



Forestry, Ecology & Environment

Collision Risk Model

Collision Risk Model Calculations
For target species at the proposed Tirawley Wind Farm

Compiled by: Veon Ltd (Veon Ecology)
David M. McGillicuddy B.Sc. (Hons) in Wildlife Biology, ACIEEM, AEnvCW.

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General Details

Details of Author(s)

Name: David M. McGillicuddy
Address: The Yard, Market Yard, Newcastle West, Co. Limerick
Company Name: Veon Ltd (Veon Ecology)
E-mail: dmccgillicuddy@veon.ie

Relevant Qualifications/ Affiliations/ Experience: David M. McGillicuddy, B.Sc. (Hons) in Wildlife Biology, Munster Technological University (MTU), formerly the Institute of Technology Tralee (ITT), ACIEEM, AEnvCW.

David is an experienced ecologist with over eight years of professional experience. He has led and contributed to a wide range of projects, producing comprehensive ecological reports and assessments, including Preliminary Ecological Appraisals (PEAs), Biodiversity Management Plans (BMPs), Biodiversity Net Gain (BNG) assessments, Appropriate Assessment (AA) reports, including Stage 1 AA Screening Reports and Stage 2 Natura Impact Statements (NIS), Ecological Impact Assessments (EclA), Environmental Impact Assessment (EIA) Screening and Biodiversity Chapters, habitat mapping, and other related ecological studies.

David has contributed to projects nationwide, including renewable energy, infrastructure, residential, commercial, industrial, and forestry developments, providing site-specific mitigation measures and producing ecological reports in accordance with national legislation, EU Directives, and best practice guidance.

David has prepared Collision Risk Models (CRMs) that integrate ecological data, species behaviour, and environmental variables, providing robust assessments of potential impacts on target species populations for a number of wind farm developments.

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Executive Summary

This report presents the results of the Collision Risk Model (CRM) for target species at the proposed Tirawley Wind Farm Development (Summer 2021 to Winter 2022/2023). The Wind Farm Site is located within the townlands of Ballymurphy, Ballynaleck, Barnhill Lower, Barnhill Upper, Barroe, Billoos, Carn, Carrickanass, Carrowmore, Castlelackan Demesne, Castletown, Conaghra, Glebe, Lackanhill, Lecarrowntemple, Lissadrone East, and Lissadrone West, Co. Mayo.

Following a revised layout for the Wind Farm Site, the CRM has been updated accordingly.

The modelling was carried out using the updated NatureScot, formerly known as Scottish Natural Heritage (SNH), CRM guidance (also referred to as the Band model (Band, 2024; NatureScot, 2024)). This approach builds on previous models developed by Band *et al.* (2007) and Band (2000).

The Revised Proposed Development now comprises 16 turbines, three fewer than originally proposed. This change is sufficient to invalidate the results of the original CRM analyses. In addition, the opportunity has been taken to carry out updated CRM analyses using the 2024 version of the model, as set out in this report.

The updated NatureScot guidance aims to standardise the approach to CRM for onshore wind farms, enhancing the transparency of calculations and increasing confidence in the results. The approach is intended to provide collision risk estimates that are consistent and comparable across different wind farm projects.

It should be noted, however, that the CRM method involves numerous parameters and assumptions, some of which rely on expert judgment rather than absolute values. As a result, outputs from one practitioner may not exactly match those of another, even when using the same ornithological data.

It is also important to note that the results of the model are solely speculative and representative of worst-case scenario estimates, only drawing conclusions by assuming likely levels of active avoidance by specific species. As such, results obtained are dependent on the quality of field observation data and the accuracy of the avoidance rates used and must therefore be interpreted with a certain degree of caution.

CRMs provide theoretical predictions of the probability of bird collisions with wind turbine rotor blades. The results are affected by sources of uncertainty including natural variability in bird populations, accuracy of the available information regarding species avoidance rates, turbine specifications, and the representativeness of the survey data. As such, the results are considered to be a best estimate of collision risk, rather than a precise figure. As a result, the predicted collision risk should be considered only an indication of the potential collision risk significance for each target species.

Due to the low frequency of recorded flights, the collision risk for Merlin can be assumed to be effectively zero. At <0.01 collisions within the nominal 35-year operational phase of the Proposed Development is predicted for Sparrowhawk, Hen Harrier and Peregrine. The collision risk for Kestrel is estimated at 0.3 birds per year (or 10.5 birds over the nominal 35-year operational phase), similarly the collision risk for Buzzard is estimated at 0.3 birds per year (or 10.5 birds over the nominal 35-year operational phase), and the collision risk for Lesser Black-backed Gull is estimated at 0.2 birds per year (or 7.0 birds over the nominal 35-year operational phase).

Section 1: INTRODUCTION

1.1 Background

Veon Ltd (Veon Ecology) has been appointed by BioSphere Environmental Services to carry out a Collision Risk Model (CRM) for target bird species at the proposed Tirawley Wind Farm Development, located within the townlands of Ballymurphy, Ballynaleck, Barnhill Lower, Barnhill Upper, Barroe, Billoos, Carn, Carrickanass, Carrowmore, Castlelackan Demesne, Castletown, Conaghra, Glebe, Lackanhill, Lecarrowntemple, Lissadrone East, and Lissadrone West, Co. Mayo. This assessment uses standardised updated CRM guidance and methods.

This document has been prepared by David McGillycuddy of Veon Ltd (Veon Ecology) to assess the collision risk for birds (i.e. target species) at the proposed Wind Farm Site. The CRM is based on vantage point surveys undertaken at the Wind Farm Site from the breeding and wintering seasons of 2021-2023 inclusive. The data represent a 24-month survey period, consisting of two breeding seasons and two non-breeding (wintering) seasons, in compliance with the Scottish Natural Heritage (SNH) guidelines (SNH, 2017).

Collision risk is calculated using a mathematical model to predict the number of individual birds of a particular species (i.e. target species) that may collide with moving wind turbine rotor blades. The modelling method and calculations used in this updated CRM follow NatureScot guidance (also referred to as the Band model) (Band, 2024; NatureScot, 2024). The calculations and outcomes obtained from the Band model should be interpreted with a degree of caution. As birds may avoid a wind farm (e.g. some individuals may be displaced from the area, while others may avoid turbines or take evasive actions to prevent a collision), the CRM accounts for this by applying an avoidance rate.

The CRM analysis estimates the number of bird collisions through a five-stage process:

- **Stage A:** Bird survey data are reviewed to determine the density of flying birds in the vicinity of the turbines and the proportion of birds flying at rotor swept height (between the minimum and maximum rotor heights).
- **Stage B:** An estimate of the potential number of bird transits through the rotors during a set time period is calculated, based on bird density and the proportion at collision risk.
- **Stage C:** The probability of collision during a single bird rotor transit is calculated.
- **Stage D:** The potential collision rate for a bird species is estimated, assuming current levels of bird use of the site and accounting for the proportion of time that turbines are not operational.
- **Stage E:** Appropriate avoidance factors are applied, assuming that most birds will avoid turbines or take evasive action to prevent collisions.

The following sections present details of how this process has been applied to the Revised Proposed Development, including the parameters used in the model. Unless otherwise stated, the ornithological data are the same as those used in the previous CRM for the Proposed Development.

A spreadsheet provided by NatureScot (2024) is available to support the completion of CRM calculations in accordance with the methodology set out in their guidance.

The CRM used data from vantage point (VP) surveys conducted during the summers of 2021 and 2022, and the winters of 2021/2022 and 2022/2023. The VP surveys were SNH compliant (SNH, 2017). Surveys were undertaken from April 2021 to March 2023, using five fixed VP locations (VP1-VP5) (see **Appendix 1**). These VP locations were strategically chosen to provide the maximum viewshed of the survey area while minimising the number of survey points.

A total of seven target species were recorded in flight within the study area during the survey period. These comprised Kestrel, Buzzard, Lesser Black-backed Gull, Sparrowhawk, Hen Harrier, Peregrine Falcon, and Merlin. Two of the target species (Lesser Black-backed Gull and Merlin) were observed only during the summer surveys, while the remaining species were present throughout the year.

1.2 Proposed Development & Site Description

The Proposed Development is located circa (c.) 14.5 km northwest of Ballina Town, c. 5.2 km northwest of the village of Killala, and c. 2.4 km east of Ballycastle village in north Co. Mayo. The Proposed Development site is extensive, covering a large number of townlands and comprising c. 108.06 hectares (ha). The receiving environment for the Wind Farm Site consists of peat bog, coniferous forestry, transitional woodland scrub, and agricultural pastures. The Proposed Development site is situated relatively close (<15 km) to other operational wind farm developments, namely Killala Wind Farm and Oweninny Wind Farm.

1.2.1 Turbine Parameters

The Proposed Development design on which this CRM is based comprises 16 no. Wind Turbine Generators (WTGs) (Turbine Model: Vestas V117 (4.3 MW) IEC IIA – T). The CRM makes certain assumptions regarding turbine specifications, including rotor diameter and rotational speed. The worst-case scenario is assumed to be a combination of the maximum collision risk area (affected by hub height and rotor blade length), the maximum number of turbines proposed, and the minimum turbine downtime (i.e., non-operational periods) using the specifications of the proposed WTGs. The turbine specifications for the Proposed Development used in this CRM are presented below in **Table 1.1**.

Table 1.1: Wind turbine specification and parameters for the proposed wind farm development.

Wind Farm Components/Turbine Parameters	
Technical Information and Wind Farm Component	Data used/Scenario Modelled
Turbine model	Vestas V117
Number of turbines	16
Number of blades per turbine rotor	3
Rotor blade maximum chord (m) (i.e., depth of blade)	4
Rotor Radius (m)	58.5
Rotor Diameter (m)	117
Circumference of blade tip (m) (Pi x Rotor Diameter)	367.6
Swept area (m ²) (Pi x Rotor Radius ²)	10751
Turbine blade tip height (m)	135
Hub height (m)	76.5
Swept height (m)	18 - 135
Maximum height to blade tip (m)	135
Minimum height to blade tip (m)	18
Speed (Dynamic Operation Range) (m/s)	6.7 - 17.5
Turbine operation time*	85%
Average blade pitch (degrees)**	15°
Mean rotational speed (rpm)***	12.1
Average Rotational period (s) (60/12.1)	4.959

* Operational time will vary throughout the year and can only be estimated. In accordance with guidance (NatureScot, 2024), in the absence of site-specific data, the default figure for operational time is 0.85 (or 85%, or 15% non-operational time).

** Pitch angle varies along the length of the blade, from a high angle close to the hub to a lower pitch 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. A range of 15-30 degrees is reasonable for a typical large turbine. In accordance with guidance (NatureScot, 2024), the figure of 15° is used in this assessment.

*** Turbine rotational speed varies with wind conditions, and a mean operational speed is used in the model. Ideally, this is based on wind data collected over time; where such data are not available, a representative speed anticipated by the wind farm developer is used. In line with guidance (NatureScot, 2024), a mean rotation speed of 12.1 rpm is applied in this assessment.

1.3 Statement of Authority

David McGillycuddy holds a B.Sc. (Hons) in Wildlife Biology from MTU and is a qualified ecologist with over 8 years of experience in ecological research, teaching, and assessment. He is a member of the Chartered Institute of Ecology and Environmental Management (CIEEM) and has a strong background in experimental design and data analysis. David has managed a range of large-scale, multi-disciplinary ecological projects, including research and targeted management work for species of conservation concern. David also has substantial Geographic Information System (GIS) knowledge, with experience in handling, presenting and analysing spatial data using a variety of software (including SPSS, ArcGIS, and QGIS).

David is a Project Ecologist with Veon Ltd (Veon Ecology) and is experienced in several key environmental projects and the production of ecological reports, including Biodiversity Management Plans (BMP), Invasive Species Management Plans (ISMP), Biodiversity Net Gain (BNG) assessments, Appropriate Assessment (AA) reports (including Stage 1 AA Screening Reports and Stage 2 Natura Impact Statements (NIS)), Ecological Impact Assessments (EclA), Environmental Impact Assessment (EIA) Screening and Biodiversity Chapters, habitat mapping, etc.

He has specific expertise in ornithological assessments for wind energy projects and has been involved in numerous wind energy projects. His input to these projects has included field surveys (including habitat surveys, vantage point surveys, and breeding wader and raptor surveys), and collision risk modelling. David has prepared collision risk models that integrate ecological data, species behaviour, and environmental variables, providing accurate assessments of potential impacts on target species populations for various wind farm developments.

1.4 Data Sources

The following data and information were provided for this collision risk assessment:

- Data outlining all observations of flight activity recorded during the VP surveys.
- Mapping of the proposed turbine locations.
- Technical specifications for the proposed WTG turbines.
- GIS mapping of flight lines recorded during the summers of 2021 and 2022, and the winters of 2021/2022 and 2022/2023 VP surveys.
- Clarification regarding survey methodology.
- Mapping of the VP locations and viewsheds.

All of the survey data used in this assessment was provided externally by the client. Additional information, including technical details (e.g. turbine specifications), were also provided by the client.

1.5 Target Species

The target species were selected based on professional judgement and best practice, thereby enabling VP surveys to focus on the species of greatest importance. In general, target species are those afforded a higher level of legislative protection and also include species which are more likely to be subject to impacts from wind farms, e.g., breeding and non-breeding species forming qualifying features for nearby Special Protection Areas (SPAs) or species listed on Annex I of the Birds Directive.

Data were examined in detail for those species for which flight activity was recorded during the baseline surveys. Not all target species were recorded at the site across all years of survey work. Bird flights considered to represent a potential collision risk were those flight lines that passed within the Collision Risk Zone (CRZ) at Potential Collision Height (PCH), i.e., at collision risk height and within the turbine envelope. For the CRM analysis of the Revised Proposed Development, the turbine envelope utilised is an area encompassing all turbines plus a surrounding 500 m buffer. This comprises an area with radius equal to the rotor length plus 500 m, extending from each turbine (NatureScot, 2024). Only flight activity within the turbine envelope has been used in the CRM calculations.

A proportionate approach to CRM was followed, whereby it was only run for species that met a specified threshold of flight activity. The threshold used was three flights, or at least ten individuals, recorded within the CRZ at PCH within either season, over the course of all survey years. As a result, any species recorded on the site only very occasionally, and for which a negligible or no collision impact could be predicted, were excluded from the analysis.

Six species fulfilled the criteria for undertaking CRM:

- Kestrel (*Falco tinnunculus*)
- Buzzard (*Buteo buteo*)
- Lesser Black-backed Gull (*Larus fuscus*)
- Sparrowhawk (*Accipiter nisus*)
- Hen Harrier (*Circus cyaneus*)
- Peregrine (*Falco peregrinus*)

Other species of conservation concern were recorded during the vantage point surveys but were excluded from consideration in the collision risk analysis for the following reasons:

Merlin (*Falco columbarius*) was observed flying within the collision risk height band during the surveys. However, only two flights (two individuals) meeting the criteria were recorded across all survey years. Due to the low frequency of recorded flights, the collision risk for Merlin can be assumed to be effectively zero. As a result, they are excluded from further consideration in the analysis.

1.5.1 Avian Biometrics & Avoidance Rates

The CRM analysis uses parameters for each species to inform potential collision risk. The parameters used are presented in **Table 1.2**. The bird biometric parameters were primarily sourced from Snow and Perrins (1998), Alerstam *et al.* (2007), Wilson *et al.* (2015), and the British Trust for Ornithology (BTO) BirdFacts website¹.

The recommended avoidance rate for each species is in accordance with NatureScot guidance (2025) and SNH (2010; SNH, 2018), with a default value of 98% applied where species-specific avoidance rates are not available.

Table 1.2: Avian biometric data and avoidance rates.

Avian Biometric Data & Avoidance Rates				
Species Name	Length (m)	Wingspan (m)	Mean flight speed (m/s)	Avoidance rates (%)
Kestrel	0.34	0.76	10.1	95
Buzzard	0.54	1.2	13.3	98
Lesser Black-backed Gull	0.58	1.43	11.9	98
Sparrowhawk	0.33	0.67	10	98
Hen Harrier	0.48	1.1	9.1	99
Peregrine Falcon	0.42	1.02	12.1	98

1.5.2 Daylight Hours & Nocturnal Activity Ranking

Daylight hours at a wind farm site depend on its latitude and the time of year. The NatureScot (2024) CRM spreadsheet provides the total daylight and night hours per month once the site’s latitude is entered. The wind farm latitude is expressed in degrees and minutes, converted to decimals for the model. For this site, the latitude is 54° 15’ North (54.25° in decimals). This value is used in the CRM to determine the total daylight and night hours in each month during which bird activity could potentially occur.

¹ British Trust for Ornithology (BTO) (2026). *BirdFacts Species*. Available at: <https://www.bto.org>.

The NatureScot (2024) CRM spreadsheet uses a scale of 1 to 5 to represent nocturnal activity (1 = hardly any night activity; 5 = as active at night as during the day).

For all target species in this assessment, flight activity is considered to occur only during daylight hours, with the birds roosting at night. In accordance with NatureScot (2024) guidance, a nocturnal activity factor of 1 has therefore been applied to all species in this assessment.

1.6 Survey Period & Coverage

1.6.1 Vantage Point Survey Effort

The data used in this CRM were collected over a period of 24 months, from April 2021 to March 2023 inclusive, thereby providing data for two breeding season cycles and two winter cycles for the target species. For each target species included in the CRM, collision risk predictions were calculated for both relevant seasonal periods within each 12-month cycle.

The summer season was defined as running from April to September inclusive (six months) for 2021 and 2022, and the winter season from October to March inclusive (six months) for 2021/22 and 2022/23. Therefore, over the entire survey period, two summer surveys and two winter surveys were completed. Survey watches were typically 2 × 3 hours = 6 hours per VP per month (see **Table 1.3**).

Table 1.3: Vantage Point (VP) data (VP1-5) survey effort overview.

Vantage Point Survey Effort (VP 1-5)			
Survey Period	Months	Effort/Month	Total hours per VP
Summer 2021	April-September	6 hours	36
Winter 2021 - 2022	October-March	6 hours	36
Summer 2022	April-September	6 hours	36
Winter 2022 - 2023	October-March	6 hours	36

1.6.2 Vantage Point Locations & Viewshed Coverage

Five VP locations were selected to cover the site (VP1-VP5). The VP locations remained the same throughout the two-year survey period. For the purposes of the CRM, a 500 m radius buffer was drawn around each proposed turbine location. This buffer was used as the flight activity survey area, in accordance with SNH (2017) and NatureScot (2024) guidance.

Spatial coverage of the viewsheds within the 2 km VP arc, and the coverage of the 500 m turbine buffers, is presented in **Table 1.4**. The locations of the VPs and their associated viewsheds are shown in **Figure 6.2**.

Table 1.4: Vantage Point (VP) locations and viewshed coverage of 500 m turbine buffers.

VP No.	Lat Lon Coordinate	VP Arc (ha)	Viewshed Area Within VP Arc (ha)	Viewshed Coverage (%)	Turbine Buffer Area Within Viewshed (ha)
VP 1	54.26876120, -9.29288640	628	418.0	66.56	115.35
VP 2	54.24429272, -9.32054222	628	607.7	96.77	296.72
VP 3	54.27990814, -9.27836387	628	392.9	62.56	218.50
VP 4	54.27318654, -9.32181124	628	565.6	90.06	118.06
VP 5	54.24201559, -9.28086986	628	571.1	90.94	169.50

1.7 Limitations & Constraints

There are a number of limitations and constraints associated with pre-planning ecological assessments for potential development sites, as well as constraints and limitations inherent to the collection and analysis of field-based ecological data. The field survey data evaluated as part of this CRM was received from the client. The data comprised the following:

- Bird flight data from timed vantage point surveys. This data consisted of flights within the rotor-swept height bands. The vantage point surveys recorded flight heights in five bands: 0-25 m; 25-50 m; 50-100 m; 100-180 m; and > 180 m. The 0-25 m, 25-50 m, 50-100 m and 100-180 m height bands have been taken to represent the flight activity within the potential collision height zone. Flight duration (in seconds) for all bird observations, along with data relevant to each flight record (date, weather conditions, timing, VP number, location, etc.) were provided.
- Vantage point survey effort data (i.e. hours of observations) on a monthly basis during the summer and winter seasons of 2021 - 2023 (April 2021 to March 2023 inclusive) for all VP survey work undertaken.
- Description and metrics for the wind farm as a whole, as well as for individual turbine parameters.
- Area viewed from each vantage point.

This CRM relates specifically to the provided vantage point survey data, which has not been independently validated by the author of this report. Any further variation in the coverage of the vantage points surveyed during fieldwork, flight data, layout of the wind farm/turbine locations, as well as the individual turbine specifications, would require the outputs from this CRM to be amended.

For field-based surveys, the availability of suitable weather conditions is important, with good visibility and little wind or rain. The flight data used as part of this CRM were collected during optimal weather conditions, as determined by best practice guidance. As a result, this required the re-arrangement of schedules in some circumstances, with certain VPs being additionally surveyed in one month to compensate for periods when survey work could not take place. These alterations in survey schedules are indicated within the data provided. It should be noted that these scheduling re-arrangements are still in line with best practice guidelines, which require a minimum coverage of two years of data. The requirement in SNH (2017) guidance is for 36 hours of VP survey effort per season. For a single species, this is equivalent to 72 hours of VP survey effort per year.

As outlined in NatureScot guidance (Band, 2025), it is important to consider potential uncertainties when interpreting predicted collisions. Sources of variability or uncertainty in the CRM process generally fall into three main categories:

- Uncertainty or variability in the survey data collected.
- Uncertainty arising from turbine specifications.
- Uncertainty arising from simplifications built into the CRM.

Uncertainty can arise during data collection, for example due to imprecision when mapping flight locations or categorising flight heights. This has been minimised by using experienced surveyors. Data were collected over multiple years to increase robustness; however, it should be noted that the data cover the period from Summer 2021 to Winter 2022/2023.

The turbine model dimensions used in the CRM were provided by the client and are based on the specifications for the proposed turbine model that will be used when the development is constructed.

The NatureScot CRM model contains simplifications, such as assuming uniform bird dimensions and flight speeds, and simplified turbine blade dimensions. While these assumptions do not capture natural variability within species populations or differences in flight speeds associated with different activities (commuting, hunting, display, etc.), they are necessary to avoid an overly complex model.

Section 2: METHODOLOGY & ASSESSMENT

This updated CRM was undertaken following the latest NatureScot guidance (NatureScot, 2024; Band, 2024). The steps used to derive the collision risk for birds observed at the Proposed Development site, according to the Band Model, are summarised through a process of five stages:

- **Stage A:** Flight activity – utilises bird survey data that has been collected through the VP surveys (see **Appendix 3**), to establish the density of flying birds within 500 m of turbines, and the proportion of birds that are flying at a potential risk height between the lowest and highest points of the rotors (the CRZ).
- **Stage B:** Number of flights through rotors – 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:** Probability of collision for a single transit – determines the collision probability during a single bird rotor transit.
- **Stage D:** Expected collisions per year – multiplies the outputs of Stage B and C to yield the potential collision rate for the bird species in question, assuming current levels of bird use of the site, but allowing for the proportion of time that turbines are not operational.
- **Stage E:** Allowing for avoidance and attraction – 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.

2.1 Stage A - Flight Activity

This stage estimates the number of flights which, in the absence of birds being displaced, taking other avoiding action, or being attracted to the wind farm, would potentially be at risk from the turbines. It requires field data to determine the levels of flight activity within the Proposed Wind Farm Site.

The data recorded during the VP flight activity surveys were examined to determine whether the flightlines of each target species identified for assessment were best considered as 'directional' or 'non-directional'; these flight patterns are analysed differently by the model. Directional flights describe movements of birds passing over the Site in a regular pattern following the same orientation (e.g. migrating geese), whereas non-directional, or random, flights describe movements with no regular pattern (e.g. foraging or local movements). Following consideration of the flight activity data, all target species assessed were determined to have non-directional flights.

For non-directional flights, two key parameters derived from survey observations are needed to describe the magnitude of flight activity:

- (i) Areal bird density (D_A), and
- (ii) Proportion of birds flying at risk height (Q_{2R})

2.1.1 Areal Bird Density (D_A)

Areal bird density (D_A) is the number of birds in flight at any height at a given point in time, per unit area. D_A is most often recorded in bird-seconds, which is particularly appropriate where bird numbers are low, and is usually expressed per square kilometre (km^2).

The use of the Band (2024) model requires an appropriate survey area to be defined in order to determine bird numbers per unit area. In the case of the Proposed Development, it was not considered appropriate to use all flight data recorded during the VP surveys, given the extent of the VP viewsheds which, in places, cover ground more than 1.5 km from proposed turbine locations. However, Band (2024) recommends that data collection extends beyond the wind farm footprint to ensure it is representative of the area as a whole.

To calculate areal bird density, the study area was defined as a 500 m buffer encompassing all turbines. Only flight activity within the turbine envelope has been used in the CRM calculations. As a precautionary measure, all flightlines that intersected the 500 m turbine buffer were included in full in the calculation of D_A . This is a conservative approach in relation to flightlines that pass both within and outside the 500 m turbine buffer. For flightlines of this nature, the full observation time, both inside and outside the buffer, has been included for modelling, rather than retrospectively splitting the observation time, i.e. all time inside and outside the site is included in the model for flightlines that intersect the site at any point.

D_A is calculated as follows:

$$D_A = b / (t \times A) \text{ bird-seconds m}^{-2}$$

where:

- (b) is the number of flight seconds from a vantage point;
- (t) is the time (in seconds) that the vantage point was watched;
- (A) is the area of the vantage point view-shed (km^2).

The full viewshed area (clipped to the turbine envelope) of each VP was used in the model to determine the watched area. Examination of the data confirmed that there was no duplication in flight activity recorded. Survey effort at each VP has also been incorporated into the model.

The latter two parameters, A and t, are provided in **Table 2.1** below.

Table 2.1: Vantage Point (VP) viewshed (A) and total watch time (t).

Years	Vantage Points	A - Area of the VP viewshed (visible area) (km^2)	t - Total watch time (Seconds)
Year 1	VP 1	1.15	259200
Year 1	VP 2	2.97	259200
Year 1	VP 3	2.18	259200
Year 1	VP 4	1.18	259200
Year 1	VP 5	1.70	259200
Year 2	VP 1	1.15	259200
Year 2	VP 2	2.97	259200
Year 2	VP 3	2.18	259200
Year 2	VP 4	1.18	259200
Year 2	VP 5	1.70	259200

The number of flight seconds recorded within the watched area was determined for each flight, with time multiplied by the number of individuals (flock size), where appropriate (see **Table 2.2**). NatureScot (2024) guidance states that where the number of flights is too few to produce reliable estimates of flight activity by month, the data should be aggregated by season (breeding and non-breeding season). Based on the flight activity recorded during baseline surveys, this approach has been taken.

Table 2.2: Bird-seconds spent by species within the Collision Risk Zone (CRZ) at Potential Collision Height (PCH).

Seconds spent within CRZ at PCH (2021-2023)							
Species Name (BTO Code)	Seconds in flight within CRZ at PCH (18-135m)						Total secs at PCH over 24 Months
	2021/2022			2022/2023			
	Summer	Winter	Total	Summer	Winter	Total	
Kestrel (K.)	705	1250	1955	705	560	1265	3220
Buzzard (BZ)	1065	2385	3450	950	575	1525	4975
Lesser Black-backed Gull (LB)	1855	0	1855	2655	0	2655	4510
Sparrowhawk (SH)	70	90	160	160	480	640	800
Hen Harrier (HH)	120	470	590	0	60	60	650
Peregrine (PE)	0	182	182	60	0	60	242

Table 2.3 presents the calculated areal bird density (D_A) for inclusion in the CRM analyses for each target species assessed within the study area over the two years of VP surveys. A value of 0.0000 is given for those species where there was no at-risk flight activity in that season, or where activity was recorded in that season but was too low to register at four decimal places.

Table 2.3: Estimated areal bird density (D_A).

Year	Areal bird density (D_A)	
	Summer	Winter
Kestrel		
Year 1	0.0004	0.0007
Year 2	0.0004	0.0002
Mean bird density (bird-secs/km²)	0.0004	0.0005
Standard Deviation	0.0004	0.0009
Buzzard		
Year 1	0.0012	0.0008
Year 2	0.0003	0.0003
Mean bird density (bird-secs/km²)	0.0008	0.0006
Standard Deviation	0.0019	0.0008
Lesser Black-backed Gull		
Year 1	0.000502641	0.0000
Year 2	0.001651885	0.0000
Mean bird density (bird-secs/km²)	0.0011	0.0000
Standard Deviation	0.0025	0.0000
Sparrowhawk		
Year 1	0.0000	0.0000
Year 2	0.0001	0.0002
Mean bird density (bird-secs/km²)	0.0000	0.0001
Standard Deviation	0.0001	0.0003
Hen Harrier		
Year 1	0.0001	0.0002
Year 2	0.0000	0.0000
Mean bird density (bird-secs/km²)	0.0000	0.0001
Standard Deviation	0.0001	0.0002
Peregrine Falcon		
Year 1	0.0000	0.0001
Year 2	0.0000	0.0000
Mean bird density (bird-secs/km²)	0.0000	0.0000
Standard Deviation	0.0001	0.0001

Variation in the flight data is acknowledged, with differences in density estimates between the survey years for some species (**Table 2.3**). For example, for Lesser Black-backed Gull, the higher density in year 2 compared to year 1 reflected a small number of concentrated observations in summer, while no birds were recorded in winter in either year. For Kestrel, summer densities were similar between years, but winter densities differed, with year 1 higher than year 2. Buzzard densities were notably higher in year 1 than in year 2. For Sparrowhawk, Hen Harrier, and Peregrine Falcon, observed densities were very low, with some variation between years.

This variation is considered within the range expected from natural fluctuations, which is why two years of baseline surveys were undertaken. Consequently, the mean density estimates are considered the most appropriate representation of bird densities.

2.1.2 Proportion of Birds Flying at Risk Height (Q_{2R})

The proportion of birds flying at risk height (Q_{2R}) is the proportion of birds recorded flying between the lowest and highest points of the proposed rotor, measured relative to the rotor base. The CRM considered the Vestas V117 (4.3 MW) turbine, with a rotor sweep zone of 18 m to 135 m (referred to as the Potential Collision Height, PCH).

The proportion of flights at risk has been assessed for each species based on turbine parameters and recorded flight heights. For each individual flight, the proportion at risk was calculated using the data recorded during the survey. During the VP flight activity surveys, flight heights were classified into the following height bands (HB):

- HB 1: 0 - 25 m
- HB 2: 25 - 50m
- HB 3: 50 - 100m
- HB 4: 100 - 180m
- HB 5: 180 m+

As the proposed rotor sweep height covers 18 m to 135 m, all observations recorded only within HB 5 were considered not at risk, as this height band does not overlap with the PCH.

Where a bird was recorded flying both inside and outside the risk height, the observation was included in the model. The minimum rotor tip height (18 m) falls within the height band 0 - 25 m, therefore including all observations within this band would overestimate the proportion of birds flying at risk height, as it would also include birds flying below 18 m. The same applies to the maximum rotor tip height (135 m), which intersects the 100 - 180 m height band. For height bands that partially overlap with the PCH, guidance (Band, 2024) recommends applying proportioning, including a calculation to refine the estimate of birds flying at risk height where this occurs.

Combining all flight activity, an overall proportion of at-risk flight activity has been calculated for each species. The percentage of flights considered to be at PCH for the six assessed species, as used in the CRM analyses, is provided in **Table 2.4**.

Table 2.4: Proportion of birds flying at risk height.

Species Name	Number of birds observed	Proportion of observed birds flying at rotor risk height between 18 m and 135 m (% Q_{2R})
Kestrel	27	84.0%
Buzzard	26	95.7%
Lesser Black-backed Gull	36	94.0%
Sparrowhawk	11	60.7%
Hen Harrier	10	49.6%
Peregrine	3	100.0%

2.2 Stage B - Estimating the Number of Bird Flights Through Rotors

Stage B considers the available figures for bird density (D_A), the proportion of flights at risk height (Q_{2R}), the nocturnal activity factor (f_{night}), and the figures for monthly daylight and night-time hours calculated at Stage A. In order to estimate the number of birds flying through rotors, the model considers the number of turbines, the turbine rotor radius, and the flight speed of the target species. For flight speed, a typical mean value is selected based on standard key literature, acknowledging that flight speed (and thus collision risk) will vary depending on bird behaviour (e.g. commuting, migration, foraging).

The output from Stage B is the estimated number of bird transits through the rotor swept area per year, presented for each species (assuming no avoidance). 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 within the CRZ at PCH.

The total number of transits per year for each species is detailed in **Table 2.5** below. For the proposed 16-turbine wind farm, with a rotor radius of 58.5 m, the total rotor frontal area is 172,021 m².

Table 2.5: Projected number of bird transits through rotors.

Species Name	Projected Number of Rotor Transits (Year Total)
Kestrel	88
Buzzard	219
Lesser Black-backed Gull	182
Sparrowhawk	5
Hen Harrier	4
Peregrine	0

2.3 Stage C - Probability of Collision for a Single Rotor Transit

Stage C utilises information on the size and speed of the turbines, and physical characteristics of the bird (including size and flight speed), to determine the risk of collision for a bird flying through a rotating rotor.

A bird is modelled as a flying cross with length, wingspan and speed, and is assumed to fly perpendicularly towards the rotor. A bird may be 'gliding' or 'flapping'. 'Gliding' flight has a marginally lower collision risk than 'flapping' flight, notably for passage at points level with the rotor hub where the wings lie parallel with potentially colliding blades. However, the difference is rarely sufficient to warrant detailed consideration of different bird behaviours; the flight type used should be that which best typifies most flights for the species in question.

It is assumed that birds can avoid stationary infrastructure, so no account is taken of the turbine towers or blades when stationary. While this may be reasonable in clear daylight conditions, it may not be entirely accurate at night or in conditions of poor visibility. Therefore, the model may underestimate collision risk under such conditions.

For the calculations relating to the Proposed Development, a conservative approach was adopted. The calculation was carried out using a mean operational turbine speed based on the most likely value anticipated by the wind farm developer, and birds were assumed to be flapping rather than gliding.

The NatureScot (2024) CRM spreadsheet calculates the risk of collision during a single transit. The collision probability for each species is shown in **Table 2.6**.

Table 2.6: Single transit risk.

Species Name	Single Transit Risk - Weighted Mean (%)
Kestrel	6.79
Buzzard	7.01
Lesser Black-backed Gull	7.68
Sparrowhawk	6.73
Hen Harrier	8.22
Peregrine	6.70

2.4 Stage D - Multiplying to Yield Expected Collisions Per Year

Stage D multiplies the outputs from Stage B, which estimated the likely number of flights through rotors across the wind farm, by the collision risk from Stage C, which calculated the probability of collision for a single bird transit through a rotor. These are combined to yield an estimate of total potential collision risk, including a factor to account for the proportion of time that the wind turbines are operational. This is before considering avoidance behaviour.

A turbine may typically be at rest or idling for a considerable proportion of time, either because the wind is too weak to generate power, or, in exceptional cases, because turbines are shut down to avoid damage in high winds. Some downtime is also required for maintenance. The default operational time of 85% is considered industry standard, originally based on guidance from the British Wind Energy Association (BWEA), now known as RenewableUK, and is a widely used assumption in CRM.

A conservative downtime estimate of 15% was applied (i.e. turbines assumed to be rotating 85% of the time); in reality, actual downtime may be higher. The collision rate for each species, before accounting for avoidance, is provided in **Table 2.7**.

Table 2.7: Predicted collision rates before avoidance.

Species Name	Collision Rates Per Year Before Avoidance
Kestrel	5
Buzzard	13
Lesser Black-backed Gull	12
Sparrowhawk	0
Hen Harrier	0
Peregrine	0

2.5 Stage E - Applying the Avoidance Rate

The preceding stages of the model assume that birds take no avoiding action in response to wind turbines. In reality, birds mostly take effective avoiding action to prevent collision with wind turbines. They may avoid the area of the wind farm altogether, or they may use more indirect flight routes to bypass the wind farm. This is referred to as behavioural displacement.

Alternatively, birds may continue to fly within or close to the wind farm but exhibit behavioural avoidance, choosing routes which pass between rotors. They may also fly lower or higher to avoid the rotors or take action in-flight to evade an approaching blade.

Band (2024) states that there are many sources of variability or uncertainty in the model output, and a list of the main sources of uncertainty is provided in the guidance. Band (2024) notes that the greatest uncertainty arises from the uncertainties surrounding bird avoidance behaviour, which are likely to dwarf the errors and uncertainties arising from an inexact collision model or variability in survey data.

The CRM analyses have been undertaken for different avoidance rate scenarios, as recommended in guidance (Band, 2024; NatureScot, 2024), and the associated outputs cover a considerable range. These outputs were evaluated assuming avoidance rates of 95%, 98%, 99% and 99.5%.

Table 2.8 presents these collision risk estimates per year for each of the avoidance rates assessed for each species. The recommended avoidance rate for each species is highlighted in bold, in accordance with NatureScot guidance (2025) and SNH (2010; SNH, 2018).

Table 2.8: Collision rates allowing for different avoidance rates.

Species	Estimated Collision Rates Per Year			
	95.00% Avoidance	98.00% Avoidance	99.00% Avoidance	99.50% Avoidance
Kestrel	0.3	0.1	0.1	0.0
Buzzard	0.7	0.3	0.1	0.1
Lesser Black-backed Gull	0.6	0.2	0.1	0.1
Sparrowhawk	0.0	0.0	0.0	0.0
Hen Harrier	0.0	0.0	0.0	0.0
Peregrine	0.0	0.0	0.0	0.0

The species that have a species-specific avoidance rate (Hen Harrier and Kestrel) are considered to have the least uncertainty, as these species have been subject to research that has informed the applicable avoidance rate.

The species for which the default avoidance rate of 98.00% has been used (Buzzard, Lesser Black-backed Gull, Sparrowhawk and Peregrine) are considered to have greater uncertainty, as there is insufficient data for these species to suggest an appropriate alternative avoidance rate. However, as it is generally the case that for most species with a species-specific avoidance rate it is higher than the default, this uncertainty is considered most likely to result in an over-estimation of collision risk rather than an under-estimation.

Although different avoidance rates result in large differences in predicted collision risk, the collision estimates used are based on the avoidance rates recommended in guidance (NatureScot, 2025), and therefore represent the best-informed and most likely scenario.

Section 3: SUMMARY RESULTS

The collision risks were calculated using flight data recorded during vantage point watches at five fixed locations (VP1-VP5) within the study area between April 2021 and March 2023. The target species recorded within the potential CRZ at PCH included Kestrel, Buzzard, Lesser Black-backed Gull, Sparrowhawk, Hen Harrier and Peregrine.

The results of the CRM assuming avoidance are provided in **Table 3.1**. The predicted collisions per year for Kestrel, Buzzard and Lesser Black-backed Gull are less than one. The Proposed Development is predicted to result in 0.3 collisions per year for Kestrel and Buzzard, and 0.2 collisions per year for Lesser Black-backed Gull according to the CRM. While the predicted collision rates for these species are relatively higher due to recorded bird activity and numbers of birds observed, it is noted that the model provides a conservative estimate, and the number of actual collisions is likely to be lower.

The numbers of predicted yearly collisions for the remaining species are either close to or at zero and are considered negligible. Where the number of predicted collisions is shown as 0.00, this indicates that predicted collisions are <0.01 per year.

Table 3.1: Summary collision modelling results.

Species	Mean No. of predicted collisions per year			Mean time between predicted collisions (years)	Mean No. of predicted collisions per 35 years
	Without Avoidance	Avoidance Rate	With Avoidance		
Kestrel	5	95%	0.3	3.33	10.5
Buzzard	13	98%	0.3	3.33	10.5
Lesser Black-backed Gull	12	98%	0.2	5	7.0
Sparrowhawk	0.0	98%	0.0	0.00	0.0
Hen Harrier	0.0	99%	0.0	0.00	0.0
Peregrine	0.0	98%	0.0	0.00	0.0

Section 4: CONCLUSION

This CRM has been completed for the proposed Tirawley Wind Farm development. The CRM was undertaken following the latest NatureScot guidance (NatureScot, 2024; Band, 2024). The VP survey data used for this CRM were collected over two summer surveys (breeding seasons) and two winter surveys (non-breeding seasons), which meets the requirements of current SNH guidelines.

CRMs provide theoretical predictions of the probability of bird collisions with wind turbine rotor blades. The results are affected by sources of uncertainty including natural variability in bird populations, accuracy of the available information regarding species avoidance rates, turbine specifications, and the representativeness of the survey data. As such, the results are considered to be a best estimate of collision risk, rather than a precise figure. Therefore, the predicted collision risk should be considered only an indication of the potential collision risk significance for each target species.

Due to the low frequency of recorded flights, the collision risk for Merlin can be assumed to be effectively zero. At <0.01 collisions within the nominal 35-year operational phase of the Proposed Development is predicted for Sparrowhawk, Hen Harrier and Peregrine. The collision risk for Kestrel is estimated at 0.3 birds per year (or 10.5 birds over the nominal 35-year operational phase), similarly the collision risk for Buzzard is estimated at 0.3 birds per year (or 10.5 birds over the nominal 35-year operational phase), and the collision risk for Lesser Black-backed Gull is estimated at 0.2 birds per year (or 7.0 birds over the nominal 35-year operational phase).

Additional mortality caused by predicted collisions, relative to the background mortality rate, should be assessed to evaluate the population-level consequences for these species. Following the magnitude of effects outlined in Percival (2003), a <1% increase in background mortality corresponds with a negligible effect, and a 1-5% increase in background mortality corresponds with a low effect.

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 the population at a national and county level. For Kestrel, Buzzard, Lesser Black-backed Gull, Sparrowhawk, Hen Harrier and Peregrine there is a <1% increase in background mortality rate (i.e. negligible effect) of the national and county populations (see **Table 6.15**).

However, it should be noted that the county population is an estimate based on the proportion of the national population split by county area, due to a lack of specific county-level estimates. This method does not account for regional variations in bird densities, which can skew estimates where certain species are more or less abundant based on local habitat conditions. In addition, seasonal fluctuations, particularly for migratory species, add further complexity. Migratory birds can cause significant seasonal shifts in population size, creating temporal variations not reflected in static population estimates. For instance, Hen Harriers are more widely distributed in winter due to an influx of migrants, which could impact the baseline population at risk of collision.

In conclusion, and with regard to the limitations and assumptions inherent in the CRM, the resulting predicted collisions should only be considered an indication and not a definitive result. Thus, the outputs of the CRM should be used solely as a comparative tool rather than an accurate indicator of bird mortality risk. It is therefore advised to interpret CRM results as indicating only the order of magnitude of the predicted collision risk for the target species.

Section 5: BIBLIOGRAPHY

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Section 6: APPENDICES
Appendix 1. FIGURES & MAPS



Figure 6.1: Site location and red line boundary indicating the area proposed for turbines.

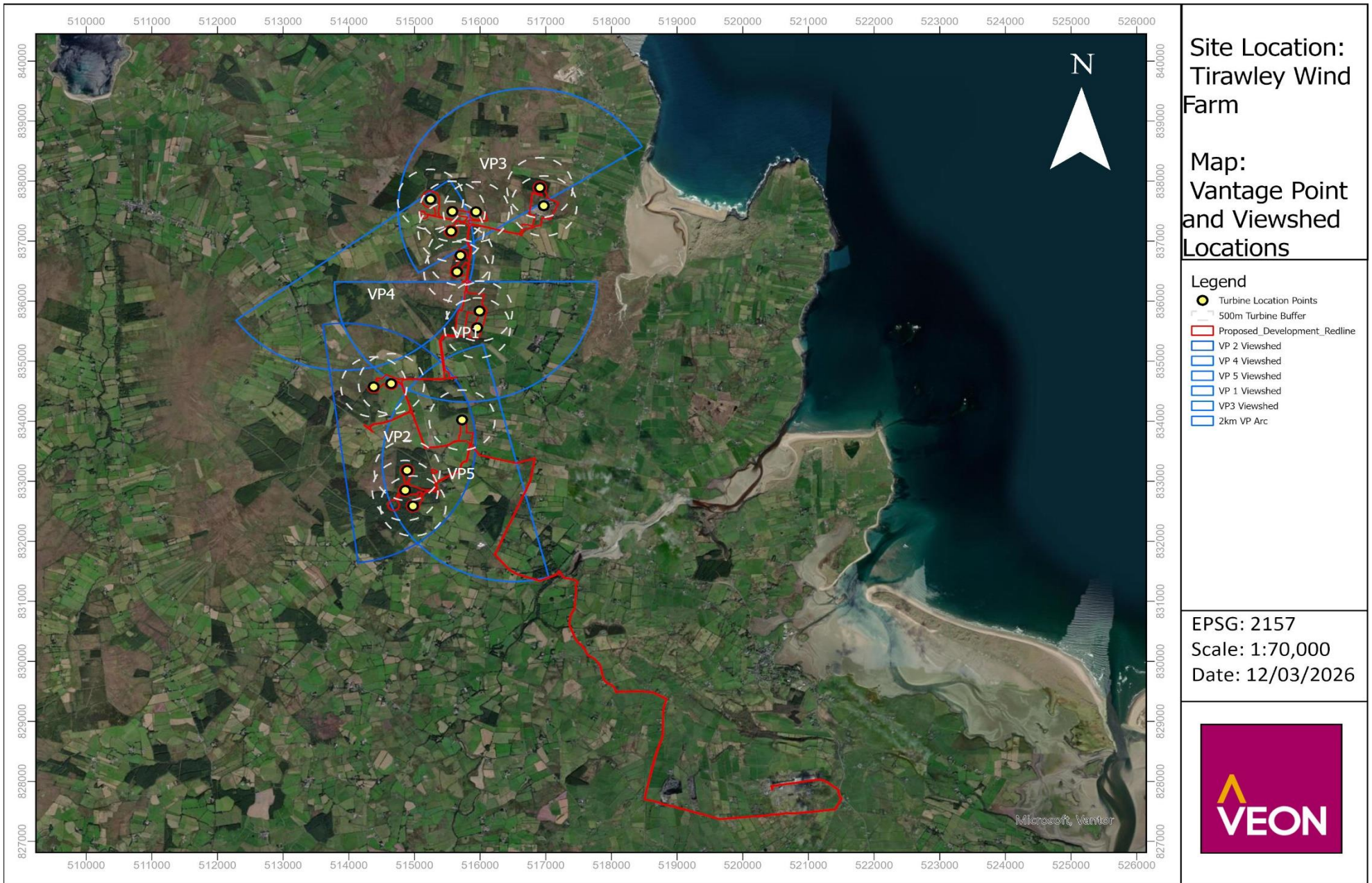


Figure 6.2: Vantage Point (VP) locations and viewshed map.

Appendix 2. VANTAGE POINT SURVEY EFFORT

VANTAGE POINT SURVEY EFFORT (HOURS) FOR SUMMER 2021

Table 6.1: Tirawley VP data (VP1-5) survey effort Summer 2021.

Survey Effort Data (Summer 2021 April-September)							
Vantage Point	April	May	June	July	August	September	Total Hours
VP 1	6	6	6	6	6	6	36
VP 2	6	6	6	6	6	6	36
VP 3	6	6	6	6	6	6	36
VP 4	6	6	6	6	6	6	36
VP 5	6	6	6	6	6	6	36
Total	30	30	30	30	30	30	180

VANTAGE POINT SURVEY EFFORT (HOURS) FOR WINTER 2021-2022

Table 6.2: Tirawley VP data (VP1-5) survey effort Winter 2021-2022.

Survey Effort Data (Winter 2021-2022 October-March)							
Vantage Point	October	November	December	January	February	March	Total Hours
VP 1	6	6	6	6	6	6	36
VP 2	6	6	6	6	6	6	36
VP 3	6	6	6	6	6	6	36
VP 4	6	6	6	6	6	6	36
VP 5	6	6	6	6	6	6	36
Total	30	30	30	30	30	30	180

VANTAGE POINT SURVEY EFFORT (HOURS) FOR SUMMER 2022

Table 6.3: Tirawley VP data (VP1-5) survey effort Summer 2022.

Survey Effort Data (Summer 2022 April-September)							
Vantage Point	April	May	June	July	August	September	Total Hours
VP 1	6	6	6	6	6	6	36
VP 2	6	6	6	6	6	6	36
VP 3	6	6	6	6	6	6	36
VP 4	6	6	6	6	6	6	36
VP 5	6	6	6	6	6	6	36
Total	30	30	30	30	30	30	180

VANTAGE POINT SURVEY EFFORT (HOURS) FOR WINTER 2022-2023

Table 6.4: Tirawley VP data (VP1-5) survey effort Winter 2022-2023.

Survey Effort Data (Winter 2022-2023 October-March)							
Vantage Point	October	November	December	January	February	March	Total Hours
VP 1	6	6	6	6	6	6	36
VP 2	6	6	6	6	6	6	36
VP 3	6	6	6	6	6	6	36
VP 4	6	6	6	6	6	6	36
VP 5	6	6	6	6	6	6	36
Total	30	30	30	30	30	30	180

SUMMARY OF VANTAGE POINT (VP) WATCH VARIABLES, APRIL 2021 TO MARCH 2023

Table 6.5: Summary of Vantage Point (VP) - Survey Details.

Date	Season	VP No.	Duration (hrs)	Start Time	Weather Conditions
Summer No. 1					
23/04/2021	Summer	2	3	07.28	Dry, Good visibility, SE F2-3
24/04/2021	Summer	1	3	10.00	Dry, Good visibility, S, F2
24/04/2021	Summer	5	3	14.00	Dry, Good visibility, S-SE, F3
25/04/2021	Summer	5	3	07.45	Dry, Good visibility, SW, F3
25/04/2021	Summer	1	3	12.00	Dry, Good visibility, SW, F3
29/04/2021	Summer	2	3	18.00	Dry, Good visibility, NE F4
29/04/2021	Summer	3	3	07.30	Dry, Good visibility, N F3
29/04/2021	Summer	3	3	11.00	Dry, Good visibility, NE F3
30/04/2021	Summer	4	3	14.00	Dry, Good visibility, N wind, F4
30/04/2021	Summer	4	3	17.30	Dry, Good visibility, N wind, F4
09/05/2021	Summer	2	3	09.05	Dry, Good visibility, SE wind, F3-4
09/05/2021	Summer	2	3	12.30	Dry, Good visibility, SE wind, F3-4
09/05/2021	Summer	1	3	09.30	Dry, Good visibility, SE wind, F3-4
09/05/2021	Summer	1	3	13.00	Dry, Good visibility, SE wind, F3
16/05/2021	Summer	4	3	07.30	Dry, Good visibility, WNW wind, F3-4
16/05/2021	Summer	4	3	11.00	Dry, Good visibility, WNW wind, F3
20/05/2021	Summer	5	3	08.00	Dry, Good visibility, NW wind, F3
20/05/2021	Summer	5	3	13.00	Dry, Good visibility, N wind, F2-3
26/05/2021	Summer	3	3	08.00	Dry, Good visibility, NE wind, F3
27/05/2021	Summer	3	3	11.00	Dry, Good visibility, NE wind, F2-3
03/06/2021	Summer	4	3	07.00	Dry, Good visibility, SW wind, F4+
03/06/2021	Summer	4	4	10.30	Dry, Good visibility, SW wind F4
07/06/2021	Summer	2	3	11.45	Dry, Good visibility, S wind, F3
07/06/2021	Summer	2	3	15:30	Dry, Good visibility, S wind, F3
12/06/2021	Summer	1	3	07.00	Dry, Good visibility, SW wind, F3
12/06/2021	Summer	5	3	14.00	Dry, Good visibility, SW wind, F3
13/06/2021	Summer	1	3	10.00	Dry, Good visibility, NW wind, F4
13/06/2021	Summer	5	3	15.00	Dry, Good visibility, NW wind, F4
25/06/2021	Summer	3	3	09:00	Dry, Good visibility, N wind, F4
25/06/2021	Summer	3	3	12:45	Dry, Good visibility, N wind, F4
01/07/2021	Summer	4	3	20.00	Dry, Good visibility, NW wind, F2-3
02/07/2021	Summer	4	3	06.00	Drizzle, Mod-good visibility, SW, F3
12/07/2021	Summer	2	3	10:30	Dry, Good visibility, NW wind, F3
12/07/2021	Summer	2	3	14:30	Dry, Good visibility, NW wind, F3
14/07/2021	Summer	1	3	07.45	Dry, Good visibility, SW wind, F2
14/07/2021	Summer	1	3	12.00	Dry, Good visibility, SW wind, F2
15/07/2021	Summer	5	3	10.00	Dry, Good visibility, SW wind, F1-2
15/07/2021	Summer	5	3	16.00	Dry, Good visibility, SW wind, F1-2
22/07/2021	Summer	3	3	10:00	Dry, Good visibility, SE wind, F2
22/07/2021	Summer	3	3	13:30	Dry, Good visibility, SE wind, F2

Date	Season	VP No.	Duration (hrs)	Start Time	Weather Conditions
11/08/2021	Summer	2	3	07:35	Dry, Good visibility, W wind, F3
11/08/2021	Summer	2	3	11:00	Dry, Good visibility, W wind, F3
13/08/2021	Summer	5	3	08.30	Dry, Good visibility, W wind, F3
13/08/2021	Summer	5	3	13.00	Dry, Good visibility, W wind, F3
24/08/2021	Summer	3	3	08:00	Dry, Good visibility, NE wind, F3
24/08/2021	Summer	3	3	11:30	Dry, Good visibility, NE wind, F3
27/08/2021	Summer	1	3	09.00	Showers, Good visibility, N wind, F3-4
27/08/2021	Summer	1	3	14.30	Dry, Good visibility, N wind, F2
31/08/2021	Summer	4	3	11.00	Dry, Good visibility, SE wind, F4
31/08/2021	Summer	4	3	14.30	Dry, Good visibility, SE wind, F3-4
09/09/2021	Summer	3	3	11.30	Dry, Good visibility, WNW wind, F3-4
09/09/2021	Summer	3	3	15.00	Dry, Good visibility, WNW wind, F3
10/09/2021	Summer	2	3	07:10	Drizzle, Good visibility, NW wind, F2-3
10/09/2021	Summer	2	3	12:00	Drizzle, Mod-good vis., NW wind, F3
15/09/2021	Summer	1	3	07.30	Dry, Good visibility, W wind, F3-4
15/09/2021	Summer	5	3	12.00	Dry, Good visibility, NW wind, F3
16/09/2021	Summer	5	3	10.20	Showers, Good visibility, NW wind, F3
16/09/2021	Summer	1	3	14.00	Showers, Good visibility, NW wind, F3
30/09/2021	Summer	4	3	12.30	Showers, Mod-good visibility, W F4-5
30/09/2021	Summer	4	3	16.00	Showers, Good visibility, W wind, F4
Winter No. 1					
10/10/2021	Winter	1	3	09.15	Dry, Good visibility, SW wind, F3-4
10/10/2021	Winter	1	3	13.00	Dry, Good visibility, SW wind, F3
14/10/2021	Winter	2	3	07.50	Dry, Good visibility, SW wind, F3
14/10/2021	Winter	2	3	11.45	Dry, Good visibility, SW wind, F4
22/10/2021	Winter	4	3	13:00	Showers, Good visibility, WSW wind, F4
22/10/2021	Winter	4	3	15:30	Showers, Good visibility, WSW wind, F4
24/10/2021	Winter	5	3	09.30	Rain, Mod-good visibility, NW wind, F3
24/10/2021	Winter	5	3	14.00	Showers, Good visibility, W wind, F2
31/10/2021	Winter	3	3	07.00	Dry, Good visibility, S wind F3
31/10/2021	Winter	3	3	10.30	Dry, Good visibility, S wind F2-3
24/11/2021	Winter	1	3	09.30	Showers, Good visibility, SW wind, F4
24/11/2021	Winter	1	3	13.00	Showers, Good visibility, SW wind, F3-4
24/11/2021	Winter	5	3	09.15	Showers, Good visibility, SW wind, F3
24/11/2021	Winter	5	3	13.00	Showers, Good visibility, SW wind, F3-4
25/11/2021	Winter	2	3	08.30	Dry, Good visibility, NE wind, F2-3
25/11/2021	Winter	2	3	12.30	Dry, Good visibility, NE wind, F2-3
25/11/2021	Winter	3	3	08.40	Dry, Good visibility, NE wind, F2-3
25/11/2021	Winter	3	3	12.45	Dry, Good visibility, NE wind, F2-3
30/11/2021	Winter	4	3	09.30	Drizzle, Mod visibility, SW wind, F1
30/11/2021	Winter	4	3	17.00	Showers, Good visibility, SW wind, F2-3
02/12/2021	Winter	2	3	08.00	Drizzle, Mod visibility, SW wind, F1-2
02/12/2021	Winter	2	3	12.00	Drizzle, Mod visibility, SW wind, F1-2
10/12/2021	Winter	5	3	09.10	Dry, Good visibility, W wind, F3

Date	Season	VP No.	Duration (hrs)	Start Time	Weather Conditions
24/04/2022	Summer	5	3	10.00	Dry, Good visibility, SW wind, F-3
24/02/2022	Summer	5	3	15.00	Dry, Good visibility, SW wind, F-3
25/04/2022	Summer	4	3	05.30	Dry, Good visibility, W wind, F1
25/04/2022	Summer	4	3	09.00	Dry, Good visibility, W wind, F1-2
17/05/2022	Summer	1	3	09.45	Dry, Good visibility, SW wind, F-4
17/05/2022	Summer	1	3	13.00	Dry, Good visibility, SW wind, F-3
18/05/2022	Summer	5	3	07.15	Dry, Good visibility, S wind, F-3
18/05/2022	Summer	5	3	11.00	Dry, Good visibility, S wind, F-3
19/05/2022	Summer	2	3	09.55	Showers, Good visibility, S wind, F4
19/05/2022	Summer	2	3	14:10	Dry, Good visibility, S wind, F4
20/05/2022	Summer	4	3	14:00	Showers, Good visibility, W wind, F4
20/05/2022	Summer	4	3	17:30	Dry, Good visibility, SW wind, F4-5
21/05/2022	Summer	3	3	11.00	Dry, Good visibility, S wind, F3-4
21/05/2022	Summer	3	3	14.30	Dry, Good visibility, S wind, F4
03/06/2022	Summer	4	3	13:40	Dry, Good visibility, E wind, F2-3
03/06/2022	Summer	4	3	17:10	Dry, Good visibility, E wind, F1
04/06/2022	Summer	3	3	11:30	Dry, Good visibility, E wind, F3
04/06/2022	Summer	3	3	15:00	Dry, Good visibility, E wind, F2
09/06/2022	Summer	2	3	09.10	Showers, Good vis., SW wind, F4-5
09/06/2022	Summer	2	3	13.40	Showers, Good vis., W wind, F5
15/06/2022	Summer	1	3	07.15	Dry, Good visibility, S wind, F1
15/06/2022	Summer	1	3	12.00	Dry, Good visibility, S wind, F2
22/06/2022	Summer	5	3	10.00	Dry, Good visibility, W wind, F2-3
22/06/2022	Summer	5	3	15.00	Dry, Good visibility, SW wind, F3
07/07/2022	Summer	2	3	06.45	Dry, Good visibility, W wind, F2
07/07/2022	Summer	2	3	10.10	Dry, Good visibility, W wind, F2
10/07/2022	Summer	3	3	13:30	Dry, Good visibility, W wind, F1-2
10/07/2022	Summer	3	3	17:00	Dry, Good visibility, W wind, F1
11/07/2022	Summer	4	3	10:00	Dry, Good visibility, S wind, F3-4
11/07/2022	Summer	4	3	13:30	Dry, Good visibility, S wind, F4+
20/07/2022	Summer	1	3	10.30	Dry, Good visibility, SW wind, F2
20/07/2022	Summer	1	3	15.00	Dry, Good visibility, SW wind, F2
21/07/2022	Summer	5	3	07.00	Dry, Good visibility, S wind, F2
21/07/2022	Summer	5	3	11.00	Dry, Good visibility, S wind, F2
11/08/2022	Summer	3	3	14:00	Dry, Good visibility, N wind, F2-3
11/08/2022	Summer	3	3	17:30	Dry, Good visibility, N wind, F3
12/08/2022	Summer	4	3	11:00	Dry, Good visibility, SSE wind, F1
12/08/2022	Summer	4	3	14:30	Dry, Good visibility, SE wind, F1
13/08/2022	Summer	2	3	08.35	Dry, Good visibility, NW wind, F3
13/08/2022	Summer	2	3	12.20	Dry, Good visibility, NW wind, F3
18/08/2022	Summer	5	3	08.45	Showers, Good visibility, NE wind, F3-4
18/08/2022	Summer	5	3	14.00	Dry, Good visibility, NE wind, F2-3
24/08/2022	Summer	1	3	09.30	Dry, Good visibility, SW wind, F3
24/08/2022	Summer	1	3	13.30	Dry, Good visibility, SW wind, F3

Date	Season	VP No.	Duration (hrs)	Start Time	Weather Conditions
12/09/2022	Summer	5	3	10.00	Showers, Good visibility, W wind, F4
12/09/2022	Summer	5	3	14.30	Dry, Good visibility, W wind, F3
15/09/2022	Summer	2	3	13.00	Dry, Good visibility, NW wind, F3
15/09/2022	Summer	2	3	19.30	Dry, Good visibility, NW wind, F3
17/09/2022	Summer	1	3	11.00	Showers, Good visibility, SW wind, F3-4
17/09/2022	Summer	1	3	16.00	Dry, Good visibility, SW wind, F3
23/09/2022	Summer	3	3	12:30	Dry, Good visibility, NW wind, F4
23/09/2022	Summer	3	3	16:00	Drizzle, Good visibility, NW wind, F4
24/09/2022	Summer	3	3	07:45	Dry, Good visibility, N wind, F4
24/09/2022	Summer	3	3	11:15	Dry, Good visibility, N wind, F3
Winter No. 2					
10/10/2022	Winter	1	3	09.45	Dry, Good visibility, SW wind, F3
10/10/2022	Winter	1	3	14.30	Dry, Good visibility, SSW wind, F2
11/10/2022	Winter	3	3	07:30	Drizzle, Good visibility, S wind, F1-2
11/10/2022	Winter	3	3	11:00	Drizzle, Mod-good visibility, S, F3-4
12/10/2022	Winter	4	3	08:15	Dry, Good visibility, W wind, F1
12/10/2022	Winter	4	3	11:45	Dry, Good visibility, W wind, F1
13/10/2022	Winter	2	3	07.20	Dry, Good visibility, S wind, F3
13/10/2022	Winter	2	3	11.00	Drizzle, Mod visibility, S wind, F2-3
18/10/2022	Winter	5	3	08.00	Showers, Good visibility, W wind, F3
18/10/2022	Winter	5	3	12.00	Showers, Good visibility, W wind, F3-4
12/11/2022	Winter	1	3	09.00	Drizzle, Mod visibility, S wind, F2
12/11/2022	Winter	5	3	11.45	Dry, Good visibility, S wind, F3
13/11/2022	Winter	1	3	08.15	Showers, Good visibility, SW wind, F3
13/11/2022	Winter	5	3	13.30	Dry, Good visibility, SW wind, F4
22/11/2022	Winter	3	3	10:00	Dry, Good visibility, SE wind, F1
22/11/2022	Winter	3	3	13:30	Dry, Good visibility, SE wind, F1
23/11/2022	Winter	4	3	08:00	Drizzle, Mod-good visibility, SE wind, F3
23/11/2022	Winter	4	3	11:30	Dry, Good visibility, S wind, F4
25/11/2022	Winter	2	3	08.15	Showers, Good visibility, SW wind, F4-5
25/11/2022	Winter	2	3	13.25	Dry, Good visibility, SW wind, F4
09/12/2022	Winter	4	3	10.00	Drizzle, Good visibility, N wind F1
09/12/2022	Winter	4	3	13.30	Drizzle, Good visibility, N wind F1-2
10/12/2022	Winter	3	3	09.00	Dry, Good visibility, N wind F1
10/12/2022	Winter	3	3	12.30	Dry, Good visibility, N wind F2
13/12/2022	Winter	5	3	09.15	Dry, Good visibility, NW wind, F3
13/12/2022	Winter	5	3	13.00	Dry, Good visibility, NW wind, F3
16/12/2022	Winter	1	3	09.30	Dry, Good visibility, W wind, F4
16/12/2022	Winter	1	3	13.30	Dry, Good visibility, W wind, F3
19/12/2022	Winter	2	3	08.30	Showers, Good visibility, S wind, F4
19/12/2022	Winter	2	3	12.20	Showers, Good visibility, S wind, F4
02/01/2023	Winter	2	3	08.15	Dry, Good visibility, S wind, F1
02/01/2023	Winter	2	3	14.10	Dry, Good visibility, S wind, F2
11/01/2023	Winter	1	3	09.00	Dry, Good visibility, W wind, F3-4

Date	Season	VP No.	Duration (hrs)	Start Time	Weather Conditions
11/01/2023	Winter	1	3	12.30	Dry, Good visibility, W wind, F4
12/01/2023	Winter	5	3	08.00	Showers, Good visibility, SW wind, F4
12/01/2023	Winter	5	3	12.00	Showers, Good visibility, SW wind, F4
22/01/2023	Winter	3	3	08.25	Dry, Mod-good visibility, E wind F1
22/01/2023	Winter	3	3	14.10	Dry, Good visibility, S wind F1
23/01/2023	Winter	4	3	08.25	Dry, Poor visibility, SE wind F2-3
23/01/2023	Winter	4	3	12.45	Dry, Good visibility, SE wind F2-3
10/02/2023	Winter	2	3	08.00	Drizzle, Mod. visibility, S wind, F1
10/02/2023	Winter	2	3	13.00	Dry, Good visibility, S wind, F2
15/02/2023	Winter	5	3	09.30	Dry, Good visibility, W wind, F3
15/02/2023	Winter	5	3	14.00	Showers, Good visibility, SW wind, F3
17/02/2023	Winter	4	3	11.30	Dry, Good visibility, SW wind, F2
17/02/2023	Winter	4	1.5	15.00	Drizzle, Mod-good visibility, SW F2
18/02/2023	Winter	4	1.5	16.30	Drizzle, Good visibility, W wind, F4-5
18/02/2023	Winter	3	3	07.50	Drizzle, Good visibility, W wind, F3
18/02/2023	Winter	3	3	11.20	Drizzle, Good visibility, W wind F4
24/02/2023	Winter	1	3	09.45	Dry, Good visibility, S wind, F3
24/02/2023	Winter	1	3	14.00	Dry, Good visibility, S wind, F2
14/03/2023	Winter	2	3	12.15	Showers, Good visibility, NW wind, F4
14/03/2023	Winter	2	3	15.45	Showers, Good visibility, NW wind, F4
19/03/2023	Winter	5	3	10.30	Showers, Good visibility, W wind, F4
19/03/2023	Winter	5	3	15.00	Dry, Good visibility, W wind, F2-3
20/03/2023	Winter	1	3	08.00	Dry, Good visibility, SW wind, F3
20/03/2023	Winter	1	3	12.00	Dry, Good visibility, SW wind, F3
25/03/2023	Winter	3	3	12.30	Dry, Good visibility, W-NW wind, F2
25/03/2023	Winter	3	3	16.00	Dry, Good visibility, NW wind, F1
28/03/2023	Winter	4	3	07.20	Showers, Good visibility, SE F3-4
28/03/2023	Winter	4	3	10.50	Showers, Good visibility, SW F2

Appendix 3. VANTAGE POINT BIRD FLIGHTLINE DATA

Table 6.6: All bird flightline data 2021-2023.

VP No.	Date	Map note / Flightline No.	Common Name	Species Quantity	Time of Obs.	Total Duration (s)	0-20 m (s)	20-50 m (s)	50-100 m (s)	100-180 m (s)	>180 m (s)	Comment
Summer 2021												
2	23/04/2021	1	Kestrel	1	10:08	60	30	30	0	0	0	Hunting
1	24/04/2021	2	Buzzard	1	11.13	180	0	0	0	180	0	Circling
5	25/04/2021	3	Kestrel	1	09.17	90	0	60	30	0	0	Male Flying / Hunting low
3	29/04/2021	4	Kestrel	1	08.58	60	60	0	0	0	0	Flying low
3	29/04/2021	5	Lesser black-backed gull	1	12.56	120	120	0	0	0	0	Flew over VP area
3	29/04/2021	6	Lesser black-backed gull	1	04:16	40	0	40	0	0	0	Flying
4	30/04/2021	7	Lesser black-backed gull	3	18.11	45	0	0	15	30	0	Flying / soaring
4	30/04/2021	8	Lesser black-backed gull	26	18.53	60	0	0	0	30	30	Flock flying high
1	09/05/2021	9	Buzzard	1	15.22	180	0		120	60	0	Flying steadily NE
4	16/05/2021	10	Lesser black-backed gull	2	09.37	75	0	0	75	0	0	Flying
4	16/05/2021	11	Kestrel	1	10.57	25	25	0	0	0	0	Flying
5	20/05/2021	12	Kestrel	1	08.43	120	0	90	30	0	0	Hunting
4	03/06/2021	13	Lesser black-backed gull	3	10.02	140	0	20	120	0	0	Drifting
4	03/06/2021	14	Kestrel	1	11.00	60	60	0	0	0	0	Flying / hunting low
2	07/06/2021	15	Lesser black-backed gull	3	09.10	150	0	50	100	0	0	Flying
2	07/06/2021	16	Lesser black-backed gull	5	14.24	135	35	40	60	0	0	Flying
1	12/06/2021	17	Kestrel	1	08.55	180	40	90	50	0	0	Male hunting edge of forest
1	12/06/2021	18	Buzzard	1	10.11	45	0	45	0	0	0	Flying NE
5	13/06/2021	19	Lesser black-backed gull	5	18.05	75	0	0	0	75	0	Loose flock flying
3	25/06/2021	20	Lesser black-backed gull	1	13.35	60	0	0	60	0	0	Flying
2	12/07/2021	21	Kestrel	1	14.30	45	0	45	0	0	0	Hunting near forest edge

VP No.	Date	Map note / Flightline No.	Common Name	Species Quantity	Time of Obs.	Total Duration (s)	0-20 m (s)	20-50 m (s)	50-100 m (s)	100-180 m (s)	>180 m (s)	Comment
2	12/07/2021	22	Lesser black-backed gull	4	15.16	120	0	70	50	0	0	Flying NNW
1	14/07/2021	23	Kestrel	1	14.09	90	30	60	0	0	0	Hovering, then dropped
3	22/07/2021	24	Sparrowhawk	1	09.15	50	50	0	0	0	0	Hunting
2	11/08/2021	25	Sparrowhawk	1	10.10	300	150	150	0	0	0	Flying / hunting
2	11/08/2021	26	Lesser black-backed gull	1	11.10	30	0	30	0	0	0	Flying
5	13/08/2021	27	Sparrowhawk	1	10.18	20	20	0	0	0	0	Hunting
1	27/08/2021	28	Buzzard	2	15.51	400	0	120	240	40	0	Two interacting
4	31/08/2021	29	Hen harrier	1	11.50	45	45	0	0	0	0	Male flying / hunting
4	31/08/2021	30	Kestrel	1	14.40	45	45	0	0	0	0	Flying
3	09/09/2021	31	Kestrel	1	12.07	30	30	0	0	0	0	Flew into quarry
3	09/09/2021	32	Kestrel	1	14.49	120	20	50	50	0	0	Flying / Hunting
2	10/09/2021	33	Hen harrier	1	13.23	60	60	0	0	0	0	Ringtail - flying then settled on bare branch for c.10 min
2	10/09/2021	34	Buzzard	1	14.31	40	20	20	0	0	0	Mobbed by pigeons
1	15/09/2021	35	Sparrowhawk	1	09.09	20	20	0	0	0	0	Male hunting
1	16/09/2021	36	Hen harrier	1	16.20	60	40	20	0	0	0	Ringtail hunting rough fields
Winter 2021-22												
1	10/10/2021	37	Buzzard	1	13.47	90	0	0	90	0	0	Flying
2	14/10/2021	38	Kestrel	1	13.41	150	0	50	100	0	0	Male hunting
2	14/10/2021	39	Buzzard	1	13.59	85	0	0	85	0	0	Adult flying
4	22/10/2021	40	Kestrel	1	14.05	480	100	180	200	0	0	Flying / Hovering / hunting
4	22/10/2021	41	Kestrel	1	14.16	400	160	100	140	0	0	Hunting - dropped and got prey item
4	22/10/2021	42	Buzzard	1	15.37	70	0	30	40	0	0	Soaring
5	22/10/2021	43	Buzzard	1	10.34	120	0	60	60	0	0	Flying
3	31/10/2021	44	Hen harrier	1	12.06	75	0	75	0	0	0	Ad male flying, appeared to land on bog, not seen again
1	24/11/2021	45	Kestrel	1	11.53	120	20	30	70	0	0	Hovering / hunting - female
5	24/11/2021	46	Sparrowhawk	1	13.12	30	0	30	0	0	0	Hunting edge forest - male
2	25/11/2021	47	Buzzard	1	10.44	90	0	0	90	0	0	Circling over forest
2	25/11/2021	48	Kestrel	1	11.06	75	0	75	0	0	0	Hunting
3	25/11/2021	49	Kestrel	1	13.15	60	0	60	0	0	0	Flying over bog, male
4	30/11/2021	50	Sparrowhawk	1	10.38	30	30	0	0	0	0	Hunting
5	10/12/2021	51	Buzzard	1	13.06	180	0	0	100	80	0	Soaring

VP No.	Date	Map note / Flightline No.	Common Name	Species Quantity	Time of Obs.	Total Duration (s)	0-20 m (s)	20-50 m (s)	50-100 m (s)	100-180 m (s)	>180 m (s)	Comment
1	10/12/2021	52	Sparrowhawk	1	10.43	25	25	0	0	0	0	Hunting
3	21/12/2021	53	Peregrine	1	09.45	32	0	32	0	0	0	Adult flying low
3	21/12/2021	54	Kestrel	1	13.47	40	0	40	0	0	0	Hunting
3	21/12/2021	55	Hen harrier	1	14.35	98	98	0	0	0	0	Ad male - actively hunting
4	30/12/2021	56	Kestrel	1	09.02	110	20	30	60	0	0	Hovering
4	30/12/2021	57	Sparrowhawk	3	11.06	90	0	40	50	0	0	2 male, 1 female rising
4	30/12/2021	58	Hen harrier	1	13.28	120	120	0	0	0	0	Ad male flying low
2	04/01/2022	59	Hen harrier	1	16.30	90	90	0	0	0	0	Flying low
1	20/01/2022	60	Peregrine	1	10.09	70	0	0	70	0	0	Flying steadily
5	24/01/2022	61	Sparrowhawk	1	11.02	25	25	0	0	0	0	Chasing prey item
3	25/01/2022	62	Sparrowhawk	1	09.28	40	0	20	20	0	0	Female flying
3	25/01/2022	63	Peregrine	1	13.53	150	70	80	0	0	0	Flying
5	15/02/2022	64	Buzzard	2	10.56	220	0	50	100	70	0	Pair circling
3	22/02/2022	65	Hen harrier	1	08.54	65	50	15	0	0	0	Ad male actively hunting
3	22/02/2022	66	Kestrel	1	10.10	45	20	25	0	0	0	Male flying
4	27/02/2022	67	Hen harrier	1	09.50	70	10	60	0	0	0	Ad male got up from bog, flew over forest and landed again on bog
4	27/02/2022	68	Kestrel	1	10.34	75	50	25	0	0	0	Hovering
2	14/03/2022	69	Buzzard	2	14.36	650	150	300	150	50	0	Pair in display
1	15/03/2022	70	Buzzard	1	13.42	80	0	80	0	0	0	Flying
3	19/03/2022	71	Hen harrier	1	06.34	22	22	0	0	0	0	Emerged from bog and flew east over quarry area - roost
4	24/03/2022	72	Kestrel	1	10.44	110	60	30	20	0	0	Hunting actively
5	27/03/2022	73	Kestrel	1	10.18	120	0	40	80	0	0	Flying / hunting
Summer 2022												
2	08/04/2022	74	Sparrowhawk	1	13.47	10	10	0	0	0	0	Male hunting
2	08/04/2022	75	Kestrel	1	14.09	60	0	0	60	0	0	Hovering
2	08/04/2022	76	Buzzard	2	15.05	80	0	0	80	0	0	Pair interacting
1	09/04/2022	77	Buzzard	2	14.18	170	0	0	120	50	0	Pair circling
5	24/04/2022	78	Lesser black-backed gull	9	10.43	180	0	0	0	100	80	Loose flock high
5	24/04/2022	79	Sparrowhawk	1	16.08	30	30	0	0	0	0	Male hunting
4	25/04/2022	80	Kestrel	1	09.26	50	20	30	0	0	0	Flying / hunting
1	17/05/2022	81	Buzzard	1	11.11	70	0	70	0	0	0	Flying
5	18/05/2022	82	Sparrowhawk	1	09.17	90	0	0	90	0	0	Circling / soaring

VP No.	Date	Map note / Flightline No.	Common Name	Species Quantity	Time of Obs.	Total Duration (s)	0-20 m (s)	20-50 m (s)	50-100 m (s)	100-180 m (s)	>180 m (s)	Comment
2	19/05/2022	83	Lesser black-backed gull	3	08.40	45	0	45	0	0	0	Adults
3	21/05/2022	84	Sparrowhawk	1	14.56	30	30	0	0	0	0	Male hunting
3	04/06/2022	85	Buzzard	2	16.18	240	0	100	100	40	0	Pair interacting / rising
2	09/06/2022	86	Sparrowhawk	1	15.55	40	40	0	0	0	0	Flying
2	09/06/2022	87	Lesser black-backed gull	2	16.10	25	25	0	0	0	0	Flying
1	15/06/2022	88	Kestrel	1	09.17	45	0	45	0	0	0	Hunting edge of forest
5	22/06/2022	89	Sparrowhawk	1	11.00	90	0	45	45	0	0	Bird circling - prob female
2	07/07/2022	90	Lesser black-backed gull	2	09.44	65	0	65	0	0	0	Flying - adults
2	07/07/2022	91	Buzzard	2	11.30	305	0	0	0	305	0	Pair interacting
3	10/07/2022	92	Kestrel	1	16.14	85	85	0	0	0	0	Hunting
4	11/07/2022	93	Lesser black-backed gull	1	14.33	45	5	40	0	0	0	Flying low
4	11/07/2022	94	Kestrel	2	14.35	210	60	60	90	0	0	Two hunting
1	20/07/2022	95	Kestrel	1	10.48	120	30	60	30	0	0	Male hunting
5	21/07/2022	96	Sparrowhawk	2	09.43	180	0	60	40	80	0	Pair rising
3	11/08/2022	97	Sparrowhawk	1	17.39	10	5	5	0	0	0	Juvenile flying along forest
3	11/08/2022	98	Kestrel	1	18.40	20	20	0	0	0	0	Male
4	12/08/2022	99	Buzzard	2	12.33	180	0	90	40	50	0	Two Soaring
2	13/08/2022	100	Merlin	1	10.13	12	12	0	0	0	0	Female after bird (pipit?) - then landed on fence post for 6 min, and flew again
2	13/08/2022	101	Merlin	1	12.25	10	10	0	0	0	0	Flying along ditch & cross road - not sexed but probably same as earlier
5	14/08/2022	102	Buzzard	1	14.54	70	0	70	0	0	0	Flying
1	24/08/2022	103	Sparrowhawk	1	10.23	75	0	75	0	0	0	Circling over forest
1	17/09/2022	104	Peregrine	1	10.09	60	0	40	20	0	0	Flying direct - prob female
1	17/09/2022	105	Lesser black-backed gull	13	18.12	180	0	120	60	0	0	Loose flock - ads & imms
Winter 2022-23												
1	10/10/2022	106	Kestrel	1	11.09	60	0	60	0	0	0	Flying / hunting
1	10/10/2022	107	Buzzard	2	14.47	160	0	80	40	40	0	Pair rising
3	11/10/2022	108	Hen harrier	1	12.38	55	55	0	0	0	0	Male hunting over wet field / bog
3	11/10/2022	109	Kestrel	1	13.05	210	0	110	100	0	0	Male hunting

VP No.	Date	Map note / Flightline No.	Common Name	Species Quantity	Time of Obs.	Total Duration (s)	0-20 m (s)	20-50 m (s)	50-100 m (s)	100-180 m (s)	>180 m (s)	Comment
5	18/10/2022	110	Buzzard	1	13.14	75	0	75	0	0	0	Flying
5	12/11/2022	111	Kestrel	1	13.09	90	60	30	0	0	0	Hovering
1	13/11/2022	112	Hen harrier	1	10.12	75	75	0	0	0	0	Male hunting fields
3	22/11/2022	113	Hen harrier	1	14.43	5	5	0	0	0	0	Male seen briefly
4	23/11/2022	114	Kestrel	1	11.36	50	40	10	0	0	0	Female hovering
5	13/12/2022	115	Buzzard	1	11.11	90	30	60	0	0	0	Hunting
1	16/12/2022	116	Kestrel	1	10.16	110	30	30	50	0	0	Male hunting on bog
2	19/12/2022	117	Kestrel	1	14.57	120	60	60	0	0	0	Male hunting
2	02/01/2023	118	Kestrel	1	09.32	50	50	0	0	0	0	Male hunting / flying
1	11/01/2023	119	Buzzard	1	09.45	90	0	90	0	0	0	Flying low over wet fields
5	12/01/2023	120	Kestrel	1	13.22	120	40	80	0	0	0	Hunting
4	23/01/2023	121	Kestrel	1	14.04	20	0	20	0	0	0	Hovering
4	23/01/2023	122	Hen harrier	1	14.14	23	23	0	0	0	0	Male along edge of forest, then dropped onto bog
4	23/01/2023	123	Hen harrier	1	15.09	88	88	0	0	0	0	Male hunting - same as above
5	15/02/2023	124	Buzzard	2	15.13	200	0	0	50	150	0	Pair in display rising
3	18/02/2023	125	Kestrel	1	11.22	10	10	0	0	0	0	Flying across quarry
5	24/02/2023	126	Sparrowhawk	2	14.58	240	0	0	120	120	0	Pair in display
5	19/03/2023	127	Sparrowhawk	1	11.08	20	20	0	0	0	0	Hunting
5	19/03/2023	128	Buzzard	1	16.21	90	0	90	0	0	0	Flying
1	20/03/2023	129	Sparrowhawk	1	10.32	120	0	0	120	0	0	Soaring
3	25/03/2023	130	Buzzard	2	14.16	220	0	0	160	60	0	Pair rising
4	28/03/2023	131	Kestrel	1	09.30	75	25	50	0	0	0	Hunting - male

Appendix 4. COLLISION RISK ASSESSMENT CALCULATIONS

Table 6.7: Avian biometric data and avoidance rates.

Avian Biometric Data & Avoidance Rates				
Species Name	Length (m)	Wingspan (m)	Mean flight speed (m/s)	Avoidance rates (%)
Kestrel	0.34	0.76	10.1	95
Buzzard	0.54	1.2	13.3	98
Lesser Black-backed Gull	0.58	1.43	11.9	98
Sparrowhawk	0.33	0.67	10	98
Hen Harrier	0.48	1.1	9.1	99
Peregrine	0.42	1.02	12.1	98

Table 6.8: Kestrel - observations in bird-seconds and bird density in bird seconds per km².

Year	Vantage Point	A - Area of the VP viewshed (visible area) (km ²)	Summer		Winter		t - Total watch time (Seconds)
			Time in flight (bird-secs)	Density (bird-secs/km ²)	Time in flight (bird-secs)	Density (bird-secs/km ²)	
Year 1	VP 1	1.15	270	0.0009	0	0.0000	259200
Year 1	VP 2	2.97	45	0.0001	225	0.0003	259200
Year 1	VP 3	2.18	210	0.0004	145	0.0003	259200
Year 1	VP 4	1.18	60	0.0002	880	0.0029	259200
Year 1	VP 5	1.70	120	0.0003	0	0.0000	259200
Year 2	VP 1	1.15	120	0.0004	110	0.0004	259200
Year 2	VP 2	2.97	60	0.0001	120	0.0002	259200
Year 2	VP 3	2.18	105	0.0002	220	0.0004	259200
Year 2	VP 4	1.18	420	0.0014	20	0.0001	259200
Year 2	VP 5	1.70	0	0.0000	90	0.0002	259200
-	Mean bird density	-	-	0.0004	-	0.0005	-
-	Standard deviation	-	-	0.0004	-	0.0009	-

Table 6.9: Buzzard - observations in bird-seconds and bird density in bird seconds per km².

Year	Vantage Point	A - Area of the VP viewshed (visible area) (km ²)	Summer		Winter		t - Total watch time (Seconds)
			Time in flight (bird-secs)	Density (bird-secs/km ²)	Time in flight (bird-secs)	Density (bird-secs/km ²)	
Year 1	VP 1	1.15	1815	0.0061	170	0.0006	259200
Year 1	VP 2	2.97	40	0.0001	1475	0.0019	259200
Year 1	VP 3	2.18	0	0.0000	0	0.0000	259200
Year 1	VP 4	1.18	0	0.0000	0	0.0000	259200
Year 1	VP 5	1.70	0	0.0000	740	0.0017	259200
Year 2	VP 1	1.15	0	0.0000	410	0.0014	259200
Year 2	VP 2	2.97	770	0.0010	0	0.0000	259200
Year 2	VP 3	2.18	0	0.0000	0	0.0000	259200
Year 2	VP 4	1.18	180	0.0006	0	0.0000	259200
Year 2	VP 5	1.70	0	0.0000	165	0.0004	259200
-	Mean bird density	-	-	0.0008	-	0.0006	-
-	Standard deviation	-	-	0.0019	-	0.0008	-

Table 6.10: Lesser Black-backed Gull - observations in bird-seconds and bird density in bird seconds per km².

Year	Vantage Point	A - Area of the VP viewshed (visible area) (km ²)	Summer		Winter		t - Total watch time (Seconds)
			Time in flight (bird-secs)	Density (bird-secs/km ²)	Time in flight (bird-secs)	Density (bird-secs/km ²)	
Year 1	VP 1	1.15	0	0.0000	0	0.0000	259200
Year 1	VP 2	2.97	1635	0.0021	0	0.0000	259200
Year 1	VP 3	2.18	220	0.0004	0	0.0000	259200
Year 1	VP 4	1.18	0	0.0000	0	0.0000	259200
Year 1	VP 5	1.70	0	0.0000	0	0.0000	259200
Year 2	VP 1	1.15	2340	0.0079	0	0.0000	259200
Year 2	VP 2	2.97	315	0.0004	0	0.0000	259200
Year 2	VP 3	2.18	0	0.0000	0	0.0000	259200
Year 2	VP 4	1.18	0	0.0000	0	0.0000	259200
Year 2	VP 5	1.70	0	0.0000	0	0.0000	259200
-	Mean bird density	-	-	0.0011	-	0.0000	-
-	Standard deviation	-	-	0.0025	-	0.0000	-

Table 6.11: Sparrowhawk - observations in bird-seconds and bird density in bird seconds per km².

Year	Vantage Point	A - Area of the VP viewshed (visible area) (km ²)	Summer		Winter		t - Total watch time (Seconds)
			Time in flight (bird-secs)	Density (bird-secs/km ²)	Time in flight (bird-secs)	Density (bird-secs/km ²)	
Year 1	VP 1	1.15	20	0.0001	25	0.0001	259200
Year 1	VP 2	2.97	0	0.0000	0	0.0000	259200
Year 1	VP 3	2.18	50	0.0001	40	0.0001	259200
Year 1	VP 4	1.18	0	0.0000	0	0.0000	259200
Year 1	VP 5	1.70	0	0.0000	25	0.0001	259200
Year 2	VP 1	1.15	0	0.0000	0	0.0000	259200
Year 2	VP 2	2.97	0	0.0000	0	0.0000	259200
Year 2	VP 3	2.18	40	0.0001	0	0.0000	259200
Year 2	VP 4	1.18	0	0.0000	0	0.0000	259200
Year 2	VP 5	1.70	120	0.0003	480	0.0011	259200
-	Mean bird density	-	-	0.0000	-	0.0001	-
-	Standard deviation	-	-	0.0001	-	0.0003	-

Table 6.12: Hen Harrier - observations in bird-seconds and bird density in bird seconds per km².

Year	Vantage Point	A - Area of the VP viewshed (visible area) (km ²)	Summer		Winter		t - Total watch time (Seconds)
			Time in flight (bird-secs)	Density (bird-secs/km ²)	Time in flight (bird-secs)	Density (bird-secs/km ²)	
Year 1	VP 1	1.15	60	0.0002	0	0.0000	259200
Year 1	VP 2	2.97	60	0.0001	90	0.0001	259200
Year 1	VP 3	2.18	0	0.0000	260	0.0005	259200
Year 1	VP 4	1.18	0	0.0000	120	0.0004	259200
Year 1	VP 5	1.70	0	0.0000	0	0.0000	259200
Year 2	VP 1	1.15	0	0.0000	0	0.0000	259200
Year 2	VP 2	2.97	0	0.0000	0	0.0000	259200
Year 2	VP 3	2.18	0	0.0000	60	0.0001	259200
Year 2	VP 4	1.18	0	0.0000	0	0.0000	259200
Year 2	VP 5	1.70	0	0.0000	0	0.0000	259200
-	Mean bird density	-	-	0.0000	-	0.0001	-
-	Standard deviation	-	-	0.0001	-	0.0002	-

Table 6.13: Peregrine - observations in bird-seconds and bird density in bird seconds per km².

Year	Vantage Point	A - Area of the VP viewshed (visible area) (km ²)	Summer		Winter		t - Total watch time (Seconds)
			Time in flight (bird-secs)	Density (bird-secs/km ²)	Time in flight (bird-secs)	Density (bird-secs/km ²)	
Year 1	VP 1	1.15	0	0.0000	0	0.0000	259200
Year 1	VP 2	2.97	0	0.0000	0	0.0000	259200
Year 1	VP 3	2.18	0	0.0000	182	0.0003	259200
Year 1	VP 4	1.18	0	0.0000	0	0.0000	259200
Year 1	VP 5	1.70	0	0.0000	0	0.0000	259200
Year 2	VP 1	1.15	60	0.0002	0	0.0000	259200
Year 2	VP 2	2.97	0	0.0000	0	0.0000	259200
Year 2	VP 3	2.18	0	0.0000	0	0.0000	259200
Year 2	VP 4	1.18	0	0.0000	0	0.0000	259200
Year 2	VP 5	1.70	0	0.0000	0	0.0000	259200
-	Mean bird density	-	-	0.0000	-	0.0000	-
-	Standard deviation	-	-	0.0001	-	0.0001	-

Table 6.14: Proportion of observed birds flying at rotor risk height (%Q_{2R}).

Species (BTO Code)	No. of birds observed	No. of birds flights observed <u>only</u> in the 0 - 25 m height band	Proportion observed in the 0 - 25 m height band	No. of bird flights observed 25 - 100 m	Proportion observed 25 - 100 m	No. of birds flights observed <u>only</u> in the 100 - 180 m height band	Proportion observed in the 100 - 180 m height band	Proportion between 18 m and 135 m at rotor risk height (%Q _{2R})
Kestrel (K.)	10	7	70.00%	3	30.00%	0	0%	49.6%
Buzzard (BZ)	26	0	0.00%	24	92.31%	2	8%	95.7%
Lesser Black-backed Gull (LB)	36	3	8.33%	33	91.67%	0	0%	94.0%
Sparrowhawk (SH)	11	6	54.55%	5	45.45%	0	0%	60.7%
Hen Harrier (HH)	10	7	70.00%	3	30.00%	0	0%	49.6%
Peregrine (PE)	3	0	0.00%	3	100.00%	0	0%	100.0%

Table 6.15: Calculations of potential increases in annual mortality rates due to the predicted collision mortality.

Parameter	Kestrel		Buzzard		Lesser Black-backed Gull		Sparrowhawk		Hen Harrier		Peregrine	
	County Population ^A	National Population ^B	County Population ^A	National Population ^B	County Population ^A	National Population ^B	County Population ^A	National Population ^B	County Population ^A	National Population ^B	County Population ^A	National Population ^B
Population Size	~ 1309.67	~ 16470	~ 238.56	~ 3000	~ 565.54	~ 7112	~ 981.26	~ 12340	~ 12.48	~ 157	~ 81.89	~ 1030
Annual Survival Rate ^C	0.69	0.69	0.9	0.9	0.913	0.913	0.69	0.69	0.81	0.81	0.81	0.81
Annual background mortality (Pop*(1-Surv))	405.998	5105.7	23.856	300	49.2	618.744	304.19	3825.4	2.37	29.83	15.56	195.7
Predicted Annual Collision Mortality	0.3	0.3	0.3	0.3	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Percentage of Population	0.023	0.002	0.126	0.010	0.035	0.003	0.000	0.000	0.000	0.000	0.000	0.000
Magnitude (Percival, 2003)	<1% (Negligible)	<1% (Negligible)	<1% (Negligible)	<1% (Negligible)	<1% (Negligible)	<1% (Negligible)	<1% (Negligible)	<1% (Negligible)	<1% (Negligible)	<1% (Negligible)	<1% (Negligible)	<1% (Negligible)

A: Estimate based on proportion of population split by county area, used due to a lack of a county estimate.

B: NPWS (2012) Article 12 Report - Ireland's bird species' status and trends for the period 2013-2018, Crowe *et al.*, (2014), etc.

C: Adult survival rates available at: www.bto.org/understanding-birds/birdfacts.

Appendix 5. WORKED CALCULATIONS

Table 6.16: Collision risk model outputs for Kestrel.

COLLISION RISK MODEL

Required input data is in orange boxes
 Calculated output is in blue boxes
 green boxes are for information only, to show variables used at each stage

		Value	Units			Value	Units			Value	Units					
Bird data				Windfarm data				Turbine data								
Species name		Kestrel		Site name		Tirawley		Model	4.3 MW type							
Bird length	L	0.34	m	Latitude		54.25	degrees	Hub height		76.5	m					
Wingspan	W	0.76	m	No of turbines	T	16		Rotor radius	R	58.5	m					
Bird flight speed	v	10.1	m s ⁻¹	Width of windfarm	w	5.5	km	No of blades	b	3						
Flight type, flapping or gliding		flapping						Rotation speed	Ω	12.1	rpm					
% of flights upwind/downwind		50%						Max blade width	C	4	m					
Nocturnal activity ranking 1-5		1						Blade pitch	λ	15	degrees					
Nocturnal activity factor	f _{night}	0%						Risk height range		18-135	m					
normal approach		Set to 'normal approach' to use survey data on bird density														
		Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A														
Stage A	Daytime bird density	D _A	birds/km ²	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year ave
	Proportion at rotor risk height	Q ₂₀	84.00%	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0005	0.0005	0.0005	0.0005
	At latitude 54.3	Daylight hours per month		247.2	271.5	366.1	420.5	495.6	512.7	515.2	461.9	383.3	328.3	257.6	230.6	4490.3
		Nighttime hours per month		496.8	400.5	377.9	299.5	248.4	207.3	228.8	282.1	336.7	415.7	462.4	513.4	4269.7
Stage B	No of turbines	T	16													
	Rotor radius	R	58.5 m													
	Total rotor frontal area	m ²		172021												
	Nocturnal activity factor	f _{night}	0%													
	Bird flight speed	v	10.1 m s ⁻¹	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
	Projected number of rotor transits			5.6	6.1	8.2	7.6	8.9	9.2	9.3	8.3	6.9	7.4	5.8	5.2	88
Stage C	No of blades	b	3													
	Rotation speed	Ω	12.1 rpm													
	Rotor radius	R	58.5 m													
	Max blade width	C	4 m													
	Pitch	λ	15 degrees													
	Blade profile	see Blade profile sheet														
	Bird length	l	0.34 m													
	Wingspan	w	0.76 m													
	Bird flight speed	v	10.1 m s ⁻¹													
	Flight type	flapping														
	% of flights upwind/downwind	50%														
	Single transit risk	up wind		9.60%												
		down wind		3.98%												
		weighted mean		6.79%												
Stage D	Proportion of time operational	Q _{op}		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year ave
				85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance														
				0.32	0.35	0.47	0.44	0.51	0.53	0.53	0.48	0.40	0.43	0.33	0.30	5
Stage E	Allow for large array correction?	No														
	Width of windfarm	w	5.5 km													
		large array correction														
	Avoidance rates modelled			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
		95.00%	100.00%	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.3
		98.00%	100.00%	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.1
		99.00%	100.00%	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.1
		99.50%	100.00%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0

Table 6.17: Collision risk model outputs for Buzzard.

COLLISION RISK MODEL

Required input data is in orange boxes
 Calculated output is in blue boxes
 green boxes are for information only, to show variables used at each stage

		Value	Units			Value	Units			Value	Units					
Bird data		Buzzard		Windfarm data				Turbine data								
Species name				Site name		Tirawley		Model		4.3 MW type						
Bird length	L	0.54	m	Latitude		54.25	degrees	Hub height		76.5	m					
Wingspan	W	1.2	m	No of turbines	T	16		Rotor radius	R	58.5	m					
Bird flight speed	v	13.3	m s ⁻¹	Width of windfarm	w	5.5	km	No of blades	b	3						
Flight type, flapping or gliding		flapping						Rotation speed	Ω	12.1	rpm					
% of flights upwind/downwind		50%	50%					Max blade width	C	4	m					
Nocturnal activity ranking 1-5		1						Blade pitch	λ	15	degrees					
Nocturnal activity factor	f _{night}	0%						Risk height range		18-135	m					
normal approach		Set to 'normal approach' to use survey data on bird density														
		Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A														
Stage A																
Daytime bird density	D _A		birds/km ²	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year ave
Proportion at rotor risk height	Q _{RH}	95.70%		0.0006	0.0006	0.0006	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0006	0.0006	0.0006	0.0007
At latitude 54.3		Daylight hours per month		247.2	271.5	366.1	420.5	495.6	512.7	515.2	461.9	383.3	328.3	257.6	230.6	4490.3
		Nighttime hours per month		496.8	400.5	377.9	299.5	248.4	207.3	228.8	282.1	336.7	415.7	462.4	513.4	4269.7
Stage B																
No of turbines	T	16														
Rotor radius	R	58.5	m													
		Total rotor frontal area m ²		172021												
Nocturnal activity factor	f _{night}	0%														
Bird flight speed	v	13.3	m s ⁻¹													
		Projected number of rotor transits		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
				10.0	11.0	14.8	22.7	26.7	27.6	27.8	24.9	20.7	13.3	10.4	9.3	219
Stage C																
No of blades	b	3		Bird length	l	0.54	m									
Rotation speed	Ω	12.1	rpm	Wingspan	w	1.2	m									
Rotor radius	R	58.5	m	Bird flight speed	v	13.3	m s ⁻¹									
Max blade width	C	4	m	Flight type		flapping										
Pitch	λ	15	degrees	% of flights upwind/downwind		50%	50%									
Blade profile		see Blade profile sheet														
		Single transit risk		upwind	9.40%											
				downwind	4.62%											
				weighted mean	7.01%											
Stage D																
Proportion of time operational	Q _{oo}	85.0%		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year ave
				85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance														
				0.60	0.65	0.88	1.35	1.59	1.65	1.65	1.48	1.23	0.79	0.62	0.56	year total
				13												
Stage E																
Allow for large array correction?		No														
Width of windfarm	w	5.5	km													
		large array correction														
Avoidance rates modelled		95.00%	100.00%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
		98.00%	100.00%	0.03	0.03	0.04	0.07	0.08	0.08	0.08	0.07	0.06	0.04	0.03	0.03	0.7
		99.00%	100.00%	0.01	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.3
		99.50%	100.00%	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.1
				0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.1

Table 6.18: Collision risk model outputs for Lesser Black-backed Gull.

COLLISION RISK MODEL

Required input data is in orange boxes
 Calculated output is in blue boxes
 green boxes are for information only, to show variables used at each stage

		Value	Units			Value	Units			Value	Units					
Bird data		Species name Lesser Black-backed Gull		Windfarm data				Turbine data								
Bird length	L	0.58	m	Site name		Tirawley		Model		4.3 MW type						
Wingspan	W	1.43	m	Latitude		54.25	degrees	Hub height		76.5	m					
Bird flight speed	v	11.9	m s ⁻¹	No of turbines	T	16		Rotor radius	R	58.5	m					
Flight type, flapping or gliding		flapping		Width of windfarm	w	5.5	km	No of blades	b	3						
% of flights upwind/downwind		50%	50%					Rotation speed	Ω	12.1	rpm					
Nocturnal activity ranking 1-5		1						Max blade width	C	4	m					
Nocturnal activity factor	f _{night}	0%						Blade pitch	λ	15	degrees					
								Risk height range		18-135	m					
normal approach		Set to 'normal approach' to use survey data on bird density														
		Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A														
Stage A														year avge		
Daytime bird density	D _A		birds/km ²	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Proportion at rot or risk height	Q _{rot}	94.00%		0	0	0	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0	0	0	0.0006
At latitude 54.3		Daylight hours per month		247.2	271.5	366.1	420.5	495.6	512.7	515.2	461.9	383.3	328.3	257.6	230.6	4490.3
		Nighttime hours per month		496.8	400.5	377.9	299.5	248.4	207.3	228.8	282.1	336.7	415.7	462.4	513.4	4269.7
Stage B														year total		
No of turbines	T	16														
Rotor radius	R	58.5	m													
		Total rotor or frontal area m ²		172021												
Nocturnal activity factor	f _{night}	0%														
Bird flight speed	v	11.9	m s ⁻¹	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
		Projected number of rotor transits		0.0	0.0	0.0	27.4	32.3	33.4	33.6	30.1	25.0	0.0	0.0	0.0	182
Stage C														year total		
No of blades	b	3		Bird length	l	0.58	m									
Rotation speed	Ω	12.1	rpm	Wingspan	w	1.43	m									
Rotor radius	R	58.5	m	Bird flight speed	v	11.9	m s ⁻¹									
Max blade width	C	4	m	Flight type		flapping										
Pitch	λ	15	degrees	% of flights upwind/downwind		50%	50%									
Blade profile		see blade profile sheet														
		Single transit risk		upwind	10.25%											
				downwind	5.11%											
				weighted mean	7.68%											
Stage D														year avge		
Proportion of time operational	Q _{co}	85.0%												85.0%		
		Collision rates before avoidance												year total		
		0.00	0.00	0.00	1.79	2.11	2.18	2.19	1.96	1.63	0.00	0.00	0.00	0.00	12	
Stage E														per year		
Allow for large array correction?		No														
Width of windfarm	w	5.5	km													
		large array correction														
Avoidance rates modelled		95.00%	100.00%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
		98.00%	100.00%	Collision rates allowing for avoidance												
		99.00%	100.00%	0.00	0.00	0.00	0.09	0.11	0.11	0.11	0.10	0.08	0.00	0.00	0.00	0.6
		99.50%	100.00%	0.00	0.00	0.00	0.04	0.04	0.04	0.04	0.04	0.03	0.00	0.00	0.00	0.2
				0.00	0.00	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.1
				0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.1

Table 6.19: Collision risk model outputs for Sparrowhawk.

COLLISION RISK MODEL

Required input data is in orange boxes
 Calculated output is in blue boxes
 green boxes are for information only, to show variables used at each stage

Value			Units	Value			Units	Value			Units						
Bird data				Windfarm data				Turbine data									
Species name	Sparrowhawk			Site name	Tirawley			Model	4.3 MW type								
Bird length	L	0.33	m	Latitude	54.25		degrees	Hub height	76.5		m						
Wingspan	W	0.67	m	No of turbines	T	16		Rotor radius	R	58.5	m						
Bird flight speed	v	10	m s ⁻¹	Width of windfarm	w	5.5	km	No of blades	b	3							
Flight type, flapping or gliding	flapping							Rotation speed	Ω	12.1	rpm						
% of flights upwind/downwind	50%		50%					Max blade width	C	4	m						
Nocturnal activity ranking 1-5	1							Blade pitch	λ	15	degrees						
Nocturnal activity factor	f _{night}	0%						Risk height range	18-135		m						
normal approach			Set to 'normal approach' to use survey data on bird density														
			Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A														
Stage A				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge	
Daytime bird density	D _{day}	birds/km ²		0.0001	0.0001	0.0001	0	0	0	0	0	0	0.0001	0.0001	0.0001	0.0001	
Proportion at rotor risk height	Q ₂₀	60.70%															
At latitude 54.3	Daylight hours per month			247.2	271.5	366.1	420.5	495.6	512.7	515.2	461.9	383.3	328.3	257.6	230.6	4490.3	
	Nighttime hours per month			496.8	400.5	377.9	299.5	248.4	207.3	228.8	282.1	336.7	415.7	462.4	513.4	4269.7	
Stage B																	
No of turbines	T	16															
Rotor radius	R	58.5 m															
	Total rotor frontal area m ²			172021													
Nocturnal activity factor	f _{night}	0%															
Bird flight speed	v	10 m s ⁻¹															
	Projected number of rotor transits			0.8	0.9	1.2	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.8	0.7	5	
Stage C																	
No of blades	b	3		Bird length	l	0.33 m											
Rotation speed	Ω	12.1 rpm		Wingspan	w	0.67 m											
Rotor radius	R	58.5 m		Bird flight speed	v	10 m s ⁻¹											
Max blade width	C	4 m		Flight type	flapping												
Pitch	λ	15 degrees		% of flights upwind/downwind	50%		50%										
Blade profile	see blade profile sheet																
	Single transit risk			upwind	9.56%												
				downwind	3.91%												
				weighted mean	6.73%												
Stage D				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge	
Proportion of time operational	Q ₂₀	85.0%		85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	
	Collision rates before avoidance																
				0.05	0.05	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.05	0.04	0
Stage E																	
Allow for large array correction?	No																
Width of windfarm	w	5.5 km															
	large array correction																
Avoidance rates modelled	95.00%		100.00%														
	98.00%		100.00%														
	99.00%		100.00%														
	99.50%		100.00%														
	Collision rates allowing for avoidance			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year	
				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	
				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	
				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	
				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	

Table 6.20: Collision risk model outputs for Hen Harrier.

COLLISION RISK MODEL

Required input data is in orange boxes
 Calculated output is in blue boxes
 green boxes are for information only, to show variables used at each stage

		Value	Units			Value	Units			Value	Units			Value	Units				
Bird data		Species name: Hen Harrier		Windfarm data				Turbine data				Model: 4.3 MW type							
	Bird length	L	0.48	m		Site name	Tirawley		Latitude	54.25	degrees		Hub height	76.5	m				
	Wingspan	W	1.1	m		No of turbines	T	16		No of blades	b	3		Rotor radius	R	58.5	m		
	Bird flight speed	v	9.1	m s ⁻¹		Width of windfarm	w	5.5	km		Rotation speed	Ω	12.1	rpm		Max blade width	C	4	m
	Flight type, flapping or gliding		flapping								Blade pitch	λ	15	degrees					
	% of flights upwind/downwind		50%	50%															
	Nocturnal activity ranking 1-5		1																
	Nocturnal activity factor	f _{night}	0%																
normal approach		Set to 'normal approach' to use survey data on bird density Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A																	
Stage A		Daytime bird density		D _A	birds/km ²	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge	
	Proportion at rotor or risk height	Q _{rot}	49.60%			0.0001	0.0001	0.0001	0	0	0	0	0	0	0.0001	0.0001	0.0001	0.0001	
	At latitude 54.3					247.2	271.5	366.1	420.5	495.6	512.7	515.2	461.9	383.3	328.3	257.6	230.6	4490.3	
	Daylight hours per month					496.8	400.5	377.9	299.5	248.4	207.3	228.8	282.1	336.7	415.7	462.4	513.4	4269.7	
	Nighttime hours per month																		
Stage B		No of turbines		T	16														
	Rotor radius	R	58.5	m															
	Total rotor or frontal area	m ²	172021																
	Nocturnal activity factor	f _{night}	0%																
	Bird flight speed	v	9.1	m s ⁻¹	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total		
	Projected number of rotor transits				0.6	0.6	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.6	0.6	4		
Stage C		No of blades		b	3	Bird length		l	0.48	m									
	Rotation speed	Ω	12.1	rpm	Wingspan		w	1.1	m										
	Rotor radius	R	58.5	m	Bird flight speed		v	9.1	m s ⁻¹										
	Max blade width	C	4	m	Flight type			flapping											
	Pitch	λ	15	degrees	% of flights upwind/downwind			50%	50%										
	Blade profile		see Blade profile sheet																
	Single transit risk		upwind	11.17%															
			downwind	5.27%															
			weighted mean	8.22%															
Stage D		Proportion of time operational		Q _{op}	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge		
					85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%		
					Collision rates before avoidance												year total		
					0.04	0.05	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.04	0.04	0	
Stage E		Allow for large array correction?																	
	Width of windfarm	w	No	5.5	km														
			large array correction																
	Avoidance rates modelled		95.00%	100.00%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year		
			98.00%	100.00%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
			99.00%	100.00%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
			99.50%	100.00%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		

Table 6.21: Collision risk model outputs for Peregrine.

COLLISION RISK MODEL

Required input data is in orange boxes
 Calculated output is in blue boxes
 green boxes are for information only, to show variables used at each stage

Value			Units	Value			Units	Value			Units					
Bird data				Windfarm data				Turbine data								
Species name	Peregrine			Site name	Tirawley			Model	4.3 MW type							
Bird length	L	0.42	m	Latitude	54.25		degrees	Hub height	76.5		m					
Wingspan	W	1.02	m	No of turbines	T	16		Rotor radius	R	58.5	m					
Bird flight speed	v	12.1	m s ⁻¹	Width of windfarm	w	5.5	km	No of blades	b	3						
Flight type, flapping or gliding	flapping							Rotation speed	Ω	12.1	rpm					
% of flights upwind/downwind	50%		50%					Max blade width	C	4	m					
Nocturnal activity ranking 1-5	1							Blade pitch	λ	15	degrees					
Nocturnal activity factor	f _{night}	0%						Risk height range	18-135		m					
normal approach			Set to 'normal approach' to use survey data on bird density													
			Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A													
Stage A				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year ave
Daytime bird density	D _A	birds/km ²		0	0	0	0	0	0	0	0	0	0	0	0	0.0000
Proportion at rotor risk height	Q ₂₅	100.00%														
At latitude 54.3	Dayflight hours per month			247.2	271.5	366.1	420.5	495.6	512.7	515.2	461.9	383.3	328.3	257.6	230.6	4490.3
	Nighttime hours per month			496.8	400.5	377.9	299.5	248.4	207.3	228.8	282.1	336.7	415.7	462.4	513.4	4269.7
Stage B																
No of turbines	T	16														
Rotor radius	R	58.5 m														
	Total rotor frontal area m ²		172021													
Nocturnal activity factor	f _{night}	0%														
Bird flight speed	v	12.1 m s ⁻¹		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
	Projected number of rotor transits			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Stage C																
No of blades	b	3		Bird length	l	0.42 m										
Rotation speed	Ω	12.1 rpm		Wingspan	w	1.02 m										
Rotor radius	R	58.5 m		Bird flight speed	v	12.1 m s ⁻¹										
Max blade width	C	4 m		Flight type	flapping											
Pitch	λ	15 degrees		% of flights upwind/downwind	50%		50%									
Blade profile	see blade profile sheet															
	Single transit risk			upwind	9.24%											
				downwind	4.16%											
				weighted mean	6.70%											
Stage D				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year ave
Proportion of time operational	Q ₂₀	85.0%		85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
	Collision rates before avoidance			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Stage E																
Allow for large array correction?	No															
Width of windfarm	w	5.5 km														
	large array correction															
Avoidance rates modelled	95.00%		100.00%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
	98.00%		100.00%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
	99.00%		100.00%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
	99.50%		100.00%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0