Appendix 7-7 – Collision Risk Modelling Report

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A7.7.1 INTRODUCTION

Scope

This appendix presents the results of collision risk modelling for the proposed Cloghercor Wind Farm, Co. Donegal.

The collision risk modelling was carried out to assess the potential collision risk to bird populations of conservation importance from the development of the wind farm.

The collision risk modelling used data from vantage point surveys to generate collision risk predictions for the waterbird and raptor species recorded flying at potential collision height during the surveys. Where relevant, species were divided into separate populations (e.g., breeding and non-breeding populations), and separate collision risks were generated for each population.

The collision risk modelling include all eight turbine types that are being considered for this wind farm. The minimum and maximum values from this range of turbine types, for the bird transit, collision probability and collision risk predictions are shown in the main sections of this appendix. All the values are shown in Annex 7.7.2.

The significance of the collision risk was assessed for the bird populations of conservation importance where at least one collision was predicted to occur during the 35 year lifespan of the wind farm.

A worst-case scenario collision risk model is also included for the breeding Golden Plover population.

The interpretation of the results of collision risk modelling is discussed in the main chapter (Chapter 7 Ornithology).

All the modelling and assessment was carried out by Tom Gittings.

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.

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. This stage can also include corrections for other factors, such as nocturnal flight activity, and the proportion of time the turbines are operational.

A7.7.2 DATA SOURCES

The flight activity data used for the collision risk modelling comes from the vantage point surveys carried out for the Cloghercor Wind Farm project. The scope and methods of these vantage point surveys are described in Appendix 7.1, the full results are included in Appendix 7.2, and the flightline maps are shown in Appendix 7.3.

The viewshed mapping used for the collision risk modelling was derived from a Digital Surface Model supplied by Bluesky, based on imagery acquired on 20/09/2019 and 13/04/2020. The viewshed maps are included in Appendix 7.1.

Vector mapping of the proposed turbine locations, and technical specifications for the turbine models, were provided by Ørsted.

A7.7.3 METHODOLOGY

General approach

The collision risk modelling methodology was based on the SNH guidance on collision risk modelling (SNH, 2000), and current practice in collision risk modelling. It also incorporated development of more detailed structured models for Golden Eagle.

Data management

Before beginning the analyses, the flight activity data was audited for data entry errors and missing data.

Review of the vantage point survey coverage and results

Before beginning the development of the collision risk model, a review was carried out of the vantage point survey coverage and results. This helped to assess the degree of spatial and temporal variability in the recorded flight activity, which needed to be taken into account in the development of the collision risk model. Note that, spatial and temporal variability can only be assessed for the regularly occurring species. With species that were only recorded occasionally, it is not possible to distinguish between sampling effects and true spatial and temporal variability.

Collision risk modelling methodology

The collision risk modelling methodology is described in Sections A7.7.4-A7.7.6 as part of a step-by-step account of the development of the collision risk model.

A7.7.4 COLLISION RISK MODEL STAGE 1: BIRD TRANSITS

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" approach 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" approach for when birds show variable patterns of flight activity within the flight risk area. I have used the "bird occupancy" approach, as this is generally the appropriate method for species that show variable patterns of flight activity, and the vantage point survey data and flightline mapping do 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 A7.7.1.

Table A7.7.1. 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_{bird}/VP_{eff}	birds	Mean number of birds observed flying at rotor height during the vantage point watches
2	n	t1 * total duration of season	$t_1 \times D_{season} \times 3600$	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 × (volume swept by rotors / flight risk volume)	$n \times (A_{rotor} \times (L_{rotor}+L_{bird}))/(A_{vis} \times H_{rotor})$	bird-secs	Predicted bird occupancy of the swept volume across the entire season
4	$N_{transits}$	b / time taken for a bird to fly through rotors of one turbine	$b/((L_{rotor}+L_{bird})/v_{bird})$	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 A7.7.1 simplify as Equation 1, as shown below.

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

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 A7.7.1, cancel out. While bird length is required for the collision probability calculations in Stage 2, the rotor depth parameter (L_{rotor}) is not usually required for collision risk modelling.

Methods

Species included

All the waterbird and raptor species recorded flying at potential collision height during the surveys, apart from Snipe, were included in the collision risk modelling. 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.

Model types

The predicted transits were calculated for all species using two modelling approaches (the combined VP and VP averaging methods). The predicted transits for Golden Eagle and the breeding Common Gull population were calculated using spatially structured versions of the combined VP method.

Detection rates

Declines in detection rates with distance from vantage points is a common issue in vantage point surveys, and the SNH guidance (SNH, 2017) recommends considering corrections for detectability effects. Therefore, analyses were carried out to assess the relationships between distance from the vantage point locations and the flightline detections.

The analyses assume that flight activity is randomly distributed in relation to distance from the vantage point locations. At individual vantage points, habitat associations and / or topography may affect the relationship between distance from the vantage point location and flight activity. Averaging across a number of vantage points is likely to minimise these biases, because the habitat / topographic effects will differ between vantage points. However, very strong habitat / topographic effects affecting a lot of the flight activity at a vantage point, could still bias these analyses.

At two of the vantage points (VPs 6 and 8), large amounts of waterbird flight activity occurred along the Gweebarra Estuary close to the vantage point locations. Inclusion of these flightlines in the analyses would have resulted in overestimation of the decline in detection rates with distance. Therefore, the following species were excluded from the analyses at these vantage points: Shelduck, Mallard, Cormorant, Grey Heron, Ringed Plover, Curlew, Black-headed Gull, Common Gull, Lesser Black-backed Gull, Herring Gull, Great Black-backed Gull and Common Tern. At VP6, after these species had been excluded, the number of remaining flightlines was too small for meaningful analysis, Therefore, VP6 was excluded from the analysis.

At VP10, a lot of gull flight activity occurred in, and beyond, the outer part of the viewshed. This was due to a commuting route to / from the mink farm located along the Stracashel River, around 4 km east of Glenties. Inclusion of these flightlines in the analyses would result in underestimation of the decline in detection rates with distance. Therefore, all the gull flightlines at VP10 were excluded from the analysis.

As detectability will be strongly affected by body size, the species recorded in the vantage point surveys were divided into three size groups, based on their cross-sectional indices (the body length multiplied by the wingspan). The small species included Mallard, Sparrowhawk, Common Sandpiper, Snipe, Common Gull, Kestrel, Merlin and Peregrine, with body lengths of 0.20-0.58 m and wingspans of 0.40-1.20 m. The medium species included Greylag Goose, Barnacle Goose, Buzzard, Osprey, Lesser Black-backed Gull, Herring Gull and Great Black-backed Gull, with body lengths of 0.54-0.90 m and wingspans of 1.20-1.64 m. The large group included Whooper Swan, Grey Heron, White-tailed Eagle and Golden Eagle, with body lengths of 0.80-1.52 m and wingspans of 1.85-2.30 m.

Each viewshed was divided into eight bands, representing increasing distance from the vantage point, from 0-250 m to 1750-200 m. The total length of flightlines for each species group in each band was then calculated. Flightlines that only occurred in the 0-25 m height band were excluded, because the viewsheds had been derived using a minimum height of 25 m.

The flightline density for each distance band in each viewshed was then calculated using Equation 2. This equation standardises the flightline density in each distance band by the total amount of flight activity recorded a that vantage point, to avoid the analyses being biased by vantage points where large amounts of flight activity were recorded.

Equation 2: $FD_{i^*} = : (FD_i / FD_{VP}) \times FD_{mean}$

FD_{i^*} = weighted flightline density in band i; FD_i = raw flightline density in band i; FD_{VP} = summed flightline densities across all bands in the viewshed containing grid square i; FD_{mean} = mean of FD_{VP} = across all the vantage points included in the analysis.

The mean flightline density across all the vantage points showed strong declines with distances for all three species groups (Figure A7.7.1). For the large species group, the flightline density was more or less constant in the first three distance bands, with a decline across the next three distance bands. In the small and medium species groups, there were large confidence intervals for the first three distance bands, but there was again a clear decline in flightline density at distances greater than 750 m, with very low detection rates in the most distant bands. The large confidence intervals in the closest distance bands (particularly the 0-250 m band) reflects the small sizes of these bands.

The detection rate / distance relationships were used to calculate adjusted viewshed areas using the formula shown in Equation 3.

Equation 3: $A_{vis^*} = sum_{i=1-10}(A_{vis(i)} \times weight_i)$

A_{vis^*}= adjusted viewshed area; i = distance band number from 0-250 m (distance band 1) to 1750-2000 m (distance band 8); $weight_i$ = mean detection rate in distance band i relative to the 250-500 m distance band.

The adjusted viewshed areas, compared to the original viewshed areas are shown in Table A7.7.2. This table also shows correction factors that represent the increase in collision risk generated by these adjusted viewshed areas. These correction factors differ between the vantage points as they depend on the distribution of the original viewshed area between the distance bands. Across all the vantage points, the mean correction factors are 3.7 for the small group, 2.8 for the medium group, and 1.7 for the large group. The viewsheds for VPs 6 and 8 had large correction factors (see footnote to A7.7.2). Excluding these viewsheds, the mean correction factors were 3.0, 2.6 and 1.6.

Table A7.7.2. Adjusted viewshed areas compared to the original viewshed areas, and the correction factors representing the increase in collision risk generated by these adjusted viewshed areas.

VP	Original viewshed area (ha)	Adjusted viewshed area (ha)			Correction factors		
		small	medium	large	small	medium	large
1	433	127	157	261	3.4	2.8	1.7
2	498	139	176	295	3.6	2.8	1.7
3	461	152	178	288	3.0	2.6	1.6
4	526	139	182	306	3.8	2.9	1.7
5	393	132	154	250	3.0	2.6	1.6
6	327	51	89	161	6.4	3.7	2.0
7	184	93	91	140	2.0	2.0	1.3
8	320	47	85	155	6.8	3.8	2.1
9	461	152	177	288	3.0	2.6	1.6
10	285	129	134	209	2.2	2.1	1.4

The low adjusted viewshed areas, and high correction factors, for VP6 and VP8, are due to the exclusion of the Gwebarra Estuary buffer from the viewsheds (see below). This meant that the closer distance bands were not included in the viewsheds.

These adjusted viewshed areas were used for the collision risk modelling. They resulted in an increase of around 1.6-3.0 in the predicted collision risks, compared to models that do not account for this factor[1]. This should be taken into account in any comparisons of predicted collision risks from this wind farm, compared to predictions from collision risk models for other wind farm projects, which do not usually account for declines in detections with distance.

Gweebarra Estuary

Two of the vantage points (VP6 and VP8) were located on the north side of the Gweebarra Estuary and their viewsheds included the Gweebarra Estuary. There were several waterbird species that were recorded in the Gweebarra Estuary, but were not recorded anywhere else within, or adjacent to, the wind farm site. There were other species for which much higher levels of activity were recorded in the Gweebarra Estuary, compared to other areas within, or adjacent to, the wind farm site.

Although the wind farm site extends to the southern shore of the estuary, there will be no wind farm infrastructure within 500 m of the estuary, while the nearest turbine location is over 1 km from the estuary. Therefore, the wind farm development is not likely to cause any disturbance or displacement impacts to bird populations in the Gweebarra Estuary.

[1] The exact value of the increase in collision risk will differ between species in each group, depending on the distribution of their flight activity between the vantage points.

Flight activity that was restricted to the estuary was excluded from the collision risk modelling. To do this, a 300 m wide buffer around the estuary shoreline was defined. This buffer distance was chosen as it included all the flightlines of birds following the estuary, but did not include any part of the 500 m buffers around the proposed turbine locations. The buffer was extended on the northern side of the Gweebarra Estuary to include the small areas of the viewsheds that were outside the buffer. Any flightlines that were wholly within this 300 m buffer were excluded from the analyses, unless otherwise stated. The flightlines that were partly within the buffer were clipped, so that only the portion outside the buffer were included in the analyses, unless otherwise stated. The sections of the VP6 and VP8 viewsheds within the buffer were also excluded from the analyses.

The viewsheds used for the collision risk modelling, after removal of the Gweebarra Estuary buffer, are shown in Figure A7.7.2.

Spatial coverage

The vantage point surveys covered the entire wind farm site. However, the proposed wind farm project will only involve development of the eastern section of the site. The eastern and western sections of the site are also topographically discrete and have some differences in their habitats. Therefore, for the analyses of the bird survey data, the wind farm site was divided into eastern and western sections. The boundary between the two sections of the site is shown in Figure 7.1 in the main chapter. This boundary follows the lowest point of the valley that divides the site.

The viewsheds of VPs 2-7 covered parts of the eastern section and did not overlap the western section. The viewsheds of VPs 9-10 covered parts of the western section and did not overlap the eastern section. The viewsheds of VP1 and VP8 covered parts of both the eastern and western sections.

Each of the basic collision risk models were run twice: an all VP analysis using the data from all the vantage points, and a main VP analysis using the data from only the viewsheds of the vantage points overlapping the eastern section of the wind farm site. For the latter models, the viewsheds of VP1 and VP8 were clipped to exclude the area outside the eastern section. The VP1 and VP8 flightlines were then clipped so that only the portions within the eastern section were included in the analyses.

The divisions of the VP1 and VP8 viewsheds are shown in Figure A7.7.2.

Re-calculation of flight durations

The Stage 1 calculations of bird transits uses 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 need to be excluded from the analyses.

For most of the vantage point surveys, durations were only recorded for flightlines within the mapped viewsheds. However, in the first season, and for some surveys in the second and third seasons, flightline durations were recorded for 500 m buffers around the wind farm, rather than for the viewsheds. These flightline durations needed to be adjusted to reflect the portion of the flight activity that occurred within the viewshed of the vantage point being surveyed.

The procedure described above for excluding flight activity along the Gweebarra Estuary also resulted in a requirement for adjustment of durations for those flightlines that were partly within the Gweebarra Estuary buffer. Similarly, in the main VP analyses, adjustment of durations were carried out for the flightlines that were only partly within the eastern section of the VP1 and VP8 viewsheds.

The flightline durations were adjusted by clipping the mapped flightlines by the viewsheds / Gweebarra Estuary buffer / eastern section of the VP1/VP8 viewsheds. The durations and bird-secs were then recalculated by multiplying their original values 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.

Height bands

Separate calculations of bird transits were carried out for each of the height bands that were used for the vantage point surveys (25-50 m, 50-160 m, and 160-220 m). This allowed the differences in the rotor area as a proportion of the airspace to be factored into the calculations.

To carry out these separate calculations, it was necessary to subdivide the overall rotor area (A_{rotor}) into the portions that occurred in each height band. To calculate the rotor area in each height band, the angles subtended by segments representing the 25-50 m and 50-160 m height bands were calculated using Equations 5 and 6:

Equation 4: $\theta_{25\text{-}50} = \cos^{-1}((H_{hub} - 25) / R_{rotor})$

Equation 5: $\theta_{50\text{-}160} = \cos^{-1}((H_{hub} - 50) / R_{rotor})$

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

The rotor areas were then calculated using the following equations:

Equation 6: $A_{rotor(25\text{-}50)} = 0.5 \times (\theta_{25\text{-}50} - \sin(\theta_{25\text{-}50})) \times R_{rotor}^2$

Equation 7: $A_{rotor(50\text{-}160)} = A_{rotor(25\text{-}50)} - (0.5 \times (\theta_{50\text{-}160} - \sin(\theta_{50\text{-}160})) \times R_{rotor}^2)$

Equation 8: $A_{rotor(160\text{-}220)} = A_{rotor} - (A_{rotor(25\text{-}50)} + A_{rotor(50\text{-}160)})$

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 30-50.5 m, while the tip heights varied from 194-200 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 25-50 m height band (except for the two turbine models with ground clearances of 50 and 50.5 m) and in the 160-220 m height band.

Vantage point survey effort

The overall survey effort varied between vantage points. Therefore, for models that combined data from more than one vantage point, the following equation was used to standardise the vantage point survey effort:

Equation 9: $VP_{eff^*} = {}_{\text{sum (i = 1 to n)}} (VP_{eff(i)} \times A_{vis^*(i)}) / {}_{\text{sum (i = 1 to n)}} (A_{vis^*(i)})$

VP_{eff^*} = the standardised vantage point survey effort; n = the number of vantage points grouped together for the analysis; $VP_{eff(i)}$ = the vantage point survey effort at VP_i; $A_{vis(i)}$ = the adjusted viewshed area at VP_i (see Equation 3).

Definition of seasonal periods of occurrence

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_{season}/VP_{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 / increase in the D_{season}/VP_{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 7.1) 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.

Restricted seasonal occurrence periods were defined for the following species included in the collision risk modelling: Whooper Swan, Barnacle Goose, Osprey, Common Sandpiper. For Common Gull, Lesser Black-backed Gull, Herring Gull, and Great Black-backed Gull, breeding and non-breeding populations were defined and the collision risks were calculated separately for each population

The seasonal periods of occurrence used in the collision risk model are shown in Table A7.7.1.4 in Annex 7.7.1.

Parameter values

The wind turbine parameters, and the bird biometric and avoidance rate parameters are shown in Annex 7.7.1.

General models

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. The simplest method (the combined VPs method) combines the data from all the vantage points, using the sum of the flight activity across all the vantage points for the D_{bird} value, and the sum of the viewshed areas for the A_{vis} value. This method assumes that flight activity is randomly distributed throughout the combined viewsheds.

A slightly more sophisticated method is the VP averaging method. 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 Management[2]. This method also assumes that there is random distribution of flight activity across the wind farm site but treats each vantage point as a separate sample.

The range of predicted transits from the combined VPs and VP averaging models, at the for the all VPs and main VPs scales, are compared in Table A7.7.3.

In each set of models, the minimum predicted transits are from the N149, and in some cases also, the V150 models. These are the two turbines with ground clearances of at least 50 m, which means that the data from the 25-50 m height bands was not included in the models. The maximum predicted transits are from the GE164. This is the turbine with the lowest ground clearance, which means that these models have the highest values of A_{rotor}.

Table A7.7.3. Range of predicted transits per year for the all VPs and main VPs variants of the combined VPs and VP averaging models.

Species	All VPs		Main VPs	
	combined VPs	VP averaging	combined VPs	VP averaging
Whooper Swan	164 - 250	112 - 171	205 - 315	161 - 250
Barnacle Goose	4 - 5	5 - 6	0	0
Mallard	40 - 64	39 - 64	7 - 12	7 - 16
Cormorant	0 - 1	0 - 2	0 - 1	0 - 7
Grey Heron	11 - 14	13 - 16	8 - 10	16 - 20
White-tailed Eagle	6 - 8	8 - 11	0	0
Sparrowhawk	20 - 29	34 - 51	4 - 7	31 - 57
Buzzard	44 - 103	64 - 139	23 - 51	76 - 149

[2] 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.

Species	All VPs		Main VPs	
	combined VPs	VP averaging	combined VPs	VP averaging
Golden Eagle	99 - 180	119 - 213	76 - 139	96 - 171
Osprey	4 - 12	4 - 15	5 - 8	5 - 13
Common Sandpiper	10 - 12	9 - 11	0	0
Snipe	4 - 6	4 - 6	0	0
Common Gull (breeding)	70 - 277	75 - 273	22 - 84	25 - 94
Common Gull (non-breeding)	0	0	0	0
Lesser Black-backed Gull (breeding)	119 - 191	134 - 224	122 - 190	130 - 218
Lesser Black-backed Gull (non-breeding)	112 - 177	109 - 173	4 - 14	5 - 19
Herring Gull (breeding)	709 - 925	939 - 1221	10 - 12	56 - 67
Herring Gull (non-breeding)	23 - 4075	35 - 3269	0 - 108	0 - 553
Great Black-backed Gull (breeding)	47 - 92	79 - 146	1 - 10	2 - 13
Great Black-backed Gull (non-breeding)	13 - 29	16 - 29	17 - 38	23 - 41
Kestrel	107 - 198	104 - 270	12 - 31	11 - 32
Merlin	0 - 1	0 - 1	0 - 0	0
Peregrine	3 - 3	2 - 3	3 - 4	4

Golden Eagle Stage 1 models

The analyses presented in the main chapter showed that Golden Eagle flight activity was strongly associated with the ridgeline along the southern / eastern margins of the wind farm site. This distribution pattern was strongly associated with both altitude and the scores from the Golden Eagle Topography model. Both parameters explained a similar amount of variation in the distribution of Golden Eagle flightlines. Therefore, separate Stage 1 models were developed using altitude and using the scores from the Golden Eagle Topography model. Variants of these models were also analysed to assess whether potential avoidance effects could have influenced the predicted transits.

Golden Eagle Stage 1 altitudinal zones model

The analysis of Golden Eagle flightline density by altitudinal zone indicated that, for analyses of Golden Eagle flight activity, the area covered by the vantage point surveys can be divided into three altitudinal zones: a low altitudinal zone (0-160 m), a middle altitudinal zone (160-210 m), and a high altitudinal zone (above 210 m).

No turbines are proposed for altitudes above 210 m, so Golden Eagle flight activity in the high altitudinal zone does not need to be included in the collision risk model. Therefore, two altitudinal zones were used: the low altitudinal zone (0-160 m), and the middle altitudinal zone (160-210 m).

The Golden Eagle flightlines were divided by these two altitudinal zones. Where the flightlines intersected both altitudinal zones, the durations and bird-secs in each zone were recalculated by multiplying their original values by (flightline length in zone) / (original flightline length).

The number of turbines were 16 in the 0-160 m zone, and 3 for the 160-210 m zone.

The predicted transits ranged from 37 per year for the N149 turbine, to 63 per year for the GE164 turbine (see Annex 7.7.2).

Golden Eagle Stage 1 GET model

The analyses of Golden Eagle flightline density by scores from the Golden Eagle Topography model indicated that, for analyses of Golden Eagle flight activity, the area covered by the vantage point surveys can be divided into three zones: low-medium suitability (GET scores of 1-5), high suitability (GET scores of 6-8) and very high suitability (GET sores of 9-10). Therefore, the viewsheds were divided into three zones representing these categories, named GET zone 1 - GET zone 3.

The Golden Eagle flightlines were divided by these zones. Where the flightlines intersected more than one GET zone, the durations and bird-secs in each zone were recalculated by multiplying their original values by (flightline length in zone) / (original flightline length).

There were nine turbines in GET zone 1, seven in GET zone 2, and three in GET zone 3.

The predicted transits ranged from 43 per year for the N149 turbine, to 77 per year for the GE164 turbine (see Annex 7.7.2).

Model variants

The analyses of Golden Eagle flightline densities indicated a possible observer avoidance effect in the 0-250 m distance band around each vantage point (see main chapter). Also, low flight activity in the 2020 breeding season, despite the presence of a nest site close to some of the vantage point locations indicated that the birds may have been avoiding the viewsheds when they entered / left the nest (see main chapter). Therefore, variants of both models were developed which excluded the 0-250 m distance band around each vantage point and excluded data from 2020.

For the variant of the altitudinal zone model, the predicted transits ranged from 32 per year for the N149 turbine, to 62 per year for the GE164 turbine.

As the values from these variants did not differ significantly from the original models, the latter were used for the Stage 3 analyses.

Common Gull model

All the breeding season Common Gull flight activity in the eastern section of the wind farm site occurred in a narrow corridor between Lough Aneane More and the Gweebarra Estuary. This means that the assumptions of random distribution of flight activity between the viewsheds required by the general models was clearly violated. Therefore, a separate model was developed for the breeding season Common Gull population.

The flightline corridor between Lough Aneane More and the Gweebarra Estuary was entirely contained within the viewshed of VP3. Parts of the corridor also overlapped the viewsheds of other vantage points. However, these were generally the more distant parts of those viewsheds, and no Common Gull flightlines were recorded in flightline corridor from those vantage points. Therefore, the model was restricted to data from VP3.

The viewshed of VP3 was clipped by generating a 200 m buffer around the Common Gull flightlines. As with the general models, the Gweebarra Estuary buffer was also clipped from the viewshed. The viewshed area was then recalculated using the band weightings procedure in Equation 3.

The predicted transits were then calculated for each turbine model using Equation 1, and a value of three for the number of turbines.

The predicted transits ranged from 44 transits/years for the N149 and V150 turbines to 167 transits / year for the GE164 turbine (see Annex 7.7.2).

Selection of transit values for the Stage 3 model

For Golden Eagle and Common Gull, the transit values from their species-specific models were selected for use in the Stage 3 model.

For the other populations, it was necessary to decide whether to use the values from the combined VPs or VP averaging models, and whether to use the all VPs or main VPs scales of analyses.

For resident / regularly occurring populations, the analyses of their distribution patterns presented in the main chapter showed strong differences in occurrence patterns across the wind farm site. Therefore, for these species, the main VPs scale was used, as this scale was focussed around the proposed turbine locations. The model (combined VPs or VP averaging) that produced the highest predicted transits was used.

For the other populations, the model and scale that produced the highest predicted transits was used.

A7.7.5 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, ϕ), 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[3]. 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, I applied a more realistic scenario 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).

Sensitivity analyses showed that collision probability values were more or less constant over the range of pitch angles from -5° to at least 12.5° (see below) . Therefore, a mean pitch angle of 3° was used for the Stage 3 models. This value represents the median of the -3° - 9° range recorded by MKOS (2019).

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 minimum and maximum collision probabilities for each species are shown in Table A7.7.4.

The minimum values were produced by the E160 or GE164 turbines, which were the models with the slowest rotation speed values used for the calculations. The GE164 had a slightly higher rotation speed than the E160, but a slightly lower maximum chord value. This turbine produced the minimum values for species with lower wingspan / body length ratios, while the E160 produced the minimum values for species with higher wingspan / body length ratios.

The maximum values were produced by the N149 or SG155 turbines. The N149 was the model with the highest rotation speed value used for the calculations, while the SG155 was the model with the highest maximum chord value. As with the minimum values, the maximum values for species with higher wingspan / body length ratios were associated with the turbine with the highest rotation speed value (N149), while the maximum values for species with lower wingspan

[3] Note that, strictly speaking, the model should be adapted for each turbine specification by changing the details of the blade profile in the model to match the blade profile of the turbine. However, in practice, this would make very little difference to the predicted collision risk, and the details of the blade profile are usually not available.

/ body length ratios were associated with the turbine with the highest maximum chord value (SG155)

Table A7.7.4. Minimum and maximum collision probabilities.

Species	Minimum collision probability		Maximum collision probability	
	Value	Turbine	Value	Turbine
Whooper Swan	0.066	E160	0.076	N149
Barnacle Goose	0.047	GE164	0.054	N149
Mallard	0.044	GE164	0.05	SG155
Cormorant	0.054	E160	0.062	N149
Grey Heron	0.063	E160	0.073	N149
White-tailed Eagle	0.06	E160	0.069	N149
Sparrowhawk	0.042	GE164	0.048	SG155
Buzzard	0.05	E160	0.056	N149
Golden Eagle	0.059	E160	0.068	N149
Osprey	0.052	E160	0.059	N149
Golden Plover	0.038	GE164	0.044	SG155
Common Sandpiper	0.036	GE164	0.041	SG155
Snipe	0.037	GE164	0.042	SG155
Common Gull	0.044	GE164	0.051	SG155
Lesser Black-backed Gull	0.05	GE164	0.056	N149
Herring Gull	0.05	E160	0.057	N149
Great Black-backed Gull	0.052	E160	0.06	N149
Kestrel	0.044	GE164	0.05	SG155
Merlin	0.041	GE164	0.047	SG155
Peregrine	0.045	GE164	0.051	SG155

Sensitivity

Rotation speed

The rotation speed has a strong influence on the collision probability values. However, the rotation speed values used in the Stage 2 model were nominal values supplied by the manufacturer. In practice, rotation speeds will vary with wind speed. Therefore, sensitivity analyses were carried out to investigate how collision probabilities varied with rotation speeds across the range of operational rotation speeds.

This analysis was carried out for the three turbines for which rotation speed ranges were available: the N149, N163 and SG155 turbines. Collision probability values were calculated for each 0.1 m/sec increment in the rotation speed value within the rotation speed ranges.

Examples of the relationships between collision probabilities and rotation speeds are shown in Figure A7.7.4 for species representing the range of body sizes and wingspans.

For small species like Golden Plover, the variation in rotation speed, within the operational speed ranges, had a negligible effect on the collision probabilities. However, for large species like Whooper Swan and Golden Eagle, there was a 2-3% variation in collision probabilities across the operational speed ranges. For these two species, this variation would result in an increase in the predicted collision risk of up to 1.5 times between the minimum and maximum rotation speeds.

Pitch angle

Modern wind turbines have variable pitch angles, so sensitivity analyses were carried out to investigate how collision probabilities varied with pitch angle.

These analyses was carried out for the same three turbines as the rotation speed sensitivity analyses: the N149, N163 and SG155 turbines. Collision probability values were calculated for each 1° increment in pitch angle between -5° and 90°.

Examples of the relationships between collision probabilities and pitch angle are shown in Figure A7.7.4 for species representing the range of body sizes and wingspans. The collision probabilities remained more or less constant up to pitch angles of around 10-15°, after which they showed steep increases.

As discussed above, monitoring data indicates that pitch angles at onshore wind farms in Ireland rarely exceed 9°. Therefore, variation in pitch angle is unlikely to affect collision risk predictions.

A7.7.6 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, including Whooper Swan, Barnacle Goose, White-tailed Eagle, Golden Eagle and Kestrel, there is some evidence available that has been used to specify species-specific avoidance rates (SNH, 2018). In addition, a recent review for Scottish Natural Heritage has recommended the use of an avoidance rate of 0.995 for large gulls (including Lesser Black-backed Gull) at onshore wind farms (Furness, 2019). For the other species included in this collision risk model, the SNH 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 Whooper Swan and Grey Heron.

Whooper Swan does not normally show significant levels of nocturnal flight activity. However, analysis of the vantage point survey data indicated that most of the Whooper Swan flightlines recorded were likely to be of birds on direct migration. As Whooper Swan can migrate at night, a nocturnal correction factor was required. In the absence of any information on the diel variation in the relative frequency of Whooper Swan migration, it was assumed that there was an equal probability of Whooper Swan flightlines occurring at any time in a 24 hour period. Therefore, the nocturnal correction factor was given by the following equation:

Equation 10: $NCF = 1 + h_{night*} / h_{day*}$

h_{night*} = mean night-time hours across seasonal period of occurrence; h_{day*} = mean day-time hours across seasonal period of occurrence.

Flight activity patterns for Grey Heron from Vessem and Draulans (1987) indicate low levels of nocturnal flight activity. For this assessment, a nominal value of 25% of daytime flight activity was used to calculate the nocturnal correction factor for Grey Heron, using the following equation:

Equation 11: $NCF = 1 + 0.25 \times h_{night*} / h_{day*}$

NCF = correction factor for nocturnal flight activity; h_{night*} = mean night-time hours across seasonal period of occurrence; h_{day*} = mean day-time hours across seasonal period of occurrence.

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.

Collision predictions

The results of the Stage 3 calculations are summarised in Table A7.7.5. This shows the minimum and maximum collision risks for the eight turbine types that were included in the collision risk modelling. The table also shows the turbine types that generated the minimum and maximum values, the scale and type of the Stage 1 model, and the approximate correction factor that was used to adjust the viewshed area for under-detection of distant flightlines. For Golden Eagle, the table shows the results from the two alternative Stage 1 models that were used.

Table A7.7.5. Minimum and maximum collision risk predictions.

Species / Population	Scale	Model	Collisions / year		Turbine		Correction factor
			min	max	min	max	
Whooper Swan	main	cVPs	0.16	0.23	V150	GE164	1.6
Barnacle Goose	all	VPa	0.00045	0.00049	V150	SG155	2.6
Mallard	main	VPa	0.006	0.012	V150	GE164	3.1
Cormorant	main	VPa	0	0.0061	V150	V162	2.6
Grey Heron	main	VPa	0.02	0.023	V150	V162	1.6
White-tailed Eagle	all	VPa	0.023	0.028	V150	GE164	1.6
Sparrowhawk	main	VPa	0.025	0.041	V150	GE164	3.1
Buzzard	main	VPa	0.071	0.13	V150	GE164	2.6
Golden Eagle	all	alt bands	0.034	0.056	V150	GE164	1.6
Golden Eagle	all	GET bands	0.040	0.068	V150	GE164	1.6
Osprey	main	VPa	0.0052	0.011	GE164	SG155	2.6
Common Sandpiper	all	VPa	0.0063	0.007	V150	GE164	3.1
Common Gull	CM	CM model	0.024	0.087	V150	GE164	3.1
Lesser Black-backed Gull (breeding)	main	VPa	0.031	0.046	V150	GE164	2.6
Lesser Black-backed Gull (non-breeding)	main	VPa	0.0012	0.0039	V150	V162	2.6
Herring Gull (breeding)	main	VPa	0.013	0.015	V150	GE164	2.6
Herring Gull (non-breeding)	main	cVPs	0	0.023	V150	GE164	2.6
Great Black-backed Gull (breeding)	main	VPa	0.00044	0.0030	V150	GE164	2.6
Great Black-backed Gull (non-breeding)	main	VPa	0.0057	0.0093	V150	V162	2.6
Kestrel	main	VPa	0.023	0.060	V150	GE164	3.1
Merlin	all	VPa	0	0.00076	V150	SG155	3.1
Peregrine	main	VPa	0.0031	0.0034	V150	GE164	3.1

Scale: all = data from all vantage points used; main = data only included from VPs2-7, and the sections of VPs 1 and 8 overlapping the eastern section of the wind farm site; CM = data only included from the section of VP3 overlapping the Common Gull flightline corridor. Model: cVPs = combined VPs; VPa = VP averaging; alt bands = Golden Eagle altitudinal zone model; GET bands = Golden Eagle GET bands model; CM model = Common Gull model. Correction factor = the mean correction factor across all viewshed for the relevant species group.

A7.7.7 COLLISION RISK ASSESSMENT

General

The potential increase in annual mortality, as a percentage of the background annual mortality, was assessed for all species / populations, with a predicted risk that would result in at least one collision within the 35 year lifespan of the wind farm. For each of these species / populations, the impact was assessed at the national scale. The impact was also assessed at the county scale where relevant population data was available, or could be estimated.

The sources of the population data are listed in the relevant species accounts. For some species, the Donegal population sizes were estimated using the BirdAtlas dataset from the National Biodiversity Data Centre. 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 Republic of Ireland breeding range of each species that occurs in Donegal. The tetrad data was used to estimate the mean relative abundance of the species in Donegal 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 Donegal population.

Whooper Swan

The predicted collision risk would result in around 6-8 collisions over the lifespan of the wind farm. This collision risk includes a correction for detectability effects (which increases the risk by a factor of around 1.6). This should be taken into account when comparing this collision risk with collision risks from other wind farm projects (which generally do not include correction for detectability effects).

The Whooper Swan flightlines recorded in the vantage point surveys were not associated with a discrete local population, but instead were considered to mainly involve birds on direct migration. As Whooper Swans migrating through Donegal in spring and autumn may be wintering anywhere in Ireland, the only relevant scale at which to consider the significance of the collision risk is the national population.

As Whooper Swan migrate by night as well as during the day, the predicted collision risk included a correction for nocturnal flight activity (which increased the risk by a factor of around 2.5). This should be taken into account when comparing this collision risk with collision risks from other wind farm projects involving local populations of Whooper Swan (which generally do not fly at night).

The calculations in Table A7.7.6 indicate that the predicted collision risk would cause a negligible increase in annual mortality to the national Whooper Swan population. Note that these calculations overestimate the likely increase as they do not take account of juvenile birds, which have higher annual background mortality rates.

Table A7.7.6. Potential increase in mortality to the national Whooper Swan population.

Parameter	Description	Source	National
pop	population size	1	1,911
surv	adult survival rate	2	0.801
m_1	annual background mortality	pop × (1-surv)	380
m_2	predicted annual collision mortality	collision risk model	0.16-0.23
Δm	increase in annual mortality due to collisions	m_1 / m_2	0.04-0.06%

1: national population size Burke *et al.* (2021).

2: Brazil (2003), as quoted by BirdFacts (www.bto.org/understanding-birds/birdfacts).

Sparrowhawk

The predicted collision risk would result in around one collision over the lifespan of the wind farm. This collision risk includes a correction for detectability effects (which increases the risk by a factor of around 3.1). This would have a negligible impact on both the Irish and Donegal Sparrowhawk populations (Table A7.7.7).

Table A7.7.7. Potential increase in mortality to the national and Donegal populations of Sparrowhawk.

Parameter	Description	Source	National	Donegal
pop	population size	1	11,965	959
surv	adult survival rate	2	0.675	0.675
m_1	annual background mortality	pop × (1-surv)	3,889	312
m_2	predicted annual collision mortality	collision risk model	0.025-0.041	0.025-0.041
Δm	increase in annual mortality due to collisions	m_1 / m_2	0.001%	0.01%

1: national population size median of range from Crowe *et al.* (2014); Donegal population estimated from BirdAtlas data (see text).

2: mean of male and female survival rates from Newton (1986), as quoted by BirdFacts (www.bto.org/understanding-birds/birdfacts).

Buzzard

The predicted collision risk would result in around 2-5 collisions over the lifespan of the wind farm. This collision risk includes a correction for detectability effects (which increases the risk by a factor of around 2.6). This collision risk would have a negligible impact on both the Irish and Donegal Buzzard populations (Table A7.7.8).

Table A7.7.8. Potential increase in mortality to the national and Donegal populations of Buzzard.

Parameter	Description	Source	National	Donegal
pop	population size	1	13,248	1,191
surv	adult survival rate	2	0.9	0.9
m_1	annual background mortality	pop × (1-surv)	1,325	119
m_2	predicted annual collision mortality	collision risk model	0.071-0.13	0.071-0.13
Δm	increase in annual mortality due to collisions	m_1 / m_2	0.005-0.01%	0.06-0.1%

1: national population size from Rooney (2013), adjusted to account for the estimate by Kenward *et al.* (2000) that only around one in four individuals breed each year; Donegal population estimated from BirdAtlas data (see text).
2: Kenward *et al.* (2000), as quoted by BirdFacts (www.bto.org/understanding-birds/birdfacts).

Common Gull

The predicted collision risk is 1-3 collisions over the lifespan of the wind farm. This collision risk includes a correction for detectability effects (which increases the risk by a factor of around 3.1).

This collision risk would have a negligible impact on the Irish Common Gull population (Table A7.7.9). The impact on the Donegal population is also likely to be very small (Table A7.7.9).

Table A7.7.9 Potential increase in mortality to the national and Donegal Common Gull breeding populations.

Parameter	Description	Source	National	Donegal	
				min	max
pop	population size	1	1,948	149	940
surv	adult survival rate	2	0.86	0.86	0.86
m_1	annual background mortality	pop × (1-surv)	273	21	132
m_2	predicted annual collision mortality	collision risk model	0.024-0.087	0.024-0.087	0.024-0.087
Δm	increase in annual mortality due to collisions	m_1 / m_2	0.009-0.03%	0.1-0.4%	0.02-0.07%

1: population sizes from Cummins *et al.* (2019); the Donegal population is shown as the minimum and maximum of the ranges given by the dot map.
2: Buckcicinski and Buckcicinski (2003), as quoted by BirdFacts (www.bto.org/understanding-birds/birdfacts).

Lesser Black-backed Gull (breeding population)

The predicted collision risk would result in around 1-2 collisions over the lifespan of the wind farm. This collision risk includes a correction for detectability effects (which increases the risk by a factor of around 2.6). This collision risk would have a negligible impact on the Irish Lesser Black-backed Gull population (Table A7.7.10).

Allowing for uncertainty in the predicted collision risk, the calculations in Table A7.7.10 suggest that, if the Donegal population is at the lower end of the range indicated by the available data, the potential increase in annual mortality to the Donegal breeding population could exceed the

1% threshold that Percival (2003) suggested for determining whether the impact is non-negligible. However, the calculated increase in annual mortality is likely to be a substantial overestimate, as it does not allow for the occurrence of immature and non-breeding birds, or birds from outside Donegal (which is a real possibility given the foraging range of Lesser Black-backed Gulls). Secondly, as discussed in the main chapter, the 1% threshold is very conservative, and an increase substantially greater than 1% is likely to be required to have a significant impact. Therefore, based on these factors, the potential increase in annual mortality to the Donegal breeding population is not likely to be significant.

Table A7.7.10. Potential increase in mortality to the national and Donegal Lesser Black-backed Gull breeding populations.

Parameter	Description	Source	National	Donegal	
				min	max
pop	population size	1	7,112	51	470
surv	adult survival rate	2	0.913	0.913	0.913
m_1	annual background mortality	pop × (1-surv)	619	4	41
m_2	predicted annual collision mortality	collision risk model	0.031-0.046	0.031-0.046	0.031-0.046
Δm	increase in annual mortality due to collisions	m_1 / m_2	0.005-0.007%	0.7-1.0%	0.08 – 0.1%

1: population sizes from Cummins *et al.* (2019); the Donegal population is shown as the minimum and maximum of the ranges given by the dot map.
2: Wanless *et al.* (1996), as quoted by BirdFacts (www.bto.org/understanding-birds/birdfacts).

Kestrel

The predicted collision would result in around 1-2 collisions over the 35 year lifespan of the wind farm. This collision risk includes a correction for detectability effects (which increases the risk by a factor of around 3.1). This would have a negligible impact on both the Irish and Donegal Kestrel populations (Table A7.7.11).

Table A7.7.11. Potential increase in mortality to the national and Donegal Kestrel breeding populations.

Parameter	Description	Source	National	Donegal
pop	population size	1	16,660	1,325
surv	adult survival rate	2	0.69	0.69
m_1	annual background mortality	pop × (1-surv)	5,165	411
m_2	predicted annual collision mortality	collision risk model	0.023-0.060	0.023-0.060
Δm	increase in annual mortality due to collisions	m_1 / m_2	0.000-0.001%	0.006-0.02%

1: national population size from NPWS (undated); Donegal population estimated from BirdAtlas data (see text).
2: Village (1990), as quoted by BirdFacts (www.bto.org/understanding-birds/birdfacts).

A7.7.8 GOLDEN PLOVER COLLISION RISK MODEL

A breeding pair of Golden Plover was recorded in the eastern corner of the wind farm site. The territory of this pair was outside the 500 m buffer around the proposed turbine locations. However, during the incubation period, breeding Golden Plover typically commute from their moorland breeding areas to feed in more productive grasslands. Therefore, there is potential for collision risks to arise if the breeding Golden Plover pair commutes across the wind farm site to feed on grasslands along the Gweebarra Estuary.

No evidence of commuting Golden Plover was recorded in the vantage point watches and the Golden Plovers appeared to stay in the moorland habitat to feed. However, the possibility of some commuting could not be ruled out.

As no Golden Plover flight activity at potential collision height was recorded, no potential collision risk was generated by the vantage point survey data. However, due to the very short time window during which commuting is likely to occur, there is a possibility of flight activity being missed by the vantage point watches. To allow for this possibility, calculations were carried out to assess the implications of a worst-case scenario.

During the incubation period the male and female take turns incubating with two changeovers per day. Therefore, the worst-case scenario, involved the incubating Golden Plovers commuting before/after every changeover. This would involve four commuting flights per day across the incubation period.

The core foraging range for breeding Golden Plover defined by SNH (2016) is 3 km. Therefore, for the worst-case scenario, a potential commuting corridor was defined from Golden Plover breeding territory to the section of the Gweebarra Estuary within 3 km of the breeding territory.

The potential commuting corridor was defined by drawing buffers of 3.2 km and 500 m around the 2022 nest site location. The 3.2 km buffer represents the likely core foraging range. The extra 200 m included in the buffer allows for movement of the nest site position from year to year. The buffer of 500 m represents the position of the Golden Plovers when they arrive / depart during incubation changeovers, as the birds do not fly directly into the nest site (Parr, 1980). Lines were then subtended from the outer edges of the 500 m buffer to the eastern and western edges of the grassland habitat along the Gweebarra Estuary included in the 3.2 km buffer. This potential commuting corridor is shown in Figure A7.7.6.

The worst-case scenario assumed that all flight activity occurred at potential collision height.

The worst-case scenario was used to calculate a theoretical collision risk using the risk window method of SNH (2000). The calculation procedure is shown in Table A7.7.7.

The worst-case scenario would result in one collision every 50-52 years (Table A7.7.7).

If the breeding Golden Plover do commute to grassland foraging areas, the actual collision risk will be much lower because they will not commute before / after every changeover, they are likely to also use other grassland areas, and not all the flight activity will be at potential collision height.

It should also be noted that these calculations use the default avoidance rate of 98%, because the guidance (SNH, 2018) does not include species-specific avoidance rates for Golden Plover.

However, a review of collision fatality monitoring studies by Gittings (2020) indicated that the non-avoidance rate for wintering Golden Plover is around an order of magnitude higher. If, as seems likely, this also applies to breeding Golden Plover populations, the collision risk from the worst-case scenario would be an order of magnitude lower: i.e., around one collision every 400 years.

Table A7.7.12 Worst-case scenario calculations of potential collision risk to breeding Golden Plover commuting over the wind farm site.

Parameter	Description	Source	National
w	Width of the commuting corridor perpendicular to the commuting route	1	2,045 m
d	Rotor diameter	2	149-164 m
n	Number of turbines	2	4
a_{RW}	Risk window	w*d	391,945-431,402 m^2
a_T	Rotor swept area	pi*$(d/2)^2$*n	104,620-126,744 m^2
ip	Duration of incubation period	3	29.5
f	Number of commuting flights	ip * 4	118
t_{RSW}	Number of transits through the rotor swept area each year	f * a_T/a_{RW}	27-30
p	Probability of collision per transit through rotor swept area	4	0.038 - 0.043
ar	Avoidance rate	5	0.98
op	Percentage of operational time	2	0.85
c	Collisions per year	t_{RSW}*p*(1-r) *(1-op)	0.019 - 0.020

Sources: 1 = weighted mean (by turbine number) of four cross-sections containing turbines; 2 = turbine specifications; 3 = median incubation period from the range given by BirdFacts (www.bto.org/understanding-birds/birdfacts); 4 = mean collision probability from the Stage 2 collision risk model (A7.7.5); 5 = SNH (2018).

A7.7.9 REFERENCES

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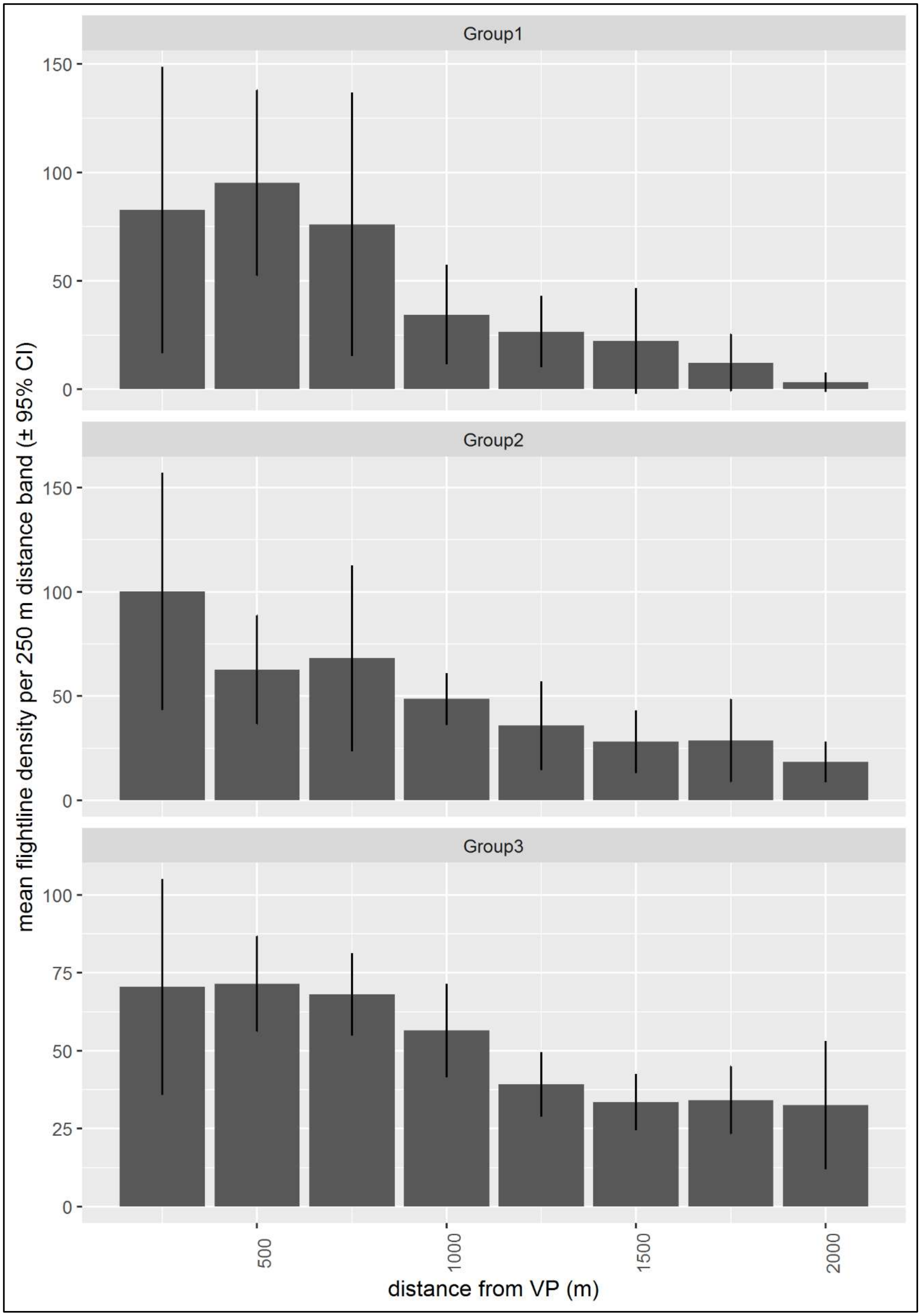

Figure A7.7.1 - Relationship between flightline density and distance from vantage point location for small (Group 1), medium (Group 2) and large (Group 3) species.

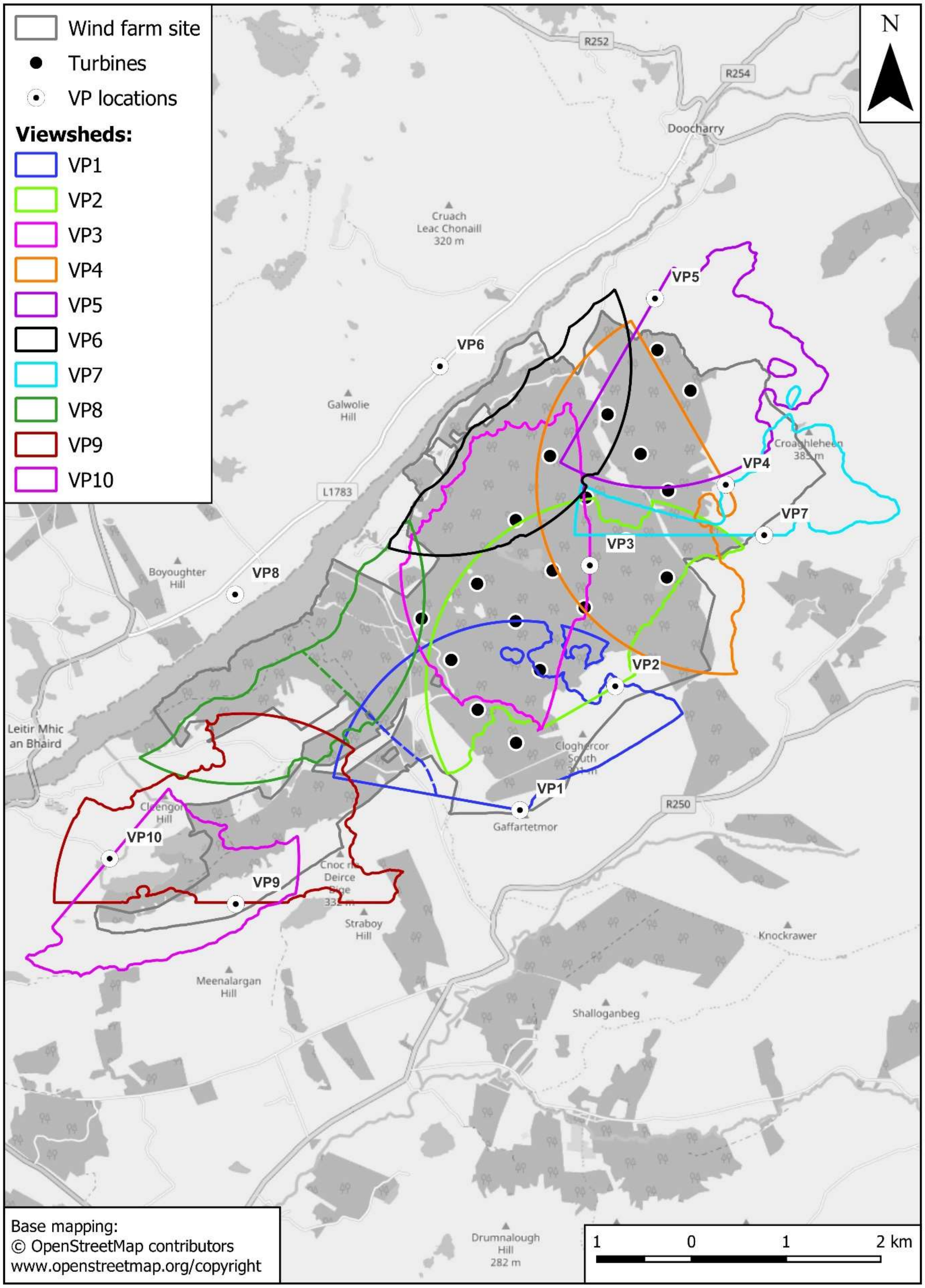

Figure A7.7.2 - Viewsheds used for the collision risk modelling, with dashed lines showing the divisions of VP1 and VP8 used for the analyses at the main VPs scale.

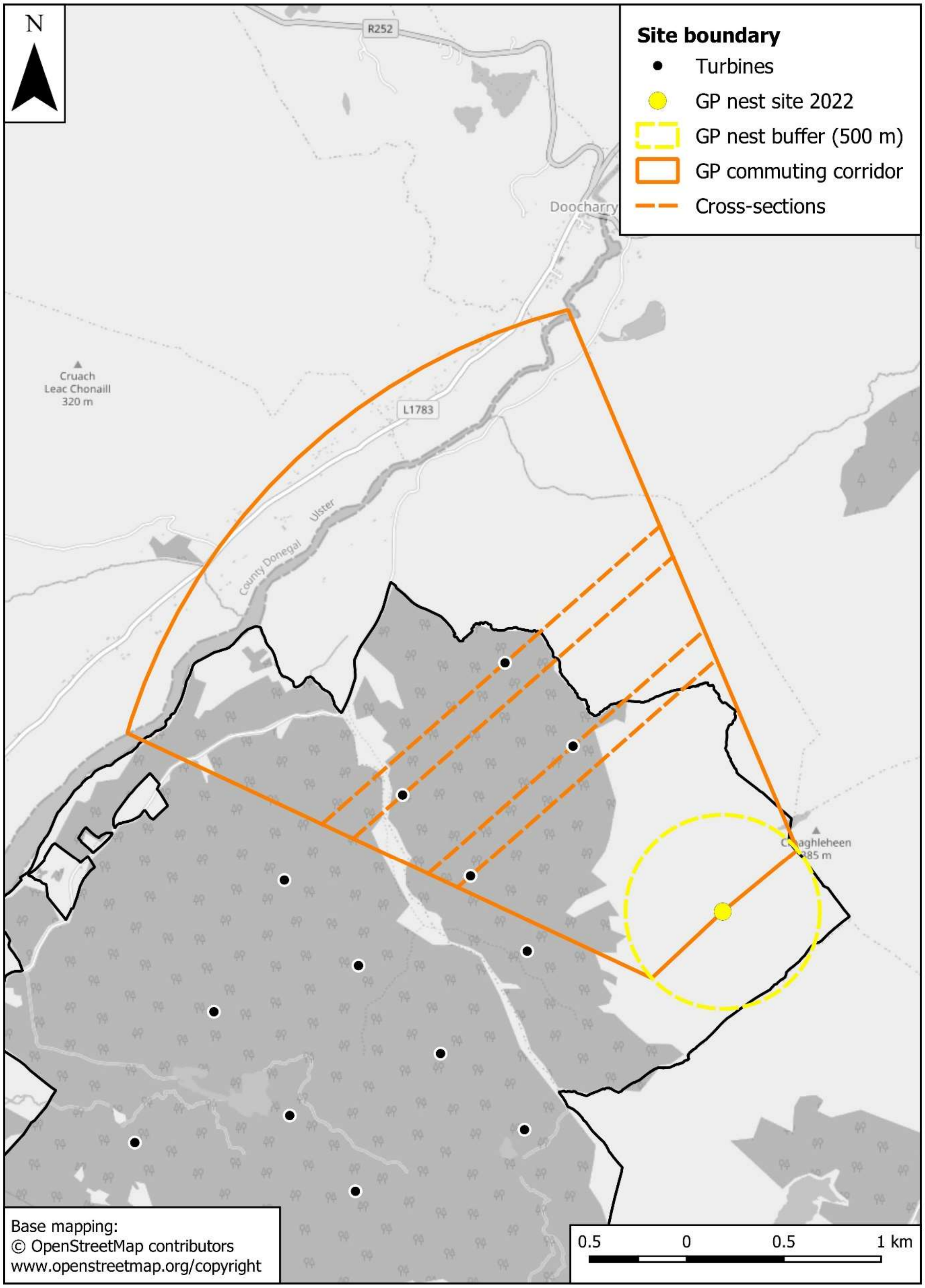

Figure A7.7.3 - Common Gull breeding season flightlines and the viewshed used for the Common Gull stage 1 model.

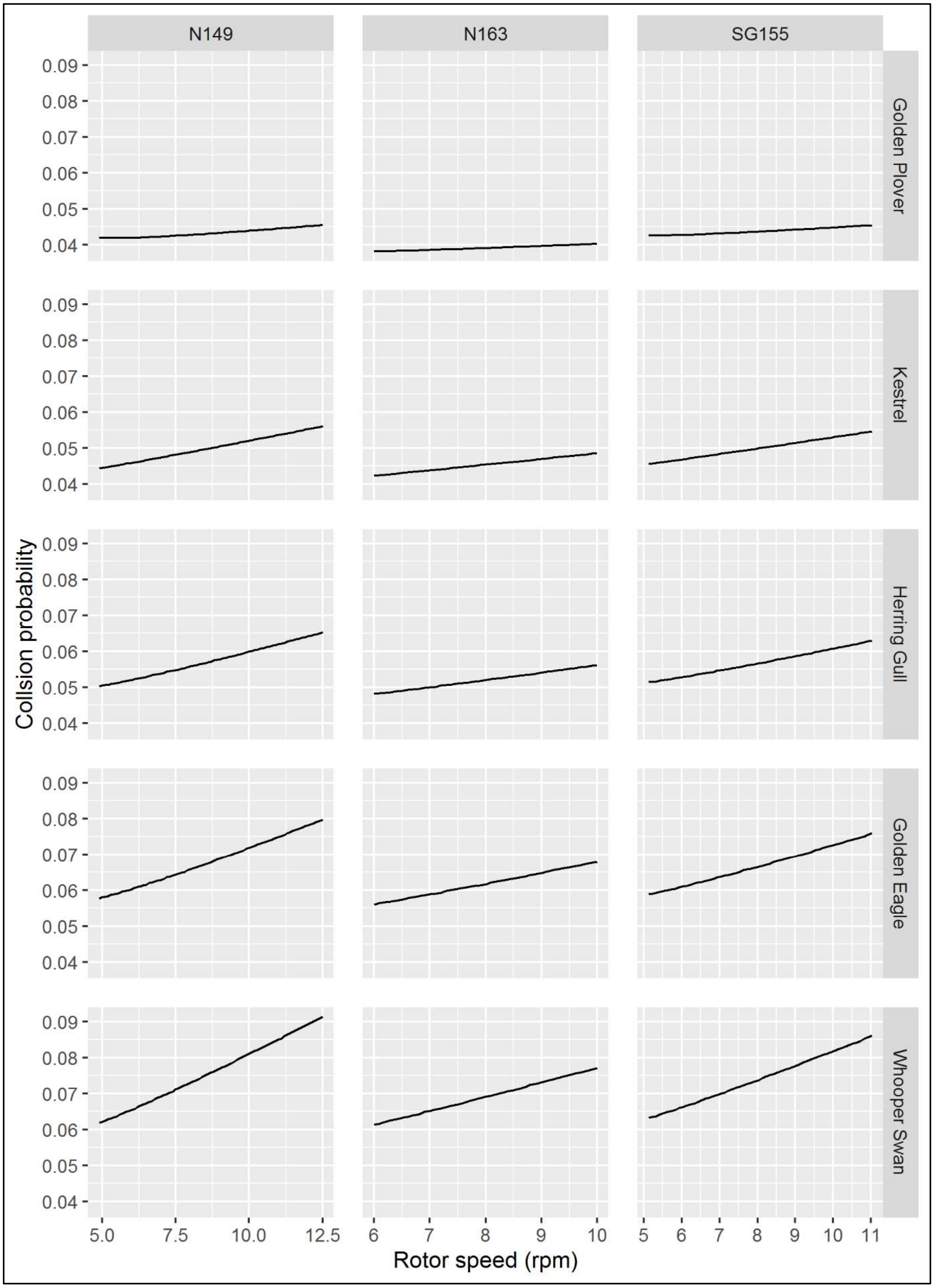

Figure A7.7.4 - Relationship between rotor speed and collision probability.

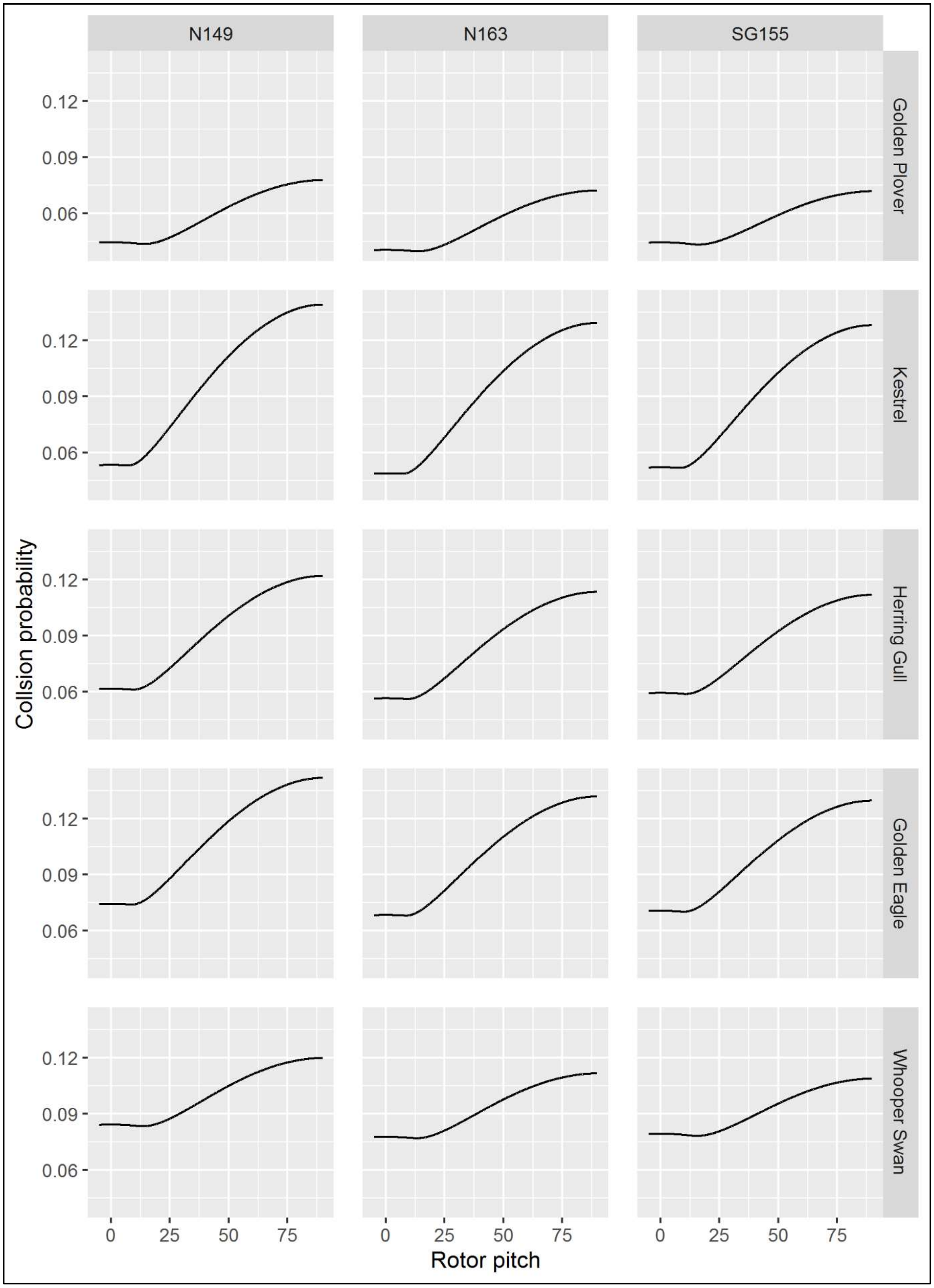

Figure A7.7.5 - Relationship between rotor pitch and collision probability.

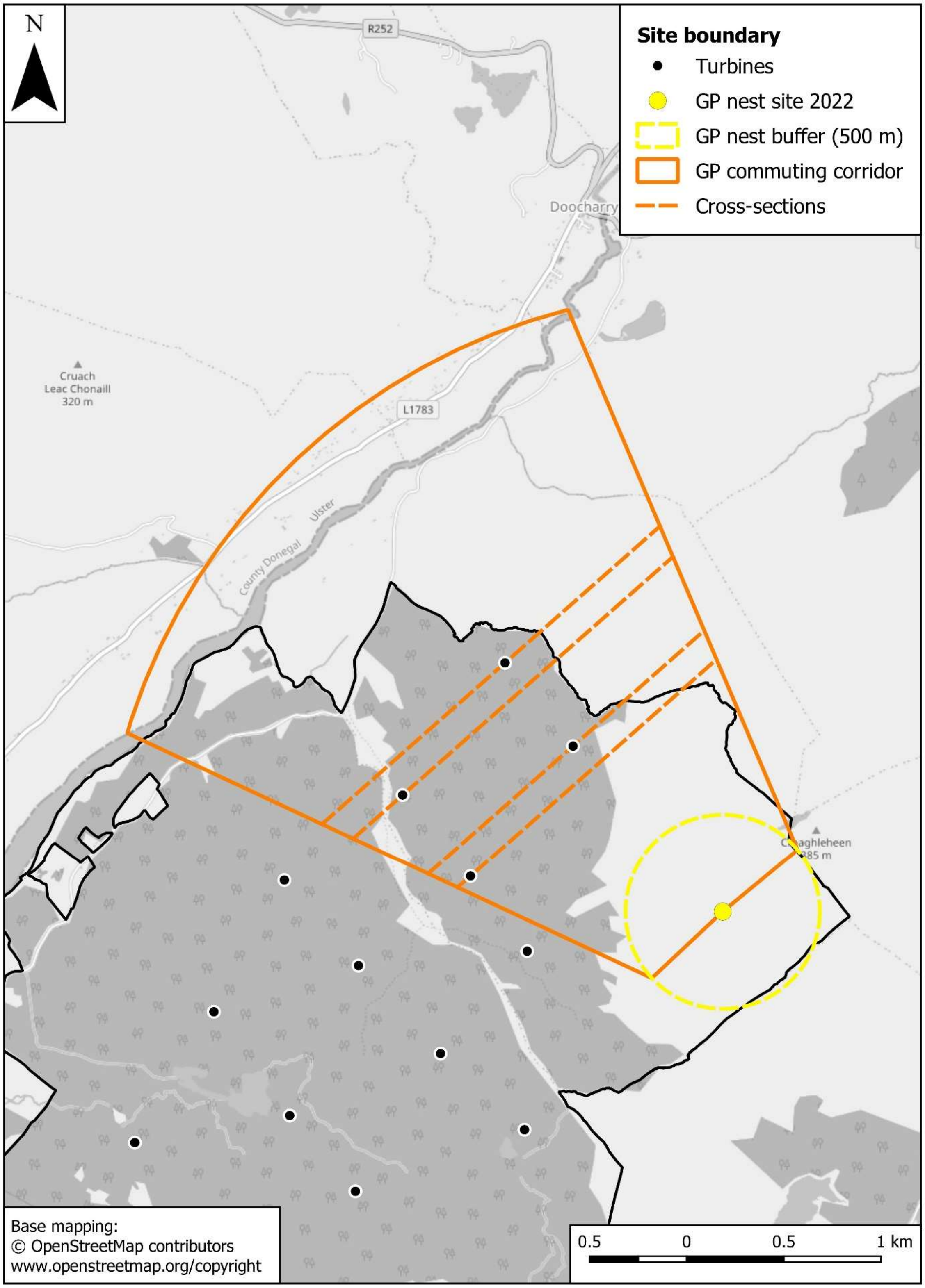

Figure A7.7.6 - Potential Golden Plover commuting corridor used for the Golden Plover worst-case scenario collision risk model..

ANNEX 7.7.1 - 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 A7.7.1.1 and Table A7.7.1.2), the biometric and avoidance rate values for the bird species included in the models (Table A7.7.1.3) and the seasonal periods used in the Stage 1 models (Table A7.7.1.4). Rounded parameter values are shown for clarity, but the unrounded values were used in the models.

Details of the viewshed areas are shown in Table A7.7.2 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 A7.7.1.1. General wind turbine parameters used in the collision risk model.

Parameter	Value
Number of turbines	19
Number of blades in rotor	3
Mean pitch angle of blade	6°
Percentage of time the turbines will be operational	85%

Table A7.7.1.2. Turbine specific wind turbine parameters used in the collision risk model.

Parameter	GE164	N163	V162	E160	GE158	SG155	V150	N149
Hub height (m)	112	118	119	120	121	122.5	125	125
Rotor diameter (m)	164	163	162	160	158	155	150	149
Tip height (m)	194	199.5	200	200	200	200	200	199.5
Ground clearance (m)	30	36.5	38	40	42	45	50	50.5
Max chord (m)	4	4.15	4.3	4.126	4	4.5	4.2	4.2
Rotor speed range (rpm)		6.0-10.1				5.13-11.17		4.9-12.6
Rotor speed nominal (m)	9.7	10.1	9.5	9.6	9.9	9.31		10.75

No rotor speed values were provided for the V150 turbine. Instead, the mean of the rotor speed values for the other turbines was used.

Table A7.7.1.3. Bird species parameters used in the collision risk model.

Species	Speed (m/sec) v_{bird}	Body length (m) L_{bird}	Wingspan (m) W_{bird}	Avoidance rate
Whooper Swan	17.3	1.52	2.3	0.995
Barnacle Goose	17.0	0.64	1.38	0.998
Mallard	18.5	0.58	0.9	0.98
Cormorant	15.2	0.9	1.45	0.98
Grey Heron	11.2	0.94	1.85	0.98
White-tailed Eagle	11.3	0.8	2.2	0.95
Sparrowhawk	11.3	0.33	0.62	0.98
Buzzard	11.6	0.54	1.2	0.98
Golden Eagle	11.9	0.82	2.12	0.99
Osprey	11.4	0.56	1.58	0.98
Golden Plover	17.9	0.28	0.72	0.98
Common Sandpiper	15.3	0.2	0.4	0.98
Common Gull	13.4	0.41	1.2	0.992
Lesser Black-backed Gull	13.1	0.58	1.42	0.995
Herring Gull	12.8	0.6	1.44	0.995
Great Black-backed Gull	13.7	0.71	1.58	0.995
Kestrel	10.1	0.34	0.76	0.95
Merlin	10.1	0.28	0.56	0.98
Peregrine	12.1	0.42	1.02	0.98

L_{bird} and W_{bird} values taken from www.bto.org/about-birds/birdfacts. v_{bird} values taken from Alerstam et al. (2007); value for Grey Plover (*Pluvialis squatarola*) used for Golden Plover, as no value given for the latter species. Avoidance rates from SNH (2018) and Furness (2019).

Table A7.7.1.4. Seasonal periods used in the Stage 1 models for calculating predicted transits.

Species / Population	Season	Months
Whooper Swan	winter	October - March
Barnacle Goose	winter	October - March
Osprey	spring and autumn	April - May and August - October
Common Sandpiper	summer	April - September
Common Gull (breeding)	breeding season	April - July
Lesser Black-backed Gull (breeding)	breeding season	April - August
Lesser Black-backed Gull (non-breeding)	non-breeding season	September - March
Herring Gull (breeding)	breeding season	April - August
Herring Gull (non-breeding)	non-breeding season	September - March

Species / Population	Season	Months
Great Black-backed Gull (breeding)	breeding season	April - August
Great Black-backed Gull (non-breeding)	non-breeding season	September - March
Other species	all year	January - December

The seasonal duration values for the Stage 1 models (D_{season}) values were calculated for each month using the *suncalc* package (Thieurmel and Elmarhraoui, 2022) in R, using an input latitude of 54.86018, and an input longitude of -8.245005. They were then summed for each species across the months included in the seasonal period of occurrence.

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ANNEX 7.7.2 – CRM RESULTS FOR EACH TURBINE MODEL

Predicted transit data

Table A7.7.2.1. Predicted transits from the combined VPs model at the all VPs scale.

Population	GE164	N163	V162	E160	GE158	SG155	V150	N149
WS	250.3	237.4	232.8	225.3	217.4	204.1	165.7	163.9
BY	5.1	5.1	5.1	5.0	4.9	4.8	4.5	4.5
MA	63.8	60.2	59.0	57.0	54.9	51.3	40.9	40.5
CA	1.0	0.8	0.7	0.7	0.6	0.5	0.0	0.0
H.	13.8	13.7	13.6	13.3	13.0	12.5	11.1	11.0
WE	8.4	8.1	8.0	7.8	7.6	7.3	6.5	6.5
SH	29.1	27.8	27.3	26.5	25.6	24.2	20.2	19.9
BZ	103.1	93.8	90.8	86.3	81.4	73.0	44.5	44.0
EA	180.1	168.0	163.8	157.3	150.4	138.5	100.4	99.4
OP	12.1	10.9	10.5	9.9	9.2	8.1	4.0	4.0
CS	11.7	11.9	11.8	11.6	11.4	11.2	10.6	10.5
CM-breeding	277.0	242.3	232.2	217.1	200.6	171.9	70.4	69.6
LB-breeding	191.4	180.4	176.6	170.5	164.0	153.0	119.9	118.6
LB-non-breeding	177.5	167.4	163.9	158.4	152.5	142.6	113.5	112.3
HG-breeding	924.9	896.5	884.1	862.9	840.7	804.6	717.0	709.1
HG-non-breeding	4074.8	3384.1	3190.8	2907.2	2595.9	2048.8	23.5	23.2
GB-breeding	92.3	85.1	82.8	79.2	75.3	68.7	47.2	46.7
GB-non-breeding	29.4	26.7	25.9	24.6	23.2	20.9	13.1	13.0
K.	198.3	184.1	179.5	172.2	164.4	151.1	108.7	107.5
ML	1.1	0.9	0.9	0.8	0.7	0.6	0.0	0.0
PE	3.2	3.1	3.1	3.0	2.9	2.8	2.7	2.6

Table A7.7.2.2. Predicted transits from the combined VPs model at the main VPs scale.

Population	GE164	N163	V162	E160	GE158	SG155	V150	N149
WS	314.9	298.3	292.4	283.0	272.9	256.1	207.3	205.0
MA	11.6	10.9	10.6	10.2	9.8	9.0	6.8	6.7
CA	1.2	1.0	1.0	0.9	0.8	0.6	0.0	0.0
H	9.9	9.9	9.8	9.6	9.3	9.0	7.9	7.9
SH	7.0	6.5	6.3	6.1	5.8	5.3	3.9	3.8

Population	GE164	N163	V162	E160	GE158	SG155	V150	N149
BZ	50.9	46.7	45.3	43.1	40.8	36.8	23.1	22.9
EA	139.1	129.6	126.4	121.3	115.9	106.6	77.1	76.3
OP	8.0	7.8	7.6	7.4	7.1	6.6	5.1	5.1
CM-breeding	84.1	73.8	70.7	66.2	61.3	52.7	22.4	22.2
LB-breeding	190.1	180.0	176.4	170.6	164.3	153.9	122.9	121.6
LB-non-breeding	14.5	12.8	12.2	11.5	10.7	9.2	4.2	4.1
HG-breeding	11.9	11.7	11.5	11.3	11.1	10.7	10.0	9.9
HG-non-breeding	108.3	89.8	84.6	77.1	68.7	54.1	0.0	0.0
GB-breeding	9.9	8.5	8.1	7.5	6.9	5.7	1.5	1.4
GB-non-breeding	37.9	34.4	33.3	31.7	30.0	27.0	17.0	16.8
K	31.1	28.0	27.0	25.6	24.0	21.3	12.1	12.0
ML	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
PE	4.1	4.0	4.0	3.9	3.8	3.7	3.5	3.4

Table A7.7.2.3. Predicted transits from the VP averaging model at the all VPs scale.

Population	GE164	N163	V162	E160	GE158	SG155	V150	N149
BY	5.8	5.7	5.7	5.6	5.5	5.4	5.1	5.0
BZ	138.7	126.8	123.1	117.3	111.0	100.3	64.4	63.7
CA	1.9	1.5	1.5	1.3	1.2	0.9	0.0	0.0
CM-breeding	273.4	240.1	230.4	215.8	200.0	172.4	75.4	74.5
CM-non-breeding	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CS	10.4	10.6	10.5	10.4	10.2	10.0	9.5	9.4
EA	213.2	199.0	194.2	186.6	178.4	164.4	119.8	118.5
GB-breeding	146.3	135.8	132.3	126.9	121.1	111.2	79.7	78.9
GB-non-breeding	28.8	26.8	26.2	25.1	24.0	22.2	16.3	16.1
H	15.7	15.6	15.4	15.1	14.8	14.2	12.7	12.6
HG-breeding	1220.6	1183.8	1167.5	1139.7	1110.6	1063.3	949.0	938.6
HG-non-breeding	3268.8	2717.5	2563.2	2336.6	2088.0	1651.2	34.9	34.5
K	270.3	243.2	235.0	222.5	208.9	185.5	105.4	104.3

Population	GE164	N163	V162	E160	GE158	SG155	V150	N149
LB-breeding	224.2	210.3	205.6	198.1	190.1	176.6	135.2	133.7
LB-non-breeding	172.9	163.0	159.6	154.2	148.4	138.8	110.4	109.2
MA	63.7	59.8	58.5	56.5	54.3	50.6	39.7	39.3
ML	1.1	0.9	0.8	0.8	0.7	0.5	0.0	0.0
OP	15.4	13.7	13.1	12.3	11.4	9.9	4.3	4.3
PE	2.6	2.5	2.5	2.5	2.4	2.3	2.2	2.2
SH	51.3	48.9	47.9	46.4	44.8	42.2	34.5	34.1
SN	5.9	5.6	5.5	5.3	5.1	4.8	4.0	3.9
WE	10.6	10.3	10.1	9.9	9.6	9.2	8.3	8.2
WS	171.2	162.6	159.5	154.4	149.0	140.0	113.7	112.5

Table A7.7.2.4. Predicted transits from the VP averaging model at the main VPs scale.

Population	GE164	N163	V162	E160	GE158	SG155	V150	N149
BY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BZ	130.7	120.7	117.4	112.4	106.9	97.6	67.4	66.7
CA	5.7	4.7	4.4	4.1	3.6	2.8	0.0	0.0
CM-breeding	70.7	62.0	59.4	55.6	51.5	44.3	18.9	18.6
CM-non-breeding	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EA	169.6	158.6	154.8	148.8	142.3	131.3	96.3	95.3
GB-breeding	11.4	9.8	9.3	8.6	7.8	6.4	1.4	1.4
GB-non-breeding	36.0	33.5	32.7	31.4	30.0	27.7	20.4	20.2
H	5.3	5.4	5.3	5.2	5.1	4.9	4.2	4.1
HG-breeding	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HG-non-breeding	4134.9	3429.7	3232.6	2943.3	2625.8	2067.7	0.0	0.0
K	32.0	28.5	27.5	25.9	24.2	21.3	11.2	11.0
LB-breeding	188.5	179.4	176.1	170.6	164.8	155.1	127.2	125.9
LB-non-breeding	15.9	14.0	13.5	12.6	11.7	10.1	4.5	4.5
MA	13.4	12.2	11.8	11.3	10.7	9.6	6.2	6.2
ML	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
OP	9.6	9.2	9.1	8.8	8.5	7.9	6.2	6.1
PE	3.7	3.6	3.6	3.5	3.5	3.3	3.1	3.1

Population	GE164	N163	V162	E160	GE158	SG155	V150	N149
SH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WS	238.1	225.5	221.0	213.8	206.1	193.3	155.9	154.2

Table A7.7.2.5. Predicted transits from the Golden Eagle altitudinal bands Stage 1 model.

Zone	GE164	N163	V162	E160	GE158	SG155	V150	N149
0-160 m	46.8	44.0	43.0	41.4	39.7	36.9	27.9	27.6
160-210 m	16.6	15.5	15.2	14.6	14.0	12.9	9.6	9.5

Table A7.7.2.6. Predicted transits from the Golden Eagle Golden Eagle Topography Stage 1 model.

Zone	GE164	N163	V162	E160	GE158	SG155	V150	N149
GET 1-5	17.4	16.6	16.3	15.8	15.2	14.3	11.7	11.6
GET 6-8	32.2	29.9	29.1	27.9	26.6	24.4	17.3	17.1
GET 9-10	27.9	25.8	25.1	24.0	22.9	20.9	14.6	14.4

Table A7.7.2.7. Predicted transits from the Common Gull Stage 1 model.

Turbine	Transits
GE164	167.4
N163	146.8
V162	140.8
E160	131.8
GE158	122.0
SG155	104.9
V150	44.7
N149	44.2

Collision probability results

Table A7.7.2.8. Collision probability values from the Stage 2 model.

Species	GE164	N163	V162	E160	GE158	SG155	V150	N149
WS	0.068	0.069	0.070	0.066	0.069	0.074	0.073	0.076
BY	0.047	0.049	0.050	0.048	0.049	0.053	0.052	0.054
MA	0.044	0.045	0.046	0.044	0.045	0.050	0.048	0.050
CA	0.055	0.057	0.058	0.054	0.056	0.061	0.060	0.062
H.	0.065	0.067	0.068	0.063	0.066	0.072	0.070	0.073
WE	0.061	0.063	0.064	0.060	0.063	0.068	0.067	0.069
SH	0.042	0.043	0.045	0.042	0.043	0.048	0.047	0.048
BZ	0.050	0.051	0.053	0.050	0.051	0.056	0.055	0.056

Species	GE164	N163	V162	E160	GE158	SG155	V150	N149
EA	0.061	0.062	0.063	0.059	0.062	0.067	0.066	0.068
OP	0.052	0.053	0.055	0.052	0.053	0.058	0.057	0.059
GP	0.038	0.039	0.040	0.039	0.039	0.044	0.042	0.043
CS	0.036	0.037	0.038	0.037	0.037	0.041	0.040	0.041
SN	0.037	0.038	0.039	0.038	0.038	0.042	0.041	0.042
CM	0.044	0.046	0.047	0.045	0.046	0.051	0.049	0.050
LB	0.050	0.051	0.052	0.050	0.051	0.056	0.054	0.056
HG	0.051	0.052	0.053	0.050	0.052	0.057	0.056	0.057
GB	0.053	0.054	0.056	0.052	0.054	0.059	0.058	0.060
K.	0.044	0.045	0.047	0.044	0.045	0.050	0.049	0.050
ML	0.041	0.043	0.044	0.042	0.043	0.047	0.046	0.047
PE	0.045	0.047	0.048	0.045	0.046	0.051	0.050	0.051

Collision risk predictions

Table A7.7.2.9. Collision risk predictions for each turbine type for Golden Eagle and Common Gull.

Turbine	Golden Eagle		Common Gull
	alt bands	GET bands	
GE164	0.056	0.068	0.087
N163	0.053	0.064	0.077
V162	0.050	0.061	0.072
E160	0.050	0.061	0.070
GE158	0.049	0.059	0.065
SG155	0.046	0.055	0.058
V150	0.034	0.040	0.024
N149	0.036	0.042	0.026

Table A7.7.2.10. Collision risk predictions for each turbine type for the other species / populations.

Species/ Population	GE164	N163	V162	E160	GE158	SG155	V150	N149
WS	0.18	0.18	0.18	0.16	0.16	0.16	0.13	0.13
BY	0.00046	0.00048	0.00048	0.00045	0.00045	0.00049	0.00045	0.00046
MA	0.047	0.046	0.046	0.042	0.041	0.043	0.033	0.033
CA	0.0017	0.0015	0.0014	0.0012	0.0011	0.00097	0	0
H	0.017	0.018	0.018	0.016	0.017	0.017	0.015	0.016
WE	0.028	0.027	0.028	0.025	0.026	0.027	0.023	0.024
SH	0.037	0.036	0.036	0.034	0.033	0.034	0.027	0.028
BZ	0.12	0.11	0.11	0.099	0.096	0.096	0.06	0.061

Species/ Population	GE164	N163	V162	E160	GE158	SG155	V150	N149
OP	0.014	0.012	0.012	0.011	0.01	0.0098	0.0042	0.0043
CS	0.0063	0.0067	0.0069	0.0065	0.0064	0.007	0.0065	0.0065
LB-breeding	0.047	0.046	0.046	0.042	0.041	0.042	0.031	0.032
LB-non-breeding	0.036	0.035	0.036	0.033	0.032	0.033	0.026	0.026
HG-breeding	0.26	0.26	0.26	0.24	0.25	0.26	0.22	0.23
HG-non-breeding	0.88	0.75	0.72	0.62	0.57	0.5	0.0055	0.0056
GB-breeding	0.033	0.031	0.031	0.028	0.028	0.028	0.02	0.02
GB-non-breeding	0.0065	0.0062	0.0062	0.0056	0.0055	0.0056	0.004	0.0041
K	0.51	0.47	0.47	0.42	0.4	0.4	0.22	0.22
ML	0.00076	0.00065	0.00063	0.00055	0.00049	0.00043	0	0
PE	0.002	0.002	0.002	0.0019	0.0019	0.002	0.0019	0.0019

The collision risk predictions in this table were calculated using the transit data from: the combined VPs models at the main VPs scale for Whooper Swan and non-breeding Herring Gull; the VP averaging models at the all VPs scale for Barnacle Goose, White-tailed Eagle, Common Sandpiper, and Merlin; and the VP averaging models at the main VPs scale for the other populations.