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Illaunbaun Wind Farm - Environmental Impact Assessment Report

Appendix A08-08: Collision Risk Modelling

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Quality Assurance

The findings outlined within this report and the data we have provided are to our knowledge true and express our bona fide professional opinions. This report has been prepared and provided in accordance with the Chartered Institute of Ecology and Environmental Management (CIEEM) Code of Professional Conduct. Where pertinent CIEEM Guidelines used in the preparation of this report include the *Guidelines for Ecological Report Writing* (CIEEM, 2017a), *Guidelines for Preliminary Ecological Appraisals* (CIEEM, 2017b) and *Guidelines for Ecological Impact Assessment in the UK and Ireland. Terrestrial, Freshwater, Coastal and Marine* (CIEEM, 2024). CIEEM Guidelines include model formats for Preliminary Ecological Appraisal and Ecological Impact Assessment. Also, where pertinent, evaluations presented herein take cognisance of recommended Guidance from the EPA such as *Draft Guidelines on the information to be contained in Environmental Impact Assessment Reports* (EPA, 2017), and in respect of European sites, *Managing Natura 2000 sites. The provisions of Article 6 of the 'Habitats' Directive 92/43/EEC* (European Commission, 2018).

Due cognisance has been given at all times to the provisions of the *Wildlife Acts 1976 - 2024,* the *European Union (Natural Habitats) Regulations. SI 378/2005*, the *European Communities (Birds and Natural Habitats) Regulations 2011,* EU Regulation on Invasive Alien Species under *EU Regulation 1143/2014*, the EU Birds *Directive 2009/147/EC* and the EU *Habitats Directive 92/43/EEC*.

No method of assessment can completely remove the possibility of obtaining partially imprecise or incomplete information. Any limitation to the methods applied or constraints however are clearly identified within the main body of this document.

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Notice

This report was produced by INIS Environmental Consultants Ltd. (INIS) on behalf of GDG, the client, for the specific purpose of undertaking an assessment of collision risk for target bird species at the proposed Illaunbaun Wind Farm, Co. Clare, with all reasonable skill, care and due diligence within the terms of the contract with the client, incorporating our terms and conditions and taking account of the resources devoted to it by agreement with the client.

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Appendices

1. INTRODUCTION

Inis Environmental Consultants Ltd. (INIS) was commissioned to undertake an assessment of collision risk for potentially sensitive avian receptors at the proposed Illaunbaun Wind Farm in Co. Clare using standardised Collision Risk Modelling (CRM) methods.

1.1. Constraints and Limitations

There are a number of constraints and limitations associated with pre-planning ecological assessments of potential development sites, as well as constraints and limitations inherent to the collection and analysis of field-based ecological data (Band *et al.*, 2012; SNH, 2017).

The data evaluated here comprises:

- Bird flight data from three timed Vantage Point (VP) watches, clipped to the proposed development footprint with a 1km buffer and consisting of flights within the rotor-swept heights (20-200 m). Flight duration (in seconds) for all bird observations, along with data relevant to each flight record (date, timing, weather conditions, VP location (number), etc.), are included;
- Vantage Point survey effort data (recorded as hours of observations) on a monthly basis during the breeding season (April to September for 2023 and 2024) and wintering season (October 2023 to March 2024 and September 2024 to March 2025) for all VP survey work undertaken;
- Area viewed from each VP collectively (in hectares);
- Area of the wind farm footprint (plus 1km buffer) as indicated above; and
- Description and metrics for the wind farm as a whole, as well as for individual turbines.

This collision risk model relates specifically to the VP survey data from the three VPs. In particular any variation in the flight data, coverage of the VPs surveyed during fieldwork, layout of the wind farm or individual turbine specifications, including upper and lower rotor swept heights, would require the outputs from this model to be amended. The model presented is specific to the Vestas V-117 turbine model.

Note that the methodology presented here involves using a 1km buffer to clip flight lines. This is beyond the minimum 800m buffer indicated by Best Practice guidelines (SNH, 2017). Therefore, the CRM results presented here indicate a substantially more conservative (i.e. higher) estimate of collision risk than is likely to be the case by incorporating additional flight lines within this extended buffer. This precautionary approach therefore allows a more robust evaluation of potential impacts (if any) arising from the data presented here.

For field-based surveys, the availability of suitable weather conditions for completing surveys, with good visibility and little wind or rain of paramount importance to ensure birds are flying during the survey period, must be considered. The avian flight data presented here were all collected in optimal weather conditions, as determined by Best Practice Guidance. In some circumstances, this required re-arrangement of monthly schedules, with some VPs being surveyed twice in one month to compensate for months when no survey work took place. These are clearly indicated within the data and are presented in **Appendix A**. It should be noted that such scheduling falls well within the tolerances of Best Practice guidelines for such survey work. In all cases, Best Practice guidance on selection and surveying at VPs has been adhered to throughout the work being reported.

When recording birds in flight, exact determination of ground location and flight height, both of which are essential to calculating collision risk, can be subject to variation between observers. It is therefore required to allow some margin of error for determining the exact location of flying birds, and this has been included within the CRM presented here by the inclusion of all recorded flight lines in an expanded 1km buffer zone, and also including data from all flight lines that intersect with this extended buffer, i.e. if a flight line originated within the buffer zone, but flew beyond the 1km boundary, the flight was continuously recorded, and the time flying outside the buffer also included within the CRM calculations. Similarly for flight height, with a lowest swept area of 33m and a maximum swept height of 150m within the Turbine Range proposed for Illaunbaun Wind Farm, all bird records consisting of flight heights between 20m and 200m are included in the model. This expanded range to include flightlines makes the overall model more robust (i.e. it inflates the collision risk assessment).

Flight speed for individual species being assessed forms part of the CRM. Flight speeds are taken from Alerstam et al. (2007). Note that golden plover (*Pluvialis apricaria*) are not listed in that study; data for the closely-related and morphologically similar grey plover (*Pluvialis squatarola*) are used.

Collectively, the inclusion of these data offer additional precautions (i.e. it increases the collision liklihood) in determining collision risk, offering a more conservative approach to assessment, supporting more robust outputs and therefore interpretation of results than would otherwise be the case.

1.2. Statement of Authority

Dr Alex Copland BSc PhD MIEnvSc MCIEEM is Technical Director with INIS and undertook the Collision Risk Modelling. He has over 30 years of professional experience working in both statutory and private companies, in third-level research institutions and with environmental NGOs. He is proficient in experimental design and data analysis and has managed several large-scale, multi-disciplinary ecological projects. These have included research and targeted management work for species of conservation concern, the design and delivery of practical conservation actions with a range of stakeholders and end-users, education and interpretation on the interface between people and the environment and the development of co-ordinated, strategic plans for birds and biodiversity.

He has written numerous scientific papers, developed and contributed to evidence-based position papers, visions and strategies on birds and habitats in Ireland. He has supervised the successful completion of research theses for several post-graduate students, including doctoral candidates. He lectures to both undergraduate and post-graduate students at UCD, as well as being a collaborative researcher with both UCD and UCC. He also sits on the Editorial Panel of the scientific journal, *Irish Birds*, and CIEEM's *Irish Policy Group*.

Ms Camille Groh BSc MSc ACIEEM reviewed this report. She is an Ecologist and Project Manager at INIS with a BSc (Hons) in environmental science from Northeastern University and an MSc (Hons) in wildlife conservation and management from University College Dublin. Camille regularly conducts a range of bird, habitat, terrestrial mammal and amphibian surveys in-line with Best Practice standards. She also undertakes Collision Risk Modelling (CRM) for proposed Wind Farm sites. Camille has experience writing Ecology Survey Reports and Ecological Impact Assessments. Her work studying Irish and British avifauna communities was published in Ecology and Evolution. Camille is a qualifying member of the Chartered Institute of Ecology and Environmental Management.

1.3. Site and Development Description

The Proposed Illaunbaun Wind Farm is located in Co. Clare, c.4km northeast of Milltown Malbay and c.5km southeast of Lahinch. The receiving environment for proposed development includes agricultural grassland and coniferous forestry. There is also a lake, Lough Keagh, adjacent to the site.

The layout of the proposed development consists of six turbines, with the Vestas V-117 4MW identified as the preferred option, with a hub height of 91.5m, a maximum tip height of 150m and a lowest swept height of the blade of 33m. Note that all flight data between 20m and 200m is used for the modelling presented here. The specifications of the preferred turbine are shown in **Table 1.1**.

Table 1.1: *Turbine specifications the proposed Illaunbaun Wind Farm.*

Technical information	Data used
Indicated wind turbine model	Vestas V-117
Number of turbines	6
Number of blades per turbine	3
Rotor diameter	117
Rotor radius	58.5m
Hub height	91.5m
Lowest swept height of blade	33m
Rotor blade maximum chord (blade width)	4.00m
Pitch angle of the blade during normal operation[1]	30°
Rotation speed	12rpm
Rotation period	5.0s
Turbine operation time[2]	85%

[1]*The pitch angle of the blade is determined by wind speed, which is variable depending upon geographical location, landscape, local topographic factors, etc. To maintain a constant operating speed for a turbine, altering the pitch angle of the blade is used. This is usually determined by wind speed, with higher wind speeds requiring greater pitch angle to "feather" the wind and thereby control the rotation speed. The figure of 30° used here is derived from Band (2012) which gives an average pitch along the blade length of between 25 – 30 degrees (30° results in greater likelihood of effects and is used within this model which has adopted a precautionary approach to the determination of risk).*

[2] *European Wind Energy Association (2016) gives the average operation time of a turbine of between 70% and 85% of the time; 85% is used in this model as this adopts the precautionary approach.*

1.4. Background to bird species assessed

The species selected for the Collision Risk Model are shown in **Tables 1.2** (breeding season) and **Table 1.3** (wintering season). Species are selected based upon their status as Birds of Conservation Concern in Ireland (BoCCI; Gilbert *et* al., 2021) and likelihood of colliding with turbines (SNH, 2017). Whilst some birds can occur at a site all year round, there tends to be differing activity levels between breeding and non-breeding seasons. This can be seen by the differences in activity between **Table 1.2** and **Table 1.3** where, for example, raptors (e.g. buzzard (*Buteo buteo*), hen harrier (*Circus cyaneus*) and kestrel (*Falco tinnunculus*)) are more regularly observed in summer months compared to winter. Conversely, wintering waders (including golden plover (*Pluvialis apricaria*) and snipe (*Gallinago gallinago*)) are only observed in winter months. To accurately reflect the changing avifauna between seasons, separate CRMs are presented for wintering and breeding seasons.

Target species for the proposed development are based upon likely collision risk as well as their status as Birds of Conservation Concern in Ireland (BoCCI) Red or Amber Lists (Gilbert *et al*., 2021). Target species were:

- All species of waterfowl;
- All species of raptor;
- All species of owl;
- All species of grouse;
- All species of wader; and
- All species of gull.

From this target species list, 12 species were recorded during VP Watches (see **Table 1.2** and **Table 1.3**; raven (*Corvus corax*) was not included in the CRM as it was not identified as a target species (BoCCI Green-listed; Gilbert *et al.*, 2021)). Of the remaining species, only those with sufficient flight activity (defined as a minimum total of five flights or minimum of ten individuals of each target species recorded during each season of analysis; expert judgement indicates that numbers below these thresholds are likely to exhibit negligible collision risk). This resulted in three species being assessed during the breeding season (herring gull (*Circus cyaneus*), kestrel and lesser black-backed gull (*Larus fuscus*); **see Table 1.2**) and six species being assessed for collision risk during the winter season (golden plover, herring gull, kestrel, lesser black-backed gull, snipe and sparrowhawk (*Accipiter nisus*); see **Table 1.3**).

For the six species being assessed, biometric data is required for inputting to the CRM. These are shown in **Table 1.4**, along with the recommended avoidance rates for use with the CRM (SNH, 2017).

Table 1.2: *Breeding season flight data for target species from Vantage Point Surveys.*

Species	Total Number of bouts	Total Number of individuals	Total Duration of bouts	Inclusion in CRM
Buzzard (*Buteo buteo*)	2	2	480	No
Golden plover (*Pluvialis apricaria*)	1	2	40	No
Great black-backed (*Larus marinus*)	3	5	310	No
Hen harrier (*Circus cyaneus*)	3	3	410	No
Herring gull (*Larus argentatus*)	**21**	**46**	**2,179**	**Yes**
Kestrel (*Falco tinnunculus*)	**45**	**46**	**6,039**	**Yes**
Lesser black-backed gull (*Larus fuscus*)	**50**	**131**	**18,399**	**Yes**
Mallard (*Anas platyrhynchos*)	1	1	35	No
Raven (*Corvus corax*)	4	7	520	No
Sparrowhawk (*Accipiter nisus*)	4	5	600	No

Table 1.3: ***Winter season flight data for target species from Vantage Point Surveys.***

Species	Total Number of Bouts	Total Number of Individuals	Total Duration of Bouts (s)	Inclusion in CRM
Buzzard (*Buteo buteo*)	1	1	120	No
Golden plover (*Pluvialis apricaria*)	**3**	**104**	**7,790**	**Yes**
Hen harrier (*Circus cyaneus*)	2	2	328	No
Herring gull (*Larus argentatus*)	**14**	**49**	**3,214**	**Yes**
Kestrel (*Falco tinnunculus*)	**50**	**50**	**7,701**	**Yes**
Lesser black-backed gull (*Larus fuscus*)	**7**	**28**	**3,119**	**Yes**
Little egret (*Egretta garzetta*)	1	1	85	No
Mallard (*Anas platyrhynchos*)	5	8	395	No
Peregrine (*Falco peregrinus*)	1	1	185	No
Raven (*Corvus corax*)	10	10	458	No
Snipe (*Gallinago gallinago*)	**7**	**8**	**471**	**Yes**
Sparrowhawk (*Accipiter nisus*)	**7**	**8**	**545**	**Yes**
Teal (*Anas crecca*)	1	5	125	No

Table 1.4: *Bird species biometrics and avoidance rates for use in CRM.*

Biometric parameter[1]	Golden plover	Herring gull	Kestrel	Lesser black-backed gull	Snipe	Sparrowhawk
Assessment season	**Winter**	**Breeding + Winter**	**Breeding + Winter**	**Breeding + Winter**	**Winter**	**Winter**
Length (bill to tail)	0.29m	0.60m	0.35m	0.64m	0.28m	0.38m
Wingspan	0.76m	1.50m	0.80m	1.50m	0.45m	0.70m
Flight speed[2]	17.9ms^{-1}	12.8ms^{-1}	10.1ms^{-1}	11.9 ms^{-1}	17.1ms^{-1}	10.0ms^{-1}
Collision Avoidance rate (%)[3]	98%	98%	95%	98%	98%	98%

[1] Data sourced from https://www.rspb.org.uk/birds-and-wildlife/wildlife-guides/bird-a-z/ [Accessed April 2025]
[2] Data sourced from Alerstam *et al*. (2007); for golden plover, data for grey plover (*Pluvialis squatarola*) are used.
[3] Avoidance rates sourced from SNH (2019)

2. Methodological Approach

Collision Risk Modelling adopts a mathematical approach to determining the likelihood of a bird species colliding with wind turbine rotors at a pre-defined site and is fully described by Band *et al*. (2007; updated in Band *et al*, 2012) and Scottish Natural Heritage (SNH, 2000), with supporting information provided by Scottish Natural Heritage (SNH, 2019)[1]. This determination is based upon field data collected at the proposed wind farm site. The output from the model indicates the number of birds likely to collide with rotors of all turbines within the wind farm per year of operation of the wind farm as a whole. The inverse of this (i.e. the number of years over which a single fatality would be likely) is also often indicated.

Data on the site (such as the number, size, dimensions and likely functioning of the turbines proposed for the site; see **Table 1.1**) forms part of the model, along with biometric data on the bird species themselves (see **Table 1.4**). These are reconciled against standardised field data collected using systematic and prescribed Best Practice methods on birds flying through the proposed site (SNH, 2017). Collectively, these data are then used to determine the number of bird flights through the rotors of all turbines within the area on an annual basis (CRM Stage 1) as well as the probability that a bird flying through the turbine will collide with the rotors (CRM Stage 2). The product of the numerical output from these two stages of assessment indicates the number of birds likely to collide with the rotors if no avoiding action is being taken by the bird species in question. This value is then corrected using published avoidance rates (CRM Stage 3; see **Table 1.4**), to give a final indication of collision risk (number of birds colliding with the rotors per annum).

2.1. Collection of field data

The CRM is based upon data collected from VPs at the proposed Illaunbaun Wind Farm, during the breeding season (March to September inclusive), for two years (2023 and 2024) and two wintering seasons (October 2023 to March 2024 and September 2024 to March 2025). These data are collected following strict adherence to Best Practice methods (SNH, 2017).

2.2. CRM Stage 1: Determination of Bird Species Activity

Stage 1 of the CRM determines the number of transits through the rotors for a given period. For the calculation below, this is expressed as the number of birds flying through the rotors per breeding season (April to September inclusive) or winter season (September/October to March inclusive). Calculations of bird flights through the rotor swept area are shown in **Table 2.1** (for the breeding season) and **Table 2.2** (for the wintering season).

A full description of all the parameters used, and the derivation for calculations for the models, is presented in **Appendix B**.

[1] *It is noted that the CRM guidance was updated in 2024 (NatureScot, 2024); this revised approach was not used here as the data were collected using the previous guidance (as stated). It is the expert opinion of the authors that there is no significant difference in collision risk between the two approaches, and the findings here are relevant and correct for assessment of effects within the overall EIAR chapter.*

Table 2.1: *Parameters used in the CRM for breeding season activity.*

Model parameter	Code	Herring gull	Kestrel	Lesser black-backed gull
Survey Area Visible from Vantage Points (ha)	Acc		826.4ha	
Flight Risk Area (ha)	A_{FR}		696.1ha	
Total Survey Time (s)	T		972,000s	
Length of Season (days)	T_{SS}		183	
Daily Duration of Bird Activity (hours)	T_{DD}		15	
Duration of Bird Activity at Rotor Height (s)	T_{TH}	2,179s	6,039s	18,399s
Proportion of Bird Activity at Rotor Height: (T_{TH}/T)	t	**0.002242**	**0.006213**	**0.018929**
Flight Activity in Visible Area (per hectare): (t/Acc)	F	**2.71 x 10^{-6}**	**7.52 x 10^{-6}**	**2.29 x 10^{-5}**
Flight Time within Flight Risk Area: (A_{FR}*F)	t_{FR}	**1.89 x 10^{-3}**	**5.23 x 10^{-3}**	**1.59 x 10^{-2}**
Occupancy of the Flight Risk Area (hrs/season): (T_{SS}*T_{DD}*t_{FR})	N	**5.183399**	**14.36556**	**43.767489**
Flight Risk Volume (m^3)	Vw		814,437,000m^3	
Combined Rotor Volume (m^3)	Vr	296,736m^3	280,609m^3	299,317m^3
Occupancy of Rotor Volume (bird-secs): ((Vr/Vw)*n)	b	**6.798770**	**17.818435**	**57.906520**
Transit Time through Rotors (s)	v	0.36	0.43	0.39
Number of Transits through Rotors (per season): (b/v)	b_{FR}	**18.918316**	**41.371539**	**148.510257**
Viewshed sufficiency (%)	Vs		92%	
Corrected Number of Transits through Rotors (per season): (b_{FR}/Vs)	b_C	**20.563387**	**44.969064**	**161.424193**

Table 2.2 *Parameters used in the CRM for winter season activity.*

Model parameter	Code	Golden plover	Herring gull	Kestrel	Lesser black-backed gull	Snipe	Sparrowhawk
Survey Area Visible from Vantage Points (ha)	Acc	826.4ha					
Flight Risk Area (ha)	A_{FR}	696.1ha					
Total Survey Time (s)	T	972,000s					
Length of Season (days)	T_{SS}	182					
Daily Duration of Bird Activity (hours)	T_{DD}	12					
Duration of Bird Activity at Rotor Height (s)	T_{TH}	7,790s	3,214s	7,701s	3,119s	471s	545s
Proportion of Bird Activity at Rotor Height: (T_{TH}/T)	t	**0.008014**	**0.003307**	**0.007923**	**0.003209**	**0.000485**	**0.000561**
Flight Activity in Visible Area (per hectare): (t/Acc)	F	**9.70×10^{-6}**	**4.00×10^{-6}**	**9.59×10^{-6}**	**3.88×10^{-6}**	**5.86×10^{-7}`**	**6.78×10^{-7}**
Flight Time within Flight Risk Area: (A_{FR}*F)	t_{FR}	**6.75×10^{-3}**	**2.79×10^{-3}**	**6.67×10^{-3}**	**2.70×10^{-3}**	**4.08×10^{-4}**	**4.72×10^{-4}**
Occupancy of the Flight Risk Area (hrs/season): (T_{SS}*T_{DD}*t_{FR})	N	**14.743655**	**6.082940**	**14.575210**	**5.903140**	**0.891433**	**1.031488**
Flight Risk Volume (m^3)	Vw	814,437,000m^3					
Combined Rotor Volume (m^3)	Vr	276,739m^3	296,736m^3	280,609m^3	299,317m^3	276,094m^3	282,545m^3
Occupancy of Rotor Volume (bird-secs): ((Vr/Vw)*n)	b	**18.035173**	**7.978647**	**18.078481**	**7.810142**	**1.087903**	**1.288238**
Transit Time through Rotors	v	0.24	0.36	0.43	0.39	0.25	0.44
Number of Transits through Rotors (per season): (b/v)	b_{FR}	**75.251653**	**22.201453**	**41.975324**	**20.030320**	**4.346529**	**2.941183**
Viewshed sufficiency (%)	Vs	**92%**					
Corrected Number of Transits through Rotors (per season): (b_{FR}/Vs)	b_C	**81.795275**	**24.132014**	**45.625352**	**21.772087**	**4.724488**	**3.196938**

2.3. CRM Stage 2: Determination of Collision Risk

The probability of a bird flying through the rotors and colliding with the blades is determined in Stage 2 of the CRM. The probability of a collision depends upon the bird's size (both length and wingspan) and flight speed. In order to simplify the calculations, birds are assumed to be of simple cruciform shape, with the wings half-way down the length of the bird. Characteristics of the turbine and rotor blades are also required, including the width and pitch of the rotor blades and the rotation speed of the turbine. The turbine blade is assumed to have no thickness for Stage 2 of the CRM, although rotor blade depth is considered in Stage 1 of the model.

The risk of a bird colliding with the rotor blades changes depending upon whether it passes through the rotor swept area next to the hub (where the blades have a wider chord width, occupy a large volume of the airspace and are travelling quite slowly) or towards the blade tips (where the blades are only present for a small proportion of the time, have a short chord width and are travelling faster). Closer to the hub, the wingspan of the bird compared to the physical distance between the blades is the controlling factor. Towards the blade tips, it is the length of the bird that offers a greater contribution to the determination of collision risk.

The bird is assumed to enter the rotor swept area at random anywhere on the disc (based on the flightline data form the VP surveys). The calculations determine the collision risk at 20 locations along the length of the rotor blade (in intervals of 0.05R, where R is the radius of the rotor swept area; Band, 2012) using numerical integration of various elements in relation to the rotors (notably chord width and angular velocity of the blade) and the bird (such as the point at which the bird enters the rotor along the radius and the flight speed of the bird). These are calculated for both up-wind and down-wind flights and averaged to give a probability of collision per season, assuming no avoiding action is taken.

These calculations are performed in the SNH collision risk model[2], where the relevant data on the turbines and bird species are entered, and the model estimates the probability of a collision when a bird flies through the rotor area. This calculation is based solely upon the behaviour and structure of the bird and the specifications of the turbines. Only a single calculation is therefore required for all the VP data collected as there is only one turbine model, and each bird species' bahaviour and its structure is assumed to be the same in each season.

For the proposed development, the average probability of a bird passing through the rotor swept area and colliding with the rotors (if it takes no avoiding action) is shown in **Table 2.3**.

Table 2.3 *Risk of collision for birds passing through turbine swept areas.*

Turbine model	Golden plover	Herring gull	Kestrel	Lesser black-backed gull	Snipe	Sparrowhawk
Vestas V-117	5.6%	8.7%	9.1%	9.4%	5.7%	9.4%

[2] https://www.nature.scot/wind-farm-impacts-birds-calculating-probability-collision [accessed March 2025]

3. RESULTS

The overall collision risk model output from the first two stages is the number of bird collisions per annum. This is the product of the number of transits through the rotors per season and the probability of a bird passing through the rotor-swept area colliding with the blade. This is the unadjusted output *prior to* incorporation of avoidance rates.

It has been well documented that birds demonstrate avoidance of wind turbines (SNH, 2019). This includes macro-avoidance, where birds avoid the whole wind farm area, as well as micro-avoidance, where birds fly within the wind farm but avoid the turbines and blades. The documented level of avoidance for different species varies (SNH, 2019), and published avoidance rates for the bird species being assessed at the proposed development are shown in **Table 1.4**.

Incorporation of these avoidance rates forms part of the stage of the CRM to determine collision risk for the species assessed.

3.1. Collision Risk Assessment for Breeding Season

Collision Risk Modelling outputs are provided below for the three species considered during the breeding season (see **Table 3.1**).

Table 3.1 *Risk of collision for breeding season birds passing through turbine swept area at Illaunbaun.*

	Herring gull	Kestrel	Lesser black-backed gull
Collisions/annum (no avoiding action)	1.51	3.49	12.88
Avoidance Rate	98%	95%	98%
Collisions/annum (with 98% avoidance)	0.0303	0.1743	0.2575
Collision likelihood (years)	33.06	5.74	3.88

Of the three species assessed, lesser black-backed gull has the greatest collision risk, with a predicted risk of 0.2575 collisions per annum, or one collision approximately every 3.88 years. This is slightly higher than the predicted collision risk for kestrel, with as estimation of 0.1743 collisions per annum (see **Table 3.1a**), equating to one collision every 5.74 years. Herring gull has the lowest risk of collision for the three species assessed during the breeding season, with an estimated collision likelihood of 0.0303 bird collisions per annum (see **Table 3.1**), equating to one collision every c.33 years.

3.2. Collision Risk Assessment for Wintering Season

Collision risk data are provided for the six species (golden plover, herring gull, kestrel, lesser black-backed gull, snipe and sparrowhawk) considered during the wintering season in **Table 3.2**.

Collision risk for lesser black-backed gull in winter (**Table 3.2**) is substantially lower than in summer (**Table 3.1**), possibly as a result of reduced occupancy of the area around the proposed development. This highlights the value of assessing the bird flight activity data in separate seasons to better understand the likelihood of collision risk for the target species.

Table 3.2: *Risk of collision for wintering birds passing through turbine swept area at Illaunbaun*

	Golden plover	**Herring gull**	**Kestrel**	**Lesser black-backed gull**	**Snipe**	**Sparrowhawk**
Collisions/annum (no avoiding action)	3.90	1.78	3.54	1.74	0.23	0.25
Avoidance Rate	98%	98%	95%	98%	98%	98%
Collisions/annum (with 98% avoidance)	0.0779	0.0355	0.1768	0.0347	0.0046	0.0051
Collision likelihood (years)	12.84	28.17	5.66	28.79	218.67	196.59

Golden plover has an estimated collision risk of 0.0779 collisions per annum (see **Table 3.2**), equating to one collision every 12.84 years. Herring gull has approximately the same collision risk between summer and winter, with an indicative 0.0355 collisions per annum in winter (compared to 0.0303 in summer (**Table 3.1**), giving a risk of one fatality every 28.17 years in winter (compared to one fatality every 33.06 years in summer).

Kestrel has a winter collision risk of 0.1768 collisions per annum (see **Table 3.2**), which equates to one collision event for kestrel occurring every 5.66 years. Lesser black-backed gull has a substantially lower collision risk in winter of 0.0347 collision per annum (one collision every 28.79 years), compared to the summer risk of 0.2575 collisions per annum (one collision every 3.88 years).

Snipe and sparrowhawk both have comparatively low risks of collision, with 0.0046 collisions every year (equating to one collision every 218.67 years) for snipe and 0.0051 collision every year for sparrowhawk (equating to one collision every 196.59 years).

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Appendix A ILLAUNBAUN VANTAGE POINT SURVEY EFFORT

Table A-1a: *Vantage Point Survey hours for the two breeding seasons used for the CRM calculations.*

VP	Breeding season 2023							Breeding season 2024							TOTAL (Two Seasons)
	Apr	May	Jun	Jul	Aug	Sep	Total	Apr	May	Jun	Jul	Aug	Sep	Total	
1	6	6	0	12	6	6	36	0	12	6	6	12	0	36	**72**
2	6	6	0	12	6	0	30	0	12	6	6	12	6	42	**72**
3	12	6	6	24	2	16	66	0	12	6	24	18	0	60	**126**
Total	**24**	**18**	**6**	**48**	**14**	**22**	**132**	**0**	**36**	**18**	**36**	**42**	**6**	**138**	**270**

Table A-1b: *Vantage Point Survey hours for the two wintering seasons used for the CRM calculations.*

VP	Winter season 2023/24								Winter season 2024/25								TOTAL (Two Seasons)
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total	
1	0	0	12	6	0	0	12	30	6	6	0	8	8	8	6	42	**72**
2	0	6	12	6	0	0	12	36	0	3	9	6	6	3	9	36	**72**
3	0	6	20	16	0	0	24	66	24	6	3	9	6	6	6	60	**126**
Total	**0**	**12**	**44**	**28**	**0**	**0**	**48**	**132**	**30**	**15**	**12**	**23**	**20**	**17**	**21**	**138**	**270**

Appendix B PARAMETERS AND CALCULATION STEPS FOR CRM STAGE 1

Survey Area visible from Vantage Points (Acc)

In order to determine the level of flight activity in an area, the total area over which observations are being made needs to be assessed. The area viewed from each VP is not necessarily mutually exclusive with the area viewed from another VP; indeed, there needs to be some overlap to maximise coverage of the survey area. As a result, the total survey area visible from each VP is calculated using viewshed analysis (which involves the complex use of Digital Terrain Models, or Digital Elevations Models in addition to bespoke View shed Analysis plugins for ArcGIS), and these are summed for each VP to give the accumulated total area surveyed. The accumulated survey area from VPs will therefore be greater than the total survey area. This total is calculated in hectares.

Flight Risk Area (A_{FR})

The area where there may be a flight risk must be established and surveyed. Determination of this will largely have taken place in advance of undertaking survey work, but an iterative design approach may result in changes to the area that is required for survey. For CRM, the area should cover the whole wind farm, defined as a polygon encompassing the outer turbines plus the rotor radius. With the layout at Illaunbaun, the wind turbine area, plus a 500m buffer around all wind turbines, can be used. However, as the exact locations of flight-lines may be subject to error, an increased buffer is recommended from which to use for the inclusion of flight lines, with 800m often applied (SNH, 2017). For Illaunbaun, a more conservative buffer of 1km was applied to all turbines to adequately cover the whole of the flight risk area and ensure the robustness of the CRM.

Total Survey time (T)

To assess flight activity in an area, the total survey time undertaken from the VP watches is needed. This is expressed as seconds.

Length of Activity Season (T_{SS})

The period when birds are likely to be active in the area during the season being assessed. This varies depending upon the season of the survey (see **Appendix A** for details). Expressed as days.

Daily Duration of Activity (T_{DD})

The number of hours that birds are potentially active during the day, within each season, forms part of the model. This is quantified as 15 hours per day for the period 1st April to 30th September, and 12 hours per day for the period 1st October to 31st March. This is likely to be an over-estimate of activity which may inflate collision risk estimates, which would be difficult to quantify in simple terms otherwise. Nevertheless, the provision of an over-estimation of activity time increases the likelihood of a collision as birds are considered to be more active (i.e. taking more flights) than if activity hours are reduced. This approach therefore offers a more robust estimation of collision risk within the CRM.

Duration of Activity at Turbine Height (T_{TH})

This metric is based on the observation of flight-lines from the VP surveys. Turbine height is determined by the hub height +/- the length of the blade. This swept area may be subject to change depending upon final design iterations. For a turbine with a hub-height of 100m and a blade length of 70m, the swept area (Turbine Height) will be 30-170m.

However, it may be difficult to be certain about individual observations of flight heights, and a precautionary approach needs to be taken about which data to include. A tolerance of +/- 5m at lower flight heights should be considered and these tolerances may need to be greater at higher flight elevations (e.g. +/- 20m at 200m height). In the example above, all birds flying in the 20m-30m band would be included, in addition to all birds flying between 30m and up to 200m. For Illaunbaun, with a lowest swept height of 33m, and turbine diameters of 117m, all records between 20m and 200m were retained for analysis within the model.

Flight-lines recorded within the determined flight height bands are therefore selected, and the total numbers of seconds for birds observed within the Survey Area are summed. To ensure a precautionary approach is applied, any flight-lines at the relevant height bands recorded wholly or partially within the survey area are retained for analysis within the CRM.

Proportion of Time at Turbine Height (t)

This metric is obtained by dividing the Duration of Activity at Turbine Height (T_{TH}) by Total Survey Time (T).

Flight Activity in the Visible Area (F)

The level of flight activity within the survey area is determined by dividing the Proportion of Time (birds were recorded) at Turbine Height (t) by the Visible Survey Area (Acc).

Flight Time within the Flight Risk Area (t_{FR})

The amount of time a bird is likely to be within the flight risk area is the product of the Flight Risk Area (A_{FR}) and the Flight Activity in the Visible Area (F).

Occupancy of the Flight Risk Area (n)

The time that a bird is likely to be within the Flight Risk Area is a product of the Length of Activity Season (T_{SS}), the Daily Duration of Activity (T_{DD}) and the Flight Time within the Flight Risk Area (t_{FR}). The output of this provides the number of hours that a bird is within the Flight Risk Area per breeding season.

Flight Risk Volume (Vw)

This is the volume of airspace within the rotor height over the whole wind farm survey area. It is calculated by multiplying the Flight Risk Area (A_{FR}) with the diameter of the rotor (117m for the proposed rotor for Illaunbaun).

Combined Rotor Volume (Vr)

This is the actual volume of airspace occupied by the rotors within the wind farm. Although the volume of airspace occupied by a single rotor is its depth (*d*) multiplied by its circumference (πr^2, where *r* is the radius of the rotor), the CRM also takes into account the length of the bird (which varies depending upon species) and the rotor depth calculation, as the rotor could collide with the bird anywhere along its length if flying through the swept area. Note the depth of the rotor is taken as the maximum chord of the blade (i.e. the width of the rotor blade at its maximum[3]). Clearly rotors do not operate within this volume (the blade is never at a 90° pitch) nor is the width constant along the length of the blade. Nevertheless, the use of this metric in the calculation ensures that the output of the model follows

[3] https://www.vestas.com/en/energy-solutions/onshore-wind-turbines/4-mw-platform/V117-3-45-MW

the precautionary approach to maximise the robustness of the model output. The volume for a single rotor is therefore expressed as $(d+l)*\pi r^2$. The combined rotor volume is this individual rotor volume multiplied by the number of turbines (n=6 for Illaunbaun). See **Table B-1** for the relevant metrics for this calculation for each of the species considered at Illaunbaun.

Table B-1: *Risk of collision for birds passing through turbine swept areas.*

Turbine model	Golden plover	Herring gull	Kestrel	Lesser black-backed gull	Snipe	Sparrowhawk
Rotor diameter	117m					
Rotor radius (*r*)	58.5m					
Rotor area (πr^2)	10,751m^2					
Rotor depth (*d*)	4.00m					
Bird Length (bill to tail) (*l*)	0.29m	0.60m	0.35m	0.64m	0.28m	0.38m
Rotor volume ($(d+l)*\pi r^2$)	46,123m^3	49,456m^3	46,768m^3	49,886m^3	46,016m^3	47,091m^3
Number of turbines	6					
Combined Rotor Volume (Vr)	276,739m^3	296,736m^3	280,609m^3	299,317m^3	276,094m^3	282,545m^3

Occupancy of the Rotor Volume (b)

This is an estimation of the time that birds will occur within the rotors. It is calculated by dividing the Combined Rotor Volume (Vr) by the Flight Risk Volume (Vw), which gives the proportion of the Flight Risk Volume that is occupied by the rotors. This is then multiplied by the Occupancy of the Flight Risk Area (n).

Transit Time through Rotors (v)

This is calculated by adding length of the bird to the depth of the rotor swept area and then dividing by the flight speed, using the formula [(d + l) / flight speed]. See **Table B-2** for the relevant metrics for this calculation for each of the four species assessed at Illaunbaun.

Table B-2: *Bird species transit times through the rotors.*

Turbine model	Golden plover	Herring gull	Kestrel	Lesser black-backed gull	Snipe	Sparrowhawk
Length (bill to tail) (*l*)	0.29m	0.60m	0.35m	0.64m	0.28m	0.38m
Flight Speed (ms^{-1})	17.9ms^{-1}	12.8ms^{-1}	10.1ms^{-1}	11.9ms^{-1}	17.1ms^{-1}	10.0 ms^{-1}
Rotor depth (*d*)	4.00m					
Transit Time (s)	0.24s	0.36s	0.43s	0.39s	0.25s	0.44s

Number of Transits through Rotors (b_{FR})

The number of times a bird will pass through the rotors in a season is calculated by dividing the Occupancy of the Rotor Volume (b) by the Transit Time through Rotors (v).

Viewshed Sufficiency (Vs)

Due to local topography, it may not be possible to achieve complete coverage of a whole Flight Risk Area from VPs due to dips or hollows in the landscape. Viewshed Analysis is a topographical model designed to determine the area that can be seen from a VP. It sets the observer height at 1.5m and the "floor" of the viewshed as required for the lowest swept area of the turbine blade (for Illaunbaun, this was set to 0m). The area visible down to 30m is then calculated. For Illaunbaun, Viewshed Sufficiency (Vs) was 92% of the Flight Risk Area (calculated using Digital Terrain Models, or Digital Elevations Models in addition to bespoke View shed Analysis plugins for ArcGIS).

Corrected Number of Transits through Rotors (b_C)

This is the Number of Transits through Rotors (b_{FR}) divided by the Viewshed Sufficiency (Vs). This correction assumes that none of the airspace within the area missed by the viewshed analysis is covered. Clearly this is not the case, as the higher the viewshed analysis floor rises, the greater the viewshed coverage will be. However, this correction factor therefore increases the number of transits used in the CRM, offering a more robust estimation of collision risk within the CRM.

This final metric concludes the calculations for Stage 1 of the CRM.