BALLINCOR WIND FARM: COLLISION RISK MODELLING REPORT

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SUMMARY

This report presents the collision risk modelling and collision risk assessment for the proposed Ballincor Wind Farm, Co. Offaly. The proposed wind farm will comprise 11 turbines. The three turbine models analysed in this collision risk model have hub heights of 98.5–105 m and rotor diameters of 149.1–163 m, which create potential collision height airspaces of 17–180 m, 30–80 m and 30.15–179.2 m.

The collision risk model was based on nine seasons of vantage point survey data from up to seven vantage points with a survey effort of around six hours / month / vantage point. The NatureScot model was used. As well calculating predicted collision risks, the uncertainty ranges around the estimates were quantified. Collision risks that would cause a 1% or greater increase in mortality to the affected population were considered potentially significant.

The central estimates of the potential increase in annual mortality due to the predicted collision risk exceeded the 1% threshold for the local Mallard wintering population, the local Black-tailed Godwit wintering population and the county Kestrel population. The upper limit of the uncertainty range exceeded the thresholds by small amounts for the Grey Heron county population, the national Black-tailed Godwit wintering population, and the local Golden Plover wintering population.

The local Golden Plover and Black-tailed Godwit wintering populations are qualifying interests of the Little Brosna Callows SPA.

The predicted collision risk for Black-tailed Godwit was driven by a single large flock event, reflecting the species' tendency to occur in large flocks and to concentrate in response to local feeding conditions. The estimate is therefore subject to increased uncertainty and should be interpreted with caution.

The uncertainty ranges did not take account of potential under-detection of distant flightlines. Inclusion of this factor would raise the mortality increases by factors of around 1.5–3 times. However, for some species, these factors may be over-estimated.

The 1% threshold is likely to be very precautionary. Therefore, substantial increases in annual mortality well above the 1% threshold are likely to be required to cause significant impacts on the affected populations.

1. INTRODUCTION

1.1. SCOPE

This report presents the collision risk modelling and collision risk assessment for the proposed Ballincor Wind Farm, Co. Offaly. The proposed wind farm will comprise 11 turbines. The site location and proposed site layout is shown in Map 1.1. The three turbine models analysed in this collision risk model have hub heights of 98.5-105 m and rotor diameters of 149.1–163 m, which create potential collision height airspaces of 17–180 m, 30-180 m and 30.15–179.2 m.

The collision risk modelling methodology was based on the NatureScot guidance on collision risk modelling (NatureScot, 2024), and current practice in collision risk modelling.

This work was commissioned by TOBIN. The collision risk modelling, assessment and reporting was carried out by Tom Gittings.

1.2. COLLISION RISK MODELLING

Collision risk modelling uses statistical modelling techniques to predict the likely collision risk. It uses flight activity data from before the construction of a wind farm to calculate the likely risk of birds colliding with turbines in the operational wind farm. The flight activity data is used to calculate flight activity densities at potential collision height within the risk area of the wind farm. These densities are then used to predict the number of transits of the rotor swept volume in the wind farm based on the proportion of the total air space that is occupied by the rotor swept volume. However, most transits of the rotor swept volume will not result in a collision, because, for the duration of a transit, most of the rotor swept volume is not occupied by the turbine blades. Therefore, the probability that a bird will collide with a turbine blade when it transits the rotor swept volume is calculated. Most birds try to avoid the turbine blades, either by avoiding the wind farm area altogether, or by taking evasive action if they are likely to collide with a blade while transiting the wind farm, so it is also necessary to factor in an avoidance rate. The final collision risk is calculated by multiplying the number of predicted transits by the probability of a collision on a single transit and correcting for the avoidance rate and other relevant factors.

1.3. COLLISION RISK ASSESSMENT

The potential impact of the predicted collision risk depends on the size of the affected population and their demographics. The collision risk assessment examines whether the level of the predicted collision risk could have a significant effect on the dynamics of the affected population.

1.4. NATURESCOT GUIDANCE

NatureScot (2024) provides detailed guidance for carrying out collision risk modelling for onshore wind farm projects. This guidance was developed by Band (2024) from the original Scottish collision risk model (SNH, 2000) and the refinement of this model by Band (2012). The basic methods remain the same, but the NatureScot guidance introduces a number of new components. It deals with issues not covered by the previous guidance, such as how to combine data from multiple vantage points and how to account for nocturnal flight activity. It also includes a specific requirement to assess the uncertainty around the collision risk estimates, which is an issue that has been poorly dealt with in Irish collision risk modelling. There is a spreadsheet that accompanies the guidance that can be used to implement the collision risk model.

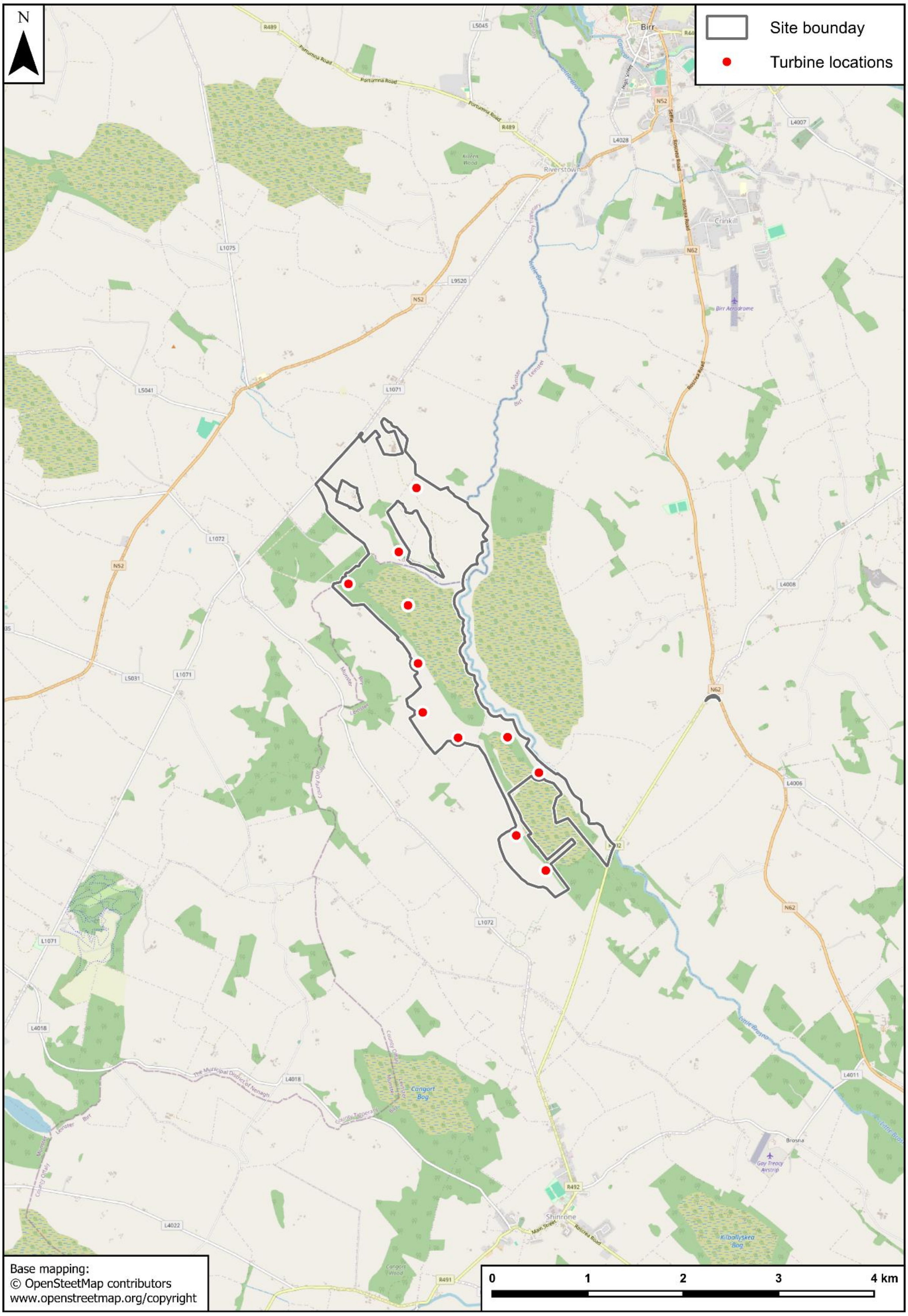
1.5. LIMITATIONS

The methodology of most of the vantage point surveys carried out for this project deviated in a number of respects from the recommended methodology (NatureScot, 2025a). Conservative assumptions have been applied where possible in this collision risk model to address the implications of these deviations, as described in the relevant sections of this report.

1.6. STATEMENT OF COMPETENCE

Tom Gittings has a BSc in Ecology, a PhD in Zoology and is a member of the Chartered Institute of Ecology and Environmental Management (CIEEM). He has 30 years' experience in professional ecological consultancy work and research. 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 variously included field surveys (including vantage point surveys, breeding wader and raptor surveys and wintering waterbird surveys), collision risk modelling, writing the ornithological sections of EIS/EIAR and NIS reports, expert witness services at oral hearings, and provision of scoping advice and peer review services.

Tom’s article on the implications for collision risk modelling of under-detection of distant flightlines in wind energy vantage point surveys (Gittings, 2024) was highly commended in the CIEEM Awards 2025.



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Map 1.1. Site location and proposed turbine layout.

2. METHODOLOGY

2.1. INTRODUCTION

The collision risk modelling methodology was based on the NatureScot guidance on collision risk modelling (NatureScot, 2024), additional guidance provided by Band (2024), and current practice in collision risk modelling.

2.2. SPECIES

All the waterbird and raptor species recorded flying at potential collision height during the surveys, apart from Snipe, were included in the collision risk modelling. Snipe was not included because vantage point surveys are not an effective method of sampling their flight activity, so the results from collision risk modelling would not be very meaningful.

2.3. DATA SOURCES

2.3.1. Flight activity data

The flight activity data used for the collision risk model comprised a nine-season vantage point survey carried out between summer 2020 and summer 2024, with the exception of summer 2022, and in the winter of 2025/26.

The surveys between summer 2020 and summer 2024 were carried out by Ecology Ireland. The winter 2025/26 survey was carried out by TOBIN. To distinguish between the two datasets, the vantage points from the Ecology Ireland surveys have been given the prefix EI while those from the TOBIN survey have been given the prefix TB.

Five vantage points were surveyed in eight seasons (EI1–EI5) by Ecology Ireland with two additional vantage points surveyed in the final four seasons of their survey (EI6–EI7). The vantage point locations are shown in Map 2.1. Note that EI6 and EI7 were labelled VPA and VPB in the original vantage point survey datasets.

A separate set of five vantage points (TB1–TB5) were surveyed in the ninth season (winter 2025/26) by TOBIN (Map 2.1).

The viewshed arcs and viewsheds for each vantage point are shown in Map 2.2-Map 2.13. See Section 2.4.2 for details of the derivation of the viewsheds.

In six of the seasons, 36 hours of watches were completed at each vantage point surveyed, while in the other three seasons, 30 hours were completed (Table 2.1). The survey effort varied between months with 12–30 hours per month surveyed at EI1–5 and 6–18 hours per month surveyed at EI6–7 (apart from April when no vantage point watches were carried out at EI6–EI7) (Table 2.2). The TOBIN vantage points were surveyed between October and February (Table 2.2). Certain aspects of the Ecology Ireland survey methodology required adjustment prior to analysis; further details are provided in Sections 2.4.3, 3.1.2 and 3.2.

The Ecology Ireland vantage point surveys were concentrated in the middle of the day, but there was some coverage of the early morning period during the winter months (see Section 2.5.5). The TOBIN surveys included full coverage from sunrise to sunset, and also covered the hours before sunrise and after sunset as recommended for waterfowl by the NatureScot guidance (NS 2025a).

The survey recorded timed flight activity of all raptor and waterbird species. The Ecology Ireland surveys did not classify flight activity by height bands, but instead recorded information for most records on the height ranges of the flight activity. The TOBIN surveys classified flight activity into five height bands: 0-25 m, 25-50 m, 50-150 m, 150-200 m, and > 200 m.

The full vantage point survey data is included in Appendix 7-1 to the Environmental Impact Assessment Report Ornithology chapter.

Table 2.1. Total number of vantage point survey hours per vantage point per season.

Season	EI1	EI2	EI3	EI4	EI5	EI6	EI7
2020 summer	30	30	30	30	30	0	0
2020/21 winter	36	36	36	36	36	0	0
2021 summer	30	30	30	30	30	0	0
2021/22 winter	36	36	36	36	36	0	0
2022/23 winter	36	30	30	30	30	30	30
2023 summer	37	36	36	36	36	36	36
2023/24 winter	36	36	36	36	36	36	36
2024 summer	30	30	30	30	30	30	30
	TB1	**TB2**	**TB3**	**TB4**	**TB5**		
2025/26 winter	36	42	36	36	36		

Seasons: summer = April – September; winter = October – March. Durations are rounded to the nearest hour.

Table 2.2. Total number of vantage point survey hours per vantage point per month.

Month	EI1	EI2	EI3	EI4	EI5	EI6	EI7	TB1	TB2	TB3	TB4	TB5
Jan	24	24	24	30	24	6	12	6	6	6	6	6
Feb	24	24	24	24	24	18	12	12	18	6	6	6
Mar	24	24	24	24	24	12	12	0	0	0	0	0
Apr	12	12	12	12	12	0	0					
May	30	30	30	30	30	18	18					
Jun	24	24	24	24	24	12	12					
Jul	24	24	24	24	24	12	12					
Aug	24	24	24	24	24	12	12					
Sep	12	12	12	12	12	12	12					
Oct	12	12	12	12	12	6	6	6	6	6	6	6
Nov	30	24	18	24	24	12	12	6	6	6	6	6
Dec	30	30	30	24	30	12	12	6	6	6	6	6

Durations are rounded to the nearest hour.

2.3.2. Turbine specifications

The turbine specifications used for the collision risk model (apart from mean pitch angle; see Section 2.6.4) were supplied by TOBIN and are shown in Table 2.3.

Table 2.3. Turbine parameters used for the collision risk model.

Turbine	Rotor radius	Ground clearance	Max chord	Rotor speed range	Mean pitch angle
N149	74.55 m	30.15 m	4.15 m	6.2-12.2 rpm	0°, 15°, 30°
N163	81.5 m	17 m	4.15 m	6.0-11.6 rpm	0°, 15°, 30°
V150	75 m	30 m	4.2 m	4.9-12.6 rpm	0°, 15°, 30°

Sources: data supplied by TOBIN, except for mean pitch for which see Section 2.6.4.

2.3.3. Bird parameters

The bird biometric parameters used for the collision risk model are shown in Table 2.4.

The seasonal periods used in the collision risk model and assessment are shown in Table 2.5. For species not included in this table, collision risk was calculated and assessed on an annual basis. These comprised species that do not exhibit distinct seasonal use of the site, as well as those that had negligible annual collision risk. Seasonal periods were not defined for the latter, as they were only included to allow monthly collision estimates to be summed in the final stage of the modelling for the purposes of the collision risk assessment.

Table 2.4. Bird biometric parameters used for the collision risk model.

Species	Length (m)	Wingspan (m)	Flight speed (m/sec)
Mute Swan	1.525	2.23	16.2
Whooper Swan	1.525	2.305	17.3
White-fronted Goose	0.715	1.475	16.1
Wigeon	0.48	0.805	20.6
Teal	0.36	0.61	19.7
Mallard	0.575	0.895	18.5
Pintail	0.585	0.875	20.6
Shoveler	0.48	0.77	20.6
Cormorant	0.9	1.45	15.2
Little Egret	0.6	0.915	10.2
Grey Heron	0.94	1.85	11.2
White-tailed Eagle	0.8	2.2	11.3
Hen Harrier	0.48	1.1	9.1
Sparrowhawk	0.33	0.625	11.3
Buzzard	0.54	1.205	11.6
Golden Plover	0.275	0.715	17.9
Lapwing	0.295	0.845	12.8
Curlew	0.55	0.9	16.3
Black-tailed Godwit	0.42	0.76	18.3
Snipe	0.26	0.46	17.1
Black-headed Gull	0.355	1.05	11.9
Common Gull	0.41	1.2	13.4
Lesser Black-backed Gull	0.58	1.425	13.1
Herring Gull	0.595	1.44	12.8
Kestrel	0.335	0.755	10.1
Merlin	0.275	0.56	10.1
Peregrine	0.42	1.025	12.1

Length and wingspan from Cramp and Simmons (2004); flight speed from Alerstam et al. (2007). For Little Egret, Great White Egret speed was used; for Golden Plover, Grey Plover speed was used.

Table 2.5. Seasonal periods used in the collision risk modelling and assessment.

Species	Season	Months
Mute Swan	breeding	Apr-Aug
	non-breeding	Sep-Mar
Whooper Swan	winter	Oct-Mar
Wigeon	winter	Sep-Mar
Cormorant	breeding	Feb-Aug
	non-breeding	Sep-Feb
Little Egret	breeding	Apr-Aug
	non-breeding	Sep-Mar
Golden Plover	winter	Sep-Mar
Lapwing	summer	Apr-Sep
	winter	Oct-Mar
Black-tailed Godwit	non-breeding	Sep-Mar
Black-headed Gull	breeding	Apr-Jul
	non-breeding	Aug-Mar
Lesser Black-backed Gull	spring	Mar
	breeding	Apr-Jul
	autumn	Aug-Oct
	winter	Nov-Feb

For species not included in this table the collision risk was calculated and assessed for the whole year.

2.4. DATA MANAGEMENT AND PREPARATION

2.4.1. General

Before beginning the analyses, I audited the flight activity data for data entry errors and missing data and removed non-flight records. I also mapped viewsheds for each vantage point.

2.4.2. Viewshed analyses

2.4.2.1 Viewshed mapping

I carried out all analyses using custom scripts in R version 4.4.1 (R Core Team, 2024), primarily using the packages *terra* (Hijmans, 2023) and *sf* (Pebesma, 2018; Pebesma and Bivand, 2023).

Viewsheds were mapped at heights of 17 m and 30 m above ground level, representing the minimum ground clearance of the turbine models under consideration.

Vantage point (VP) locations and initial viewshed arcs were provided by Ecology Ireland and TOBIN. Because the Ecology Ireland arcs did not align precisely with the VP coordinates, I generated revised arcs using the azimuths of the supplied arc boundaries, ensuring geometric alignment with the VP locations. A 10 m buffer was applied during raster processing to avoid edge artefacts; final outputs were clipped to the unbuffered arcs.

Topographic inputs comprised Bluesky Digital Surface Model (DSM) data (1 m resolution; acquired 12/08/2022) and Digital Terrain Model (DTM) data (5 m resolution; acquired 19/09/2019). The DTM was resampled to the 1 m DSM grid using bilinear interpolation to produce a continuous terrain surface aligned exactly with the DSM. A canopy height raster was then derived as: Canopy height = DSM − DTM

Negative values (arising from interpolation differences) were set to zero.

Viewsheds were required to represent turbine clearance relative to ground level (DTM) while accounting for screening by vegetation and structures (DSM). To achieve this, DSM-based viewsheds were generated in 1 m vertical increments from 0 m up to the target height above ground level using the *viewshed* function in the *terra* package. For each raster cell, the appropriate viewshed layer was selected according to the local canopy height. For example, where canopy height was 10 m and the target clearance was 30 m above ground level, the viewshed calculated at 20 m above the DSM was selected, thereby ensuring that clearance was referenced consistently to ground level while incorporating DSM-derived obstruction.

This procedure produced binary raster maps (1 m resolution) representing visibility at the specified height above ground level. Raw 1 m outputs exhibited highly irregular pixel-scale boundaries, reflecting fine-scale DSM variation and interpolation artefacts. Such detail exceeds the spatial precision achievable in VP survey recording and substantially increases geometric complexity in subsequent analyses.

To ensure outputs reflected ecologically meaningful spatial resolution, simplification was performed in raster space prior to vector conversion. First, a modal (majority) focal filter (5 × 5 window) was applied to remove single-pixel noise and minor jaggedness while preserving overall visibility structure. Second, contiguous visible regions were identified using eight-direction (queen) connectivity, and visible “islands” smaller than 10 ha were reclassified as non-visible. This threshold approximates the spatial scale at which visibility differences are likely to be practically distinguishable in VP surveys and relevant to collision risk modelling, recognising that no formally defined minimum mapping unit exists for such surveys.

The cleaned visibility rasters were then converted to vector polygons, simplified using a small tolerance (5 m), and lightly smoothed to remove residual geometric artefacts. Holes within visible polygons smaller than 1 ha were filled. This threshold reflects the spatial precision of flightline recording and the ecological irrelevance of very small internal visibility gaps at VP survey scales.

Finally, the vectorised viewsheds were clipped to the unbuffered viewshed arcs to produce the final viewshed maps used in subsequent collision risk modelling and analysis.

The resulting viewshed maps are shown in Map 2.2–Map 2.13.

2.4.2.2 Viewsheds used for the collision risk model

The Ecology Ireland viewsheds had large overlaps. EI1 and EI2 shared much of the closest sections of their viewsheds, where detection rates would have been highest, while there were large overlaps between EI3 and EI5, EI4 and EI7, and EI6 and EI7. Vantage point watches were frequently carried out concurrently at these overlapping viewsheds, resulting in duplicated spatial coverage and a high risk that the same flightlines were recorded at more than one vantage point. Conversely, periods of low activity would also have been spatially duplicated.

Some effort appears to have been made during assembly of the vantage point dataset to identify flightlines recorded at multiple vantage points. However, the proportion identified (approximately 10%) appears low given the extent of viewshed overlap, the prevalence of concurrent watches, and the concentration of flight activity along corridors that passed through multiple viewsheds.

The method for calculating flight activity densities in the NatureScot model assumes that each vantage point represents an independent sample. When this assumption is violated, as in the present case, the flight activity densities may be biased through double-counting of the same flightlines.

To address this issue, I removed overlapping sections of viewsheds so that each area of the site was allocated to a single vantage point. I then adjusted flight activity recorded at the affected vantage points pro rata based on the ratio of mapped flightline lengths within the reduced viewshed relative to the original viewshed.

The original 2 km viewsheds exhibited complex overlap patterns. To allow consistent rules to be applied, I first reduced the viewsheds to 1.5 km, which eliminated most of the three- and four-way overlaps. For the remaining pairwise overlaps, allocation was determined using the overlap areas weighted by distance from each vantage point. The small number of remaining three-way overlaps were peripheral. I allocated these visually to maintain coherent viewshed boundaries. I also removed small outlying segments that had been isolated by the overlap removal. The resulting viewshed extents as used for the collision risk model are shown in Map 2.14–Map 2.15.

The TOBIN vantage point surveys did not include any concurrent watches at vantage points with overlapping viewsheds.

2.4.2.3 Spatial structure

The NatureScot methodology recommends dealing with spatial-structure by using a weighted averaging procedure to calculate the mean flight activity densities across the vantage points included in the model (see Section 2.6.2.1). However, while my review of the flightline distributions showed that there was significant spatial-structure for eleven species, the spatial-structure was generally not captured by differences between vantage points: e.g., the concentration of flight activity along the River Brosna involved small sections of the viewsheds of all the vantage points.

To analyse the spatial structure, I divided the viewsheds into sections reflecting the structure indicated by my review of the flightline distributions. The sections are described in Table 2.6 and shown in Map 2.16 and Map 2.17.

Table 2.6. Sections used for the spatially-structured models.

Species	Sections	VPs	Turbines	Notes
Mute Swan, Mallard, Cormorant, Little Egret, Grey Heron and Black-tailed Godwit	Brosna South Corridor	EI1, EI2, EI3, EI4, EI5, TB2–TB5	2	500 m wide corridor along the River Brosna south of confluence with tributary
	Brosna North Corridor	EI3–EI7, TB1–TB3	0	500 m wide corridor along the River Brosna north of confluence with tributary; excluded from collision risk model
	Other	EI1–EI7, TB1–TB5	9	Remainder of survey area
Whooper Swan, Wigeon and Lapwing	Brosna North Corridor	EI3–EI7, TB1–TB3	0	500 m wide corridor along the River Brosna north of confluence with tributary; excluded from collision risk model
	Other	EI1–EI7, TB2–TB5	11	Remainder of survey area
Black-headed Gull and Lesser Black-backed Gull	Brosna North Corridor	EI3–EI7, TB1–TB3	0	500 m wide corridor along the River Brosna north of confluence with tributary; excluded from collision risk model
	Commuting Corridor	EI3, EI5, EI6 and EI7, TB1–TB2	2	Corridor with concentration of flight activity west of the River Brosna and north of the tributary
	Other	EI1–EI6, TB1–TB5	9	Remainder of survey area

I first analysed the species distribution across all these sections by calculating their flight activity densities in each section using the NatureScot methodology (see Section 2.6.2.1). I used the results of these analyses (Section 2.5.3) to define the appropriate spatial structure to use for each species in the collision risk model, as shown in Table 2.6.

The Brosna North Corridor did not include any turbine locations. I excluded the flight activity within the Brosna North Corridor from the spatially-structured models because of the high concentration of flight activity associated with birds feeding on flooded fields and/or the differences in flight activity densities between the Brosna North Corridor and Brosna South Corridor. I did not include a separate section for the Brosna South Corridor in the Whooper Swan, Wigeon and Lapwing spatially-structured models because their flight activity densities in this section was similar to their densities in the remainder of the survey area.

I divided the viewsheds of each vantage point between the relevant sections. Where the viewshed only included a very small component of a particular section, I excluded that component of the viewshed from the model. This was to prevent the mean flight activity densities for the section being biased by unrepresentative samples.

I calculated flight activity densities separately for each section of each viewshed and averaged the flight activity densities across vantage points separately for each section type.

2.4.3. Vantage point survey data

The vantage point survey data provided the core dataset for the collision risk model. However, some processing of the data was required before it could be used in the collision risk model. This included identifying and addressing vantage point watches that did not fully align with the NatureScot survey guidance (referred to hereafter as non-compliant watches), dealing with various issues in the Ecology Ireland vantage point records, selecting the appropriate height bands, and dealing with flightlines outside the viewsheds.

2.4.3.1 Non-compliant watches

The Ecology Ireland vantage point watches were all continuous six hour watches without the 30-minute break after three hours required by the NatureScot survey guidance (see Section 3.2.2). There were also some watches that were carried out in conditions of poor visibility (see Section 3.2.3). While analyses of recording rates (see Section 3.2.2) did not show any decline after three hours, I created a set of survey data that was restricted to the first three hours of each watch and excluded the watches with poor visibility.

However, as some non-compliant watches recorded relatively high activity for certain species, the collision risk modelling was carried out both including and excluding the non-compliant survey effort. In accordance with the precautionary principle, I used the higher of the two collision risk estimates for assessment purposes. This approach ensured that potential bias associated with survey non-compliance did not result in underestimation of collision risk.

2.4.3.2 Ecology Ireland vantage point survey effort

The review of the flightline mapping (Section 3.1.2) indicated that a substantial proportion of the Ecology Ireland survey time was spent tracking flightlines outside the viewshed arcs, with less than 50% of mapped flightlines falling within the defined viewshed arcs at some vantage points. This means that the effective survey effort will have been lower than the total vantage point survey durations, as time spent tracking flightlines outside the arcs was not directed at the defined viewshed areas. It was therefore necessary to adjust the vantage point survey durations to account for this factor.

For each vantage point, I calculated the proportion of total flightline duration occurring within the viewshed arc, excluding records that were not mapped as flightlines. This included flightlines beyond the 2 km boundary where they fell within the viewing angle subtended by the arc. I then used these proportions to adjust the vantage point survey durations for each vantage point. This resulted in adjustments of the vantage point survey durations by factors of 0.4 (VP6) to 0.9 (VP5).

2.4.3.3 Ecology Ireland vantage point survey records

The vantage point survey dataset required a number of preparation steps prior to use in the collision risk model. These included standardising the classification of flight, addressing records with incomplete information on flight durations and flight heights and/or that were not mapped, and filtering or refining records to ensure that only relevant flight activity by the target species was included in the analysis.

Most of the records had information in their notes on the height ranges of the flight activity. I extracted the maximum flight heights from this information and assumed that when the maximum flight height was above the ground clearance of the turbine, all the flight activity was at potential collision height. Where there was no data on the maximum flight height, I also assumed that the flight activity was at potential collision height.

There were some records included in the vantage point survey dataset with no data on flight durations. Where these records had mapped flightlines, I used the flightline length and the mean flight speed from Table 2.4 to estimate the flight duration. For records with no flight durations or mapped flightlines, I used the 95th percentile of the distribution of flight durations for the relevant species in the dataset to make estimates of the missing flight durations. The 95th percentile was used rather than the maximum to avoid undue influence of a small number of exceptionally long recorded durations, which may reflect the aggregation of multiple flight events or other recording inconsistencies. Also, if the records had involved such long durations, it is likely that there would have been some indication of this in the notes.

I reviewed the notes for all records potentially included in the collision risk model and excluded records that referred entirely to non-flight activity. Where the records involved a mixture of flight activity and non-flight activity, I used details from the records notes to correct the recorded durations to only refer to the flight activity component, where the notes contained relevant details. For some records, the notes indicated that the activity consisted predominantly of non-flight behaviour (e.g. perching / on the ground for long periods with short flights), but did not allow the flight component to be quantified, or the recorded duration corresponded to non-flight activity. For these records, I used the medians of distribution of flight durations for the relevant species in the dataset to make estimates of the flight durations.

For records with no flightline mapping, I made the precautionary assumption that the flightlines were entirely within the relevant viewsheds. For the spatially-structured models, I had to allocate these records to sections within the viewsheds. To do this, I used details from the record notes: e.g., records described as “following the river” were assigned to the Brosna sections.

There were a few records that referred to the following non-species taxa: swan species, goose species, wader species and gull species. I allocated the swan species records to both Mute Swan and Whooper Swan, the wader species records to Black-tailed Godwit (the notes for one of the two records described the birds as “godwit species”) and the gull species records to Lesser Black-backed Gull (the notes for most of the records indicated that they were large gulls and Lesser Black-backed Gull was the most frequent large gull).

2.4.3.4 TOBIN vantage point survey data

The TOBIN vantage point survey dataset contains timed durations of flight activity for each record in specified height bands.

The potential collision height zones for the turbine models that are proposed for this project occupy height bands of 17-180 m (N163) and 30-180 m (N149 and V150) above ground level.

I used data from the following vantage point survey height bands for the collision risk modelling for the N163 turbine: 0-20 m, 20-50 m, 50-150 m and 150-200 m. For the N149 and V150 turbines, I used the same height bands apart from the 0-20 m band.

The 0-20 m height band will have included a significant amount of flight activity below the potential collision height zone of the N163 turbine; in fact, the majority of flight activity in this height band may have occurred below the potential collision height zone. Similarly, but to a lesser degree, the 20-50 m height band will have overestimated flight activity for the N149 and V150 turbines.

The 150-200 m height band may have included flight activity above the potential collision height zone. However, the low level of flight activity in this height band means that the inclusion of excess flight activity in this height band will not have had much effect on the predicted collision risk.

2.4.3.5 Flightlines

The collision risk model uses the viewshed area to derive the density of flight activity recorded during the vantage point surveys. Therefore, flight activity that occurred outside the viewshed of the vantage point being surveyed should be excluded from the collision risk model analyses.

For the collision risk model analyses and the analyses of distance effects, I excluded flightlines that occurred entirely outside the relevant viewshed. Where a flightline occurred partly outside the relevant viewshed, I adjusted its duration by the proportion of the flightline length that occurred in the viewshed. The flightline was clipped by the viewshed. The duration was then recalculated by multiplying the original value by (clipped flightline length) / (original flightline length). It should be noted that, this recalculation procedure assumes that the flight speed and flight height distribution were similar between the segments used for the recalculation.

I used similar procedures to split flightlines between sections within viewsheds in the spatially-structured models.

There were some records that were mapped as polygons, not polylines. For these records, I used the relative areas to make the same calculations as above.

2.4.3.6 Survey seasons

The vantage point survey dataset includes data from nine survey seasons (five winters and four summers) dating back to the summer of 2020. The minimum requirement of the NatureScot guidance is data from two winter and two summer seasons. Inclusion of additional seasons above the minimum requirement will generally improve the collision risk model by reducing the uncertainty due to sampling effects (see Section 4.7.2.1) and incorporating more annual variation. However, where a species shows a long-term increasing or decreasing trend, the older data may not reflect the current and likely future occurrence patterns. In this case, there was a large increase in Little Egret flight activity across the nine seasons covered by the vantage point survey, with only 0–1 records/200 hours in the first two winters, 6–15 records/200 hours in the final three winters, while there were no records in the first two summers and 1–2 records/200 hours in the last two summers (Section 3.4.1). Therefore, the collision risk model for Little Egret only used data from the most recent five seasons (winter 2022/23, summer 2023, winter 2023/24, summer 2024 and winer 2025/26).

2.5. EXPLORATORY ANALYSES

2.5.1. Scope

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

Details of the specific methodologies used for some of these exploratory analyses are provided in the following sections.

2.5.2. Distance effects

Declines in detection rates with distance from vantage points is a common issue in vantage point surveys (Gittings, 2024), and the guidance on vantage point surveys (NatureScot, 2025a) recommends considering corrections for detectability effects. Therefore, I carried out analyses to assess the relationships between distance from the vantage point locations and the flightline detections.

I carried out these analyses separately for the Ecology Ireland and TOBIN datasets due to differences in the vantage points and viewsheds. For the Ecology Ireland analyses, I used the full

2 km viewsheds as the purpose was to examine distribution patterns within the viewsheds, not across viewsheds.

The analyses assumed that flight activity is randomly distributed in relation to distance from the vantage point locations. At individual vantage points, habitat associations and / or topography may affect the relationship between distance from the vantage point location and flight activity. Averaging across a number of vantage points is likely to minimise these biases, because the habitat / topographic effects will differ between vantage points. However, very strong habitat / topographic effects affecting a lot of the flight activity at a vantage point could still bias these analyses. This was the case at the Ballincor Wind Farm site where there were very high levels of flight activity along the River Brosna. Therefore, I carried out two sets of analyses: one using the entire viewsheds and one using viewsheds with a 200 m wide corridor along the River Brosna removed.

As detectability will be strongly affected by body size, I divided the species recorded in the vantage point surveys into size groups, based on their cross-sectional indices (the body length multiplied by the wingspan).

I used three size groups for the Ecology Ireland dataset. The small species included Sparrowhawk, Golden Plover, Lapwing, Snipe, Black-headed Gull, Kestrel, and Merlin with body lengths of 0.26-0.36 m and wingspans of 0.46-1.05 m. The medium species included, Little Egret, Hen Harrier, Buzzard, Common Gull, Lesser Black-backed Gull, Herring Gull, and Peregrine with body lengths of 0.41-0.60 m and wingspans of 0.90-1.44 m. The large species included Mute Swan, Whooper Swan, White-fronted Goose, Mallard, Cormorant, Grey Heron with body lengths of 0.715-1.525 m and wingspans of 1.45-2.305 m.

Due to more limited data, I was only able to use two size groups for the TOBIN dataset. The smaller species included Wigeon, Mallard, Shoveler, Pintail, Little Egret, Hen Harrier, Sparrowhawk, Golden Plover, Lapwing, Black-tailed Godwit, Snipe, Black-headed Gull, Kestrel, and Merlin, and Peregrine with body lengths of 0.26-0.60 m and wingspans of 0.46-1.1 m. The larger species included Mute Swan, Whooper Swan, Cormorant, Grey Heron, White-tailed Eagle, Buzzard and Lesser Black-backed Gull with body lengths of 0.54-1.525 m and wingspans of 1.205-2.305 m.

I carried out the analyses using the 30 m viewsheds and divided each viewshed into eight bands, representing increasing distance from the vantage point, from 0-250 m to 1750-200 m.

I then calculated the total length of flightlines for each species group in each band. Flightlines with a maximum height lower than 30 m, or where heights were not recorded, in the Ecology Ireland dataset were excluded, as were flightlines with durations only recorded for the lowest height band in the TOBIN dataset, because the viewsheds had been derived using a minimum height of 30 m.

I then calculated the flightline density for each distance band in each viewshed using Equation EX1. This equation standardises the flightline density in each distance band by the total amount of flight activity recorded at that vantage point, to avoid the analyses being biased by vantage points where large amounts of flight activity were recorded.

Equation EX1: $FD_{i^*} = \sum(FD_i / FD_{VP}) \times FD_{mean}$

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

I used the ratio of the weighted flightline density in each band to the maximum weighted flightline density across all bands to calculate weightings for each distance band. These weightings indicate the degree of under-recording in each distance band, based on the assumption that all flightlines were detected in the band with the maximum density. The latter was the 0–250 m, or the 250–500 m distance band.

I used the band weightings to calculate corrected viewshed areas that were adjusted to allow for the effects of under-estimation of distant flightlines. For each viewshed, I multiplied the area in each 250 m distance band by the band weightings. The ratio of the raw viewshed area to the corrected viewshed area indicates the potential degree of under-estimation of flight activity densities due to distance effects.

2.5.3. Species-specific spatial structure

The basic model assumes random distribution of flight activity across the wind farm site, or across portions of it. Therefore, in addition to considering the distance effects on detectability, it is also necessary to consider whether deviations from this assumption are likely to significantly bias the model. In large wind farm sites, such as the Ballincor Wind Farm site, species are likely to show significant deviations from this assumption.

I investigated spatial structure for species / populations of conservation importance that had strong associations with the wind farm site. These included breeding populations within the wind farm site, non-breeding populations regularly using the wind farm site, and populations regularly commuting over the wind farm site.

First, I examined the flightline mapping to assess whether there were obvious concentrations of flight activity in particular areas, taking account of distance effects.

Where I identified potential spatial structure, I defined sections of the overall survey area (the combined viewsheds) to represent this structure and then calculated flight activity densities separately for each section (see Section 2.4.2.3).

2.5.4. Flight directions

Flight direction influences the single-transit collision risk in the NatureScot collision risk model, as birds flying upwind and downwind experience different relative airspeeds through the rotor-swept zone. Therefore, I examined the distribution of flight directions for all flightlines used for the collision risk modelling.

The mapped flightlines frequently comprised complex movement patterns, including circling and repeated manoeuvring associated with foraging and local commuting. As collision risk depends on flight direction at any given moment rather than the net bearing of an entire flight, I used flightline segments for the analyses.

First, I split each mapped flightline into their constituent segments using the st_segments function from the R package nngeo (Dorman, 2024). I then calculated the bearing of each segment using the line_bearing function from the R package stplanr (Lovelace and Ellison, 2018).

The prevailing winds at the Ballincor Wind Farm site are from the SE-NW[1]. Therefore, I assigned flightline segments with bearings of 315–360° and 0–135° to the downwind category and segments with bearings of 135–315° to the upwind category. I used the prevailing wind direction rather than the wind direction at the time of the observation because flight direction is more likely to be influenced by habitat, topography and commuting routes, rather than wind direction.

To ensure that longer periods of flight contributed proportionately more information than very short digitised segments, I weighted segments by their mapped length. I therefore calculated the raw upwind proportion for each species as the total length of segments classified as upwind divided by the total mapped flightline length for that species.

Segments within the same flight are not statistically independent, particularly where birds circle or make repeated passes through the site. Treating individual segments as independent observations would underestimate uncertainty and risk overstating evidence for directional bias. To address this, I quantified uncertainty in the upwind proportion using a cluster bootstrap, that resampled whole flight events with replacement, ensuring that within-flight correlation was preserved in each replicate. Resampling clusters rather than individual observations is appropriate for hierarchical or nested data structures and yields consistent confidence intervals.

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[1] Wind-rose for 20 m above ground level at ITM grid reference 604000 69900 from Sustainable Energy Authority of Ireland - Wind Atlas (https://maps.seai.ie/apps/WindAtlas).

For each species, I assigned a unique identifier to every observed flight event and identified the set of n unique flights available for analysis. For each bootstrap replicate, I resampled n flight events with replacement from this set. I included all segments belonging to each selected flight in the resample, and when a flight appeared multiple times I included its segments multiple times by multiplying segment weights by the frequency with which that flight was selected. I then recalculated the length-weighted upwind proportion for the resample. Repeating this process 5,000 times generated a bootstrap distribution of the upwind proportion, from which I derived percentile-based 95% confidence intervals.

This approach preserves within-flight correlation in segment directions while appropriately reflecting uncertainty arising from the finite number of independent flight events.

For each species, I examined whether the 95% cluster-bootstrap confidence interval for the upwind proportion included 0.5. Where the interval included 0.5, I inferred no consistent directional bias. Where the interval excluded 0.5, I considered this as possible evidence of a directional bias, while recognising that marginal exclusions of 0.5 may arise by chance given the number of species examined.

I conducted all analyses using customised code in R version 4.4.1 (R Core Team 2025).

2.5.5. Temporal patterns of flight activity

I used record rates (number of records per unit time) to analyse patterns of seasonal, monthly and diel variation in flight activity. An alternative would have been to use flight activity (bird-seconds), but this parameter would be highly sensitive to occasional long-duration flights, resulting in large variation that may not reflect broader activity patterns.

I used the vantage point survey records after processing against the 30 m viewsheds used for the collision risk model. This mitigated the issue of duplication of flight events across viewsheds in the Ecology Ireland dataset (although some level of duplication will have remained; e.g. a Cormorant commuting along the River Brosna could have been recorded in multiple non-overlapping viewsheds).

2.6. COLLISION RISK MODELLING METHODOLOGY

2.6.1. General

I followed the NatureScot guidance for the collision risk modelling methodology.

The NatureScot guidance includes a spreadsheet that can be used to implement the collision risk model. However, use of spreadsheets for complex modelling is not best practice due to the difficulty of auditing the code. Also, in this case, where there were multiple species to model, and where I was running multiple variants of the model, use of spreadsheets would be very cumbersome. Therefore, I implemented the NatureScot methodology using custom scripts in R version 4.4.1 (R Core Team, 2024). I audited the scripts against the spreadsheet to ensure that they produced identical results. The scripts used for the modelling can be provided on request.

2.6.2. Stage A: flight activity

2.6.2.1 NatureScot methodology

Stage A involves calculating the density of flight activity in the area where collision risk will be generated by the installation of wind turbines. It also includes ranking nocturnal activity and calculating the distribution of daytime and nighttime hours.

Flight activity density

For onshore wind farms, calculations of flight activity density are usually based on flight durations recorded by vantage point surveys. This involves adjusting the total amount of flight activity recorded in the vantage point surveys by the area surveyed and the survey duration. Where data from multiple vantage points is available, it is also necessary to consider how to combine the data.

The NatureScot methodology for Stage A first calculates the mean areal density of flight activity in the viewshed of each vantage point:

Equation A1: $D1 = b / (t \times A)$ birds m^{-2}

b = total flight activity (bird-seconds); t = total duration of vantage point watches (seconds); A = viewshed area (km^2).

Note that flight activity is expressed as the sum of the duration of each flight multiplied by the number of birds: e.g., a record of 20 birds flying for 10 seconds = 200 bird-seconds.

The flight activity density is then averaged across all the vantage points. The NatureScot guidance presents two methods for doing this.

Where there were significant differences in survey effort between the vantage points, the flight activity density can be averaged by weighting for the viewshed area and the duration of the vantage point survey at each vantage point (Equation A2). This reflects the fact that, in principle, larger survey areas and/or survey durations will sample more flights and will, therefore, be less affected by sampling effects. However, note that there are some issues with this weighting method (see Section 4.7.3).

Equation A2: $D^* = \Sigma(D_i \sqrt{(t_i \times A_i)}) / \Sigma \sqrt{(t_i \times A_i)}$

D_i = flight activity areal density at VP i ; t = total duration of vantage point watches at VP i (seconds); A = viewshed area at VP i (km^2).

Where the variation in flight activity density between vantage points is likely to reflect real differences in flight activity, the flight activity density can be averaged by weighting for the number of turbines within the viewshed of each vantage point. However, before applying the weighting it is important to consider whether apparent variation between vantage points could be due to sampling effects.

Equation A3: $D^* = \Sigma(N_i \times D_i) / \Sigma N_i$

D_i = flight activity areal density at VP i ; N_i= the number of turbines in the viewshed of VP i.

Although not discussed in the NatureScot guidance, the weightings in Equations A2 and A3 could be combined to weight for both differences in survey effort and real differences in flight activity between vantage points.

Daytime and nighttime hours

The NatureScot methodology uses the formula in Forsythe et al. (1995) to calculate daytime and nighttime hours.

Nocturnal flight activity

Vantage point surveys only record flight activity during daylight hours (normally sunrise to sunset). Therefore, for species that also fly at night, it is necessary to adjust the flight activity densities to allow for nocturnal flight activity.

The NatureScot methodology adjusts for nocturnal flight activity by using a nocturnal activity ranking to categorise each species by its degree of nocturnal activity on a scale of 1-5, where 1 = hardly any nocturnal activity and 5 = as active at night as by day. It then uses this categorisation to include nocturnal flight activity in the calculation of predicted transits in Stage B.

To illustrate the effect of nocturnal flight activity on the collision risk predictions, I calculated nocturnal correction factors for species with non-zero nocturnal flight activity (nocturnal activity rankings of more than one), as shown in Equation A4.

Equation A4: $NCF = 1 + ((NAR - 1) \times 0.25) \times h_{night^*} / h_{day^*}$

NAR = nocturnal activity ranking (see text); h_{night^*} = mean night-time hours across seasonal period of occurrence; h_{day^*} = mean day-time hours across seasonal period of occurrence.

The nocturnal correction factor represents the increase in flight activity densities that is generated by the adjustment for nocturnal flight activity in the calculation of predicted transits in Stage B.

2.6.2.2 Data sources and preparation

Parameters

The parameters required for the Stage A modelling of flight activity densities using Equation A1 are the flight activity duration (b), the vantage point survey duration (t) and the viewshed area (A).

Stage A also requires classifications of nocturnal activity rankings for all species included in the model and calculations of monthly totals of daytime and nighttime hours.

The derivation of the data required for these parameters is described in the following sections.

Flight activity durations

The flight activity durations were obtained from the vantage point survey dataset. The processing of this dataset for use in the collision risk model is described in Section 2.4.3.

The flight activity durations included in Equation A1 comprise the sum of the duration of each flightline multiplied by the number of birds recorded on the flightline: e.g., a flock of 100 Golden Plover recorded flying for 10 seconds would generate a flight activity duration (b) value of 1000 bird-secs.

Vantage point survey durations (t)

The vantage point survey duration parameter represents the total vantage point survey effort over the seasonal period used for the collision risk modelling. I calculated this duration separately for each vantage point and each month in each dataset.

The Ecology Ireland durations were adjusted for estimated proportions of time tracking flightlines outside the viewshed arcs (see Section 2.4.3.2).

Some of the TOBIN vantage point surveys included the hour before sunset and the hour after sunrise. For waterfowl species, I included these periods in the total durations. For the other species, I excluded these periods from the total durations.

Viewshed area (A)

The viewshed area represents the spatial extent of the area covered by the vantage point survey. I calculated the viewshed areas from the mapped viewsheds for each vantage point. For the spatially-structured models, I calculated areas separately for each section within each viewshed.

Daytime and nighttime hours

I used the formula in Forsythe et al. (1995) to calculate day-time and night-time hours. I used the latitude of the centroid of the turbine locations and a p-value of 0.8333. The p-value represents the position of the sun relative to the horizon at sunrise and sunset.

Nocturnal activity ranking

The nocturnal activity ranking is an estimation of the degree of nocturnal activity ranked on a scale from 1 (hardly any nocturnal activity) to 5 (as active at night as by day). I applied nocturnal activity rankings of more than one to Wigeon, Teal, Mallard, Little Egret, Grey Heron, Golden Plover, Lapwing, Curlew and Black-tailed Godwit.

For Mallard, visual inspection of Figure 2 in Korner et al. (2016) suggests that nocturnal activity is around half that of diurnal activity, so I set the nocturnal activity ranking as 3. I applied the same rate to the ecologically similar Wigeon and Teal.

For Golden Plover, a figure of 25% of the day-time activity levels across the night-time hours is often used in collision risk modelling (e.g., MKOS, 2019), so I set the nocturnal activity ranking as 2. I applied the same rate to the ecologically similar Lapwing, Curlew and Black-tailed Godwit.

Flight activity patterns for Grey Heron from Vessem and Draulans (1987) indicate low levels of nocturnal flight activity, so I set the nocturnal activity ranking at the same rate as Golden Plover. I applied the same rate to the ecologically similar Little Egret.

I used nocturnal activity rankings of 1 for all the other species. This resulted in no nocturnal flight activity being included in the model for those species.

2.6.2.3 Implementation

Flight activity densities

The NatureScot spreadsheet requires the user to enter mean flight activity densities for each month. I used custom scripts in R to calculate these densities.

I calculated monthly flight activity densities separately for each vantage point, and each section in each viewshed in the spatially-structured models.

I used the weighted averaging method in Equation A2 to calculate mean flight activity densities for each month across all the vantage points. This method down weighted the contribution of EI6–EI7 and TB1–TB5 reflecting the lower survey effort at these vantage points.

For the spatially-structured models, I applied the weighted averaging method separately to each section.

I used viewshed areas adjusted for detectability based on the results of the distance analysis (see Section 2.5.2) in the weighted averaging. Use of the adjusted areas allowed for the fact that the removal of overlaps from the Ecology Ireland viewsheds resulted in some viewsheds losing much of the area closest to the vantage points. Consequently, similar nominal viewshed areas could have markedly different detection characteristics between vantage points.

Daytime and nighttime hours

The NatureScot spreadsheet requires the user to enter the latitude of the wind farm site, and nocturnal activity rankings for each species. It then uses the formula from Forsythe et al. (1995) to calculate the day-time and night-time hours. The correction for nocturnal flight activity is applied in Stage B.

I used a custom script in R to implement the formula from Forsythe et al. (1995) and calculate the day-time and night-time hours. For waterfowl species, I added two hours to the day-time hours and subtracted two from the night-time hours to reflect the fact that they are active in the hour before sunrise and the hour after sunset.

Nocturnal correction factors

I used a custom script in R to implement Equation A4 to calculate the nocturnal correction factors.

2.6.3. Stage B: transits

2.6.3.1 NatureScot methodology

Stage B involves calculating the number of bird transits through the turbine rotors. It uses the flight activity densities, distribution of daylight and nighttime hours, and nocturnal activity rankings derived in Stage A.

The NatureScot guidance does not provide details of the calculation procedure for Stage B, but Band (2024) includes an equation (Equation B1).

Equation B1: $v \times (D \times Q_{2R} / 2R) \times (T \times \pi R^2) \text{ x } (t_{day} + f_{night} \times t_{night})$

v = bird flight speed; D = flight activity density; Q_{2R} = proportion of flight activity at potential collision height; R = rotor radius; T = number of turbines; t_{day} = total daylight hours; f_{night} = nocturnal activity ranking - 1 × 0.25; t_{night} = total night-time hours.

The equation converts the areal density to a volumetric density by dividing the flight activity density by the rotor diameter and adjusting for the proportion of flight activity at potential collision height ($D \times Q_{2R} / 2R$). It then converts the density to a flux rate by multiplying by the rotor area ($T \times \pi R^2$) and the bird flight speed (v). It converts the flux rate to an absolute number of transits by multiplying by the total number of hours available for flight activity, including a correction for nocturnal flight activity ($t_{day} + f_{night} \times t_{night}$).

2.6.3.2 Data sources and preparation

The parameters required for the Stage B modelling are the bird flight speed (v), the flight activity density (D), the vantage point survey duration (t), the proportion of flight activity at potential collision height (Q_{2R}), the rotor area (R), the number of turbines (T), the total daylight and nighttime hours (t_{day} and t_{night}) and the nocturnal activity ranking.

The flight activity density, total daylight and nighttime hours and nocturnal activity ranking were derived in Stage A. The derivation of the data required for the remaining parameters is described in the following sections.

Bird flight speed

The NatureScot guidance states that for bird flight speed, “a typical mean flight speed as given in standard references will usually be adequate” but consideration should be given to exploring “the collision risk arising from different types of bird behaviour involving very different flight speeds”.

Most collision risk modelling for onshore wind farms uses the mean bird flight speeds from Alerstam et al. (2007). This source covers most species relevant to collision risk modelling for Irish onshore wind farms. I used the mean bird flight speeds from this source. The values used in this collision risk model are shown in Table 2.4.

Proportion of flight activity at potential collision height (Q_{2R})

The NatureScot methodology involves calculating the total areal flight activity density across all height bands and then adjusting for the proportion of flight activity at potential collision height. However, this may introduce biases in the calculations due to variation between viewsheds in the proportion of viewshed that was visible below the height used to map the viewshed. In this collision risk model, I only used the flight activity at potential collision height to calculate the flight activity density. Therefore, for Equation B1, the value of the Q_{2R} parameter is 1.

Turbine parameters

The proposed number of turbines (T) was 11 and the proposed rotor radius (R) for each turbine model is shown in Table 2.3. The numbers of turbines in each section used for the spatially-structured models is shown in Table 2.6.

Implementation

The NatureScot spreadsheet automatically calculates the projected number of transits per month from the bird density and hours per month values calculated in Stage A and data entered by the user for the other parameters.

I implemented Equation B1 through a custom script in R to calculate the predicted number of transits per month.

2.6.4. Stage C: single transit collision risk

2.6.4.1 NatureScot methodology

Stage C involves calculating the probability of a collision when a bird makes a transit of the rotor swept volume (the single transit collision risk).

The NatureScot methodology for Stage C is based on the Scottish Natural Heritage collision risk model (SNH, 2000; Band et al., 2007; Band, 2012). This calculates the probability, $p(r, \varphi)$, of collision for a bird at radius r from the hub and at a position along the radius that is at angle φ from the vertical. This probability is then integrated over the entire rotor disc, assuming that the bird transit may be anywhere at random within the area of the disc. Separate calculations are made for flapping and gliding birds and for upwind and downwind transits. This method assumes that: birds are of a simple cruciform shape; they fly through turbines in straight lines with a perpendicular approach to the plane of the rotor; their flight is not affected by the slipstream of the turbine blade; and that the turbine blades have width and pitch angle, but no thickness.

2.6.4.2 Parameters

The parameters required for Stage C are the bird body length, wingspan, flight speed and flight type, the percentage of flights upwind/downwind, and the turbine rotation speed, rotor radius, mean blade width, pitch angle and blade profile.

Turbine parameters

The turbine rotation speed, rotor radius, mean blade width and pitch angle values used for the modelling are shown in Table 2.3; for rotation speed I used the maximum values from the rotation speed ranges. I used the default blade profile values from the NatureScot spreadsheet for the modelling.

One of the turbine parameters used to calculate single transit collision risk is the mean pitch angle of the turbine blade. This parameter specifies the angle of the blade from the vertical, so the risk will generally increase as the mean pitch angle increases.

Data on mean pitch angle are surprisingly difficult to obtain, so generic values are often used in collision risk models. The limited available information is inconsistent. The NatureScot guidance states that a mean pitch angle of "15-30 degrees is reasonable for a typical large turbine", although the higher end of this range may be more typical for offshore turbines. Byrne and MacArtain (2022) reported that over 15 years of operation of an 850 kW turbine at Dundalk the pitch angle in normal operation was always less than 20°, with higher angles only used for stopping/feathering. Monitoring at an onshore wind farm (Meenwaun, Co. Offaly) indicated that much lower pitch angles are typical for onshore turbines (MKOS, 2019); over a continuous 12-month period, the pitch angle was between -3° and 9° for approximately 90% of the time.

I modelled single transit collision risks using four values for mean pitch angle: 0°, 9°, 15° and 30°. The 0° value lies within the –3° to 9° range recorded at Meenwaun and, in sensitivity analyses (Section 4.7.3), produced the highest collision probabilities for most species within this range. For the collision risk predictions I used the single transit collision risks calculated with a mean pitch angle of 15°. This value provides a pragmatic balance between NatureScot guidance and the limited operational data available from Irish onshore wind farms.

Bird parameters

The bird body length and wingspan values were obtained from Cramp and Simmons (2004). The bird flight speed values were obtained from Alerstam et al. (2007). The values used in the modelling are shown in Table 2.3.

While the review of the vantage point survey flightlines indicated some apparent directional biases, these biases are likely to have been artefacts due to properties of the datasets (see Section 0). Therefore, I set the percentages of flights upwind/downwind at 50% for all species.

2.6.4.3 Implementation

I carried out all the calculations of single transit collision risks in R, using an adapted version of the R code provided by Masden (2015). This code implements the methodology of Band (2012) and provides identical values to the spreadsheet provided by that source and to the values generated by the NatureScot spreadsheet.

I carried out separate sets of calculations using pitch angle values of 0°, 15° and 30°.

I calculated separate values for upwind and downwind flapping and gliding flight.

The NatureScot spreadsheet only allows values for either flapping or gliding flight to be used. I used the values for flapping flight, as these were slightly higher.

The spreadsheet uses the mean of values for upwind and downwind flight weighted by the relative proportion of these flight directions. I used a simple mean of the upwind and downwind single transit collision risks (i.e. a 50/50 weighting).

2.6.5. Stage D: non-avoidance collision risk

2.6.5.1 NatureScot methodology

Stage D multiplies the number of predicted transits from Stage B and the single transit collision risk from Stage C to provide an estimate of the overall predicted collision risk before avoidance. It also includes a correction for the proportion of time that the turbines are operational.

Equation D1: collision rate before avoidance = transits × stcr × Q_{op}

transits = predicted transits from Stage B; stcr = single transit collision risk from Stage C; Q_{op} = proportion of time that the turbines are operational.

2.6.5.2 Parameters

The parameters required for Stage D are the predicted transits from Stage B, the single transit collision risk values from Stage C, and the proportion of time that the turbines are operational (Q_{op}).

Site-specific values for Q_{op} were not available for this project. Therefore, I used a value of 0.85 for all the species in the model, which is a widely value for this parameter in collision risk modelling for onshore wind farms in Ireland.

2.6.5.3 Implementation

The NatureScot spreadsheet automatically calculates the projected number of transits per month from the bird density and hours per month values calculated in Stage A and data entered by the user for the other parameters.

I implemented Equation D1 through a custom script in R to calculate the collision rate before avoidance.

2.6.6. Stage E: collision risk after avoidance

2.6.6.1 NatureScot methodology

Stage E applies an avoidance rate to the non-avoidance collision risk to reflect the fact that most potential collisions are avoided due to birds taking evasive action (SNH 2010).

Equation E1: collision rate after avoidance = collision rate before avoidance × (1 – A)

collision rate before avoidance = predicted rates from Stage D; A = avoidance rate.

The avoidance rate includes both behavioural avoidance (micro-avoidance) and behavioural displacement (macro-avoidance).

Behavioural avoidance is "action taken by a bird, when close to an operational wind farm, which prevents a collision". Behavioural displacement refers to the process by which a "bird may (possibly over time) change its home range, territory, or flight routes between roosting areas and feeding areas, so that its range use (or flight paths) no longer brings the bird into the vicinity of an operational wind farm".

The NatureScot guidance for Stage E also notes that "consideration should be given to whether any habitat changes associated with developing the wind farm may result in attracting bird species". This issue is considered in Section 4.7.2.

Stage E can also include a large turbine array correction factor. This reflects the fact that "where the overall probability of a bird colliding is appreciable, it may be appropriate to take account of the fact that a declining proportion of the birds will survive passage through early rows of turbines and will thus be exposed to collision risk in later rows". However, this correction factor is only likely to be significant for wind farms with much larger numbers of turbines than are proposed for the Ballincor Wind Farm. Therefore, I did not apply this correction factor.

The NatureScot spreadsheet sums the monthly collision risks to provide a total annual collision risk. However, for some species it is more appropriate to calculate seasonal collision risks (e.g., to differentiate between separate breeding and wintering populations).

2.6.6.2 Parameters

The parameters required for Stage E are the non-avoidance collision risks from Stage D and avoidance rates for each species included in the model. In addition, definitions of the months included in seasonal periods are required if seasonal collision risks are to be calculated.

Avoidance rates

The default set-up in the NatureScot spreadsheet calculates the predicted collision risk after avoidance using four avoidance rates: 95%, 98%, 99% and 99.5%. However, the guidance states "if possible, use avoidance rates which have been established from previous monitoring studies for this species, and an appropriate range to cover the uncertainties involved".

Scottish Natural Heritage / NatureScot provides guidance on avoidance rates to use in collision risk modelling for onshore wind farms (SNH, 2010; NatureScot, 2025b). For some species, including Mute Swan, Whooper Swan, White-fronted Goose, Hen Harrier and Kestrel, there is some evidence available that has been used to specify species-specific avoidance rates (NatureScot, 2025b). In addition, a recent review for Scottish Natural Heritage recommended the use of an avoidance rate of 0.992 for small gulls (including Black-headed Gull and Common Gull) and 0.995 for large gulls (including Lesser Black-backed Gull and Herring Gull) at onshore wind farms (Furness, 2019).

For Golden Plover, my review of collision monitoring data from four UK wind farms recommended that collision risk modelling for wintering Golden Plover populations should use two avoidance rate values: 99.6% and 99.8% (Gittings, 2022).

For the other species included in this collision risk model, the Scottish Natural Heritage guidance specifies a default avoidance rate of 98%.

Seasonal periods

The periods used to calculate seasonal collision risks are defined in Table 2.5. For the species not included in this table the final collision risk was calculated for the whole year.

2.6.6.3 Implementation

The NatureScot spreadsheet automatically calculates the collision rate after avoidance per month from the collision rate before avoidance values calculated in Stage D and the avoidance rate values entered by the user.

I implemented Equation E1 through a custom script in R to calculate the collision rate after avoidance. This produced monthly predicted collision risks for various avoidance rates and for pitch angles of 0°, 15 ° and 30°.

For the final predicted collision risks used in the collision risk assessments, I summed the monthly predicted collision risks for the recommended avoidance rate and a pitch angle of 0° to produce annual or seasonal collision risks, as appropriate.

2.6.7. Stage F: assessing uncertainty

Stage F involves assessing the level of uncertainty that applies to the collision risk predictions.

In this assessment, I carried out analyses to provide some degree of quantification of the potential uncertainty in the flight activity data due to sampling effects, the under-detection of distant flightlines, and imprecision in the estimates of nocturnal flight activity.

I also carried out analyses to quantify potential uncertainty in the single transit collision risk predictions due to variation in pitch angle and rotation speed.

I carried out qualitative assessments of other sources of potential uncertainty.

2.6.7.1 Sampling effects

The standard vantage point survey effort of 36 hours per season only samples around 1.5-2% of the total daylight hours across the season. The temporal distribution of flight activity is often highly aggregated, while a small number of long-duration flightlines can make a large contribution to the overall collision risk. Therefore, sampling effects are likely to strongly influence the collision risk predictions.

I assessed the potential influence of sampling effects on the collision risk predictions by using a simulation model.

Simulation model structure

The model used the observed distribution of flight activity to simulate flight activity across the entire season. This simulated distribution was then sampled to generate samples of vantage point survey data. I then compared the flight activity densities in the samples to the flight activity densities across the entire season.

I first calculated the total duration of daylight hours across the season using the R package suncalc (Thiermel and Elmarhraoui, 2022) and divided this duration by three to set up a dataframe representing all 3-hour periods of daylight hours across the season.

I used the negative binomial distribution to simulate the distribution of records in each 3-hour period at each vantage point across the entire season and the distribution of flock sizes per record (excluding simulated zero values for flock sizes). I used the fitdist function with the maximum likelihood estimation method in the R package fitdistplus (Muller and Dutang, 2015) to fit these negative binomial distributions. I used the exponential distribution to simulate the distribution of flight durations at potential collision height per record (excluding simulated zero durations). I used the rexp function in the R package stats (R Core Team, 2024), with a rate that was the reciprocal of the mean duration of observed flights at potential collision height, to fit the exponential distributions.

For each species / season, I compared the distribution of the simulated values with the observed values to assess the validity of the simulated data.

I then took 10,000 sets of random samples without replacement of twelve 3-hour periods per vantage point per survey season to simulate vantage point survey samples.

I calculated the flight activity densities for the entire season, and for each set of vantage point survey samples, by summing the bird-secs per record, dividing by the total duration of daylight hours (for the entire season dataset) or by the total duration of the sampled periods (for the vantage point survey datasets).

I used the distribution of the simulated vantage point survey datasets to calculate a 95% simulation interval for the resulting flight activity densities. The lower limit of the interval was defined as the 2.5th percentile of the distribution and the upper limit as the 97.5th percentile. This simulation interval can be interpreted as follows: if the underlying process behaved as represented by the fitted model, and the survey were repeated many times under the same design, the resulting estimates of flight activity density would fall within this interval in approximately 95% of cases.

I assessed the potential influence of sampling effects by comparing the upper and lower limits of the simulation interval with the flight activity density calculated from the complete dataset. This comparison provides an indication of the potential magnitude of over- or underestimation of flight activity density that could arise if a vantage point survey happened, by chance, to produce a sample near the upper or lower limits of the simulated distribution. For example, if the lower limit of the simulation interval was half the value of the overall flight activity density calculated from the complete dataset, this would imply that a survey sample representing this lower limit would underestimate the true flight activity density by a factor of two. Because predicted collision risk is directly proportional to flight activity density in the collision risk model, the true collision risk in such a case would also be approximately twice the value predicted from that survey sample.

Simulation model implementation

I carried out these simulations for the species included in the collision risk assessment, with the exception of Wigeon and Black-tailed Godwit for which the number of records were too low to fit the simulated distributions.

I modelled scenarios based on an increasing number of survey years, from one year to five years. This allowed me to assess how the increase in the survey effort affected the uncertainty.

I used six vantage points, which was the mean number of vantage points surveyed per season.

Relative error method

The technical report (Band 2024) accompanying the NatureScot collision risk modelling guidance (NS 2024) includes a method for calculating the sampling effects uncertainty from the relative error of the monthly flight activity densities. This method is shown in Equation F1[2].

Equation F1: $E_{se} = 1.96 \times SD_{monthly} / mean_{monthly}$

E_{se} = sampling effects error; $SD_{monthly}$ = standard deviation of the monthly flight activity densities; $mean_{monthly}$ = mean of the monthly flight activity densities.

I implemented this method to provide sampling effects uncertainties that are comparable with other collision risk models that follow this method. However, there are statistical issues with this method (see Section 4.7.2.1).

2.6.7.2 Distance effects

The exploratory data analyses included analyses of the distribution of flightline densities across distance bands from the vantage points and used the results to calculate corrected viewshed areas that that were adjusted to allow for the effects of under-estimation of distant flightlines (Section 2.5.2).

To assess the potential uncertainty in the predicted collision risks due to distance effects, I calculated flight activity densities using the corrected viewshed areas. The ratios of these densities to those from the collision risk model provided an indication of the potential underestimation of the collision risk due to distance effects.

2.6.7.3 Nocturnal flight activity

The NatureScot collision risk model uses a crude ranking of the degree of nocturnal flight activity to calculate nocturnal correction factors and the information available about the degree of nocturnal flight activity for most species is very limited. I examined the effects of uncertainty about nocturnal flight activity for each species. I did this by calculating nocturnal correction factors using nocturnal activity rankings of ±1 of the values used in the model (but not including values < 1 or > 5, which would be outside the range defined for these rankings). The ratio of these nocturnal correction factors to the nocturnal correction factor value used in the collision risk model indicates the potential effect on the predicted collision risk: e.g., if the nocturnal correction factor calculated using the NAR+1 value is 1.25 times the nocturnal correction factor using the NAR value, the true collision risk could be 25% higher than the predicted collision risk.

2.6.7.4 Single transit collision risk

I carried out analyses to quantify potential uncertainty in the single transit collision risk predictions due to variation in pitch angle and rotation speed. These involved calculating single transit collision risk values for each 1° increment in pitch angle between -5° and 90° and each 0.1 rpm increment in rotor speed between the minimum and maximum rotor speed values. I used the maximum rotor speed value for the pitch calculations and a pitch angle value of 0° for the rotor speed calculations.

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[2] Band 2024's worked example includes using the root sum of squares to calculate the mean of the breeding and non-breeding season standard deviations. However, that procedure was not required for this model as the seasons were assessed separately.

2.6.7.5 Overall uncertainty

I used the quantitative uncertainty ranges from the analyses of sampling effects and nocturnal flight activity variation, and the ± 20% uncertainty range for single transit collision risk from Band (2024) to quantify the overall uncertainty. I did not include the uncertainty associated with distance effects because distance effects are not incorporated within the NatureScot methodology; however, this source of uncertainty is discussed separately.

Band (2024) uses the root sum of squares method to combine the uncertainties to obtain an overall uncertainty estimate. This method sum the squares of individual uncertainties and then takes the square root of that sum:

Equation F2: $E = \sqrt{} (e_1^2 + e_2^2 + e_3^2 \ldots)$

E = overall uncertainty ; e_1, e_2, e_3 … = individual uncertainties.

However, this method assumes that the uncertainties are additive. In fact, in a collision risk model they are multiplicative, because the components of the model are multiplied not summed. This means that the root sum of squares method underestimates the overall uncertainty. In addition, the statistical assumptions underlying the root sum of squares method are not well aligned with the types of uncertainty distributions generated by the collision risk model.

Instead of the root sum of squares approach, I used a multiplicative method to combine the individual uncertainties. However, for sampling effects and single transit collision risk uncertainties, which represent distributions of potential values, simple multiplication of the extreme limits would overestimate the uncertainty because it would assume that the extreme values of each factor would co-occur. Instead, I used a Monte Carlo procedure with 10,000 iterations to sample from the distributions representing these uncertainties. For each iteration, I sampled values from the simulation outputs representing the sampling effects and from a uniform distribution representing the ±20% uncertainty range in the single transit collision risk parameter. The resulting products formed a distribution of combined uncertainty multipliers, from which I used the 95% interval to define the limits of the combined uncertainty range for these two components.

The uncertainty associated with the nocturnal activity correction factor is a different type of uncertainty. It represents uncertainty about whether the classification of the degree of nocturnal flight activity is correct. Therefore, if it is wrong, it is always wrong so sampling a distribution of nocturnal correction factor uncertainties would not be appropriate. Instead, I multiplied the lower and upper limits derived from the combined sampling effects and single transit collision risk uncertainties by the lower and upper nocturnal correction factor multipliers as appropriate.

For comparison with collision risk models that follow the Band (2024) guidance, I also calculated overall uncertainty using the root sum of squares method.

2.7. COLLISION RISK ASSESSMENT

The significance of the predicted collision risk is a function of the size of the predicted collision risk, the size of the affected population, and the typical level of background mortality in the affected population. The same predicted collision risk will have larger impacts in small populations and/or populations with low levels of annual mortality, compared to large populations and/or populations with high levels of annual mortality. Therefore, the significance can be assessed by calculating the percentage increase in annual mortality that would be generated by the predicted collision risk.

A threshold level of a 1% increase in annual mortality has been suggested to determine whether the impact is nonnegligible (Percival, 2003). Note that this refers to the increase in absolute mortality not the increase in the percentage mortality rate. This 1% threshold is widely used in UK wind farms assessments as a threshold for assessing significance. However, this is likely to be a very conservative threshold, and in some cases, such as small populations with low mortality rates, biologically implausible.

I assessed the potential increase in annual mortality, as a percentage of the background annual mortality, for most species / populations, with a predicted risk that would result in at least one collision within the 30 year lifespan of the wind farm. The species / populations with this level of risk that I did not assess were Buzzard, the non-breeding Black-headed Gull population and the spring and autumn Lesser Black-backed Gull populations. I did not assess Buzzard because this species has been rapidly increasing in Ireland and there are no recent national or county population estimates available. I did not assess the non-breeding Black-headed Gull population and the spring and autumn Lesser Black-backed Gull populations because suitable data on national or county population sizes is not available (Irish Wetland Bird Survey data does not produce reliable estimates for gull populations).

For each of the species / populations, I assessed the impact at the national scale. I also assessed the impact at regional and/or local scales where relevant population data was available or could be estimated. The wind farm site is on the border between County Offaly and County Tipperary, but the majority of the site is in Offaly. Therefore, I used data from County Offaly for the regional (county) scale.

The sources of the population data are listed in Table 2.7.

For Whooper Swan, Wigeon, Mallard, Golden Plover, Lapwing and Black-tailed Godwit, I used Irish Wetland Bird Survey data for the Little Brosna Callows for the local scale. This site is around 7 km from the wind farm site and is connected to the wind farm site by wetland habitat along the River Brosna. The wind farm site is likely to be well within the potential foraging range of Golden Plovers and Lapwing from the Little Brosna Callows. While it is beyond the Whooper Swan core foraging range distance from the Little Brosna Callows, as defined by SNH (2016), it seems likely that there is some degree of connectivity between the two areas for the local Whooper Swan population.

For Mallard, Little Egret and Grey Heron, there are national estimates available for both the breeding and non-breeding populations. These species were recorded throughout the year in the vantage point surveys. Their local breeding populations are likely to be resident, although the populations may be supplemented in the non-breeding season. Mallard and Grey Heron are poorly covered by the Irish-Wetland Bird Survey (the source for the non-breeding population estimate) as they are widespread outside the monitored sites. Therefore, while their national populations are likely to be larger in the non-breeding season, the estimates of their national breeding populations are larger than the estimates of their national non-breeding populations. Therefore, for Mallard and Grey Heron, I used the estimates of their breeding populations for the national population. For Little Egret, I used the estimates of its non-breeding population for the national population. This species is increasing in Ireland, and the estimate of its breeding population is probably out of date.

Sparrowhawk and Kestrel are widespread species that are not likely to show highly aggregated distribution patterns. I estimated the Offaly population sizes of these species using the Bird Atlas dataset from the National Biodiversity Data Centre[3]. This included hectad presence-absence data covering the whole of the Republic of Ireland, and tetrad data of relative abundance for samples of tetrads from most of the hectads. I used the hectad data to estimate the proportion of the Republic of Ireland breeding range of each species that occurs in Offaly. I then used the tetrad data to estimate the mean relative abundance of the species in Offaly as a percentage of its mean relative abundance throughout its range in the Republic of Ireland. I then used the product of these two factors to multiply the Republic of Ireland population figure to give an estimate for the Offaly population.

Kestrel has been red-listed due to a large decline in its breeding population. Therefore, its current population is likely to be considerably smaller than the estimate in Crowe et al. (2014), which was based on survey data from 2006-2010. I used the mean annual change (-2.50%) from the

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[3] BirdWatch Ireland, Bird Atlas 2007 - 2011, National Biodiversity Data Centre, Ireland, accessed 07 September 2022, https://maps.biodiversityireland.ie/Dataset/220.

Countryside Bird Survey data[4] to calculate the decline in the Irish population from 2008 to 2024 and used the estimate for the 2024 population in the collision risk assessment calculations.

The background mortality rates that I used were derived from the adult survival rates on the BirdFacts website[5]. Where separate rates were given for males and females, I used the mean of the rates.

Table 2.7. Population data used for the collision risk assessment.

Species	Population	Scale	Geographic extent	Value	Units	Period / Source
Whooper Swan	winter	national	all-Ireland	19,111	individuals	1
		county	Offaly	1,506	individuals	1
		local	Little Brosna Callows	337	individuals	2
Wigeon	winter	national	all-Ireland	66,720	individuals	3
		local	Little Brosna Callows	6,452	individuals	2
Mallard	breeding	national	Republic of Ireland	15,400	pairs	4
		county	Offaly	546	individuals	5
	winter	national	all-Ireland	25,160	individuals	3
		local	Little Brosna Callows	96	individuals	6
Cormorant	breeding	national	all-Ireland	4,685	AON	7
		local	Lough Derg	272	AON	7
	non-breeding	national	all-Ireland	12,310	individuals	3
Little Egret	breeding	national	Republic of Ireland	375	pairs	4
	non-breeding	national	all-Ireland	1,340	individuals	3
Grey Heron	breeding	national	Republic of Ireland	3,087	pairs	4
		county	Offaly	102	individuals	5
	non-breeding	national	all-Ireland	2,490	individuals	3
Sparrowhawk	breeding	national	Republic of Ireland	17,580	individuals	8
		county	Offaly	358	individuals	5
Golden Plover	winter	national	all-Ireland	90,770	individuals	3
		local	Little Brosna Callows	9,247	individuals	2
Lapwing	winter	national	all-Ireland	81,580	individuals	3
		local	Little Brosna Callows	5,637	individuals	2
Black-tailed Godwit	non-breeding	national	all-Ireland	24,790	individuals	3
		local	Little Brosna Callows	3,553	individuals	2
Kestrel	breeding	national	Republic of Ireland	13,660	individuals	9
		county	Offaly	314	individuals	10

1 = 2020, Burke et al., 2021; 2 = 2018/19-2022/23, Burke et al., 2026; 3 = 2018-2023, Burke et al., 2026; 4 = 2008-2011, NPWS, undated; 5 = 2006-2011, derived from Crowe et al. (2014) and Bird Atlas data (see text); 6 = 2018/19-2022/23, mean annual Irish Wetland Bird Survey peak counts; 7 = 2015-2021, Burnell et al., 2023; 8 = 2006-2011, Crowe et al., 2014; 9 = 2006-2011, Crowe et al., 2014 and CBS change for 2008-2023; 10 = 2006-2011, derived from Crowe et al. (2014), Countryside Bird Survey change for 2008-2024 and Bird Atlas data (see text). Data were supplied by the Irish Wetland Bird Survey (I-WeBS), a scheme coordinated by BirdWatch Ireland under contract to the National Parks and Wildlife Service of the Department of Housing, Local Government and Heritage.

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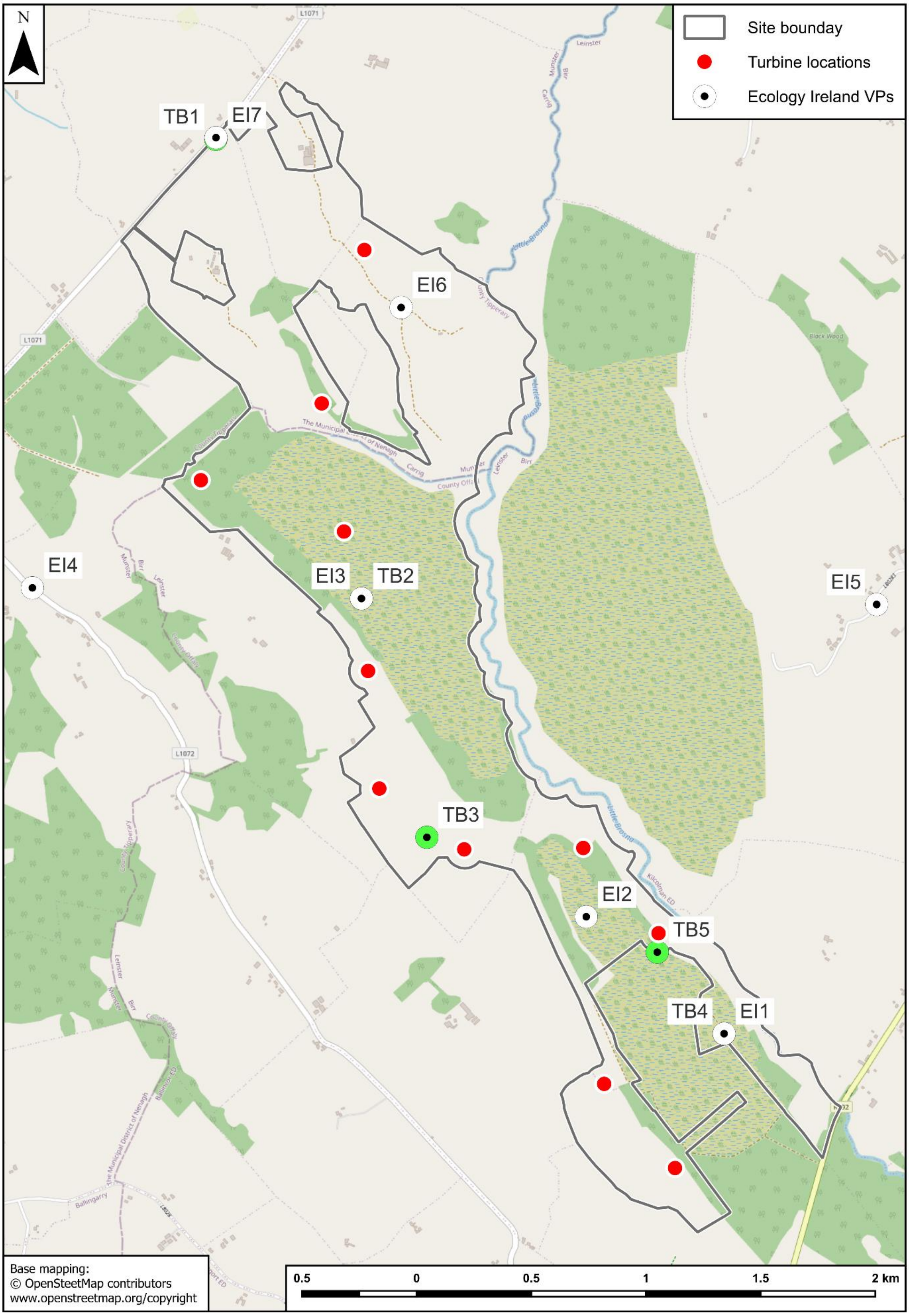
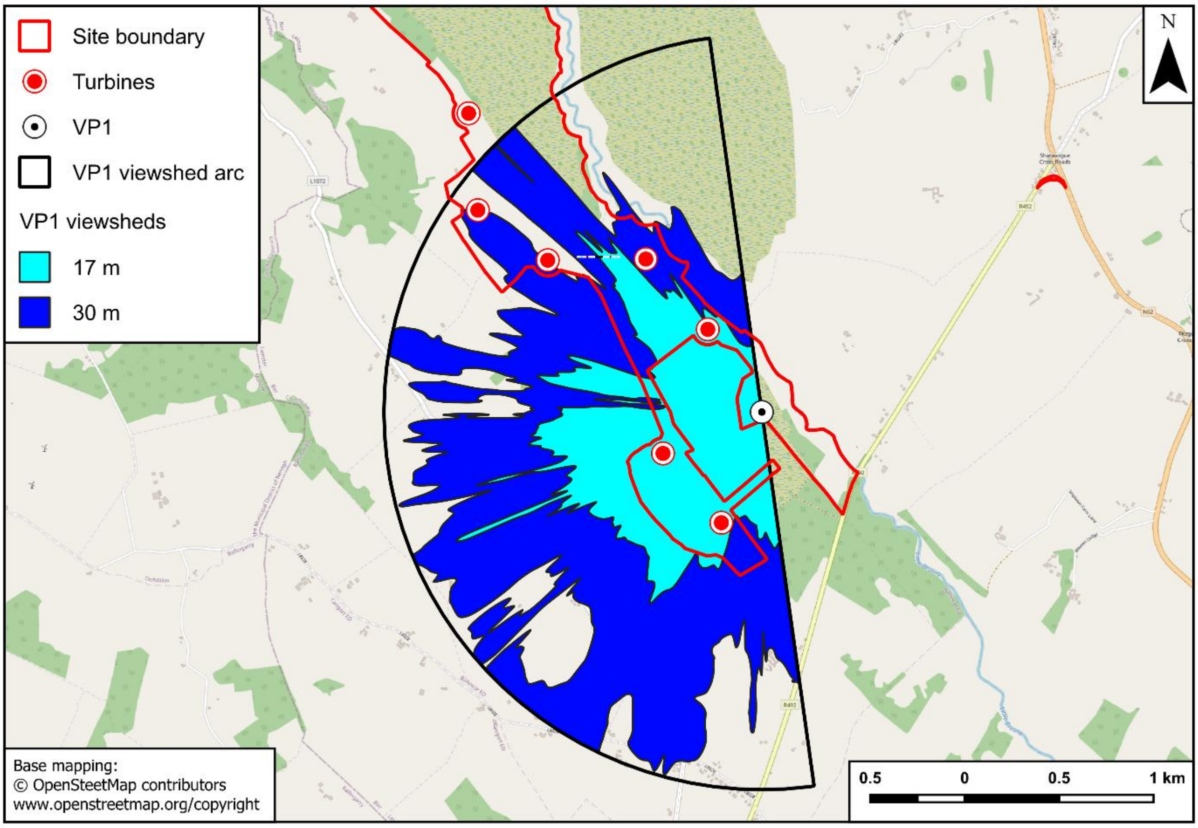
[4] https://c0cre470.caspio.com/dp/4bae3000b11f2454575141d6884b; accessed 01/04/2026.

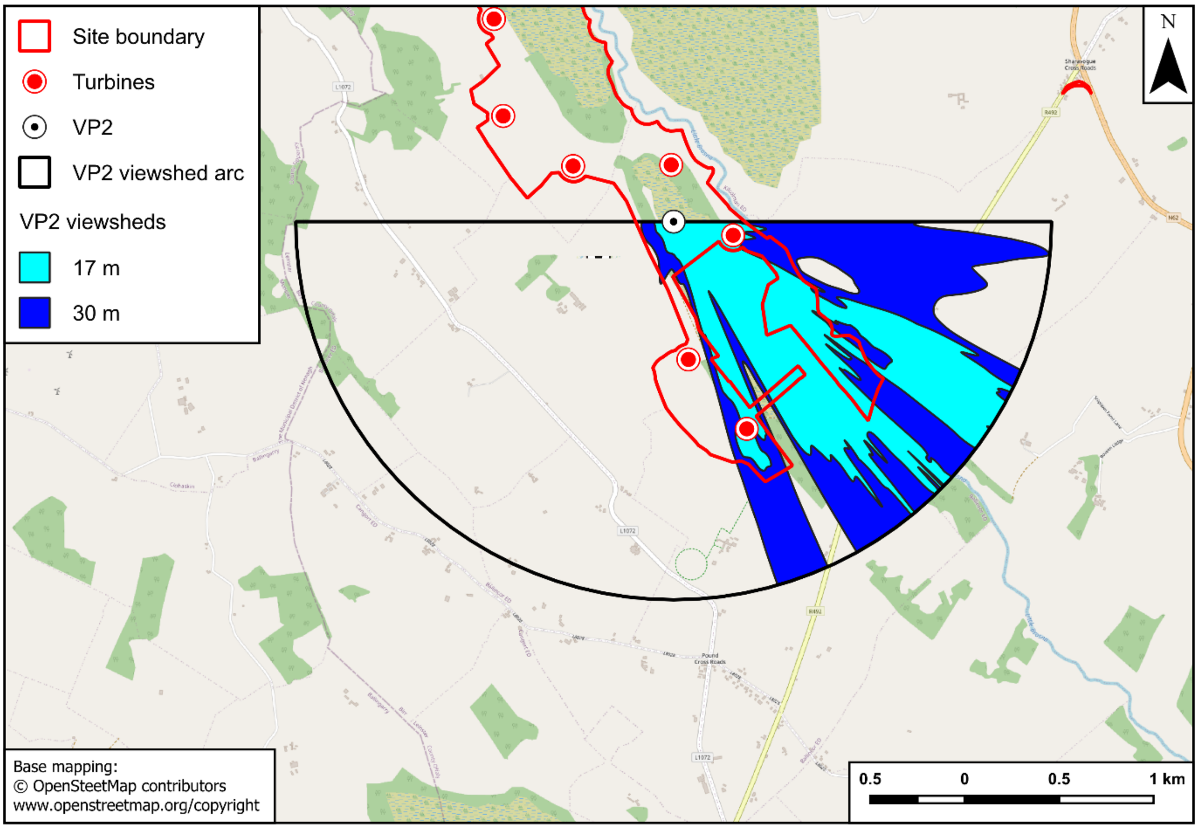
[5] www.bto.org/understanding-birds/birdfacts; accessed 19/02/2024 and 05/07/2025.



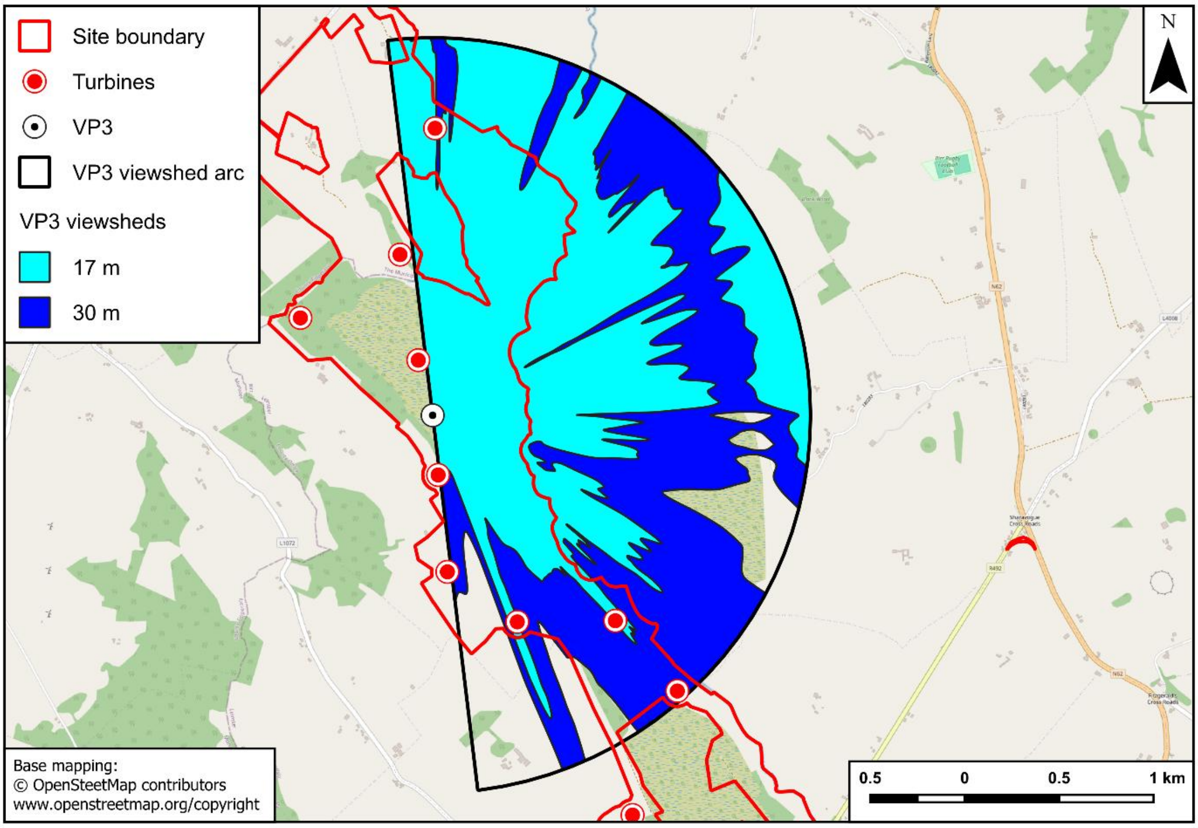
Map 2.1. Vantage point locations.



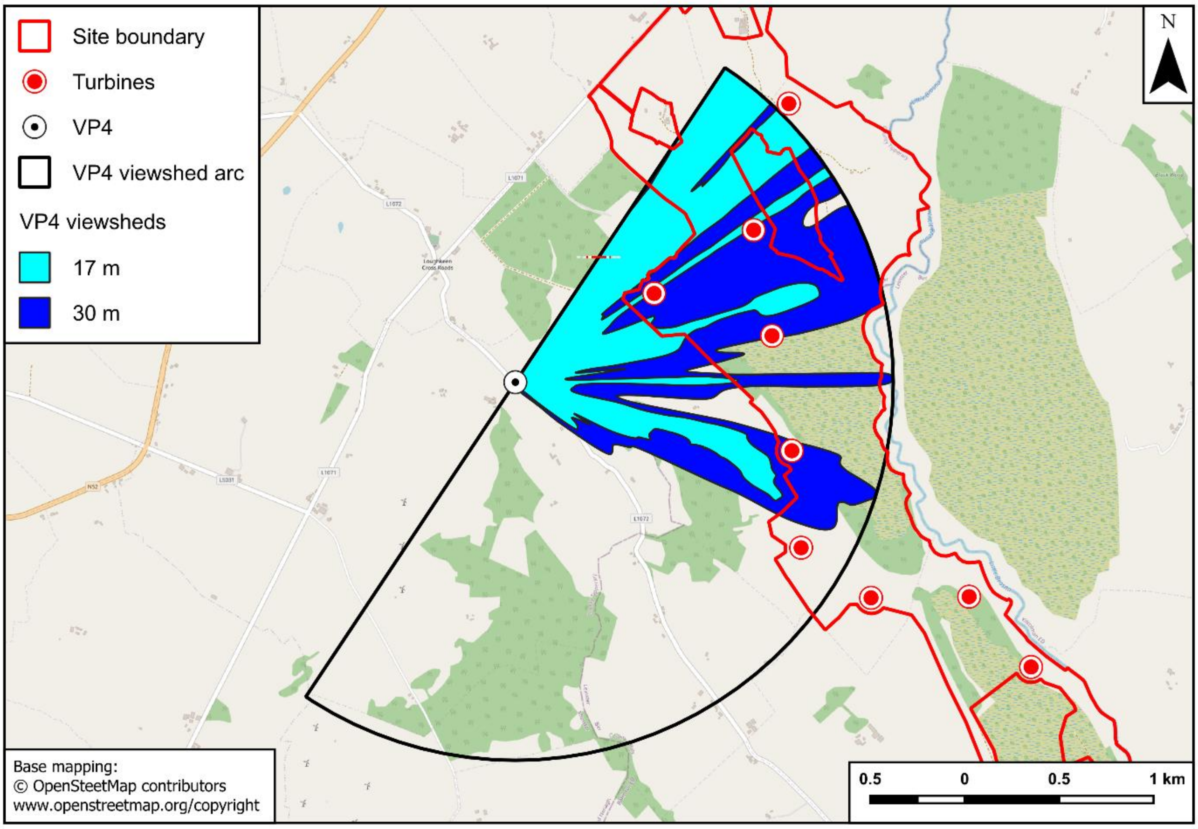
Map 2.2. Ecology Ireland VP1 viewsheds.



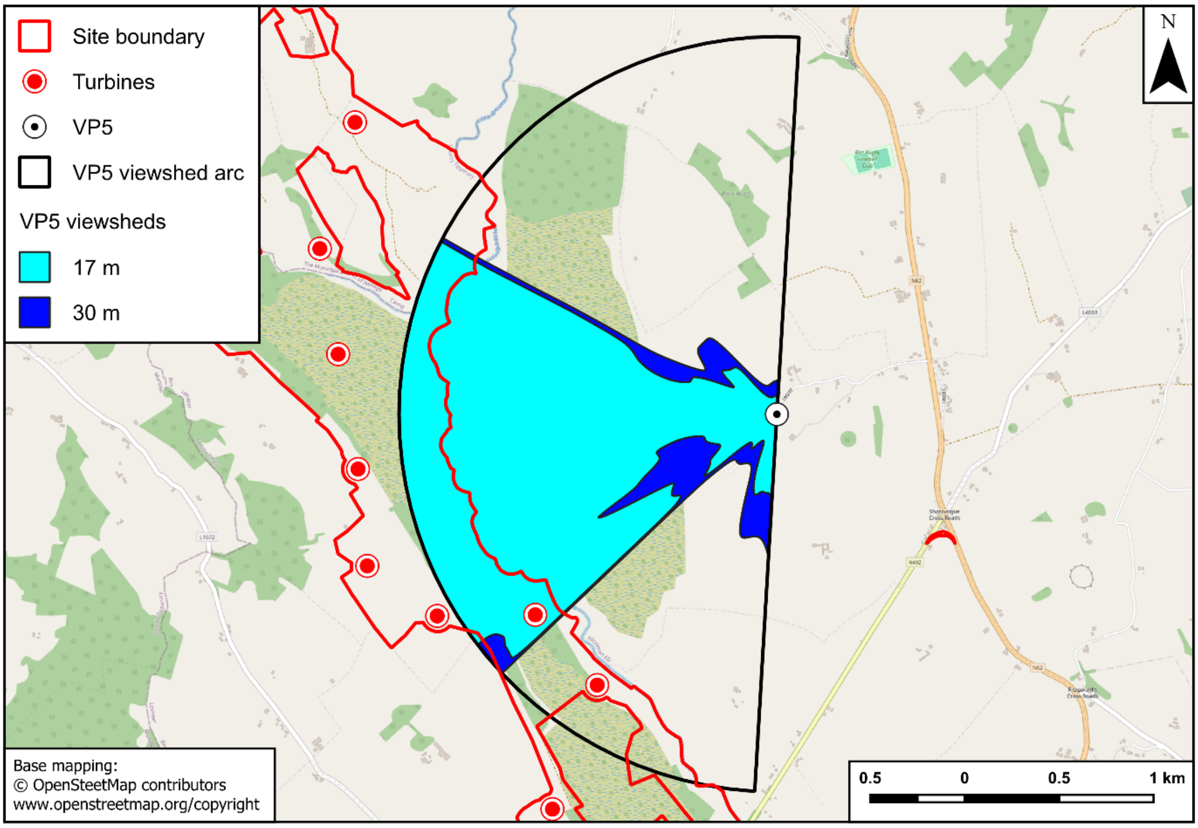
Map 2.3. Ecology Ireland VP2 viewsheds.



Map 2.4. Ecology Ireland VP3 viewsheds.



Map 2.5. Ecology Ireland VP4 viewsheds.



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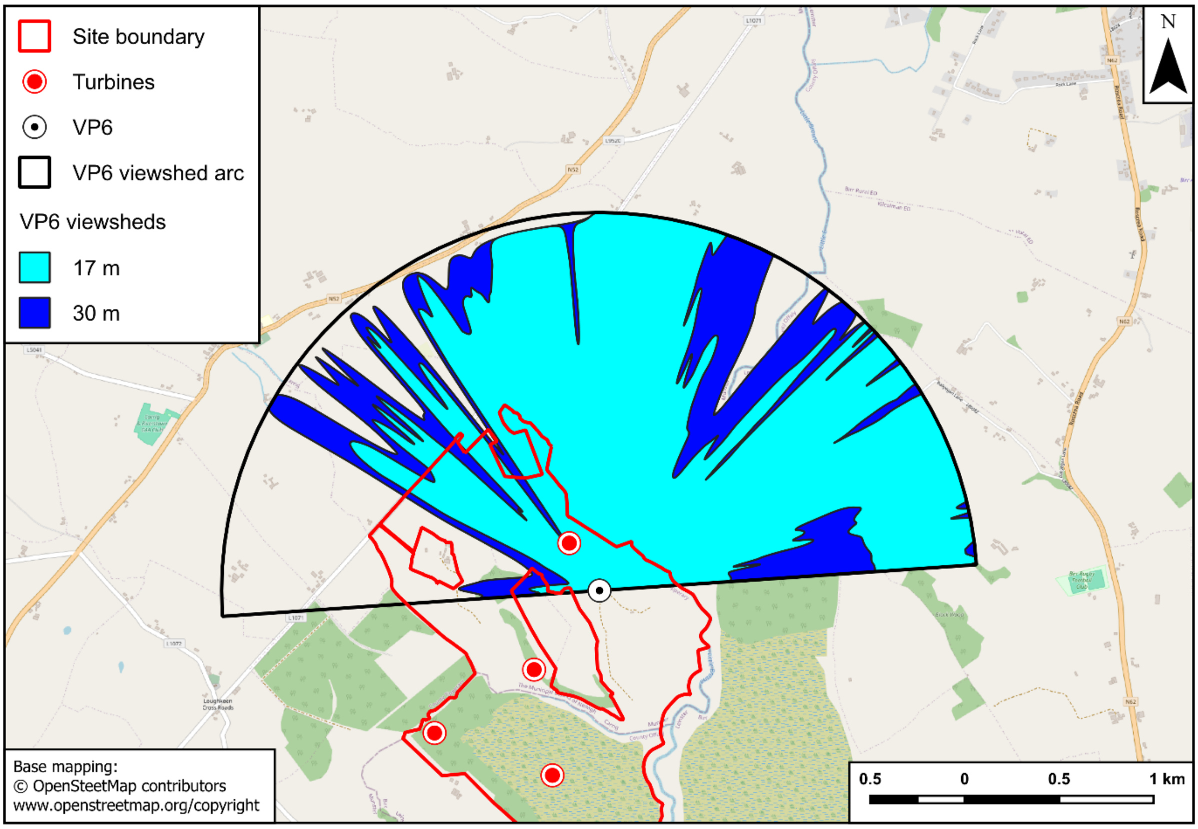
Map 2.6. Ecology Ireland VP5 viewsheds.



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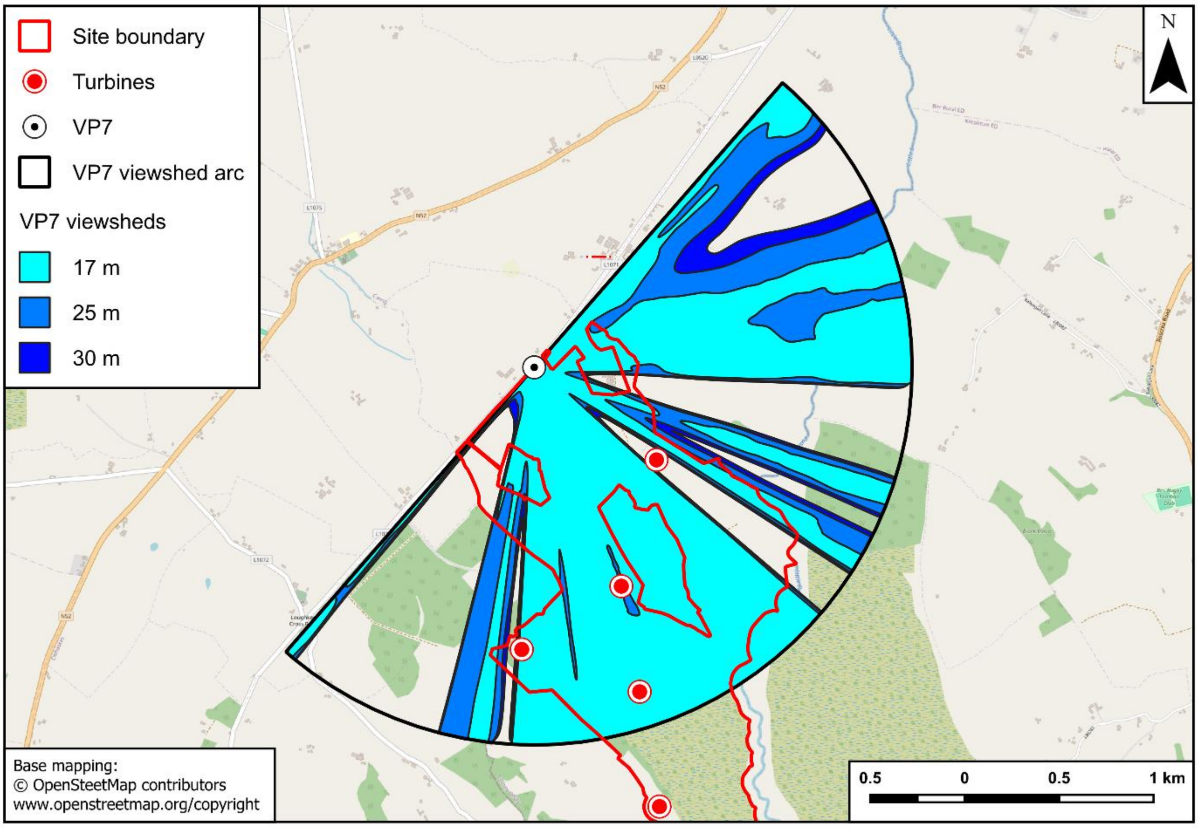
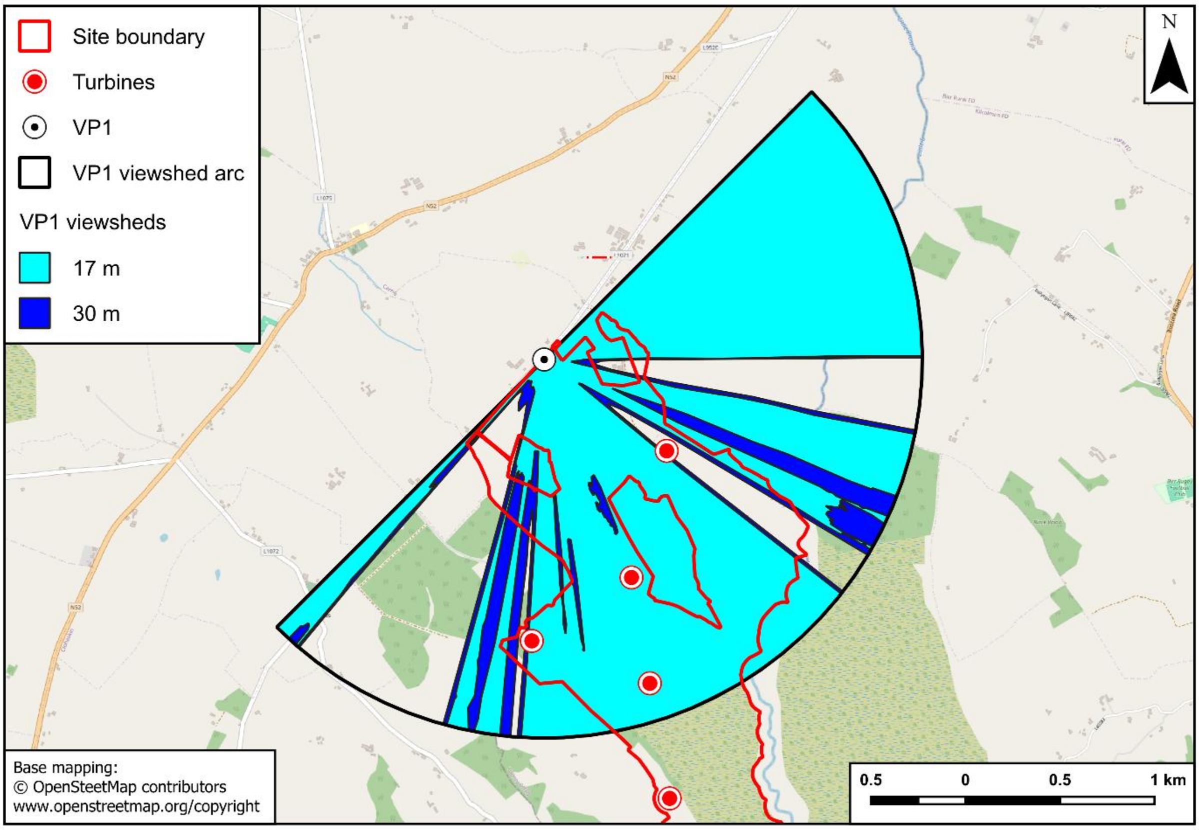
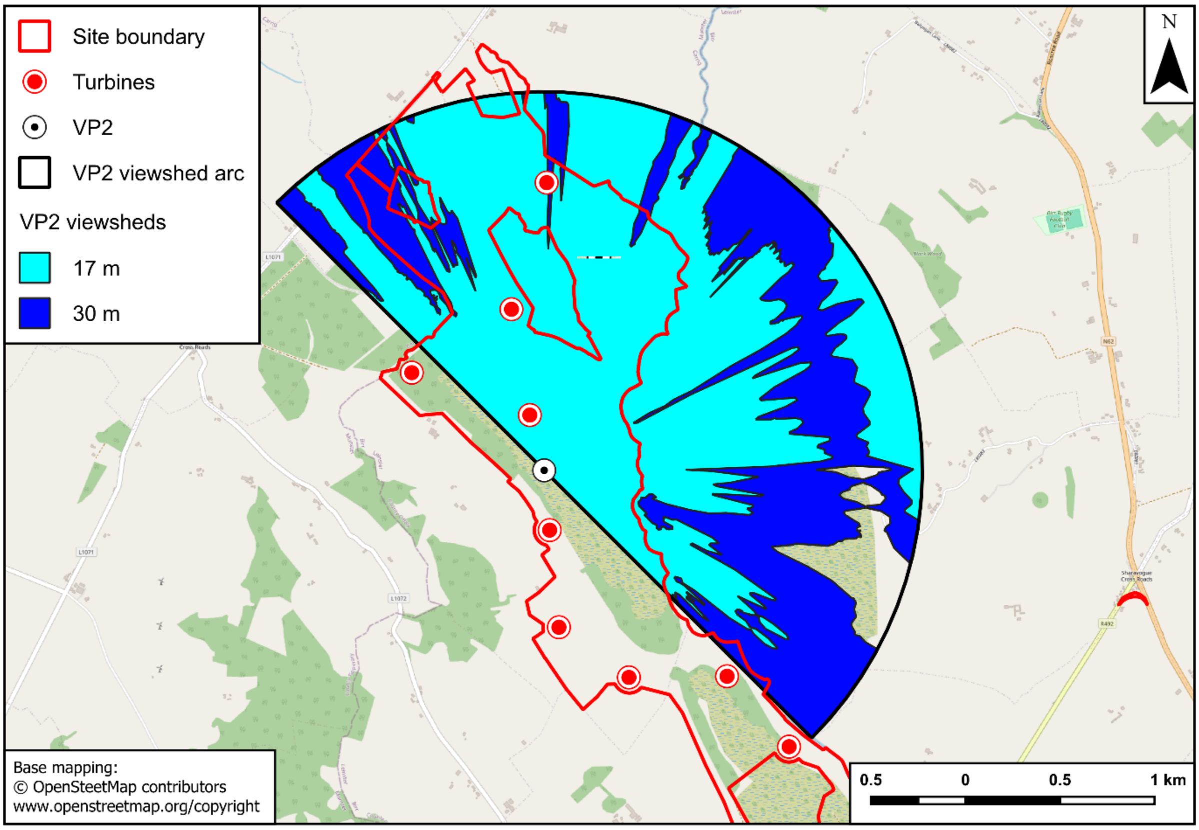
Map 2.7. Ecology Ireland VP6 viewsheds.



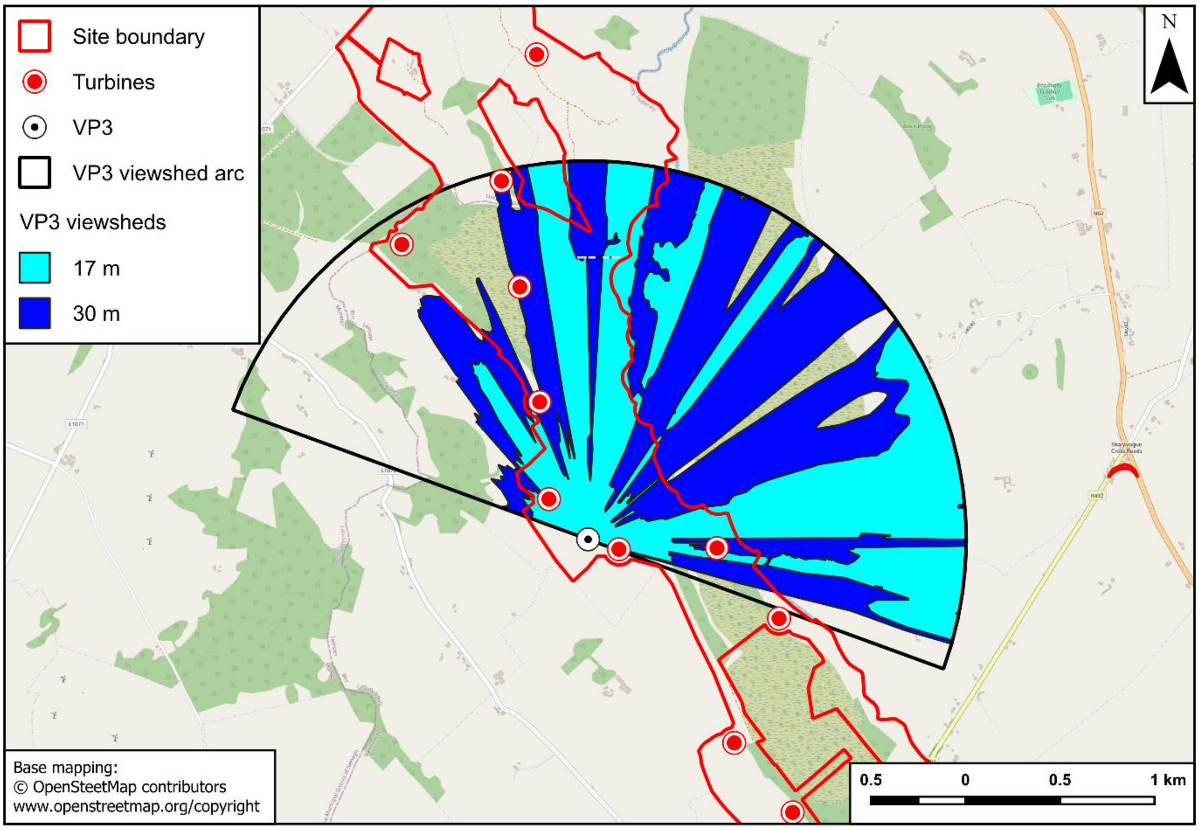
Map 2.8. Ecology Ireland VP7 viewsheds.



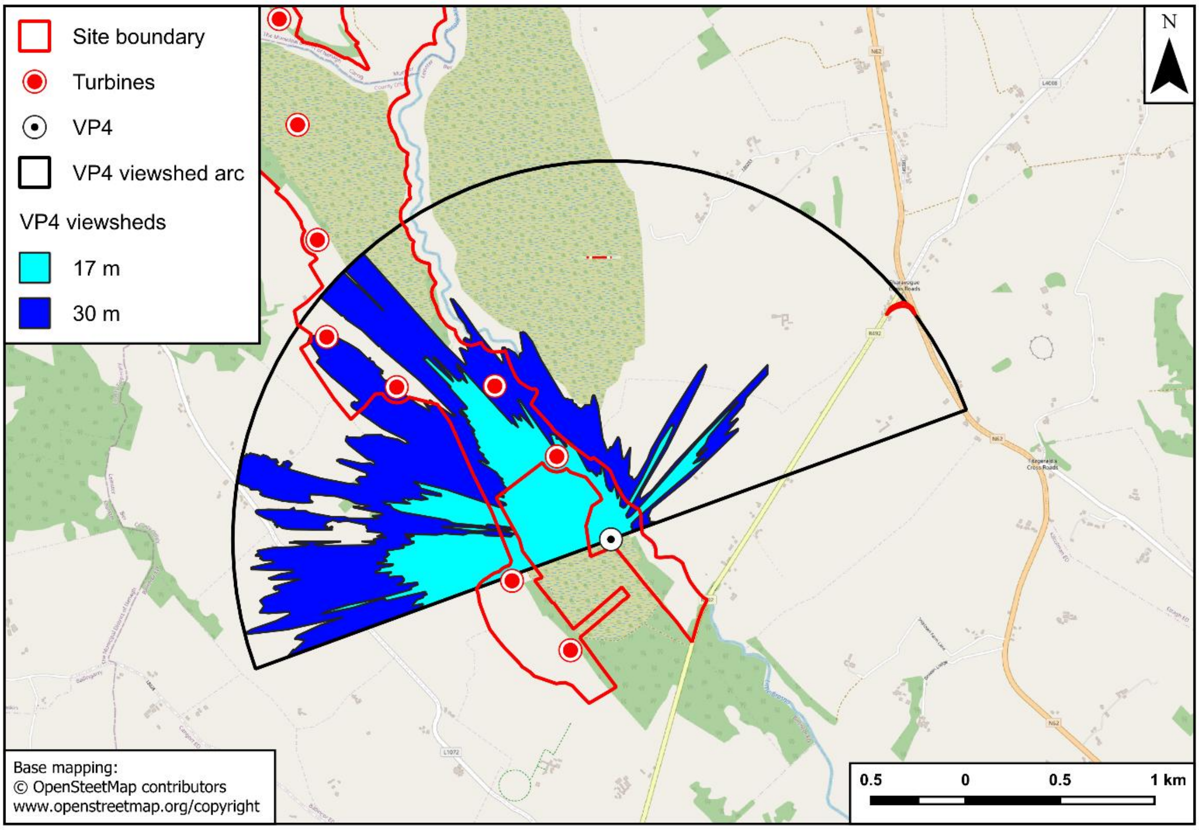
Map 2.9. TOBIN VP1 viewsheds.



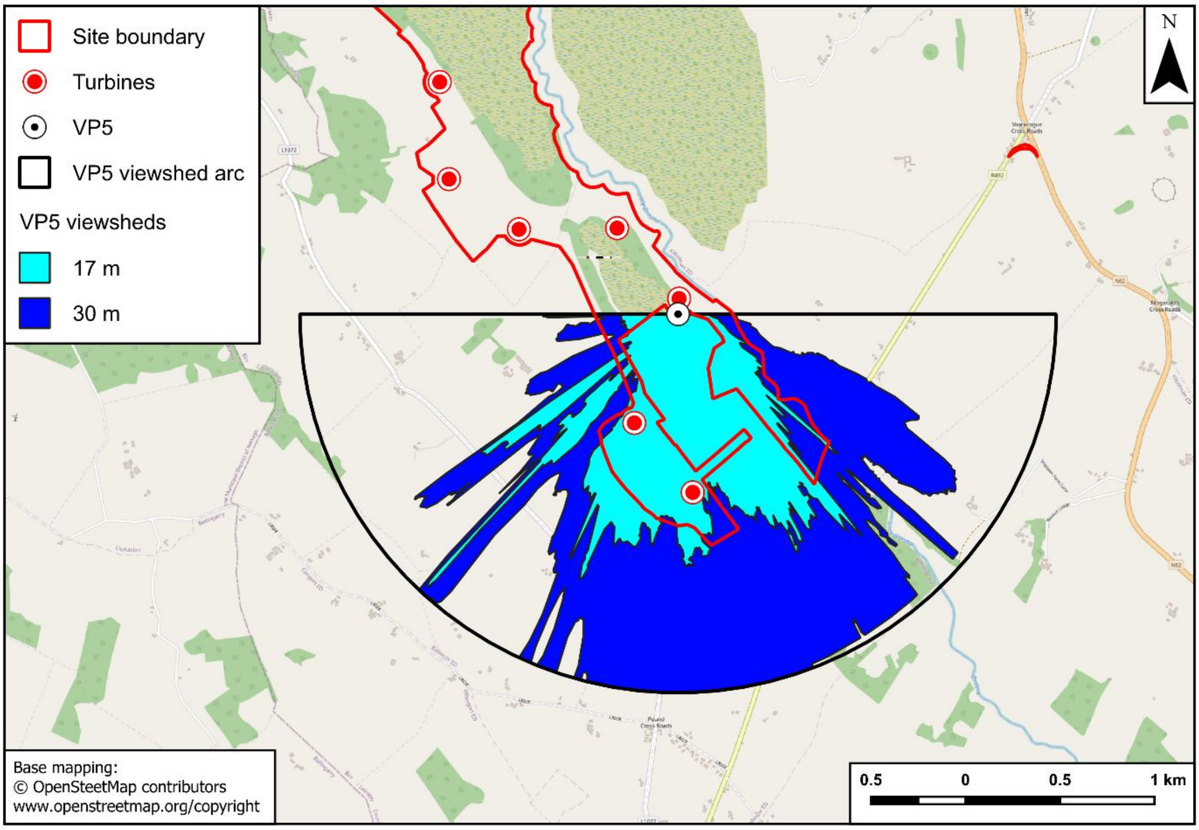
Map 2.10. TOBIN VP2 viewsheds.



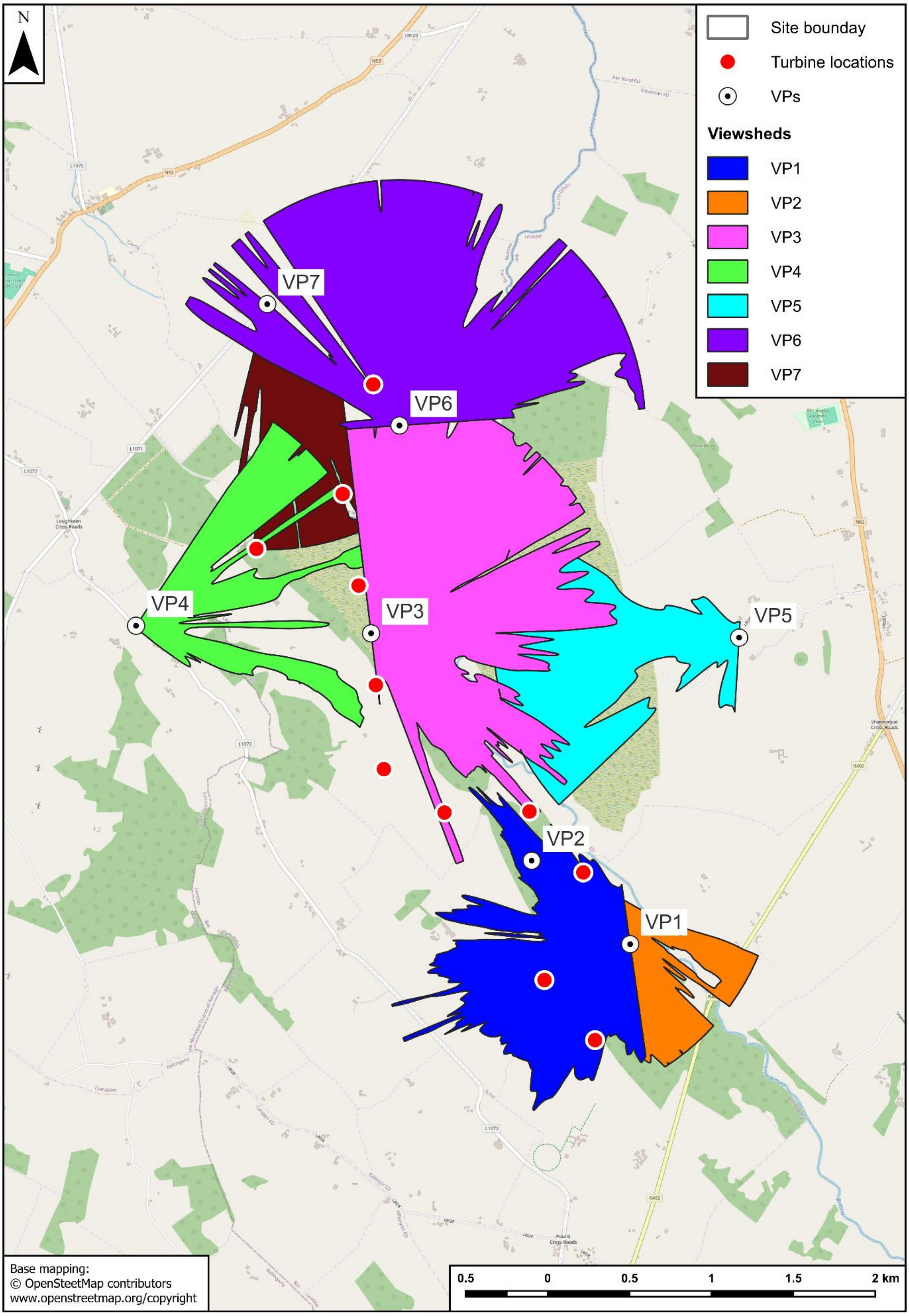
Map 2.11. TOBIN VP3 viewsheds.



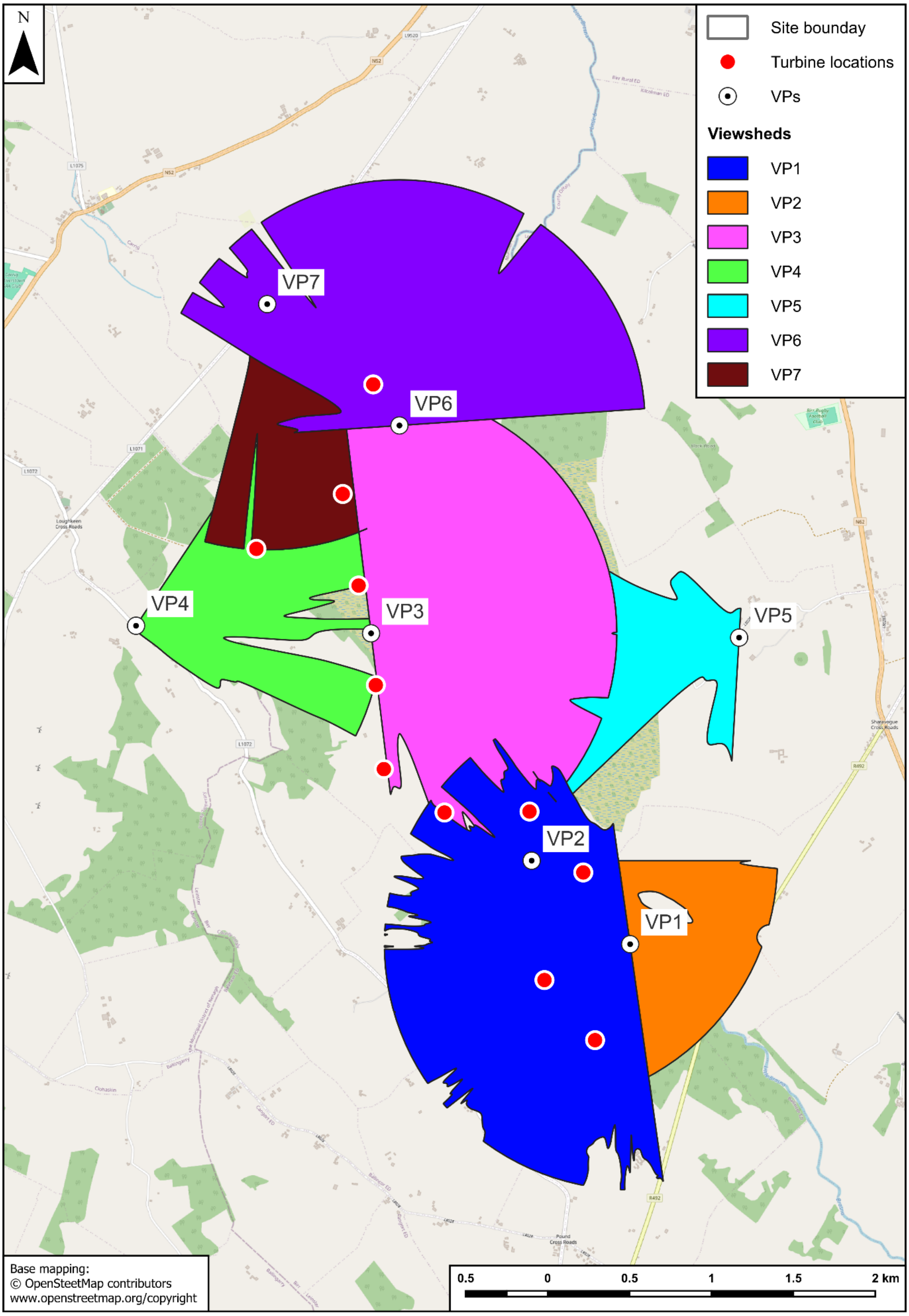
Map 2.12. TOBIN VP4 viewsheds.



Map 2.13. TOBIN VP5 viewsheds.



Map 2.14. 1.5 km Ecology Ireland 17 m viewsheds with overlaps removed, as used for the collision risk model.



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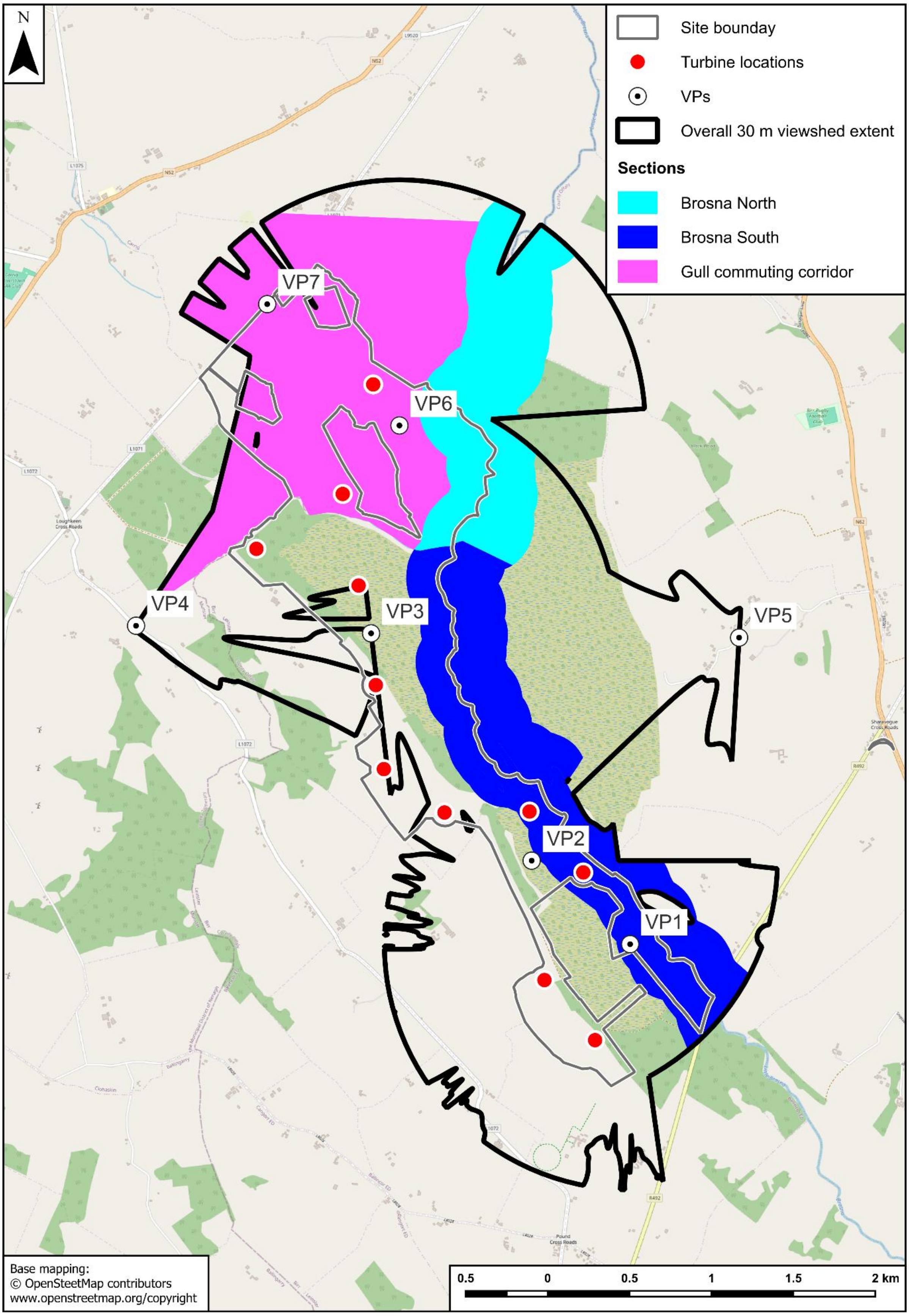
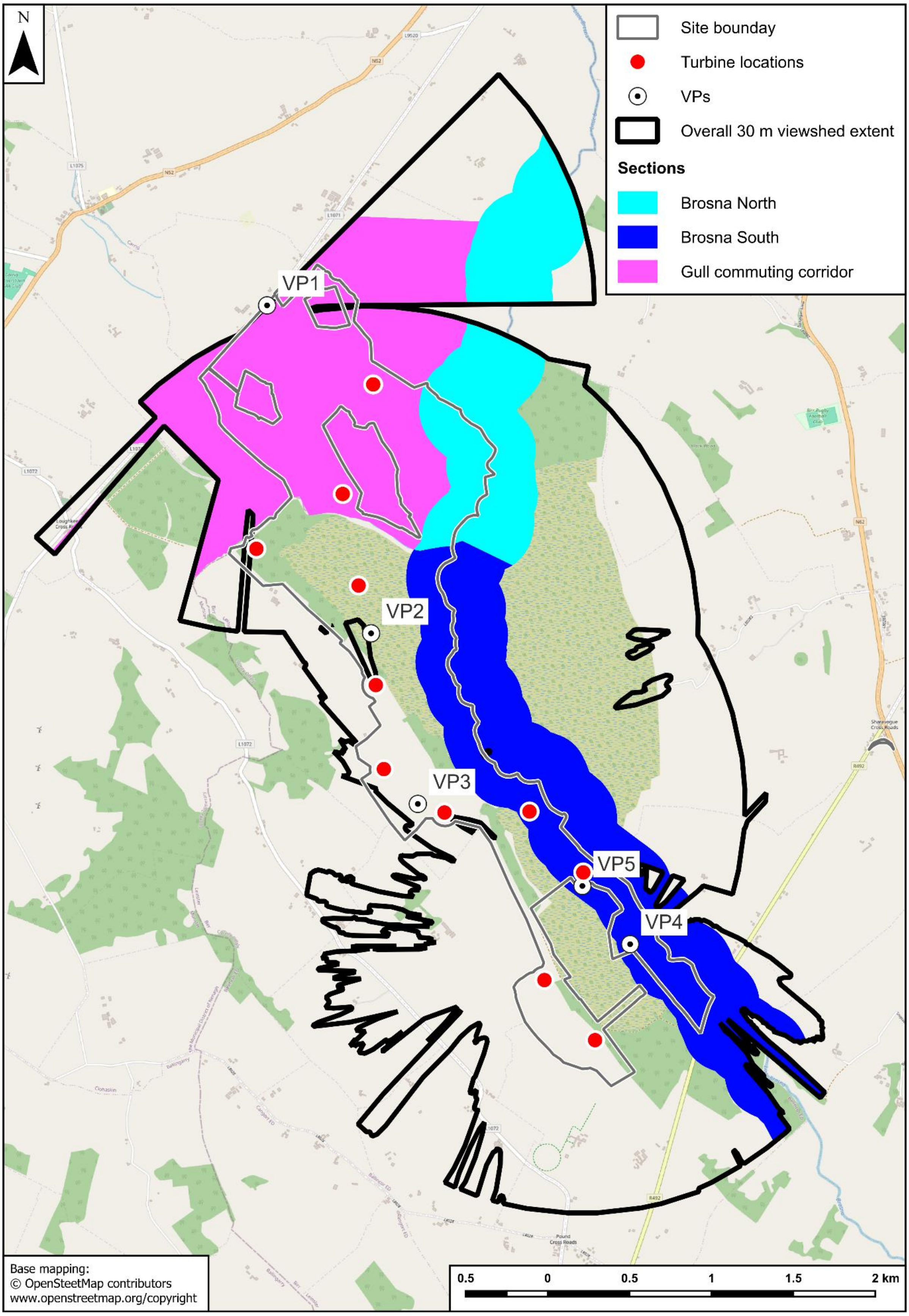
Map 2.15. 1.5 km Ecology Ireland 30 m viewsheds with overlaps removed, as used for the collision risk model.



Map 2.16. Ecology Ireland viewshed sections used for the spatially-structured models.



Map 2.17. TOBIN viewshed sections used for the spatially-structured models.

3. REVIEW OF THE VANTAGE POINT SURVEY COVERAGE AND RESULTS

3.1. SPATIAL COVERAGE AND VIEWSHEDS

3.1.1. Overall viewshed coverage

3.1.1.1 Ecology Ireland

The overall coverage by the 1.5 km viewsheds with overlaps removed is shown in Map 3.1.

The viewshed coverage at 17 m above ground level included eight turbine locations, while the 30 m coverage included nine turbine locations. The two turbine locations not covered by the 30 m viewshed (T5 and T6) were within 25 m of the viewshed boundary. T5 was also within 25 m of the 17 m viewshed boundary, but T6 was around 200 m from the 17 m viewshed boundary. The other turbine location not covered by the 17 m viewshed (T4) was within 40 m of the viewshed boundary.

The 17 m viewshed coverage included 62% of the 500 m turbine buffer while the 30 m viewshed coverage included 85% of this buffer.

While there is incomplete coverage of the turbine locations and the 500 m buffer around the turbine locations, the gaps in coverage are small and there are not any significant areas lacking coverage.

3.1.1.2 TOBIN

The overall coverage by the TOBIN viewsheds is shown in Map 3.2.

The viewshed coverage at 17 m above ground level included eight turbine locations, while the 30 m viewshed coverage included ten turbine locations. The one turbine location not covered by the 30 m viewshed (T5) was around 10 m from the viewshed boundary and 35 m from the 17 m viewshed boundary. The other two turbine locations not covered by the 17 m viewshed were around 1 m (T7) or 15 m (T8) from the viewshed boundary.

The 17 m viewshed coverage included 68% of the 500 m turbine buffer while the 30 m viewshed coverage included 91% of this buffer.

While there is incomplete coverage of the turbine locations and the 500 m buffer around the turbine locations, the gaps in coverage are small and there are not any significant areas lacking coverage.

3.1.2. Survey effort

3.1.2.1 Ecology Ireland

The mapped flightlines included many that were outside the viewshed arcs, and, at some vantage points, there was a more or less 360° distribution of flightlines around the vantage points. This indicates that the surveyors spent some of the observation time watching areas outside the viewshed arcs. The percentages of the total flight durations corresponding to mapped flightlines within the viewshed arcs at each vantage point varied from 40% at VP6 to 92% at VP7 (Table 3.1). This appears to reflect the orientation of the viewshed arcs in relation to the wind farm site and patterns of bird activity: e.g., the viewshed arc for VP6 faced north away from the main part of the wind farm site and the flooded grasslands along the River Brosna, while VP5 and VP7 were located at the periphery / outside the wind farm site and their viewshed arcs faced the wind farm site.

Table 3.1. Distribution of mapped flight durations from the Ecology Ireland vantage point survey within and outside viewshed arcs at each vantage point.

VP	Total flight durations (seconds)		
	outside	within	percentage within
VP1	12,578	26,841	68%
VP2	20,482	16,083	44%
VP3	12,137	45,737	79%
VP4	18,280	25,615	58%
VP5	3,074	28,182	90%
VP6	28,831	19,534	40%
VP7	2,072	23,225	92%

Flight durations for flightlines that spanned both within and outside the viewshed arcs were split by the ratio of their lengths within and outside the viewshed arcs.

3.1.2.2 TOBIN

The flightlines recorded by the TOBIN vantage point survey were concentrated within the viewshed arcs. A small number of flightlines extended outside the arcs, mainly comprising flightlines that were tracked for a short distance past the boundary of the arc. The pattern of the mapped flightlines did not suggest that surveyors spent significant amounts of time watching areas outside the viewshed arcs.

3.2. VANTAGE POINT WATCHES

3.2.1. Concurrent watches

In the Ecology Ireland vantage point surveys, the majority of watches were carried out concurrently across multiple vantage points. Over 50% of the survey days included watches at all the vantage points, while another 20% included watches at all but one of the vantage points, and all survey days included watches at least two vantage points. On each survey day, all the vantage points watched were covered more or less concurrently with start/finish times not varying by more than ± 10–20 minutes between vantage points. As there were large overlaps between viewsheds, the predominance of concurrent watches created significant issues for the statistical independence of the flight activity sampled at each vantage point (see Section 2.4.2.2).

In the TOBIN vantage point surveys the vantage points were mainly surveyed on separate days in each month. There was only one day when multiple vantage points were surveyed on the same day. On that day TB1 and TB5 were surveyed, but these are at opposite ends of the site with no overlaps in their viewsheds, while the temporal overlap was only 45 minutes out of a total of 6 hours watches at each vantage point.

3.2.2. Durations

All the Ecology Ireland vantage point watches were continuous 6-hour watches without the 30-minute break after three hours recommended by the NatureScot survey guidance (NS 2025a). However, there was no evidence of a decline in recording rate after the first three hours of the watches (Figure 3.1).

3.2.3. Visibility

Both sets of vantage point surveys included some watches with reduced visibility where the full 2 km viewsheds at potential collision height were not fully visible. These comprised 11% of the Ecology Ireland watches and 7% of the TOBIN watches. The latter case comprised two 6-hour surveys (split into 3-hour watches). A repeat survey in good visibility was carried out to replace one of these surveys.

3.3. SPATIAL PATTERNS OF FLIGHT ACTIVITY

3.3.1. Distance effects

The analyses of the full Ecology Ireland dataset showed large reductions in flightline densities with distance from the vantage points (referred to hereafter as distance effects) for small (Group 1) and medium (Group 2) sized species but weak / inconsistent distance effects for large species (Group 3) (Figure 3.2). The peaks in flightline densities in the analysis of large species appear to be associated with the distances of the River Brosna from the vantage points in the viewsheds. When I repeated the analysis, but excluded flight activity that occurred in a 200 m wide corridor along the River Brosna, the large species showed a similar pattern of distance effects to the other groups but with a lower magnitude of decline (Figure 3.3).

The analyses of the TOBIN dataset showed similar patterns, but with wider confidence intervals due to the smaller sample size (Figure 3.4 and Figure 3.5)

The correction factors calculated from the weighted viewshed areas are shown in Table 3.2 and Table 3.3. These indicate the increase in collision risk that results from correcting for the distance effects. The NatureScot correction factors were derived using the theoretical maximum possible viewshed that complies with NatureScot guidance (NatureScot, 2025a). The Ballincor correction factors were derived using the actual viewsheds from the relevant datasets. The NatureScot correction factors allow comparison of the detectability effects across datasets. The Ballincor correction factors indicate the approximate values of the corrections for under-detection of distant flightlines that were applied in Stage F of the collision risk modelling. Note that for each species, the actual correction factor that was applied will vary depending on the species distribution between the vantage points included in the model.

The NatureScot correction factors had higher values because the NatureScot viewsheds are perfect semi-circles extending to 2 km from the vantage points, while most real viewsheds have some reduction in coverage in their more distant parts. The correction factors for the 17 m viewsheds were smaller than those for the 30 m viewsheds because the 17 m viewsheds had more reduced coverage in their more distant sections compared to the 30 m viewsheds.

The correction factors for the Ecology Ireland and TOBIN datasets are not directly comparable due to the differences in the groupings of species used for the analyses (see Section 2.5.2).

Table 3.2. Correction factors to adjust for under-detection of distant flightlines in the Ecology Ireland dataset.

Correction factor	Group1	Group2	Group3
NatureScot correction	4.21	3.24	2.26
Ballincor correction (17 m)	3.23	2.59	1.99
Ballincor correction (30 m)	3.73	2.93	2.13

The correction factors were calculated from the analyses that excluded flight activity within the 200 m Brosna corridor. Group1 = small species; Group2 = medium-sized species; Group3 = large species.

Table 3.3. Correction factors to adjust for under-detection of distant flightlines in the TOBIN dataset.

Correction factor	Group1	Group2
NatureScot correction	3.26	3.25
Ballincor correction (17 m)	2.65	2.55
Ballincor correction (30 m)	2.96	2.90

The correction factors were calculated from the analyses that excluded flight activity within the 200 m Brosna corridor. Group1 = small species; Group2 = large species.

3.3.2. Species-specific spatial structure

Eleven species showed clear spatial structure in the distribution of their flight activity: Mute Swan, Whooper Swan, Wigeon, Mallard, Cormorant, Little Egret, Grey Heron, Lapwing, Black-tailed Godwit, Black-headed Gull and Lesser Black-backed Gull (Map 3.3-Map 3.13). This was mainly associated with movement along the River Brosna, as well as with feeding on flooded fields adjacent to the River Brosna, and a commuting corridor in the north-western section of the wind farm site for Black-headed Gull and Lesser Black-backed Gull.

Calculations of flight activity densities showed large differences between sections defined based on the patterns described above (Table 3.4). Most species showed much higher densities in the northern and/or southern parts of a 500 m wide corridor along the River Brosna, and, for the gulls, in a commuting corridor, compared to elsewhere in the survey area. The densities of Cormorant and Grey Heron were higher in the southern part of the Brosna corridor, compared to the northern part. For Whooper Swan, Wigeon and the gulls, the densities in the southern part of the Brosna corridor were not higher than elsewhere in the survey area. The gull densities were higher in the commuting corridor compared to the remainder of the survey area, with the exception of Lesser Black-backed Gull densities using the 30 m viewsheds.

Table 3.4. Mean flight activity densities at potential collision height (birds/km^2/month) in different sections of the survey area.

Species	Viewshed height	Brosna N	Brosna S	Commuting corridor	Remainder
Mute Swan	17 m	69	109	15	30
	30 m	10	48	9	10
Whooper Swan	17 m	901	161	22	191
	30 m	508	242	5	111
Wigeon	17 m	8,434	212	931	1,058
	30 m	4,512	40	464	423
Mallard	17 m	240	442	29	133
	30 m	186	285	14	70
Cormorant	17 m	538	1,520	45	328
	30 m	277	1,216	9	264
Little Egret	17 m	103	116	35	38
	30 m	2	8	0	2
Grey Heron	17 m	73	172	52	57
	30 m	62	113	16	40
Lapwing	17 m	7,845	1,483	1,259	1,363
	30 m	4,128	1,142	895	762
Black-tailed Godwit	17 m	10,573	10,973	109	3,377
	30 m	9,031	6,441	97	1,887
Black-headed Gull	17 m	3,106	215	4,010	632
	30 m	3,053	138	1,612	512
Lesser Black-backed Gull	17 m	4,575	3,330	1,581	1,333
	30 m	2,696	369	373	382

The high densities of Mute Swan, Whooper Swan, Wigeon, Mallard, Little Egret, Lapwing and Black-tailed Godwit in the northern part of the Brosna corridor were associated with birds feeding on flooded grassland adjacent to the western bank of the River Brosna in this section. The high densities of the gulls in this section may also have been similarly associated but they could also have reflected a commuting route along the River Brosna and through the commuting corridor. The high densities of various species in the southern part of the Brosna corridor are likely to have been largely due to commuting routes along the river, although, for Cormorant, they would also have been influenced by the presence of roost sites.

There are no turbine locations within, or close to, the northern part of the Brosna corridor. Therefore, this analysis suggested that the flight activity within this section should be excluded from the spatially-structured models. For Mute Swan, Mallard, Cormorant, Little Egret and Grey

Heron, the analysis suggested that the southern part of the Brosna corridor should be treated separately from the remainder of the site in the spatially-structured models. For Black-headed Gull and Lesser Black-backed Gull, the analysis suggested that the commuting corridor should be treated separately from the remainder of the site in the spatially-structured models.

3.3.3. Flight directions

The proportion of upwind flight activity recorded during the vantage point watches ranged from 0.38 for Hen Harrier to 0.57 for Little Egret (Table 3.5). For most species, the bootstrap confidence intervals overlapped 0.5, indicating no evidence of directional bias. Two species (Grey Heron and Buzzard) had confidence intervals that narrowly excluded 0.5, but the deviations were small (0.40–0.46) and the limits were very close to 0.5. Given the number of species examined, these marginal results may reflect sampling variation rather than genuine directional preferences.

Table 3.5. Length-weighted upwind flight proportions derived from mapped flightlines, with 95% cluster-bootstrap confidence intervals.

Species	Number of flights	Upwind proportion	Lower 95% CI	Upper 95% CI	Directional bias
Mute Swan	41	0.48	0.33	0.64	NO
Whooper Swan	42	0.43	0.27	0.58	NO
Mallard	122	0.52	0.45	0.59	NO
Cormorant	301	0.54	0.49	0.58	NO
Little Egret	108	0.57	0.49	0.65	NO
Grey Heron	126	0.40	0.32	0.48	YES
Hen Harrier	12	0.38	0.16	0.60	NO
Sparrowhawk	80	0.55	0.47	0.63	NO
Buzzard	260	0.46	0.43	0.49	YES
Golden Plover	51	0.43	0.34	0.52	NO
Lapwing	44	0.56	0.47	0.65	NO
Black-headed Gull	87	0.41	0.32	0.51	NO
Lesser Black-backed Gull	115	0.52	0.43	0.61	NO
Kestrel	230	0.51	0.47	0.55	NO
Merlin	30	0.55	0.36	0.74	NO
Peregrine	25	0.43	0.29	0.59	NO

Upwind proportions are weighted by flightline segment length. Confidence intervals were derived using a flight-level cluster bootstrap (5,000 replicates). Upwind = bearings of 135-315°. Downwind = bearings of 0-135° and 315-360°.

3.4. TEMPORAL PATTERNS OF FLIGHT ACTIVITY

3.4.1. Seasonal patterns

The recording rates of regularly occurring species across the nine seasons of vantage point surveys are compared in Table 3.6. The recording rates are used, rather than actual number of records, to standardise comparisons across seasons with variable survey effort.

Allowing for the level of variation that would be expected from sampling effects, the recording rates of most species were fairly consistent across the eight seasons of the vantage point surveys. However, there was a large increase in the Little Egret recording rate from winter 2022/23. The recording rates of several species were much higher in winter 2025/26, but this may reflect differences in the vantage point layout, rather than actual seasonal differences.

Table 3.6. Seasonal recording rate (records / 200 hours) of flightline records during the vantage point survey.

Species	2020 summer	2020/21 winter	2021 summer	2021/22 winter	2022/23 winter	2023 summer	2023/24 winter	2024 summer	2025/26 winter
Mute Swan	1	0	0	3	6	0	2	5	8
Whooper Swan	0	1	0	4	11	0	6	0	13
Wigeon	0	0	0	0	0	0	1	0	12
Mallard	3	0	3	3	8	12	11	5	24
Cormorant	25	38	5	66	40	13	16	27	91
Little Egret	0	1	0	0	7	2	6	1	15
Grey Heron	11	1	4	4	13	9	5	12	16
Sparrow-hawk	0	11	1	6	15	10	2	4	8
Buzzard	52	27	27	27	38	54	12	54	42
Golden Plover	0	8	0	2	8	2	6	1	24
Lapwing	0	16	0	4	8	0	2	0	20
Black-tailed Godwit	0	0	0	0	1	0	0	0	3
Black-headed Gull	0	7	4	1	17	2	4	0	30
Lesser Black-backed Gull	9	13	1	2	6	17	1	17	28
Kestrel	32	26	9	19	21	42	8	24	39
Merlin	0	4	0	2	3	1	1	2	1
Peregrine	0	2	0	1	3	2	3	3	6

The data in this table is derived from the Ecology Ireland vantage point survey records after processing against the 1.5 km viewsheds with overlaps removed, and all records from the TOBIN vantage point survey. Additional species recorded with a total of less than 10 records, or outside the Ecology Ireland 1.5 km viewsheds: White-fronted Goose, Teal, Pintail, Shoveler, Little Grebe, Moorhen, Curlew, Jack Snipe, Herring Gull, Great Black-backed Gull, Kingfisher, Unidentified swan, Unidentified goose, Unidentified wader, Unidentified gull. Black-tailed Godwit had a total of < 10 records but are included in this table because of the large collision risks that those records generated.

3.4.2. Monthly variation

The monthly recording rates of regularly occurring species are compared in Table 3.7. The recording rates are used, rather than actual number of records, to standardise comparisons across months with variable survey effort.

For species with low numbers of records, any apparent seasonal variation in recording rates may not be reliable, as this variation may just reflect random sampling effects. Of the more frequently recorded species, several show clear seasonal patterns of variation.

Whooper Swan and Golden Plover are winter visitors and their main seasonal occurrence patterns were typical for these species in Ireland: October–March for Whooper Swan and September–March for Golden Plover. Wigeon is also a winter visitor. It was recorded between November and February, which is shorter than its typical wintering period in Ireland (October–March) but reflected the low number of records. While Lapwing breeds in this part of Ireland, it was a winter visitor to the wind farm site (October–March[6]). Mute Swan, Cormorant, Little Egret and Black-headed Gull were recorded throughout the year but were more frequent in winter. Lesser Black-backed Gull was most frequent in autumn (July–October) while there was also a high recording rate in spring; these patterns are typical of the timings of its autumn post-breeding dispersal / migration and spring migration in Ireland.

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[6] There was a single record in July but it was not included in the dataset used for the monthly analyses (see Section 2.5.5).

Table 3.7. Monthly recording rate (records / 40 hours) of flightline records during the vantage point survey.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Mute Swan	1.4	0.9	0.3	0.0	0.2	0.0	0.0	0.6	1.4	0.4	0.2	1.4
Whooper Swan	2.3	0.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.8	3.2	2.3
Wigeon	0.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.5
Mallard	0.0	4.6	3.6	1.3	0.9	1.4	2.2	0.6	1.4	2.7	0.2	0.0
Cormorant	12.9	6.3	3.1	1.3	4.3	2.2	3.0	3.6	6.7	6.3	14.2	12.9
Little Egret	1.8	0.7	0.6	0.0	0.2	0.0	0.3	0.6	0.0	1.2	1.4	1.8
Grey Heron	1.4	2.8	1.9	0.7	2.8	1.7	0.8	2.5	1.4	2.0	0.7	1.4
Sparrowhawk	1.1	1.3	2.2	0.0	1.3	1.9	0.3	0.6	0.5	1.2	2.5	1.1
Buzzard	2.1	7.4	14.2	3.3	10.9	16.7	9.7	5.3	6.7	4.7	3.2	2.1
Golden Plover	1.6	2.2	3.3	0.0	0.0	0.0	0.0	0.0	1.4	0.8	1.6	1.6
Lapwing	0.5	2.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	2.7	3.9	0.5
Black-tailed Godwit	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Black-headed Gull	1.8	0.9	0.0	0.0	0.2	0.8	0.3	0.0	0.0	0.0	4.1	1.8
Lesser Black-backed Gull	0.7	0.6	2.2	0.0	0.9	1.1	3.6	5.0	3.8	6.7	3.0	0.7
Kestrel	2.3	3.9	6.7	2.0	4.1	8.1	8.3	3.6	7.1	3.9	3.0	2.3
Merlin	0.7	0.6	0.6	0.0	0.2	0.3	0.0	0.3	0.0	0.8	0.0	0.7
Peregrine	0.2	0.7	0.0	0.0	0.2	0.3	0.3	0.0	1.0	1.2	0.7	0.2

The data in this table is derived from the Ecology Ireland vantage point survey records after processing against the 1.5 km viewsheds with overlaps removed, and all records from the TOBIN vantage point survey. Additional species recorded with a total of less than 10 records, or outside the Ecology Ireland 1.5 km viewsheds: White-fronted Goose, Teal, Pintail, Shoveler, Little Grebe, Moorhen, Curlew, Jack Snipe, Herring Gull, Great Black-backed Gull, Kingfisher, Unidentified swan, Unidentified goose, Unidentified wader, Unidentified gull. Black-tailed Godwit had a total of < 10 records but are included in this table because of the large collision risks that those records generated.

3.4.3. Diel patterns

The diel distribution of the survey effort is compared to the diel distribution of total daylight hours in Table 3.8 and Table 3.9.

The Ecology Ireland survey effort was heavily concentrated in the middle of the day. In summer there was no survey coverage during the first hour after sunrise or the two hours before sunset, and only 15 minutes of survey effort (across all vantage points and survey seasons) in the 1–2 hour period after sunrise. In winter the survey effort in the hour after sunrise and in the two hours before sunset was lower than in the remainder of the daylight hours.

The TOBIN survey effort was more evenly distributed (Table 3.9). There was still a concentration in the middle of the day, which is hard to avoid for winter vantage point surveys. However, there was good coverage of the early morning and evening, including the hours before sunrise and after sunset, which are potentially important for commuting swans and geese (NS 2025a).

The variation in the diel recording rates of the species included in the collision risk assessment (Section 5) is summarised in Figure 3.6–Figure 3.8. However, the lack of Ecology Ireland survey effort in the early morning in summer and in the evening in both seasons (as described above) limits the usefulness of these analyses.

In winter, there were higher recording rates in the Ecology Ireland dataset of Mute Swan and Whooper Swan in the early morning, which could have been due to birds commuting from nocturnal roost sites. There was not sufficient survey effort to calculate recording rates for the evening period in the Ecology Ireland dataset. The TOBIN dataset did not show higher recording rates in either the early morning or evening, although it had sufficient temporal coverage in both periods to detect such patterns if they existed.

Cormorant showed a more consistent pattern, with higher rates in the early morning and afternoon in both datasets and in the evening in the TOBIN dataset. This pattern is consistent with a typical pattern of Cormorants commuting from roost sites in a concentrated pattern in the morning with a more dispersed pattern of return to roost sites in the afternoon and evening once they had finished feeding for the day.

Table 3.8. Diel distribution of survey effort during the summer (April–September) vantage point surveys.

Hour	Daylight hours	VP minutes	VP minutes / daylight hour
Sunrise - 1	183	0	0
Sunrise	183	0	0
Sunrise + 1	183	15	0.1
Sunrise + 2	183	776	4.2
Sunrise + 3	183	2135	11.7
Sunrise + 4	183	5270	28.8
Sunrise + 5	183	7582	41.5
Sunrise + 6	282	12669	44.9
Solar Noon			
Sunset + 6	282	12227	43.3
Sunset + 5	183	3655	20
Sunset + 4	183	1268	6.9
Sunset + 3	183	219	1.2
Sunset + 2	183	0	0
Sunset + 1	183	0	0
Sunset	183	0	0
Sunset - 1	183	0	0

The Sunrise + 6 and Sunset – 6 hours included all the time between six hours after sunrise, or six hours before sunset, and solar noon. Sunrise and sunset times were calculated using the suncalc package (Thieurmel and Elmarhraoui, 2022) in R version 4.4.4 (R Core Team, 2024).

Table 3.9. Diel distribution of survey effort during the winter (October–March) vantage point surveys.

Hour	Daylight hours	VP minutes		VP minutes / daylight hour	
		Ecology Ireland	TOBIN	Ecology Ireland	TOBIN
Sunrise - 1	182	152	612	0.8	3.4
Sunrise	182	2326	942	12.8	5.2
Sunrise + 1	182	5917	1007	32.5	5.5
Sunrise + 2	182	7652	712	42.0	3.9
Sunrise + 3	317	13850	2274	43.7	7.2
Solar Noon					
Sunset + 3	317	12450	2256	39.3	7.1
Sunset + 2	182	4993	994	27.4	5.5
Sunset + 1	182	1984	956	10.9	5.3
Sunset	182	16	869	0.1	4.8
Sunset - 1	182	0	538	0.0	3.0

The Sunrise + 3 and Sunset – 3 hours included all the time between three hours after sunrise, or three hours before sunset, and solar noon. Sunrise and sunset times were calculated using the suncalc package (Thieurmel and Elmarhraoui, 2022) in R version 4.4.4 (R Core Team, 2024).

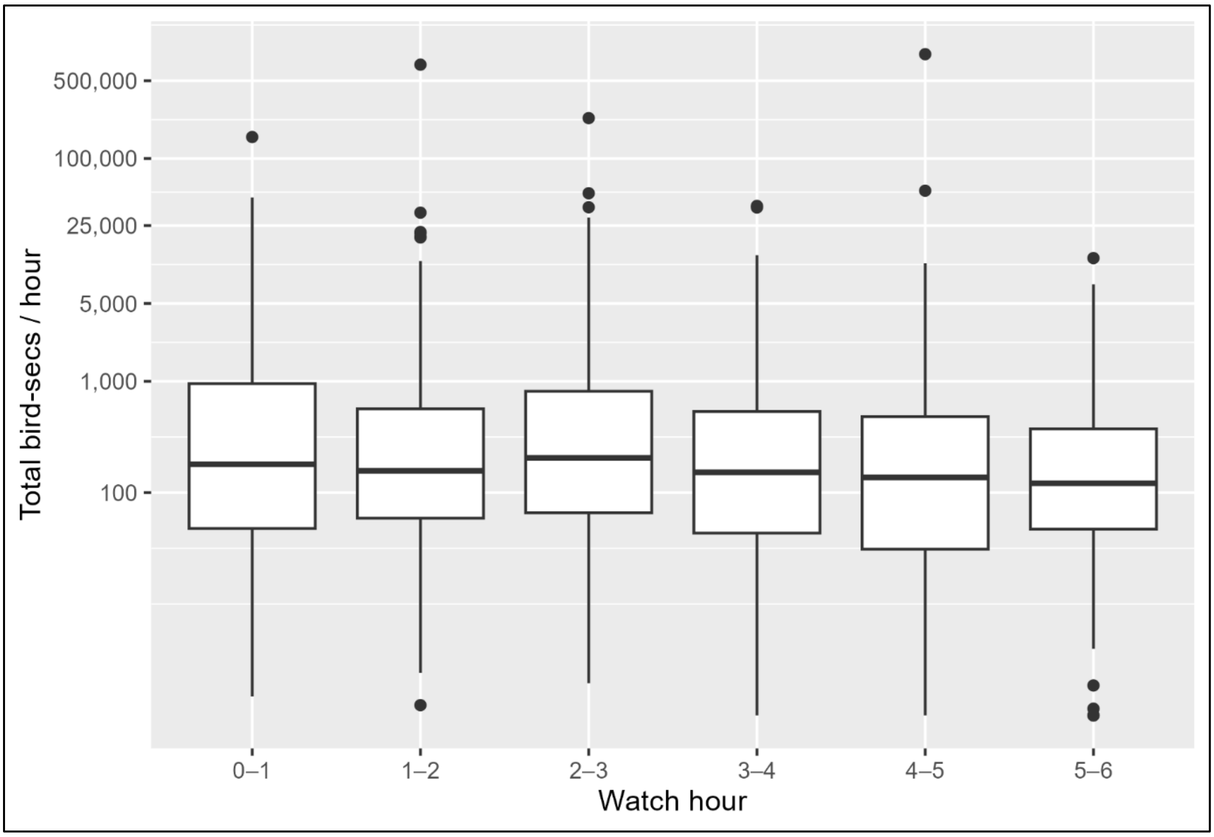


Figure 3.1. Flight activity recording rate per watch hour in 6-hour Ecology Ireland vantage point watches.

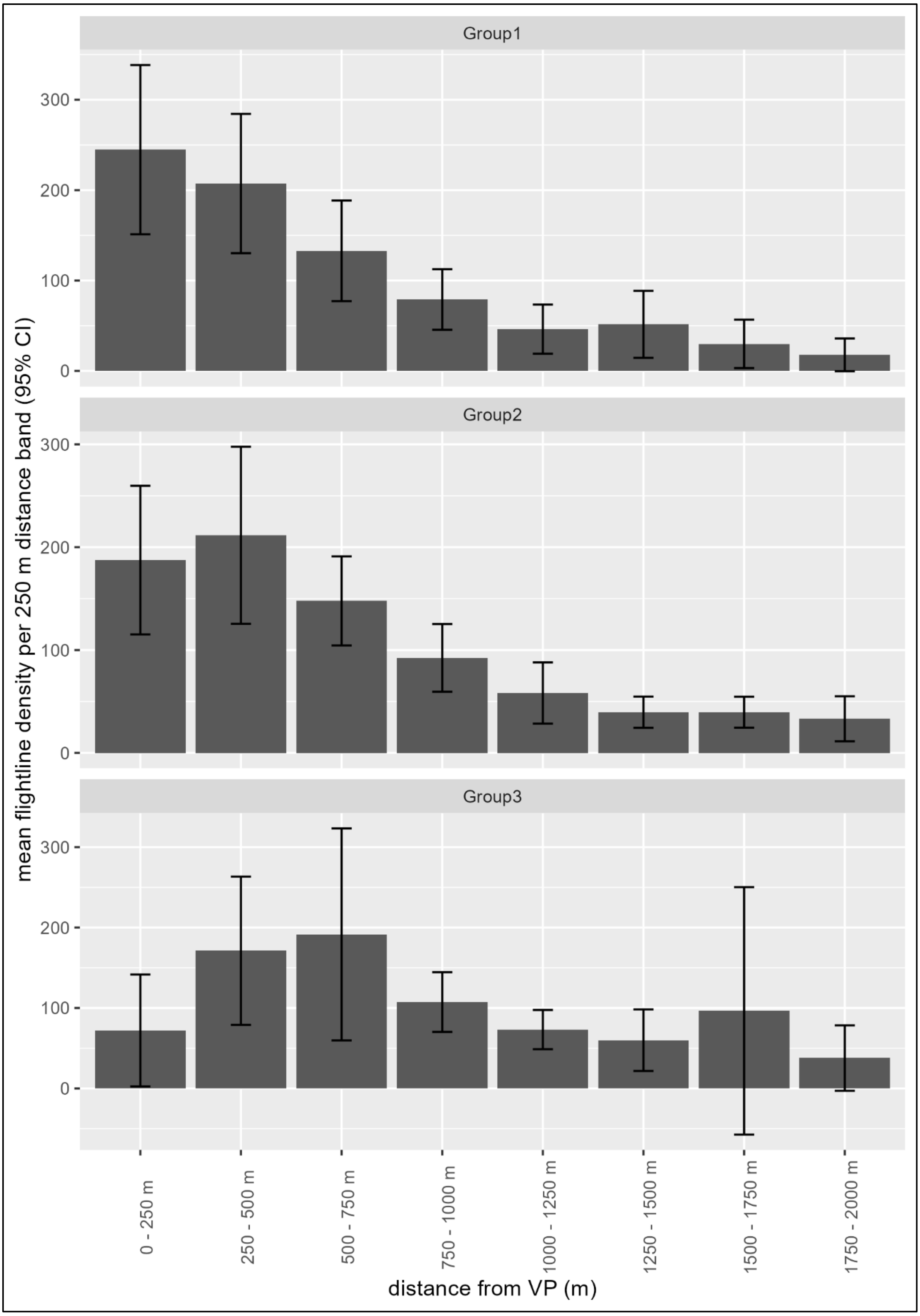


Figure 3.2. Relationship between flightline density and distance from vantage point location in the Ecology Ireland dataset for small (Group 1), medium (Group 2) and large (Group 3) species, including data from a 200 m wide corridor along the River Brosna.

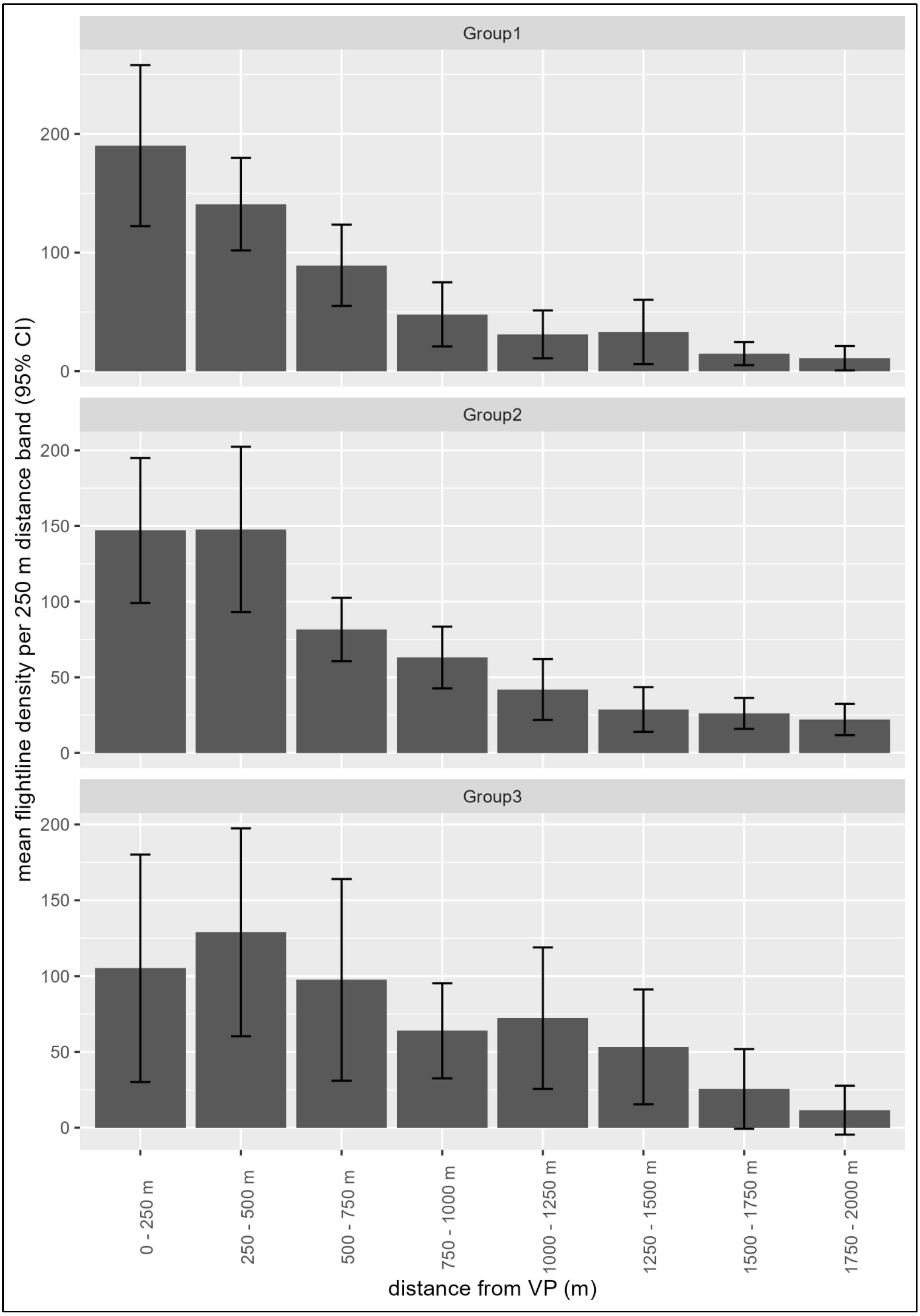


Figure 3.3. Relationship between flightline density and distance from vantage point location in the Ecology Ireland dataset for small (Group 1), medium (Group 2) and large (Group 3) species, excluding data from a 200 m wide corridor along the River Brosna.

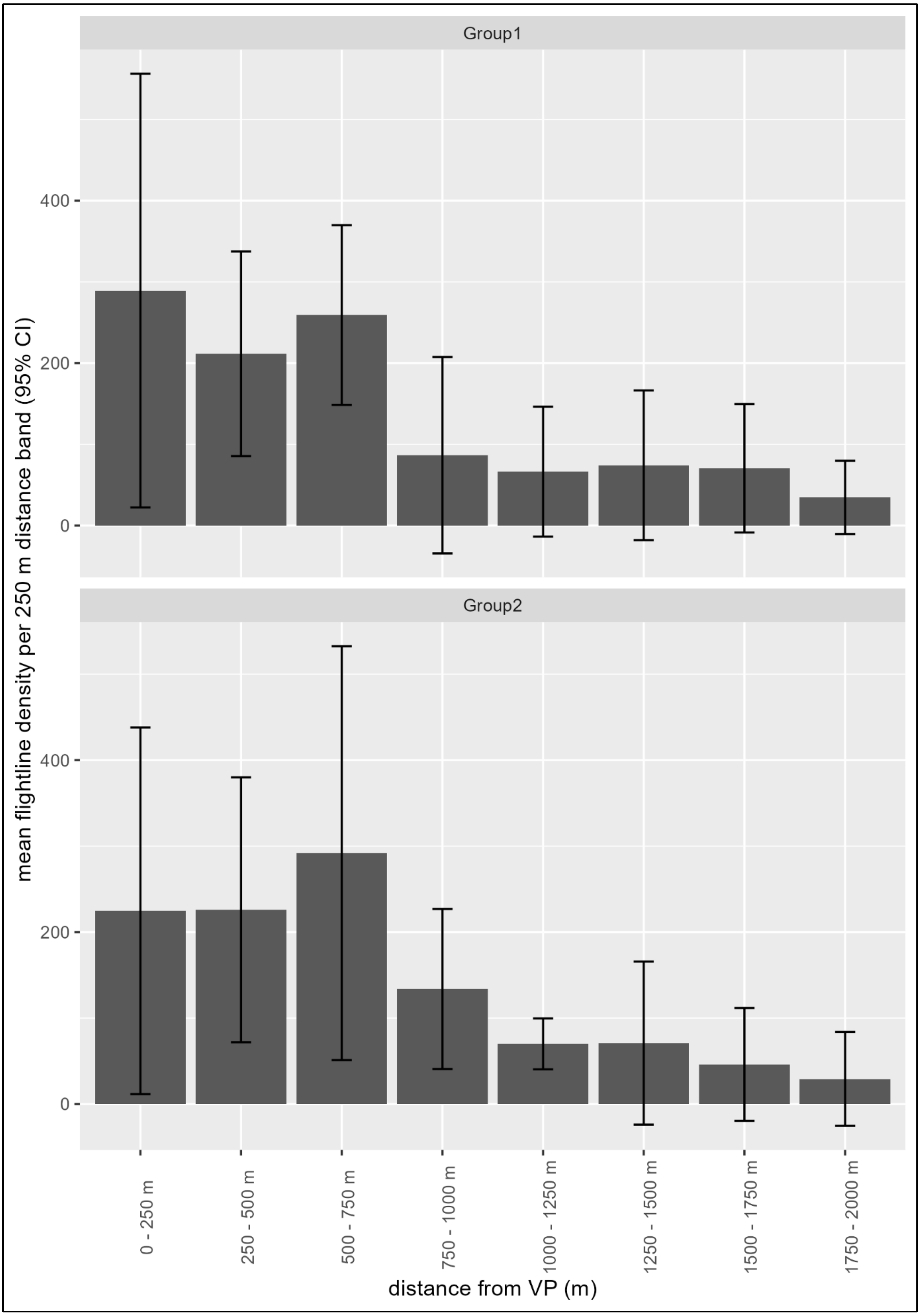


Figure 3.4. Relationship between flightline density and distance from vantage point location in the TOBIN dataset for small (Group 1) and large (Group 2) species, including data from a 200 m wide corridor along the River Brosna.

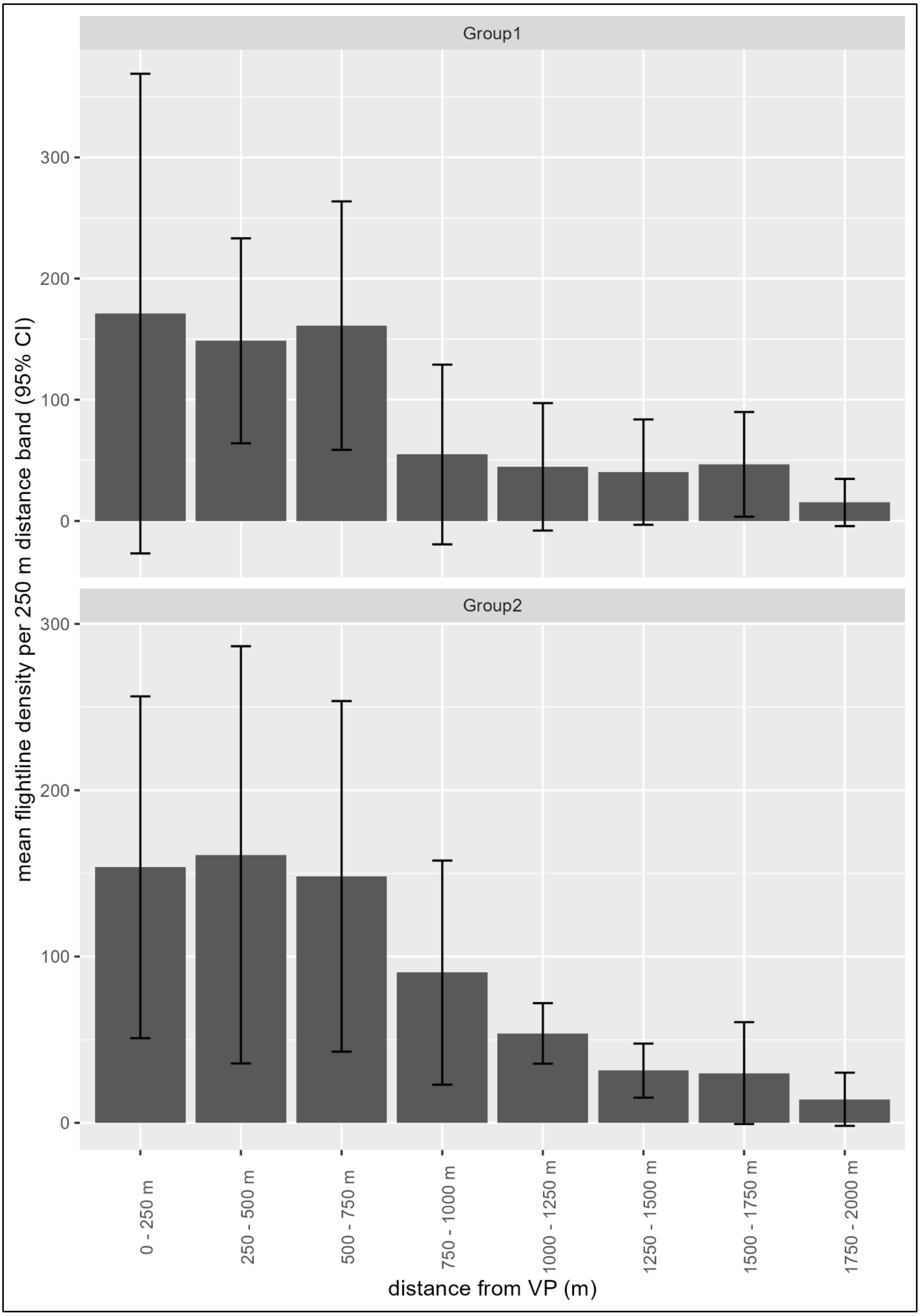
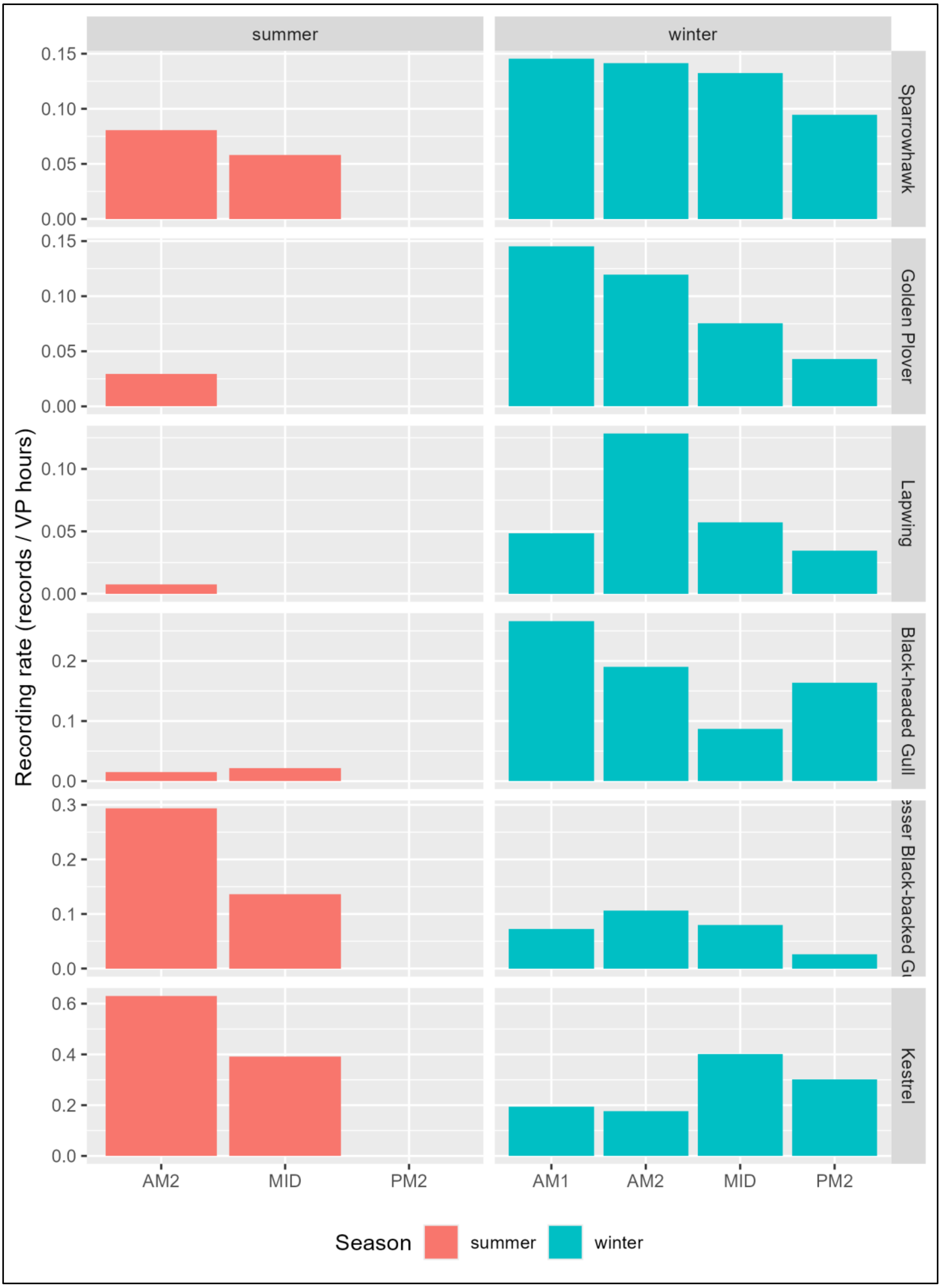


Figure 3.5. Relationship between flightline density and distance from vantage point location in the TOBIN dataset for small (Group 1) and large (Group 2) species, excluding data from a 200 m wide corridor along the River Brosna.

Summer: AM2 = 2 hours after sunrise to 6 hours after sunrise; MID = 6 hours after sunrise to 6 hours before sunset; PM2 = 6 hours before sunset to 2 hours before sunset. Winter: AM1 = 1 hour before sunrise to 1 hour after sunrise; AM2 = 1 hour after sunrise to 3 hours after sunrise; MID = 3 hours after sunrise to 3 hours before sunset; PM2 = 3 hours before sunset to 1 hour before sunset. There was not sufficient survey effort to calculate recording rates for the AM1 period in summer or for the PM1 period in both seasons.

Figure 3.6. Recording rates in the Ecology Ireland vantage point survey of Mute Swan, Whooper Swan, Mallard, Cormorant Little Egret and Grey Heron during the early morning, mid-morning, midday and mid-afternoon periods.



Summer: AM2 = 2 hours after sunrise to 6 hours after sunrise; MID = 6 hours after sunrise to 6 hours before sunset; PM2 = 6 hours before sunset to 2 hours before sunset. Winter: AM1 = 1 hour before sunrise to 1 hour after sunrise; AM2 = 1 hour after sunrise to 3 hours after sunrise; MID = 3 hours after sunrise to 3 hours before sunset; PM2 = 3 hours before sunset to 1 hour before sunset. There was not sufficient survey effort to calculate recording rates for the AM1 period in summer or for the PM1 period in both seasons.

Figure 3.7. Recording rates in the Ecology Ireland vantage point survey of Sparrowhawk, Golden Plover, Lapwing, Black-headed Gull, Lesser Black-backed Gull and Kestrel during the early morning, mid-morning, midday and mid-afternoon periods.

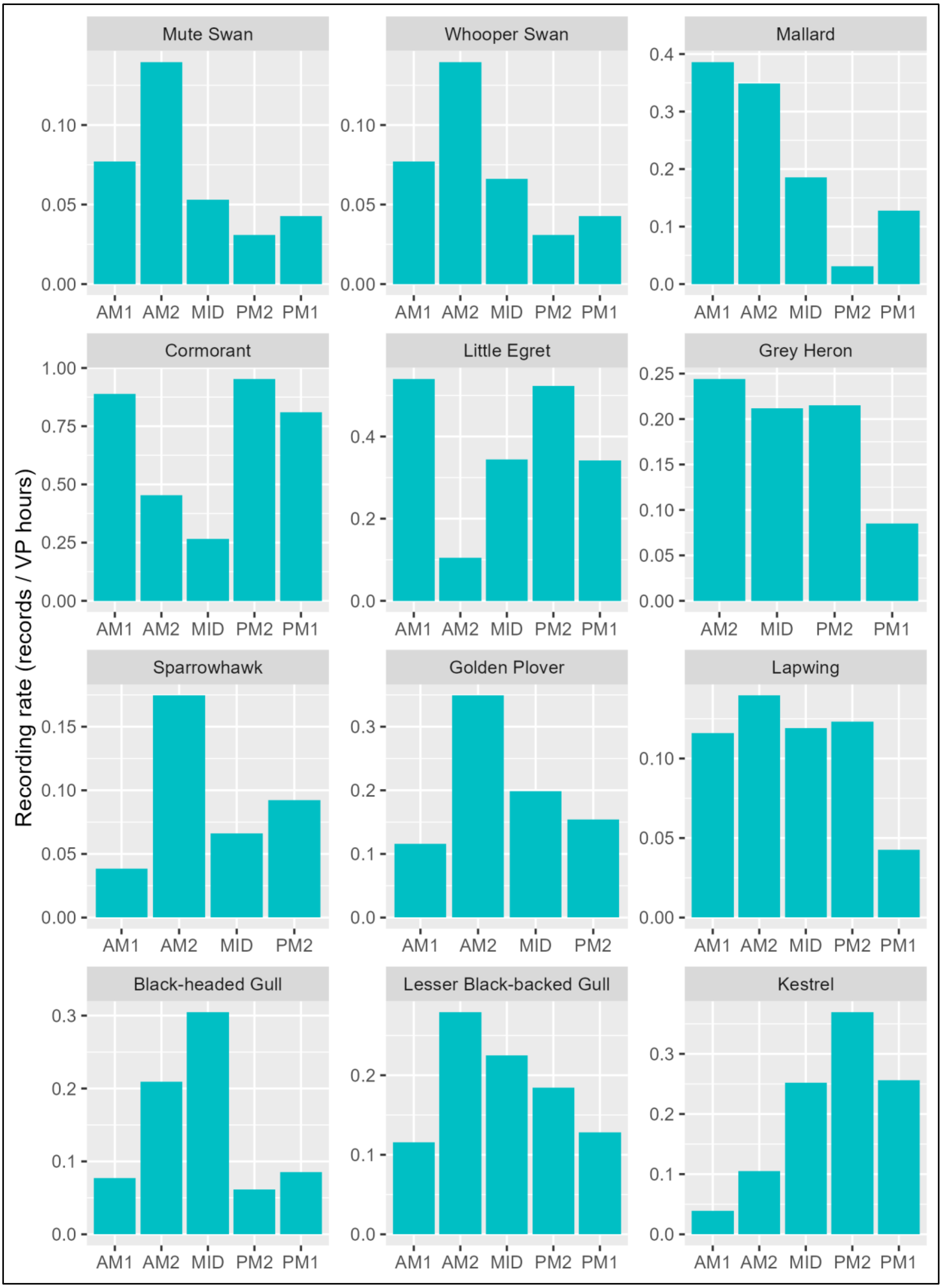
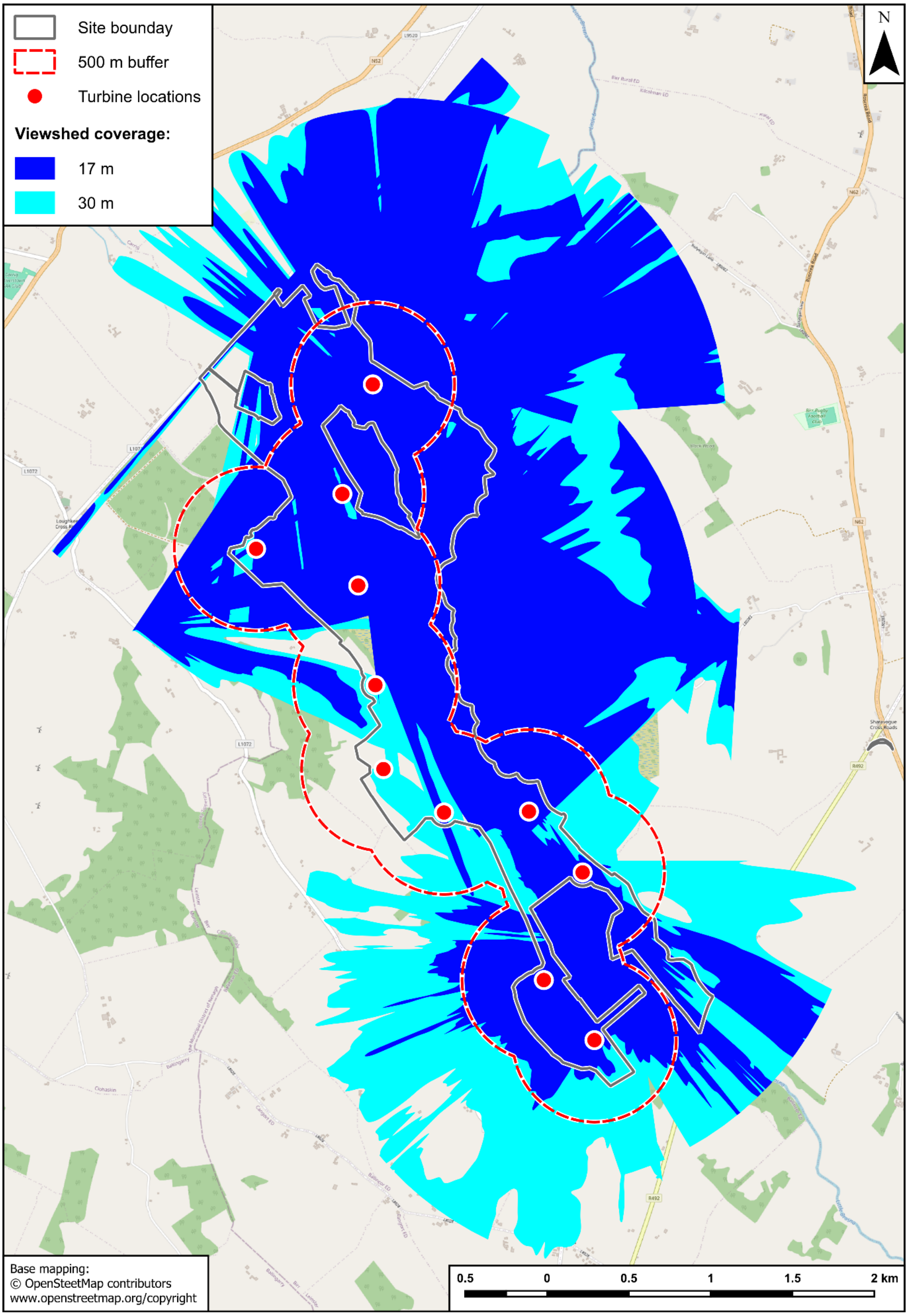
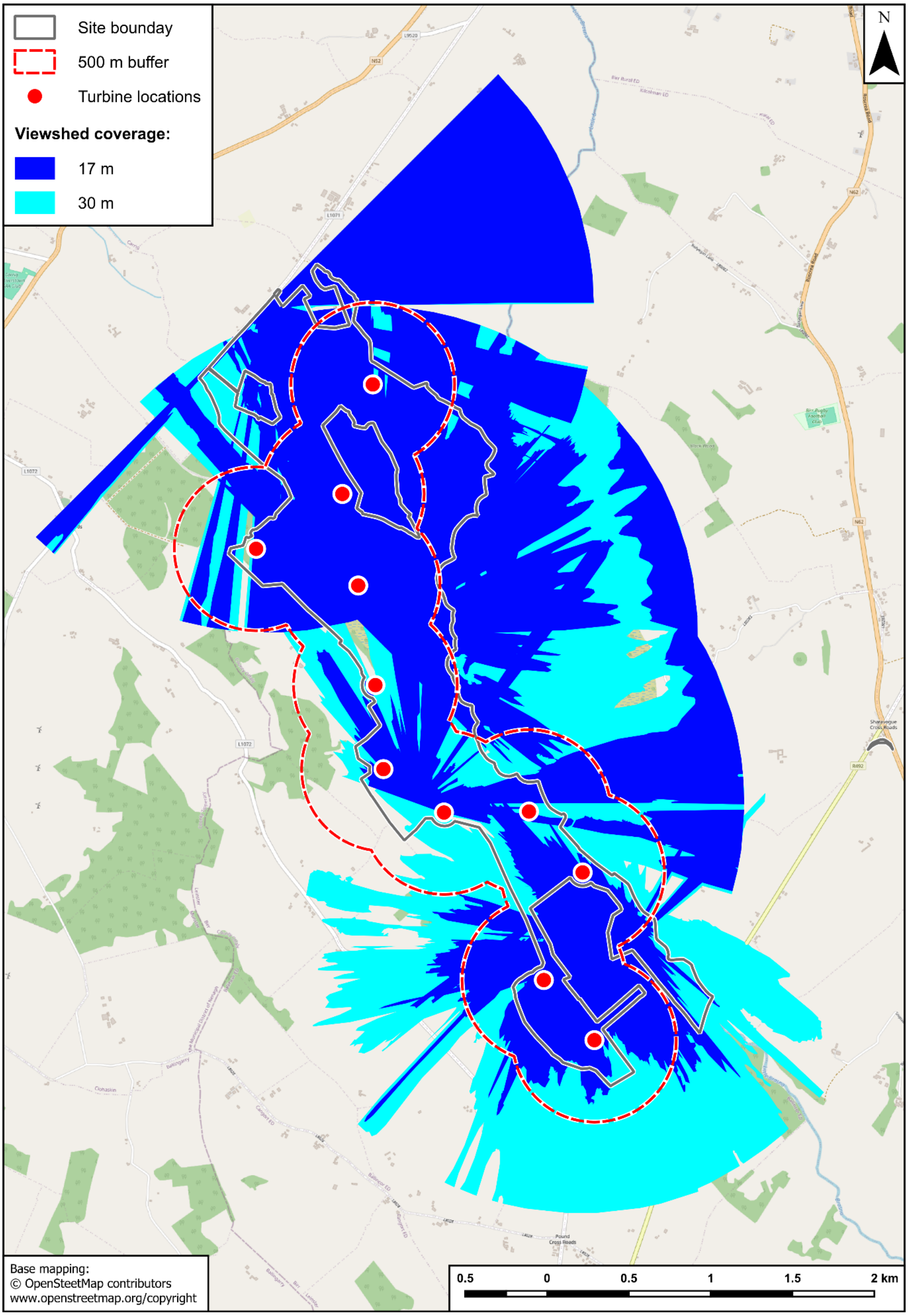


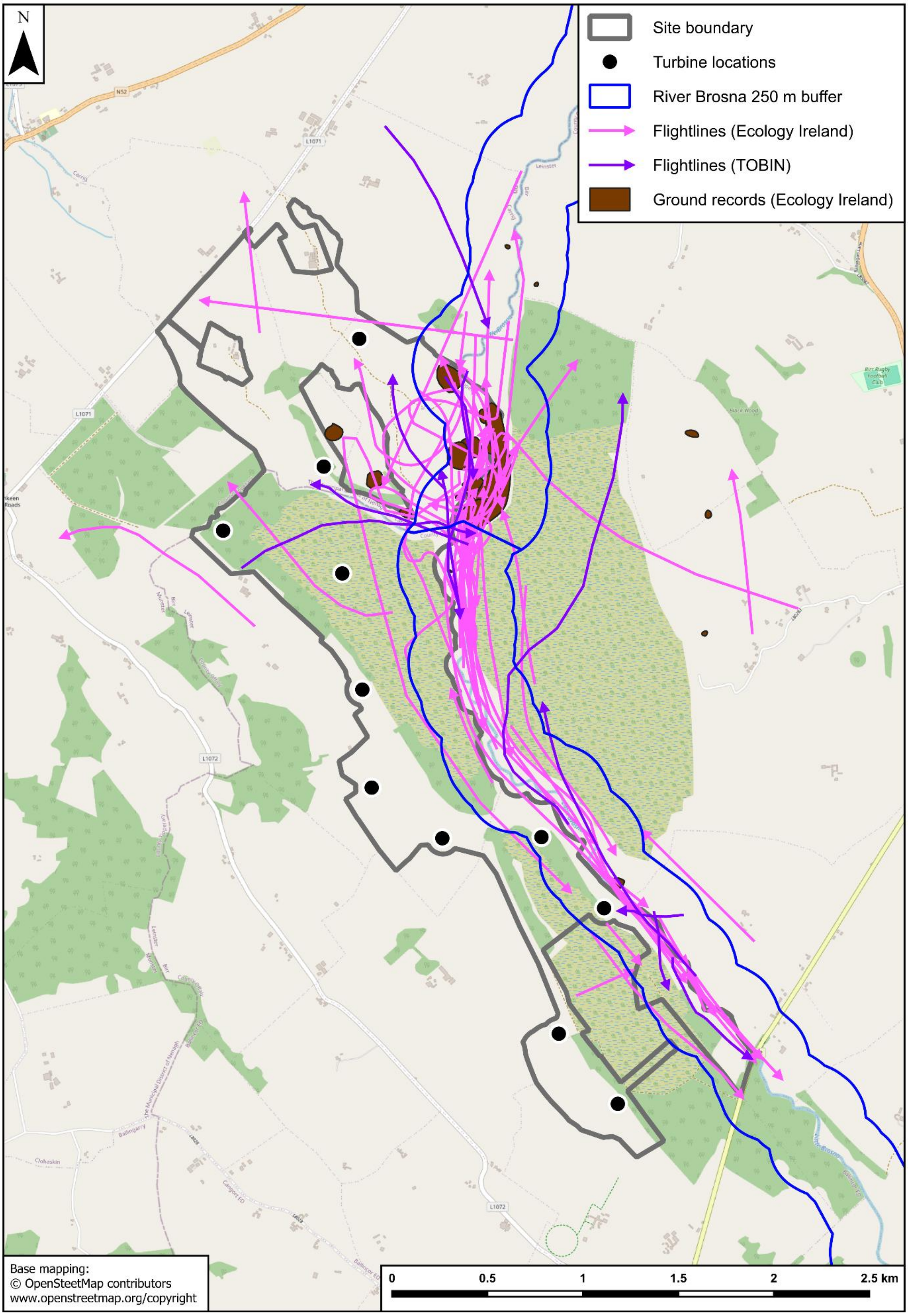
Figure 3.8. Winter recording rates in the TOBIN vantage point surveys during the early morning, mid-morning, midday and mid-afternoon and evening periods.



Map 3.1. Coverage of the Ecology Ireland 1.5 km viewsheds with overlaps removed at 17 m and 30 m above ground level.



Map 3.2. Coverage of the TOBIN viewsheds at 17 m and 30 m above ground level.



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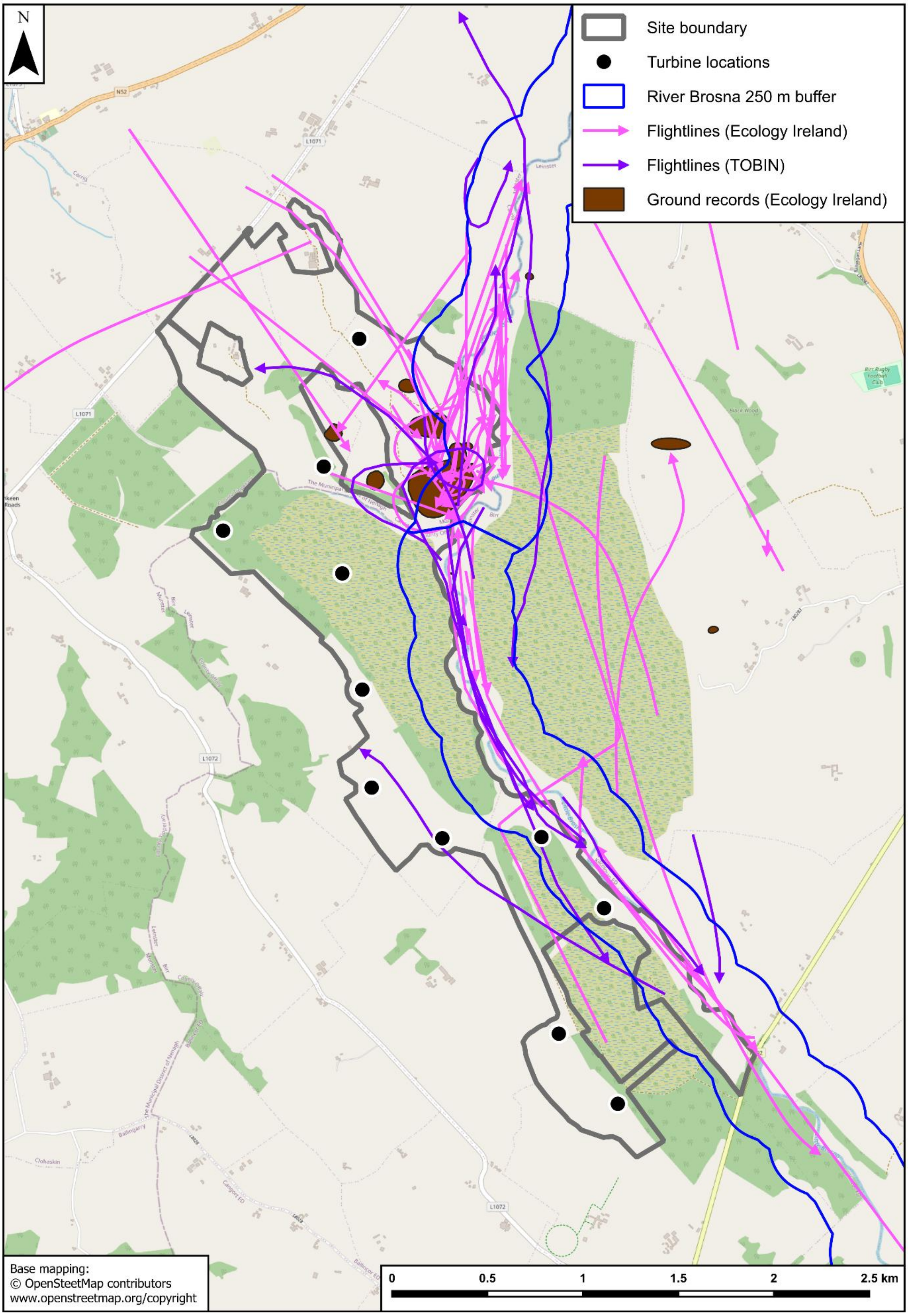
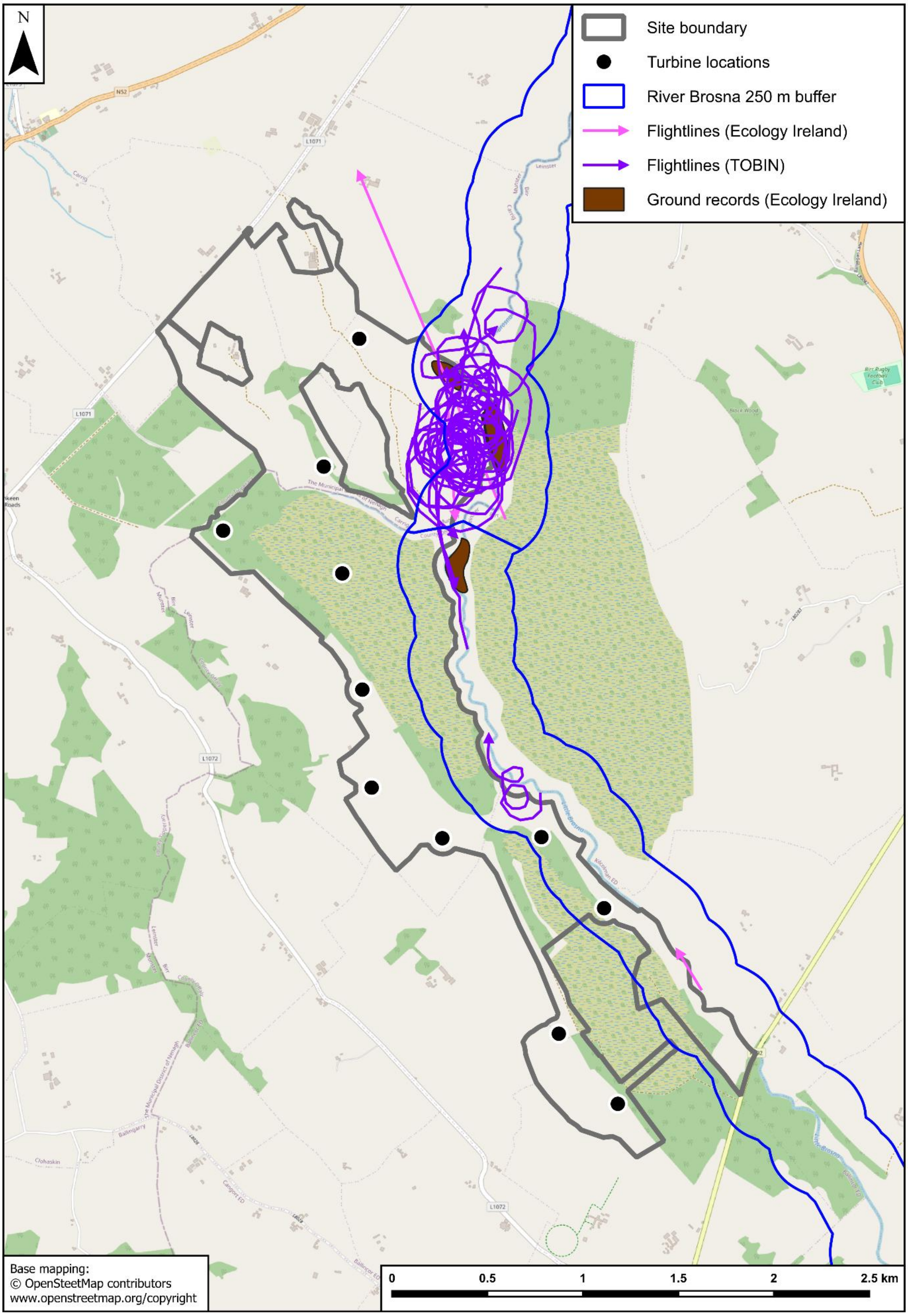
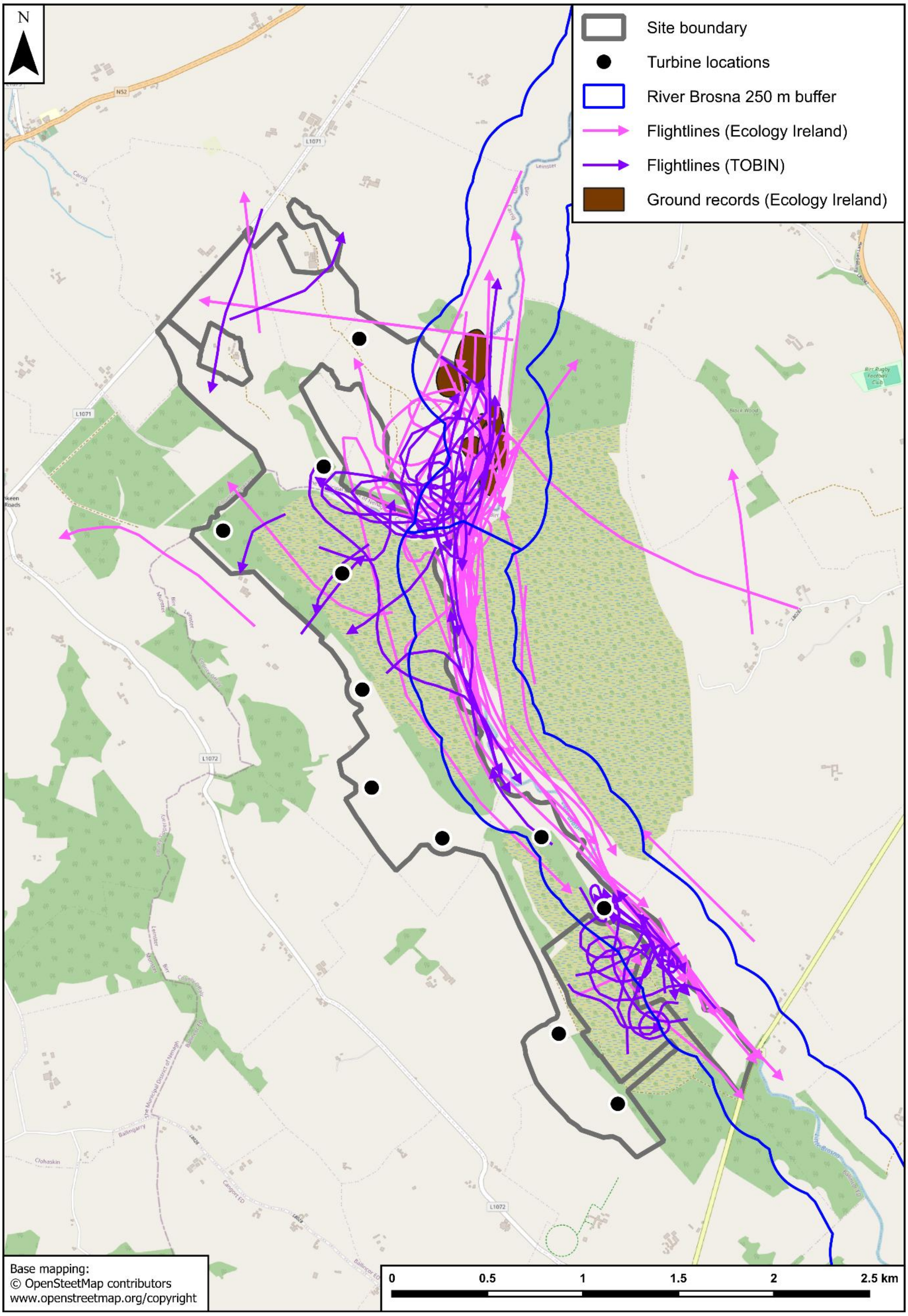
Map 3.3. Mute Swan flightlines.



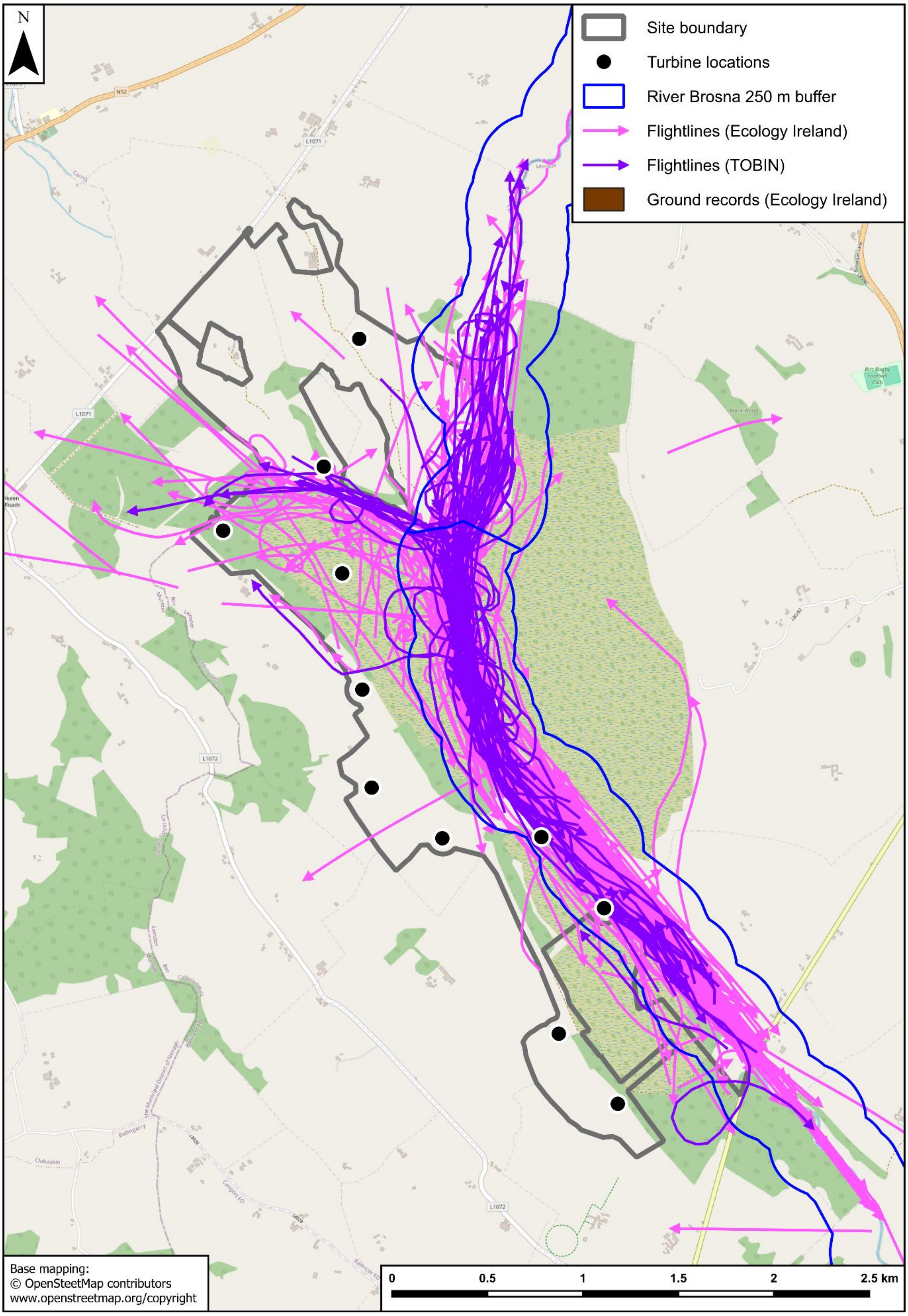
Map 3.4. Whooper Swan flightlines.



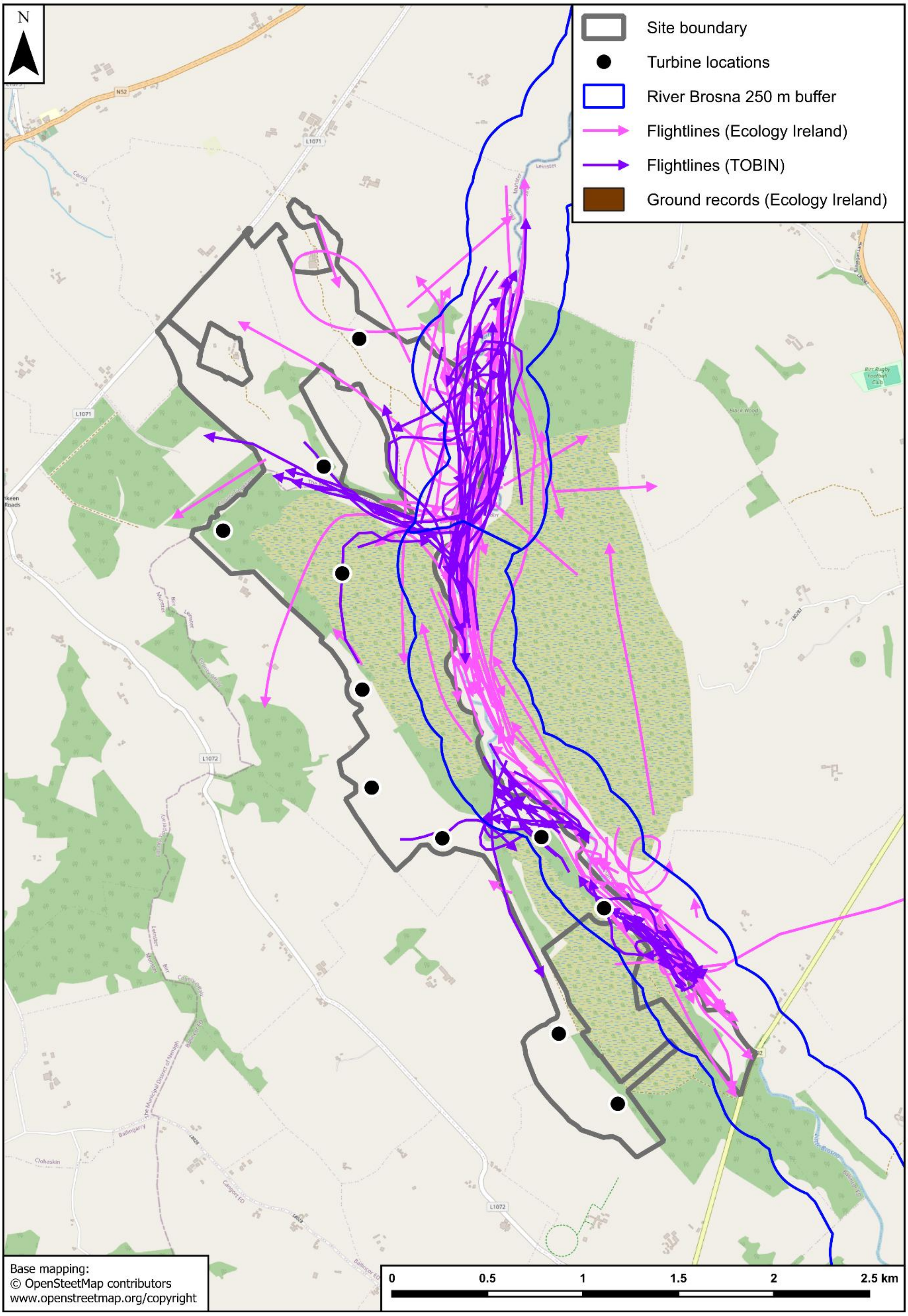
Map 3.5. Wigeon flightlines.



Map 3.6. Mallard flightlines.



Map 3.7. Cormorant flightlines.



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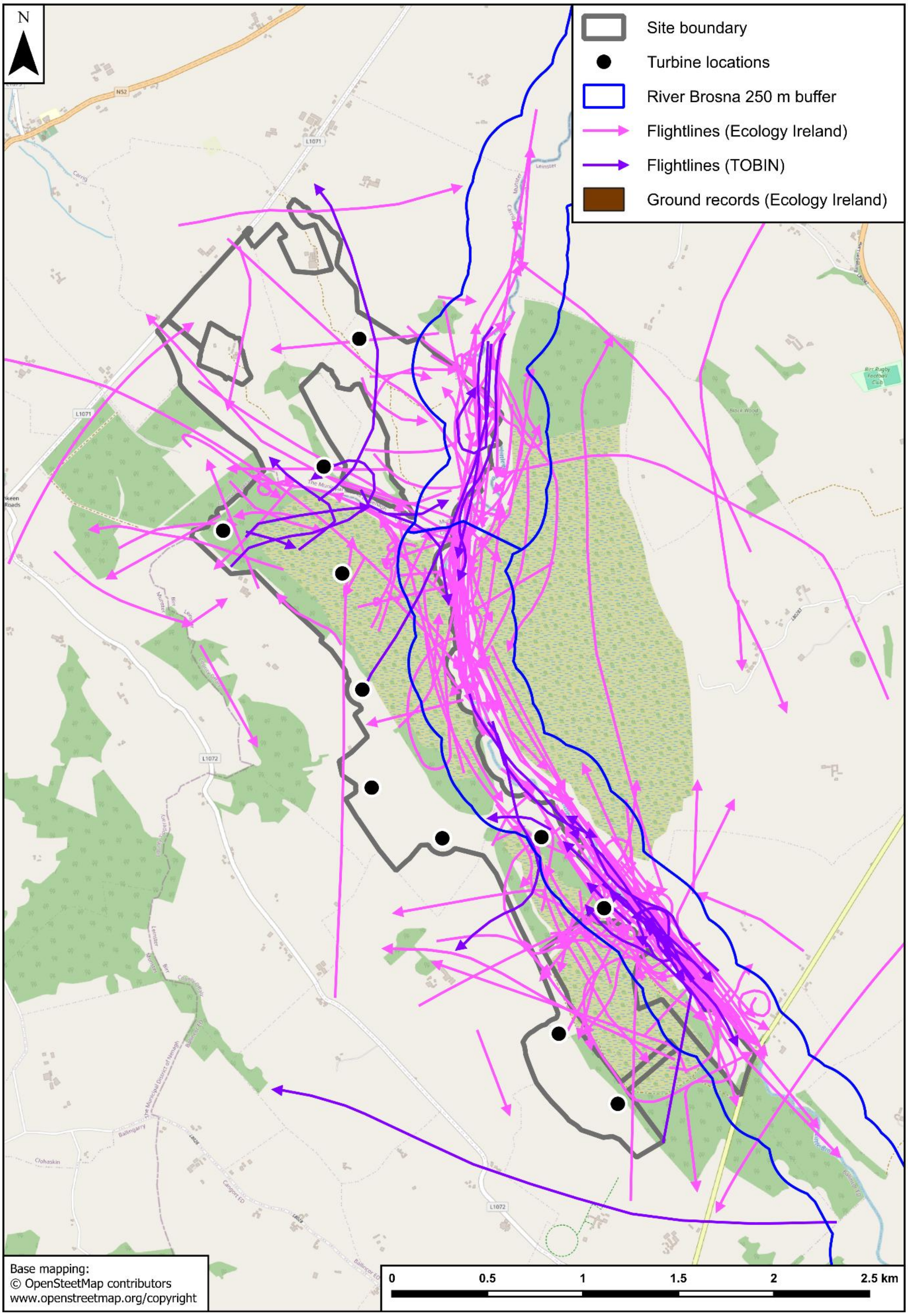
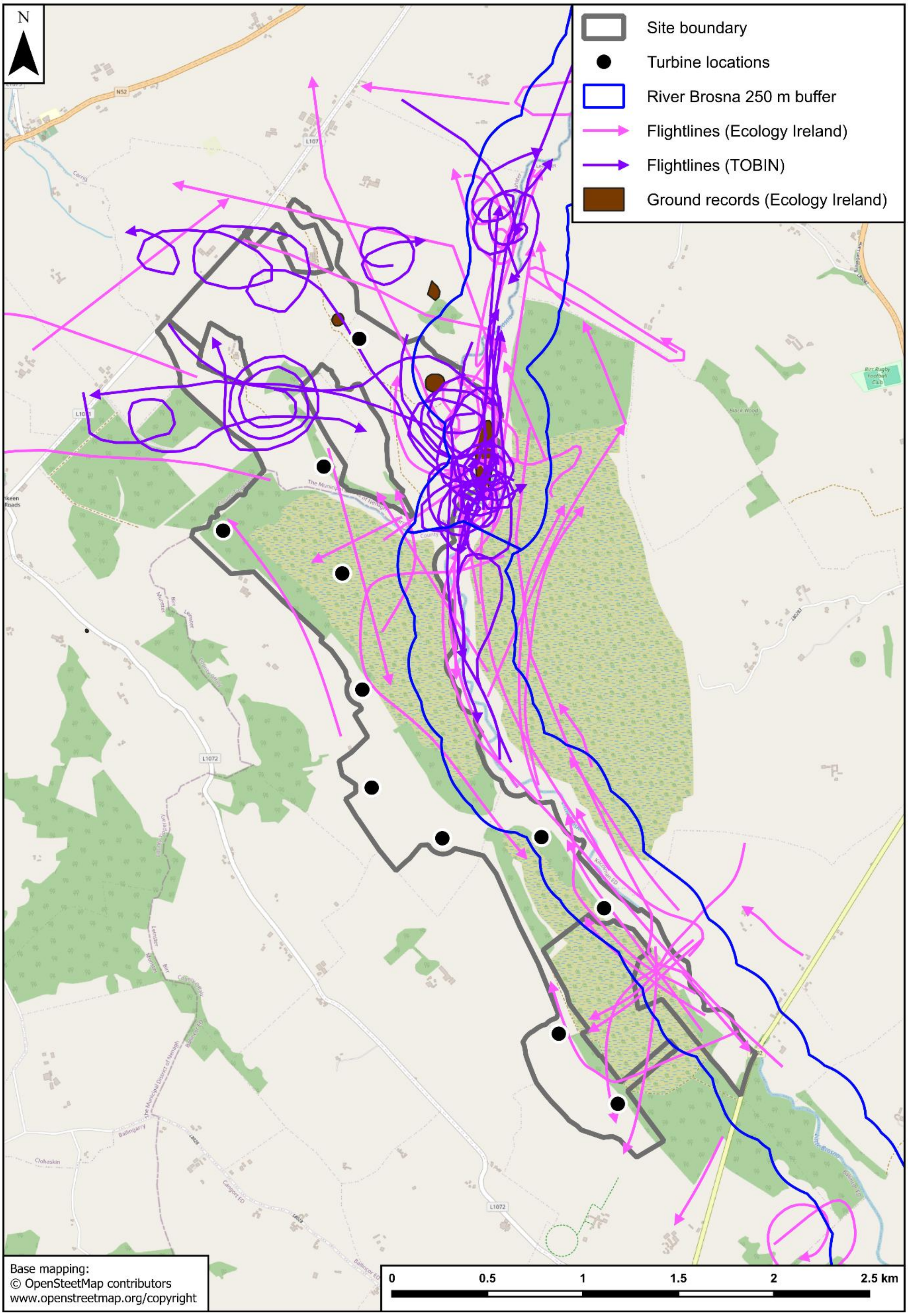
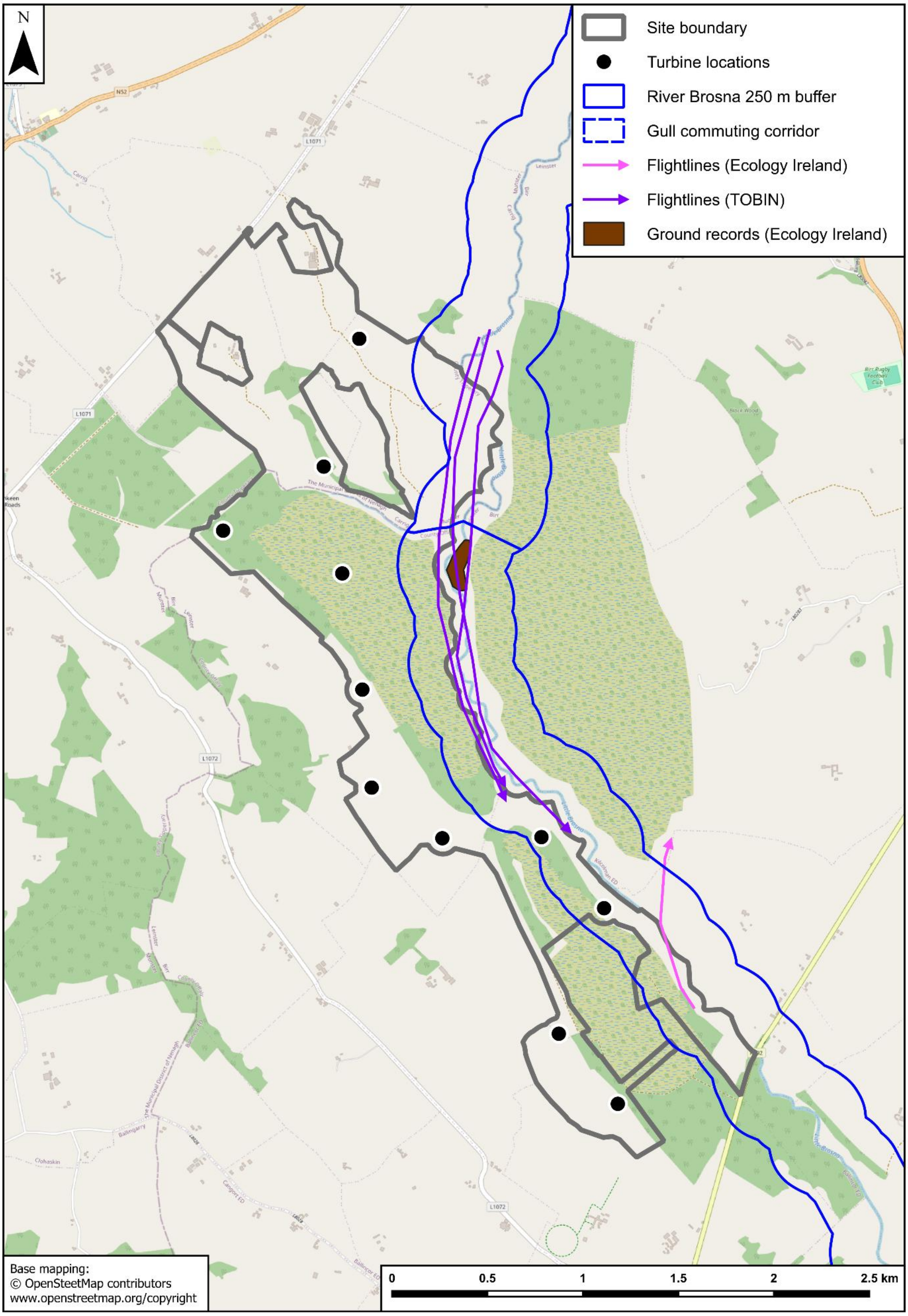
Map 3.8. Little Egret flightlines.



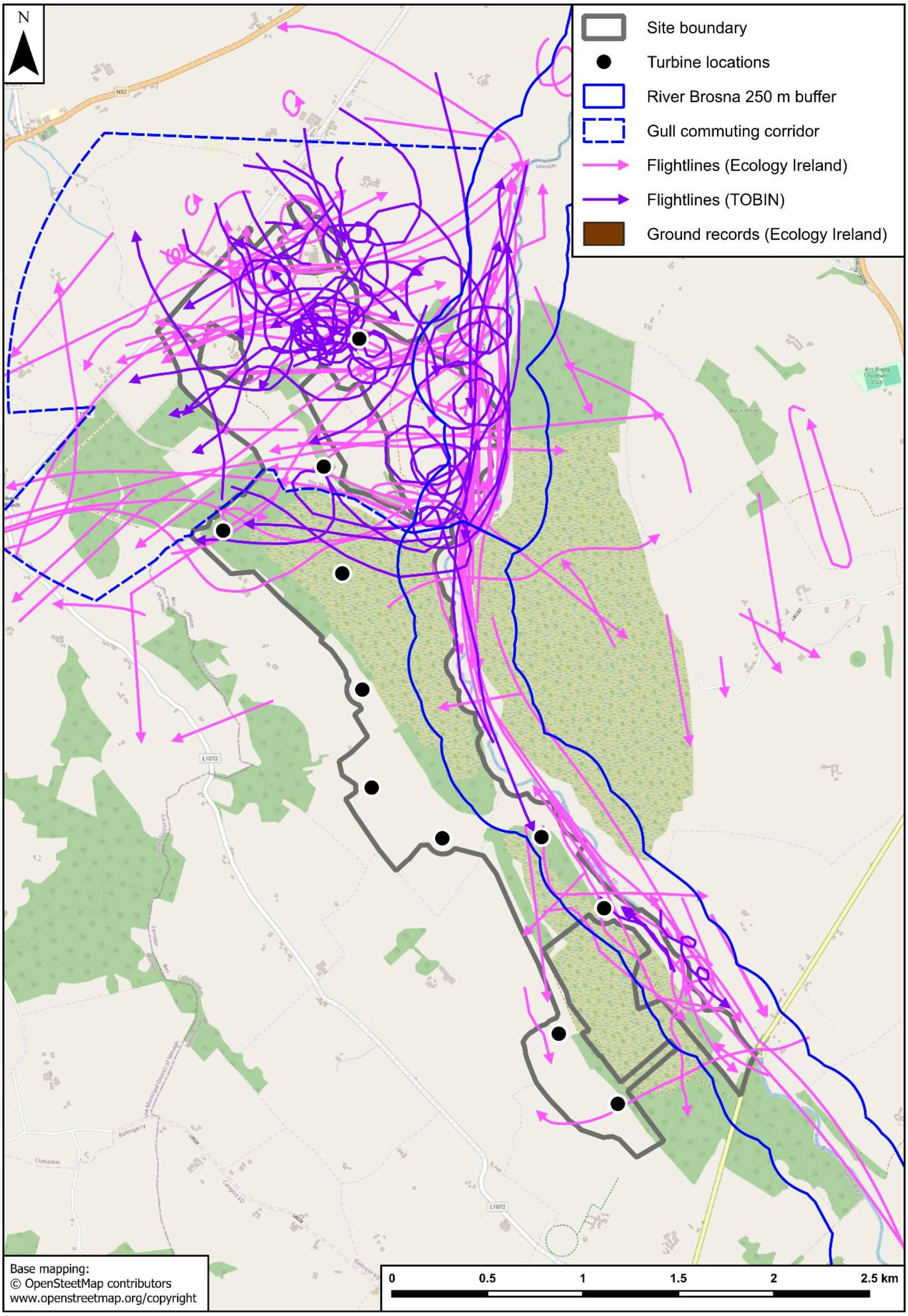
Map 3.9. Grey Heron flightlines.



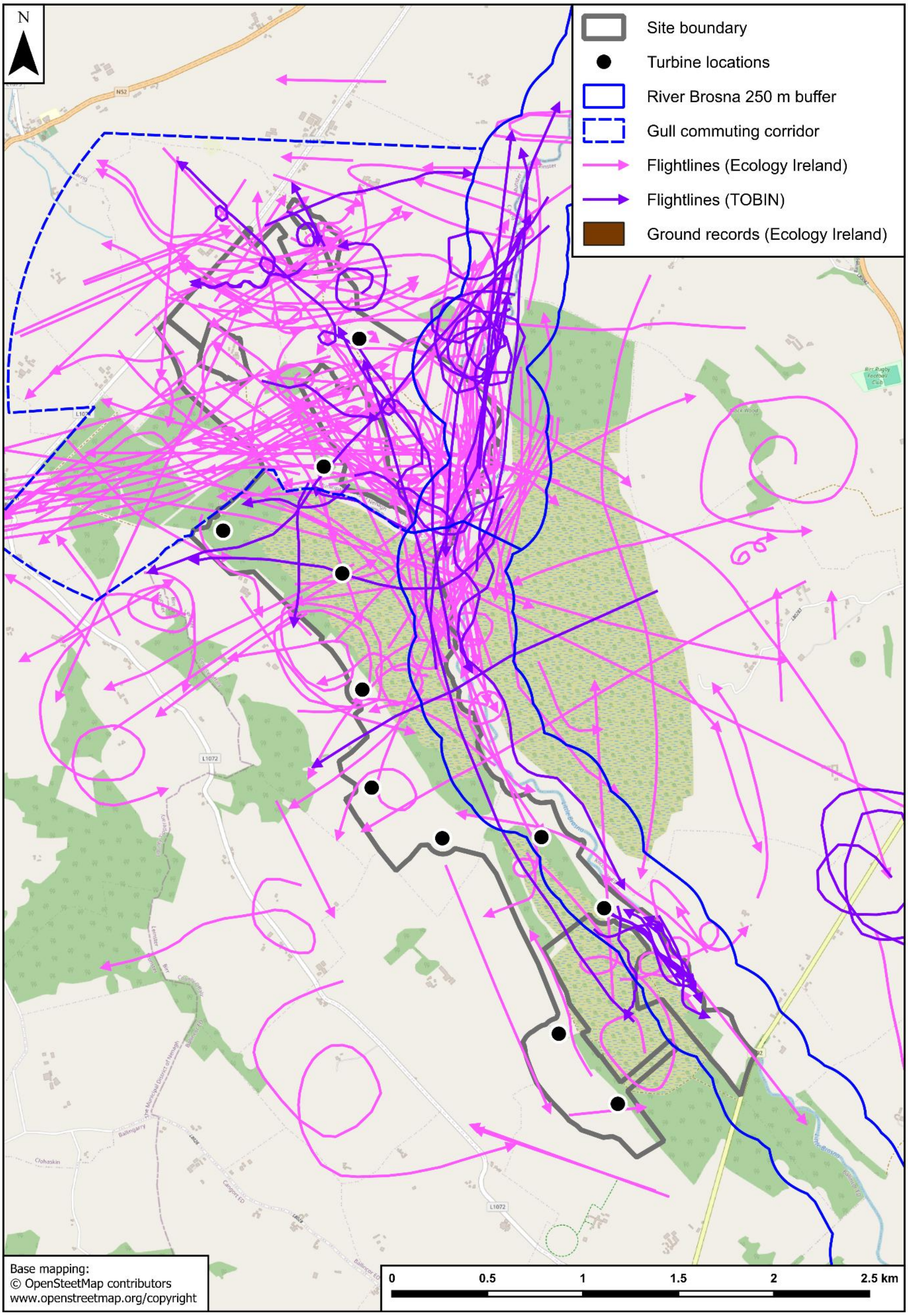
Map 3.10. Lapwing flightlines.



Map 3.11. Black-tailed Godwit flightlines.



Map 3.12. Black-headed Gull flightlines.



Map 3.13. Lesser Black-backed Gull flightlines.

4. COLLISON RISK MODELLING RESULTS

4.1. INTRODUCTION

The results from the sequential stages of the NatureScot collision risk model are described below. The detailed results tables for the intermediate stages are included in Appendix 1, with the final collision risk estimates used for the collision risk assessment presented in this chapter.

4.2. STAGE A: FLIGHT ACTIVITY

4.2.1. Flight activity densities

The monthly daytime flight activity densities calculated in Stage A of the collision risk model are shown in Table A1.1 and Table A1.2 in Appendix 1. These are the values that would be entered in the *Daytime bird density* row in the Stage A section of the NatureScot spreadsheet if the spreadsheet was being used for the modelling.

Table A1.1 shows the densities calculated using data from all the qualifying watches while Table A1.2 shows the densities calculated using only the watches that complied with the NatureScot vantage point survey guidance. The mean ratios of these densities were 1.25 (range 0.60–3.32) for the 17 m viewshed height and 1.14 (range 0.13–3.32) for the 30 m viewshed height. However, the extreme values were for species that only occurred occasionally. For the regularly occurring species, the range was 0.62–1.64.

For each species, the highest of the two density values was selected for the collision risk model. Overall, out of the 27 species analysed, the densities from all watches were selected for 6 species for the 17 m viewshed height, and 10 species for the 30 m viewshed height.

The daytime flight activity densities in Table A1.1 and Table A1.2 are weighted averages of the flight activity densities for each vantage point. These were calculated using the formula provided in the NatureScot guidance (Equation A2). The weightings included in the averaging generally did not have large effects on the mean densities (Table 4.1). The largest differences mainly occurred in species that had highly concentrated patterns of flight activity.

Table 4.1. Ratios of the weighted:unweighted daytime flight activity densities.

Model	Section	Viewshed height	Ratio	
			Mean	Range
unstructured		17 m	1.14	0.54-2.18
unstructured		30 m	1.11	0.56-2.02
structured	Brosna S	17 m	1.21	0.85-1.88
structured	Brosna S	30 m	1.11	0.88-1.60
structured	Commuting corridor	17 m	1.32	1.05-1.60
structured	Commuting corridor	30 m	1.12	0.97-1.26
structured	Other	17 m	1.21	0.78-1.92
structured	Other	30 m	1.05	0.49-1.98

The flight activity densities calculated by the spatially-structured models for the sections defined to represent high concentrations of flight activity were factors of 2-64 times higher than the densities in the remainder of the survey area (Table 4.2).

Table 4.2 does not include the Brosna N section, as this section did not have any turbines so was not included in the collision risk model. The densities of Whooper Swan, Wigeon and Black-tailed Godwit in Table 4.2 are 2–65 times lower than their densities in the Brosna N section in Table 3.4.

Table 4.2. Mean flight activity densities at potential collision height (birds/km^2/month) in the different sections used for the spatially-structured models.

Species	Viewshed height	Brosna S	Commuting corridor	Other
Mute Swan	17 m	135		3
	30 m	54		4
Whooper Swan	17 m			421
	30 m			236
Wigeon	17 m			196
	30 m			69
Mallard	17 m	1,254		48
	30 m	1,055		20
Cormorant	17 m	1,724		32
	30 m	1,351		21
Little Egret	17 m	159		13
	30 m	57		4
Grey Heron	17 m	297		92
	30 m	193		52
Lapwing	17 m			661
	30 m			362
Black-tailed Godwit	17 m	8,333		30
	30 m	4,831		18
Black-headed Gull	17 m		5,622	442
	30 m		2,047	372
Lesser Black-backed Gull	17 m		1,979	1,460
	30 m		472	211

The Brosna N section is not included in this table, as this section did not have any turbines so was not included in the collision risk model.

4.2.2. Daylight and nighttime hours

The daylight and nighttime hours per month calculated in Stage A of the collision risk model are shown in Table A1.3 in Appendix 1. These are the values that would be entered in the *Daylight hours per month* and *Nighttime hours per month* rows in the Stage A section of the NatureScot spreadsheet.

4.3. STAGE B: TRANSITS

4.3.1. Nocturnal correction factors

The nocturnal correction factors for species with nocturnal activity rankings greater than one are shown in Table A1.4 in Appendix 1. These represent the correction for nocturnal flight activity that is applied by $f_{night} \times t_{night}$ term in Equation B1. That is the formula that generates the *Projected number of rotor transits* values in the Stage B section of the NatureScot spreadsheet.

4.3.2. Transits

The monthly number of predicted transits calculated in Stage B of the collision risk model are shown in Table A1.5 in Appendix 1. These are the values that are produced in the *Projected number of rotor transits row* in Stage B section of the NatureScot spreadsheet.

4.4. STAGE C: SINGLE TRANSIT COLLISION RISK

4.4.1. Single transit collision risk values

The single transit collision risk values calculated in Stage C of the collision risk model are shown in Table A1.6 in Appendix 1. These are the values that are produced in the *Single transit risk* rows in the Stage C section of the NatureScot spreadsheet.

All the single transit collision risk values used in the collision risk model were calculated using flapping flight (see Section 2.6.4). The single transit collision risks generated by gliding flight were a mean of 98% lower (range 96-99%).

The upwind and downwind single transit collision risks were the same with a pitch angle of 0° but the upwind risks were around 2.0-2.1 times higher (range 1.5-2.6) with pitch angles of 15° and 30°.

The single transit collision risks calculated with a pitch angle of 15° were a mean of 1.05-1.06 times higher than those calculated with a pitch angle of 0° (range 0.98-1.18). The values calculated with a pitch angle of 30° were a mean of 1.34-1.37 times higher than those calculated with a pitch angle of 0° (range 1.10-1.74).

4.4.2. Interpretation of single transit collision risk values

Single transit collision risk values are often misinterpreted. They represent the probability of a collision on a single transit of the rotor airspace. While they contribute to the calculation of the predicted collision risk, they should not be interpreted as providing any information about the likely magnitude of the predicted collision risk. The predicted transits have a much larger influence on the predicted collision risk and a species with a relatively high single transit collision risk may have a very low predicted collision risk if the number of predicted transits is low.

4.5. STAGE D: NON-AVOIDANCE COLLISION RISK

The non-avoidance collision risk values calculated in Stage D of the collision risk model are shown in Table A1.7 in Appendix 1. These are the values that are produced in the *Collision rates before avoidance row* in the Stage D section of the NatureScot spreadsheet.

4.6. STAGE E: COLLISION RISK AFTER AVOIDANCE

4.6.1. Monthly collision risks

The monthly collision risk after avoidance values calculated in Stage E of the collision risk model are shown in Table A1.8 in Appendix 1. These are the values that are produced in the *Collision rates allowing for avoidance rows in the Stage E* section of the NatureScot spreadsheet.

The values in Appendix 1 are shown rounded to two decimal places (following the formatting of the NatureScot spreadsheet). Note that for some cells, non-zero collision risks < 0.005 are shown as 0.00 due to the rounding. The annual / seasonal collision risks used for the collision risk assessment were calculated from the unrounded monthly collision risks.

4.6.2. Collision risks used for the collision risk assessment

The predicted annual/seasonal collision risks used for the collision risk assessment are shown in Table 4.3. These are the collision risks that were generated by the most suitable avoidance rate for each species using the single transit collision risk values for a pitch angle of 15°.

The output from the NatureScot spreadsheet means that collision risks less than 0.005 (less than 0.01 when rounded to two decimal places) are shown as zero. Therefore, only species/seasons with rounded collision risks ≥ 0.01 are included in Table 4.3.

Table 4.3. Collision risks used for the collision risk assessment.

Species	Season	Avoidance rate	Collisions / year		
			N149	N163	V150
Mute Swan	non-breeding	0.995	0.01	0.02	0.01
Whooper Swan	winter	0.995	0.02	0.05	0.02
White-fronted Goose	all year	0.998	0.00	0.01	0.00
Wigeon	winter	0.980	1.4	2.4	1.4
Teal	all year	0.980	0.00	0.01	0.00
Mallard	all year	0.980	0.56	0.68	0.58
Pintail	all year	0.980	0.01	0.01	0.01
Cormorant	breeding	0.980	0.10	0.12	0.11
	non-breeding	0.980	0.32	0.44	0.33
Little Egret	breeding	0.980	0.01	0.00	0.01
	non-breeding	0.980	0.01	0.05	0.01
Grey Heron	all year	0.980	0.10	0.17	0.11
White-tailed Eagle	all year	0.950	0.02	0.04	0.02
Hen Harrier	all year	0.990	0.01	0.02	0.01
Sparrowhawk	all year	0.980	0.11	0.17	0.11
Buzzard	all year	0.980	1.4	1.7	1.4
Golden Plover	winter	0.996	7.9	9.4	8.1
Lapwing	winter	0.980	1.4	1.6	1.4
Curlew	all year	0.980	0.02	0.02	0.02
Black-tailed Godwit	non-breeding	0.980	3.3	4.7	3.4
Black-headed Gull	non-breeding	0.992	0.31	0.43	0.32
Common Gull	all year	0.992	0.00	0.01	0.00
Lesser Black-backed Gull	autumn	0.995	0.02	0.05	0.02
	spring	0.995	0.01	0.13	0.01
	winter	0.995	0.05	0.04	0.05
Kestrel	all year	0.950	1.4	2.9	1.5
Merlin	all year	0.980	0.00	0.01	0.00
Peregrine	all year	0.980	0.02	0.03	0.02

Collision risks are shown rounded to two significant figures, or to two decimal places if < 0.1. Other species/seasons with collision risk < 0.005 collisions/year: Shoveler, Lapwing (summer), Lesser Black-backed Gull (breeding) and Herring Gull.

4.7. STAGE F: ASSESSING UNCERTAINTY

4.7.1. General

The NatureScot guidance lists three broad categories to consider:

- *uncertainty or variability in flight activity data, including imprecision on flight height estimates and lack of knowledge about night-time behaviour;*
- *uncertainty due to the limitations of the collision model, including the variability of bird dimensions and flight speed, the simplification in shape of a bird and turbine blades; and*
- *uncertainty arising from turbine options yet to be decided, in number, size and speed. These options should include a 'worst case' in terms of the option likely to present greatest bird collision risk.*

In addition, the discussion about Stage F in the NatureScot guidance also refers to the influence of sampling effects and natural variability in bird populations. Other factors that should also be considered are the effects of sampling biases, behavioural effects, and uncertainty about avoidance rates. There are also some issues with aspects of the NatureScot guidance and the design of the NatureScot spreadsheet.

4.7.2. Uncertainty or variability in flight activity data

4.7.2.1 Sampling effects

The results of the simulations that examined the influence of sampling effects are summarised in Figure 4.1. No simulations were carried out for Wigeon or Black-tailed Godwit due to the low number of records in the dataset that was used to parameterise the simulation.

For most species, uncertainty decreased substantially when the number of survey seasons represented in the simulation increased from one to two, with smaller reductions as additional seasons were added. This indicates that most of the reduction in sampling uncertainty occurred when survey coverage increased from one to two seasons, with additional seasons producing only modest reductions in the simulation interval. This suggests that the principal source of uncertainty arises from within-season sampling variability rather than the number of seasons included in the dataset. A strong year effect could still exist, and this type of variation was not included in the simulations. Therefore, the true potential uncertainty due to sampling effects is likely to fall somewhere between the extremes of the one-year and four/five-year ranges shown in Figure 4.1. For this assessment, I have used the two-year ranges to quantify the potential uncertainty due to sampling effects.

I used the simulation ranges to calculate under-estimation and over-estimation ratios. The under-estimation ratios indicated the potential effect if the vantage point survey happened to sample low levels of flight activity relative to the overall distribution of flight activity across the season: e.g., an under-estimation ratio of 3 indicates that the true collision risk is three times higher than the collision risk estimated from the vantage point survey data. The over-estimation ratios indicate the potential effect if the vantage point survey happened to sample high levels of flight activity relative to the overall distribution of flight activity across the season: e.g., an over-estimation ratio of 0.5 indicates that the true collision risk is only half the value of the collision risk estimated from the vantage point survey data. The range from the over-estimation ratio to the under-estimation ratio provides an indication of the uncertainty due to sampling effects around the predicted collision risk.

Table 4.4 shows the uncertainty ranges calculated from the simulations. The species with the largest uncertainty ranges were species with low record rates (Mallard and Sparrowhawk). Golden Plover and Lapwing also had relatively large uncertainty ranges, reflecting their variable patterns of flight activity.

Table 4.4 also shows the uncertainty ranges calculated from Band (2024)'s relative error method. Apart from Sparrowhawk, these ranges were always higher than the ranges calculated from the simulations. This reflected high variability in the monthly flight activity densities. While months outside the seasonal occurrence periods were excluded, the remaining months still included some with zero, or very low flight activity densities. These may have represented true monthly variation, sampling error, or a combination of both. The relative error method also produces symmetric errors, which due to their large values usually resulted in lower limits of the uncertainty range below zero, which is biologically implausible. This reflects the right-skewed nature or bird flight activity, which makes errors based on the normal distribution inappropriate.

Overall, the monthly relative-error method appears poorly suited to flight activity data from vantage point surveys because monthly values aggregate across daily variation. As a result, the method can either inflate uncertainty if days with high levels of activity were aggregated in some months and days with low activity in other months , or understate uncertainty where short-duration peaks are smoothed by monthly aggregation. The frequent occurrence of negative lower bounds further indicates that the approach imposes an inappropriate symmetric error structure on a non-negative and strongly skewed variable.

Table 4.4. Potential uncertainty ranges due to sampling effects in the flight activity data.

Species	Season	Simulation method range	Relative error method range	
			N163	N149 / V150
Whooper Swan	winter	0.56–2.29	0.00–4.63	0.00–4.32
Wigeon	winter		0.00–5.48	0.00–5.59
Mallard	all year	0.51–3.03	0.00–9.02	0.00–10.54
Cormorant	breeding	0.58–2.19	0.00–4.47	0.00–4.17
	non-breeding	0.79–1.32	0.00–4.57	0.00–5.28
Little Egret	non-breeding	0.55–2.47	0.00–6.18	0.00–5.66
Grey Heron	all year	0.55–2.27	0.00–5.54	0.00–5.45
Sparrowhawk	all year	0.47–3.34	0.00–3.16	0.00–3.43
Golden Plover	winter	0.54–2.47	0.00–5.44	0.00–5.27
Lapwing	winter	0.53–2.45	0.00–4.96	0.00–5.16
Black-tailed Godwit	all year		0.00–9.18	0.00–9.38
Kestrel	all year	0.66–1.66	0.00–3.54	0.00–2.62

The simulation method ranges are from the two-year simulations. No uncertainty ranges were calculated from the simulation method for Black-tailed Godwit and Wigeon because there were too few records to model. The uncertainty ranges from the relative error method are shown separately for the N163 and the N149 / V150 turbines.

4.7.2.2 Nocturnal flight activity

The effects on the nocturnal correction factors of increasing or decreasing the nocturnal activity rankings by one unit caused potential variation in the predicted collision risks of around 10-30% (Table 4.5).

Table 4.5. Variation in nocturnal correction factors generated by decreasing or increasing the nocturnal activity rankings by one unit, and the range of effects on the predicted collision risks generated by this variation.

Species	Season	Nocturnal correction factors calculated using			Range of effects on collision risk
		NAR-1	NAR	NAR+1	
Whooper Swan	winter	1.00	1.27	1.55	0.79-1.21
Wigeon	winter	1.25	1.51	1.76	0.83-1.17
Mallard	all year	1.17	1.34	1.51	0.87-1.13
Cormorant	breeding	1.00	1.00	1.15	1.00-1.15
	non-breeding	1.00	1.00	1.37	1.00-1.37
Little Egret	non-breeding	1.00	1.35	1.71	0.74-1.26
Grey Heron	all year	1.00	1.24	1.48	0.81-1.19
Sparrowhawk	all year	1.00	1.00	1.24	1.00-1.24
Golden Plover	winter	1.00	1.35	1.71	0.74-1.26
Lapwing	winter	1.00	1.38	1.77	0.72-1.28
Black-tailed Godwit	all year	1.00	1.24	1.48	0.81-1.19
Kestrel	all year	1.00	1.00	1.24	1.00-1.24

For species with minimum or maximum nocturnal correction factors the NAR-1 or NAR+1 value is the same as the NAR value.

4.7.2.3 Natural variability

Species populations show natural variability from year to year due to stochastic effects and external factors (such as cold winters), while some populations may show longer term increasing or decreasing trends.

If the usage of the wind farm site tracks the population variation, the collision risk will change but the significance of the collision risk should remain the same as the population against which the risk is assessed will increase or decrease in line with the changes in the collision risk. However, for territorial species, population increases may cause expansion into unoccupied habitat rather than increased occurrence within already occupied habitat.

Even if the population remains the same, there may be variation in usage of the wind farm site due to habitat changes within the site. Unlike many wind farm sites that are dominated by commercial forestry, such habitat changes may not have large long-term effects on the usage of the site over the lifetime of the project. However, for several waterbird species, there may be large annual variation driven by flooding patterns associated with water levels in the Little Brosna River.

4.7.2.4 Attraction

While wind farms are generally considered to cause displacement impacts to sensitive bird populations, there are some circumstances where development of a wind farm could cause increased bird activity within a site. This would result from habitat changes associated with the wind farm development that make the area more suitable for certain species. For example, placement of turbines in closed-canopy forestry creates open habitat that could potentially attract bird species that did not use the closed-canopy forestry. However, in this case, the proposed turbines will mainly be located in open bog or agricultural land, and no habitat changes of a nature and scale sufficient to significantly alter patterns of bird flight activity are likely to occur.

4.7.2.5 Sampling biases

Sampling biases could arise if the survey effort has uneven spatial, seasonal or diel coverage in relation to factors that affect species occurrence.

Spatial coverage

Uneven spatial coverage is difficult to avoid in vantage point surveys of large wind farm sites due to overlapping viewsheds and the under-detection of distant flightlines. The analyses of distance effects (Section 3.3.1) showed large declines in flightline densities with distance from vantage points. These effects were larger for smaller species and were consistent with patterns that I have recorded from vantage point survey datasets across multiple wind farm sites (Gittings, 2024 and unpublished data). Therefore, it is likely that, as with most vantage point survey datasets, there were large degrees of under-detection of flightlines in the more distant parts of the viewsheds.

The species-specific correction factors calculated from the weighted viewshed areas and the distribution of flight activity between the vantage points are shown in Table 4.6. These quantify the degree to which the predicted collision risk should be increased to account for under-detection of distant flightlines.

The larger species generally had smaller correction factors, reflecting the results of the distance effects analyses. However, the factors also reflect species-specific differences in how flight activity is distributed across viewsheds, as each viewshed's correction factor depends on the proportion of its area within different distance bands. This was particularly important for this project, where the Ecology Ireland viewsheds were refined to remove overlapping areas between vantage points, ensuring that flight activity was not double-counted. As a result, some viewsheds had a reduced proportion of their area in the nearest distance bands.

Correction factors were consistently higher for the 30 m viewshed analyses, as these included relatively greater contributions from more distant areas.

These correction factors do not take account of species-specific variation in flight behaviour and may over-estimate the under-detection effects in some cases. In particular, for species like Golden Plover and Lapwing, where extended flight activity by large flocks, usually contributes most of the collision risk, it seems likely that observers will detect most such activity even when it is distant from the vantage point.

Table 4.6. Correction factors to adjust for under-detection of distant flightlines.

Species	Season	Correction factors	
		Viewshed height 17 m	Viewshed height 30 m
Whooper Swan	winter	1.52	1.80
Wigeon	winter	2.65	2.88
Mallard	all year	1.85	1.97
Cormorant	breeding	1.52	1.69
	non-breeding	1.48	1.65
Little Egret	non-breeding	1.77	2.23
Grey Heron	all year	1.51	1.70
Sparrowhawk	all year	2.66	2.78
Golden Plover	winter	2.94	3.09
Lapwing	winter	2.68	2.88
Black-tailed Godwit	all year	1.51	1.86
Kestrel	all year	2.73	2.81

Temporal coverage

The survey effort was not distributed uniformly across the survey months (Table 2.2). However, the minimum survey effort required by the NatureScot guidelines was completed at each of the original Ecology Ireland vantage points in each month. Two additional vantage points were added midway through the survey period and met the minimum seasonal effort requirements in three of the four seasons that they were surveyed. The TOBIN surveys added additional winter coverage.

The diel distribution of the Ecology Ireland survey effort was concentrated in the middle of the day, with limited coverage in the early morning and evening. This may have resulted in some under-detection of Whooper Swan and/or Cormorant flight activity.

Whooper Swan showed higher levels of flight activity in the early morning in the Ecology Ireland surveys and, if this was due to commuting flights from roosts, it is likely that they would also have shown higher levels of flight activity in the evening. However, the TOBIN surveys, which had good coverage in the early morning and evening did not detect higher rates of Whooper Swan flight activity at these times.

Cormorant showed higher levels of flight activity in the early morning, afternoon and evening in the TOBIN surveys, and this pattern was supported by the Ecology Ireland surveys where they covered the relevant periods.

Flight heights

Observer error in flight height estimation is a potential source of significant uncertainty for most collision risk models.

The limited information on flight heights recorded in the Ecology Ireland vantage point surveys is likely to have caused some over-estimation of the predicted collision risks. I used the maximum flight heights to identify records for inclusion in the collision risk model (see Section 2.4.3.3). When the maximum flight height was greater than or equal to the viewshed height, I used the full duration value recorded for the record. However, there were a significant number of records where the lower part of the height range was below the viewshed height. For these records, only part of the recorded flight duration will have been at potential collision height.

In the TOBIN surveys, inclusion of all activity within the 0–20 m height band for the N163 turbine (ground clearance 17 m) also likely resulted in a significant overestimate of activity at collision height. A similar, though smaller, effect was also likely from the inclusion of activity within the 20–50 m height band for the N149 and V150 turbines (ground clearance 30 m) (see Section 2.4.3.4).

These approaches introduced a precautionary margin that reduced the risk of flight height estimation errors leading to the exclusion of flights from the collision risk model, and in the case of the TOBIN surveys for the N163 turbine, effectively eliminated this risk.

4.7.2.6 Behavioural effects

The equation for calculating predicted transits (Equation B1) includes the mean bird flight speed as part of the numerator. However, for Kestrel, a significant proportion of their flight activity will typically involve hovering birds. The flight speed of a hovering Kestrel is close to zero (a small amount of drift in position will often occur during long bouts of hovering). Therefore, using the mean flight speed for Kestrel (10.1 m/sec; Alerstam et al., 2007) in Equation 1 to predict transits of hovering Kestrel is clearly inappropriate and will result in highly inflated estimates.

In the collision risk model for the Castlebanny Wind Farm (Gittings, 2020), I used data collected during the vantage point survey on the duration of hovering flight, and the mean number of hovering positions per second, to calculate separate predicted transits for hovering Kestrels, with the standard collision risk model only used for direct Kestrel flight activity. This resulted in a predicted collision risk that was less than half the value of the collision risk that would have been generated by using the standard model for all Kestrel flight activity.

4.7.3. Uncertainty due to collision risk model limitations

4.7.3.1 Stage A

The weighted averaging procedure used to calculate mean flight activity densities in Stage A (Equation A2) assumes that longer durations of vantage point surveys and large viewsheds will produce more reliable estimates. This will be true for longer durations of vantage point surveys. However, in general, there is likely to be an increased risk of under-detection of all flightlines in larger viewsheds. More specifically, larger viewsheds usually have higher proportions of their survey area occupied by the more distant parts of the viewshed, which is likely to result in increased under-detection of distant flightlines.

In this collision risk model, viewshed areas were adjusted for detectability based on the results of the distance analysis (see Section 2.5.2), and these adjusted areas were then used in the weighted averaging. This adjustment was necessary because the removal of overlaps from the Ecology Ireland viewsheds resulted in some viewsheds losing much of the area closest to the vantage points. Consequently, similar nominal viewshed areas had markedly different detection characteristics between vantage points. This approach also largely addressed the issue identified above.

Another issue with the weighted averaging procedure is that the penalty imposed on a vantage point with a smaller viewshed and/or lower survey effort increases with the number of vantage points. This is a mathematical property of the formula, but it is somewhat counter-intuitive. When a weaker vantage point contributes a larger proportion of the available data (as occurs when there are few vantage points), its potential influence on the overall estimate is greater and it would therefore be reasonable for it to be down-weighted more strongly. Conversely, when many vantage points are available, the influence of any single vantage point is inherently reduced.

In principle, this issue could be addressed by allowing the exponent in the weighting formula to vary with the number of vantage points. The NatureScot procedure uses weights proportional to $\sqrt{(t_iA_i)}$, which corresponds to the general relationship $w_i \propto (t_iA_i)^{0.5}$, where w is the weighting, t is the survey effort and A is the viewshed area. A more flexible formulation would be $w_i \propto (t_iA_i)^{\alpha}$, where the exponent α varies with the number of vantage points. Under such an approach, α could decrease toward 0.5 as the number of vantage points increases (approaching the current procedure when many vantage points are available), but increase toward 1 when the number of vantage points is small, thereby placing greater weight on vantage points with higher survey coverage when the dataset is more limited.

4.7.3.2 Stage B

Monthly calculations

Stage B calculates transits separately for each month. By combining Equations A1 and B1, it can be seen that the predicted transits are proportional to the ratio of the total daylight hours to the vantage point survey effort (t_{day} / t). As vantage point survey effort is usually more or less constant between months the ratio will vary between months, with the highest values in mid-winter and the lowest values in mid-summer.

If variation in the distribution of flight activity densities between months reflects real differences in flight activity, the variation in the t_{day} / t ratio will not affect the reliability of the predicted collision risk. However, in practice, the variation in flight activity densities between months is likely to include a large component that is due to sampling effects. This means that calculating transits separately for each month is likely to exacerbate the influence of sampling effects on the degree of uncertainty around the predicted collision risk. The effects will be reduced for species with non-zero nocturnal flight activity included in the model.

A better procedure would be to calculate flight activity densities for groups of months where there are unlikely to be real differences in flight activity: e.g., across the entire winter period for wintering species. This is the procedure that I have followed in previous collision risk modelling. In fact, the worked example that is provided in Annex 1 of the NatureScot guidance uses this procedure. However, it is not possible to implement this method using the NatureScot spreadsheet. Therefore, as I have tried to implement the calculation procedures in the NatureScot spreadsheet, I have used the monthly calculation of predicted transits, despite the above issues.

4.7.3.3 Stage C

Pitch angle

The relationships between single transit collision risks and pitch angles are shown in Figure 4.2-Figure 4.4 for a selection of the species included in the collision risk model. The single transit collision risk values showed little variation up to pitch values of around 10-20°, after which they increased sharply with increasing pitch. The transition point was related to flight speed: the start of the increase in single transit collision risk with pitch angle occurred at around 6-7° in the species with the slowest flight speeds (Hen Harrier and Kestrel), and at around 15-20° in the species with the fastest flight speeds (Mallard and Wigeon). This reflects the influence of flight speed on the duration of rotor transit and therefore the probability of blade encounter.

The final collision risk predictions used a pitch angle of 15°. Monitoring data from an onshore Irish wind farm indicates that lower pitch angles may be typical. Conversely the NatureScot collision risk modelling guidance (NS 2024) refers to pitch angles of 15–30° as typical.

The single transit collision risks with a pitch angle of 0° were on average 0.96 times those at 15° (range 0.85–1.02), while those calculated at 30° were 1.26 times than those at 15° (range 1.11–1.47).

Rotation speed

The relationships between single transit collision risks and rotation speeds are shown in Figure 4.5 for a selection of the species included in the collision risk model.

The effects of variation in rotation speed generally increased with body size because larger birds present a larger frontal area and therefore have a greater probability of intersecting the swept path of the blades during a transit. However, species with slower flight speeds (Merlin, Sparrowhawk, Kestrel and Little Egret) showed larger increases relative to body size. Slower flight speeds lengthen the time that a bird spends passing through the rotor-swept disc, increasing the number of blade passages encountered during a transit and therefore enhancing the effect of increasing blade rotation speed.

The collision risk model used the maximum rotation speed so the uncertainty in single transit collision risk due to variation in rotation speed can only decrease the collision risk. The risk values at the minimum rotation speed were a mean of 83-85%% (range 72–94% to 74–96%), depending on turbine model, of the risk values at the maximum rotation speed.

Overall effects

There are a number of other sources of potential uncertainty in the calculations of single transit collision risks. Band (2024) notes that "having regard for the various simplifications in the model, and the potential sources of under- and over-estimation …, it is judged that [Stage C] of the model should be regarded as indicative of collision probability within around ± 20%".

The extreme ends of the results of the sensitivity analyses reported here would exceed the ± 20% uncertainty range. However, these extremes are not likely to be typical, and the more likely variation is within that uncertainty range.

4.7.3.4 Stage E

The avoidance rates that are applied in the Stage E of the collision risk model have large effects, causing 20-fold to 500-fold decreases in the predicted collision risk. However, the evidence for most avoidance rates used in collision risk modelling for onshore wind farms is very limited, while there are also conceptual issues about the way that the model applies avoidance rates to large flocks.

Species avoidance rates

I applied the default avoidance rate of 98% when species-specific avoidance rates were not available. In most cases, the latter were higher: 99% for Hen Harrier, 99.2% for Black-headed Gull and Common Gull, 99.5% for Mute Swan, Whooper Swan and Lesser Black-backed Gull and Herring Gull, 99.6-99.8% for Golden Plover, and 99.8% for White-fronted Goose. Increasing the avoidance rate from 98% to 99% halves the predicted collision risk, while increasing the avoidance rate from 98% to 98.8% causes a 10-fold reduction in the predicted collision risk.

The exception were Kestrel and White-tailed Eagle, which have recommended avoidance rate of 95% (NatureScot, 2025b). This causes a 2.5-fold increase in the collision risk compared to the default avoidance rate of 98%.

The evidence for the Kestrel avoidance rate is weak. The avoidance rate is described as being based on: "sufficient evidence from flight behaviour (including hovering) and collision monitoring studies for vulnerability to collisions". The cited source (Whitfield and Madders, 2006) is, in fact, a review of avoidance rates for Red Kite. The information on Kestrel is derived from an analysis which finds a significant correlation between the "numbers of individuals seen" against numbers of carcasses found for 16 raptor species at a single wind farm in Spain. Kestrel is a large outlier above the regression line, and this appears to be the only empirical evidence that has been used by Scottish Natural Heritage to support the 95% avoidance rate for Kestrel. However, even taken at face value, all this analysis does is indicate that Kestrel has a lower avoidance rate than other raptor species, but it does not provide any quantitative data that can be used to estimate the avoidance rate. More seriously, this analysis does not account for behavioural and ecological differences between species that may affect the relationship between bird activity and collisions. It is also subject to the perennial problem with analyses of collision rates: the small absolute numbers of collisions which means that random sampling error may have significant effects.

Large flocks

The NatureScot collision risk model scales predicted risk directly with the number of birds recorded, implicitly treating a single flock of 100 birds as equivalent to 100 independent single-bird passages. This assumes that the probability of avoidance by each bird is independent and unaffected by flocking behaviour. However, for a cohesive flock, collision risk and avoidance behaviour are unlikely to be independent among individuals, so the model may not fully reflect how risk arises from such events.

In simple terms, for a large flock the outcome is unlikely to reflect many independent collision risks; instead, it is more likely to be driven by a single event in which either most birds avoid the turbines or multiple birds are affected together.

In principle, this type of scenario would be better represented by an event-based collision model. Although such a model could, in principle, distinguish between collective and individual avoidance, there is unlikely to be sufficient empirical evidence to parameterise these separately. A more practical adaptation would be to retain a single overall avoidance term while treating large flocks as discrete events, rather than as large numbers of independent bird transits, thereby avoiding the need to assume independence among individuals within flocks. Such an approach would separate the frequency of large-flock events from the number of birds involved in each event and would allow for correlated avoidance behaviour within flocks.

4.7.4. Uncertainty due to turbine options

This collision risk model is based on fixed turbine models so there is no uncertainty due to turbine options.

4.7.5. Overall uncertainty

Table 4.7 shows the overall uncertainty factors generated by sampling effects from the simulation model and the uncertainties about the nocturnal activity ranking and the single transit collision risks, combined using the multiplicative method (the simulation/multiplicative uncertainties). It also shows the range of uncertainty these factors create around the central estimate of the annual collision risks from Table 4.3.

The uncertainty factors generated by sampling effects from the relative error method and the uncertainties about the nocturnal activity ranking and the single transit collision risks, combined using the root sum of squares (the relative error/root sum of squares uncertainties) are shown in Table 4.8.

In both cases the overall uncertainties are dominated by the sampling effects uncertainties, although the influence of these are greater in the relative error/RSS uncertainties where the overall uncertainties are almost identical to the sampling effects uncertainties

The uncertainty due to distance effects is not included in the overall uncertainty estimates in Table 4.7 and Table 4.8 because distance effects are not included in the NatureScot methodology. Also, the correction factors were not species-specific, and were likely to be significant over-estimates for some species (e.g., Golden Plover and Lapwing; see Section 4.7.2). This uncertainty would double the upper end of the collision risk range by a factor of around 1.5–3 times.

Uncertainty due to limited knowledge of avoidance rates is also not included in these estimates. The variation in the predicted collision risks with avoidance rates of 95%, 98%, 99% and 99.5% is shown in Table 4.9. This table includes some additional species/seasons to those included in Table 4.3 that had non-zero collision risks rounded to two decimal places at avoidance rates lower than the recommended avoidance rate.

Other factors that may cause additional uncertainty are uneven diel coverage which may have caused under-estimation of Cormorant and (possibly) Whooper Swan collision risk (see Section 4.7.2.5), and precautionary approaches to the assignment of flight heights, which may have caused general overestimation of collision risks (see Section 4.7.2.5).

Table 4.7. Overall uncertainty factors and collision risk ranges, using the uncertainty factors from the simulation model and the multiplicative method for combining uncertainties (the simulation/multiplicative uncertainties).

Species	**Season**	**Turbine**	**Uncertainty factors**	**Collision risk**	
				central estimate	**range**
Whooper Swan	winter	N149	0.46–2.97	0.02	0.01–0.07
		N163	0.46–2.97	0.05	0.02–0.13
		V150	0.46–2.97	0.02	0.01–0.07
Wigeon	winter	N149	0.44–4.14	1.36	0.59–5.62
		N163	0.44–4.14	2.44	1.06–10.09
		V150	0.44–4.14	1.39	0.61–5.74
Mallard	all year	N149	0.48–3.64	0.56	0.27–2.04
		N163	0.48–3.64	0.68	0.33–2.48
		V150	0.48–3.64	0.58	0.28–2.09
Cormorant	breeding	N149	0.60–2.69	0.10	0.06–0.28
		N163	0.60–2.69	0.12	0.07–0.32
		V150	0.60–2.69	0.11	0.06–0.29
	non-breeding	N149	0.71–2.00	0.32	0.23–0.64
		N163	0.71–2.00	0.44	0.31–0.88
		V150	0.71–2.00	0.33	0.24–0.66
Little Egret	non-breeding	N149	0.43–3.30	0.01	0.00–0.03
		N163	0.43–3.30	0.05	0.02–0.17
		V150	0.43–3.30	0.01	0.00–0.03
Grey Heron	all year	N149	0.46–2.87	0.10	0.05–0.30
		N163	0.46–2.87	0.17	0.08–0.48
		V150	0.46–2.87	0.11	0.05–0.31
Sparrowhawk	all year	N149	0.53–4.39	0.11	0.06–0.48
		N163	0.53–4.39	0.17	0.09–0.74
		V150	0.53–4.39	0.11	0.06–0.50
Golden Plover	winter	N149	0.42–3.31	7.91	3.34–26.21
		N163	0.42–3.31	9.42	3.98–31.21
		V150	0.42–3.31	8.08	3.42–26.76
Lapwing	winter	N149	0.40–3.35	1.37	0.55–4.58
		N163	0.40–3.35	1.57	0.63–5.25
		V150	0.40–3.35	1.41	0.56–4.72
Black-tailed Godwit	all year	N149	0.43–4.21	3.32	1.41–13.95
		N163	0.43–4.21	4.67	1.99–19.67
		V150	0.43–4.21	3.39	1.45–14.27
Kestrel	all year	N149	0.64–2.23	1.45	0.92–3.23
		N163	0.64–2.23	2.93	1.86–6.52
		V150	0.64–2.23	1.50	0.95–3.35

The overall uncertainty factors were derived from the 95% limits of a Monte Carlo permutation of the simulation model sampling effects and single transit collision risk uncertainty factors multiplied by the nocturnal correction factor uncertainty factors. No sampling effects uncertainty factors were calculated for Wigeon and Black-tailed Godwit (see Section 4.7.2.1); the overall uncertainty factors for these species used the maximum sampling effects uncertainty factors from the species modelled.

Table 4.8. Overall uncertainty factors and collision risk ranges, using the uncertainty factors from the relative error method and the root sum of squares method for combining uncertainties (the relative error/RSS uncertainties).

Species	Season	Turbine	Uncertainty factors	Collision risk	
				central estimate	range
Whooper Swan	winter	N149	0.00–4.65	0.05	0.00–0.21
		N163	0.00–4.33	0.02	0.00–0.10
		V150	0.00–4.33	0.02	0.00–0.10
Wigeon	winter	N149	0.00–5.48	2.44	0.00–13.37
		N163	0.00–5.59	1.36	0.00–7.60
		V150	0.00–5.59	1.39	0.00–7.75
Mallard	all year	N149	0.00–9.02	0.68	0.00–6.15
		N163	0.00–10.55	0.56	0.00–5.92
		V150	0.00–10.55	0.58	0.00–6.06
Cormorant	breeding	N149	0.00–4.47	0.12	0.00–0.53
		N163	0.00–4.18	0.10	0.00–0.43
		V150	0.00–4.18	0.11	0.00–0.44
	non-breeding	N149	0.00–4.59	0.44	0.00–2.01
		N163	0.00–5.30	0.32	0.00–1.71
		V150	0.00–5.30	0.33	0.00–1.76
Little Egret	non-breeding	N149	0.00–6.19	0.05	0.00–0.31
		N163	0.00–5.67	0.01	0.00–0.04
		V150	0.00–5.67	0.01	0.00–0.05
Grey Heron	all year	N149	0.00–5.55	0.17	0.00–0.93
		N163	0.00–5.45	0.10	0.00–0.57
		V150	0.00–5.45	0.11	0.00–0.59
Sparrowhawk	all year	N149	0.00–3.19	0.17	0.00–0.54
		N163	0.00–3.45	0.11	0.00–0.38
		V150	0.00–3.45	0.11	0.00–0.39
Golden Plover	winter	N149	0.00–5.45	9.42	0.00–51.41
		N163	0.00–5.29	7.91	0.00–41.83
		V150	0.00–5.29	8.08	0.00–42.71
Lapwing	winter	N149	0.00–4.97	1.57	0.00–7.79
		N163	0.00–5.17	1.37	0.00–7.07
		V150	0.00–5.17	1.41	0.00–7.28
Black-tailed Godwit	all year	N149	0.00–9.19	4.67	0.00–42.93
		N163	0.00–9.39	3.32	0.00–31.12
		V150	0.00–9.39	3.39	0.00–31.83
Kestrel	all year	N149	0.00–3.56	2.93	0.00–10.41
		N163	0.00–2.65	1.45	0.00–3.85
		V150	0.00–2.65	1.50	0.00–3.99

The overall uncertainty factors were derived by the root sum of squares method from relative error method sampling effects uncertainty factors and the single transit collision risk and nocturnal correction factor uncertainty factors.

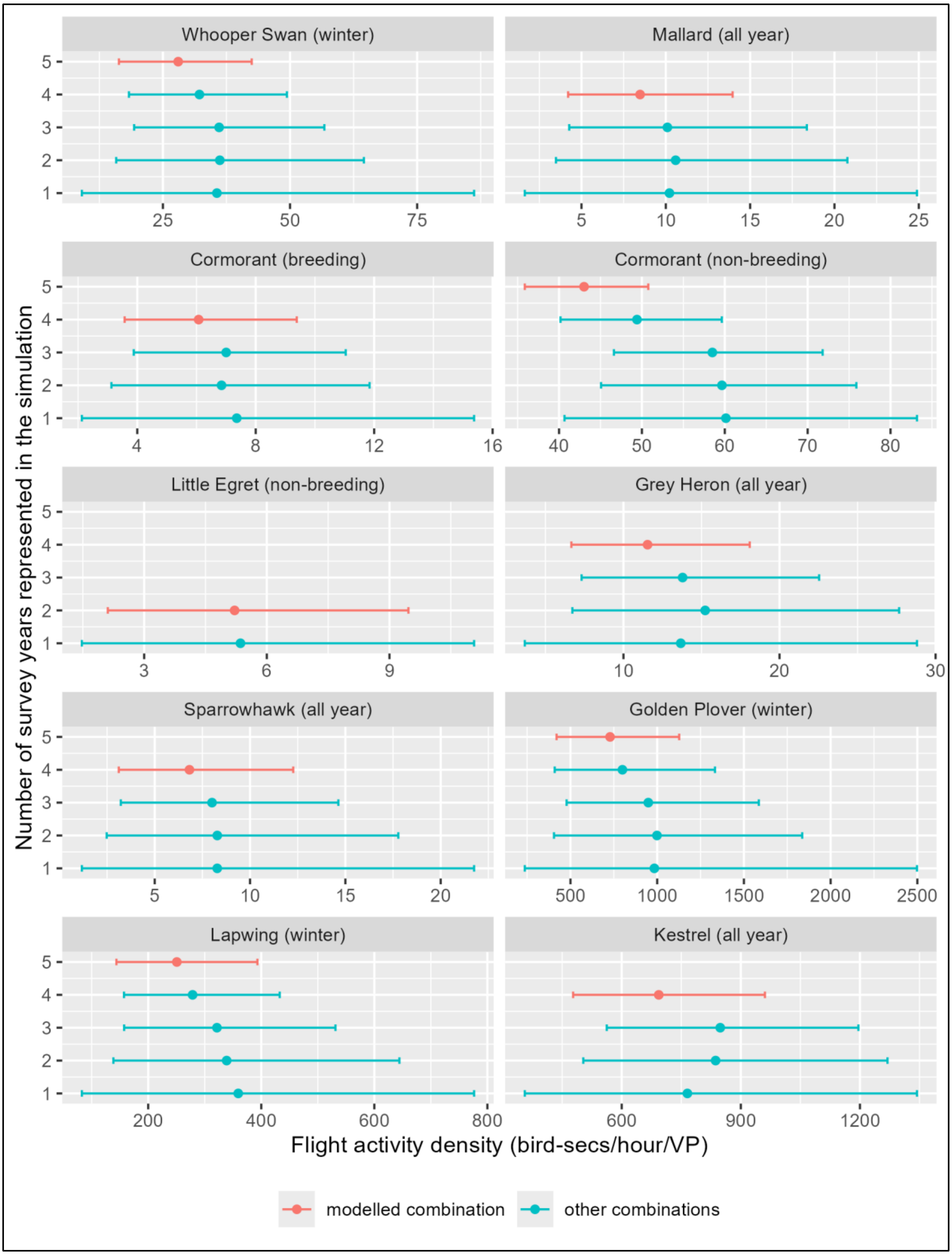
Table 4.9. Potential variation in central estimates of predicted collision risks due to uncertainty about avoidance rates.

Species	Season	Turbine	Predicted collision risk with avoidance rates of			
			95%	98%	99%	99.5%
Mute Swan	breeding	N149	0.02	0.01	0.00	0.00
		N163	0.01	0.01	0.00	0.00
		V150	0.02	0.01	0.00	0.00
	non-breeding	N149	0.06	0.03	0.01	0.01
		N163	0.20	0.08	0.04	0.02
		V150	0.07	0.03	0.01	0.01
Whooper Swan	winter	N149	0.22	0.09	0.04	0.02
		N163	0.45	0.18	0.09	0.05
		V150	0.23	0.09	0.05	0.02
White-fronted Goose	all year	N149	0.09	0.03	0.02	0.01
		N163	0.13	0.05	0.03	0.01
		V150	0.09	0.04	0.02	0.01
Wigeon	winter	N149	3.39	1.36	0.68	0.34
		N163	6.09	2.44	1.22	0.61
		V150	3.46	1.39	0.69	0.35
Teal	all year	N163	0.01	0.01	0.00	0.00
Mallard	all year	N149	1.40	0.56	0.28	0.14
		N163	1.70	0.68	0.34	0.17
		V150	1.44	0.58	0.29	0.14
Pintail	all year	N149	0.02	0.01	0.00	0.00
		N163	0.02	0.01	0.00	0.00
		V150	0.02	0.01	0.00	0.00
Cormorant	breeding	N149	0.26	0.10	0.05	0.03
		N163	0.30	0.12	0.06	0.03
		V150	0.27	0.11	0.05	0.03
	non-breeding	N149	0.81	0.32	0.16	0.08
		N163	1.09	0.44	0.22	0.11
		V150	0.83	0.33	0.17	0.08
Little Egret	breeding	N149	0.03	0.01	0.01	0.00
		V150	0.03	0.01	0.01	0.00
	non-breeding	N149	0.02	0.01	0.00	0.00
		N163	0.13	0.05	0.03	0.01
		V150	0.02	0.01	0.00	0.00
Grey Heron	all year	N149	0.26	0.10	0.05	0.03
		N163	0.42	0.17	0.08	0.04
		V150	0.27	0.11	0.05	0.03
White-tailed Eagle	all year	N149	0.02	0.01	0.00	0.00
		N163	0.04	0.01	0.01	0.00
		V150	0.02	0.01	0.00	0.00
Hen Harrier	all year	N149	0.05	0.02	0.01	0.01
		N163	0.10	0.04	0.02	0.01
		V150	0.05	0.02	0.01	0.01

Species	Season	Turbine	Predicted collision risk with avoidance rates of			
			95%	98%	99%	99.5%
Sparrowhawk	all year	N149	0.28	0.11	0.06	0.03
		N163	0.42	0.17	0.08	0.04
		V150	0.29	0.11	0.06	0.03
Buzzard	all year	N149	3.39	1.35	0.68	0.34
		N163	4.23	1.69	0.85	0.42
		V150	3.50	1.40	0.70	0.35
Golden Plover	winter	N149	98.92	39.57	19.78	9.89
		N163	117.81	47.12	23.56	11.78
		V150	101.01	40.40	20.20	10.10
Lapwing	winter	N149	3.42	1.37	0.68	0.34
		N163	3.91	1.57	0.78	0.39
		V150	3.52	1.41	0.70	0.35
Curlew	all year	N149	0.05	0.02	0.01	0.00
		N163	0.05	0.02	0.01	0.01
		V150	0.05	0.02	0.01	0.00
Black-tailed Godwit	all year	N149	8.29	3.32	1.66	0.83
		N163	11.68	4.67	2.34	1.17
		V150	8.48	3.39	1.70	0.85
Black-headed Gull	non-breeding	N149	1.95	0.78	0.39	0.20
		N163	2.71	1.09	0.54	0.27
		V150	2.01	0.80	0.40	0.20
Common Gull	all year	N149	0.02	0.01	0.00	0.00
		N163	0.03	0.01	0.01	0.00
		V150	0.02	0.01	0.00	0.00
Lesser Black-backed Gull	autumn	N149	0.20	0.08	0.04	0.02
		N163	0.47	0.19	0.09	0.05
		V150	0.20	0.08	0.04	0.02
	breeding	N149	0.03	0.01	0.01	0.00
		N163	0.02	0.01	0.00	0.00
		V150	0.03	0.01	0.01	0.00
	spring	N149	0.06	0.03	0.01	0.01
		N163	1.33	0.53	0.27	0.13
		V150	0.07	0.03	0.01	0.01
	winter	N149	0.48	0.19	0.10	0.05
		N163	0.41	0.16	0.08	0.04
		V150	0.49	0.20	0.10	0.05
Herring Gull	all year	N149	0.01	0.00	0.00	0.00
		V150	0.01	0.00	0.00	0.00
Kestrel	all year	N149	1.45	0.58	0.29	0.14
		N163	2.93	1.17	0.59	0.29
		V150	1.50	0.60	0.30	0.15
Merlin	all year	N149	0.01	0.00	0.00	0.00
		N163	0.03	0.01	0.01	0.00
		V150	0.01	0.00	0.00	0.00

Species	Season	Turbine	Predicted collision risk with avoidance rates of			
			95%	98%	99%	99.5%
Peregrine	all year	N149	0.06	0.02	0.01	0.01
		N163	0.08	0.03	0.02	0.01
		V150	0.06	0.02	0.01	0.01

Additional species/seasons are included in this table because they had non-zero collision risks rounded to two decimal places at avoidance rates lower than the recommended avoidance rate.



Points show mean simulated flight activity densities and horizontal bars show 95% simulation intervals (2.5–97.5 percentiles) derived from 10,000 simulation runs. The results for the number of years used in the collision risk model for each species are shown in red. For most species the simulation interval decreases substantially between one and two seasons, with smaller reductions thereafter.

Figure 4.1. Simulation intervals for flight activity density estimated from vantage point survey data under different numbers of surveyed years.

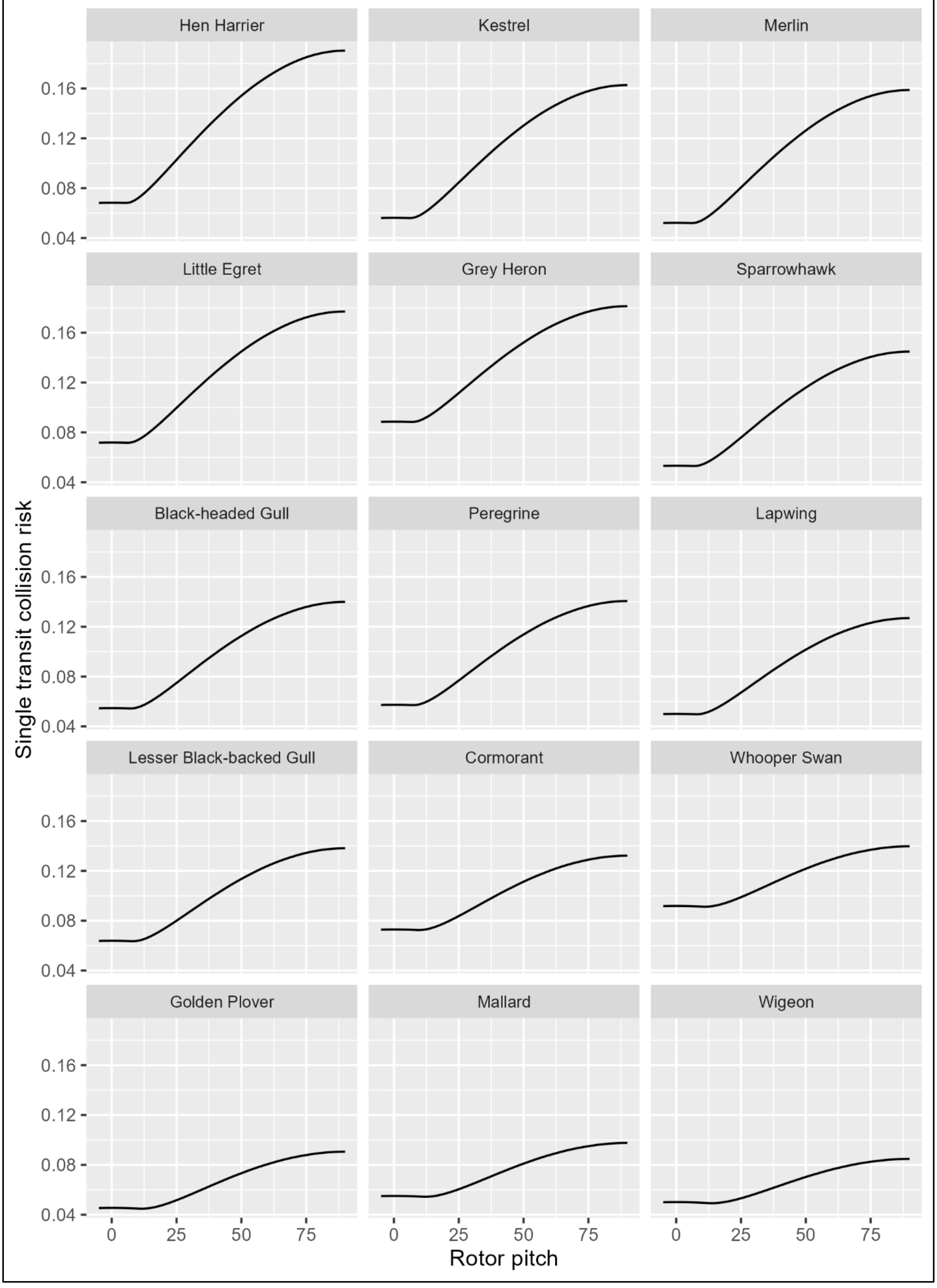


Figure 4.2. Relationship between pitch angle and single transit collision risk for the V150 turbine and pitch angles between -5 and 90°, with species arranged in order of increasing flight speed.

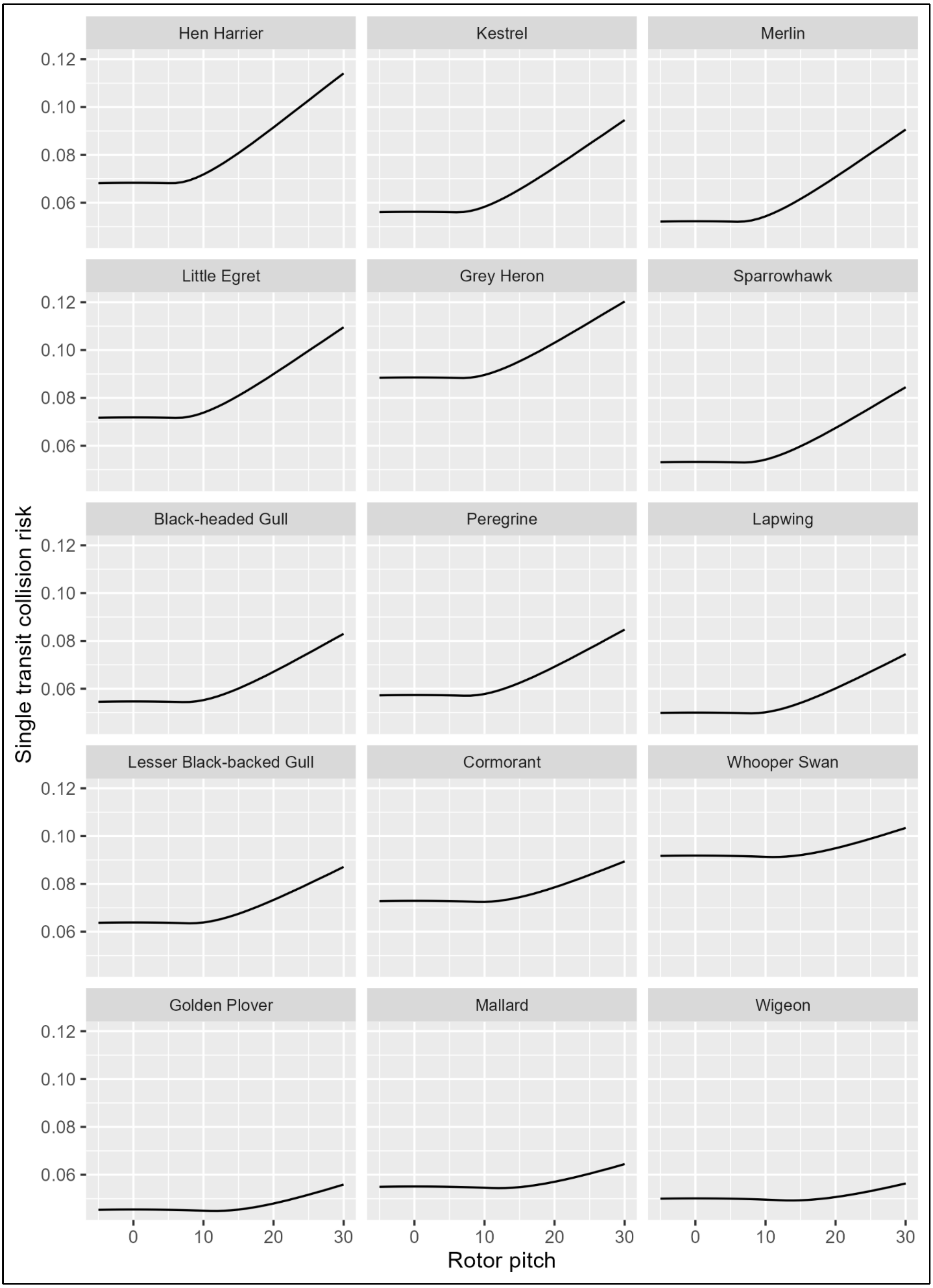


Figure 4.3. Relationship between pitch angle and single transit collision risk for the V150 turbine and pitch angles between -5 and 30°, with species arranged in order of increasing flight speed

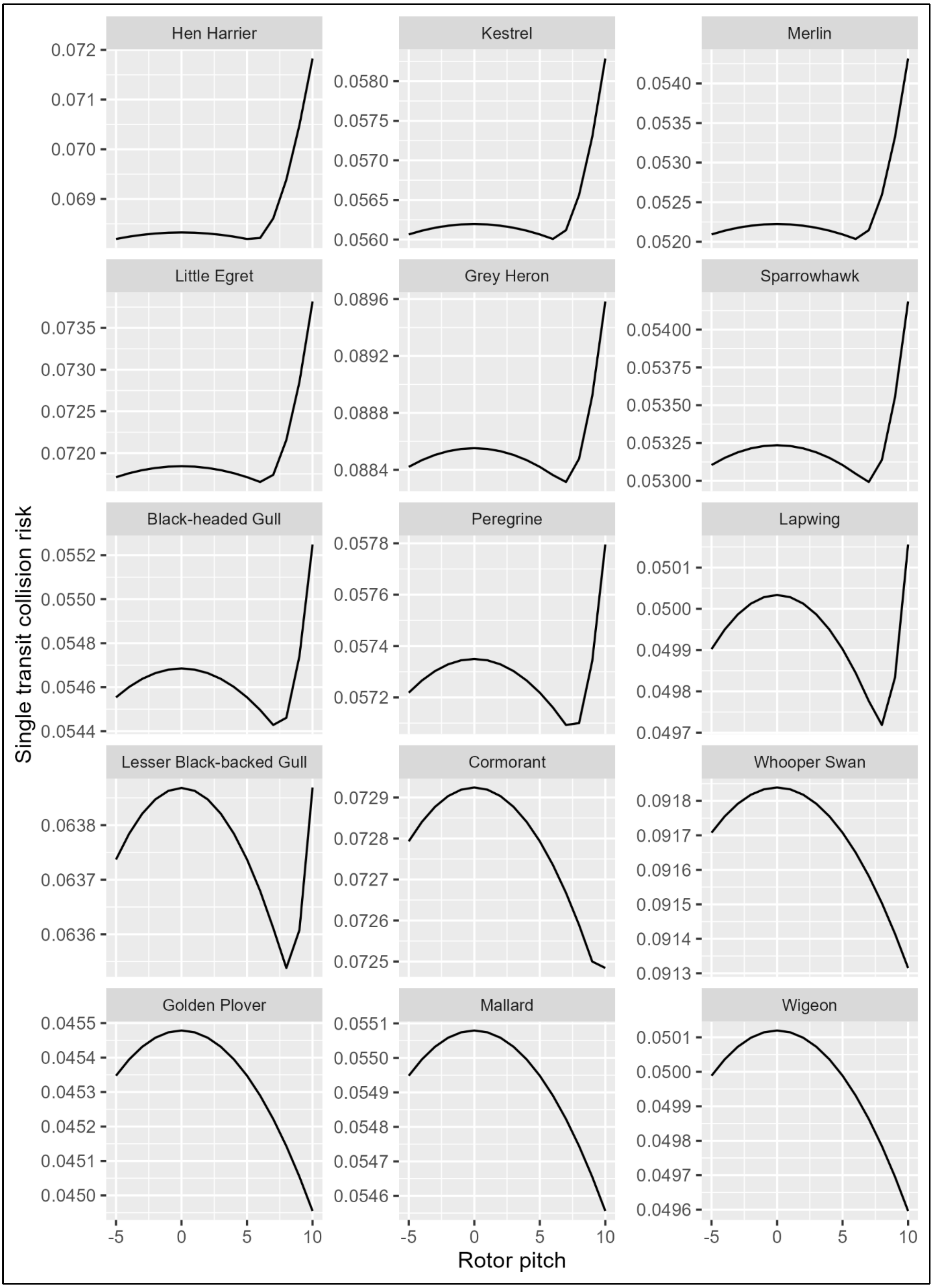


Figure 4.4. Maximum single transit collision risks for the V150 turbine with pitch angle of between -5 and 10°, with species arranged in order of increasing flight speed.

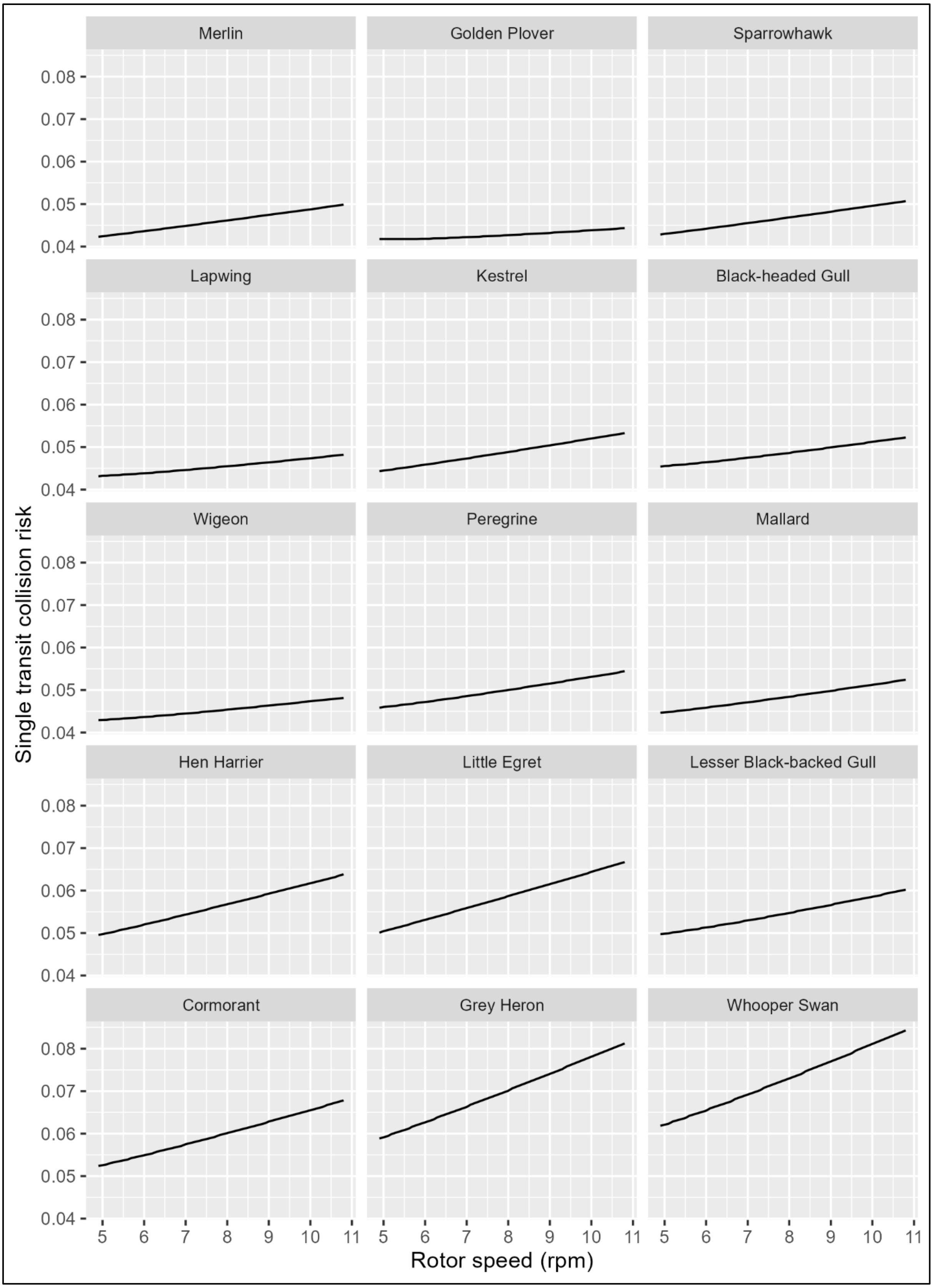


Figure 4.5. Relationship between rotor speed and single transit collision risk for the V150 turbine, with species arranged in order of increasing body size (body length × wingspan).

5. COLLISION RISK ASSESSMENT

5.1. RESULTS

The results of the collision risk assessment are shown in Table 5.1. The range of uncertainty around the mortality increases due to the calculated uncertainty in the predicted collision risk is also shown.

These uncertainty ranges are based on the simulation/multiplicative uncertainty factors. These were used instead of the relative error/RSS factors due to the methodological issues with the latter (see Sections 2.6.7.5 and 4.7.2.1)

Table 5.1. Potential increase in annual mortality rates due to the predicted collision risk from the Ballincor Wind Farm.

Species	Population	Scale	Turbine		
			N149	N163	V150
Whooper Swan	winter	national	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)
		county	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)
		local	0.0% (0.0% - 0.1%)	0.1% (0.0% - 0.2%)	0.0% (0.0% - 0.1%)
Wigeon	winter	national	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)
		local	0.0% (0.0% - 0.2%)	0.1% (0.0% - 0.3%)	0.0% (0.0% - 0.2%)
Mallard	winter	national	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)
		local	1.6% (0.8% - 5.7%)	1.9% (0.9% - 6.9%)	1.6% (0.8% - 5.8%)
Cormorant	breeding	national	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)
		local	0.2% (0.1% - 0.4%)	0.2% (0.1% - 0.5%)	0.2% (0.1% - 0.4%)
	non-breeding	national	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.1%)	0.0% (0.0% - 0.0%)
Little Egret	non-breeding	national	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)
Grey Heron	breeding	national	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)
		county	0.4% (0.2% - 1.1%)	0.6% (0.3% - 1.8%)	0.4% (0.2% - 1.1%)
Sparrowhawk	breeding	national	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)
		county	0.1% (0.1% - 0.4%)	0.2% (0.1% - 0.7%)	0.1% (0.1% - 0.5%)
Golden Plover (99.6%)	winter	national	0.0% (0.0% - 0.1%)	0.0% (0.0% - 0.1%)	0.0% (0.0% - 0.1%)
		local	0.3% (0.1% - 1.0%)	0.4% (0.2% - 1.3%)	0.3% (0.1% - 1.1%)
Golden Plover (99.8%)	winter	national	0.0% (0.0% - 0.1%)	0.0% (0.0% - 0.1%)	0.0% (0.0% - 0.1%)
		local	0.2% (0.1% - 0.5%)	0.2% (0.1% - 0.6%)	0.2% (0.1% - 0.5%)
Lapwing	winter	national	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)	0.0% (0.0% - 0.0%)
		local	0.1% (0.0% - 0.3%)	0.1% (0.0% - 0.3%)	0.1% (0.0% - 0.3%)
Black-tailed Godwit	non-breeding	national	0.2% (0.1% - 0.9%)	0.3% (0.1% - 1.3%)	0.2% (0.1% - 1.0%)
		local	1.6% (0.7% - 6.5%)	2.2% (0.9% - 9.2%)	1.6% (0.7% - 6.7%)
Kestrel	breeding	national	0.0% (0.0% - 0.1%)	0.1% (0.0% - 0.2%)	0.0% (0.0% - 0.1%)
		county	1.5% (0.9% - 3.3%)	3.0% (1.9% - 6.7%)	1.5% (1.0% - 3.4%)

Separate estimates of mortality increases are included for Golden Plover using avoidance rates of 99.6% and 99.8%. The values in parentheses indicate the range of uncertainty around the mortality increases due to uncertainty in the predicted collision risk.

The central estimates of the potential increase in annual mortality due to the predicted collision risk exceeded the 1% threshold for the local Mallard wintering population, the local Black-tailed Godwit wintering population and the county Kestrel population. The upper limit of the uncertainty range exceeded the thresholds by small amounts for the Grey Heron county population, the national Black-tailed Godwit wintering population (N163 and V150 turbines), and the local Golden Plover wintering population (99.6% avoidance rate).

The potential increase in annual mortality to the local Mallard wintering population may be overestimated. This population was quantified using Irish Wetland Bird Survey count data for the Little Brosna Callows. However, this is likely to be a substantial under-estimate of the local population as wintering Mallards occur widely across the Irish countryside.

The local Golden Plover and Black-tailed Godwit wintering populations are qualifying interests of the Little Brosna Callows SPA.

5.2. BLACK-TAILED GODWIT

The predicted impact on the local Black-tailed Godwit wintering population was driven by a collision risk largely generated by a single record of a flock of 1,750 birds. This record accounted for around 95% of the flight activity included in the collision risk model. The remaining records involved much smaller flock sizes (<100 birds). The collision risk estimate is therefore highly sensitive to a single observation and should be interpreted with caution.

The available data were insufficient to estimate the frequency with which such large flocks occur at the site or to meaningfully characterise sampling uncertainty. This is reinforced by the fact that the record was obtained during an additional replacement watch, illustrating how the result was sensitive to the chance timing of survey effort.

The predicted impact on the local Black-tailed Godwit wintering population was negligible when the record of the large flock was excluded, demonstrating that the collision risk estimate for Black-tailed Godwit is not robust.

If occurrences of large Black-tailed Godwit flocks at the wind farm site are rare, the predicted collision risk is more appropriately interpreted as a plausible worst-case scenario rather than a reliable estimate of average risk. Vantage point surveys typically sample only around 1.5–2% of daylight hours across the season. As a result, if the survey effort, by chance, coincided with one of the relatively few occasions when a large flock occurred, the collision risk could be overestimated by at least an order of magnitude. This highlights the sensitivity of the estimate to the timing of survey effort relative to infrequent, high-magnitude events.

An alternative possibility is that the survey effort may have under-sampled the occurrence of large flocks, and that the recorded event reflects a more regular but infrequently detected pattern of site use. This uncertainty cannot be resolved from the available data and is inherent in datasets where activity is dominated by infrequent, high-magnitude events, and therefore represents an irreducible source of uncertainty in the collision risk estimates.

5.3. CAVEATS

The uncertainty ranges did not take account of potential under-detection of distant flightlines. Inclusion of this factor would raise the mortality increases by factors of around 1.5–3 times. However, for some species, these factors may be over-estimated (see Section 4.7.2).

The uncertainty ranges also did not take account of uncertainty due to limited knowledge of avoidance rates.

As discussed in Section 2.7, the 1% threshold is likely to be very precautionary. The calculations of the increase in annual mortality also made strong precautionary assumptions that all the collision fatalities were adult birds, and that the collision mortality was additive not compensatory. Therefore, substantial increases in annual mortality well above the 1% threshold are likely to be required to cause significant impacts on the affected populations.

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Appendix 1 Results tables for intermediate stages of the collision risk model

Table A1.1. Monthly daytime flight activity densities (bird/km^2), all watches.

BTO	Viewshed height	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
BH	17 m	0.2497	0.0031	0.0019	0.0000	0.0002	0.0007	0.0000	0.0007	0.0000	0.0000	0.0439	0.5643
BH	30 m	0.2482	0.0033	0.0000	0.0000	0.0001	0.0003	0.0000	0.0000	0.0000	0.0000	0.0475	0.3288
BW	17 m	0.0000	1.5464	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
BW	30 m	0.0000	1.1117	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
BZ	17 m	0.0018	0.0036	0.0129	0.0059	0.0039	0.0074	0.0091	0.0048	0.0093	0.0016	0.0015	0.0015
BZ	30 m	0.0008	0.0019	0.0094	0.0040	0.0048	0.0060	0.0089	0.0041	0.0071	0.0010	0.0008	0.0016
CA	17 m	0.0269	0.0118	0.0063	0.0007	0.0087	0.0052	0.0035	0.0053	0.0639	0.0069	0.0212	0.0348
CA	30 m	0.0180	0.0075	0.0041	0.0006	0.0073	0.0025	0.0066	0.0067	0.0623	0.0014	0.0114	0.0271
CM	17 m	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006
CM	30 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006
CU	17 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CU	30 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ET	17 m	0.0022	0.0001	0.0105	0.0000	0.0002	0.0000	0.0000	0.0001	0.0000	0.0006	0.0011	0.0031
ET	30 m	0.0002	0.0000	0.0011	0.0000	0.0001	0.0000	0.0017	0.0001	0.0000	0.0003	0.0008	0.0008
GP	17 m	0.0128	0.0356	0.1259	0.0000	0.0000	0.0000	0.0000	0.0000	0.6920	0.0014	0.0383	0.0056
GP	30 m	0.0132	0.0253	0.6504	0.0000	0.0000	0.0000	0.0000	0.0000	0.5692	0.0014	0.0296	0.0174
H.	17 m	0.0040	0.0019	0.0111	0.0008	0.0050	0.0029	0.0025	0.0053	0.0015	0.0015	0.0003	0.0005
H.	30 m	0.0036	0.0015	0.0048	0.0001	0.0061	0.0024	0.0019	0.0035	0.0013	0.0007	0.0002	0.0003
HG	17 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
HG	30 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
HH	17 m	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	0.0000	0.0000	0.0001	0.0003	0.0002
HH	30 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0001	0.0002	0.0001
K.	17 m	0.0010	0.0015	0.0032	0.0012	0.0031	0.0034	0.0216	0.0035	0.0057	0.0013	0.0019	0.0048
K.	30 m	0.0005	0.0008	0.0044	0.0004	0.0028	0.0019	0.0062	0.0016	0.0051	0.0007	0.0011	0.0024
L.	17 m	0.0001	0.0458	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1511	0.3958	0.0833
L.	30 m	0.0001	0.0337	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1252	0.3608	0.0838
LB	17 m	0.0853	0.0063	0.1139	0.0000	0.0004	0.0024	0.0013	0.0138	0.0117	0.0349	0.0713	0.0035
LB	30 m	0.0818	0.0047	0.0110	0.0000	0.0003	0.0021	0.0016	0.0170	0.0079	0.0053	0.0286	0.0033
MA	17 m	0.0000	0.0114	0.0058	0.0046	0.0015	0.0081	0.0501	0.0004	0.0100	0.0012	0.0001	0.0001
MA	30 m	0.0000	0.0021	0.0014	0.0038	0.0010	0.0078	0.0483	0.0000	0.0082	0.0008	0.0000	0.0000
ML	17 m	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0002
ML	30 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
MS	17 m	0.0017	0.0027	0.0003	0.0000	0.0007	0.0003	0.0000	0.0007	0.0033	0.0004	0.0001	0.0024
MS	30 m	0.0017	0.0015	0.0003	0.0000	0.0005	0.0000	0.0000	0.0009	0.0016	0.0000	0.0000	0.0000
PE	17 m	0.0000	0.0001	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0001	0.0002	0.0002	0.0001
PE	30 m	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0003	0.0001	0.0002	0.0001
PT	17 m	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PT	30 m	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SH	17 m	0.0001	0.0004	0.0014	0.0000	0.0009	0.0002	0.0005	0.0001	0.0028	0.0010	0.0005	0.0006
SH	30 m	0.0001	0.0002	0.0010	0.0000	0.0006	0.0002	0.0001	0.0001	0.0021	0.0007	0.0003	0.0004
SV	17 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SV	30 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
T.	17 m	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
T.	30 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WE	17 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000
WE	30 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000
WG	17 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000
WG	30 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000
WN	17 m	0.0072	0.0315	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2505	0.2112
WN	30 m	0.0000	0.0150	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1407	0.1256
WS	17 m	0.0020	0.0003	0.0091	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011	0.0046	0.0038
WS	30 m	0.0013	0.0000	0.0035	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0042	0.0010

BH = Black-headed Gull; BW = Black-tailed Godwit; BZ = Buzzard; CA = Cormorant; CM = Common Gull; CU = Curlew; ET = Little Egret; GP = Golden Plover; H. = Grey Heron; HG = Herring Gull; HH = Hen Harrier; K. = Kestrel; L. = Lapwing; LB = Lesser Black-backed Gull; MA = Mallard; ML = Merlin; MS = Mute Swan; PE = Peregrine; PT = Pintail; SH = Sparrowhawk; SV = Shoveler; T. = Teal; WE = White-tailed Eagle; WG = White-fronted Goose; WN = Wigeon; WS = Whooper Swan.

Table A1.2. Monthly daytime flight activity densities (bird/km^2), compliant watches.

BTO	Viewshed height	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
BH	17 m	0.0000	0.0061	0.0027	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0969	0.7651
BH	30 m	0.0000	0.0065	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.1069	0.4450
BW	17 m	0.0000	1.9047	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
BW	30 m	0.0000	1.3714	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
BZ	17 m	0.0012	0.0035	0.0091	0.0104	0.0034	0.0064	0.0077	0.0019	0.0020	0.0006	0.0017	0.0005
BZ	30 m	0.0006	0.0017	0.0050	0.0077	0.0043	0.0053	0.0097	0.0020	0.0007	0.0006	0.0010	0.0005
CA	17 m	0.0278	0.0128	0.0027	0.0011	0.0095	0.0083	0.0024	0.0065	0.0668	0.0061	0.0184	0.0443
CA	30 m	0.0144	0.0064	0.0032	0.0009	0.0084	0.0040	0.0022	0.0067	0.0600	0.0018	0.0051	0.0376
CM	17 m	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CM	30 m	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CU	17 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CU	30 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ET	17 m	0.0008	0.0002	0.0120	0.0000	0.0004	0.0000	0.0000	0.0002	0.0000	0.0009	0.0027	0.0032
ET	30 m	0.0004	0.0000	0.0013	0.0000	0.0002	0.0000	0.0034	0.0002	0.0000	0.0000	0.0013	0.0004
GP	17 m	0.0083	0.0478	0.0901	0.0000	0.0000	0.0000	0.0000	0.0000	1.3840	0.0026	0.0465	0.0012
GP	30 m	0.0086	0.0319	0.1108	0.0000	0.0000	0.0000	0.0000	0.0000	1.1385	0.0027	0.0358	0.0167
H.	17 m	0.0004	0.0024	0.0177	0.0009	0.0042	0.0009	0.0045	0.0096	0.0011	0.0024	0.0000	0.0000
H.	30 m	0.0005	0.0011	0.0096	0.0003	0.0044	0.0000	0.0034	0.0066	0.0009	0.0010	0.0000	0.0000
HG	17 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
HG	30 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
HH	17 m	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0009	0.0000
HH	30 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0006	0.0000
K.	17 m	0.0009	0.0017	0.0037	0.0000	0.0024	0.0049	0.0093	0.0009	0.0044	0.0010	0.0016	0.0049
K.	30 m	0.0007	0.0010	0.0057	0.0000	0.0017	0.0028	0.0064	0.0001	0.0036	0.0005	0.0014	0.0025
L.	17 m	0.0002	0.0133	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1736	0.5089	0.1107
L.	30 m	0.0001	0.0116	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1417	0.4579	0.1102
LB	17 m	0.0000	0.0078	0.2253	0.0000	0.0001	0.0013	0.0011	0.0167	0.0080	0.0553	0.0834	0.0049
LB	30 m	0.0000	0.0061	0.0177	0.0000	0.0002	0.0001	0.0013	0.0107	0.0011	0.0086	0.0229	0.0046
MA	17 m	0.0000	0.0162	0.0112	0.0003	0.0024	0.0162	0.1007	0.0000	0.0000	0.0003	0.0001	0.0001
MA	30 m	0.0000	0.0022	0.0028	0.0008	0.0017	0.0157	0.0970	0.0000	0.0000	0.0002	0.0000	0.0000
ML	17 m	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
ML	30 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MS	17 m	0.0021	0.0021	0.0000	0.0000	0.0000	0.0005	0.0000	0.0003	0.0067	0.0006	0.0000	0.0036
MS	30 m	0.0020	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0032	0.0000	0.0000	0.0000
PE	17 m	0.0000	0.0001	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0002	0.0004	0.0003	0.0002
PE	30 m	0.0000	0.0001	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0002	0.0002	0.0003	0.0001
PT	17 m	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PT	30 m	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SH	17 m	0.0000	0.0003	0.0018	0.0000	0.0006	0.0000	0.0000	0.0003	0.0001	0.0016	0.0001	0.0007
SH	30 m	0.0000	0.0001	0.0009	0.0000	0.0004	0.0000	0.0000	0.0002	0.0000	0.0012	0.0001	0.0007
SV	17 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SV	30 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
T.	17 m	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
T.	30 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WE	17 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000
WE	30 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000
WG	17 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000
WG	30 m	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011	0.0000

BH = Black-headed Gull; BW = Black-tailed Godwit; BZ = Buzzard; CA = Cormorant; CM = Common Gull; CU = Curlew; ET = Little Egret; GP = Golden Plover; H. = Grey Heron; HG = Herring Gull; HH = Hen Harrier; K. = Kestrel; L. = Lapwing; LB = Lesser Black-backed Gull; MA = Mallard; ML = Merlin; MS = Mute Swan; PE = Peregrine; PT = Pintail; SH = Sparrowhawk; SV = Shoveler; T. = Teal; WE = White-tailed Eagle; WG = White-fronted Goose; WN = Wigeon; WS = Whooper Swan.

Table A1.3. Daylight (t_{day}) and nighttime (t_{night}) hours per month.

Month	**Non-waterfowl species**		**Waterfowl species**	
	t_{day}	**t_{night}**	**t_{day}**	**t_{night}**
Jan	253.3	490.7	315.3	428.7
Feb	274.5	397.5	330.5	341.5
Mar	366.4	377.6	428.4	315.6
Apr	417.8	302.2	477.8	242.2
May	489.7	254.3	551.7	192.3
Jun	505.1	214.9	565.1	154.9
Jul	508.2	235.8	570.2	173.8
Aug	457.8	286.2	519.8	224.2
Sept	382.3	337.7	442.3	277.7
Oct	330.3	413.7	392.3	351.7
Nov	262.4	457.6	322.4	397.6
Dec	237.7	506.3	299.7	444.3

Table A1.4. Nocturnal correction factors.

Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Mute Swan	1.13	1.11	1.37	1.26	1.34	1.08	1.07	1.18	1.09	1.31	1.22	1.16
Whooper Swan	1.13	1.11	1.37	1.26	1.34	1.08	1.07	1.18	1.09	1.31	1.22	1.16
White-fronted Goose	1.18	1.16	1.53	1.36	1.48	1.12	1.11	1.26	1.13	1.44	1.31	1.22
Wigeon	1.25	1.22	1.74	1.52	1.68	1.15	1.14	1.37	1.17	1.62	1.45	1.31
Teal	1.25	1.22	1.74	1.52	1.68	1.15	1.14	1.37	1.17	1.62	1.45	1.31
Mallard	1.25	1.22	1.74	1.52	1.68	1.15	1.14	1.37	1.17	1.62	1.45	1.31
Pintail	1.25	1.22	1.74	1.52	1.68	1.15	1.14	1.37	1.17	1.62	1.45	1.31
Shoveler	1.25	1.22	1.74	1.52	1.68	1.15	1.14	1.37	1.17	1.62	1.45	1.31
Little Egret	1.18	1.16	1.53	1.36	1.48	1.12	1.11	1.26	1.13	1.44	1.31	1.22
Grey Heron	1.18	1.16	1.53	1.36	1.48	1.12	1.11	1.26	1.13	1.44	1.31	1.22
Golden Plover	1.18	1.16	1.53	1.36	1.48	1.12	1.11	1.26	1.13	1.44	1.31	1.22
Lapwing	1.18	1.16	1.53	1.36	1.48	1.12	1.11	1.26	1.13	1.44	1.31	1.22
Curlew	1.18	1.16	1.53	1.36	1.48	1.12	1.11	1.26	1.13	1.44	1.31	1.22
Black-tailed Godwit	1.18	1.16	1.53	1.36	1.48	1.12	1.11	1.26	1.13	1.44	1.31	1.22

This table only includes species with nocturnal correction factors > 1.

Table A1.5. Projected number of rotor transits.

BTO	Turbine	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
BH	N149	315	5	0	0	0	1	0	0	0	0	63	392
BH	N163	0	9	5	0	0	2	0	0	0	0	139	997
BH	V150	317	5	0	0	0	1	0	0	0	0	63	394
BW	N149	0	3956	0	0	0	0	0	0	0	0	0	0
BW	N163	0	6006	0	0	0	0	0	0	0	0	0	0
BW	V150	0	3980	0	0	0	0	0	0	0	0	0	0
BZ	N149	11	28	185	90	127	162	245	102	147	19	12	20
BZ	N163	26	59	278	144	113	221	272	129	208	31	24	21
BZ	V150	11	28	186	90	128	163	246	103	148	19	12	20
CA	N149	29	13	10	2	23	8	21	20	153	3	19	41
CA	N163	49	25	7	3	33	29	8	21	179	14	34	74
CA	V150	29	13	10	2	23	8	22	20	154	3	19	42
CM	N149	0	0	0	0	0	0	0	0	0	0	0	8
CM	N163	0	4	0	0	0	0	0	0	0	0	0	9
CM	V150	0	0	0	0	0	0	0	0	0	0	0	8
CU	N149	0	0	0	0	0	19	0	0	0	0	0	0
CU	N163	0	0	0	0	0	23	0	0	0	0	0	0
CU	V150	0	0	0	0	0	19	0	0	0	0	0	0
ET	N149	1	0	3	0	1	0	8	0	0	0	2	1
ET	N163	1	0	26	0	1	0	0	0	0	2	5	5
ET	V150	1	0	3	0	1	0	8	0	0	0	2	1
GP	N149	268	991	4238	0	0	0	0	0	44108	97	1118	506
GP	N163	282	1620	3766	0	0	0	0	0	58620	104	1592	39
GP	V150	270	997	4264	0	0	0	0	0	44375	98	1125	509
H.	N149	1	2	21	1	12	0	9	16	2	2	0	0
H.	N163	1	5	42	2	12	3	13	26	3	5	0	0
H.	V150	1	2	21	1	12	0	9	17	2	2	0	0
HG	N149	0	0	0	0	0	0	0	3	0	0	0	0
HG	N163	0	0	0	0	0	0	0	2	0	0	0	0
HG	V150	0	0	0	0	0	0	0	3	0	0	0	0
HH	N149	0	0	0	0	0	0	11	0	0	1	2	1
HH	N163	1	0	0	0	0	0	24	0	0	2	4	2
HH	V150	0	0	0	0	0	0	11	0	0	1	2	1
K.	N149	6	11	75	9	64	45	148	35	91	10	14	27
K.	N163	13	21	61	25	78	89	563	82	112	22	26	58
K.	V150	6	11	76	9	64	45	149	35	92	10	14	27
L.	N149	0	23	0	0	0	0	0	0	0	332	931	217
L.	N163	0	29	0	0	0	0	0	0	0	444	1131	238
L.	V150	0	23	0	0	0	0	0	0	0	334	937	218
LB	N149	114	7	22	0	1	6	5	43	17	10	41	4
LB	N163	0	13	498	0	0	4	3	46	18	110	132	7
LB	V150	115	7	22	0	1	6	5	43	17	10	42	4
MA	N149	0	9	13	4	8	78	497	0	0	1	0	0
MA	N163	0	69	56	2	14	89	564	0	0	2	1	0
MA	V150	0	9	13	4	8	79	500	0	0	1	0	0
ML	N149	0	0	0	0	1	0	0	0	0	1	0	0
ML	N163	2	1	1	0	1	1	0	1	0	2	1	3
ML	V150	0	0	0	0	1	0	0	0	0	1	0	0
MS	N149	5	4	1	0	2	0	0	4	6	0	0	0
MS	N163	7	6	0	0	0	2	0	1	25	2	0	11
MS	V150	5	4	1	0	2	0	0	4	6	0	0	0
PE	N149	0	1	0	0	6	0	1	0	4	3	4	2
PE	N163	0	1	0	0	7	0	1	0	5	8	6	3
PE	V150	0	1	0	0	6	0	1	0	4	3	4	2
PT	N149	8	0	0	0	0	0	0	0	0	0	0	0

BTO	Turbine	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
PT	N163	10	0	0	0	0	0	0	0	0	0	0	0
PT	V150	8	0	0	0	0	0	0	0	0	0	0	0
SH	N149	1	2	19	0	15	5	4	3	42	11	4	5
SH	N163	1	6	30	0	24	6	15	4	61	20	7	8
SH	V150	1	2	19	0	15	5	4	3	42	12	4	5
SV	N149	0	0	0	0	0	0	0	0	0	0	0	1
SV	N163	0	0	0	0	0	0	0	0	0	0	0	2
SV	V150	0	0	0	0	0	0	0	0	0	0	0	1
T.	N149	0	0	0	0	0	0	0	0	0	0	0	0
T.	N163	8	0	0	0	0	0	0	0	0	0	0	0
T.	V150	0	0	0	0	0	0	0	0	0	0	0	0
WE	N149	0	0	0	0	0	0	0	0	0	0	4	0
WE	N163	0	0	0	0	0	0	0	0	0	0	10	0
WE	V150	0	0	0	0	0	0	0	0	0	0	4	0
WG	N149	0	0	0	0	0	0	0	0	0	0	31	0
WG	N163	0	0	0	0	0	0	0	0	0	0	51	0
WG	V150	0	0	0	0	0	0	0	0	0	0	32	0
WN	N149	0	81	0	0	0	0	0	0	0	0	805	739
WN	N163	9	186	0	0	0	0	0	0	0	0	1581	1372
WN	V150	0	81	0	0	0	0	0	0	0	0	810	743
WS	N149	6	0	26	0	0	0	0	0	0	3	18	4
WS	N163	11	1	74	0	0	0	0	0	0	6	20	13
WS	V150	6	0	26	0	0	0	0	0	0	3	18	4

BH = Black-headed Gull; BW = Black-tailed Godwit; BZ = Buzzard; CA = Cormorant; CM = Common Gull; CU = Curlew; ET = Little Egret;; GP = Golden Plover; H. = Grey Heron; HG = Herring Gull; HH = Hen Harrier; K. = Kestrel; L. = Lapwing; LB = Lesser Black-backed Gull; MA = Mallard; ML = Merlin; MS = Mute Swan; PE = Peregrine; PT = Pintail; SH = Sparrowhawk; SV = Shoveler; T. = Teal; WE = White-tailed Eagle; WG = White-fronted Goose; WN = Wigeon; WS = Whooper Swan.

Table A1.6. Single transit collision risks for flapping flight.

Species	Turbine	Pitch	Single transit collision risk		
			upwind	downwind	weighted mean
Mute Swan	N149	0	0.095	0.095	0.095
	N163	0	0.088	0.088	0.088
	V150	0	0.096	0.096	0.096
	N149	15	0.115	0.075	0.095
	N163	15	0.108	0.070	0.089
	V150	15	0.118	0.077	0.097
	N149	30	0.132	0.082	0.107
	N163	30	0.124	0.078	0.101
	V150	30	0.136	0.085	0.110
Whooper Swan	N149	0	0.091	0.091	0.091
	N163	0	0.085	0.085	0.085
	V150	0	0.093	0.093	0.093
	N149	15	0.111	0.072	0.091
	N163	15	0.104	0.067	0.086
	V150	15	0.113	0.073	0.093
	N149	30	0.126	0.077	0.102
	N163	30	0.119	0.073	0.096
	V150	30	0.130	0.080	0.105
White-fronted Goose	N149	0	0.064	0.064	0.064
	N163	0	0.060	0.060	0.060
	V150	0	0.065	0.065	0.065
	N149	15	0.085	0.044	0.065
	N163	15	0.079	0.041	0.060
	V150	15	0.087	0.045	0.066
	N149	30	0.102	0.052	0.077
	N163	30	0.096	0.049	0.073
	V150	30	0.105	0.054	0.079
Wigeon	N149	0	0.050	0.050	0.050
	N163	0	0.046	0.046	0.046
	V150	0	0.051	0.051	0.051
	N149	15	0.066	0.032	0.049
	N163	15	0.061	0.030	0.046
	V150	15	0.067	0.032	0.050
	N149	30	0.079	0.032	0.055
	N163	30	0.074	0.030	0.052
	V150	30	0.081	0.033	0.057
Teal	N149	0	0.047	0.047	0.047
	N163	0	0.043	0.043	0.043
	V150	0	0.047	0.047	0.047
	N149	15	0.063	0.028	0.046
	N163	15	0.059	0.026	0.042
	V150	15	0.065	0.028	0.046
	N149	30	0.077	0.029	0.053
	N163	30	0.072	0.028	0.050
	V150	30	0.079	0.030	0.055

Species	Turbine	Pitch	Single transit collision risk		
			upwind	downwind	weighted mean
Mallard	N149	0	0.055	0.055	0.055
	N163	0	0.051	0.051	0.051
	V150	0	0.055	0.055	0.055
	N149	15	0.073	0.036	0.054
	N163	15	0.068	0.033	0.050
	V150	15	0.074	0.036	0.055
	N149	30	0.087	0.039	0.063
	N163	30	0.081	0.037	0.059
	V150	30	0.089	0.040	0.065
Pintail	N149	0	0.053	0.053	0.053
	N163	0	0.049	0.049	0.049
	V150	0	0.054	0.054	0.054
	N149	15	0.069	0.035	0.052
	N163	15	0.064	0.033	0.048
	V150	15	0.071	0.036	0.053
	N149	30	0.082	0.035	0.058
	N163	30	0.076	0.033	0.055
	V150	30	0.084	0.036	0.060
Shoveler	N149	0	0.050	0.050	0.050
	N163	0	0.046	0.046	0.046
	V150	0	0.051	0.051	0.051
	N149	15	0.066	0.032	0.049
	N163	15	0.061	0.029	0.045
	V150	15	0.067	0.032	0.050
	N149	30	0.078	0.032	0.055
	N163	30	0.073	0.030	0.052
	V150	30	0.081	0.033	0.057
Cormorant	N149	0	0.072	0.072	0.072
	N163	0	0.067	0.067	0.067
	V150	0	0.074	0.074	0.074
	N149	15	0.094	0.052	0.073
	N163	15	0.088	0.049	0.069
	V150	15	0.097	0.054	0.075
	N149	30	0.113	0.062	0.087
	N163	30	0.106	0.059	0.082
	V150	30	0.116	0.064	0.090
Little Egret	N149	0	0.071	0.071	0.071
	N163	0	0.066	0.066	0.066
	V150	0	0.072	0.072	0.072
	N149	15	0.104	0.053	0.079
	N163	15	0.098	0.051	0.074
	V150	15	0.107	0.055	0.081
	N149	30	0.133	0.079	0.106
	N163	30	0.125	0.075	0.100
	V150	30	0.137	0.082	0.110

Species	Turbine	Pitch	Single transit collision risk		
			upwind	downwind	weighted mean
Grey Heron	N149	0	0.088	0.088	0.088
	N163	0	0.082	0.082	0.082
	V150	0	0.089	0.089	0.089
	N149	15	0.118	0.069	0.093
	N163	15	0.111	0.065	0.088
	V150	15	0.121	0.071	0.096
	N149	30	0.144	0.090	0.117
	N163	30	0.136	0.086	0.111
	V150	30	0.148	0.094	0.121
White-tailed Eagle	N149	0	0.081	0.081	0.081
	N163	0	0.076	0.076	0.076
	V150	0	0.083	0.083	0.083
	N149	15	0.111	0.063	0.087
	N163	15	0.104	0.059	0.082
	V150	15	0.114	0.064	0.089
	N149	30	0.137	0.083	0.110
	N163	30	0.129	0.080	0.104
	V150	30	0.141	0.087	0.114
Hen Harrier	N149	0	0.068	0.068	0.068
	N163	0	0.063	0.063	0.063
	V150	0	0.069	0.069	0.069
	N149	15	0.105	0.052	0.079
	N163	15	0.099	0.050	0.074
	V150	15	0.108	0.054	0.081
	N149	30	0.138	0.083	0.110
	N163	30	0.130	0.079	0.105
	V150	30	0.142	0.087	0.115
Sparrowhawk	N149	0	0.053	0.053	0.053
	N163	0	0.049	0.049	0.049
	V150	0	0.054	0.054	0.054
	N149	15	0.083	0.034	0.058
	N163	15	0.078	0.032	0.055
	V150	15	0.085	0.035	0.060
	N149	30	0.108	0.055	0.082
	N163	30	0.102	0.053	0.077
	V150	30	0.112	0.058	0.085
Buzzard	N149	0	0.064	0.064	0.064
	N163	0	0.060	0.060	0.060
	V150	0	0.065	0.065	0.065
	N149	15	0.094	0.045	0.070
	N163	15	0.088	0.043	0.065
	V150	15	0.096	0.047	0.071
	N149	30	0.119	0.065	0.092
	N163	30	0.111	0.062	0.087
	V150	30	0.122	0.068	0.095

Species	Turbine	Pitch	Single transit collision risk		
			upwind	downwind	weighted mean
Golden Plover	N149	0	0.046	0.046	0.046
	N163	0	0.042	0.042	0.042
	V150	0	0.046	0.046	0.046
	N149	15	0.064	0.027	0.045
	N163	15	0.060	0.024	0.042
	V150	15	0.065	0.027	0.046
	N149	30	0.079	0.030	0.055
	N163	30	0.074	0.029	0.052
	V150	30	0.081	0.032	0.056
Lapwing	N149	0	0.050	0.050	0.050
	N163	0	0.046	0.046	0.046
	V150	0	0.051	0.051	0.051
	N149	15	0.077	0.030	0.053
	N163	15	0.071	0.029	0.050
	V150	15	0.078	0.031	0.055
	N149	30	0.099	0.046	0.073
	N163	30	0.093	0.044	0.069
	V150	30	0.102	0.049	0.075
Curlew	N149	0	0.056	0.056	0.056
	N163	0	0.052	0.052	0.052
	V150	0	0.057	0.057	0.057
	N149	15	0.077	0.036	0.057
	N163	15	0.072	0.034	0.053
	V150	15	0.078	0.037	0.058
	N149	30	0.093	0.043	0.068
	N163	30	0.088	0.042	0.065
	V150	30	0.096	0.045	0.071
Black-tailed Godwit	N149	0	0.050	0.050	0.050
	N163	0	0.046	0.046	0.046
	V150	0	0.050	0.050	0.050
	N149	15	0.068	0.031	0.049
	N163	15	0.063	0.028	0.046
	V150	15	0.069	0.031	0.050
	N149	30	0.082	0.034	0.058
	N163	30	0.077	0.032	0.055
	V150	30	0.085	0.035	0.060
Black-headed Gull	N149	0	0.055	0.055	0.055
	N163	0	0.051	0.051	0.051
	V150	0	0.055	0.055	0.055
	N149	15	0.083	0.035	0.059
	N163	15	0.078	0.033	0.055
	V150	15	0.085	0.036	0.061
	N149	30	0.107	0.054	0.081
	N163	30	0.101	0.052	0.076
	V150	30	0.111	0.057	0.084

Species	Turbine	Pitch	Single transit collision risk		
			upwind	**downwind**	**weighted mean**
Common Gull	N149	0	0.056	0.056	0.056
	N163	0	0.052	0.052	0.052
	V150	0	0.056	0.056	0.056
	N149	15	0.081	0.036	0.058
	N163	15	0.075	0.033	0.054
	V150	15	0.083	0.037	0.060
	N149	30	0.102	0.050	0.076
	N163	30	0.096	0.048	0.072
	V150	30	0.105	0.052	0.079
Lesser Black-backed Gull	N149	0	0.064	0.064	0.064
	N163	0	0.059	0.059	0.059
	V150	0	0.065	0.065	0.065
	N149	15	0.090	0.044	0.067
	N163	15	0.084	0.041	0.063
	V150	15	0.092	0.045	0.068
	N149	30	0.111	0.059	0.085
	N163	30	0.105	0.056	0.080
	V150	30	0.115	0.062	0.088
Herring Gull	N149	0	0.065	0.065	0.065
	N163	0	0.061	0.061	0.061
	V150	0	0.066	0.066	0.066
	N149	15	0.092	0.045	0.069
	N163	15	0.086	0.043	0.064
	V150	15	0.094	0.047	0.070
	N149	30	0.114	0.061	0.088
	N163	30	0.107	0.059	0.083
	V150	30	0.117	0.064	0.091
Kestrel	N149	0	0.055	0.055	0.055
	N163	0	0.051	0.051	0.051
	V150	0	0.056	0.056	0.056
	N149	15	0.089	0.038	0.064
	N163	15	0.084	0.036	0.060
	V150	15	0.092	0.040	0.066
	N149	30	0.118	0.064	0.091
	N163	30	0.111	0.061	0.086
	V150	30	0.122	0.067	0.095
Merlin	N149	0	0.051	0.051	0.051
	N163	0	0.048	0.048	0.048
	V150	0	0.052	0.052	0.052
	N149	15	0.085	0.034	0.060
	N163	15	0.080	0.033	0.056
	V150	15	0.088	0.036	0.062
	N149	30	0.114	0.060	0.087
	N163	30	0.108	0.058	0.083
	V150	30	0.118	0.063	0.091

Species	Turbine	Pitch	Single transit collision risk		
			upwind	downwind	weighted mean
Peregrine	N149	0	0.057	0.057	0.057
	N163	0	0.053	0.053	0.053
	V150	0	0.058	0.058	0.058
	N149	15	0.085	0.038	0.061
	N163	15	0.080	0.036	0.058
	V150	15	0.087	0.039	0.063
	N149	30	0.109	0.056	0.082
	N163	30	0.102	0.053	0.078
	V150	30	0.112	0.058	0.085

Table A1.7. Collision risk before avoidance.

BTO	Turbine	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
BH	N149	15.89	0.23	0.00	0.00	0.01	0.04	0.00	0.00	0.00	0.00	3.15	19.75
BH	N163	0.00	0.44	0.26	0.00	0.00	0.08	0.00	0.00	0.00	0.00	6.57	47.01
BH	V150	16.38	0.24	0.00	0.00	0.01	0.05	0.00	0.00	0.00	0.00	3.25	20.35
BW	N149	0.00	165.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	N163	0.00	233.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	V150	0.00	169.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BZ	N149	0.64	1.67	10.93	5.29	7.51	9.56	14.45	6.03	8.69	1.09	0.69	1.17
BZ	N163	1.45	3.25	15.45	8.00	6.26	12.28	15.11	7.16	11.55	1.70	1.31	1.16
BZ	V150	0.66	1.73	11.30	5.46	7.76	9.88	14.93	6.23	8.98	1.13	0.72	1.21
CA	N149	1.82	0.82	0.59	0.10	1.43	0.50	1.33	1.22	9.53	0.19	1.20	2.57
CA	N163	2.88	1.44	0.41	0.19	1.91	1.72	0.49	1.21	10.45	0.82	1.98	4.31
CA	V150	1.87	0.84	0.61	0.10	1.47	0.51	1.37	1.25	9.81	0.19	1.23	2.65
CM	N149	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41
CM	N163	0.00	0.21	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42
CM	V150	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42
CU	N149	0.00	0.00	0.00	0.00	0.00	0.90	0.00	0.00	0.00	0.00	0.00	0.00
CU	N163	0.00	0.00	0.00	0.00	0.00	1.01	0.00	0.00	0.00	0.00	0.00	0.00
CU	V150	0.00	0.00	0.00	0.00	0.00	0.93	0.00	0.00	0.00	0.00	0.00	0.00
ET	N149	0.04	0.00	0.17	0.00	0.04	0.00	0.56	0.03	0.00	0.00	0.14	0.04
ET	N163	0.09	0.02	1.64	0.00	0.06	0.00	0.00	0.03	0.00	0.12	0.30	0.35
ET	V150	0.05	0.00	0.17	0.00	0.04	0.00	0.58	0.03	0.00	0.00	0.14	0.05
GP	N149	10.34	38.20	163.36	0.00	0.00	0.00	0.00	0.00	1700.15	3.76	43.10	19.50
GP	N163	10.08	57.83	134.39	0.00	0.00	0.00	0.00	0.00	2091.99	3.70	56.80	1.41
GP	V150	10.56	39.01	166.82	0.00	0.00	0.00	0.00	0.00	1736.08	3.84	44.01	19.92
H.	N149	0.07	0.15	1.65	0.05	0.92	0.01	0.73	1.30	0.16	0.16	0.00	0.00
H.	N163	0.06	0.35	3.16	0.18	0.91	0.19	0.99	1.96	0.20	0.39	0.01	0.00
H.	V150	0.07	0.16	1.71	0.06	0.95	0.01	0.75	1.35	0.17	0.16	0.00	0.00
HG	N149	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00
HG	N163	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00
HG	V150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00
HH	N149	0.01	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.09	0.16	0.07
HH	N163	0.04	0.00	0.00	0.00	0.00	0.00	1.49	0.00	0.00	0.13	0.25	0.13
HH	V150	0.01	0.00	0.00	0.00	0.00	0.00	0.76	0.00	0.00	0.09	0.16	0.07
K.	N149	0.33	0.59	4.07	0.47	3.46	2.43	8.04	1.90	4.94	0.56	0.75	1.46
K.	N163	0.66	1.05	3.09	1.27	3.95	4.53	28.67	4.18	5.70	1.10	1.33	2.97
K.	V150	0.34	0.61	4.21	0.49	3.58	2.52	8.33	1.96	5.12	0.58	0.77	1.51
L.	N149	0.01	1.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.07	42.33	9.84
L.	N163	0.02	1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.87	48.05	10.11
L.	V150	0.01	1.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.52	43.60	10.14
LB	N149	6.51	0.40	1.27	0.00	0.05	0.33	0.26	2.44	0.94	0.54	2.36	0.25
LB	N163	0.00	0.69	26.53	0.00	0.02	0.20	0.18	2.46	0.98	5.87	7.04	0.37
LB	V150	6.71	0.41	1.31	0.00	0.05	0.34	0.26	2.52	0.97	0.56	2.43	0.26
MA	N149	0.00	0.39	0.59	0.16	0.39	3.61	22.90	0.00	0.00	0.03	0.00	0.00
MA	N163	0.00	2.97	2.40	0.07	0.58	3.81	24.16	0.00	0.00	0.07	0.02	0.02
MA	V150	0.00	0.40	0.60	0.17	0.40	3.70	23.45	0.00	0.00	0.03	0.00	0.00
ML	N149	0.02	0.02	0.01	0.00	0.03	0.02	0.00	0.00	0.00	0.07	0.00	0.00
ML	N163	0.09	0.04	0.04	0.00	0.05	0.03	0.00	0.03	0.00	0.09	0.05	0.13
ML	V150	0.02	0.02	0.01	0.00	0.03	0.02	0.00	0.00	0.00	0.07	0.00	0.00
MS	N149	0.40	0.33	0.08	0.00	0.18	0.00	0.00	0.29	0.45	0.00	0.00	0.01
MS	N163	0.50	0.49	0.00	0.00	0.00	0.17	0.00	0.10	1.93	0.15	0.00	0.84
MS	V150	0.41	0.34	0.08	0.00	0.18	0.00	0.00	0.30	0.46	0.00	0.00	0.01
PE	N149	0.02	0.06	0.00	0.00	0.32	0.00	0.06	0.00	0.23	0.15	0.22	0.10
PE	N163	0.01	0.07	0.00	0.00	0.34	0.00	0.06	0.00	0.25	0.37	0.27	0.13
PE	V150	0.02	0.06	0.00	0.00	0.33	0.00	0.06	0.00	0.23	0.16	0.22	0.10
PT	N149	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

BTO	Turbine	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
PT	N163	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PT	V150	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SH	N149	0.04	0.11	0.93	0.00	0.75	0.23	0.20	0.14	2.09	0.57	0.22	0.23
SH	N163	0.06	0.26	1.39	0.00	1.14	0.28	0.69	0.18	2.86	0.91	0.33	0.37
SH	V150	0.04	0.12	0.96	0.00	0.78	0.24	0.20	0.15	2.16	0.59	0.23	0.24
SV	N149	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
SV	N163	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
SV	V150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
T.	N149	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T.	N163	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T.	V150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WE	N149	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00
WE	N163	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.00
WE	V150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00
WG	N149	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.72	0.00
WG	N163	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.60	0.00
WG	V150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.77	0.00
WN	N149	0.00	3.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.64	30.89
WN	N163	0.34	7.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	61.22	53.10
WN	V150	0.00	3.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34.33	31.52
WS	N149	0.50	0.00	2.03	0.00	0.00	0.00	0.00	0.00	0.00	0.24	1.36	0.29
WS	N163	0.77	0.09	5.37	0.00	0.00	0.00	0.00	0.00	0.00	0.41	1.47	0.96
WS	V150	0.51	0.00	2.09	0.00	0.00	0.00	0.00	0.00	0.00	0.25	1.40	0.30

BH = Black-headed Gull; BW = Black-tailed Godwit; BZ = Buzzard; CA = Cormorant; CM = Common Gull; CU = Curlew; ET = Little Egret; GP = Golden Plover; H. = Grey Heron; HG = Herring Gull; HH = Hen Harrier; K. = Kestrel; L. = Lapwing; LB = Lesser Black-backed Gull; MA = Mallard; ML = Merlin; MS = Mute Swan; PE = Peregrine; PT = Pintail; SH = Sparrowhawk; SV = Shoveler; T. = Teal; WE = White-tailed Eagle; WG = White-fronted Goose; WN = Wigeon; WS = Whooper Swan.

Table A1.8. Collision risk after avoidance.

BTO	Turbine	Avoidance rate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
BH	N149	0.95	0.79	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.99
BH	N163	0.95	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	2.35
BH	V150	0.95	0.82	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	1.02
BH	N149	0.98	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.39
BH	N163	0.98	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.94
BH	V150	0.98	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.41
BH	N149	0.99	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.20
BH	N163	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.47
BH	V150	0.99	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.20
BH	N149	0.995	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.10
BH	N163	0.995	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.24
BH	V150	0.995	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.10
BW	N149	0.95	0.00	8.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	N163	0.95	0.00	11.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	V150	0.95	0.00	8.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	N149	0.98	0.00	3.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	N163	0.98	0.00	4.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	V150	0.98	0.00	3.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	N149	0.99	0.00	1.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	N163	0.99	0.00	2.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	V150	0.99	0.00	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	N149	0.995	0.00	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	N163	0.995	0.00	1.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	V150	0.995	0.00	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BZ	N149	0.95	0.03	0.08	0.55	0.26	0.38	0.48	0.72	0.30	0.43	0.05	0.03	0.06
BZ	N163	0.95	0.07	0.16	0.77	0.40	0.31	0.61	0.76	0.36	0.58	0.09	0.07	0.06
BZ	V150	0.95	0.03	0.09	0.56	0.27	0.39	0.49	0.75	0.31	0.45	0.06	0.04	0.06
BZ	N149	0.98	0.01	0.03	0.22	0.11	0.15	0.19	0.29	0.12	0.17	0.02	0.01	0.02
BZ	N163	0.98	0.03	0.07	0.31	0.16	0.13	0.25	0.30	0.14	0.23	0.03	0.03	0.02
BZ	V150	0.98	0.01	0.03	0.23	0.11	0.16	0.20	0.30	0.12	0.18	0.02	0.01	0.02
BZ	N149	0.99	0.01	0.02	0.11	0.05	0.08	0.10	0.14	0.06	0.09	0.01	0.01	0.01
BZ	N163	0.99	0.01	0.03	0.15	0.08	0.06	0.12	0.15	0.07	0.12	0.02	0.01	0.01
BZ	V150	0.99	0.01	0.02	0.11	0.05	0.08	0.10	0.15	0.06	0.09	0.01	0.01	0.01
BZ	N149	0.995	0.00	0.01	0.05	0.03	0.04	0.05	0.07	0.03	0.04	0.01	0.00	0.01
BZ	N163	0.995	0.01	0.02	0.08	0.04	0.03	0.06	0.08	0.04	0.06	0.01	0.01	0.01
BZ	V150	0.995	0.00	0.01	0.06	0.03	0.04	0.05	0.07	0.03	0.04	0.01	0.00	0.01
CA	N149	0.95	0.09	0.04	0.03	0.00	0.07	0.02	0.07	0.06	0.48	0.01	0.06	0.13
CA	N163	0.95	0.14	0.07	0.02	0.01	0.10	0.09	0.02	0.06	0.52	0.04	0.10	0.22
CA	V150	0.95	0.09	0.04	0.03	0.00	0.07	0.03	0.07	0.06	0.49	0.01	0.06	0.13
CA	N149	0.98	0.04	0.02	0.01	0.00	0.03	0.01	0.03	0.02	0.19	0.00	0.02	0.05
CA	N163	0.98	0.06	0.03	0.01	0.00	0.04	0.03	0.01	0.02	0.21	0.02	0.04	0.09
CA	V150	0.98	0.04	0.02	0.01	0.00	0.03	0.01	0.03	0.03	0.20	0.00	0.02	0.05
CA	N149	0.99	0.02	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.10	0.00	0.01	0.03
CA	N163	0.99	0.03	0.01	0.00	0.00	0.02	0.02	0.00	0.01	0.10	0.01	0.02	0.04
CA	V150	0.99	0.02	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.10	0.00	0.01	0.03
CA	N149	0.995	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.05	0.00	0.01	0.01
CA	N163	0.995	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.05	0.00	0.01	0.02
CA	V150	0.995	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.05	0.00	0.01	0.01
CM	N149	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
CM	N163	0.95	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
CM	V150	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
CM	N149	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
CM	N163	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
CM	V150	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01

BTO	Turbine	Avoidance rate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
CU	N149	0.95	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
CU	N163	0.95	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
CU	V150	0.95	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
CU	N149	0.98	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
CU	N163	0.98	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
CU	V150	0.98	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
CU	N149	0.99	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
CU	N163	0.99	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
CU	V150	0.99	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
CU	N163	0.995	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
ET	N149	0.95	0.00	0.00	0.01	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.01	0.00
ET	N163	0.95	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02
ET	V150	0.95	0.00	0.00	0.01	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.01	0.00
ET	N149	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
ET	N163	0.98	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
ET	V150	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
ET	N149	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
ET	N163	0.99	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ET	V150	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
ET	N163	0.995	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GP	N149	0.95	0.52	1.91	8.17	0.00	0.00	0.00	0.00	0.00	85.01	0.19	2.16	0.98
GP	N163	0.95	0.50	2.89	6.72	0.00	0.00	0.00	0.00	0.00	104.60	0.19	2.84	0.07
GP	V150	0.95	0.53	1.95	8.34	0.00	0.00	0.00	0.00	0.00	86.80	0.19	2.20	1.00
GP	N149	0.98	0.21	0.76	3.27	0.00	0.00	0.00	0.00	0.00	34.00	0.08	0.86	0.39
GP	N163	0.98	0.20	1.16	2.69	0.00	0.00	0.00	0.00	0.00	41.84	0.07	1.14	0.03
GP	V150	0.98	0.21	0.78	3.34	0.00	0.00	0.00	0.00	0.00	34.72	0.08	0.88	0.40
GP	N149	0.99	0.10	0.38	1.63	0.00	0.00	0.00	0.00	0.00	17.00	0.04	0.43	0.20
GP	N163	0.99	0.10	0.58	1.34	0.00	0.00	0.00	0.00	0.00	20.92	0.04	0.57	0.01
GP	V150	0.99	0.11	0.39	1.67	0.00	0.00	0.00	0.00	0.00	17.36	0.04	0.44	0.20
GP	N149	0.995	0.05	0.19	0.82	0.00	0.00	0.00	0.00	0.00	8.50	0.02	0.22	0.10
GP	N163	0.995	0.05	0.29	0.67	0.00	0.00	0.00	0.00	0.00	10.46	0.02	0.28	0.01
GP	V150	0.995	0.05	0.20	0.83	0.00	0.00	0.00	0.00	0.00	8.68	0.02	0.22	0.10
H.	N149	0.95	0.00	0.01	0.08	0.00	0.05	0.00	0.04	0.07	0.01	0.01	0.00	0.00
H.	N163	0.95	0.00	0.02	0.16	0.01	0.05	0.01	0.05	0.10	0.01	0.02	0.00	0.00
H.	V150	0.95	0.00	0.01	0.09	0.00	0.05	0.00	0.04	0.07	0.01	0.01	0.00	0.00
H.	N149	0.98	0.00	0.00	0.03	0.00	0.02	0.00	0.01	0.03	0.00	0.00	0.00	0.00
H.	N163	0.98	0.00	0.01	0.06	0.00	0.02	0.00	0.02	0.04	0.00	0.01	0.00	0.00
H.	V150	0.98	0.00	0.00	0.03	0.00	0.02	0.00	0.02	0.03	0.00	0.00	0.00	0.00
H.	N149	0.99	0.00	0.00	0.02	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00
H.	N163	0.99	0.00	0.00	0.03	0.00	0.01	0.00	0.01	0.02	0.00	0.00	0.00	0.00
H.	V150	0.99	0.00	0.00	0.02	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00
H.	N149	0.995	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
H.	N163	0.995	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
H.	V150	0.995	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
HG	N149	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
HG	V150	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
HH	N149	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.01	0.00
HH	N163	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.01	0.01	0.01
HH	V150	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.01	0.00
HH	N149	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
HH	N163	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
HH	V150	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
HH	N149	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
HH	N163	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
HH	V150	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
HH	N163	0.995	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00

BTO	Turbine	Avoidance rate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
K.	N149	0.95	0.02	0.03	0.20	0.02	0.17	0.12	0.40	0.09	0.25	0.03	0.04	0.07
K.	N163	0.95	0.03	0.05	0.15	0.06	0.20	0.23	1.43	0.21	0.29	0.05	0.07	0.15
K.	V150	0.95	0.02	0.03	0.21	0.02	0.18	0.13	0.42	0.10	0.26	0.03	0.04	0.08
K.	N149	0.98	0.01	0.01	0.08	0.01	0.07	0.05	0.16	0.04	0.10	0.01	0.01	0.03
K.	N163	0.98	0.01	0.02	0.06	0.03	0.08	0.09	0.57	0.08	0.11	0.02	0.03	0.06
K.	V150	0.98	0.01	0.01	0.08	0.01	0.07	0.05	0.17	0.04	0.10	0.01	0.02	0.03
K.	N149	0.99	0.00	0.01	0.04	0.00	0.03	0.02	0.08	0.02	0.05	0.01	0.01	0.01
K.	N163	0.99	0.01	0.01	0.03	0.01	0.04	0.05	0.29	0.04	0.06	0.01	0.01	0.03
K.	V150	0.99	0.00	0.01	0.04	0.00	0.04	0.03	0.08	0.02	0.05	0.01	0.01	0.02
K.	N149	0.995	0.00	0.00	0.02	0.00	0.02	0.01	0.04	0.01	0.02	0.00	0.00	0.01
K.	N163	0.995	0.00	0.01	0.02	0.01	0.02	0.02	0.14	0.02	0.03	0.01	0.01	0.01
K.	V150	0.995	0.00	0.00	0.02	0.00	0.02	0.01	0.04	0.01	0.03	0.00	0.00	0.01
L.	N149	0.95	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	2.12	0.49
L.	N163	0.95	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.94	2.40	0.51
L.	V150	0.95	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.78	2.18	0.51
L.	N149	0.98	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.85	0.20
L.	N163	0.98	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.96	0.20
L.	V150	0.98	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.87	0.20
L.	N149	0.99	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.42	0.10
L.	N163	0.99	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.48	0.10
L.	V150	0.99	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.44	0.10
L.	N149	0.995	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.21	0.05
L.	N163	0.995	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.24	0.05
L.	V150	0.995	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.22	0.05
LB	N149	0.95	0.33	0.02	0.06	0.00	0.00	0.02	0.01	0.12	0.05	0.03	0.12	0.01
LB	N163	0.95	0.00	0.03	1.33	0.00	0.00	0.01	0.01	0.12	0.05	0.29	0.35	0.02
LB	V150	0.95	0.34	0.02	0.07	0.00	0.00	0.02	0.01	0.13	0.05	0.03	0.12	0.01
LB	N149	0.98	0.13	0.01	0.03	0.00	0.00	0.01	0.01	0.05	0.02	0.01	0.05	0.00
LB	N163	0.98	0.00	0.01	0.53	0.00	0.00	0.00	0.00	0.05	0.02	0.12	0.14	0.01
LB	V150	0.98	0.13	0.01	0.03	0.00	0.00	0.01	0.01	0.05	0.02	0.01	0.05	0.01
LB	N149	0.99	0.07	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.02	0.00
LB	N163	0.99	0.00	0.01	0.27	0.00	0.00	0.00	0.00	0.02	0.01	0.06	0.07	0.00
LB	V150	0.99	0.07	0.00	0.01	0.00	0.00	0.00	0.00	0.03	0.01	0.01	0.02	0.00
LB	N149	0.995	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00
LB	N163	0.995	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.01	0.00	0.03	0.04	0.00
LB	V150	0.995	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00
MA	N149	0.95	0.00	0.02	0.03	0.01	0.02	0.18	1.14	0.00	0.00	0.00	0.00	0.00
MA	N163	0.95	0.00	0.15	0.12	0.00	0.03	0.19	1.21	0.00	0.00	0.00	0.00	0.00
MA	V150	0.95	0.00	0.02	0.03	0.01	0.02	0.19	1.17	0.00	0.00	0.00	0.00	0.00
MA	N149	0.98	0.00	0.01	0.01	0.00	0.01	0.07	0.46	0.00	0.00	0.00	0.00	0.00
MA	N163	0.98	0.00	0.06	0.05	0.00	0.01	0.08	0.48	0.00	0.00	0.00	0.00	0.00
MA	V150	0.98	0.00	0.01	0.01	0.00	0.01	0.07	0.47	0.00	0.00	0.00	0.00	0.00
MA	N149	0.99	0.00	0.00	0.01	0.00	0.00	0.04	0.23	0.00	0.00	0.00	0.00	0.00
MA	N163	0.99	0.00	0.03	0.02	0.00	0.01	0.04	0.24	0.00	0.00	0.00	0.00	0.00
MA	V150	0.99	0.00	0.00	0.01	0.00	0.00	0.04	0.23	0.00	0.00	0.00	0.00	0.00
MA	N149	0.995	0.00	0.00	0.00	0.00	0.00	0.02	0.11	0.00	0.00	0.00	0.00	0.00
MA	N163	0.995	0.00	0.01	0.01	0.00	0.00	0.02	0.12	0.00	0.00	0.00	0.00	0.00
MA	V150	0.995	0.00	0.00	0.00	0.00	0.00	0.02	0.12	0.00	0.00	0.00	0.00	0.00
ML	N163	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
MS	N149	0.95	0.02	0.02	0.00	0.00	0.01	0.00	0.00	0.01	0.02	0.00	0.00	0.00
MS	N163	0.95	0.02	0.02	0.00	0.00	0.00	0.01	0.00	0.01	0.10	0.01	0.00	0.04
MS	V150	0.95	0.02	0.02	0.00	0.00	0.01	0.00	0.00	0.01	0.02	0.00	0.00	0.00
MS	N149	0.98	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
MS	N163	0.98	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.02
MS	V150	0.98	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
MS	N163	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.01

BTO	Turbine	Avoidance rate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
MS	N163	0.995	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
PE	N149	0.95	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.01	0.01	0.01
PE	N163	0.95	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.02	0.01	0.01
PE	V150	0.95	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.01	0.01	0.01
PE	N149	0.98	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PE	N163	0.98	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.00
PE	V150	0.98	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PT	N149	0.95	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PT	N163	0.95	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PT	V150	0.95	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PT	N149	0.98	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PT	N163	0.98	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PT	V150	0.98	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SH	N149	0.95	0.00	0.01	0.05	0.00	0.04	0.01	0.01	0.01	0.10	0.03	0.01	0.01
SH	N163	0.95	0.00	0.01	0.07	0.00	0.06	0.01	0.03	0.01	0.14	0.05	0.02	0.02
SH	V150	0.95	0.00	0.01	0.05	0.00	0.04	0.01	0.01	0.01	0.11	0.03	0.01	0.01
SH	N149	0.98	0.00	0.00	0.02	0.00	0.02	0.00	0.00	0.00	0.04	0.01	0.00	0.00
SH	N163	0.98	0.00	0.01	0.03	0.00	0.02	0.01	0.01	0.00	0.06	0.02	0.01	0.01
SH	V150	0.98	0.00	0.00	0.02	0.00	0.02	0.00	0.00	0.00	0.04	0.01	0.00	0.00
SH	N149	0.99	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.02	0.01	0.00	0.00
SH	N163	0.99	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.03	0.01	0.00	0.00
SH	V150	0.99	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.02	0.01	0.00	0.00
SH	N149	0.995	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
SH	N163	0.995	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
SH	V150	0.995	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
T.	N163	0.95	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T.	N163	0.98	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WE	N149	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
WE	N163	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
WE	V150	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
WE	N149	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
WE	N163	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
WE	V150	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
WE	N163	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
WG	N149	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00
WG	N163	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00
WG	V150	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00
WG	N149	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
WG	N163	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
WG	V150	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
WG	N149	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
WG	N163	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
WG	V150	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
WG	N149	0.995	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
WG	N163	0.995	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
WG	V150	0.995	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
WN	N149	0.95	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.68	1.54
WN	N163	0.95	0.02	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.06	2.65
WN	V150	0.95	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.72	1.58
WN	N149	0.98	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.62
WN	N163	0.98	0.01	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.22	1.06
WN	V150	0.98	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.63
WN	N149	0.99	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.31
WN	N163	0.99	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.53
WN	V150	0.99	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.32
WN	N149	0.995	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.15

BTO	Turbine	Avoidance rate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
WN	N163	0.995	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.27
WN	V150	0.995	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.16
WS	N149	0.95	0.02	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.01
WS	N163	0.95	0.04	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.07	0.05
WS	V150	0.95	0.03	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.01
WS	N149	0.98	0.01	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01
WS	N163	0.98	0.02	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.02
WS	V150	0.98	0.01	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.01
WS	N149	0.99	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
WS	N163	0.99	0.01	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
WS	V150	0.99	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
WS	N149	0.995	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
WS	N163	0.995	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
WS	V150	0.995	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00

Species/turbine combinations with collision risks < 0.005 in all months are not included in this table. BH = Black-headed Gull; BW = Black-tailed Godwit; BZ = Buzzard; CA = Cormorant; CM = Common Gull; CU = Curlew; ET = Little Egret; GP = Golden Plover; H. = Grey Heron; HG = Herring Gull; HH = Hen Harrier; K. = Kestrel; L. = Lapwing; LB = Lesser Black-backed Gull; MA = Mallard; ML = Merlin; MS = Mute Swan; PE = Peregrine; PT = Pintail; SH = Sparrowhawk; SN = Snipe; SV = Shoveler; T. = Teal; WE = White-tailed Eagle; WG = White-fronted Goose; WN = Wigeon; WS = Whooper Swan.