regular pattern. This may occur, for example, when birds are using a wind farm site as a commuting corridor between roosting and feeding grounds or migratory routes, as is often observed in geese and swans. The Random Flight Model generally applied to situations where flightlines form no discernible patterns or routes. This is often observed, for example when raptors are in foraging or hunting flights.

The Regular Flight Model predicts the number of transits through a cross-sectional area of a wind farm which represents the width of the commuting corridor. A "risk window" is identified: a 2-dimensional line the width of a wind farm to a 500m buffer of the turbines, multiplied by the rotor diameter. All commuting flights which pass through this risk window within the rotor swept height (potential collision height; PCH) are included in collision risk modelling. Any regular flights more than 500m from the turbine layout can be excluded from analysis. There are a number of key assumptions and limitations:

- 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.
- Bird activity is spatially explicit.
- 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).
- Habitat and bird activity will remain the same over time and be unchanged during the operational stage of the windfarm.
- All flight activity used in the model occurred within the viewshed area calculated at the lowest swept rotor height.

The Random Flight Model predicts the number of transits through a wind farm while assuming that all flights within the vantage point viewshed are randomly occurring, i.e. any observed flight could just as easily occur within a wind farm site as outside it. All flights within PCH inside the viewshed are included in the model. There are a number of key assumptions and limitations:

- 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.

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- Habitat and bird activity will remain the same over time and be unchanged during the operational stage of the windfarm.
- All flight activity used in the model occurred within the viewshed area calculated at the lowest swept rotor height.

More detail on both the Random and Regular Flight Model calculations are available from SNH: https://www.nature.scot/wind-farm-impacts-birds-calculating-theoretical-collision-risk-assuming-no-avoiding-action. In the case of the Proposed Project, six species recorded in flight in the study area were randomly distributed. Therefore, a Random Flight Model was conducted for all species.

2.2 Modelling Process

The steps used in the Band Model to derive the collision mortality rate for each species observed at a wind farm site are outlined below.

- Stage 1: Estimate the number of bird transits through the air space swept by the rotor blades of the wind turbines. Transits are calculated using either the "Regular" or "Random" flight model (Band *et al.,* 2007), depending on flight distribution and behaviour.
- Stage 2: Calculate the collision risk for an individual bird flying through a rotating turbine blade. Collision risk is calculated using a formula which incorporates the number of bird transits (Stage 1), individual species' biometrics, individual species' flight speed and style, and the proposed turbine parameters. This formula is publicly available on the SNH website: https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision. Biometrics are available from the British Trust of Ornithology (BTO, 2021) and flight speeds are available from Alerstam *et al.* (2007). For species that can both flap and glide, the mean of the collision risk for flapping and for gliding flight is taken.
- The product of the number of birds transits per year multiplied by the collision risk provides an annual collision mortality rate. There is an assumption that birds flying towards the turbines make no attempt to avoid them.
- To account for birds attempting to avoid collision, an avoidance factor is applied to the annual collision mortality rate. This corrects for the ability of the birds to detect and manoeuvre around the turbines. Avoidance rates are available from SNH (2018). Bird avoidance rates are generally 98-99% or higher for most species, based on empirical evidence, targeted studies and literature reviews, and continue to be updated following further studies of bird behaviour and mortality rates at wind farm sites.

The final annual collision risk corrected for avoidance is a "real-world" estimation of the number of collisions that may occur at a wind farm, based on observed bird activity during the vantage point survey period.

2.3 Turbine specifications

Birds in flight within the viewshed at heights between 25-200m above ground level have been included in the collision risk model. The turbine specifications used in the model are available in Table 7-5-1.

Table 7 – 5 – 1 Turbine specifications

Wind Farm Component	Scenario Modelled
Scenario 1 – Viewshed at 25m	
Number of turbines	7
Blades per turbine rotor	3
Rotor diameter (m)	155
Rotor radius (m)	77.5
Hub height (m)	102.5

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Wind Farm Component	Scenario Modelled
Swept height (m)	25 – 180
Pitch of blade (degrees)	6
Maximum chord (m) (i.e. depth of blade)	4.5
Rotational period (s)	7.2
Turbine operational time[1]	35 years
Scenario 2 – Viewshed at 30m	
Number of turbines	7
Blades per turbine rotor	3
Rotor diameter (m)	150
Rotor radius (m)	75
Hub height (m)	105
Swept height (m)	30 – 180
Pitch of blade (degrees)	6
Maximum chord (m) (i.e. depth of blade)	4.2
Rotational period (s)	7.1
Turbine operational time[1]	35 years
Scenario 3 – Viewshed at 30.5m	
Number of turbines	7
Blades per turbine rotor	3
Rotor diameter (m)	149
Rotor radius (m)	74.5
Hub height (m)	105
Swept height (m)	30.5 – 179.5
Pitch of blade (degrees)	6
Maximum chord (m) (i.e. depth of blade)	4.5
Rotational period (s)	6.4
Turbine operational time[1]	35

2.4 Ornithological Receptors

The species of conservation concern recorded at potential collision height during vantage point surveys at the Proposed Wind Farm site were:

- Hen Harrier
- Peregrine Falcon
- Kestrel
- Snipe
- Buzzard
- Sparrowhawk

A CRM was conducted for each of these species. It is assumed that waterbirds (snipe) are active for 25% of the night along with daylight hours (as per SNH guidance) and this is accounted for in the model.

[1] 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%.

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2.5 Calculation Parameters

The calculation parameters for the vantage point are outlined in Table 7-5-2. Bird biometrics are presented in Table 7-5-3. Table 7-5-4 presents the model input values for the random model: bird seconds in flight at PCH observed from the vantage points during the relevant survey period. Bird seconds in flight at PCH is calculated by multiplying the number of birds observed per flight by the duration of the flight spent within PCH (PCH – height band of 25-200m).

Table 7- 5 - 2 Survey effort and viewshed coverage

Vantage Point	Visible Area (ha)	Risk Area (ha)	Turbines visible	Total Survey Effort (hrs)
Scenario 1 – Viewshed at 25m				
VP1	423	52	1	66
VP2	582	257	5	183
VP3a	518	99	2	75
VP4	584	105	3	108
VP4a	485	134	3	72
Scenario 2 – Viewshed at 30m				
VP1	438	54	1	66
VP2	589	262	5	183
VP3a	531	104	2	75
VP4	597	105	3	108
VP4a	505	139	3	72
Scenario 3 – Viewshed at 30.5m				
VP1	448	54	1	66
VP2	584	262	5	183
VP3a	537	104	2	75
VP4	605	105	3	108
VP4a	510	140	3	72

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Table 7 – 5 – 3 Bird biometrics

Species	Body Length (m)	Wingspan (m)	Flight Speed (m/s)
Hen Harrier	0.48	1.1	9.1
Peregrine Falcon	0.45	1.05	12.1
Kestrel	0.34	0.76	10.1
Snipe	0.26	0.42	17.1
Buzzard	0.54	1.2	11.6
Sparrowhawk	0.33	0.63	10.0

Table 7 – 5 – 4 Model input values

Species	Model	Period	Bird Seconds at PCH
Hen Harrier	random	Winter	100
Hen Harrier	random	Breeding	366
Peregrine Falcon	random	All	603
Kestrel	random	All	6,203
Snipe	random	All	30
Buzzard	random	All	11,427
Sparrowhawk	random	All	170

The avoidance rates applied to the collision risk were: 99% for hen harrier, 95% for kestrel and 98% for the remaining species.

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3. RESULTS AND DISCUSSION

A "Random" collision risk model has been conducted for birds observed during vantage points surveys at the Proposed Wind Farm using the Band Model, following best practice guidance from NatureScot. Collision risk models provide theoretical predictions of the probability of bird collision with wind turbine rotor blades. The results are affected by sources of uncertainty including the representativeness of the survey data, natural variability in bird populations, model assumptions and estimates on bird attraction and avoidance rates. As such, the results are considered to be a best estimate of collision risk, rather than a precise figure. The predicted number of transits per year and the estimated collision risk is presented in Table 7-5-5, along with the final predicted number of collisions per year. Note that for birds that both flap and glide, the average collision risk percentage between flapping and gliding is taken.

Table 7 – 5 – 5 Collision rate predictions.[2]

Species	Survey Period	Model	Transits	Collision Risk			Collision Rate			Estimated Collisions Over Lifetime of Wind Farm	One Bird Collision
				flapping	gliding	overall	without avoidance	avoidance factor	with avoidance		
Scenario 1 (25m – 180m)											
Hen Harrier	Winter	random	3	5.85%	5.71%	5.78%	0.17	99%	0.002	0.06 birds	584 years
Hen Harrier	Breeding	random	8.5	5.85%	5.71%	5.78%	0.49	99%	0.005	0.17 birds	203 years
Peregrine Falcon	All	random	17.8	5.25%	5.07%	5.16%	0.92	98%	0.018	0.64 birds	54 years
Kestrel	All	random	151.6	4.99%	4.88%	4.94%	7.48	95%	0.374	13.09 birds	3 years
Snipe	All	random	1.1	4.19%	no gliding flight	4.19%	0.04	98%	0.001	0.03 birds	1112 years
Buzzard	All	random	277.5	5.66%	5.46%	5.56%	15.43	98%	0.309	10.8 birds	3 years

[2] *For each species, the survey period and model type are specified, along with the predicted number of transits through the risk area and the collision risk (for flapping flight, gliding flight and the average of both). Two values for collision rate are presented: the initial collision rate without avoidance and a final estimated collision rate (with an avoidance factor). Finally, the estimated number of collisions over the lifetime of the turbines in presented, along with the corresponding estimated number of years of operation for one collision to occur.*

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Species	Survey Period	Model	Transits	Collision Risk			Collision Rate			Estimated Collisions Over Lifetime of Wind Farm	One Bird Collision
				flapping	gliding	overall	without avoidance	avoidance factor	with avoidance		
Sparrowhawk	All	random	3.8	4.94%	4.86%	4.9%	0.19	98%	0.004	0.13 birds	270 years
Scenario 2 (30m – 180m)											
Hen Harrier	Winter	random	2.8	5.77%	5.63%	5.7%	0.16	99%	0.002	0.06 birds	628 years
Hen Harrier	Breeding	random	8	5.77%	5.63%	5.7%	0.45	99%	0.005	0.16 birds	220 years
Peregrine Falcon	All	random	16.9	5.16%	4.95%	5.06%	0.85	98%	0.017	0.6 birds	59 years
Kestrel	All	random	142.9	4.9%	4.78%	4.84%	6.92	95%	0.346	12.1 birds	3 years
Snipe	All	random	1	4.08%	no gliding flight	4.08%	0.04	98%	0.001	0.03 birds	1194 years
Buzzard	All	random	262.7	5.58%	5.37%	5.48%	14.39	98%	0.288	10.07 birds	3 years
Sparrowhawk	All	random	3.6	4.84%	4.76%	4.8%	0.17	98%	0.003	0.12 birds	292 years
Scenario 3 (30.5 – 179.5m)											
Hen Harrier	Winter	random	1.4	6.25%	6.11%	6.18%	0.08	99%	0.001	0.03 birds	1180 years
Hen Harrier	Breeding	random	8.1	6.25%	6.11%	6.18%	0.5	99%	0.005	0.17 birds	200 years
Peregrine Falcon	All	random	12.7	5.57%	5.38%	5.47%	0.69	98%	0.014	0.49 birds	72 years
Kestrel	All	random	115.5	5.29%	5.2%	5.25%	6.06	95%	0.303	10.6 birds	3 years
Snipe	All	random	1	4.4%	no gliding flight	4.4%	0.05	98%	0.001	0.03 birds	1105 years
Buzzard	All	random	234.3	6.03%	5.85%	5.94%	13.91	98%	0.278	9.74 birds	4 years
Sparrowhawk	All	random	3	5.24%	5.18%	5.21%	0.16	98%	0.003	0.11 birds	319 years

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Table 7 - 5 – 6 Results Comparison: The highest rates of predicted collisions have been written in bold text.

Species	Survey Period	Collision Risk (with avoidance)			Estimated Collisions Over Lifetime of Wind Farm			One Bird Collision		
		Scenario 1 (25-180m)	Scenario 2 (30-180m)	Scenario 3 (30.5-179.5m)	Scenario 1 (25-180m)	Scenario 2 (30-180m)	Scenario 3 (30.5-179.5m)	Scenario 1 (25-180m)	Scenario 2 (30-180m)	Scenario 3 (30.5-179.5m)
Hen Harrier	Winter	**0.002**	**0.002**	0.001	0.06 birds	0.06 birds	0.03 birds	584 years	628 years	1180 years
Hen Harrier	Breeding	**0.005**	**0.005**	**0.005**	0.17 birds	0.16 birds	0.17 birds	203 years	220 years	200 years
Peregrine Falcon	All	**0.018**	0.017	0.014	0.64 birds	0.6 birds	0.49 birds	54 years	59 years	72 years
Kestrel	All	**0.374**	0.346	0.303	13.09 birds	12.1 birds	10.6 birds	3 years	3 years	3 years
Snipe	All	**0.001**	**0.001**	**0.001**	0.03 birds	0.03 birds	0.03 birds	1112 years	1194 years	1105 years
Buzzard	All	**0.309**	0.288	0.278	10.8 birds	10.07 birds	9.74 birds	3 years	3 years	4 years
Sparrowhawk	All	**0.004**	0.003	0.003	0.13 birds	0.12 birds	0.11 birds	270 years	292 years	319 years

Taking into account the uncertainties associated with the model, the predicted collision risk is negligible for the species hen harrier, peregrine falcon, snipe and sparrowhawk. At least one collision over the lifetime of the Proposed Wind Farm is predicted for the species kestrel and buzzard in all three scenarios. For all species, there is a <1% increase in background mortality rate (negligible effect). Further assessment of these species is conducted in Chapter 7 of the associated Environmental Impact Assessment.

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