
Appendix 7.7 – Collision risk modelling and assessment

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A7.4.1 INTRODUCTION

Scope

This appendix includes the collision risk modelling and collision risk assessment for the proposed Scart Mountain Wind Farm.

Collision risk modelling

Collision risk modelling uses statistical modelling techniques to predict the likely collision risk. It uses flight activity data from before the construction of a wind farm to calculate the likely risk of birds colliding with turbines in the operational wind farm. There are three stages to the collision risk model. In stage 1, the flight activity data that was recorded is scaled up to represent the overall level of flight activity in the wind farm site across the relevant period (e.g., a full year for a resident species, or a summer or winter for a migrant species). The number of predicted transits of the rotor swept volume in the wind farm is then calculated based on the proportion of the total air space that is occupied by the rotor swept volume. However, most transits of the rotor swept volume will not result in a collision, because for the duration of a transit, most of the rotor swept volume is not occupied by the turbine blades. Therefore, stage 2 of the collision risk model involves calculating the probability that a bird will collide with a turbine blade when it transits the rotor swept volume. Most birds try to avoid the turbine blades, either by avoiding the wind farm area altogether, or by taking evasive action if they are likely to collide with a blade while transiting the wind farm, so it is also necessary to factor in an avoidance rate. This is done in the final stage, where the predicted number of transits are converted to predicted number of collisions by multiplying by the collision probability (assuming no avoidance behaviour) and then correcting for the avoidance rate and other relevant factors.

Collision risk assessment

The potential impact of the predicted collision risk depends on the size of the affected population and their demographics. The collision risk assessment examines whether the level of the predicted collision risk could have a significant effect on the dynamics of the affected population.

A7.4.2 COLLISION RISK MODEL STAGE 1: BIRD TRANSITS

Methods (general approach)

The Stage 1 calculations use the vantage point survey data to calculate the predicted number of bird transits across the rotor swept volume. There are two methods described by SNH (2000) for carrying out stage 1 calculations: the risk window method for when birds make regular flights through the flight risk area (e.g., geese commuting between roost sites and feeding areas); and the bird occupancy method for when birds show variable patterns of flight activity within the flight risk area.

The bird occupancy method was used for this assessment. This is generally the appropriate method for species that show variable patterns of flight activity, and the vantage point survey data and flightline mapping did not indicate regular flightlines through the wind farm site.

The sequential calculations that derive the predicted number of bird transits across the swept volume are shown in Table A7.4.1.

Table A7.4.1. Calculations of predicted number of bird transects across the rotor swept volume.

Step	Parameter	Calculation	Formula	Units	Details
1	t_1	bird-secs observed at potential collision height / total duration of VP watches	$D_{\text{bird}}/VP_{\text{eff}}$	birds	Mean number of birds observed flying at rotor height during the vantage point watches
2	n	$t_1 \times \text{total duration of season}$	$t_1 \times D_{\text{season}} \times 3600$	bird-secs	Predicted total number of birds observed flying at rotor height if the vantage point watches had covered the entire season
3	b	$n \times (\text{volume swept by rotors} / \text{flight risk volume})$	$n \times (A_{\text{rotor}} \times (L_{\text{rotor}} + L_{\text{bird}})) / (A_{\text{vis}} \times H_{\text{rotor}})$	bird-secs	Predicted bird occupancy of the swept volume across the entire season
4	N_{transits}	$b / \text{time taken for a bird to fly through rotors of one turbine}$	$b / ((L_{\text{rotor}} + L_{\text{bird}}) / v_{\text{bird}})$	bird transits	Predicted number of transits across the swept volume across the entire season

Note: The SNH (2000) calculation procedure include additional steps, which calculate flight activity within the “risk area”, and then correct for the proportion of the risk area airspace occupied by the rotor swept volume of the turbines. However, these steps cancel out, so the calculation procedure shown in this table produces identical results.

The calculations in Table A7.4.1 simplify as Equation 1, as shown below.

Equation 1: $(D_{\text{bird}} \times D_{\text{season}} \times N_{\text{turb}} \times A_{\text{rotor}} \times v_{\text{bird}}) / (H_{\text{rotor}} \times VP_{\text{eff}} \times A_{\text{vis}})$

D_{bird} = bird-secs observed at potential collision height, D_{season} = total daylight hours across the season, N_{turb} = number of turbines, A_{rotor} = area of rotor discs, v_{bird} = bird flight speed, H_{rotor} = rotor diameter, VP_{eff} = total duration of vantage point watches, and A_{vis} = total area of viewshed.

Note that the rotor depth (L_{rotor}) and bird length (L_{bird}), which are included in the sequential calculations in Table A7.4.1, cancel out. While bird length is required for the collision probability



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calculations in Stage 2, the rotor depth parameter (L_{rotor}) is not usually required for collision risk modelling.

Methods (datasets)

Two vantage point survey datasets were used for the collision risk modelling: the APEM dataset and the MWP dataset.

The APEM dataset included data from eight vantage points: SC1- SC7 and SC9. These vantage points were surveyed over three seasons: summer 2023, winter 2023/24 and summer 2024. The summer 2023 surveys included some vantage point watches carried out in late March. These watches were allocated to April for the stage 1 analyses, so that the allocations matched the definition used for the Hen Harrier breeding season (see below).

The MWP dataset included data from thirteen vantage points: BM1-BM9 and KN1-KN4. However, three vantage points were not used for the collision risk modelling. One of these vantage points had a viewshed that was almost entirely outside the wind farm site (BM1). The other two vantage points (BM7 and KN2) had very poor mapped viewshed coverage. The MWP vantage point data used for the modelling came from one season (winter 2022/23).

Details of the vantage point survey coverage and methods are included in Appendix 7.4.1. Details of the vantage point survey results are included in Appendix 7.4.2.

Methods (species and populations)

Species included

All the waterbird and raptor species recorded flying at potential collision height during the surveys, apart from Snipe, were included in the modelling of predicted transits. Snipe was not included because vantage point surveys are not an effective method of sampling their flight activity, so the results from collision risk modelling would not be very meaningful.

Definition of seasonal populations

In developing a collision risk model, it is important to consider seasonal patterns of occurrence for two reasons.

Firstly, if a species has more than one population using the wind farm site (e.g., a wintering population that is distinct from the breeding population), separate collision risks need to be calculated so that the impact on each population can be assessed.

Secondly, the $D_{\text{season}} / VP_{\text{eff}}$ ratio in Equation 1 means that if a species has uneven patterns of seasonal occurrence, the calculation of predicted transits may be biased, assuming that the monthly survey effort was not proportional to daylength (which will usually be the case).

For species with resident populations, definition of separate seasonal periods of occurrence is only required where there are clear differences in seasonal activity patterns that could bias the collision risk modelling. This would occur if there were significantly higher levels of activity in summer or winter. Where there are month to month variations without clear seasonal trends, these differences could reflect sampling effects, rather than actual seasonal variation. Where there are higher levels of activity spanning the spring and / or autumn equinoxes, the reduction



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/ increase in the $D_{\text{season}} / VP_{\text{eff}}$ ratio before the spring / autumn equinox will be compensated by the increase / decrease in this ratio after the spring / autumn equinox. Therefore, in these cases, there is no need for seasonal subdivision to prevent bias in the model.

The results of the analysis of the vantage point survey data (Appendix 7.2) for the regularly occurring species, and knowledge of the general occurrence patterns of the species in Ireland, for all the species, was used to define seasonal periods of occurrence for all the species included in the collision risk model.

Separate breeding and non-breeding seasons were defined for Hen Harrier. The breeding season was defined as April – August and the non-breeding season was defined as September – March, following the definitions in SNH (2017).

Golden Plover is mainly a winter visitor to southern Ireland between October and April, with small numbers of passage migrants occurring outside this period. Golden Plover transits were modelled separately for the summer (April – September) and winter (October – March) periods due to the structure of the datasets used for the analyses (see below). The data used for the summer period included a few records outside the main wintering season. However, for simplicity of reporting, all Golden Plover transits have been allocated to the wintering population.

Hobby is a summer migrant, and its seasonal occurrence period was defined as May – August.

The seasonal occurrence period for the other species was defined as all year.

The seasonal durations used for the stage 1 model are shown in Annex 7.4.1, Table A7.4.1.4.

Modelling techniques

Modelling techniques (multiple VPs)

The basic mathematical method for calculating predicted transits using the occupancy method (as described above) is explained by SNH (2000), and, in any case, can be easily derived from first principles. However, SNH (2000) does not provide guidance on how to incorporate data from multiple vantage points in calculations of predicted transits.

In this assessment, the VP averaging method was used to calculate predicted transits for all species except Woodcock. This involves calculating the flight activity density separately for each vantage point and then using the mean flight activity density across all vantage points to calculate the overall number of transits predicted across the entire wind farm site. This is a variant of a method that is widely used (in Ireland) and has also been taught at courses on collision risk modelling run by the Chartered Institute of Ecology and Environmental Management¹. This method assumes that there is random distribution of flight activity across the wind farm site but treats each vantage point as a separate sample.

¹ The method that is widely used calculates predicted transits per turbine separately for each vantage point and then uses the mean predicted transits/turbine across all vantage points to calculate the overall number of transits predicted across the entire wind farm site. This is equivalent to the method used in this report when all viewsheds contain turbines. However, the method used in this report can also include data from viewsheds that do not contain turbines.



The assumption of random distribution of flight activity was clearly violated for Hen Harrier, which showed a strong concentration of flight activity during the breeding season in the northern half of the wind farm site. Therefore, predicted transits for Hen Harrier were also calculated using a spatially structured version of VP averaging method. The vantage points were divided into two groups: a northern group representing areas with high levels of Hen Harrier flight activity, and a southern group representing areas with low levels of Hen Harrier breeding season flight activity. The northern group comprised APEM vantage points SC1-SC3, SC7 and SC9 and contained seven turbines. The southern group comprised APEM vantage points SC4-SC6 and contained eight turbines. The mean flight activity density was calculated separately for each group and multiplied by the number of turbines in the relevant group.

Modelling techniques (height bands)

Two sets of collision risk models were prepared for each species. One set used a single height band covering the entire potential collision height zone for modelling predicted transits. The other set modelled predicted transits separately for two height bands: 20-50 m and 50-190 m.

The one height band model usually produces more conservative results and is the standard model used in most collision risk modelling. However, the two height band model allows comparison of the effects of different turbine ground clearances on the collision risk.

Modelling techniques (combining datasets)

The APEM and MWP datasets used different vantage point locations and viewsheds. Therefore, predicted transits were modelled separately for each dataset and then combined to produce overall estimates.

This involved modelling the transits for the APEM dataset separately for summer (April – September) and winter (October – March). The mean of the winter transits from the APEM and MWP datasets were then used as the overall winter estimate. Where relevant, the summer and winter transits were summed to provide an estimate of the annual number of transits.

Modelling techniques (Woodcock)

Woodcock transits were calculated by developing a model based on the observed number of roding Woodcock recorded, the typical flight height distribution of roding Woodcock, and typical durations of roding Woodcock activity.

Hoodless *et al.* (2009) includes a formula for converting maximum numbers of roding Woodcock into densities. This formula is based on results from point surveys, rather than transect surveys. However, because roding Woodcock range over wide areas, both survey methods should produce similar results in sites where roding Woodcock are widespread across the survey areas. This formula was used to calculate the density of male Woodcock in the proposed wind farm site. The densities were calculated separately for each transect / transect group (Table A7.4.2). These calculations may have overestimated the densities: the formula was based on the maximum counts from sets of three surveys, while the maximum counts in Table A7.4.2 came from five or six surveys per transect.

Table A7.4.2. Transect data used in the calculation of Woodcock transits.

Transect	Turbines	Maximum count of roding males	Density (males / km ²)
1	1	1	0.7
2	7	4	2.0
3	2	4	2.0
4	3	3	1.6

Transects 2a and 2c were grouped together because they overlapped and the maximum count of roding males was taken as the mean of the maximum counts across the three transects.

There is limited data available on the flight height distribution of roding Woodcock recorded in the surveys of the Scart Mountain Wind Farm, and there are some issues with the interpretation of the data that is available (see Appendix 7.1). Therefore, this collision risk model used the flight height distribution of roding Woodcock recorded in surveys for the Castlebanny Wind Farm (Gittings, 2020). Of a total of 96 records with estimated flight heights, 35% were assigned to the 20-25 m height band and 2% were assigned to the 25-30 m height band. There were no records with estimated flight heights greater than 30 m.

Hoodless *et al.* (2006) provides data on the duration of roding per night. This increased from 24 minutes in March to 66 minutes in June. However, individual Woodcock do not always perform roding displays every night during this period: six Woodcock followed by radio-tracking over a total period of 380 nights did not carry out roding displays on around 11% of the nights (Hirons, 1980).

The above information was used to calculate the cumulative density of roding Woodcock activity in each height band across the roding season using Equation 2 below:

$$\text{Equation 2: } D_{\text{bird-density-season}} = N_{\text{WK}} \times \text{CF} \times D_{\text{season}} \times p_{\text{nr}} \times \text{hb}_{\text{perc}}$$

N_{WK} = maximum number of roding Woodcock recorded during the standard survey period; CF = conversion formula provided by Hoodless *et al.* (2009); D_{season} = total duration of roding activity periods across the season, calculated from the data in Hoodless *et al.* (2006); p_{nr} = proportion of days on which roding takes place (0.89; calculated from Hirons, 1980); hb_{perc} = percentage of roding flights in the height band.

The total number of transits was then calculated using Equation 3 below:

$$\text{Equation 3: } \text{Transits} = (D_{\text{bird-density-season}} \times N_{\text{turb}} \times A_{\text{rotor}} \times v_{\text{bird}}) / (H_{\text{rotor}} \times \text{VP}_{\text{eff}} \times A_{\text{vis}})$$

$D_{\text{bird-density-season}}$ = cumulative density of roding Woodcock activity across the roding season, N_{turb} = number of turbines, A_{rotor} = area of rotor discs, v_{bird} = bird flight speed, H_{rotor} = rotor diameter.

This is a simplified version of Equation 1, with $D_{\text{bird-density-season}}$ replacing the terms $(D_{\text{bird}} \times D_{\text{season}}) / (\text{VP}_{\text{eff}} \times A_{\text{vis}})$.

The cumulative density of roding Woodcock activity and transits were calculated separately for each transect / transect group. The number of turbines (N_{turb}) values used for each transect / transect group were based on the distribution of the turbines relative to the transect routes and are shown in Table A7.4.2. Three turbines on Knockanask Hill were not allocated to any of the transects / transect groups due to their exposed positions and distances from the forest edge.

Modelling techniques (implementation)

All the modelling was carried out using custom scripts in R version 4.4.1(R Core Team, 2024).



Methods (data sources and preparation)

Parameters

The parameters required for stage 1 modelling using Equation 1 are the flight activity duration (D_{bird}), the seasonal duration (D_{season}), the number of turbines (N_{turb}), the rotor area (A_{rotor}), the bird flight speed (v_{bird}), the rotor diameter (H_{rotor}), the vantage point survey duration (VP_{eff}) and viewshed area (A_{vis}).

The derivation of the data required for these parameters is described in the following sections.

Flight activity duration (D_{bird})

The flight activity durations included in Equation 1 comprise the sum of the duration of each flightline multiplied by the number of birds recorded on the flightline: e.g., a flock of 100 Golden Plover recorded flying for 10 seconds would generate a D_{bird} value of 1000 bird-secs.

The flight activity durations were obtained from the vantage point survey datasets. These contain timed durations of flight activity for each record in specified height bands.

In the APEM dataset, the data from the 20-50 m, 50-100 m and 100-190 m height bands was used.

In the MWP dataset, the data from the 20-50 m, 50-100 m and 100-180 m and > 180 m height bands was used.

The Stage 1 calculations of bird transits use the viewshed area to derive the density of flight activity recorded during the vantage point surveys. Therefore, flight activity that occurred outside the viewshed of the vantage point being surveyed should be excluded from the analyses.

Flightlines that occurred entirely outside the relevant viewshed were excluded from the analyses.

Where a flightline occurred partly outside the relevant viewshed, its duration was adjusted by the proportion of the flightline length that occurred in the viewshed. The flightline was clipped by the viewshed. The duration was then recalculated by multiplying the original value by (clipped flightline length) / (original flightline length).

It should be noted that, this recalculation procedure makes two assumptions. Firstly, it assumes that the flight speed was similar between the segments used for the recalculation. Secondly, it assumes that, where a flightline includes flight activity at multiple height bands, the relative distribution between the height bands was similar between the segments used for the recalculation. The latter assumption only applies to the MWP dataset as the APEM dataset mapped each height band component of a flightline separately.

There were a small number of records in the MWP dataset for which no flightline mapping was available. These records were all assumed to have occurred entirely within the relevant viewsheds.

Seasonal duration (D_{season})

The seasonal duration parameter represents the total duration of daylight across the relevant seasonal period. This was calculated using the *sunalc* R package (Thieurmél and Elmarhraoui, 2022).

Seasonal durations were calculated separately for summer and winter for each seasonal occurrence period defined in Annex 7.4.1, Table A7.4.1.4. Daylight was defined as the period between sunrise and sunset.

Number of turbines (N_{turb})

The proposed number of turbines for the Scart Mountain Wind Farm is 15. For the spatially-structured Hen Harrier model, seven turbines were allocated to the northern group of vantage points and eight turbines were allocated to the southern group of turbines.

Rotor area (A_{rotor}) and rotor diameter (H_{rotor})

The rotor areas and rotor diameters of each turbine model included in the collision risk modelling are shown in Annex 7.4.1, Table A7.4.1.2. These values were used for the one height band model.

The two height band model calculated bird transits separately for the 20-50 m and 50-190 m height bands. To carry out these separate calculations, it was necessary to subdivide the overall rotor areas and overall rotor diameters into the portions that occurred in each height band.

To calculate the rotor area in each height band, the angles subtended by the segment representing the 20-50 m height band was calculated using the following equation:

$$\text{Equation 4: } \theta_{20-50} = \cos^{-1} ((H_{hub} - 20) / R_{rotor})$$

H_{hub} = hub height; R_{rotor} = rotor radius.

The rotor areas were then calculated using the following equations:

$$\text{Equation 5: } A_{rotor(20-50)} = 0.5 \times (\theta_{20-50} - \sin(\theta_{20-50})) \times R_{rotor}^2$$

$$\text{Equation 6: } A_{rotor(50-190)} = A_{rotor} - A_{rotor(20-50)}$$

Similarly, the rotor height (H_{rotor}) values for each height band were adjusted to equal the height of the rotor segment in the height band.

These ground clearances for the turbine models included in the collision risk modelling varied from 22-35 m. The use of the A_{rotor} values calculated above for the Stage 1 model assumed that all the flight activity within a height band occurred within the portion of the height band that was occupied by the rotor areas. This will have overestimated the flight activity density within the rotor area in the 20-50 m height band.

Bird flight speed (v_{bird})

The bird flight speeds were obtained from Alerstam *et al.* (2007). The values used in the collision risk modelling are shown in Annex 7.4.1, Table A7.4.1.3.



Vantage point survey duration (VP_{eff})

The vantage point survey duration parameter represents the total vantage point survey effort over the seasonal period used for the collision risk modelling. This was calculated separately for each vantage point and for each seasonal period defined in Annex 7.4.1, Table A7.4.1.4. The total vantage point survey durations at each vantage point in each month are shown in Annex 7.4.1, Table A7.4.1.5.

Viewshed area (A_{vis})

The viewshed area represents the spatial extent of the area covered by the vantage point survey. The viewshed areas were calculated from the mapped viewsheds for each vantage point (see Appendix 7.4.1).

Results

The predicted transits from the basic VP averaging models are shown in Table A7.4.3, the predicted Hen Harrier transits from the spatially-structured VP averaging model are shown in Table A7.4.4 and the predicted transits of roding Woodcock from the Woodcock model are shown Table A7.4.5.

The one height band models almost always produced higher numbers of predicted transits than the two height band models. The difference was greatest for Hen Harrier breeding season models, due to the concentration of flight activity in the 20-50 m height band. In the non-breeding season, the Hen Harrier flight activity used for the modelling was less concentrated in the 20-50 m height band, due to the inclusion of the MWP dataset. The difference between the one height band and two height band models was smallest for Golden Plover, due to their more even distribution of flight activity across the 20-50 m and 50-190 m height bands.

The N163 and V162 turbines had the highest predicted transits. In the one height band models, this was due to the fact that they had the largest rotor diameters, while in the two height band models, the fact that they also had the lowest ground clearances was important.

The spatially-structured models reduced the predicted Hen Harrier breeding season transits by around 20-25%. The reduction in the predicted Hen Harrier non-breeding season transits in the spatially-structured models was negligible, due to the more even distribution of Hen Harrier flight activity across the wind farm site during this season.

The N163 and V162 were the only turbine models with ground clearances below 30 m, so these were the only models that generated predicted transits from the Woodcock model. The N163 turbine had slightly higher predicted transits than the V162 due to its lower ground clearance (Table A7.4.3). The highest number of predicted transits were generated by transect 2 (Table A7.4.3), which had the highest number of allocated turbines, and the joint highest density of roding Woodcock.

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Table A7.4.3. Predicted transits per year from the basic VP averaging model.

Species	Season	Model	N149	N163	SG155	V150	V162
Hen Harrier	breeding	1 height band	18	20	19	18	19
		2 height band	9	13	11	9	13
	non-breeding	1 height band	4.2	4.6	4.4	4.2	4.6
		2 height band	2.1	3.1	2.6	2.2	3.0
Golden Plover	winter	1 height band	1696	1856	1765	1708	1844
		2 height band	1606	1841	1713	1625	1826
Curlew	all year	1 height band	25	28	27	26	28
		2 height band	13	19	16	13	18
Kestrel	all year	1 height band	241	264	251	243	263
		2 height band	148	197	171	152	194
Merlin	all year	1 height band	0.24	0.26	0.25	0.24	0.26
		2 height band	0.12	0.17	0.14	0.12	0.17
Hobby	summer	1 height band	7.3	8.0	7.6	7.3	7.9
		2 height band	3.7	5.3	4.4	3.8	5.2
Peregrine	all year	1 height band	65	71	68	66	71
		2 height band	41	54	47	42	53
Chough	all year	1 height band	0.38	0.42	0.40	0.39	0.42
		2 height band	0.19	0.28	0.23	0.20	0.27

Table A7.4.4. Predicted transits per year from the spatially structured Hen Harrier VP averaging model.

Species	Season	Model	N149	N163	SG155	V150	V162
Hen Harrier	breeding	1 height band	13.8	15.1	14.3	13.9	15.0
		2 height band	7.0	10.0	8.4	7.2	9.8
	non-breeding	1 height band	4.0	4.3	4.1	4.0	4.3
		2 height band	3.5	4.0	3.7	3.5	4.0



Table A7.4.5. Predicted transits per year from the Woodcock model.

Turbine	Transect	Transits (20-25 m)	Transits (25-30 m)	Total transits
N163	1	49	6	55
N163	2	922	105	1027
N163	3	263	30	293
N163	4	322	37	359
V162	1	40	5	45
V162	2	752	94	846
V162	3	215	27	242
V162	4	263	33	296



A7.4.3 COLLISION RISK MODEL STAGE 2: COLLISION PROBABILITY

Methodology

Stage 2 of the collision risk model involves calculating the probability of a collision when a bird makes a transit of the rotor swept volume.

The Scottish Natural Heritage collision risk model (SNH, 2000; Band *et al.*, 2007; Band, 2012) calculates the probability, $p(r, \phi)$, of collision for a bird at radius r from the hub and at a position along the radius that is at angle ϕ from the vertical. 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. Separate calculations are made for flapping and gliding birds and for upwind and downwind transits. This method assumes that: birds are of a simple cruciform shape, fly through turbines in straight lines with a perpendicular approach to the plane of the rotor, and their flight is not affected by the slipstream of the turbine blade; and that turbine blades have width and pitch angle, but no thickness.

The collision probability calculations for the original Scottish Natural Heritage collision risk model can be carried out using an Excel spreadsheet which is provided as an accompaniment to the SNH (2000) guidance. This spreadsheet was updated by Band (2012) by changing the details of the blade profile used in the model. The updated model is included in R code provided by Masden (2015). For the present assessment, R code was adapted from that provided by Masden (2015) to carry out the collision probability calculations. This R code was audited against the Band (2012) spreadsheet to confirm that it produced matching collision probability calculations.

One of the turbine parameters used to calculate collision probability is the mean pitch angle of the turbine blade. This parameter specifies the angle of the blade from the horizontal, so the collision probability will increase as the mean pitch angle increases. Data on mean pitch angle can be difficult to obtain so generic values are often used in collision risk models. These are often based on the statement by Band (2012) that a mean pitch angle of “25-30 degrees is reasonable for a typical large turbine”. However, Band was referring to offshore wind farms where wind speeds are higher than at onshore wind farms, resulting in higher mean pitch angles. For this assessment, a more realistic scenario was applied from an onshore wind farm (Meenwaun, Co. Offaly). The pitch angle over a continuous 12 month period at this site was for approximately 90% of the time between -3° and 9° (MKOS, 2019).

A pitch value of 0° was used for the collision probability calculations, as this was the pitch value within the -3° to 9° range that produced the highest collision probability values for most species in the sensitivity analyses (see below).

The bird biometrics and turbine parameter values used in the calculations of collision probability are shown in Annex 7.7.1.

Collision probability values

The collision probability values are shown in Table A7.7.6.

The differences between the collision probabilities for flapping and gliding flight were negligible.

For each species, the collision probabilities were usually inversely related to the rotor diameter, which reflects the fact that turbines with smaller rotor diameters have a greater proportion of



the rotor space occupied by the turbine blades. The one exception was Golden Plover, where the SG155 turbine had a greater collision probability than the V150 turbine.

Interpretation of collision probability values

Collision probability values are often misinterpreted. The collision probabilities represent the probability of a collision on a single transit of the rotor airspace. While they contribute to the calculation of the predicted collision risk, they should not be interpreted as providing any information about the likely magnitude of the predicted collision risk. The predicted transits have a much larger influence of the predicted collision risk and a species with a relatively high collision probability may have a very low predicted collision risk if the number of predicted transits is low.

Sensitivity analyses

Pitch angle

Modern wind turbines have variable pitch angles, so sensitivity analyses were carried out to investigate how collision probabilities varied with pitch angle. Collision probability values were calculated for each 0.5° increment in pitch angle between -5° and 90°.

The relationships between collision probabilities and pitch angles are shown in Text Figure A7.4.1 for key species included in the collision risk models. The collision probability values showed little variation up to pitch values of around 10-20°, after which they increased sharply with increasing pitch. The rate of increase was broadly related to flight speed, with species with slower flight speeds showing steeper increases.

As discussed above, monitoring data indicates that pitch angles at onshore wind farms in Ireland rarely exceed 9°. In the pitch angle range from -5° to 9°, the maximum collision probability for most species occurred at a pitch angle of around 0° (Text Figure A7.4.2). Therefore, a pitch angle of 0° was used for modelling the collision probability for all species included in the collision risk model.

Rotation speed

The rotation speed has a strong influence on the collision probability values. However, the rotation speed value used in the collision probability calculations were nominal values. In practice, rotation speeds will vary with wind speed. Therefore, sensitivity analyses were carried out to investigate how collision probabilities varied with rotation speed. The range of speeds analysed were based on typical operational speed ranges for onshore wind farms in Ireland.

The relationships between collision probabilities and rotation speeds are shown in Text Figure A7.4.3 for key species included in the collision risk model.

The effects of variation in rotation speed generally increased with body size, but species with slow flight speeds showed steeper increases relative to their body sizes. For the smallest species (Golden Plover), the variation in rotation speed, within the operational speed ranges, had negligible effects on the collision probabilities. However, for the largest species (Hen Harrier), there was a 2% variation in collision probabilities across the speed range analysed. This variation would result in an increase in the predicted collision risk of up to 1.2 times between the minimum and maximum rotation speeds.



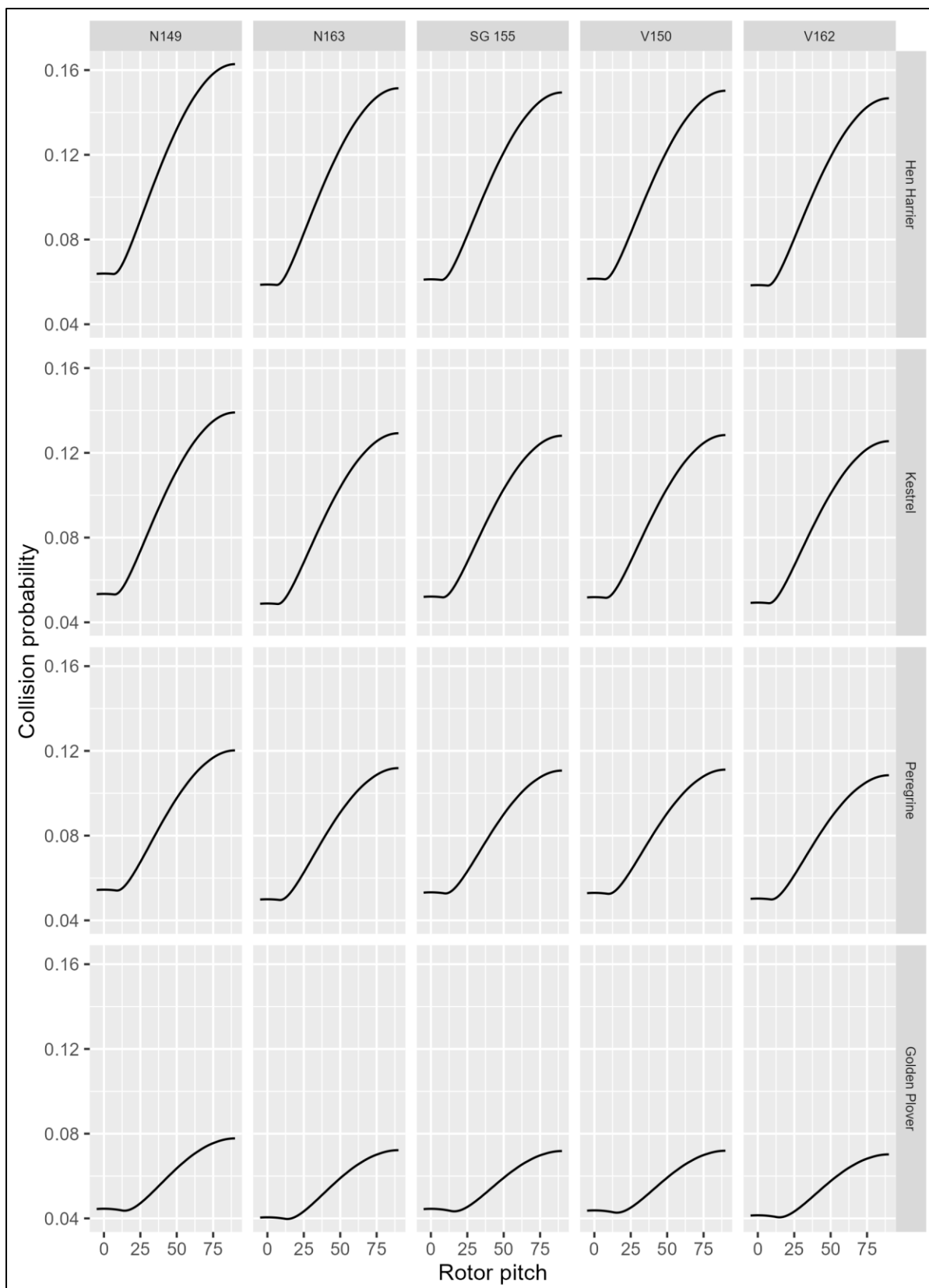
Table A7.7.6. Collision probabilities.

Species	Turbine	Flapping	Gliding	Mean
Hen Harrier	N149	0.064	0.063	0.064
	N163	0.059	0.058	0.059
	SG155	0.062	0.061	0.061
	V150	0.064	0.063	0.064
	V162	0.059	0.058	0.059
Golden Plover	N149	0.045	0.044	0.045
	N163	0.041	0.040	0.041
	SG155	0.046	0.044	0.045
	V150	0.045	0.043	0.044
	V162	0.042	0.041	0.041
Curlew	N149	0.054	0.053	0.054
	N163	0.050	0.049	0.049
	SG155	0.053	0.052	0.052
	V150	0.054	0.053	0.054
	V162	0.050	0.049	0.050
Woodcock	N149	0.051	0.050	0.050
	N163	0.046	0.046	0.046
	SG155	0.050	0.049	0.049
	V150	0.050	0.050	0.050
	V162	0.047	0.046	0.047
Kestrel	N149	0.054	0.053	0.053
	N163	0.049	0.048	0.049
	SG155	0.053	0.052	0.052
	V150	0.054	0.053	0.053
	V162	0.050	0.049	0.049
Merlin	N149	0.050	0.050	0.050
	N163	0.046	0.045	0.046
	SG155	0.049	0.049	0.049
	V150	0.050	0.050	0.050
	V162	0.047	0.046	0.046
Hobby	N149	0.052	0.051	0.051
	N163	0.048	0.046	0.047
	SG155	0.051	0.050	0.050
	V150	0.052	0.050	0.051
	V162	0.048	0.047	0.048

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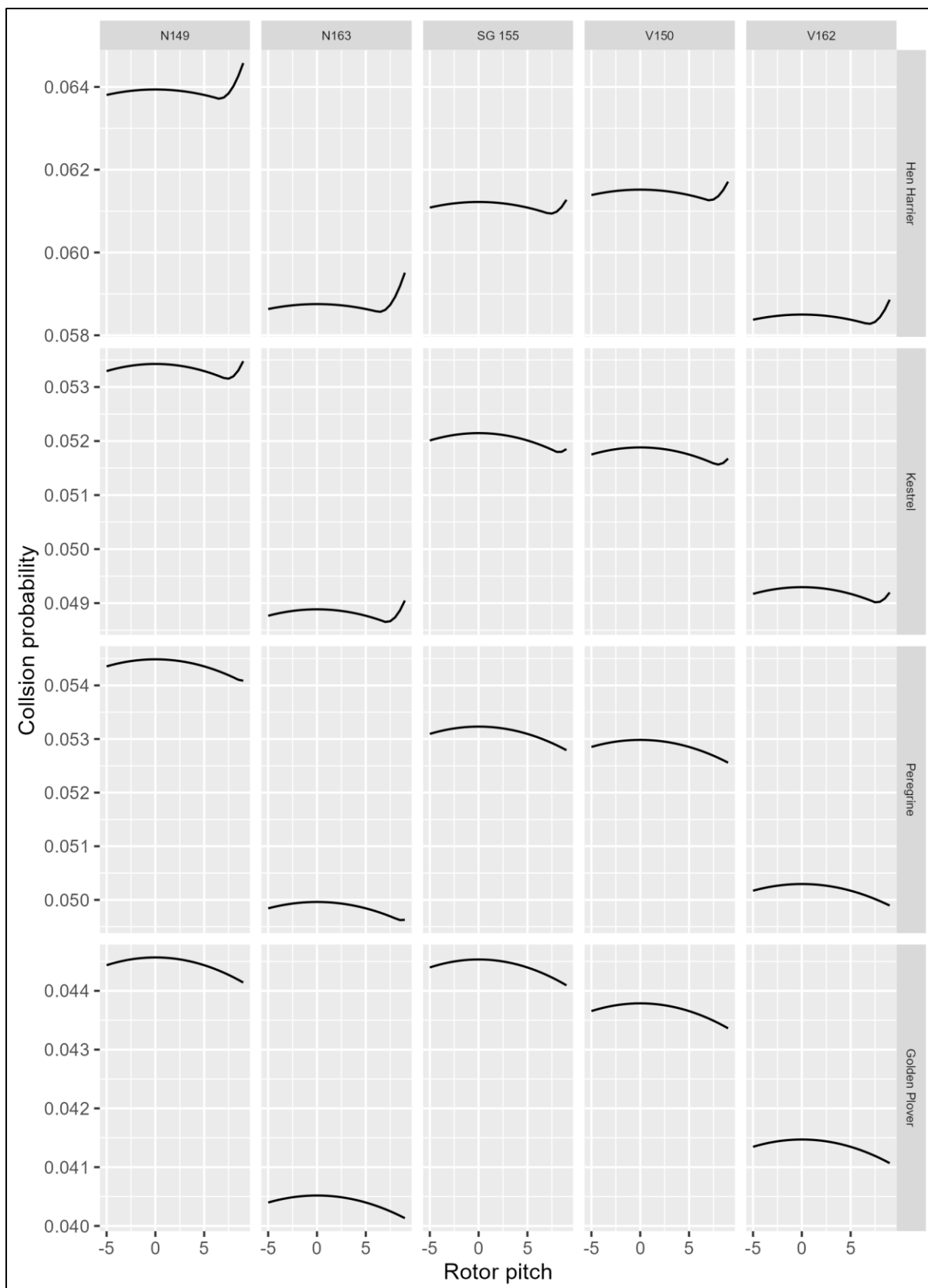
Species	Turbine	Flapping	Gliding	Mean
Peregrine	N149	0.055	0.054	0.054
	N163	0.051	0.049	0.050
	SG155	0.054	0.052	0.053
	V150	0.055	0.054	0.054
	V162	0.051	0.050	0.050
Chough	N149	0.053	0.052	0.052
	N163	0.048	0.048	0.048
	SG155	0.052	0.051	0.051
	V150	0.053	0.052	0.052
	V162	0.049	0.048	0.048

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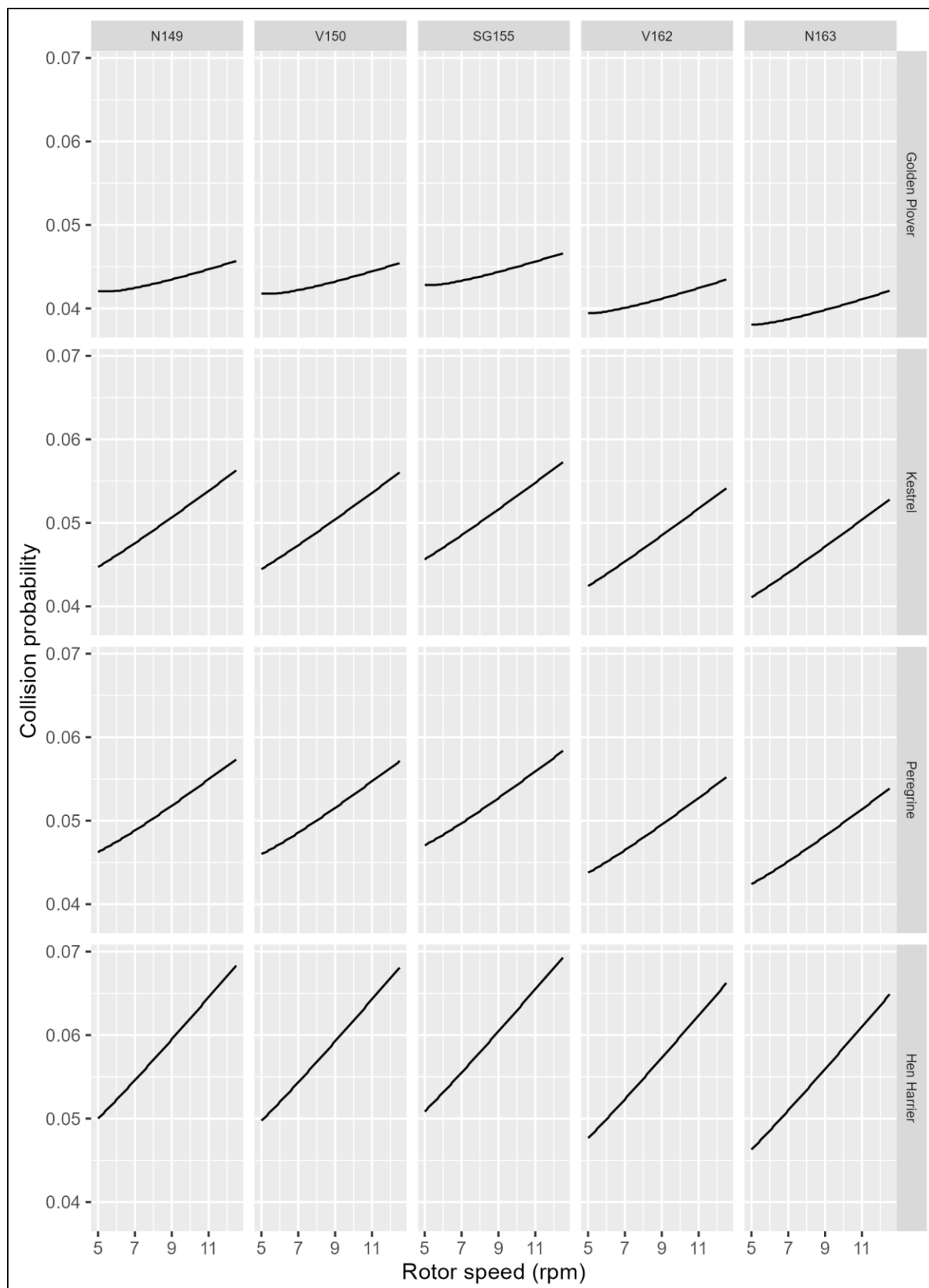
Text Figure A7.4.1. Relationship between collision probability and pitch angle, with species arranged in order of increasing flight speed.

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Text Figure A7.4.2. Maximum collision probabilities with pitch angle of between -5 and 9°, with species arranged in order of increasing flight speed.

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Text Figure A7.4.3. Relationship between collision probability and rotor speed, with species arranged in order of increasing body length.

A7.4.4 COLLISION RISK MODEL STAGE 3: COLLISION PREDICTION

General

Stage 3 of the collision risk model uses the predicted transits from Stage 1 and the collision probabilities from Stage 2 to calculate the predicted collisions. However, three further factors need to be considered: the avoidance rate; the degree of any nocturnal flight activity; and the proportion of time the wind farm is operational.

Correction factors

Avoidance rates

The avoidance rate reflects the fact that most potential collisions are avoided due to birds taking evasive action (SNH, 2010). This avoidance rate includes both behavioural avoidance (micro-avoidance) and behavioural displacement (macro-avoidance).

Behavioural avoidance is “action taken by a bird, when close to an operational wind farm, which prevents a collision”. Behavioural displacement refers to the process by which a “bird may (possibly over time) change its home range, territory, or flight routes between roosting areas and feeding areas, so that its range use (or flight paths) no longer bring the bird into the vicinity of an operational wind farm”.

Scottish Natural Heritage provides guidance on avoidance rates to use in collision risk assessments (SNH, 2010, 2018). For some species, there is some evidence available that has been used to specify species-specific avoidance rates (SNH, 2018). These include Hen Harrier, which has a recommended avoidance rate of 99%, and Kestrel, which has a recommended avoidance rate of 95%. For the other species included in this collision risk model, the Scottish Natural Heritage guidance specifies a default avoidance rate of 98%.

Nocturnal flight activity

Another factor that needs to be considered is the degree of nocturnal flight activity that is likely to occur. The calculations of predicted transits are based on flight activity during daylight hours only. Therefore, if a species is likely to have a significant amount of nocturnal flight activity, a correction should be made to account for this nocturnal flight activity.

Correction factors for nocturnal flight activity were included for Golden Plover and Curlew. These correction factors were calculated using the following equation:

Equation 7: $n_{cf} = 1 + n_{fr} \times h_{night}^* / h_{day}^*$

n_{cf} = correction factor for nocturnal flight activity; n_{fr} = nocturnal flight activity rate as a proportion of the diurnal flight activity rate; h_{night}^* = mean night-time hours across seasonal period of occurrence; h_{day}^* = mean day-time hours across seasonal period of occurrence.

For Golden Plover, a figure of 25% of the day-time activity levels across the night-time hours is often used in collision risk modelling (e.g., MKOS, 2019), so the nocturnal flight activity rate was set as 0.25. The same value was used for Curlew, due to the ecological similarity to Golden Plover of the habitat use of field-feeding non-breeding populations.

The nocturnal flight activity rate for all other species was set as zero.



The nocturnal correction factors used in the stage 3 model are shown in Annex 7.4.1.

Operational time

Wind turbines in operational wind farms will have periods when they are not turning due to maintenance or wind speeds. Therefore, the predicted collisions need to be corrected by the percentage of time the wind turbines will be operational. This value was set at 0.85 for all the species in the model, which is a widely value for this parameter in collision risk modelling for onshore wind farms in Ireland.

Calculations

The collision risk was calculated using the following equation:

Equation 8: $cr = n_{transits} \times cp \times (1-ar) \times ncf \times op$

Cr = collision / year; $n_{transits}$ = predicted transits per year; cp = collision probability (probability of a collision on a single transit); ar = avoidance rate; ncf = nocturnal correction factor; op = proportion of operational time.

Collision risk predictions

The results of the stage 3 calculations are summarised in Table A7.4.7.

Table A7.4.7. Collision risk predictions.

Species	Season	Model	Collisions / year				
			N149	N163	SG155	V150	V162
Hen Harrier	breeding	1 height band	0.0075	0.0075	0.0075	0.0075	0.0074
	non-breeding	1 height band	0.0022	0.0022	0.0021	0.0022	0.0021
	breeding	2 height bands	0.0038	0.005	0.0044	0.0039	0.0049
	non-breeding	2 height bands	0.0011	0.0014	0.0013	0.0011	0.0014
Golden Plover	winter	1 height band	1.7	1.7	1.8	1.7	1.7
		2 height bands	1.6	1.7	1.7	1.6	1.7
Curlew	all year	1 height band	0.029	0.029	0.029	0.029	0.029
		2 height bands	0.015	0.019	0.017	0.015	0.019
Woodcock	breeding	WK model	0	1.4	0	0	1.1
Kestrel	all year	1 height band	0.55	0.55	0.56	0.55	0.55
		2 height bands	0.34	0.41	0.38	0.34	0.41
Merlin	all year	1 height band	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
		2 height bands	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Hobby	summer	1 height band	0.0064	0.0064	0.0065	0.0064	0.0064
		2 height bands	0.0032	0.0042	0.0038	0.0033	0.0042
Peregrine	all year	1 height band	0.06	0.061	0.061	0.061	0.061
		2 height bands	0.038	0.046	0.043	0.039	0.046
Chough	all year	1 height band	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
		2 height bands	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Interpretation of collision risk predictions

General



A collision risk figure should be thought of as a probabilistic prediction, which can be used to predict the likely distribution of collisions, rather than an absolute value.

Consideration should be given to the uncertainty around the prediction. Some of the uncertainty relates to measurement error and imprecise specification of parameters, while sampling effects will also cause uncertainty. There may be species-specific behavioural effects that contradict assumptions of the collision risk modelling.

Distribution of collisions

The predicted collision risk represents the mean collision risk that would occur if the recorded flight activity density occurred over a large number of years. However, the actual number of collisions that would occur each year will vary.

The Poisson distribution is an appropriate statistical distribution for simulating discrete events that occur at low rates.

As an example, the total number of expected Hen Harrier breeding season collisions over the 35-year lifespan of the wind farm was simulated by generating 10,000 replicate samples from a Poisson distribution with a mean rate of 0.013, and a sample size of 35. Around 37% of the samples include at least one collision, around 7% included at least two collisions, around 1% included at least three collisions, and there were small numbers of samples with 4-6 collisions.

Measurement error and imprecise specification of parameters

Declines in detection rates with distance from vantage points is a common issue in vantage point surveys and causes potential under-estimation of collision risks (Gittings, 2024).

Other possible measurement errors in vantage point surveys include errors in allocation of flight activity to height bands, and errors in flightline mapping and/or determining when flightlines enter or leave viewsheds.

The use of the midpoint of the rotation speed range for the turbine rotation speed in the stage 2 model will affect the collision probability calculations, as the actual values of the turbine rotation speed during each potential collision event will vary. However, the sensitivity analyses (Section A7.4.3) suggest that this factor is not likely to have large effects on the predicted collision risk.

The stage 2 model also uses a mean pitch value, while the actual pitch values during each potential collision event will vary. However, the sensitivity analyses suggest that the effect of this factor is on the predicted collision risk will be negligible, within the range of pitch values that are considered typical for onshore wind farms in Ireland (Section A7.4.3).

The stage 3 model uses avoidance rates to account for the fact that most potential collisions are avoided due to birds taking evasive action. However, the evidence base for avoidance rates used in collision risk modelling for onshore wind farm projects is very limited. For most of the species included in this assessment, species-specific avoidance rates were not available. Even when they are available, they may not be supported by strong evidence: e.g., the avoidance rate for Kestrel

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is based on very sketchy evidence². Small numerical differences in avoidance rates have large effects on the predicted collision risk: e.g., an increase in the avoidance rate from 98% to 99% would cause a 50% reduction in the predicted collision risk.

The Scottish Natural Heritage guidance (SNH, 2018) does not provide a species-specific avoidance rate for Golden Plover, so the default 98% avoidance rate was used. However, a review of collision fatality monitoring studies by Gittings (2020b) indicated that the non-avoidance rate for wintering Golden Plover is around an order of magnitude higher. Therefore, the likely collision risks for Golden Plovers may be an order of magnitude lower than the predicted values in Table A7.4.7.

Sampling effects

The standard vantage point survey effort following the Scottish Natural Heritage guidelines (SNH, 2017) only samples around 1.5-2% of the available daylight hours. The hours are usually distributed in a clustered way: e.g., the six hours per month at a vantage point are often done as back-to-back three-hour surveys for logistical reasons. As flight activity patterns for many species will not be evenly distributed, the low proportion of daylight hours sampled and the clustered distribution of the sampling, mean that the flight activity sampled may not be representative of the overall pattern of flight activity. This is a particular issue for species where a small number of flights could generate a large collision risk: e.g., a large Golden Plover flock circling around for an extended period of time.

There will also be year-to-year variation in flight activity patterns, due to a variety of factors such as variation in local population sizes, habitat changes, etc. As the lifespan of a wind farm is measured in decades, the survey period will only represent a snapshot of the potential variation in flight activity across the period when the potential collision risk will occur.

In the collision risk model for the Ummeras Wind Farm, bootstrapping procedures were used to resample the flight activity data and generate confidence intervals for the predicted collision risk for four species that had high levels of flight activity (Gittings, 2020b). These collision risk models produced upper limits of the confidence intervals that were around 1.4 (Buzzard) to 2.4 (Golden Plover) times higher than the mean predicted collision risk. Conversely, the actual collision risk could be lower than the predicted collision risk.

² The 95% avoidance rate for Kestrel is described by SNH (2018) as being based on: “sufficient evidence from flight behaviour (including hovering) and collision monitoring studies for vulnerability to collisions”. The cited source (Whitfield and Madders, 2006) is, in fact, a review of avoidance rates for Red Kite. The information on Kestrel is derived from an analysis which finds a significant correlation between the “numbers of individuals seen” against numbers of carcasses found for 16 raptor species at a single wind farm in Spain. Kestrel is a large outlier above the regression line, and this appears to be the only empirical evidence that has been used by Scottish Natural Heritage to support the 95% avoidance rate for Kestrel. However, even taken at face value, all this analysis does is indicate that Kestrel has a lower avoidance rate than other raptor species, but it does not provide any quantitative data that can be used to estimate the avoidance rate. More seriously, this analysis does not account for behavioural and ecological differences between species that may affect the relationship between bird activity and collisions. It is also subject to the perennial problem with analyses of collision rates: the small absolute numbers of collisions which means that random sampling error may have significant effects.



Behavioural effects

The equation for calculating predicted transits (Equation 1) includes the mean bird flight speed as part of the numerator. However, for Kestrel, a significant proportion of their flight activity will typically involve hovering birds. The flight speed of a hovering Kestrel is close to zero (a small amount of drift in position will often occur during long bouts of hovering). Therefore, using the mean flight speed for Kestrel (10.1 m/sec; Alerstam *et al.*, 2007) in Equation 1 to predict transits of hovering Kestrel is clearly inappropriate and will result in highly inflated estimates of the numbers of predicted transits.

In the collision risk model for the Castlebanny Wind Farm (Gittings, 2020a), data collected during the vantage point survey on the duration of hovering flight, and the mean number of hovering positions per second, was used to calculate separate predicted transits for hovering Kestrels, with the standard stage 1 model only used for direct Kestrel flight activity. This resulted in a predicted collision risk that was less than half the value of the collision risk that would have been generated by using the standard stage 1 model for all Kestrel flight activity.

Allowing for uncertainty

Two of the main potential sources of uncertainty in collision risk modelling are the effects of under-detection of distant flightlines and sampling effects.

Correction factors can be applied to correct for the under-detection of distant flightlines (Gittings, 2024). However, these have not been used in the present assessment to keep the results comparable with collision risk predictions from the other wind farm projects included in the cumulative assessment.

To allow for the uncertainty associated with sampling effects, the predicted collision risks should be multiplied by factors of around 2-3 to represent a worst case scenario of the sampled flight activity being at the lower limit of the theoretical confidence intervals of the distribution of samples from the complete flight activity dataset. However, for Kestrel, the potential overestimation of the collision risk due to inclusion of hovering flight activity in the standard stage 1 model should also be considered.

A7.4.5 COLLISION RISK ASSESSMENT

General

The impact of the predicted collision risks was assessed by calculating the potential increase in annual mortality, as a percentage of the background annual mortality, to relevant populations. This assessment was carried out for: national and regional Red Grouse and Kestrel populations; national, regional and local Golden Plover populations; and the national Peregrine population. Population modelling was used to assess the impact of the predicted collision risks to the regional Hen Harrier population (see Section A7.4.6).

For Golden Plover, Kestrel and Peregrine, cumulative collision risk assessments were also carried out. A cumulative collision risk assessment was not carried out for Red Grouse, because there were no other wind farm projects with reported resident Red Grouse populations within the region used for the collision risk assessment.



Methods

Calculation method

The potential increases in mortality rates were calculated using the following equation:

Equation 9: $\Delta mr = cr / (pop \times (1-sr))$

Δmr = increase in annual mortality; cr = predicted collision risk; population size (individuals); sr = annual survival rate.

Population data

The population data used for the collision risk assessments is listed in Table A7.4.8.

The Golden Plover Co. Waterford population was estimated from the sum of the mean peak counts for Irish Wetland Bird Survey sites in Waterford for the period 2016/17-2020/21³

The Kestrel Co. Waterford population was estimated using the Bird Atlas dataset from the National Biodiversity Data Centre⁴. This included hectad presence-absence data covering the whole of the Republic of Ireland, and tetrad data of relative abundance for samples of tetrads from most of the hectads. The hectad data was used to estimate the proportion of the Kestrel's Republic of Ireland breeding range that occurs in Co. Waterford. The tetrad data was used to estimate the mean relative abundance of the species in Co. Waterford as a percentage of its mean relative abundance throughout its range in the Republic of Ireland. The product of these two factors was then used to multiply the Republic of Ireland population figure to give an estimate for the Co. Waterford population, as shown in the following equation.

Equation 10: $pop_{CW} = pop_{ROI} \times (hec_{CW} / hec_{ROI}) \times (tet_{CW} / tet_{ROI})$

pop_{CW} = estimated Co. Waterford population; pop_{ROI} = Republic of Ireland population from Crowe *et al.* (2014); hec_{CW} = number of hectads occupied in Co. Waterford; hec_{ROI} = number of hectads occupied in Republic of Ireland; tet_{CW} = mean relative abundance in Co. Waterford tetrads; tet_{ROI} = mean relative abundance in Republic of Ireland tetrads.

³ <https://c0amf055.caspio.com/dp/f4db30005dbe20614b404564be88>; accessed 24/10/2024.

⁴ BirdWatch Ireland, Bird Atlas 2007 - 2011, National Biodiversity Data Centre, Ireland, accessed 07/09/2022, <<https://maps.biodiversityireland.ie/Dataset/220>>.



Table A7.4.8. Population data used for the collision risk assessments.

Species	Population	Type	Period	Number	Units	Source
Red Grouse	Republic of Ireland	modelled	2006-2008	4,218	individuals	2
	Knockmealdowns and Comeraghs	modelled	2006-2008	84	individuals	2
Golden Plover	all-Ireland	mean peak	2011/12-2015/16	92,060	individuals	3
	Waterford	mean peak	2016/17-2020/21	4,352	individuals	4
	Lower Blackwater River	mean peak	2016/17-2020/21	207	individuals	4
Woodcock	Local	modelled	2024	17	roding males	5
Kestrel	Republic of Ireland	modelled	2006-2010	19,970	individuals	6
	Waterford	estimate	2006-2010	575	individuals	7
Peregrine	Republic of Ireland	min count	2017	425	pairs	8

Sources: 2 = Cummins *et al.* (2010); 3 = Burke *et al.* (2018); 4 = I-WeBS data; 5 = see Ornithology chapter, Section 7.3.3.2; 6 = Crowe *et al.* (2014); 7 = calculated from Bird Atlas dataset and Crowe *et al.* (2014); 8 = Wilson-Parr and O'Brien (2017). I-WeBS data were supplied by the Irish Wetland Bird Survey (I-WeBS), a joint scheme of BirdWatch Ireland and the National Parks and Wildlife Service of the Department of Arts, Heritage & the Gaeltacht.

Survival rate data

The survival rates used for the collision risk assessments were the adult survival rates from BirdFacts⁵. These were 0.47 for Red Grouse, 0.73 for Golden Plover, 0.61 for Woodcock, 0.69 for Kestrel, and 0.81 for Peregrine.

Collision risk estimates

The collision risks for Golden Plover, Kestrel and Peregrine were the maximum predicted collision risks from the one height band and two height band models in Table A7.4.7. The collision risk for Woodcock was the maximum predicted collision risk from the Woodcock model in Table A7.4.7. These collision risks were doubled to allow for uncertainty in the collision risk modelling (see Section A7.4.4).

The cumulative collision risk assessments used the predicted collision risks reported by other wind farm projects within the relevant regions (Table A7.4.9). Note that predicted collision risks were only available for 45 out of the 67 wind turbines in Co. Waterford (see Table 7.2 in the Environmental Impact Assessment Report Ornithology chapter).

⁵ <https://www.bto.org/understanding-birds/welcome-birdfacts>; accessed 24/10/2024.



Table A7.4.9. Predicted collision risks from other wind farm projects used for the cumulative collision risk assessments.

Species	Region	Wind farm	Collision risk
Golden Plover	Co. Waterford	Barranafaddock	1.27
		Coumnagappul	0.136
		Dyrick Hill	6.21
		Lyrenacarriga	3.29
Kestrel	Co. Waterford	Barranafaddock	0.044
		Coumnagappul	0.23
		Dyrick Hill	2.72
		Lyrenacarriga	0.55
Peregrine	Co. Waterford	Barranafaddock	0.0062
		Coumnagappul	0.001
		Dyrick Hill	0.02
		Lyrenacarriga	0.02

Sources: Ecological Impact Assessment for Barranafaddock; Environmental Impact Assessment Reports for Coumnagappul, Dyrick Hill and Lyrenacarriga.

Collision risk modelling was not carried out for Red Grouse. No Red Grouse were recorded flying at potential collision height, which means that its effective collision risk with turbine blades is zero within the limits of accuracy of the collision risk model. However, there is a potential collision risk to Red Grouse from collisions with turbine bases. The collision risk assessment used the maximum collision rate from Stokke *et al.* (2020) of 0.03 collisions/turbine/year. There are five turbines in Red Grouse habitat, so this collision rate generates an annual collision risk of 0.15 collisions / year. This is likely to be a large overestimate of the actual collision risk (see the Environmental Impact Assessment Report Ornithology chapter, Section 7.4.5.5).

Results

The calculated increases in annual mortality due to the predicted collision risks from the Scart Mountain Wind Farm are shown in Table A7.4.10. The calculated increases in annual mortality due to the cumulative predicted collision risks from the Scart Mountain Wind Farm in combination with the other wind farm projects in the relevant region are shown in Table A7.4.11.

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Table A7.4.10. Potential increases in annual mortality due to the predicted collision risks from the Scart Mountain Wind Farm.

Species	Population	Collision risk model / source		
		1 height band	2 height bands	other
Red Grouse	Republic of Ireland	-	-	0.01%
	Knockmealdowns and Comeraghs	-	-	0.67%
Golden Plover	all-Ireland	0.01%	0.01%	-
	Waterford	0.30%	0.30%	-
	Lower Blackwater River	6.40%	6.22%	-
Woodcock	Local	-	-	41.22%
Kestrel	Republic of Ireland	0.02%	0.01%	-
	Waterford	0.62%	0.46%	-
Peregrine	Republic of Ireland	0.08%	0.06%	-

Table A7.4.11. Potential increases in annual mortality due to the predicted collision risks from the Scart Mountain Wind Farm in-combination with the predicted collision risks from other wind farm projects in Co. Waterford.

Species	Population	Collision risk model / source	
		1 height band	2 height bands
Golden Plover	all-Ireland	28.63%	28.44%
	Waterford	0.13%	0.13%
	Lower Blackwater River	4.60%	4.44%
Kestrel	Republic of Ireland	0.13%	0.12%
	Waterford	0.20%	0.18%
Peregrine	Republic of Ireland	0.16%	0.14%

A7.4.6 HEN HARRIER POPULATION MODELLING

Introduction

The predicted Hen Harrier collision risk indicates that there is uncertainty about whether or not any Hen Harrier collisions will occur within the lifespan of the proposed wind farm project (see Section A7.4.4, Interpretation of collision risk predictions). Therefore, using the collision risk to calculate potential increases in mortality rate is not appropriate. Instead, population modelling was used to assess the potential significance of the predicted collision risk.

The population modelling approach was based on the Golden Eagle Population Model, was first developed by O'Toole *et al.* (2002) and subsequently refined by Whitfield *et al.* (2006, 2008) and Haworth Conservation (2010). This model is widely used in Scottish wind farm assessments (e.g., MacArthur Green, 2018, 2021).

The model used in this assessment is also comparable to the model used by Sheridan *et al.* (2020) for the Hen Harrier population in the Slieve Bloom Mountains SPA.

As with the examples above, the population model did not include density dependent factors, or immigration and emigration. Therefore, the results should not be regarded as realistic predictions of the likely population trends. Instead, the model provided a mechanism to examine the possible effects of counterfactual scenarios, such as various levels of collision risk.

Methods

An age-structured population matrix model was used to simulate the dynamics of the Knockmealdown, Kilworth and Comeraghs Hen Harrier population. This included three age-classes with age-specific survival rates and stochastic variation in productivity and survival rates. The effects of the predicted collision risks were incorporated by using a Poisson distribution to simulate the distribution of collisions across the lifespan of the wind farm.

Each run of the model was for a period of 40 years and the model was run 10,000 times for each scenario. The 40-year period included five years for the model to stabilise (burn-in) before applying the relevant collision risk scenario.

Male Hen Harriers can be polygynous (mate with multiple females) and their age of first breeding may differ from females. Therefore, the model was a female-only model. Such models are often used in population modelling, including the Golden Eagle Population model and the Hen Harrier modelling carried out by Sheridan *et al.* (2020).

The input values used in the model are shown in Table A7.4.12. All the parameters were derived from Irish sources, except the adult and sub-adult survival rates. The model was run separately for three different productivity rates: the minimum, mean and maximum rates reported by NPWS (2022).

Stochastic variation in the productivity and survival rates were generated by sampling from normal distributions. Truncated normal distributions were used for the survival rates to avoid generating negative survival rates, or survival rates greater than one, which are biologically impossible.

Table A7.4.12. Demographic parameters used for the Hen Harrier population modelling.

Parameter	Values	Source
Initial population size (adults)	2.6	Mean number of confirmed pairs for the Knockmealdowns, Kilworth and Comeraghs Hen Harrier population across the five national surveys (Ruddock <i>et al.</i> , 2024)
Initial population size (juveniles and sub-adults)	variable	Juveniles: calculated from the adult population and the productivity rate Sub-adults: calculated from the juvenile population and the juvenile survival rate
Productivity rate	0.6 (s.d. 0.3) 1.1 (s.d. 0.6) 1.6 (s.d. 0.7)	Minimum, mean and maximum productivity rates from Table 2.3 in NPWS (2022).
Survival rate (juveniles)	0.25 (s.d. 0.106)	McCarthy (2022).
Survival rate (sub-adults and adults)	0.78 (s.d. 0.05)	Mean from Sheridan <i>et al.</i> (2020); standard deviation from BirdFacts.
Proportion breeding	Sub-adults = 0.78 Adults = 1	Sheridan <i>et al.</i> (2020)

Note 1. The standard deviation for the mean productivity rate in Table 2.3 of NPWS (2022) is the standard deviation of the mean values for the six Special Protection Areas included in the table. The standard deviation used in this model was the standard deviation of the 24 individual values reported in the table.

Note 2. Ruddock *et al.* (2024) cites a juvenile survival rate of 0.16, which they attribute to O'Donoghue (2010). However, that research reported by that reference provides a juvenile survival rate of 0.275 (Section 7.3.5 of O'Donoghue, 2010).

The model was run without any collisions, to provide a baseline, with the predicted collision risks for the Scart Mountain Wind Farm alone, with the predicted cumulative collision risk for the Scart Mountain Wind Farm in-combination with the other wind farms included in the cumulative assessment, and with precautionary doubling of each collision risk. The precautionary doubling was carried out to allow for the uncertainty that is inherent collision risk modelling. The collision risk values used in the modelling are shown in

A Poisson distribution was used to simulate the distribution of collisions across the 35-year lifespan of the wind farm. This distribution was generated separately for each run of the model. This meant that some runs of the model included no collisions, while other runs included multiple collisions, reflecting the uncertainty about whether or not any Hen Harrier collisions will occur within the lifespan of the proposed wind farm project.

Table A7.4.13. Collision risks values used in the Hen Harrier population modelling.

Wind farm	Collision risk	Source
Scart	0.0097	Maximum all-year value from the one height band model.
Barranafaddock	0.00046	Ecological Impact Assessment report
Coumnagappul	0.002	Environmental Impact Assessment Report
Dyrick Hill	0.02	Environmental Impact Assessment Report

The collisions were applied randomly to the three age-classes weighted by the proportional representation of the age-classes in the relevant year. For these calculations, the number of juveniles was adjusted by a factor of 60 / 365 to reflect the fact that juveniles typically leave their breeding areas at 60 days post-fledging (McCarthy, 2022).

The number of pairs was calculated for each year in each run of the model as the number of adult females plus the number of sub-adults adjusted for the proportion of sub-adults breeding.

The output parameters used to evaluate the scenarios were the counterfactual growth rate (CGR) and the counterfactual population size (CPS), which are the parameters recommended by NatureScot (2023). The first five years of the model (the burn-in period) was excluded from the calculations of these parameters.

The counterfactual growth rate is the mean annual growth rate when the collision risk is applied divided by the mean annual growth rate of the baseline model. The annual growth rate was calculated as the ratios of pairs between consecutive years.

The counterfactual population size is the final population size when the collision risk is applied divided by divided by the final population size of the baseline model.

Results

The simulations using the mean and maximum productivity rates produced exponential growth in the population, while the simulations using the minimum productivity rates produced exponential decline in the population. The exponential nature of the growth / decline is an inherent property of the modelling technique due to the fact that it does not include density-dependent factors.

The collision risk scenarios examined had negligible effects on the growth rates in the simulations using the mean productivity rates, with counterfactual growth ratios of 0.998 or higher. In these simulations, the populations reached sizes of 19-22 pairs with counterfactual final population size ratios of 0.93-0.98.

In the simulations using the maximum productivity rates, the populations reached ecologically implausible sizes, due to the limitations of the modelling method. Therefore, the results from these simulations are not presented here.

In the simulations using the minimum productivity rate the collision risk had larger effects on growth rates with counterfactual growth ratios of 0.86-0.97. In these simulations, the populations became extinct, or nearly extinct, by year 35. Therefore, counterfactual final population size ratios were not calculated. Using thresholds for extinction of less than one pair,

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or less than 0.5 pairs (to allow for rounding), the mean extinction year differed by a maximum of two years between the baseline and collision risk scenarios.

Table A7.4.14. Summary of the results of the Hen Harrier population modelling (growth rates).

Model	Collision risk scenario	Mean growth rate (95% CI)		Counterfactual growth rate ratio
		baseline	collisions	
mean productivity rate	Scart	1.049 (1.048-1.049)	1.047 (1.047-1.048)	0.999
	Scart (doubled)	1.048 (1.048-1.049)	1.047 (1.046-1.047)	0.999
	cumulative	1.048 (1.048-1.049)	1.047 (1.046-1.047)	0.998
	cumulative (doubled)	1.048 (1.047-1.048)	1.046 (1.043-1.048)	0.998
minimum productivity rate	Scart	0.908 (0.907-0.908)	0.882 (0.88-0.884)	0.972
	Scart (doubled)	0.908 (0.907-0.908)	0.855 (0.851-0.859)	0.942
	cumulative	0.908 (0.907-0.908)	0.814 (0.802-0.827)	0.897
	cumulative (doubled)	0.908 (0.907-0.908)	0.778 (0.696-0.859)	0.857

Note that the baseline was run separately for each collision risk scenario.

Table A7.4.15. Summary of the results of the Hen Harrier population modelling (final population sizes).

Model	Collision risk scenario	Final population size		Counterfactual final population size ratio
		baseline	collisions	
mean productivity rate	Scart	21.6	20.4	0.942
	Scart (doubled)	21.1	20.8	0.984
	cumulative	21.3	20.4	0.956
	cumulative (doubled)	20.9	19.3	0.924

Note that the baseline was run separately for each collision risk scenario.



Table A7.4.16. Summary of the results of the Hen Harrier population modelling (extinction year).

Model	Extinction threshold	Collision risk scenario	Mean extinction year	
			baseline	collisions
minimum productivity rate	< 1 pair	Scart	2035	2035
		Scart (doubled)	2035	2035
		cumulative	2035	2035
		cumulative (doubled)	2035	2034
	< 0.5 pairs	Scart	2042	2042
		Scart (doubled)	2042	2041
		cumulative	2042	2041
		cumulative (doubled)	2041	2039

Note that the baseline was run separately for each collision risk scenario.

Assessment

NatureScot (2023) state that counterfactual final population size ratios of at least 0.95, or counterfactual growth ratios of at least 0.90 “might be considered to be a small enough effect size that the development would not lead to an adverse effect on site integrity”. However, they warn against strict use of threshold values for assessing these counterfactual ratios and suggest that the ratios should be assessed against site-specific management requirements and reference populations.

The simulations using the mean and maximum productivity rates had very high counterfactual growth ratios and high counterfactual final population size ratios. A target size for the Hen Harrier population of the Knockmealdowns, Kilworth and Comeraghs Region has not been defined but is unlikely to be significantly greater than the final population sizes reached in the simulations using the mean productivity rates. Therefore, the simulations using the mean and maximum productivity rates suggest that, if these rates apply, the predicted collision risks are unlikely to have significant effects on the potential for the Hen Harrier population of the Knockmealdowns, Kilworth and Comeraghs Hen Harrier Region to reach a favourable conservation status.

The simulations using the minimum productivity rates indicated a slightly increased risk of extinction to the Hen Harrier population of the Knockmealdowns, Kilworth and Comeraghs Hen Harrier Region under the collision risk scenarios examined. However, a modelled fractional population size of less than one is not ecologically meaningful. Using a more meaningful metric of the time for the population to decline to a size less than one, or to less than 0.5 (to allow for rounding), the collision risk scenarios had little effect on the extinction risk.

Fixed collision risk values were used in the modelling, following the practise used for applications of the Golden Eagle Population Model (MacArthur Green, 2018, 2021). For increasing populations, this was generally appropriate. The collision risk at Scart was based on flight activity associated with established territories, while population increases would generate occupation of additional territories in the region rather than increased activity in existing territories. However, in the cumulative collision risk scenarios, population growth

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increases might result in increased collision risk at other wind farms without established territories during the period used for their collision risk modelling. Therefore, the simulations using doubling of the cumulative collision risk may provide better indications of the likely cumulative impact on increasing populations.

In declining populations, the use of fixed collision risk values may overestimate the effect of the collision risk.

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ANNEX 7.4.1 - PARAMETER VALUES USED IN THE COLLISION RISK MODELLING

Introduction

This annex provides details of the parameter values used in the collision risk modelling. These include the wind turbine parameters (Table A7.4.1.1 and Table A7.4.1.2), the biometric and avoidance rate values for the bird species included in the models (Table A7.4.1.3). Rounded parameter values are shown for clarity, but the unrounded values were used in the models.

Details of the viewshed areas are shown in **Error! Reference source not found.** above, and viewshed maps are included in Appendix 7.1. Details of the vantage point survey effort are included in Appendix 7.1. The flight activity data is included in Appendix 7.2, and the flightline maps are included in Appendix 7.3.

Data tables

Table A7.4.1.1. General wind turbine parameters used in the collision risk modelling.

Parameter	Value
Number of turbines	15
Number of blades in rotor	3
Mean pitch angle of blade	0°
Percentage of time the turbines will be operational	85%

Table A7.4.1.2. Turbine specific wind turbine parameters used in the collision risk modelling.

Parameter	N149	N163	SG155	V150	V162
Hub height (m)	110.5	103.5	107.5	110	104
Rotor diameter (m)	149	163	155	150	162
Tip height (m)	185	185	185	185	185
Ground clearance (m)	36	22	30	35	23
Max chord (m)	4.2	4.15	4.5	4.2	4.3
Rotor speed (rpm)	10.75	10.1	9.31	9.91	9.5

Rotor speeds are nominal values. No rotor speed value was supplied for the V150 turbine, so the mean turbine speed value across the other turbines was used for this turbine.



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Table A7.4.1.3. Bird species parameters used in the collision risk modelling.

Species	Length (m)	Wingspan (m)	Flight speed (m/sec)	Avoidance rate
Hen Harrier	0.48	1.10	9.1	0.99
Golden Plover	0.28	0.72	17.9	0.98
Curlew	0.55	0.90	16.3	0.98
Woodcock	0.34	0.58	12.0	0.98
Kestrel	0.34	0.76	10.1	0.95
Merlin	0.28	0.56	10.1	0.98
Hobby	0.33	0.87	11.3	0.98
Peregrine	0.42	1.02	12.1	0.98
Chough	0.395	0.815	12.5	0.98

Flight speed values from Alerstam *et al.* (2007); value for Grey Plover (*Pluvialis squatarola*) used for Golden Plover, as no value given for the latter species. Body length and wingspan values from Cramp and Simmons (2004). Avoidance rates from SNH (2018).

Table A7.4.1.4. Seasonal periods and durations used in the Stage 1 models for calculating predicted transits.

Species	Biological season	VP season	Months	Daylight hours	D _{season}
Hen Harrier	breeding	summer	Apr-Aug	2,361	8,500,787
	non-breeding	summer	Sep	381	1,370,723
		winter	Oct-Mar	1,740	6,265,720
Golden Plover	winter	summer	Apr-Sep	2,742	9,871,510
		winter	Oct-Mar	1,740	6,265,720
Curlew	all year	summer	Apr-Sep	2,742	9,871,510
		winter	Oct-Mar	1,740	6,265,720
Kestrel	all year	summer	Apr-Sep	2,742	9,871,510
		winter	Oct-Mar	1,740	6,265,720
Merlin	all year	summer	Apr-Sep	2,742	9,871,510
		winter	Oct-Mar	1,740	6,265,720
Hobby	summer	summer	May-Aug	1,944	6,999,570
Peregrine	all year	summer	Apr-Sep	2,742	9,871,510
		winter	Oct-Mar	1,740	6,265,720
Chough	all year	summer	Apr-Sep	2,742	9,871,510
		winter	Oct-Mar	1,740	6,265,720

The biological seasons are the seasons used for reporting the collision risk predictions. The VP seasons are the seasons used for the stage 1 modelling of predicted transits.



Table A7.4.1.5. Vantage point survey durations (hours) used in the Stage 1 models for calculating predicted transits.

VP	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BM2	6	6	6	0	0	0	0	0	0	3	9	6
BM3	6	6	6	0	0	0	0	0	0	6	6	6
BM4	6	6	6	0	0	0	0	0	0	6	6	6
BM5	6	6	6	0	0	0	0	0	0	6	6	6
BM6	6	6	6	0	0	0	0	0	0	6	6	6
BM8	9	6	6	0	0	0	0	0	0	6	3	3
BM9	9	6	6	0	0	0	0	0	0	6.8	6	3
KN1	6	6	6	0	0	0	0	0	0	6	6	6
KN3	6	6	6	0	0	0	0	0	0	6	6	6
KN4	6	6	6	0	0	0	0	0	0	6	6	6
SC1	12	12	6	30	12	12	12	12	0	0	0	6
SC2	12	12	6	24	12	12	8	10	6	0	0	6
SC3	12	12	6	24	12	12	9	9	6	0	0	6
SC4	12	12	6	24	12	12	12	12	0	0	0	6
SC5	12	12	6	24	12	12	12	6	6	0	0	6
SC6	12	12	6	24	12	12	12	12	0	0	0	6
SC7	12	12	6	21	12	12	12	12	0	0	0	6
SC9	12	12	6	24	12	12	12	12	0	0	0	6

The vantage point watches carried out at the SC1-SC9 vantage points in late March 2023 were allocated to April (see text).

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