



Islandmore Wind Farm

Environmental Impact Assessment
Report

Annex 5.9: Collision Risk Modelling

Islandmore Wind Farm Limited

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1.1 INTRODUCTION

APEM Group Woodrow was commissioned by Galettech Energy Services (GES) to undertake ornithological survey work for the proposed Islandmore Wind Farm (hereafter referred to as the project). The project is located in Co. Roscommon and is for a ten-turbine wind farm.

The intention of this report is to display modelled data, based on observed bird usage of the area, to provide an indication of the likely collision risk imposed by the proposed wind farm on potentially sensitive avian populations. The report uses bird usage data derived from vantage point (VP) watches conducted by appropriately experienced ornithological surveyors. Furthermore, the new guidance published by Scottish Natural Heritage (SNH) (2007, 2014, 2024) was used, which aims to promote a standardised approach to collision risk assessment for onshore wind farms, to increase the transparency of calculations and to promote greater confidence in the results. A detailed report is available explaining the derivation of the model (Band 2024).

Flightline data for selected target species was collected from four VPs between October 2021 and September 2023. The survey period covered two breeding seasons and two non-breeding seasons of VP watches. This amounted to a total of 582 hours of VP watch data (294 hours during the non-breeding seasons and 288 hours during breeding seasons). Further information on VP locations and survey effort can be found in the main ornithological report (**Annex 5.7**) and supporting documentation (see **Annex 5.7b** and **5.7c**), which provide details of timings for VP watches and demonstrates that the minimum requirement of 36 hours per VP per season was achieved over the two-year survey period.

Two turbine models have been specified for use in the proposed development; one with a hub height of 104m, a rotor diameter of 162m and an overall tip height of 185m, and a second with a hub height of 82m, a rotor diameter of 136m and an overall tip height of 150m. The Vestas V162-7.2MW (V162) and the Vestas V136-4.5MW (V136) turbines have been utilised as models representative of these dimensions. The model has been run for each turbine model based on turbines T1-T3 comprising the V162 and turbines T4-T10 comprising the V136. The collision risk zone (CRZ, defined as the height between the minimum and maximum swept height of the turbine rotor within a 500 m buffer of turbines) is 14-150 m for the V136 and 23-185 for the V162 model, as detailed in **Table 2**.

Based on professional judgement, Collision Risk Modelling (CRM) was run for target species with a total aggregate flight time (i.e., number of individuals x flight time) of > 300 seconds occurring within the potential CRZ over the two years (i.e. at collision risk height and within the turbine envelope = 500 m turbine buffer), and with more than 3 observations over the study period. Target species with an aggregate flight time of < 300 seconds were excluded from this analysis as collision risk for them would be negligible. Based on the criteria outlined above, CRMs were run for the following three target species (**Table 1**).

Species	Total flight time (seconds) recorded across all height bands
Curlew	478
Golden plover	174,441
Kestrel	458

Table 1: Target species total aggregated flight time within the 500m turbine buffer over three years of surveys

Further information on the species recorded within the 500m turbine buffer along with the number of observations per species can be found in the Ornithological Baseline Report (**Annex 5.7**).

1.2 METHODOLOGY

The collision risk analysis was undertaken using the SNH model and guidelines (Band 2000, 2024, Band et al. 2007). The SNH model uses two approaches for different situations (SNH 2024). The first approach is for birds that take regular flights through a wind farm area and the second is for birds that may occupy an area, including a wind farm, as a regular territory. The model approach used in this case is the second, relating to birds occupying a given area.

The model estimates the number of collisions through a process of five stages:-

- Stage A utilises bird survey data that has been collected through the VP surveys (detailed in **Annex 5.7c**), to establish the density of flying birds within 500m of turbines, and the proportion of birds that are flying at a potential risk height between the lowest and highest points of the rotors;
- Stage B estimates the potential number of bird passages through rotors in the relevant time period, based on both the bird density, and the proportion of birds flying at risk height;
- Stage C determines the collision probability during a single bird rotor transit;
- Stage D estimates the rate of potential collision for a given bird species based on current levels of bird usage of the site, whilst taking into consideration the proportional of time in which the turbines are not in operation;
- Stage E takes into consideration the likely proportion of birds avoiding either the wind farm or its turbines. This may either be due to displacement from the site, birds undertaking evasive action or birds being attracted to the wind farm, for example, as a response to habitat changes; and,
- Stage F considers potential uncertainties and an estimate of error in the number of predicted collisions.

1.2.1 STAGE A - FLIGHT ACTIVITY

Stage A estimated the number of flights that may potentially be at risk of turbine collision in the absence of the displacement of birds, birds taking other avoidance actions, or birds being attracted towards the wind farm.

In the case of non-directional flights, there are two key parameters derived from survey observations that are needed in order describe the magnitude of flight activity:-

- Areal bird density (DA); and,
- Proportion of birds flying at risk height (Q2R)

The definition of areal bird density (DA) is the number of birds that are in flight at any height at a particular time, per unit area (generally per square kilometer, km²). Bird occupancy was converted to areal bird density (per m²) by dividing by the area watched from each VP (the VP viewshed, shown in **Annex 5.7b**). The flight activity from VP watches was recorded in bird seconds, which is particularly appropriate for low bird numbers. DA was calculated as shown in Equation 1.

$$DA = b / (t \times A) \text{ birds } m^{-2} \text{ (Equation 1)}$$

where:-

- (b) is the number of target species flight seconds recorded from a VP;
- (t) is the duration (in seconds) of all VP watches during either a month, season or year; and,
- is the area of the VP viewshed (km²) as shown in **Annex 5.7b**.

DA was calculated for each VP separately, with the figure subsequently averaged. However, where there exists a considerable difference in the time and/or area that is covered by relevant VP surveys the average figure should be weighted appropriately. Thus, the weighting factor used acknowledges that the quantity of data collected in a watch is proportional both to the size of the area observed and the duration of the VP watch.

The mean density DA is calculated using Equation 2:-

$$\text{Mean density } DA = \sum b_i \sqrt{(t_i \times A_i)} / (\sum t_i \times A_i) \text{ (Equation 2)}$$

In the case of conditions where a VP viewshed results in a significant difference in mean density DA (for example, due to a difference in underlying habitat), the bird density should then either be calculated separately for each individual VP site and then applied to determine the likely collision risk within that area. Alternatively, a turbine-weighted average bird density should be employed instead, i.e. the bird density for each VP should be weighted by the number of turbines present within that viewshed.

In this case, the average areal bird density (D average) was estimated using Equation 3.

The formula for this is:-

$$D_{\text{average}} = \sum (N_i \times D_i) / \sum N_i \text{ (Equation 3)}$$

where:-

- D_i is the areal bird density within the VP viewshed (i);
- N_i is the number of turbines to be sited in that VP viewshed; and
- D_{average} is the average areal bird density.

The definition of proportion of birds flying at risk height (Q2R) is the proportion of birds present between the lowest and highest points of a rotor, measured relative to the rotor base. In cases where flights are only recorded in the rotor swept height band, Q2R will be 100%.

1.2.1.1 Daylight Hours and Nocturnal Activity

Bird surveys are generally undertaken diurnally, with recorded levels of flight activity assumed to be representative of flight activity across all daylight hours. Daylight hours depend on the wind farm site's latitude and the time of year. Daylight and night hours per month are provided within the NatureScot CRM spreadsheet when the latitude of a particular site is inputted. The latitude of the wind farm site is expressed as degrees and minutes in degrees with decimal places. This data is subsequently utilised to calculate the daylight hours for each given month. The latitude of the wind farm site in question is 53° 56' north (entered in decimals as 53.93°).

Calculations used in the collision model account for collision risk associated with

diurnal and nocturnal flights. Diurnal activity is based on the flight activity recorded for each target species during field surveys. As nocturnal surveys were not possible, nocturnal flight activity is based on the diurnal flight activity, and professional judgement regarding the likely levels of nocturnal activity for each target species.

Levels of nocturnal activity by all target species were estimated, using a one to five scale to approximate nocturnal flight (with a score of one equal to 0% nocturnal activity, two equal to 25% of diurnal activity, three equal to 50% of diurnal activity, four equal to 75% of diurnal activity and five whereby nocturnal activity is equal to diurnal activity, see Table 3. It should be noted that for truly nocturnal species, this will underestimate nocturnal flight activity, which will be >100% of diurnal activity.

1.2.2 STAGE B - ESTIMATING NUMBER OF BIRD FLIGHTS THROUGH ROTORS

The total amount of bird transit flights anticipated through rotors is proportional to the number of turbines, as well as the cross-sectional area of the turbine rotors, and the density of birds in the airspace flying at risk height (calculated at Stage A). The total number of bird transits through rotors was calculated separately for each month. Therefore, a key output within the collision risk assessment is a statement of the potential number of bird transits per month and season or year through the wind farm turbines, assuming that birds exhibit no avoidance behaviour. As such, the risk of collision is considered to be directly proportional to the potential number of bird transit flights.

Stage B considers the available figures for bird density (DA), the proportion of risk height flights (Q2R), the nocturnal activity factor (f_{night}), and the figures for monthly daylight and night hours calculated at Stage A. In order to estimate the number of birds flying through rotors, the model takes into account the number of turbines, the turbine rotor radius and the flight speed of the target species. For flight speed, a typical mean flight speed is selected based on standard key literature, acknowledging that flight speed (and thus collision risk) will vary depending on bird behaviour (commuting, migration, foraging etc).

The number of bird transits expected through rotors was calculated using Equation 4.

$$\text{Number of transits} = v * (\text{Daverage } Q2R / 2R) * (T \pi R^2) * (t_{\text{day}} + f_{\text{night}} t_{\text{night}})$$

(Equation 4)

where:-

- v is bird speed, relative to the ground (m sec⁻¹);
- D_{average} is the average areal bird density (Birds m⁻²);
- $Q2r$ is the proportion of birds flying at risk height (%);
- R is the length of the rotor blades, from axis to tip (m);
- T is the number of turbines;
- f_{night} is the nocturnal activity factor; and,
- t_{day} and t_{night} the wind farm latitude is used to calculate daylight and night-time hours for each month, and the total for a year.

1.2.3 STAGE C- PROBABILITY OF COLLISION FOR A SINGLE ROTOR TRANSIT

Stage C utilises information on turbine size and speed (**Table 2**), as well as physical details on bird size and speed in order to accurately calculate the collision risk for birds flying through an active turbine rotor (**Table 3**).

It is presumed that birds have the ability to avoid stationary infrastructure. This model therefore estimates the likely probability of collisions occurring if a bird passes at random at any point through the rotor disk on a flight path perpendicular to the rotor plane. The collision probability for birds approaching at an oblique angle is the same as the probability for those approaching at a perpendicular angle; there is no additional effect of turbulence in the wake of a rotor blade; and also, no slipstream effect, i.e. air rushing over a blade may carry a bird clear of it.

Due to the geometry of the blades relational to the direction of flight, upwind flights carry a higher collision risk than downwind flights. This remains the case even when the flight speed of the bird relative to the ground is taken to be the same. In situations where there is an equal likelihood of both upwind and downwind flights, it is considered suitable to take an average of both collision probabilities. As such, the relative proportion of both upwind and downwind flights was utilised in this case to weigh the respective probabilities of collision. The default proportion was set to a probability of 50:50 upwind:downwind.

The NatureScot CRM spreadsheet provides a collision risk calculator for a single passage through the rotor. This calculator assesses the collision risk probability for a bird taking a single passage flight through a rotor at each radius (r) and angle (ϕ), in increments from $r/R=0.05$ out to $r/R=1$, and at 10-degree intervals of ϕ . The probability of collision was then averaged out over the entire area of the rotor disc to generate the average collision risk for a passage at any given point across the rotor.

By design, wind turbines operate at a range of various speeds. Typically, wind turbines do not operate below a cut-in speed, which is generally between three and four m/sec. The turbines then increase in speed in line with wind speed, up to a maximum operating wind speed of around 12 m/sec.

The model assessed the probability of collision risk using the turbine rotational speed for the two turbine models. In such cases where wind turbines operate at a range of different rotational speeds, the calculation should be carried out using a mean operational turbine speed. Preferably, the mean speed utilised in the calculation should be measured over time using an analysis of available wind data to determine the likely frequency distribution of turbine speeds. However, in cases where this is not available, the speed used should be based on the most likely value as anticipated by the wind farm developer. At Stage D of the model, an allowance is made to account for the proportion of time in which a wind turbine is not in operation. This may be due either because of low wind speeds or maintenance being carried out on the turbine. In this case, the mean turbine speed used in the calculation takes only the operational time of the turbine into account and excludes times when the turbine was idle or stationary.

Symbol	Description	Units	Turbine model	
			V162	V136
b	Number of blades		3	3
	Hub height	m	104	82
R	Rotor radius	m	81	68
	Minimum swept height	m	23	14
	Maximum swept height	m	185	150
C	Maximum blade width	m	4.8	4.1
γ	Average blade pitch*	°	9	9
Ω	Average rotation speed	rpm	5.71	5.45
	Average rotational period	s	10.5	11

Table 2: Turbine Data

Note: Pitch angle varies along the length of the blade, from a high angle close to the hub, to a low pitch angle towards the blade tips, i.e. the blade is twisted. Pitch angle also varies as the pitch is controlled to alter the rotation speed of the turbine. In the model, an average angle is used, representing an average pitch along the blade length. 6-15 degrees is reasonable for a typical large turbine.

Target species	Bird length (m)	Wingspan (m)	Bird speed (m/s)	% of flight upwind/downwind	Nocturnal activity (From 1 to 5)	Avoidance rate*
Curlew	0.55	0.9	16.3	50/50	2	0.980
Golden plover	0.28	0.72	17.9	50/50	2	0.998
Kestrel	0.34	0.76	10.1	50/50	1	0.950
*Source SNH 2018, 2024 and Furness 2019 T Gittings (2022)						

Table 3: Bird Data and Avoidance Rates for Target Species

1.2.4 STAGE D - MULTIPLYING TO YIELD EXPECTED COLLISIONS PER YEAR

1.2.4.1 Single Transit Risk

Stage D multiplies the number of flights through rotors across the wind farm (Stage B) and the risk of collision for each single bird transit through a rotor (Stage C) to yield an estimate of total potential collision risk using Equation 5.

$$\text{Single transit risk} = (\text{No. of bird transits through rotors} * \text{Weighted probability of collision single}) / 100 \quad (\text{Equation 5})$$

1.2.4.2 Non-Operational Time

The factor Qop accounts for the time in which the turbine is not in operation, by representing the proportion of time in which the turbine is operational. Wind turbines are not in constant operation. Generally, a wind turbine is either idle or at rest for a certain proportion of time due either to wind speeds being too weak to generate power or, in exceptional cases, due to the turbines being intentionally shut down in order to avoid damage in the event of exceptionally high winds. Additionally, there is a requirement that wind turbines are occasionally shut down to allow for maintenance to be carried out.

Finally, the single transit risk is multiplied by the factor Qop to allow for the proportion of time that the wind turbines are operational. This is before considering avoidance behaviour, which is stage E.

1.2.5 STAGE E- APPLYING THE AVOIDANCE RATE

1.2.5.1 Avoidance

The preceding stages of the model operate on the assumption that birds will not undertake any avoidance action in response to the presence of wind turbines. However, birds do generally undertake avoidance action in order to prevent wind turbine collisions. Data derived from collision monitoring based on frequent searches of the wind farm site for bird corpses and observations of habitat use in the vicinity indicates avoidance rates of 98% and over for many bird species. This data therefore indicates the collision risk to be less than 2% of that calculated from Stages A-D alone.

During this project, the potential collision mortality, for each month and for a year, after avoidance was calculated using a range of assumed avoidance rates of 95%, 98%, 99% and 99.5%.

1.2.5.2 Large Turbine Array Correction Factor

The large turbine array correction factor should be included only for large wind farms developments (more than 50 turbine wind farm). Therefore, this is not a requirement for the project site and there is no need for further discussion.

1.2.6 STAGE F - EXPRESSING UNCERTAINTY

In the estimate of collision risk following the method detailed above, there exists numerous sources of variability or uncertainty in the output. Band (2024) sets out an accurate description of potential sources of uncertainty, as well as a procedure of evaluating and presenting these sources.

The aim of this stage is to reflect the range of uncertainty in the collision estimate that could impact target species populations and/or growth rates. Information to include should reflect:-

- uncertainty or variability in flight activity data, such as imprecise flight height estimates and lack of knowledge about night-time behaviour;
- uncertainty surrounding the limitations of the collision model, such as the variability of bird dimensions and flight speed, the simplification in the shape of a bird and turbine blades; and
- uncertainty arising from turbine options such as the number, size and speed.

1.3 RESULTS

1.3.1 VIEWSHED SPATIAL COVERAGE

The VP locations used were the same during two-year survey period October 2021 to September 2023. Viewshed analysis was undertaken to determine spatial coverage from each VP. This was calculated using ArcGIS Pro, and the accuracy of viewsheds was confirmed in the field by surveyors. The viewshed analysis was calculated using a surface offset of 14m (the lowest rotor swept height of both turbine models) which mapped visible airspace available to surveyors (of an assumed height of 1.75m) at 14m. This illustrates the visible area at collision risk height.

Given the difference in size (and location) between the proposed turbine models, the 500m turbine buffer was comprised two areas, a northern sector that included only three turbines and was covered by VP2 and VP4 and a southern sector that included the remaining seven turbines and was covered by all four VPs .

Spatial coverage of the viewsheds within the 500m turbine buffer is given as a proportion in **Table 4** (Northern sector) and **Table 5** (Southern sector). The locations of the VPs and their viewsheds are mapped in **Annex 5.7b**.

VP	Area of CRZ visible within 500 m turbine buffer (Km ²)	% Coverage of the 500 m turbine buffer	VP survey effort (hrs)		
			Non-breeding season (Oct - Mar)	Breeding season (Apr-Sep)	Total
VP1	3.27	80.37	75	72	147
VP2	2.21	54.23	72	72	144
VP3	1.59	39.02	74	72	146
VP4	1.55	38.06	73	72	145
Total	4.07	100.00*	294	288	582

*This is the total area within the 500m turbine buffer that is covered by at least one viewshed

Table 1: Viewshed coverage of 500m buffer of turbines located in the Southern sector and VP survey effort

VP	Area of CRZ visible within 500 m turbine buffer (Km ²)	% Coverage of the 500 m turbine buffer	VP survey effort (hrs)		
			Non-breeding season (Oct - Mar)	Breeding season (Apr-Sep)	Total
VP2	0.714	43.43	72	72	144
VP4	1.620	98.54	73	72	145
Total	1.64	100.00*	145	144	289

*This is the total area within the 500m turbine buffer that is covered by at least one viewshed

Table 5: Viewshed coverage of 500m buffer of turbines in the Northern sector and VP survey effort

1.3.2 STAGE A: FLIGHT ACTIVITY

1.3.2.1 Bird Density

VP watches have been undertaken over two years (two breeding seasons and two non-breeding seasons), covering the entire site plus a buffer area of 500 m around the proposed turbine locations (100% coverage, see **Annex 5.7b**). The project site was covered from four VP locations. Overlapping viewsheds are discussed in **Table 4** and **Table 5**. Two separate CRMs were built for each section of the study area, one for the Northern sector that includes three turbines, and the proposed turbine model was the V162 and another for the Southern sector that included the remaining seven turbines, and the proposed turbine model was the V136.

VP watches were undertaken for a minimum of 72 hours per year; 36 hours during the breeding season (April – September) and 36 hours during the non-breeding season (October – March) in each of two years in line with SNH guidance (SNH, 2017, 2018). The watches were divided into sessions of less than three hours in duration with breaks between sessions to limit observer fatigue, and the sessions spread to include a representative sample of daylight hours. All flights of target species were recorded during each watch period, yielding total flying time in bird-seconds throughout the watch. Flying time was divided by the period of the watch (in seconds) and the area watched to give the average density of birds in flight per square kilometre.

Survey results are presented in **Table 6**. The number of VP watches is detailed in the Ornithological Baseline Report (see **Annex 5.7**), including flightlines tables and maps.

Flight times within the study area (500 m turbine buffer) and the analysis period are provided in **Table 6** for the three target species included in the model.

It should also be noted that, golden plover is a winter visitor in Ireland, which also remains during the passage season (i.e., the month of April) and this was accounted for in the model. There are also localised breeding populations of golden plover in Ireland, however no breeding birds were recorded during baseline surveys.

The mean density (DA) is given in **Table 6** for each target species and was calculated for each period (breeding and non-breeding); except for golden plover where the DA was estimated using flight time recorded during the non-breeding season and the month of April.

Target species	Analysis Period	Time in flight (bird-secs)				Northern sector: DA (birds/km ²)		Southern sector: DA (birds/km ²)	
		VP1	VP2	VP3	VP4	Non-breeding season	Breeding season	Non-breeding season	Breeding season
Curlew	Year-round	13	411	-	54	0.001	0.0001	0.0002	0.00003
Golden plover	Non-breeding (+ April)	-	173,099	1,342	-	0.468	-	0.076	-
Kestrel	Year-round	36	210	30	182	-	0.001	0.00001	0.0002

*Birds recorded in April were included in the density estimation for the non-breeding period, as these were birds recorded on passage, rather than breeding birds.

Table 6: Flight seconds and mean bird density for all target species during two years of survey in the Northern and Southern sector

1.3.2.2 Proportion Flying at Risk Height

The assessment considers two turbine options of which have rotor swept heights of 14-150 m (V136) and 23-185 m (V162) respectively (see **Table 2**). The surveys recorded the flight heights of birds, estimated visually. The proportion of observed birds at rotor risk height (or within the CRZ), was calculated for the Northern sector (turbine model V162) and for the Southern sector (turbine model V136) (**Table 7** and **Table 8**), respectively.

It is important to note that since there were no curlew and kestrel observed at rotor risk height (%Q2R) during all VP watches in the Northern sector, these species were removed from further CRM analysis, and only golden plover CRM was run for the Northern sector.

Target species	Number of birds observed	%Q2R for V162
Curlew	30	0.00
Golden Plover	2,580	24.11
Kestrel	8	0.00

Table 7: Proportion of observed birds flying at rotor risk height (%Q2R) during all VP watches in the Northern sector

Target species	Number of birds observed	%Q2R for V136
Curlew	37	35.14
Golden Plover	2,646	25.70
Kestrel	14	42.86

Table 8: Proportion of observed birds flying at rotor risk height (%Q2R) during all VP watches in the Southern sector

1.3.3 STAGE B: ESTIMATING NUMBER OF FLIGHTS THROUGH ROTORS

The output from Stage B is the potential number of bird transits through rotors, per month and per annum (**Table 9**). The total number of bird transits expected through rotors is proportional to the number and cross-sectional area of the rotors, and to the density of birds in the airspace at risk height or in the CRZ.

Model	Target species	Projected number of rotor transits												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
V162	Golden plover	1,029	1,028	1,272	-	-	-	-	-	-	1,194	1,033	995	6,551
V136	Curlew	1	1	1	-	-	-	-	-	-	1	1	1	6
	Golden Plover	302	302	374	-	-	-	-	-	-	351	303	292	1,924
	Kestrel	-	-	-	1	1	1	1	1	1	-	-	-	6

Table 9: Potential Number of Bird Transits through Rotors per Month and Year

1.3.4 STAGE C: PROBABILITY OF COLLISION FOR SINGLE ROTOR TRANSIT

Data relating to the likelihood of a bird being hit when flying through the rotor is derived from the NatureScot CRM spreadsheet. The outputs are provided for each target species in **Table 10**.

Target species	Average single transit	
	V162	V136
Curlew	4.75%	4.91%
Golden plover	4.35%	4.56%
Kestrel	4.67%	4.79%

Table 10: Probability of collision for a single rotor transit for target species

1.3.5 STAGE D: MULTIPLYING TO YIELD EXPECTED COLLISIONS PER YEAR

Following the above steps, the number of bird transits per year through the rotors can be combined with the probability of a bird being hit when flying through the rotor to give a likely collision rate per month and per year (assuming no avoidance). An avoidance figure is then applied to get a predicted likely collision rate, and thus a likely mortality rate. This stage considers the proportion of time that turbines are likely to be operational. The collision rate before this avoidance figure is applied is illustrated in **Table 11**.

Model	Target species	Collision rate before avoidance												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
V162	Golden plover	38.03	37.99	47.01	-	-	-	-	-	-	44.15	38.19	36.78	242.17
V136	Curlew	0.04	0.04	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.04	0.04	0.04	0.30
	Golden plover	11.72	11.70	14.48	-	-	-	-	-	-	13.60	11.76	11.33	74.59
	Kestrel	-	-	-	0.04	0.04	0.05	0.05	0.04	0.03	-	-	-	0.25

Table 11: Collision Rate before Avoidance for Target Species

1.3.6 STAGE E: APPLYING THE AVOIDANCE RATE

NatureScot (2018) guides the use of avoidance rates in collision risk assessments. Collision risks have been calculated using the avoidance rate suggested by SNH (2018) except for Golden plover (Gittings, 2022) (**Table 3**) to provide estimates of the number of collisions per annum, per decade and for the operational lifespan of the project (40 years) (**Table 12**).

Table 12 provides the collision probability of the selected target species passing through the rotors, taking into account different avoidance rate estimates for the non-breeding and breeding seasons and years. Species in bold denote a rate of more than 0.05 collisions per year.

Taking into account the V136 model, the CRMs generated low levels of theoretical collision risk (i.e. less than 1 collision per decade, with SNH suggested avoidance rate) over the 40-year life span of the project for curlew and kestrel (**Table 12**). This level of predicted collisions would be considered negligible and would not affect these species at the population level, i.e., collision-mediated mortality would not add significantly (>1%) to background levels of mortality.

Higher levels of predicted collision risk (i.e. more than 1 collision per decade), with the use of Gittings, (2022) 0.998 avoidance rate for golden plover, were predicted for both turbine models (**Table 12**).

These levels of predicted collision risk warrant further investigation in terms of potential effects on these species populations. The population-level consequences of predicted collision risks can be assessed by considering the additional mortality that would be caused (assuming that the collision risk is non-additive) relative to background mortality rates in the population, with a threshold level of a 1% increase in annual mortality used to determine whether the impact will be significant (Percival, 2003). Estimates of the potential increase in annual mortality rates for target species are delineated within the species account in **Chapter 5** of the EIAR.

Turbine	Target species	Collision rate after 0.95 avoidance			Collision rate after 0.98 avoidance			Collision rate after 0.99 avoidance			Collision rate after 0.998 avoidance ¹			Per decade using suggested avoidance rate*	Per 40 years using suggested avoidance rate*
		NB	B	Year	NB	B	Year	NB	B	Year	NB	B	Year		
V162	Golden plover	12.108		12.108	4.843		4.843	2.422		2.422	0.484		0.484	4.84	19.36
V136	Curlew	0.013	0.003	0.016	0.005	0.001	0.006	0.003	0.001	0.003				0.06	0.24
	Golden plover	3.73		3.73	1.492		1.492	0.746		0.746	0.149		0.149	1.49	5.96
	Kestrel		0.011	0.011		0.004	0.004		0.002	0.002				0.11	0.44

Table 12: Collision rate estimated by the non-breeding (NB) and the breeding seasons (B) and year-round, applying different avoidance rates

**Golden plover 0.998, Curlew 0.98 and Kestrel 0.95 avoidance rate*

¹ Use of 0.998 for golden plover only (Gittings, 2022).

1.3.7 STAGE F: EXPRESSING UNCERTAINTY

As outlined in NatureScot guidance, it is important to consider potential uncertainties when interpreting predicted collisions and quantifying this uncertainty as much as possible. There are many sources of uncertainty throughout the CRM process, however these generally fall into three main categories:-

- Uncertainty or variability in the survey data collected;
- Uncertainty arising from limitations which are inbuilt into the CRM due to the requirement for simplification; and,
- Uncertainty arising from turbine specifications.

Uncertainty can arise during data collection, for example imprecisions when mapping the location of flights or categorising flight heights. This has been limited as much as possible by using experienced surveyors, and the same survey team throughout the survey programme. Data has been collected over multiple years to increase robustness; however, it should be acknowledged that data is recorded over a relatively short survey period and is extrapolated to predict activity across the year. The inability to collect nocturnal survey data means that there is uncertainty in predicted nocturnal flight activity throughout the operational phase, however significant nocturnal activity is only predicted for snipe. It is considered that data collection introduces uncertainty of $\pm 20\%$.

The NatureScot CRM model contains simplifications, for example assuming uniform bird dimensions and flight speeds, and simplifications of turbine blade dimensions. This is inaccurate due to inherent natural variability within species populations and different flight speeds associated with different activities (commuting, hunting, display etc), however it is necessary to ensure that the model is not overly complex. It is considered that simplifications in the model introduce uncertainty of $\pm 20\%$.

The turbine model dimensions used in the CRM have been provided by the client and are based on specifications for the proposed turbine model that will be used when the project is constructed. However, an allowance for turbine micro-siting means that there is uncertainty over the precise turbine layout, while their average rotor speed is assumed based on the highest and lowest possible rotor speeds. It is considered that simplifications relating to the turbine model and layout introduce uncertainty of $\pm 10\%$.

Overall uncertainty can be quantified by combining the three sources of uncertainty using the following equation.

$$\sqrt{(0.2)^2 + (0.2)^2 + (0.1)^2}$$

This gives an overall uncertainty of $\pm 30\%$.

1.4 SUMMARY

The model presents very low-levels theoretical collision risk for both Curlew and Kestrel not amounting a single predicted collision over the 40-year operational life. For both these species collision risk would appear to be negligible for the life span of the development.

For golden plover the model predicts a theoretical collision rate of 4.84 for the V162 and 1.49 for the V136, combined predicating 6.33 collisions per decade. Theoretical collision risk would appear to be low but will be further examined against background mortality and tested for any population level effects greater than 1% within the EIAR.

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