



Forestry, Ecology & Environment

Collision Risk Modelling

Collision Risk Modelling Calculations
For target species at the proposed Tirawley Wind Farm
(Summer 2021 to Winter 2022/2023)

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

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Executive Summary

This report presents the outcomes of a Collision Risk Assessment for target species at the proposed Tirawley Wind Farm Development (Summer 2021 to Winter 2022/2023) located in Conaghra, Barroe, Lissadrone East, Lissadrone West, Billoos, Lecarrowntemple, Lackanhill, Ballymurphy, Carrowmore, Castletown, Castlelackan Demense, Aghaleague, Carrownedden, Ballynaleck, Carrowmachshane, Carn, Carrowmore, and others, Ballina, Co. Mayo.

Following a revised layout for the wind farm, this Collision Risk Model (CRM) has been updated accordingly.

The modelling was carried out using the Scottish Natural Heritage Collision Risk Model (Scottish Natural Heritage 2000; Band *et al.*, 2007). The bird occupancy method (SNH 2000) was used to calculate the number of bird transits through the rotors, and the spreadsheet accompanying the SNH report was used to calculate collision probabilities for birds transiting the rotors.

It is 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 accuracy of the avoidance rates used and must therefore be interpreted with a certain degree of caution.

Collision risk models 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 least one collision within the nominal 30-year operational phase of the wind farm is predicted for Sparrowhawk, Hen Harrier and Peregrine. The collision risk for Kestrel is estimated at 1.48 birds per year (or 44.4 birds over the nominal 30-year operational phase), collision risk for Buzzard is estimated at 1.28 birds per year (or 38.5 birds over the nominal 30-year operational phase) and the collision risk for Lesser Black-backed Gull is estimated at 1.2 birds per year (or 37.2 birds over the nominal 30-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 Assessment for target bird species at the proposed Tirawley Wind Farm Development located in Conaghra, Barroe, Lissadrone East, Lissadrone West, Billoos, Lecarrowntemple, Lackanhill, Ballymurphy, Carrowmore, Castletown, Castlelackan Demense, Aghaleague, Carrownedden, Ballynaleck, Carrowmachshane, Carn, Carrowmore, and others, Ballina, Co. Mayo. This Assessment uses standardised Collision Risk Modelling (CRM) methods.

This document has been prepared by David McGillicuddy of (Veon Ecology) Veon Ltd. to assess the collision risk for birds (i.e. target species) at the proposed Wind Farm Site. The collision risk assessment, prepared by David McGillicuddy B.Sc. (Hons) in Wildlife Biology at MTU, ACIEEM, AEnvCW, is based on vantage point surveys undertaken at the development site from the breeding and wintering seasons of 2021 - 2023 inclusive. The data represents a 24-month survey period, consisting of two breeding seasons and two non-breeding (wintering) seasons, in full compliance with the Scottish Natural Heritage guidelines SNH (2017).

Collision risk is calculated using a mathematical model to predict the numbers 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 collision risk assessment follows Scottish Natural Heritage (SNH) guidance often referred to as the Band Model (Band et al. 2007). The calculations and results attained from the Band model must be interpreted with a degree of caution. The bird occupancy method (SNH, 2000) was used to calculate the number of bird transits through the rotors, and the spreadsheet accompanying the SNH report was used to calculate collision probabilities for birds transiting the rotors occupied space.

The collision risk modelling used data from vantage point (VP) surveys carried out in the summers of 2021 and 2022, and winters of 2021/2022 and 2022/2023. Vantage point surveys were SNH compliant (SNH, 2017). Surveys were undertaken from April 2021 to March 2023, from No. 5 fixed Vantage Point (VP) locations, (i.e. VP1 – VP5) (**See Appendix 1**). The locations of these VPs were strategically positioned to provide the maximum viewshed of the survey area from the minimum number of locations. No. 7 target species were recorded in flight within the study area during survey work. These include the following species; Kestrel, Buzzard, Lesser Black-backed Gull, Sparrowhawk, Hen Harrier, Peregrine Falcon and Merlin. No. 2 of the target species recorded (i.e. Lesser Black-backed Gull and Merlin), were present during the summer surveys only, while the remaining species were present throughout the year.

Two stages are involved in the model:

- **Stage 1:** This includes the estimation of the number of birds or flights passing through the wind turbines rotor blades swept air space. Two forms of collision risk modelling are considered when referencing the Band Model. These are referred to as the “Regular Flight Model” and the “Random Flight Model”. Transits are calculated in this assessment using the “Random Flight” model, due to the bird flight distribution and behaviour recorded.
- **Stage 2:** This includes the calculation of the probability of a bird strike occurring with rotor blades. The probability is calculated using a statistical spreadsheet which considers the turbine parameters and avian biometrics. This spreadsheet is publicly available on the NatureScot (formerly SNH) website¹.

The results of Stage 1 and Stage 2 modelling, gives a theoretical annual collision mortality rate and is based on the assumption that birds (i.e. target species) make no attempt to avoid colliding with the proposed turbines. Thus, an informal third stage is applied to the Stage 1 and Stage 2 results. The final stage of the assessment provides for a “real life” scenario, i.e. to account for the avoidance measures taken by each bird species, worked out as a percentage applied to the stage 1 and 2 results. Birds usually demonstrate high rates of avoidance (i.e. 95-99%) according to SNH (2018). This final stage as a result is typically the most important feature of collision risk modelling.

¹ NatureScot, Wind farm impacts on birds - Calculating the probability of collision, available at: <https://www.nature.scot/sites/default/files/2018-09/Wind%20farm%20impacts%20on%20birds%20-%20Probability%20of%20collision.xls>

1.2 Proposed Development and Site Description

The proposed wind farm development is located in north county Mayo approximately 5km northwest of the town of Killala, and east and southeast of Ballycastle. The proposed development site is extensive and covers a large number of townlands, comprising of c. 119.2 hectares. The receiving environment for the proposed wind turbine locations is representative of peatland habitats and adjoining lands under active management for forestry and agriculture. The proposed development site is located relatively close (< 15km) to other constructed windfarm developments (i.e. Killala windfarm and Oweninny Wind Farm).

The proposed wind farm design on which this CRM is based, is comprised of No. 19 Wind Turbine Generators (WTGs) (Turbine Models: Vestas V117 and V105). The Collision Risk Assessment (CRA) makes certain assumptions regarding the turbine specifications, such as rotor diameter and rotational speed. Given that the final design includes two different turbine models, a worst-case scenario is assumed. The worst-case scenario is a combination of the maximum collision risk area (affected by hub height and rotor blade length), maximum number of turbines proposed, and minimum turbine downtime (i.e. non-operational time) using the specifications of the proposed WTG turbines. The turbine specifications for the proposed development site used as per this CRM are shown 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	19
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 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
Mean Speed (m/s)	12.1
Average Rotational period (s) (60/12.1)	4.959
Turbine operation time*	85%
Mean pitch angle of the blade during normal operation (degrees)**	13°

* The European Wind Energy Association (2016) provides an average operation time of a turbine of between 70% and 85%. In following the precautionary principal approach this CRM uses the 85% figure.

** The pitch angle of the turbine blade is determined by wind speed, which is variable depending on several factors including, location, local topographic, landscape etc. To maintain a constant operating speed the pitch angle of the blade is altered. The pitch angle of the turbine blade is greater in higher wind speeds to “feather” the wind in order to control rotation speed. The figure of 13° used in this assessment is derived from specifications provided by the client which advocates an average pitch of between 6 – 13 degrees along the length of the turbine blade. In following the precautionary principal approach, the greater 13° figure has been adopted as part of this model.

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 GIS knowledge with experience in handling, presenting and analysing spatial data using a variety of software (including use of SPSS, ArcGIS, and QGIS).

David is a Project Ecologist with Veon Ltd. and Veon Ecology and is experienced in several key environmental projects and the production of ecological reports regarding Biodiversity Action Plans (BAP), Invasive Species Management Plans (ISMP), Natura Impact Statement (NIS), Ecological Impact Assessment (EcIA), Environmental Impact Assessment (EIA) etc. David has prepared Collision Risk Models (CRMs) 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 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 in line with SNH (2017) guidance, thereby enabling VP surveys to focus on the species of greatest importance. In general target species are those species that are afforded a higher level of legislation protection and also includes 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 was 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 two 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 purposes of collision risk modelling, a 500m radius buffer was drawn around each of the proposed turbine locations. This buffer was used as the flight activity survey area, following SNH (2017) guidance.

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 of No. 3 flights, or at least 10 individuals, recorded within the CRZ at PCH within either season, over the course of all survey years. As a result, any species that were 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 Falcon (*Falco peregrinus*)

Other species of conservation concern were recorded during the vantage point surveys but were excluded from consideration in the collision risk analysis due to 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. Thus, 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.

1.6 Seasonal Definitions

The data used in this CRM was 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 sum of these separate summer and winter CRM results was taken as the predicted annual collision risk rather than using results from a single all-year CRM. This method minimised any potential biases that may arise from seasonal variation in daylength and the number of hours of activity available to each species in each month. This was to increase precision of the CRM and to ensure that any potential underestimation or overestimation for a species risk of collision was minimised as much as possible.

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 1.2**).

Table 1.2: Tirawley 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

The number of hours that birds are potentially active during the day for the breeding and non-breeding season forms part of the CRM model. This is calculated as 15 hours per day for the summer survey period (i.e. the breeding season) and 10 hours per day for the winter survey period (i.e. the non-breeding season). These figures of activity are based on the average calculation of daylight minutes within the season of analysis and are likely to be over-estimated. These figures would be difficult to quantify in simple terms otherwise, although, the use of an over-estimation of species activity time increases the likelihood of a collision as birds are considered to be more active (i.e. increased flights) than if activity hours were reduced. This approach therefore offers an additional precaution in determining collision risk, and therefore a more robust estimation for collision risk assessment. These flight activity hours were calculated from timeanddate.com.

1.7 Limitations and 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 Collision Risk Assessment was received from the client. The data comprised of 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 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 was 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 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 requires a minimum coverage of two years of data. The requirement in the 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.

Section 2: ASSESSMENT AND METHODOLOGY

In regard to the Band Model, two forms of collision risk modelling are typically considered. These are generally referred to as the “Regular Flight Model” and the “Random Flight Model”. The “Regular Flight Model” is generally applied to flightlines which comprise of a more regular pattern such as a commuting corridor between feeding grounds, migratory routes and roosting sites. As a result, the “Regular Flight Model” is typically more relevant for aquatic bird species, particularly swans and geese. The alternative “Random Flight Model” is more relevant for species and scenarios whereby no apparent flight routes or patterns can be associated with a species within the survey area. Thus, Random flights is most prevalent when investigating hunting or foraging flight behaviour.

Collision risk modelling adopts a mathematical approach to determining the probability of a bird species colliding with wind turbine rotors at a pre-defined site and is described in detail by Band *et al.* (2007) and Scottish Natural Heritage (SNH, 2000), with additional supporting information provided by Scottish Natural Heritage (SNH, 2018).

The model output estimates the number of birds likely to collide with the rotors of all turbines within the proposed wind farm development per year of operation. The inverse of this (i.e. the number of years over which a single fatality would be likely) is also calculated.

The **Random Flight Model** examines the predicted number of transits through the windfarm site with regard to all flights recorded within the viewshed (i.e. a 2km arc of the vantage point) as randomly occurring. The random flight model therefore assumes that any observed flight could occur both within and outside of the wind farm site with equal likelihood. The viewshed of a given VP should extend to a distance no greater than 2km and include an arc of no greater than 180 degrees, as per the SNH (2017) guidelines. Any flights recorded within the rotor swept height and inside the 2km arc of the vantage point are included in the model.

The Random Flight Model has a number of limitations and assumptions.

- Both habitat and bird activity will remain the same over time and be unchanged during the operational stage of the proposed windfarm development.
- Bird activity is not spatially explicit, i.e. bird activity is equal throughout the viewshed area, and this is equal to activity in the proposed windfarm development area.
- All flight activity used in the model occurred within the viewshed area calculated at the lowest swept rotor height. Thus, all flights are assumed to have occurred within the visible area, although many are likely to have been above this. The calculation for survey area visible (Avp) from each VP in the model is therefore highly precautionary as it is likely to have been a larger area of coverage for much of the flight activity.

The **Regular Flight Model** examines the predicted number of transits through a cross-sectional area of the windfarm which represents the width of the commuting corridor. A “risk window” comprises of a 2-dimensional line which represents the width of the windfarm in addition to a 500m buffer for each of the turbines, multiplied by the rotor diameter. All flights which pass through the identified risk window, within the swept height of the turbines, are included in the collision risk modelling. Any regular flights more than 500m from the turbine layout can be excluded from analysis.

The Regular Flight Model has a number of limitations and assumptions.

- The turbine rotor swept area is 2-dimensional, i.e. there is a single row of turbines in the windfarm. This represents all turbines within the commuting corridor accounted for by a single straight-line.
- Birds in an observed flight only cross the turbine area once and do not pass through the cross-section a second time (or multiple times).
- It is assumed that bird activity is spatially explicit.

Further details regarding both the Random and Regular Flight Model calculations are available on the NatureScot (formerly SNH) website².

The data used as part of the model, such as the number, size, dimensions and likely functioning of the proposed turbines for the Wind Farm Development Site (See **Table 1.1**) forms part of the calculations, along with the available bird biometric data (See **Table 3.2**). These values are modelled with the standardised field data collected using best practice methods on surveying birds flight activity within the proposed development site.

The data is collectively modelled to predict the number of bird flights through the rotors of all turbines within the site on an annual basis (CRM Stage 1), as well as the probability that a bird flying through the turbine will collide with the rotors (CRM Stage 2). The product of the numerical output from these two stages of assessment predicts the number of birds likely to collide with the turbine rotors if no avoidance measures are taken. This value is then adjusted using the available avoidance rates (CRM Stage 3), to provide a final assessment of collision risk, which indicates the anticipated number of birds colliding with the turbine rotors each year.

The steps used to derive the collision risk for birds observed at the proposed development site, according to the Band Model, are summarised below:

- Stage 1 (Band model): This model uses observations of birds flying through the study area during vantage point surveys to estimate the number of birds expected to fly through the proposed turbine blade swept areas.
- Stage 2 (Band model): This model calculates the collision risk for an individual bird flying through a rotating turbine blade. The collision risk depends on the bird's flight behaviour and biometrics.
- The result of the estimated number of birds flying through the turbines annually is then multiplied by the collision risk probability. This calculation represents the worst-case scenario, assuming that birds flying through the site make no attempt to avoid the turbines.
- Stage 3: An avoidance factor is applied to the results of the collision risk model to account for the avoidance of turbine rotors by bird species. Avoidance rates are available from SNH's online bird collision risk guidance (SNH 2018). This avoidance rate corrects for the birds' ability to detect and navigate around the turbines. The final output, after all modelling steps, provides a realistic estimation of the number of collisions that may occur at the proposed wind farm, based on observed bird activity during the survey period.

Several assumptions were made in calculating the collision risk for the proposed Tirawley Wind Farm Development. These assumptions are tailored specifically to the Tirawley Wind Farm Development and are as follows:

- Birds in flight within the study area at heights between 18 m and 135 m above ground level are assumed to be at risk of collision with the rotating turbine blades.
- No preference was given to birds using gliding or flapping flight through the study area for target species, as they exhibit both behaviours. In calculating the percentage risk of collision for a bird flying through a rotating turbine, the mean of the worst-case scenario (i.e. a bird flying upwind through a turbine using flapping flight whilst the turbine is at its fastest rotation speed) and the best-case scenario (i.e. a bird flying downwind through a rotating turbine using a gliding flight, whilst the turbine is at its slowest rotation speed) has been used for birds which exhibit both flapping and gliding flight.

The collision risk assessment includes certain assumptions regarding turbine specifications, such as rotor diameter and rotational speed. The worst-case scenario is defined as a combination of the maximum collision risk area (i.e., the swept area determined by hub height and rotor blade length), the maximum number of proposed turbines, and the operational time of the turbines. The turbine and wind farm characteristics relevant to this assessment are presented in **Table 1.1**.

² NatureScot, Wind Farms and Birds: Calculating a theoretical collision risk assuming no avoiding action, available at: <https://www.nature.scot/sites/default/files/2017-09/Guidance%20Note%20-%20Windfarms%20and%20birds%20-%20Calculating%20a%20theoretical%20collision%20risk%20assuming%20no%20avoiding%20action.pdf>

2.1 Determination of Bird Flights Through the Rotor Swept Area

Stage 1 of the CRM determines the number of transits through the rotors for a given period or season. For the calculations below, this is expressed as the number of birds flying through the rotors per season (Breeding and Non-breeding).

Flight data was recorded at fixed vantage point locations from April 2021 to March 2023 inclusive, and the data was provided to Veon Ecology to undertake the collision risk modelling for the relevant target species. Behavioural observations were also recorded, with a minimum requirement of 36 hours per VP per season (breeding and non-breeding), and 72 hours of VP survey effort per year achieved.

A potential collision height (PCH) of between 18m and 135m above ground was established based on the proposed turbines having a maximum blade tip height of 135m, and a rotor diameter of 117m. This ensured that the PCH was within the turbine swept area. The flight heights of species were classified into different height bands (HB). The height bands used during flight activity surveys were as follows:

- 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 swept height covers the range from 18m to 135m, all flights within height bands 1, 2, 3, and 4 were considered to be at potential collision risk. Note that the actual height range covered by height bands 1, 2, 3, and 4 is 0m to 180m. This represents a precautionary approach, as any bird flights at a height of 0m to 17m and 136m to 180m would be outside the PCH but have been included within the model as being at risk.

The arc for each vantage point is a 180° arc with a radius of 2km from the vantage point location, representing the theoretical maximum coverage area. The viewshed represents the actual area visible to the surveyor at a specified height above ground level from the vantage point location within each vantage point arc. GIS computer software was used to generate the viewsheds for each VP. Flight data from the viewshed mapping for each VP was used to inform this CRM.

For all target species observed during surveys, flights recorded were classified for the purpose of analysis, as “randomly” distributed flights, which could occur anywhere within the given viewsheds. The “Random Flight Model” is used in cases of irregular flight activity, such as those displayed by raptors occupying a recognised territory, or by waders. This model requires the calculation of the proportion of time birds were observed flying per unit of survey area. Therefore, the “Random Flight Model” was applied for each target species to calculate the predicted number of transits through the proposed Wind Farm site.

The proportion of flight time between 0m and 180m for a bird species for each of the VPs was calculated. If multiple birds were observed in one flight, the seconds spent at PCH were calculated by multiplying the number of birds observed per flight by the duration of the flight at PCH (in line with SNH, 2000).

The hours that a species may potentially be active in either a breeding or non-breeding season were calculated to include daylight, one hour before sunrise, and one hour after sunset (dusk) for all species. These flight activity hours were calculated from timeanddate.com. During the summer survey period (breeding season), the calculation assumes 15 hours of activity per day, while for the winter survey period (non-breeding season), it assumes 10 hours of activity per day. These activity figures are derived from the average calculation of daylight minutes within the respective seasons under analysis. However, it's important to note that these figures are likely to be over-estimated.

Flight activity was used to calculate the number of bird passes through the rotor for each VP in turn, and per turbine within each viewshed, before being calculated for the entire wind farm. The Stage 1 calculation was carried out for each season (i.e. breeding and wintering) for each species.

2.2 Probability of Collision of Birds Passing Through the Rotor Swept Area

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

The risk of a bird colliding with the turbine rotor blades varies depending on whether the bird passes through the rotor swept area towards the tip of the blade (where the blades are present for a smaller proportion of the time, have a shorter chord width, and a faster rotational speed), or next to the turbine hub (where the blades have a wider chord width, occupy a larger volume of airspace, and travel at slower speeds). Towards the blade tips, it is the length of the bird that offers a greater contribution to the determination of the risk of collision. Closer to the turbine hub, the wingspan of the bird compared to the physical distance between the blades is the controlling factor. The bird is assumed to enter the rotor swept area at random anywhere along the disc.

The calculations assess the collision risk at several points along the rotor blade's length (in intervals of $0.05R$, where R is the radius of the rotor swept area). This assessment uses numerical integration of various factors in relation to the rotors (notably angular velocity of the blade and chord width) and the bird (such as the point at which the bird enters the rotor along the radius and its flight speed). These are calculated for both downwind and up-wind flights and averaged to give a probability of collision per season, assuming no avoiding action is taken.

The SNH collision risk model³ is used to carry out the calculations, where relevant data regarding the turbines and bird biometrics are inputted. The model then estimates the probability of a collision occurring when a bird passes through the rotor area. This calculation is based solely upon the behaviour and biometrics of the bird and the specifications of the turbines proposed at the Tirawley site.

For the Tirawley Wind Farm development site, the average probability of each species passing through the wind farm and colliding with the rotors if it takes no avoiding action, is presented in **Table 3.4**.

³ NatureScot (formerly SNH): Wind farm impacts on birds - Probability of collision, available at: [Wind farm impacts on birds - Calculating the probability of collision | NatureScot](#)

Section 3: RESULTS

The collision risks were calculated using flight data recorded during vantage point watches at No. 5 fixed vantage point locations (VP1-VP5) within the study area between April 2021 and March 2023. The target species recorded within the potential collision risk zone included Kestrel, Buzzard, Lesser Black-backed Gull, Sparrowhawk, Hen Harrier and Peregrine Falcon.

The calculation parameters are outlined in **Tables 3.1, 3.2** and **Table 3.3**. A worked example of the collision risk calculation for Kestrel is available in **Appendix 5**. **Table 3.1** below presents details on the viewshed area for each VP.

Table 3.1: Summary of CRM parameters for VPS at Tirawley Wind Farm.

Vantage Point	VP Arc (ha)	Viewshed area within VP Arc (ha)	Viewshed Coverage (%)	Turbine Buffer Area Within Viewshed (ha)	No. of Turbines Within Viewshed	Total Survey Effort (hrs)
VP 1	628	418.0	66.56	253.11	5	144
VP 2	628	607.7	96.76	320.98	6	144
VP 3	628	392.9	62.56	234.31	5	144
VP 4	628	565.6	90.06	269.38	7	144
VP 5	628	571.1	90.93	221.69	4	144

Species-specific morphometric measurements, flight speeds, and avoidance rates are shown in **Table 3.2**. The amount of time a species was observed flying at heights of between 18 - 135 m, i.e. within the potential collision height, is presented in **Table 3.3** below. Birds in flight within the study area at heights between 18m and 135m are assumed to be in danger of collision with the rotating turbine blades. Bird biometric parameters were obtained from Alerstam *et al.* (2007), Wilson *et al.* (2015), and the British Trust for Ornithology (BTO) (2000).

Table 3.2: Avian Biometric Data and Avoidance Rates.

Avian Biometric Data and 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	12	99
Peregrine Falcon	0.42	1.02	12.1	98

Table 3.3: Bird-seconds spent by species at potential collision height (18-135m).

Seconds spent at PCH (2021-2023)							
Species Name (BTO Code)	Seconds in flight at PCH (18-135m)						Total secs at PCH over 24 Months
	2021/2022			2022/2023			
	Summer	Winter	Total	Summer	Winter	Total	
Kestrel (K.)	925	1785	2710	800	915	1715	4425
Buzzard (BZ)	1245	2455	3700	2090	1505	3595	7295
Lesser Black-backed Gull (LB)	3715	0	3715	3600	0	3600	7315
Sparrowhawk (SH)	390	420	810	735	620	1355	2165
Hen Harrier (HH)	165	450	615	90	246	336	951
Peregrine (PE)	20	252	272	60	0	60	332

Table 3.4: Number of collisions predicted for target species without the application of avoidance rates.

Species	Year	Predicted collisions per season without avoidance rates applied		
		Summer	Winter	Total
Kestrel	2021/22	12.30	23.36	35.66
	2022/23	11.82	11.70	23.52
Buzzard	2021/22	29.94	32.66	62.60
	2022/23	41.94	23.66	65.60
Lesser Black-backed Gull	2021/22	59.43	0.00	59.43
	2022/23	64.41	0.00	64.41
Sparrowhawk	2021/22	4.93	5.19	10.12
	2022/23	4.11	3.37	7.48
Hen Harrier	2021/22	2.93	9.07	12.00
	2022/23	1.35	4.80	6.15
Peregrine	2021/22	0.06	5.52	5.58
	2022/23	1.26	0.00	1.26

Table 3.5: Number of collisions predicted for target species with the application of avoidance rates.

Species	Year	Predicted collisions per season with avoidance rates applied			Predicted collisions over 30-year lifetime of the windfarm		
		Summer	Winter	Total	Summer	Winter	Total
Kestrel	2021/22	0.615	1.168	1.783	18.451	35.037	53.488
	2022/23	0.591	0.585	1.176	17.728	17.556	35.284
Buzzard	2021/22	0.599	0.653	1.252	17.963	19.597	37.560
	2022/23	0.839	0.473	1.312	25.165	14.196	39.361
Lesser Black-backed Gull	2021/22	1.189	0.000	1.189	35.656	0.000	35.656
	2022/23	1.288	0.000	1.288	38.647	0.000	38.647
Sparrowhawk	2021/22	0.099	0.104	0.203	2.958	3.113	6.071
	2022/23	0.082	0.067	0.149	2.465	2.023	4.488
Hen Harrier	2021/22	0.029	0.091	0.120	0.878	2.722	3.600
	2022/23	0.013	0.048	0.061	0.404	1.441	1.845
Peregrine	2021/22	0.001	0.110	0.111	0.037	3.314	3.351
	2022/23	0.025	0.000	0.025	0.754	0.000	0.754

Table 3.6: Mean number of collisions predicted for target species with avoidance rates.

Target Species number of collisions predicted			
Species Name	Mean no. of predicted collisions per year	Mean no. of predicted collisions per 30 years	Equivalent to 1 bird every x (years)
Kestrel (K.)	1.480	44.386	0.676
Buzzard (BZ)	1.282	38.461	0.780
Lesser Black-backed Gull (LB)	1.239	37.152	0.807
Sparrowhawk (SH)	0.176	5.280	5.682
Hen Harrier (HH)	0.091	2.723	11.017
Peregrine (PE)	0.068	2.053	14.613

Table 3.7: Summary collision modelling results.

Species	Model	Collision Risk			Mean no. of predicted collisions per year			Estimated collisions per 30 years	One Bird Collision
		Flapping	Gliding	Overall	Without Avoidance	Avoidance Factor	With Avoidance		
Kestrel	Random	6.6%	6.4%	6.5%	29.59	95%	1.480	44.386	<1 year
Buzzard	Random	6.9%	6.6%	6.75%	64.10	98%	1.282	38.461	<1 year
Lesser Black-backed Gull	Random	7.5%	7.2%	7.35%	61.92	98%	1.239	37.152	<1 year
Sparrowhawk	Random	6.5%	6.4%	6.45%	8.80	98%	0.176	5.280	<6 years
Hen Harrier	Random	6.8%	6.6%	6.7%	9.075	99%	0.091	2.723	11 years
Peregrine	Random	6.5%	6.3%	6.4%	3.42	98%	0.068	2.053	<15 years

Section 4: CONCLUSION

This CRM has been completed for the proposed Tirawley Wind Farm development. A “Random” collision risk model has been conducted for birds observed during vantage point surveys at the proposed Wind Farm using the Band Model, following best practice guidance from NatureScot. The VP survey data used for this CRM was collected over two summer surveys (breeding seasons) and two winter surveys (non-breeding seasons), which meets the requirements of current SNH guidelines.

Collision risk models 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 least one collision within the nominal 30-year operational phase of the wind farm is predicted for Sparrowhawk, Hen Harrier and Peregrine. The collision risk for Kestrel is estimated at 1.48 birds per year (or 44.4 birds over the nominal 30-year operational phase), collision risk for Buzzard is estimated at 1.28 birds per year (or 38.5 birds over the nominal 30-year operational phase) and the collision risk for Lesser Black-backed Gull is estimated at 1.2 birds per year (or 37.2 birds over the nominal 30-year operational phase).

Additional mortality caused by 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 6.16**).

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 presented by collision risk modelling, the resulting predicted collisions should only be considered an indication and not a definitive result. Thus, the outputs of the collision risk modelling should be used solely as a comparative tool rather than an accurate indicator of bird mortality risk. Therefore, it is advised to interpret the results of CRM analyses as indicating only the order of magnitude of the predicted collision risk for given target species.

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Section 6: APPENDICES

Appendix 1. FIGURES AND MAPS

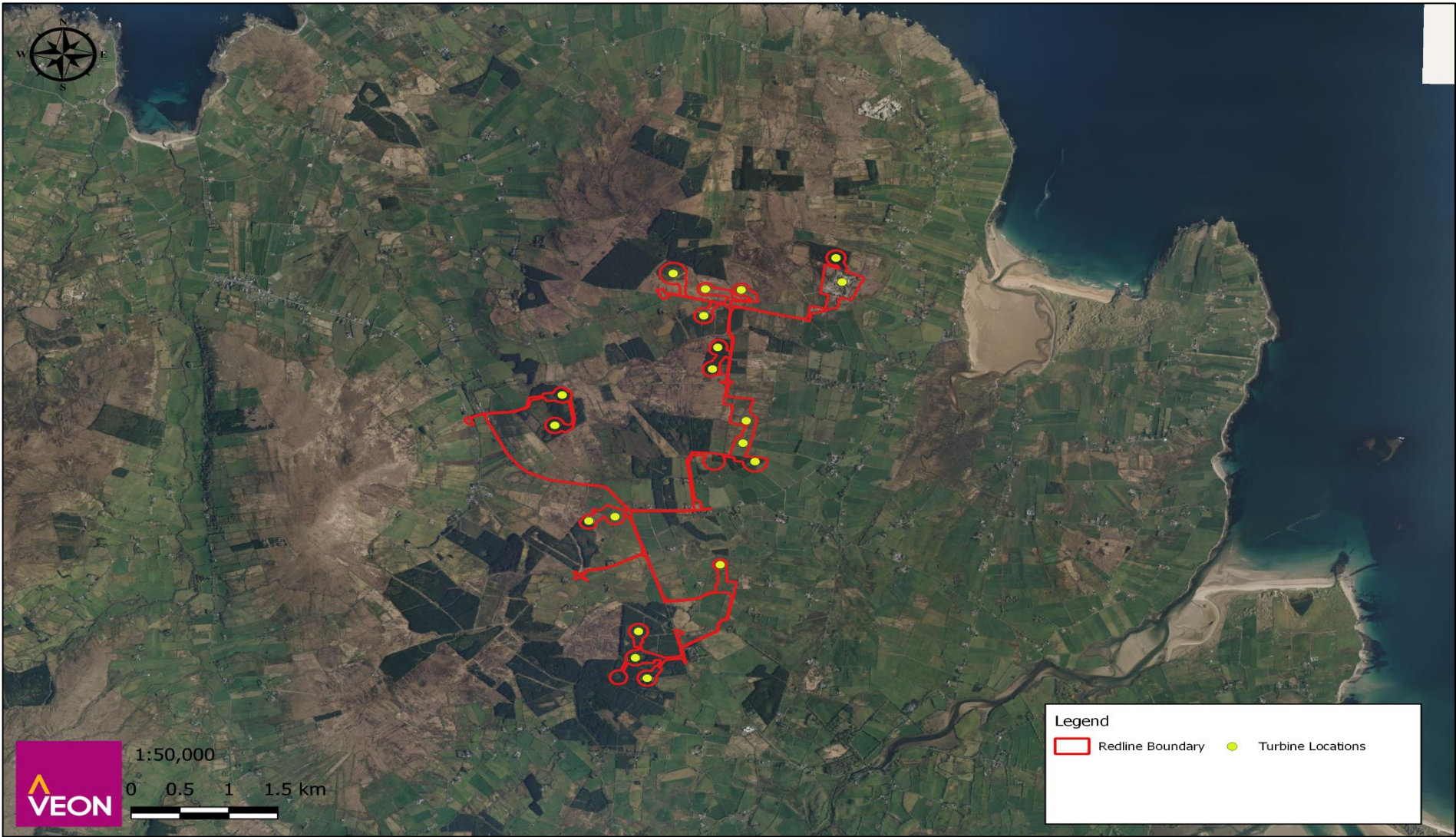


Figure 6.1: Site location and redline boundary indicating the area proposed for turbines.

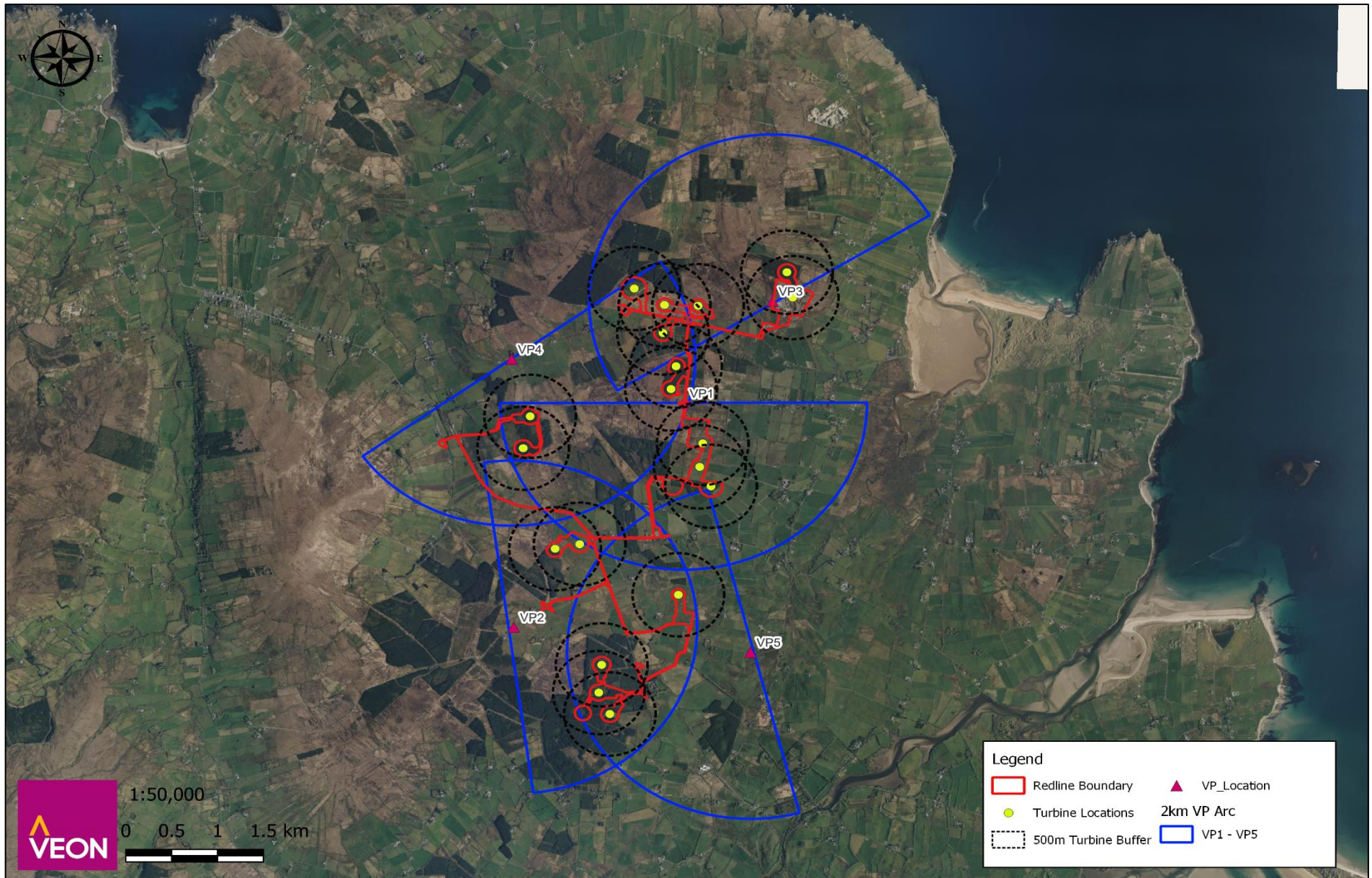


Figure 6.2: Vantage Point locations and viewshed map.

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

Date	Season	VP no.	Duration (hrs)	Start Time	Weather conditions
10/12/2021	Winter	5	3	09.10	Dry, Good visibility, W wind, F3
10/12/2021	Winter	5	3	12.45	Dry, Good visibility, SW wind, F2-3
10/12/2021	Winter	1	3	09.00	Dry, Good visibility, W wind, F3
10/12/2021	Winter	1	3	12.45	Dry, Good visibility, SW wind, F2-3
21/12/2021	Winter	3	3	09:00	Dry, Good visibility, SE wind, F3-4
21/12/2021	Winter	3	3	12:30	Dry, Good visibility, SE wind, F3
30/12/2021	Winter	4	3	08.15	Drizzle, Mod-good vis., SW wind, F4
30/12/2021	Winter	4	3	11.45	Showers, Good visibility, SW wind, F3-4
05/01/2022	Winter	3	3	11.16	Dry, Good visibility, NW wind, F1
05/01/2022	Winter	3	3	14.30	Dry, Good visibility, S wind, F3
20/01/2022	Winter	1	3	08.15	Showers, Good visibility, NE wind, F2
20/01/2022	Winter	5	3	13.00	Dry, Good visibility, NW wind, F3
24/01/2022	Winter	5	3	09.30	Showers, Good visibility, SW wind, F3-4
24/01/2022	Winter	1	3	13.15	Showers, Good visibility, SW wind, F2-3
25/01/2022	Winter	3	3	08:00	Dry, Good visibility, S wind, F2
25/01/2022	Winter	3	3	11:30	Dry, Good visibility, S wind, F2-3
28/01/2022	Winter	4	3	07.55	Drizzle, Mod-good vis, SW wind, F4
28/01/2022	Winter	4	3	11.30	Dry, Good visibility, SW wind, F4
15/02/2022	Winter	5	3	09.00	Showers, Good visibility, SW wind, F3
15/02/2022	Winter	5	3	12.30	Showers, Good visibility, SW wind, F3-4
15/02/2022	Winter	2	3	07.20	Showers, Good vis., SW wind, F3-4
15/02/2022	Winter	2	3	15.30	Showers, Mod-good vis., SW wind, F4
22/02/2022	Winter	3	3	07.05	Drizzle, Good visibility, W wind, F3-4
22/02/2022	Winter	3	3	10:45	Dry, Good visibility, W wind, F3
23/02/2022	Winter	1	3	08.30	Showers, Good visibility, W wind, F3-4
23/02/2022	Winter	1	3	12.45	Dry, Good visibility, W wind, F3
27/02/2022	Winter	4	3	07:15	Showers, Mod visibility, SW wind, F4
27/02/2022	Winter	4	3	10:45	Showers, Mod-good vis., SW wind, F3-4
14/03/2022	Winter	2	3	12.00	Dry, Good visibility, W wind, F4
14/03/2022	Winter	2	3	15.45	Dry, Good visibility, SW wind, F4
15/03/2022	Winter	1	3	07.30	Dry, Good visibility, SW wind, F3
15/03/2022	Winter	1	3	12.00	Dry, Good visibility, SW wind, F3
19/03/2022	Winter	3	3	06.10	Dry, Good visibility, SW wind, F4
19/03/2022	Winter	3	3	09.45	Dry, Good visibility, SW wind, F3-4
24/03/2022	Winter	4	3	05.55	Dry, Good visibility, S wind, F1
24/03/2022	Winter	4	3	09:45	Dry, Good visibility, S wind, F1
27/03/2022	Winter	5	3	08.15	Dry, Good visibility, SW wind, F2
27/03/2022	Winter	5	3	14.00	Dry, Good visibility, SW wind, F3
	Summer no. 2				
08/04/2022	Summer	2	3	08:00	Showers, Good visibility, N wind, F4
08/04/2022	Summer	2	3	12:15	Showers, Good visibility, N wind, F-4
09/04/2022	Summer	1	3	07.30	Dry, Good visibility, W wind, F-3
09/04/2022	Summer	1	3	12.00	Dry, Good visibility, W wind, F-2-3
22/04/2022	Summer	3	3	05:50	Dry, Good visibility, NW wind, F3

Date	Season	VP no.	Duration (hrs)	Start Time	Weather conditions
22/04/2022	Summer	3	3	09:30	Dry, Good visibility, NW wind, F3
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

Date	Season	VP no.	Duration (hrs)	Start Time	Weather conditions
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
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

Date	Season	VP no.	Duration (hrs)	Start Time	Weather conditions
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
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: 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	-	-	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: Probability of collision – Stage 2 Calculations.

Key Target Species Stage 2 Calculations							
Species Name (BTO Code)	Flapping bird			Gliding bird			Mean probability of Collision Risk (Flapping + Gliding)/2
	Upwind	Downwind	Average	Upwind	Downwind	Average	
Kestrel (K.)	9.2%	3.9%	6.6%	9.1%	3.8%	6.4%	6.5%
Buzzard (BZ)	9.1%	4.6%	6.9%	8.8%	4.4%	6.6%	6.75%
Lesser Black-backed Gull (LB)	9.9%	5.1%	7.5%	9.6%	4.8%	7.2%	7.35%
Sparrowhawk (SH)	9.2%	3.8%	6.5%	9.1%	3.7%	6.4%	6.45%
Hen Harrier (HH)	9.2%	4.5%	6.8%	9.0%	4.3%	6.6%	6.7%
Peregrine (PE)	8.9%	4.1%	6.5%	8.7%	3.9%	6.3%	6.4%

Table 6.8: Avian Biometric Data and Avoidance Rates.

Avian Biometric Data and 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	12	99
Peregrine Falcon	0.42	1.02	12.1	98

Table 6.9: Bird-seconds spent by species at Potential Collision Height (18-135m) within VP 1 Viewshed.

Species (BTO Code)	Year	Bird-seconds spent by species at Potential Collision Height (18-135m) for each month within Vantage Point 1 viewshed											
		April	May	June	July	August	September	October	November	December	January	February	March
Kestrel (K.)	2021/22	0	0	180	90	0	0	0	120	0	0	0	0
	2022/23	0	0	45	120	0	0	60	0	110	0	0	0
Buzzard (BZ)	2021/22	180	180	45	0	800	0	90	0	0	0	0	80
	2022/23	340	70	0	0	0	0	320	0	0	90	0	0
Lesser Black-backed Gull (LB)	2021/22	0	0	0	0	0	0	0	0	0	0	0	0
	2022/23	0	0	0	0	0	2340	0	0	0	0	0	0
Sparrowhawk (SH)	2021/22	0	0	0	0	0	20	0	0	25	0	0	0
	2022/23	0	0	0	0	75	0	0	0	0	0	0	120
Hen Harrier (HH)	2021/22	0	0	0	0	0	60	0	0	0	0	0	0
	2022/23	0	0	0	0	0	0	0	75	0	0	0	0
Peregrine (PE)	2021/22	0	0	0	0	0	0	0	0	0	70	0	0
	2022/23	0	0	0	0	0	60	0	0	0	0	0	0

Table 6.10: Bird-seconds spent by species at Potential Collision Height (18-135m) within VP 2 Viewshed.

Species (BTO Code)	Year	Bird-seconds spent by species at Potential Collision Height (18-135m) for each month within Vantage Point 2 viewshed											
		April	May	June	July	August	September	October	November	December	January	February	March
Kestrel (K.)	2021/22	60	0	0	45	0	0	150	75	0	0	0	0
	2022/23	60	0	0	0	0	0	0	0	120	50	0	0
Buzzard (BZ)	2021/22	0	0	0	0	0	40	85	90	0	0	0	1300
	2022/23	160	0	0	610	0	0	0	0	0	0	0	0
Lesser Black-backed Gull (LB)	2021/22	0	0	1125	480	30	0	0	0	0	0	0	0
	2022/23	0	135	50	130	0	0	0	0	0	0	0	0
Sparrowhawk (SH)	2021/22	0	0	0	0	300	0	0	0	0	0	0	0
	2022/23	10	0	40	0	0	0	0	0	0	0	0	0
Hen Harrier (HH)	2021/22	0	0	0	0	0	60	0	0	0	0	0	0
	2022/23	90	0	0	0	0	0	0	0	0	0	0	0
Peregrine (PE)	2021/22	0	0	0	0	0	0	0	0	0	0	0	0
	2022/23	0	0	0	0	0	0	0	0	0	0	0	0

Table 6.11: Bird-seconds spent by species at Potential Collision Height (18-135m) within VP 3 Viewshed.

Species (BTO Code)	Year	Bird-seconds spent by species at Potential Collision Height (18-135m) for each month within Vantage Point 3 viewshed											
		April	May	June	July	August	September	October	November	December	January	February	March
Kestrel (K.)	2021/22	60	0	0	0	0	150	0	60	40	0	45	0
	2022/23	0	0	0	85	20	0	210	0	0	0	10	0
Buzzard (BZ)	2021/22	0	0	0	0	0	0	0	0	0	0	0	0
	2022/23	0	0	480	0	0	0	0	0	0	0	0	440
Lesser Black-backed Gull (LB)	2021/22	160	0	60	0	0	0	0	0	0	0	0	0
	2022/23	0	0	0	0	0	0	0	0	0	0	0	0
Sparrowhawk (SH)	2021/22	0	0	0	50	0	0	0	0	0	40	0	0
	2022/23	0	30	0	0	10	0	0	0	0	0	0	0
Hen Harrier (HH)	2021/22	0	0	0	0	0	0	75	0	98	0	65	22
	2022/23	0	0	0	0	0	0	55	5	0	0	0	0
Peregrine (PE)	2021/22	0	0	0	0	0	0	0	0	32	150	0	0
	2022/23	0	0	0	0	0	0	0	0	0	0	0	0

Table 6.12: Bird-seconds spent by species at Potential Collision Height (18-135m) within VP 4 Viewshed.

Species (BTO Code)	Year	Bird-seconds spent by species at Potential Collision Height (18-135m) for each month within Vantage Point 4 viewshed											
		April	May	June	July	August	September	October	November	December	January	February	March
Kestrel (K.)	2021/22	0	25	60	0	45	0	880	0	110	0	75	110
	2022/23	50	0	0	420	0	0	0	50	0	20	0	75
Buzzard (BZ)	2021/22	0	0	0	0	0	0	70	0	0	0	0	0
	2022/23	0	0	0	0	360	0	0	0	0	0	0	0
Lesser Black-backed Gull (LB)	2021/22	915	150	420	0	0	0	0	0	0	0	0	0
	2022/23	0	0	0	45	0	0	0	0	0	0	0	0
Sparrowhawk (SH)	2021/22	0	0	0	0	0	0	0	30	270	0	0	0
	2022/23	0	0	0	0	0	0	0	0	0	0	0	0
Hen Harrier (HH)	2021/22	0	0	0	0	45	0	0	0	120	0	70	0
	2022/23	0	0	0	0	0	0	0	0	0	111	0	0
Peregrine (PE)	2021/22	0	0	0	0	0	0	0	0	0	0	0	0
	2022/23	0	0	0	0	0	0	0	0	0	0	0	0

Table 6.13: Bird-seconds spent by species at Potential Collision Height (18-135m) within VP 5 Viewshed.

Species (BTO Code)	Year	Bird-seconds spent by species at Potential Collision Height (18-135m) for each month within Vantage Point 5 viewshed											
		April	May	June	July	August	September	October	November	December	January	February	March
Kestrel (K.)	2021/22	90	120	0	0	0	0	0	0	0	0	0	120
	2022/23	0	0	0	0	0	0	0	90	0	120	0	0
Buzzard (BZ)	2021/22	0	0	0	0	0	0	120	0	180	0	440	0
	2022/23	0	0	0	0	70	0	75	0	90	0	400	90
Lesser Black-backed Gull (LB)	2021/22	0	0	375	0	0	0	0	0	0	0	0	0
	2022/23	900	0	0	0	0	0	0	0	0	0	0	0
Sparrowhawk (SH)	2021/22	0	0	0	0	20	0	0	30	0	25	0	0
	2022/23	30	90	90	360	0	0	0	0	0	0	480	20
Hen Harrier (HH)	2021/22	0	0	0	0	0	0	0	0	0	0	0	0
	2022/23	0	0	0	0	0	0	0	0	0	0	0	0
Peregrine (PE)	2021/22	0	0	0	0	0	0	0	0	0	0	0	0
	2022/23	0	0	0	0	0	0	0	0	0	0	0	0

Table 6.14: Bird-seconds spent by species at Potential Collision Height (18-135m) for each VP (1-3).

Species (BTO Code)	Year	VP 1 Seconds spent at PCH		VP 2 Seconds spent at PCH		VP 3 Seconds spent at PCH	
		Summer	Winter	Summer	Winter	Summer	Winter
Kestrel (K.)	2021/22	270	120	105	225	210	145
	2022/23	165	170	60	170	105	220
Buzzard (BZ)	2021/22	1205	170	40	1475	0	0
	2022/23	410	410	770	0	480	440
Lesser Black-backed Gull (LB)	2021/22	0	0	1635	0	220	0
	2022/23	2340	0	315	0	0	0
Sparrowhawk (SH)	2021/22	20	25	300	0	50	40
	2022/23	75	120	50	0	40	0
Hen Harrier (HH)	2021/22	60	0	60	0	0	260
	2022/23	0	75	90	0	0	60
Peregrine (PE)	2021/22	0	70	0	0	0	182
	2022/23	60	0	0	0	0	0

Table 6.15: Bird-seconds spent by species at Potential Collision Height (18-135m) for each VP (4-5).

Species (BTO Code)	Year	VP 4 Seconds spent at PCH		VP 5 Seconds spent at PCH	
		Summer	Winter	Summer	Winter
Kestrel (K.)	2021/22	130	1175	210	120
	2022/23	470	145	0	210
Buzzard (BZ)	2021/22	0	70	0	740
	2022/23	360	0	70	655
Lesser Black-backed Gull (LB)	2021/22	1485	0	375	0
	2022/23	45	0	900	0
Sparrowhawk (SH)	2021/22	0	300	20	55
	2022/23	0	0	570	500
Hen Harrier (HH)	2021/22	45	190	0	0
	2022/23	0	111	0	0
Peregrine (PE)	2021/22	0	0	0	0
	2022/23	0	0	0	0

Table 6.16: 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	~ 40.95	~ 515
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	7.78	97.85
Predicted annual collision mortality	1.480	1.480	1.282	1.282	1.239	1.239	0.176	0.176	0.091	0.091	0.068	0.068
Percentage of population	0.113	0.009	0.537	0.043	0.219	0.017	0.018	0.001	0.729	0.058	0.166	0.013
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 6.17: Calculation of collision probability for Kestrel passing (Flapping) through rotor area.

K: [1D or [3D] (0 or 1)	1	Calculation of alpha and p(collision) as a function of radius									
NoBlades	3					Upwind:			Downwind:		
MaxChord	4	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	13		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.34	m	0.025	0.575	5.45	16.88	1.00	0.00125	15.84	0.95	0.00119
Wingspan	0.76	m	0.075	0.575	1.82	5.97	0.36	0.00268	4.94	0.30	0.00222
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.09	4.44	0.27	0.00332	3.18	0.19	0.00238
			0.175	0.860	0.78	3.98	0.24	0.00417	2.43	0.15	0.00255
Bird speed	10.1	m/sec	0.225	0.994	0.61	3.70	0.22	0.00499	1.91	0.11	0.00258
RotorDiam	117	m	0.275	0.947	0.50	3.06	0.18	0.00503	1.35	0.08	0.00223
RotationPeriod	4.96	sec	0.325	0.899	0.42	2.62	0.16	0.00510	1.00	0.06	0.00195
			0.375	0.851	0.36	2.31	0.14	0.00519	0.78	0.05	0.00175
			0.425	0.804	0.32	2.07	0.12	0.00526	0.62	0.04	0.00158
			0.475	0.756	0.29	1.87	0.11	0.00531	0.51	0.03	0.00144
Bird aspect ratio: β	0.45		0.525	0.708	0.26	1.69	0.10	0.00532	0.42	0.03	0.00132
			0.575	0.660	0.24	1.54	0.09	0.00532	0.36	0.02	0.00123
			0.625	0.613	0.22	1.41	0.08	0.00529	0.37	0.02	0.00139
			0.675	0.565	0.20	1.29	0.08	0.00523	0.40	0.02	0.00163
			0.725	0.517	0.19	1.18	0.07	0.00514	0.43	0.03	0.00185
			0.775	0.470	0.18	1.08	0.06	0.00503	0.44	0.03	0.00205
			0.825	0.422	0.17	0.99	0.06	0.00490	0.45	0.03	0.00221
			0.875	0.374	0.16	0.90	0.05	0.00474	0.45	0.03	0.00236
			0.925	0.327	0.15	0.82	0.05	0.00455	0.45	0.03	0.00247
			0.975	0.279	0.14	0.74	0.04	0.00434	0.44	0.03	0.00256
			Overall p(collision) =				Upwind	9.2%		Downwind	3.9%
								Average	6.6%		

Table 6.18: Calculation of collision probability for Kestrel passing (Gliding) through rotor area.

K: [1D or 3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius									
NoBlades	3					Upwind:				Downwind:		
MaxChord	4	m	r/R	c/C	α	collide		contribution	collide		contribution	
Pitch (degrees)	13		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r	
BirdLength	0.34	m	0.025	0.575	5.45	15.37	0.92	0.00115	14.34	0.86	0.00107	
Wingspan	0.76	m	0.075	0.575	1.82	5.47	0.33	0.00246	4.43	0.27	0.00199	
F: Flapping (0) or gliding (+1)	1		0.125	0.702	1.09	4.14	0.25	0.00310	2.88	0.17	0.00215	
			0.175	0.860	0.78	3.76	0.23	0.00394	2.21	0.13	0.00232	
Bird speed	10.1	m/sec	0.225	0.994	0.61	3.54	0.21	0.00476	1.75	0.10	0.00235	
RotorDiam	117	m	0.275	0.947	0.50	2.92	0.17	0.00481	1.22	0.07	0.00200	
RotationPeriod	4.96	sec	0.325	0.899	0.42	2.62	0.16	0.00510	1.00	0.06	0.00195	
			0.375	0.851	0.36	2.31	0.14	0.00519	0.78	0.05	0.00175	
			0.425	0.804	0.32	2.07	0.12	0.00526	0.62	0.04	0.00158	
			0.475	0.756	0.29	1.87	0.11	0.00531	0.51	0.03	0.00144	
Bird aspect ratio: β	0.45		0.525	0.708	0.26	1.69	0.10	0.00532	0.42	0.03	0.00132	
			0.575	0.660	0.24	1.54	0.09	0.00532	0.36	0.02	0.00123	
			0.625	0.613	0.22	1.41	0.08	0.00529	0.37	0.02	0.00139	
			0.675	0.565	0.20	1.29	0.08	0.00523	0.40	0.02	0.00163	
			0.725	0.517	0.19	1.18	0.07	0.00514	0.43	0.03	0.00185	
			0.775	0.470	0.18	1.08	0.06	0.00503	0.44	0.03	0.00205	
			0.825	0.422	0.17	0.99	0.06	0.00490	0.45	0.03	0.00221	
			0.875	0.374	0.16	0.90	0.05	0.00474	0.45	0.03	0.00236	
			0.925	0.327	0.15	0.82	0.05	0.00455	0.45	0.03	0.00247	
			0.975	0.279	0.14	0.74	0.04	0.00434	0.44	0.03	0.00256	
				Overall p(collision) =			Upwind	9.1%		Downwind	3.9%	
								Average	6.4%			

Table 6.19: Calculation of collision risk parameters for Kestrel Summer VP Surveys 2021.

Kestrel, Summer VP Surveys: April 2021-Sept 2021							
Measurements	Code	Value					
Rotor radius (metres)	R	58.5					
Rotor diameter (metres)	RD	117					
Max chord width of turbine blades (metres)	d	4					
Bird length (metres)	l	0.34					
Average flight speed (m/s)	s	10.1					
Daily Duration of Activity (hrs)	TDD	15					
Length of Season (days)	Tss	183					
Wingspan (m)		0.76					
Mean pitch of blade (degrees)		13					
Rotors per turbine		3					
Rotational period (seconds)		4.959					
Turbine operational time (%)		85					
			Vantage Point				
			VP 1	VP 2	VP 3	VP 4	VP 5
Total Survey time over 6 months (secs)	T		129600	129600	129600	129600	129600
Total flight at Rotor Height 18 – 135m (bird-secs)	sPCH		270	105	210	130	210
No. of turbines in viewshed	x		5	6	5	7	4
Survey area visible from VP (hectares)	Avp		418	607.7	392.9	565.6	571.1
Flight Risk Area, i.e. 500m buffer of turbines within viewshed (hectares)	Afr		253.11	320.98	234.31	269.38	221.69
Availability of species activity during survey period (hrs)	Sa		2745	2745	2745	2745	2745

Table 6.20: Stage 1 calculation of collision risk for Kestrel Summer VP Surveys 2021.

Stage 1 Calculations							
Measurements	Code	Calculation	VP 1	VP 2	VP 3	VP 4	VP 5
Proportion of Bird flight-time between 18 - 135m	t	sPCH/T	0.00208	0.0008	0.00162037	0.00100309	0.00162
Flight activity in visible area per hectare	F	t/Avp	4.98405E-06	1.3332E-06	4.1241E-06	1.7735E-06	2.84E-06
Proportion of Bird flight time in Risk Area	Trisk	F*Afr	0.001261513	0.00042793	0.00096632	0.00047774	0.000629
Bird occupancy of Risk Area (hrs/season)	n	Trisk*Sa	3.462853618	1.17466866	2.65256135	1.31140443	1.726595
Flight Risk volume (m ³)	Vw	(Afr*RD)*10000	296138700	375546600	274142700	315174600	2.59E+08
Actual volume of air swept by rotors (m ³)	o	$x*(\pi r^2(d+l))$	233185.2705	279822.325	233185.271	326459.379	186548.2
Bird occupancy of rotor swept area (bird-secs)	b	3600*(n*(o/Vw))	9.816181565	3.15091298	8.12254949	4.89009265	4.47046
Time taken for Bird to pass through rotors (secs)	v	(d+l)/s	0.42970297	0.42970297	0.42970297	0.42970297	0.429703
Number of Bird passes through the rotor during survey period	N	b/v	22.84410917	7.33276984	18.9027073	11.3801695	10.40361
Total transits adjusted for maximum operation of turbines (85%)	Tn	N*0.85	19.4174928	6.23285436	16.0673012	9.6731441	8.843064
Number of transits per turbine within viewshed	TnT	Tn/x	3.883498559	1.03880906	3.21346025	1.38187773	2.210766
Average TnT of all VP's (VP 1-5)	ATnT	(TnT1+TnT2+TnT3+...)/5	9.959798821				
Number of transits across windfarm	NT	ATnT*(Total no. turbines)	189.2361776				

Table 6.21: Stage 2 calculation of collision risk for Kestrel Summer VP Surveys 2021.

Stage 2 Calculation	Calculation	Result
Collision Probability (%)	(Model)	6.50%
Collisions during study period	NT*Collision Probability	12.30
Collisions during study period with 95% Avoidance Rate	*0.05	0.615017577
Over 30-year duration of windfarm	*30	18.45052732