



## **APPENDIX 8**

***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 proposed Carrow Wind Farm. The collision risk assessment is based on vantage point surveys undertaken at the wind farm study area from April 2021 to March 2023. This represents a 24-month survey period, consisting of two breeding seasons and two winter seasons, which is in full compliance with Scottish Natural Heritage guidance (SNH, 2017). Surveys were undertaken from five fixed vantage points.

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. The NatureScot (2024) collision risk model and associated guidance were considered as part of the assessment. Of note in the 2024 guidance is the statement that the collision risk estimates should not differ substantively from those derived from the earlier guidance.

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.

## 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 turbine will be 103.5m at hub height, with 3 blades of a diameter of 163m, giving a maximum rotor height of 185m and a minimum rotor height of 22m. 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

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.
- 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 Carrow Wind Farm, golden plover, hen harrier, peregrine falcon, kestrel, snipe, buzzard and sparrowhawk recorded in flight in the study area were randomly distributed. Therefore, a Random Flight Model was conducted for these 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 15-200m 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
Turbine model	Nordex N163
Number of turbines	14
Blades per turbine rotor	3
Rotor diameter (m)	163
Rotor radius (m)	81.5
Hub height (m)	103.5
Swept height (m)	22m
Pitch of blade (degrees)	6
Maximum chord (m) (i.e. depth of blade)	4.5
Rotational period (s)	6.75
Turbine operational time <sup>1</sup>	85%

## 2.4 Ornithological Receptors

The species of conservation concern recorded during surveys at the proposed Carrow Wind Farm were:

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

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

## 2.5 Calculation Parameters

The calculation parameters for the vantage point are outlined in Table 7-5-2.

*Table 7-5-2 Survey effort and viewshed coverage*

Vantage Point	Visible Area at 22m	Risk Area	Turbines visible	Total Survey Effort
VP1	332	173	3	01/04/2021-31/03/2023
VP2	375	296	6	01/04/2021-31/03/2023
VP3	335	212	3	01/04/2021-31/03/2023
VP4	312	128	2	01/04/2021-31/03/2023
VP5	244	167	4	01/04/2021-31/03/2023

Bird biometrics are presented in Table 7-5-3.

*Table 7-5-3 Bird biometrics*

Species	Body Length(cm)	Width(cm)	Flight Speed (m/s)
Hen Harrier	48.0	110.0	9.1

<sup>1</sup> 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%.

Species	Body Length(cm)	Width(cm)	Flight Speed (m/s)
Peregrine Falcon	44.5	105.0	12.1
Kestrel	33.5	75.5	10.1
Snipe	25.5	42.0	17.1
Buzzard	54.0	120.5	11.6
Sparrowhawk	33.0	62.5	10.0

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.

*Table 7 - 5 - 4 Model input values*

Species	Model	Period	Input value (s)
Hen Harrier	random	All seasons	565
Peregrine Falcon	random	All seasons	384
Kestrel	random	All seasons	30,866
Snipe	random	September to April	284
Buzzard	random	All seasons	33,248
Sparrowhawk	random	All seasons	1,010

The avoidance rates applied to the collision risk were: 99% for hen harrier, 98% for peregrine, snipe, buzzard and sparrowhawk, and 95% for kestrel.

### 3. RESULTS AND DISCUSSION

A “Random” collision risk model has been conducted for birds observed during vantage points surveys at the proposed Carrow 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. 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 is presented, along with the corresponding estimated number of years of operation for one collision to occur.*

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		
Hen Harrier	All	random	44.5	5.79%	5.69%	5.74%	2.55	99%	0.026	0.89 birds	39 years
Peregrine Falcon	All	random	30.3	5.14%	4.97%	5.06%	1.53	98%	0.031	1.07 birds	33 years
Kestrel	All	random	2241.7	4.89%	4.8%	4.85%	108.65	95%	5.432	190.13 birds	<1 year
Snipe	September to April	random	36.4	4.05%	no gliding flight	4.05%	1.47	98%	0.029	1.03 birds	34 years
Buzzard	All	random	2637.4	5.58%	5.41%	5.5%	144.98	98%	2.9	101.49 birds	<1 year
Sparrowhawk	All	random	69.2	4.85%	4.79%	4.82%	3.33	98%	0.067	2.33 birds	15 years

Taking into account the uncertainties associated with the model, the predicted collision risk is negligible for hen harrier. At least one collision over the lifetime of the wind farm is predicted for the species peregrine falcon, kestrel, snipe, buzzard and sparrowhawk.

4. **BIBLIOGRAPHY**

- Alerstam, T., Rosen M., Backman J., G P., Ericson P. and Hellgren O. (2007). Flight Speeds among Bird Species: Allometric and Phylogenetic Effects. *PLoS Biology*, 5: 1656-1662.
- Band, W., Madders, M. and Whitfield, D. (2007). 'Developing Field and Analytical Methods to Assess Avian Collision Risk at Wind Farms', in de Lucas, M., Janss, G. and Ferrer, M. (eds) *Birds and Wind Farms: Risk Assessment and Mitigation*. Madrid: Quercus/Libreria Linneo.
- BTO (2021) BirdFacts. Available at <https://www.bto.org/about-birds/birdfacts> (accessed 10/08/2021).
- Chamberlain, D.E., Rehfisch, M.R., Fox, A.D., Desholm, M. and Anthony, S.J. (2006). The effect of avoidance rates on bird mortality predictions made by wind turbine collision risk models. *Ibis*, 148: 198-202.
- Drewitt, A. and Langston, R. (2006). Assessing the impacts of wind farms on birds. *Ibis*, 148: 29-42.
- Fernley, J., Lowther, S. and Whitfield P. (2006). *A review of goose collisions at operating wind farms and estimation of the goose avoidance rate*. Unpublished report by West Coast Energy, Hyder Consulting and Natural Research, UK.
- Madders, M. and Whitfield, P.D. (2006). Upland raptors and the assessment of wind farm impacts. *Ibis*, 148: 43-56.
- NatureScot (2024). Guidance on using an updated collision risk model to assess bird collision risk at onshore wind farms. NatureScot, Inverness, Scotland. Available at: <https://www.nature.scot/doc/guidance-using-updated-collision-risk-model-assess-bird-collision-risk-onshore-wind-farms>
- Percival, S.M. (2003). Birds and wind farms in Ireland: a review of potential issues and impact assessment. Ecology Consulting, Durham, UK. Available at: [https://tethys.pnnl.gov/sites/default/files/publications/Percival\\_2003.pdf](https://tethys.pnnl.gov/sites/default/files/publications/Percival_2003.pdf)
- SNH (2017). Recommended bird survey methods to inform impact assessment of onshore wind farms. Scottish Natural Heritage, Inverness, Scotland.
- SNH (2018). Avoidance rates for the onshore SNH wind farm collision risk model. Scottish Natural Heritage, Inverness, Scotland. Available at: <https://www.nature.scot/sites/default/files/2018-09/Wind%20farm%20impacts%20on%20birds%20-%20Use%20of%20Avoidance%20Rates%20in%20the%20SNH%20Wind%20Farm%20Collision%20Risk%20Model.pdf> (accessed 10/08/2021)