Technical Appendix 7.2: Collision Risk Assessment

Alba Ecology Ltd.

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Introduction

As part of the assessment of the potential ornithological impacts of the proposed Neshion Energy Park (the 'Proposed Development'), Alba Ecology Ltd. was commissioned to carry out a Collision Risk Assessment (CRA), based on the eight turbine wind farm design layout (provided by Ramboll via email on 5th February 2026), and the turbine metrics (provided by the Applicant via email on the 15th January 2026) for the main ornithological interest species of the Site.

This is an assessment of collision risk only, and does not take into account construction, displacement, or any other potential impacts on birds, which are dealt with separately in Chapter 7: Ornithology (EIAR Volume 2).

The main sources of NatureScot (NS) guidance used to assess collision risk are:

- Band (2024) - Using a collision risk model to assess bird collision risks for onshore wind farms. NatureScot Research Report 909.
- NatureScot (2025) - Recommended bird survey methods to inform impact assessment of onshore wind farms.
- SNH (2018) - Avoidance Rates for the onshore NS Wind Farm Collision Risk Model.

The CRA has been run for the Proposed Development using the original bird data collected by Alba Ecology from 2022 to 2024. In the CRA undertaken, twelve species were considered, as follows:

- Arctic skua (*Stercorarius parasiticus*)
- Great skua (*Stercorarius skua*)
- Golden plover (*Pluvialis apricaria*)
- Whimbrel (*Numenius phaeopus*)
- Merlin (*Falco columbarius*)
- Red-throated diver (*Gavia stellata*)
- Herring gull (*Larus argentatus*)
- Common gull (*Larus canus*)
- Great black-backed gull (*Larus marinus*)
- Curlew (*Numenius arquata*)
- Lapwing (*vanellus vanellus*)
- Redshank (*Tringa totanus*)

It should be noted that collecting gull flight-line data and conducting CRA on gulls was not part of best practice survey guidance when the surveys were conducted in 2022-2023. This has only been undertaken because gull data was collected at the time the surveys were undertaken.

Methods

Turbine Locations and Risk Envelope

The proposed turbine locations are depicted in Figure 1. The area within which the CRA should be applied is known as the Risk Envelope. It is defined as a 500-meter buffer around the blade-sweep radius of each turbine (86 meters in the case of the Proposed Development). The Risk Envelope is illustrated in blue in Figure 1.

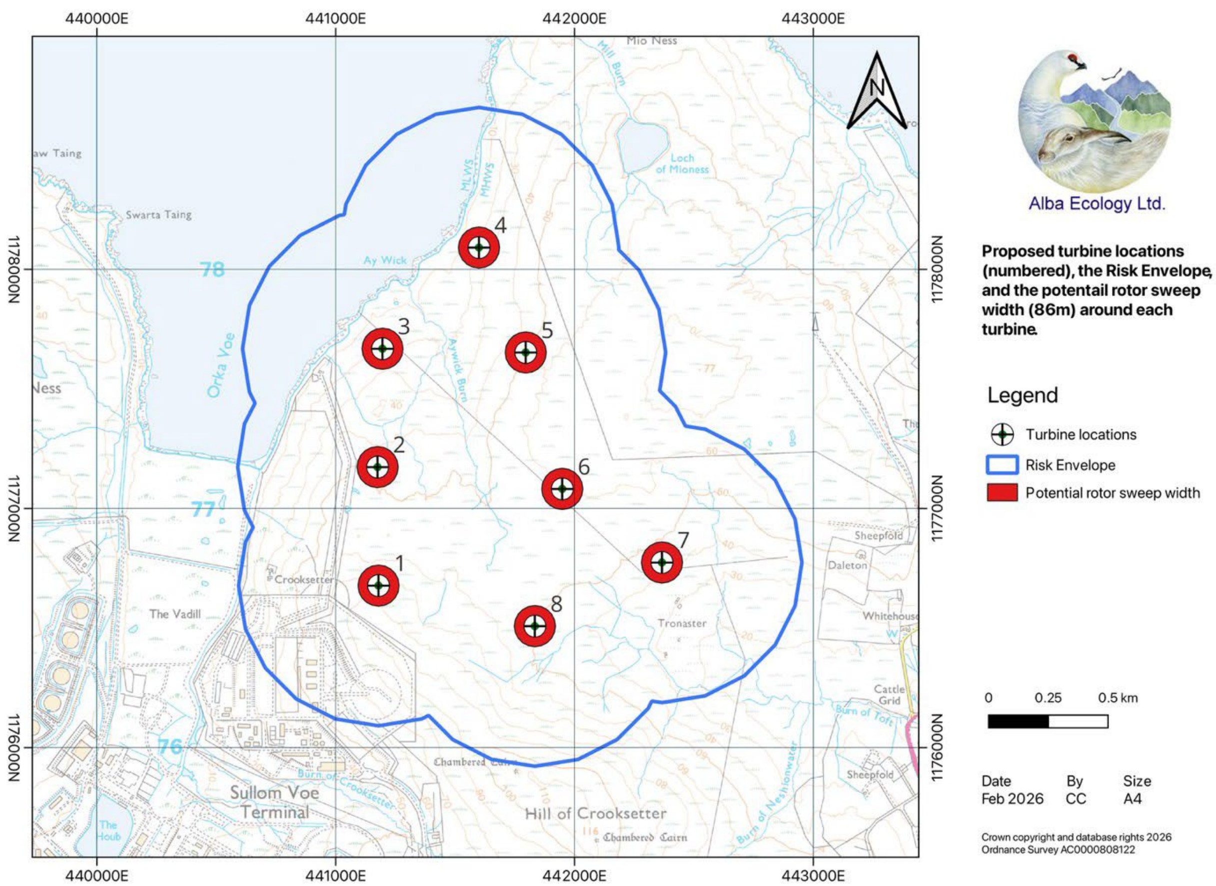

Figure 1. The Proposed Turbine Locations and Risk Envelope.

Development Parameters

The technical parameters for the turbines/wind farm used in this CRA (2026) are provided in Table 1. These technical parameters were provided by the Applicant in January 2026.

Table 1. Technical wind farm/turbine parameters.

Parameter	Value
No. of turbines	8
Number of blades	3
Pitch (degrees)	15
Rotation period (average, s)	5.7
Rotation period (average, rpm)	10.5
Rotor radius (m)	86
Operation time average, estimated (%)	85
Turbine height to hub (m)	114
Max chord (m)	5.4
Latitude of wind farm	60.48

Survey Methods

The avian survey components follow NatureScot best practice guidelines (NatureScot, 2025).

The Vantage Point (VP) data was collected by Alba Ecology from April 2022 to the end of March 2024. For assessment purposes, two years were used, Year One (1st April 2022, to 31st March 2023) and Year Two (1st April 2023 to 31st March 2024). Additionally, bird activity was summarised over both Summer (1st April to 30th September) and Winter (1st October to 31st March) periods.

VP watches are designed to record larger birds present within the Study Area but not necessarily breeding there; and included the collection of data on the activities and flight paths (flight-lines) of these birds, including height from the ground, duration of sighting, and activities of the birds. Birds recorded by this method include raptors, wildfowl, divers, waders and other large birds such as gulls.

Methods are outlined in *Recommended bird survey methods to inform impact assessment of onshore wind farms* (NatureScot, 2025) with data collected ultimately resulting in an analysis of collision risk (Band, 2024) and flight-line distribution. This method involves selecting VP locations that provide a good view of the potential turbine locations and surrounding land, but do not make the observer too conspicuous to birds potentially using the proposed turbine airspace. For the purpose of this survey, four VPs were selected to provide the best coverage of the entire potential development area. A design of eight turbines within the northern end of the Proposed Development area was chosen, which was covered by three VPs. These are shown in Figure 2 and Table 2. Viewsheds were calculated for each VP using QGIS and represent the area a surveyor can see well and accurately record flight data. Following NatureScot guidance

(NatureScot, 2025), these viewsheds are clipped to 2km. Only three VP viewsheds intersected with the risk envelope of the eight proposed turbines and consequently the data from VP 1 was not required for this CRA.

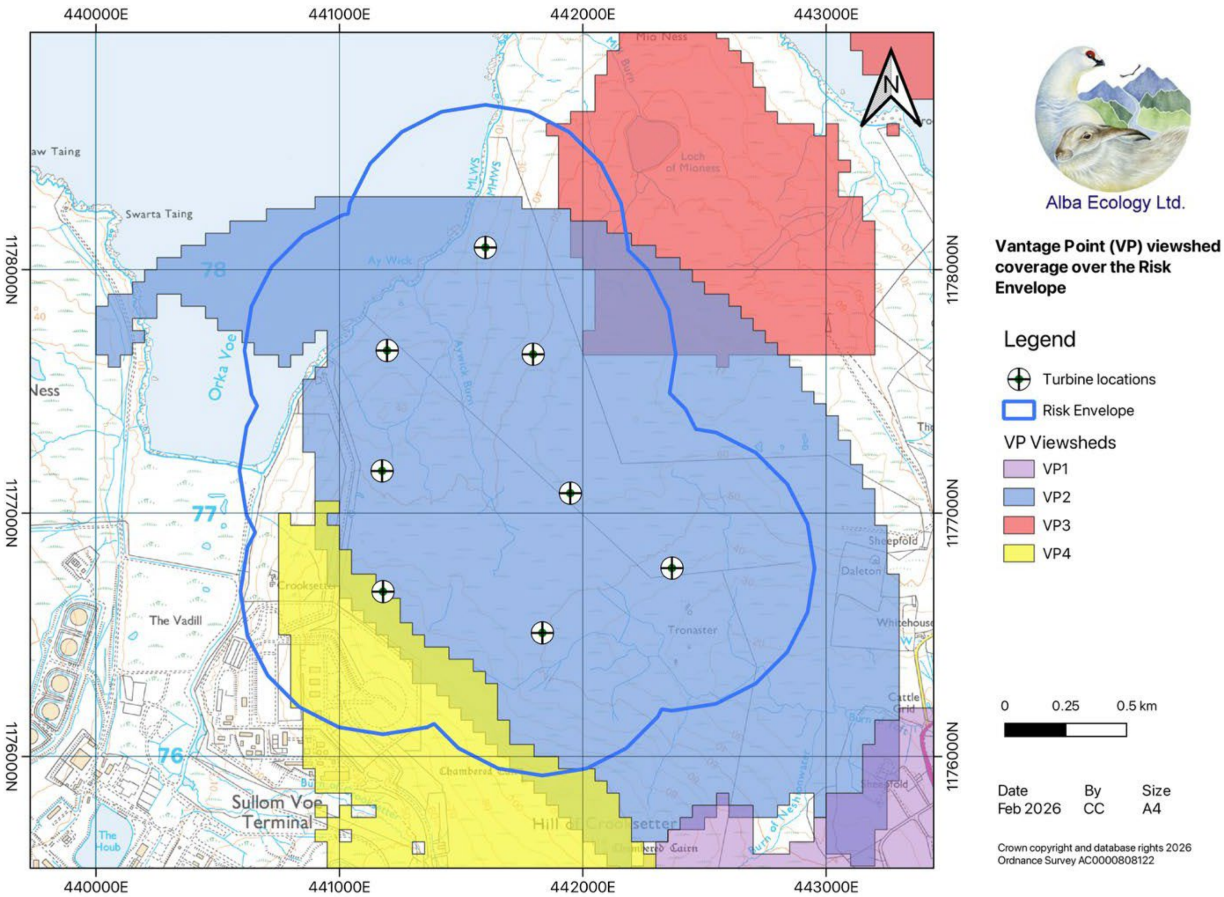

Figure 2. Vantage Point (VP) Viewsheds within the Risk Envelope.

Table 2. Locations of VPs Overlooking the Risk Envelope and Survey Effort.

			Number of hours watched					
Vantage point (VP)	Grid reference	Main viewing direction	Summer 2022	Winter 2022-2023	Summer 2023	Winter 2023 - 2024	Viewshed area within Risk Envelope (km²)	Baseline length (km)
2	HU 41327 76341	Northeast	36	36	36	36	3.61	1.63

			Number of hours watched					
Vantage point (VP)	**Grid reference**	**Main viewing direction**	**Summer 2022**	**Winter 2022-2023**	**Summer 2023**	**Winter 2023 - 2024**	**Viewshed area within Risk Envelope (km^2)**	**Baseline length (km)**
3	HU 42566 77623	Northeast	36	36	36	36	0.22	1.07
4	HU 41017 75077	East	36	36	36	36	0.52	0.51

The number of hours spent at the selected VPs is cumulative, and a minimum of 36 survey hours per season per VP were conducted. Best practice recommends not spending longer than three hours VP watching at any one time, as the attention of the observer is known to become less efficient after this period. An effort was made to vary the timing of surveys, although properly stratifying this was impractical with only two visits per month. VP surveys were conducted in daylight hours, when visibility allowed a clear view of the surrounding area (i.e. VP surveys were not undertaken during thick low cloud/foggy conditions when viewsheds were obscured). Full details of the VP data collection methods and results are provided in Technical Appendix 7.1: Bird Technical Report (EIAR Volume 4).

Weather permitting, VP watches typically lasted for a three-hour period. If successive VP watches were undertaken, a minimum of a 30-minute break was taken between surveys as per best practice guidance. Up to an 180° arc was scanned with binoculars every five minutes. All target birds that were seen were recorded. Where a bird was seen, the length of time the bird was in view for was recorded, with the flight path mapped every 15 seconds alongside details of direction, height from the ground and behaviour.

Flights of target species seen from VPs (raptors, wildfowl, divers, waders and other large birds) were recorded within four height bands.

- Below turbine height (<15m);
- Turbine ('at-risk') height (15-150m);
- Turbine ('at-risk') height (150-200m); and
- Above turbine height (>200m).

There is a certain recognised margin of error on the part of the fieldworker in estimating heights of birds from a distance, and fieldworkers are practised in estimating heights, and this is regularly reinforced by using a hand-held clinometer on objects of known height. In practice, birds vary their flight height all the time, but it is usually easy to place bird heights within altitudinal bands: high flights (>200m) are usually well above turbine height. If in doubt, surveyors were instructed to always put all birds close to turbine 'at-risk' height into that height band. Consequently, all birds at or just above the 200m height band, which was defined as within 25m of it, i.e. at least up to 225m were included in the turbine 'at-risk' height band. Only where the flight height was judged to be well above the turbine 'at-risk' height band were flights recorded as above turbine height (>200m). Any borderline records are placed precautionarily in an at-risk height band. Additionally, the proposed turbines for use at the Proposed Development have a minimum rotor sweep height of 28 meters above the ground, which exceeds the minimum height of one of the height bands used by surveyors (15 to 150m). Following the methodology outlined in the CRA guidance (Band, 2024), the time spent in this height band by birds was reduced proportionally (by c. 9.6%) to account for the proportion of this height band that is not at risk of collision.

CRA Study Area

The Study Area for the CRA is shown in Figure 3. It integrates the eight proposed turbines plus the Risk Envelope and the intersecting viewsheds of three VPs. This configuration results in a cumulative Study Area of 402.3ha covering all but c. 53.3ha Risk Envelope (i.e., c. 88.3% coverage).

Due to survey constraints and the Site's topography, not all areas within the Risk Envelope had VP coverage (c. 11.7%). These small, areas (hatched in Figure **3**) contain similar habitat characteristics to the Study Area and the exclusion of these areas does not affect the representative sample of bird flight activity collected over the Study Area or the quality of the CRA output. All recorded flight-lines of target species within the Study Area, as observed from the VPs were used in the CRA.

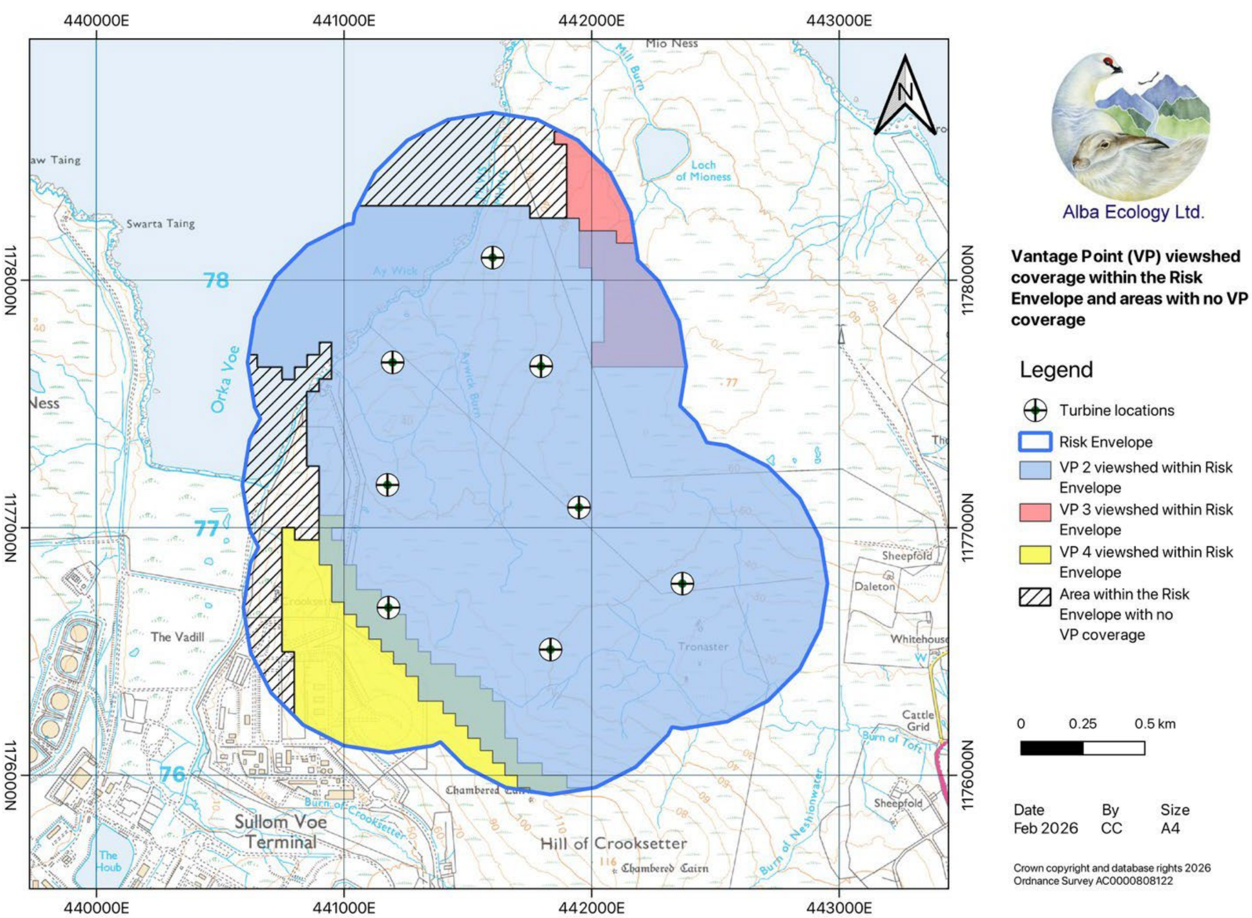

Figure 3. The CRA Study Area - defined by the area of VP viewshed coverage within the Risk Envelope. Hatched areas within the Risk Envelope are not part of the Study Area.

Collision Risk Assessment Methodology

The updated NatureScot guidance "*Guidance on using an updated collision risk model to assess bird collision risk at onshore wind farms*" and the associated report "*Using a collision risk model to assess bird collision risks for onshore wind farms"* (Band, 2024) was followed for this CRA.

The model provides a quantitative estimate of the likely number of bird collisions over a defined period (typically per month and per year) for each species for which collision risk could be ecologically important.

The NatureScot modelling approach is a multiplicative model consisting of six steps (A-F) and is structured as a sequence of linked calculation stages that combine site-specific bird survey data with turbine specifications, species characteristics, and behavioural assumptions. Survey flight data for the Study Area collected from VP surveys over two years enter the model at stage A and form the empirical basis for estimating collision risk.

Bird survey data are used to derive:

- flight activity (areal bird density - D_A (bird-seconds km^{-2})) within the Study Area,

- the height of bird flights within the Study Area, and
- the proportion of flight activity (Q_{2r}) occurring within the rotor-swept zone (maximum and minimum blade tip heights).

The collision risk model estimates collision risk through six core stages:

Stage A - Flight activity at risk height:

Bird survey data (species identification, flight-lines, and height of flights collected from VP surveys) are used to estimate the density of flying birds within each VP viewshed (D_A) and the proportion of flights occurring between the minimum and maximum rotor heights (Q_{2r}). Flight-lines recorded from VP surveys are clipped to the Study Area and the viewshed of the VP they were viewed from, ensuring only flight activity relevant for collision risk is considered in the analysis.

Stage B - Rotor transits:

The density of birds at risk height is converted into an estimate of the number of bird passages through turbine rotor areas over the relevant time period.

Stage C - Single-transit collision probability:

The probability of collision during a single rotor transit is calculated using turbine parameters (e.g. rotor diameter, blade width, rotation speed) and species-specific bird characteristics (e.g. body size, wingspan, flight speed).

Stage D - Potential collision rate:

The number of rotor transits is combined with the single-transit collision probability and adjusted for turbine operational time to estimate the potential collision rate, assuming no behavioural response by birds such as avoidance.

Stage E - Avoidance behaviour:

The potential collision rate is adjusted to account for bird avoidance, which refers to the behaviour birds employ to evade turbine blades.

Stage F – Calculating uncertainty in the collision estimates:

The 95% confidence interval around the estimate is calculated and then used to give an overall confidence interval for the best estimate of the number of collisions per year. As described above, for this analysis three independent sources of uncertainty are combined to give an overall 95% confidence interval: i) uncertainty in areal flight density (D_A), ii) survey flight height error, and iii) simplifications in the collision model error.

Directional vs Non-directional Flights

The CRM distinguishes between directional and non-directional flights because these flight behaviours influence how flight activity is quantified from survey data.

Non-directional flights occur when birds fly in multiple directions with no predominant movement axis within the Study Area. Bird activity recorded as bird-seconds in the airspace is converted to areal density.

Directional flights involve movements along a characteristic bearing (e.g., migration flyways, commuting routes) and birds often transit fully through the Study Area along this bearing. For these flights, it is more appropriate to measure bird flux as a metric of flight activity (Band, 2024). Flight counts are summarised as a Mean Traffic Rate (MTR) (i.e., the number of birds crossing an imaginary 1km line per hour) and this is converted to an equivalent areal density using a conversion that accounts for bird flight speed and the height bands surveyed. This conversion enables directional movements to be incorporated into the same CRM framework as non-directional data.

The formula for the conversion is:

$$D_A = MTR \times (\pi/2) / (v \times h) \text{ birds m}^{-2}$$

where:

MTR is expressed as number of birds per m (of baseline), per second

v is bird speed (m per sec); and

h is the height band within which bird flights are recorded (m).

Three species exhibited at least some directional flight behaviour in the Study Area:

- Common gull
- Herring gull
- Great black-backed gull

Where individual flightlines of these three species exhibited non-directional behaviour (e.g. circling, foraging) they were treated separately and analysed using the non-directional approach. Collision estimates for each species were then summed across directional and non-directional behaviour to yield the overall collision risk for the species.

Red-throated divers are not treated as a directional species in this CRA as the diver flightlines recorded do not come from foraging flights to and from lochans, rather the flight paths recorded were observed to come from immature non-breeders that were scoping the Study Area for potential nesting opportunities or were from groups (2 – 5 birds) of non-breeders passing through the Site in an arbitrary direction. As the recorded diver data was not in a defined direction and, often, not a straight flight, it was treated as non-directional movement in this case.

The baseline used to measure flux were defined as a cross section of each VP viewshed perpendicular to bird movement. The baselines are shown in Figure 4 and their lengths are shown in Table 2. These were chosen as they best capture the dominant flight direction within each VP viewshed. The three directional gull species most often entered the Study Area from the north-west off the ocean and continued straight through the Study Area, or they entered the Study Area from the north-east traveling south-west for a time, then turning south-east continuing to exit the Study Area.

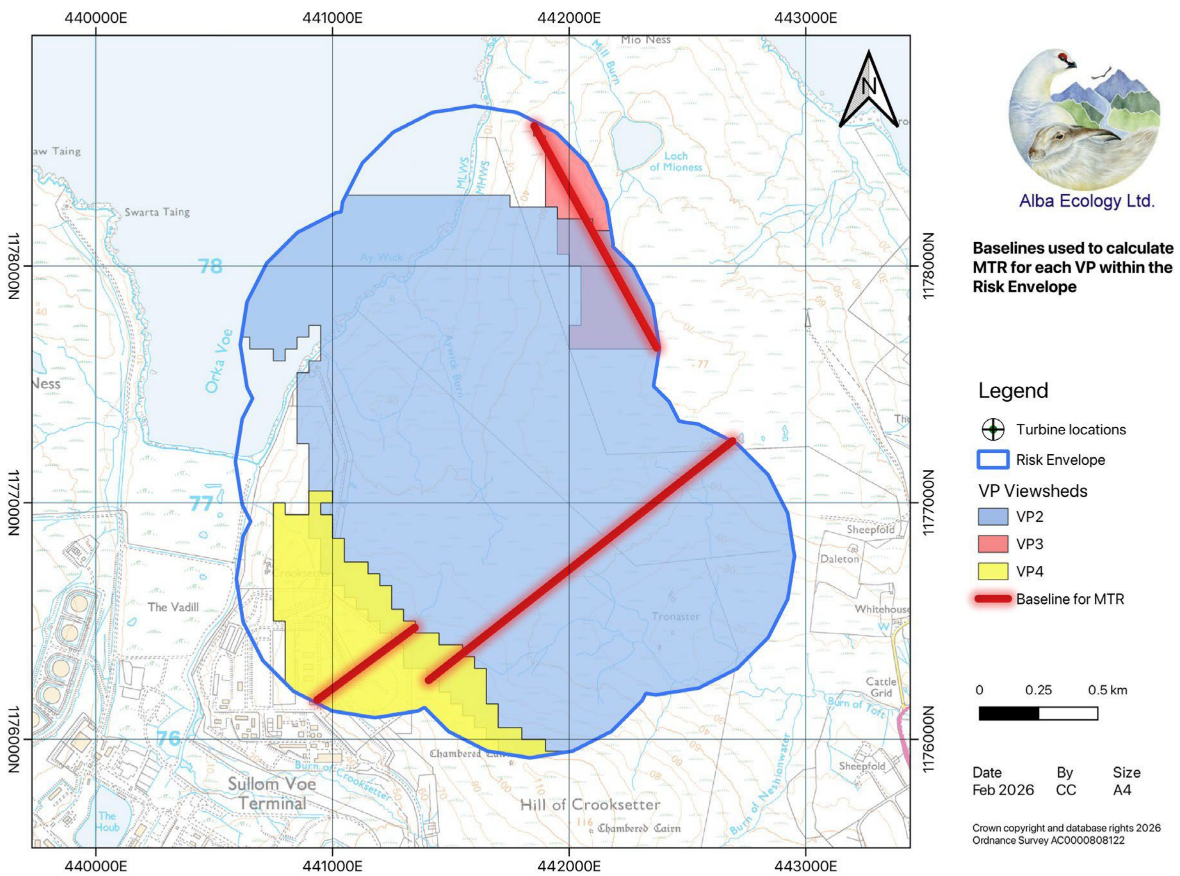

Figure 4. Baselines used to calculate MTR for each VP within the Risk Envelope.

Areas of Different Bird Density

NatureScot's guidance (Band, 2024) permits CRA to be conducted on subsets or clusters of turbines — for example, groups of turbines within areas of higher flight activity — by applying the same CRM steps (density, proportion at risk height, rotor transit calculation, collision probability and avoidance) to the subset's bird activity and turbine configuration. Focusing on specific turbine clusters, where appropriate, allows targeted evaluation of hotspots of collision risk within the wider turbine layout. This approach is useful for sites where flight activity is not uniformly distributed across the Study Area and when the flight data is sufficiently robust to allow for discrimination of areas of long-term preferential use.

Three species (lapwing, curlew, and redshank) exhibited higher flight activity within an area to the south-east of the Study Area (Figure 5). Lapwing, curlew, and redshank were observed to use an area surrounding grassland (Phase 1 habitat codes: B1.1, B.1.2, B.5) disproportionately more than the surrounding heathland and mire habitat (Figure 6, taken from Technical Appendix 6.2: Habitat Survey Report (EIAR Volume 4)). All other species either exhibited no discernible spatial preference or had insufficient flight data to robustly determine preferential habitat use.

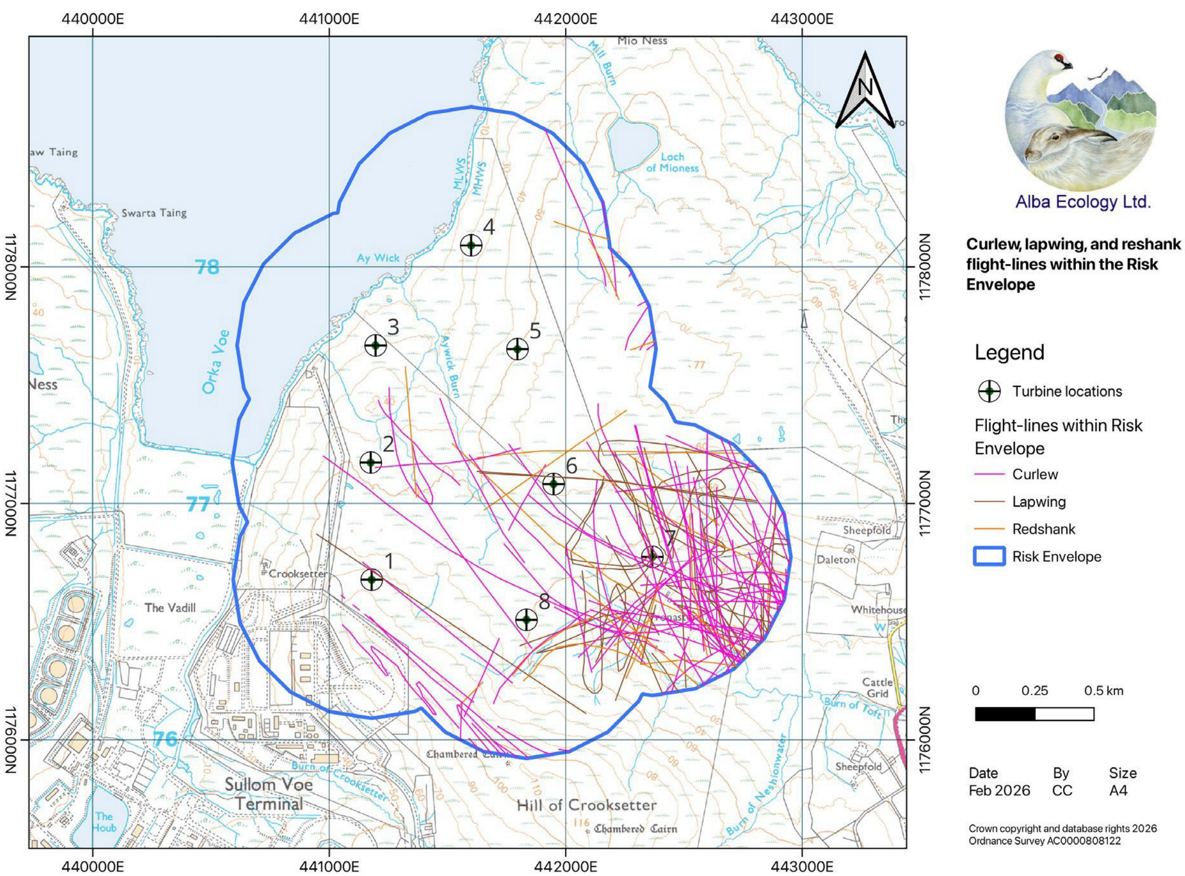

Figure 5. Flight-lines for curlew, lapwing, and redshank within the Study Area.

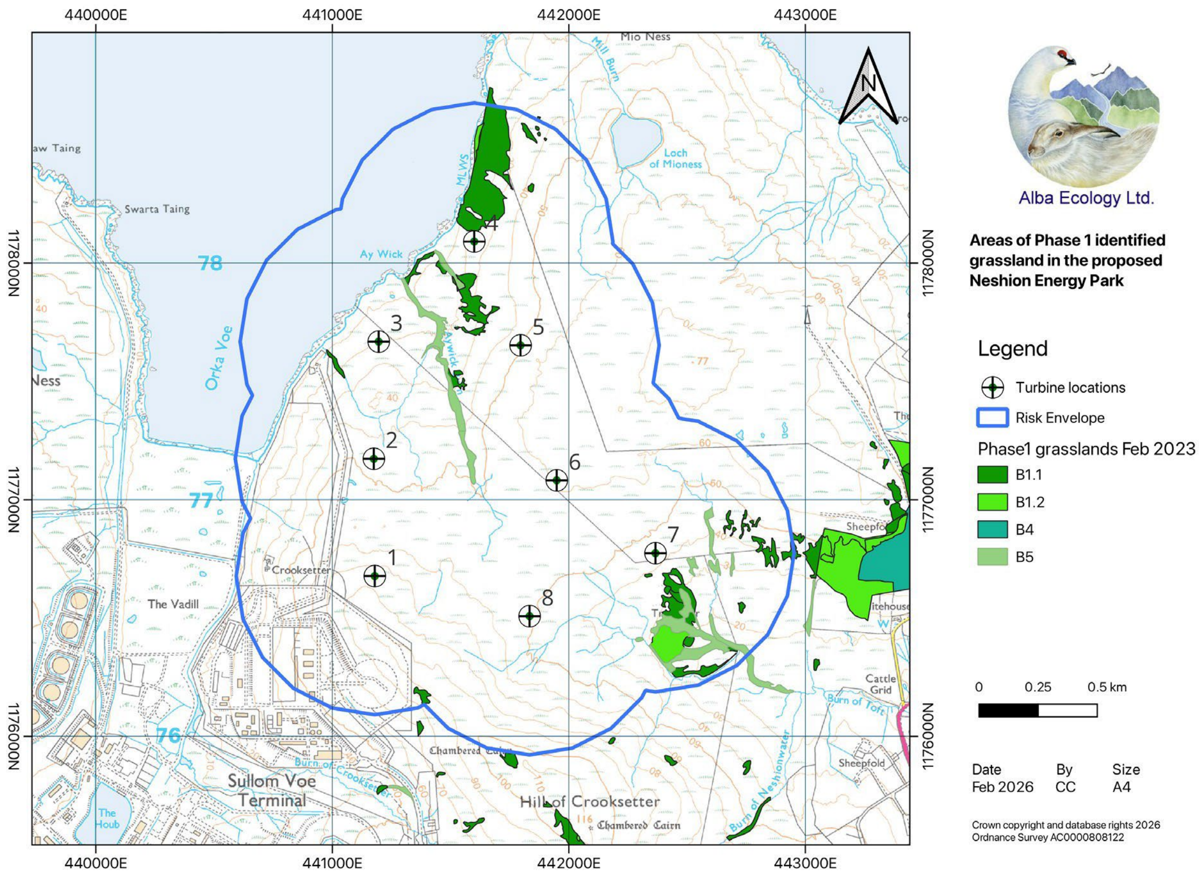

Figure 6. Areas of Phase 2 identified grassland in the Proposed Development.

For these species CRA results are presented for two distinct clusters of turbines that capture the Lower-Use Area and Higher-Use Area. As the outputs of the NatureScot model can be considered cumulatively, the collision estimate from both clusters are summed to provide an overall collision risk for the Proposed Development.

The turbine subset, VP coverage, and Risk Envelopes areas are shown for the Lower-Use area in Figure 7 and Table 3 and for the high use area in Figure 8 and Table 4.

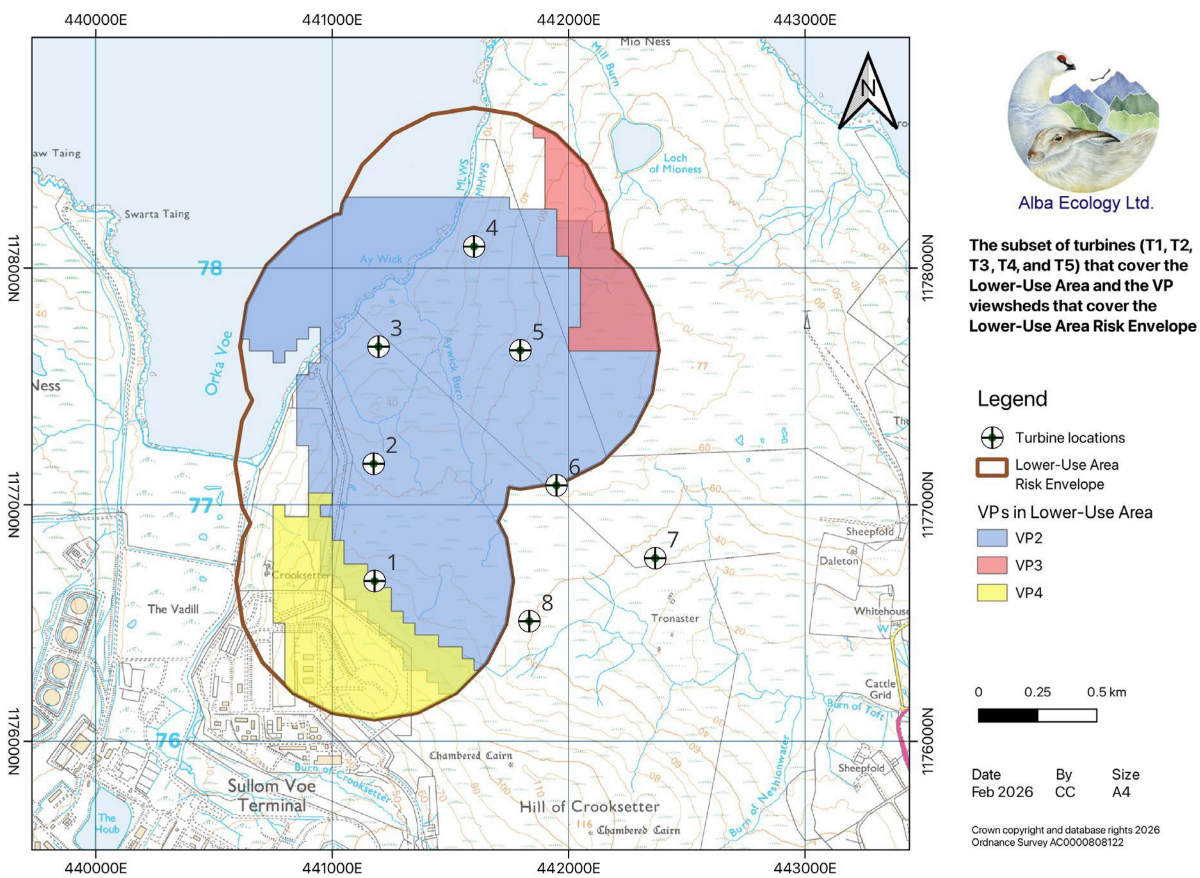

Figure 7. The Lower-Use Area: The subsets of turbines (T1, T2, T3, T4, and T5) and the VP viewsheds that cover the Lower-Use Area.

Table 3. Locations of VPs overlooking the Lower-Use Area Risk Envelope and survey effort.

			Number of hours watched				
Vantage point (VP)	**Grid reference**	**Main viewing direction**	**Summer 2022**	**Winter 2022-2023**	**Summer 2023**	**Winter 2023 - 2024**	**Viewshed area within the Lower-Use Area Risk Envelope (km^2)**
2	HU 41327 76341	Northeast	36	36	36	36	2.3
3	HU 42566 77623	Northeast	36	36	36	36	0.22
4	HU 41017 75077	East	36	36	36	36	0.45

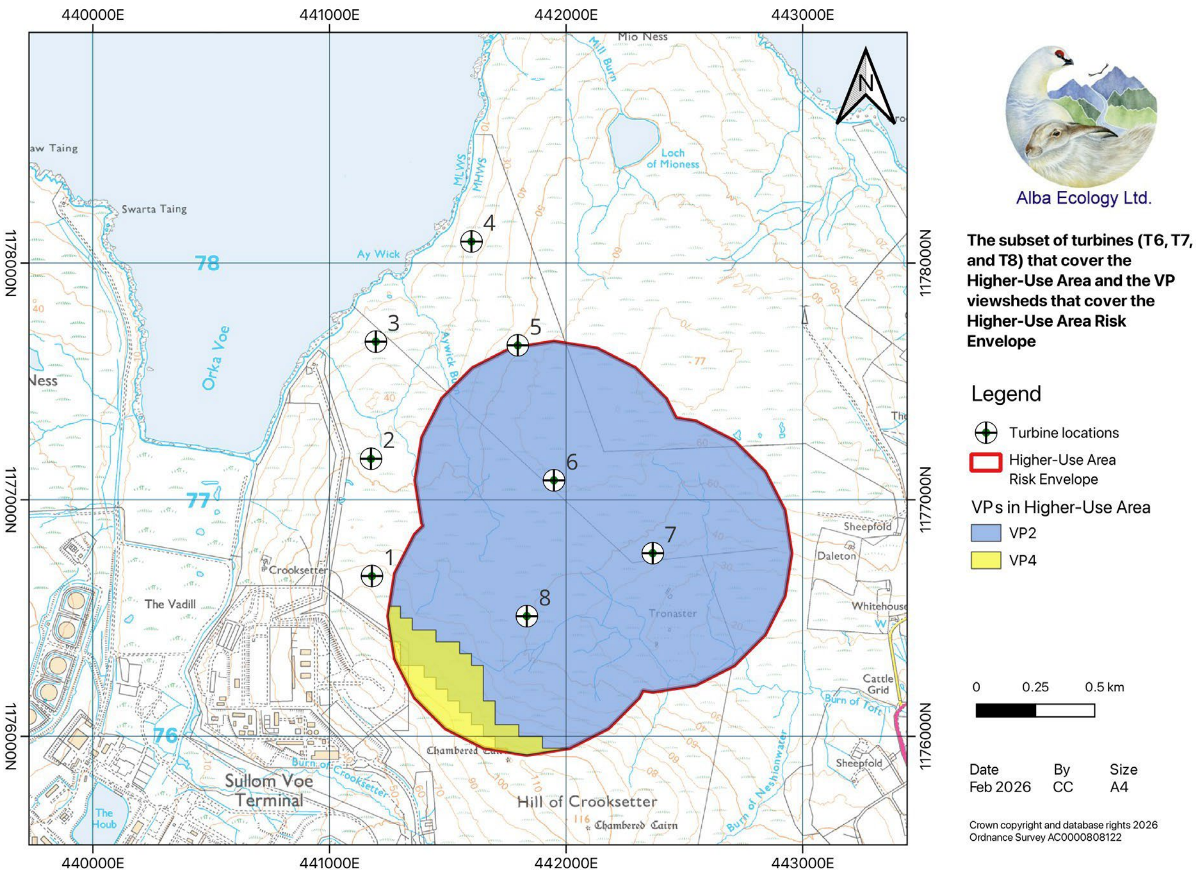

Figure 8. The Higher-Use Area: The subsets of turbines (T6, T7, and T8) and the VP viewsheds that cover the Higher-Use Area.

Table 4. Locations of VPs overlooking the Higher-Use Risk Envelope and survey effort.

			Number of hours watched				
Vantage point (VP)	**Grid reference**	**Main viewing direction**	**Summer 2022**	**Winter 2022-2023**	**Summer 2023**	**Winter 2023 - 2024**	**Viewshed area within the Higher-Use Area Risk Envelope (km^2)**
2	HU 41327 76341	Northeast	36	36	36	36	2.1
4	HU 41017 75077	East	36	36	36	36	0.16

For all other species analysed for the CRA, variations in observed flight activity are expected to result primarily from sampling variability and the area of the VP viewshed.

Combining Observations from Multiple VPs

The method recommended in Annex 6 of the NatureScot CRA guidance (Band, 2024) for combining observations from multiple VPs is used, which involves using a weighted average to combine areal density estimates from each viewshed.

The guidance (Band, 2024) specifies a weighting factor calculated as the square root of the product of the viewshed area and the total observation time at each viewshed during each summer/winter period annually. This approach increases the influence of areal density estimates derived from VPs with larger fields of view and longer observation durations. In the case of the Proposed Development Study Area, VP 2 represents the largest viewshed and subsequently areal bird density data from VP 2 is weighted higher when calculating the average Study Area areal density. For lapwing, curlew, and redshank, where subclusters of turbines are analysed, the corresponding viewsheds within the respective risk envelopes are used when combining observations from multiple VPs.

For directional analysis, survey effort does not depend on VP area, rather it depends on the length of the baseline used to measure MTR. Accordingly, in combining areal density estimates derived from directional flux data, the length of the baseline was used in place of VP area when calculating the weighted average. The baseline lengths for each VP are given in Table 2.

Treatment of Uncertainty

A key methodological change in the 2024 NatureScot guidance, compared to earlier versions, is the shift from a best-case/worst-case framing towards an explicit representation of uncertainty and variability around a best estimate. The best estimates presented in this report represent the collision rate most strongly supported by the available data and are considered reflective of the expected long-term average collision risk at the Proposed Development. The associated uncertainty range is intentionally broad and represents a 95% uncertainty interval designed to encompass the observed ecological variability, including infrequent but plausible periods of high bird activity. Collision estimates toward the upper end of this range reflect rare high-activity conditions, characterised by increased use of airspace at risk height, and are not considered representative of typical flight behaviour within the Study Area. Accordingly, the upper bound should not be interpreted as a worst-case scenario; rather, it demonstrates confidence that the assessment has not excluded any plausible ecological conditions, even higher collision risk conditions that we do not expect to be common. The inclusion of this upper range ensures that unlikely but plausible high-activity conditions are captured, without implying that such conditions are expected or likely to occur. Explicit quantification of the sources of uncertainty also makes clearer the cause of uncertainty in the collision estimates, clarifying to what level biological variability, observer error, or model error contribute to the precision of the results.

The CRA presented in this report identifies three primary sources of independent uncertainty:

1. Uncertainty in areal flight density (D_A): This arises from the variability in bird flight activity observed during VP surveys. For the species analysed in this CRA, uncertainty primarily stems from real biological variability in flight activity rather than a limited survey sample. This

component of uncertainty emerges from the standard deviation (SD) of D_A estimates and is quantified as:

$$\text{Relative error of } D_A = (1.96 * \text{SD of } D_A) / (D_{A\ Summer} + D_{A\ Winter})$$

Where:

$$\text{SD of } D_A = \sqrt{((\text{SD of } D_{A\ Summer})^2 + (\text{SD of } D_{A\ Winter})^2)}$$

2. Survey flight height error: This error captures the anticipated uncertainty around how surveyors assigned birds into height bands. Due to the precautionary approach used by surveyors (i.e., borderline flight height assigned to an at-risk height band), we assign a small relative error of 5% to this component of uncertainty.

3. Simplifications in the collision model error: This error arises from the assumptions made in the collision model and is stated as a relative error of 20% in the guidance (Band, 2024).

When combining collision estimates from the Lower-Use and Higher-Use Area CRAs, associated uncertainties were propagated accordingly. For each cluster, the reported 95% confidence interval was converted to an approximate standard deviation under an assumption of normality; independent uncertainties were then combined using the root-sum-of-squares of variances, and the resulting pooled standard deviation was converted back to a 95% confidence interval around the summed mean.

Key CRA Assumptions

The CRA model assumes birds fly on straight, uninterrupted flight paths at a constant speed and that collision probability is independent of flight direction, with birds assumed to approach the rotor plane perpendicularly. Birds are represented using simplified cruciform shape (parameterised by wingspan and body length). Bird flight activity and the proportion of flights at collision risk height are assumed to be representative of long-term conditions within the Study Area.

In addition, to clip the flight-line data collected over the entire VP viewshed to the viewshed within the Study Area and proportionally adjust flights at risk height within the 15-150m range, two assumptions about flight behaviour were made.

1. All birds had a consistent flight speed during all flights.
2. Flights were equally distributed across the entire elevation range of each height band that surveyors used to record flight heights.

Unless otherwise specified, species analysed in this CRA are assumed to exhibit non-directional flight behaviour, have a 50% split in upwind/downwind flights, and have a nocturnal activity ranking of 1. Additionally, a large array correction was not applied to the collision estimates.

Results

Arctic Skua

Arctic skua were recorded in the Study Area during the summer over both years. No Arctic skua were observed in the winter months (Figure 9). A total of 70 flights were observed in the Study Area (Figure 10).

The biological parameters used within the CRA for Arctic skua are in Table 5:

Table 5. Biological parameters for arctic skua CRA.

Bird length (m) (Snow *et al.*, 1998)	0.43
Wingspan (m) (Snow *et al.*, 1998)	1.18
Assumed bird speed (m/s) (Alerstam *et al.*, 2007)	13.8
Avoidance rate (%) (SNH, 2018)	99.5
Flight type	Flapping

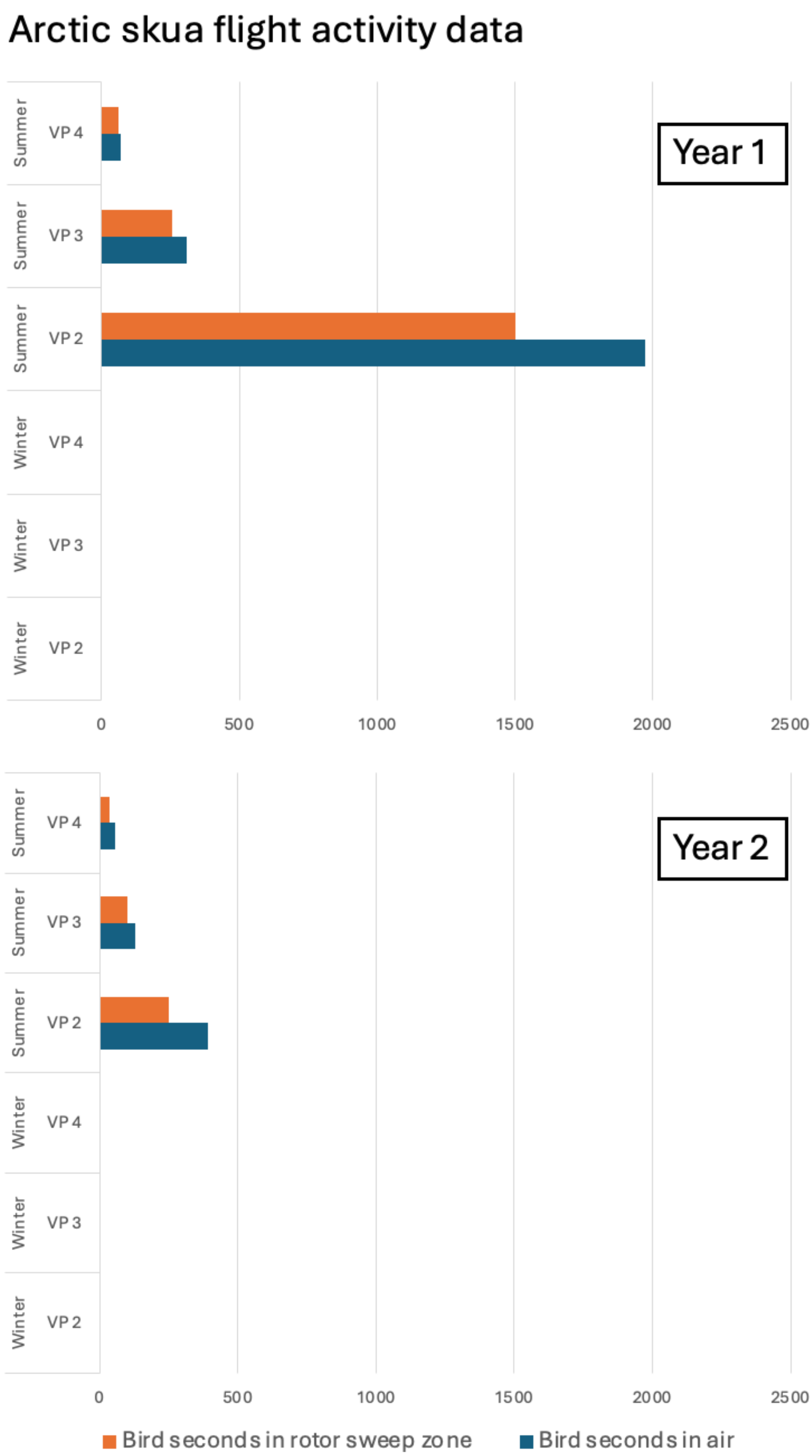

Figure 9. Flight activity of Arctic skua across years, seasons, and vantage point (VP) locations. Blue bars show the total flight activity in bird seconds (time spent in the air), and orange bars show the subset of seconds birds spent at risk height.

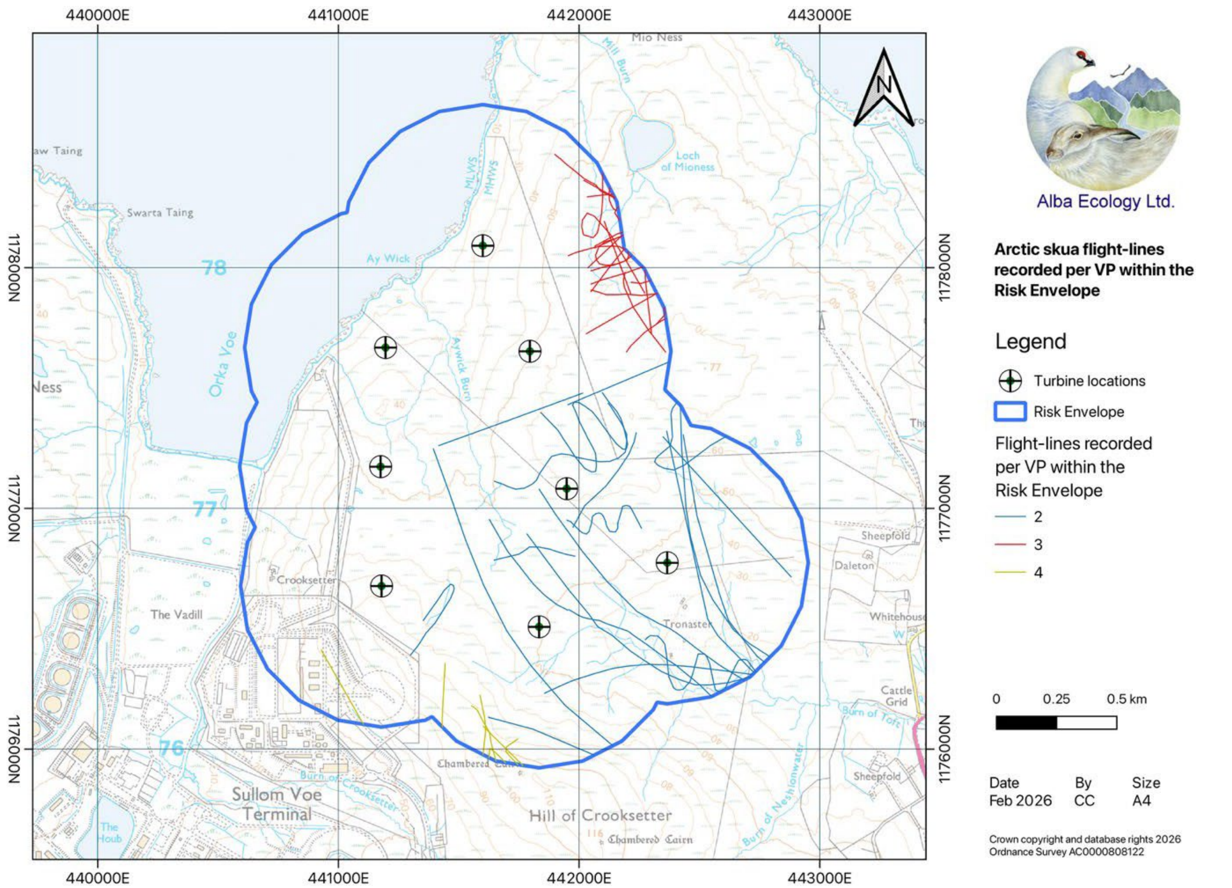

Figure 10. Arctic skua flight-line data collected in Year One and Year Two.

The CRA for Arctic skua with two years combined data is shown in Table 6 - Table 9. Table 6 provides a summary of arctic skua flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 7 gives the survey results for Arctic skua across seasons and VPs. Table 8 estimates the uncertainty for the Arctic skua CRA and Table 9 presents the estimated number of collisions per year.

Table 6. A summary of Arctic skua flight activity in bird seconds, including Q2r which is the proportion of flight activity that occurred in the risk height range (rotor sweep area).

Total bird seconds in air (s)	2929
Total bird seconds in rotor sweep area (s)	2208
Q_{2r} – Proportion of time in rotor sweep area	75.4%

Table 7. Survey results for Arctic skua across seasons and VPs. Time shows the seconds birds were in the air, and D_A shows the areal density (bird seconds per km²).

			Summer		Winter	
Year	**VP**	**Area (km²)**	**Time (bird seconds)**	**D_A**	**Time (bird seconds)**	**D_A**
1	VP 2	3.61	1972	0.00426	0	0
1	VP 3	0.22	309	0.0107	0	0
1	VP 4	0.52	69	0.00102	0	0
2	VP 2	3.61	392	0.000838	0	0
2	VP 3	0.22	129	0.00446	0	0
2	VP 4	0.52	58	0.000854	0	0
			Weighted Mean	**0.00292**	**Weighted Mean**	**0**
			Weighted SD	0.00275	**Weighted SD**	0

Table 8. Sources of uncertainty for the Arctic skua CRA.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	1.84
Survey flight height error	0.05
Simplifications in the collision model	0.2
Combined uncertainty	+/- 185%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Arctic skua were assessed using 99.5% avoidance as recommended by NatureScot as a precautionary measure (SNH, 2018). Assuming an avoidance factor of 99.5% by which Arctic skua may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions (Table 9):

Table 9. CRA outputs for arctic skua

Potential annual bird transits through rotors	342
Collisions assuming no avoidance	18
Collisions assuming 95% avoidance	0.9
Collisions assuming 98% avoidance	0.36
Collisions assuming 99% avoidance	0.17
Collisions assuming 99.5% avoidance	**0.09 (one collision every 11.1 years)**

At a 99.5% avoidance rate, the estimated collision rate was 0.09 collisions per year, equivalent to one bird strike every 11.1 years. The associated uncertainty ranged from 0 to 0.26 collisions per year (one bird strike every 3.8 years), reflecting a 95% confidence interval with an uncertainty range of 185% (truncated at zero to maintain biological realism).

The estimated collision risk (excluding avoidance assumptions) exhibited a substantial uncertainty range of 185%. This large spread of values primarily stems from the diversity of areal flight density estimates (D_A) presented in Table 7, which result from real heterogeneity in Arctic skua flight activity, such as many true absences (no Arctic skuas present during the winter), rather than from measurement errors or insufficient sampling.

Great Skua

Great skua were recorded in the Study Area during the summer over both years, although more flight time was recorded in Year Two. No great skua were observed in the winter months (Figure 11). A total of 20 flights were observed in the Study Area (Figure 12).

The biological parameters used within the CRA for great skua are in Table 10:

Table 10. Biological parameters for great skua CRA.

Bird length (m) (Snow *et al*., 1998)	0.55
Wingspan (m) (Snow *et al*., 1998)	1.36
Assumed bird speed (m/s) (Gyimesi *et al*., 2017)	11.6
Avoidance rate (%) (SNH, 2018)	99.5
Flight type	Flapping

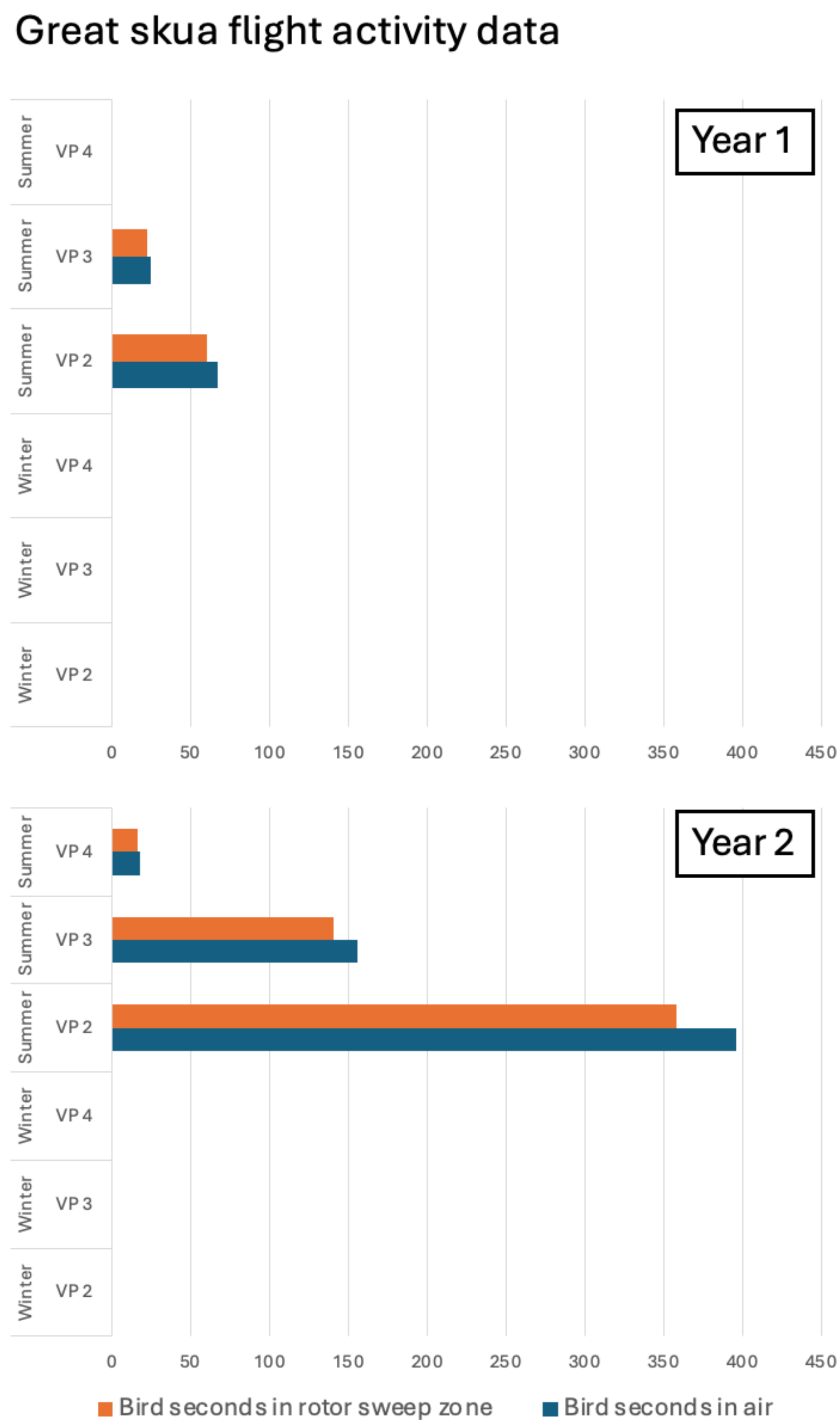

Figure 11. Flight activity of great skua across years, seasons, and vantage point (VP) locations. Blue bars show the total flight activity in bird seconds (time spent in the air), and orange bars show the subset of seconds birds spent at risk height.

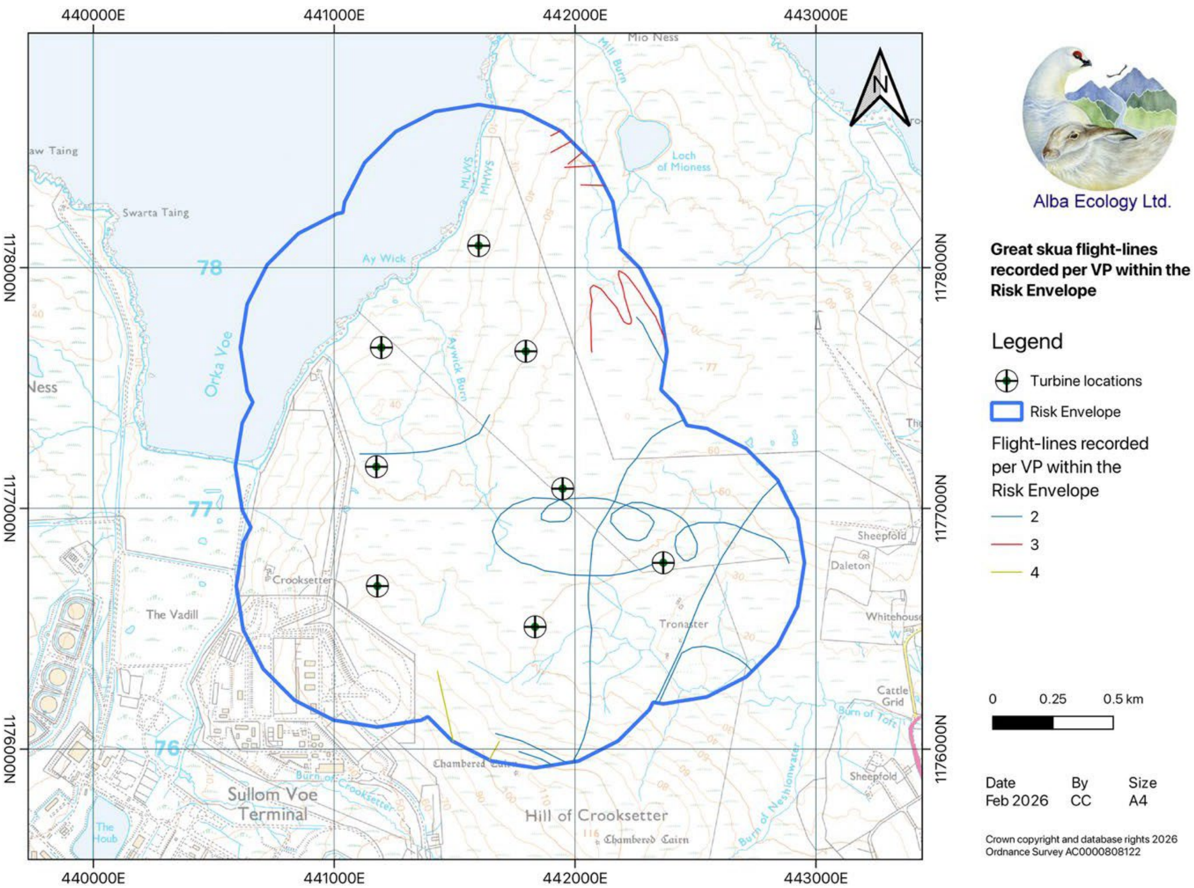

Figure 12. Great skua flight-line data collected in Year One and Year Two.

The CRA for great skua with two years combined data is shown in Table 11-Table 14. Table 11 provides a summary of great skua flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 12 gives the survey results for great skua across seasons and VPs. Table 13 estimates the uncertainty for the great skua CRA and Table 14 presents the estimated number of collisions per year.

Table 11. A summary of great skua flight activity in bird seconds, including Q2r which is the proportion of flight activity that occurred in the risk height range (rotor sweep area).

Total bird seconds in air (s)	662
Total bird seconds in rotor sweep area (s)	598
Q_{2r} – Proportion of time in rotor sweep area	90.37%

Table 12. Survey results for great skua across seasons and VPs. Time shows the seconds birds were in the air, and D_A shows the areal density (bird seconds per km^2).

			Summer		**Winter**	
Year	**VP**	**Area (km^2)**	**Time (bird seconds)**	**D_A**	**Time (bird seconds)**	**D_A**
1	VP 2	3.61	67	0.000143	0	0
1	VP 3	0.22	25	0.000865	0	0
1	VP 4	0.52	0	0	0	0
2	VP 2	3.61	396	0.0008468	0	0
2	VP 3	0.22	156	0.00540	0	0
2	VP 4	0.52	18	0.000265	0	0
			Weighted Mean	0.000812	**Weighted Mean**	**0**
			Weighted SD	0.00136	**Weighted SD**	0

Table 13. Sources of uncertainty for the great skua CRA.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	3.28
Survey flight height error	0.05
Simplifications in the collision model	0.2
Combined uncertainty	+/- 329%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Great skua were assessed using 99.5% avoidance as recommended by NatureScot as a precautionary measure (SNH, 2018). Assuming an avoidance factor of 99.5% by which great skua may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions Table 14:

Table 14. CRA outputs for great skua.

Potential annual bird transits through rotors	99
Collisions assuming no avoidance	6

Collisions assuming 95% avoidance	0.3
Collisions assuming 98% avoidance	0.12
Collisions assuming 99% avoidance	0.06
Collisions assuming 99.5% avoidance	**0.03 (one collision every 33.3 years)**

At a 99.5% avoidance rate, the estimated collision rate was 0.03 collisions per year, equivalent to one bird strike every 33.3 years. The associated uncertainty ranged from 0 to 0.13 collisions per year (one bird strike every 7.7 years), reflecting a 95% confidence interval with an uncertainty range of 329% (truncated at zero to maintain biological realism).

The estimated collision risk (excluding avoidance assumptions) exhibited a substantial uncertainty range of 329%. This large spread of values primarily stems from the diversity of areal flight density estimates (D_A) presented in Table 11, which result from real heterogeneity in great skua flight activity, such as many true absences (no great skuas present during the winter), rather than from measurement errors or insufficient sampling.

Golden Plover

Golden Plover were recorded in the Study Area during the summer and winter over both years (Figure 13). The large Year One winter flight activity value in VP 2 is driven by three large flocks (19-60 birds). A total of 163 flights were observed in the Study Area over two years (Figure 14).

The biological parameters used within the CRA for golden plover are in Table 15. The flight speed of American golden plover (*Pluvialis dominica*) was used in the absence of a stated golden plover flight speed.

Table 15. Biological parameters for golden plover CRA.

Bird length (m) (Snow *et al.*, 1998)	0.64
Wingspan (m) (Snow *et al.*, 1998)	0.28
Assumed bird speed (m/s) (Alerstam *et al.*, 2007) **Pluvialis dominica* proxy	13.7
Avoidance rate (%) (SNH, 2018)	98
Flight type	Flapping

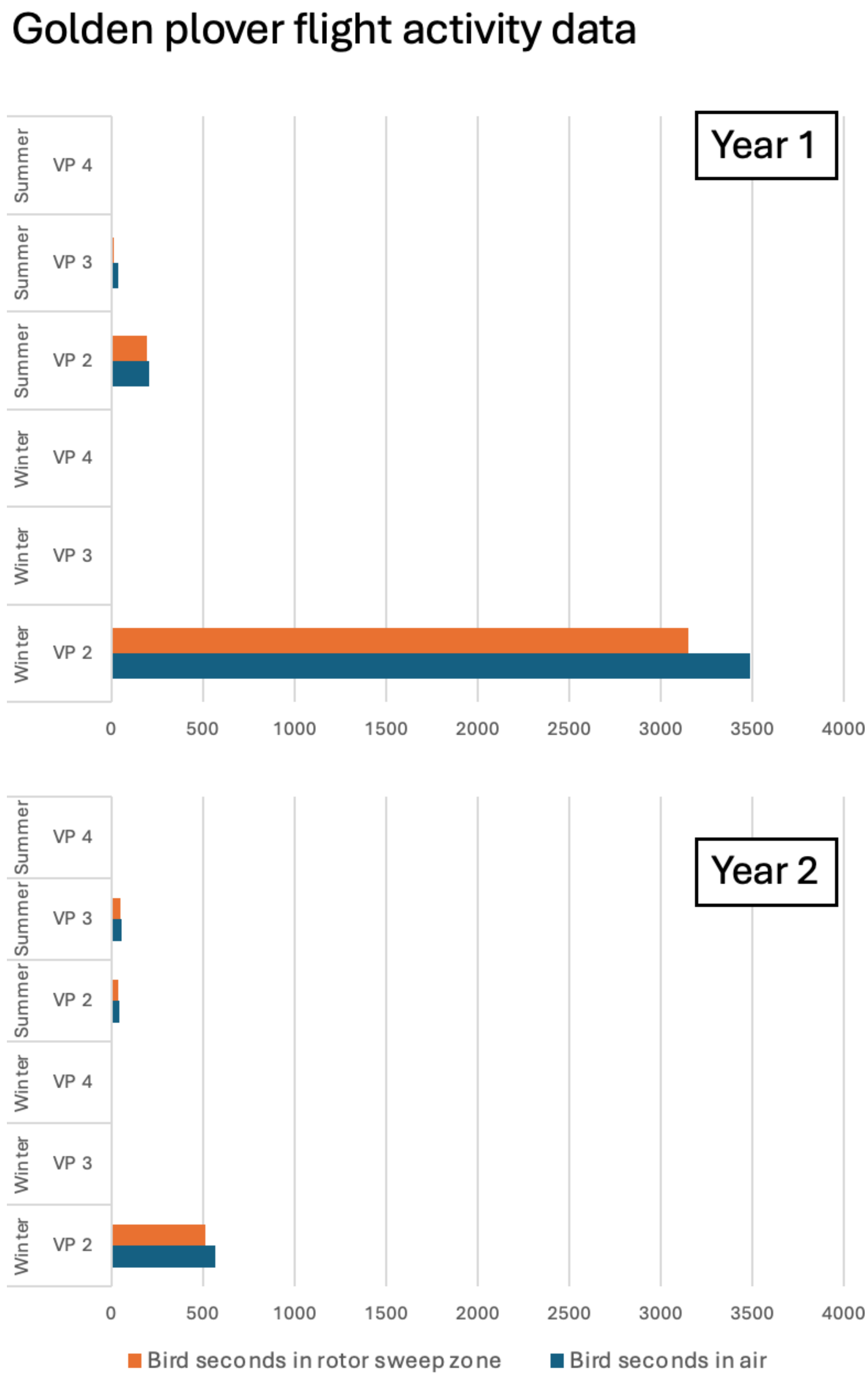

Figure 13. Flight activity of golden plover across years, seasons, and vantage point (VP) locations. Blue bars show the total flight activity in bird seconds (time spent in the air), and orange bars show the subset of seconds birds spent at risk height.

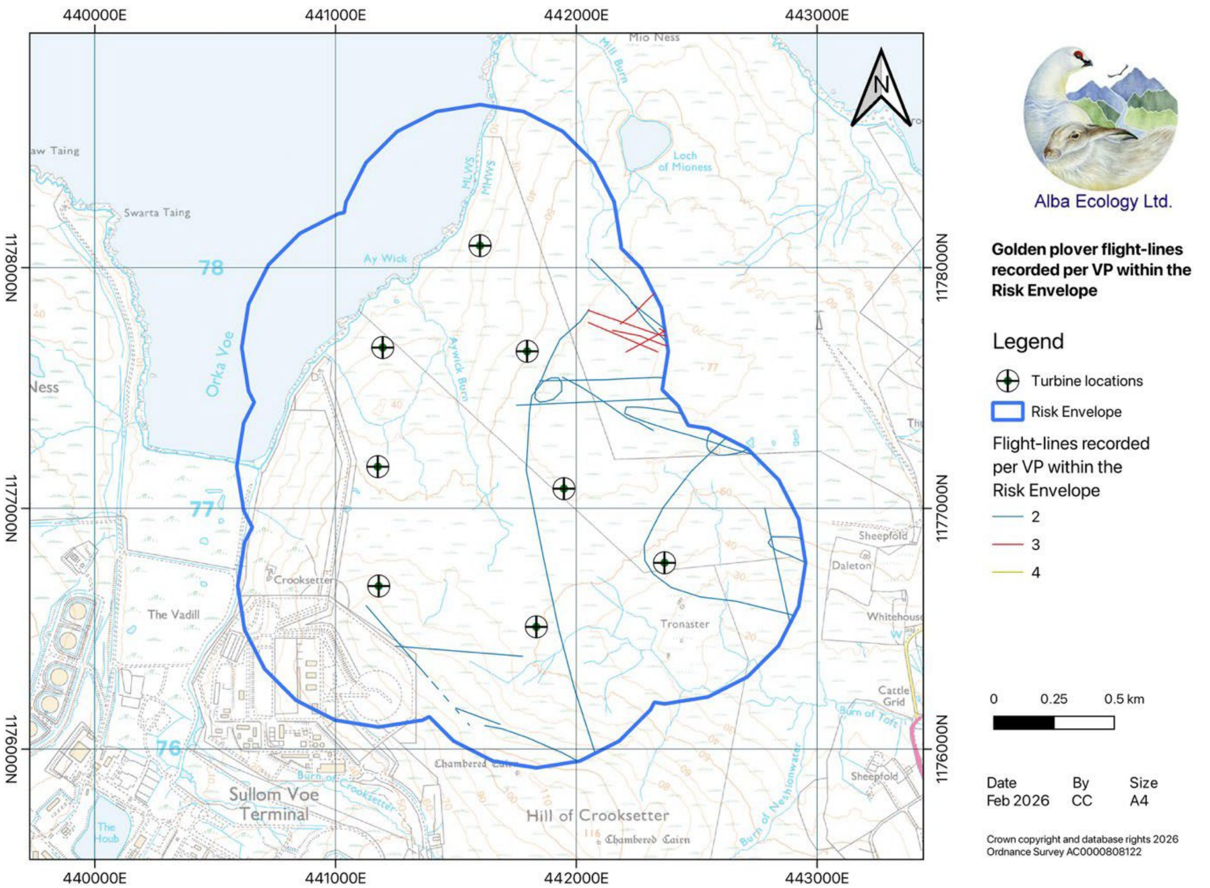

Figure 14. Golden plover flight-line data collected in Year One and Year Two.

The CRA for golden plover with two years combined data is shown in Table 16-Table 19. Table 16 provides a summary of golden plover flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 17 gives the survey results for golden plover across seasons and VPs. Table 18 estimates the uncertainty for the golden plover CRA and Table 19 presents the estimated number of collisions per year.

Table 16. A summary of golden plover flight activity in bird seconds, including Q2r which is the proportion of flight activity that occurred in the risk height range (rotor sweep area).

Total bird seconds in air (s)	4396
Total bird seconds in rotor sweep area (s)	3958
Q_{2r} – Proportion of time in rotor sweep area	90%

Table 17. Survey results for golden plover across seasons and VPs. Time shows the seconds birds were in the air, and D_A shows the areal density (bird seconds per km^2).

			Summer		Winter	
Year	**VP**	**Area (km^2)**	**Time (bird seconds)**	**D_A**	**Time (bird seconds)**	**D_A**
1	VP 2	3.61	207	0.000443	3486	0.00745
1	VP 3	0.22	39	0.00135	0	0
1	VP 4	0.52	0	0	0	0
2	VP 2	3.61	43	0.0000919	568	0.00121
2	VP 3	0.22	53	0.00183	0	0
2	VP 4	0.52	0	0	0	0
			Weighted Mean	0.000407	**Weighted Mean**	0.00266
			Weighted SD	0.000541	**Weighted SD**	0.00323

Table 18. Sources of uncertainty for the golden plover CRA.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	2.09
Survey flight height error	0.5
Simplifications in the collision model	0.2
Combined uncertainty	+/- 210%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Golden plover were assessed using 98% avoidance as recommended by NatureScot as a precautionary measure (SNH, 2018). Assuming an avoidance factor of 98% by which golden plover may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions (Table 19):

Table 19. CRA outputs for golden plover.

Potential annual bird transits through rotors	256
Collisions assuming no avoidance	11

Collisions assuming 95% avoidance	0.55
Collisions assuming 98% avoidance	**0.24 (One collision every 4.2 years)**
Collisions assuming 99% avoidance	0.08
Collisions assuming 99.5% avoidance	0.06

At a 98% avoidance rate, the estimated collision rate was 0.24 collisions per year, equivalent to one bird strike every 4.2 years. The associated uncertainty ranged from 0 to 0.74 collisions per year (one bird strike every 1.35 years), reflecting a 95% confidence interval with an uncertainty range of 210% (truncated at zero to maintain biological realism).

The estimated collision risk (excluding avoidance assumptions) exhibited a substantial uncertainty range of 210%. This large spread of values primarily stems from the diversity of areal flight density estimates (D_A) presented in Table 17, which result from real heterogeneity in golden plover flight activity, such as many true absences, rather than from measurement errors or insufficient sampling.

Whimbrel

Whimbrel were recorded in the Study Area during the summer over both years (Figure 15). No whimbrel were recorded in the winter months. A total of 36 flights were observed in the Study Area over two years (Figure 16).

The biological parameters used within the CRA for whimbrel are in Table 20.

Table 20. Biological parameters for whimbrel CRA.

Bird length (m) (Snow *et al*., 1998)	0.41
Wingspan (m) (Snow *et al*., 1998)	0.83
Assumed bird speed (m/s) (Alerstam *et al*., 2007)	16.3
Avoidance rate (%) (SNH, 2018)	98
Flight type	Flapping

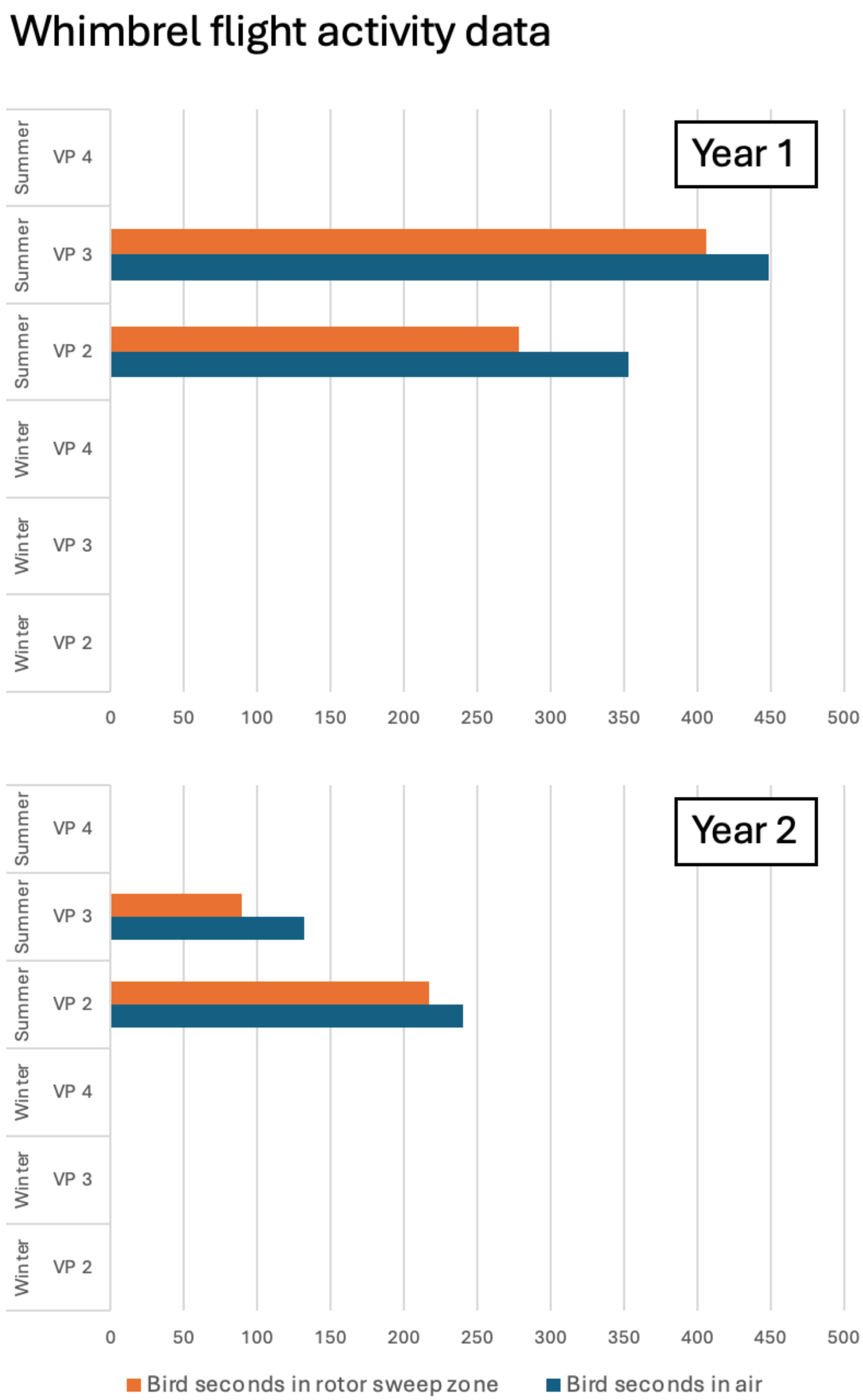

Figure 15. Flight activity of whimbrel across years, seasons, and vantage point (VP) locations. Blue bars show the total flight activity in bird seconds (time spent in the air), and orange bars show the subset of seconds birds spent at risk height.

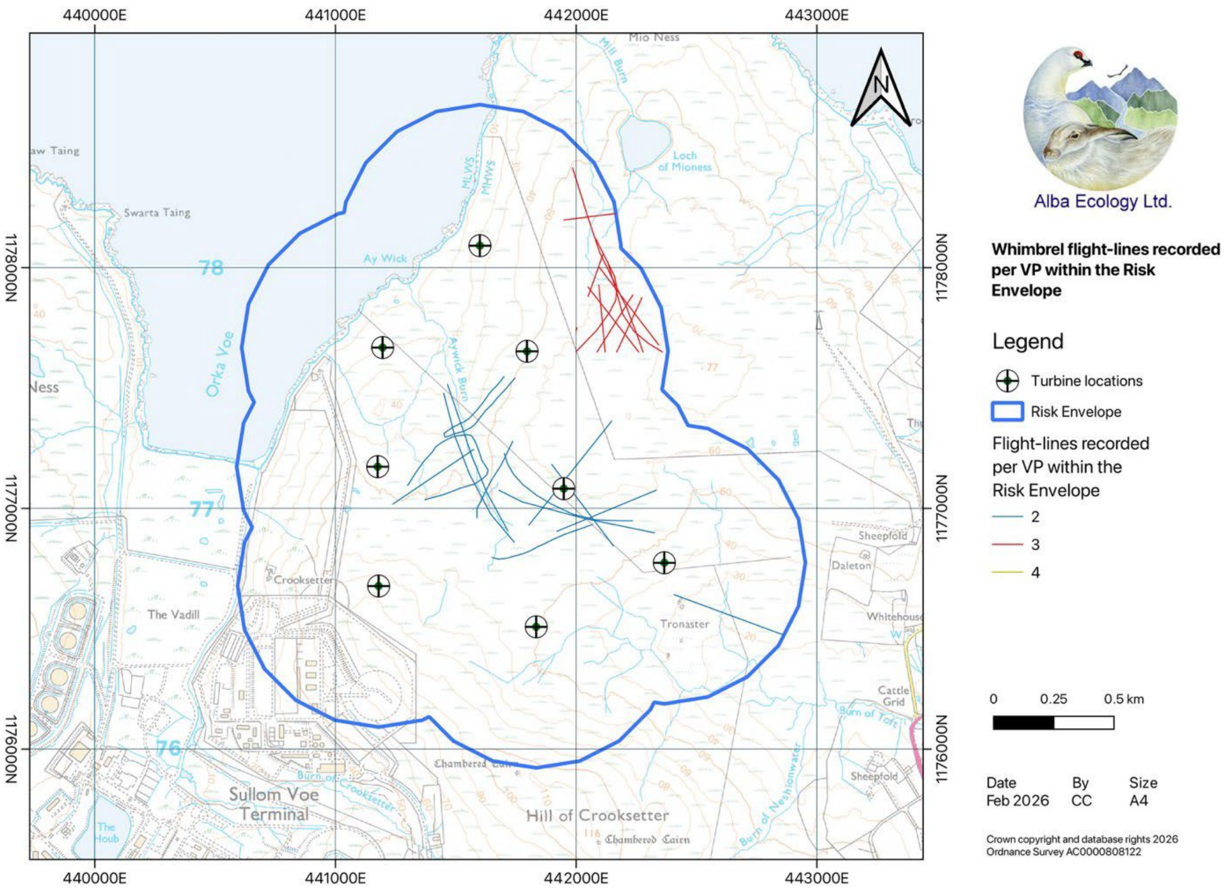

Figure 16. Whimbrel flight-line data collected in Year One and Year Two.

The CRA for whimbrel with two years combined data is shown in Table 21-Table 24. Table 21 provides a summary of whimbrel flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 22 gives the survey results for whimbrel across seasons and VPs. Table 23 estimates the uncertainty for the whimbrel CRA and Table 24 presents the estimated number of collisions per year.

Table 21. A summary of whimbrel flight activity in bird seconds, including Q2r which is the proportion of flight activity that occurred in the risk height range (rotor sweep area).

Total bird seconds in air (s)	1174
Total bird seconds in rotor sweep area (s)	990
Q_{2r} – Proportion of time in rotor sweep area	84.4%

Table 22. Survey results for whimbrel across seasons and VPs. Time shows the seconds birds were in the air, and D_A shows the areal density (bird seconds per km^2).

			Summer		Winter	
Year	**VP**	**Area (km^2)**	**Time (bird seconds)**	**D_A**	**Time (bird seconds)**	**D_A**
1	VP 2	3.61	353	0.000755	0	0
1	VP 3	0.22	449	0.0155	0	0
1	VP 4	0.52	0	0	0	0
2	VP 2	3.61	240	0.000513	0	0
2	VP 3	0.22	132	0.00457	0	0
2	VP 4	0.52	0	0	0	0
			Weighted Mean	0.00192	**Weighted Mean**	0
			Weighted SD	0.00407	**Weighted SD**	0

Table 23. Sources of uncertainty for the whimbrel CRA.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	4.15
Survey flight height error	0.05
Simplifications in the collision model	0.2
Combined uncertainty	+/- 415%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Whimbrel were assessed using 98% avoidance as recommended by NatureScot as a precautionary measure (SNH, 2018). Assuming an avoidance factor of 98% by which whimbrel may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions (Table 24):

Table 24. CRA outputs for whimbrel

Potential annual bird transits through rotors	306
Collisions assuming no avoidance	14

Collisions assuming 95% avoidance	0.69
Collisions assuming 98% avoidance	**0.28 (One collision every 3.6 years)**
Collisions assuming 99% avoidance	0.12
Collisions assuming 99.5% avoidance	0.06

At a 98% avoidance rate, the estimated collision rate was 0.28 collisions per year, equivalent to one bird strike every 3.6 years. The associated uncertainty ranged from 0 to 1.4 collisions per year (one bird strike every 0.7 years), reflecting a 95% confidence interval with an uncertainty range of 415% (truncated at zero to maintain biological realism).

The estimated collision risk (excluding avoidance assumptions) exhibited a very large uncertainty range of 415%. This large spread of values primarily stems from the diversity of areal flight density estimates (D_A) presented in Table 22, which result from real heterogeneity in whimbrel flight activity, such as many true absences, rather than from measurement errors or insufficient sampling.

Merlin

Merlin were recorded in the Study Area during the summer and winter over both years (Figure 17). A total of 36 flights were observed in the Study Area over two years (Figure 18). Most flights were recorded low to the ground in the <15m height band, so the recorded bird seconds at rotor risk height is very low for merlin at 8.6% of flights.

The biological parameters used within the CRA for merlin are in Table 25.

Table 25. Biological parameters for merlin CRA.

Bird length (m) (Snow *et al*., 1998)	0.28
Wingspan (m) (Snow *et al*., 1998)	0.56
Assumed bird speed (m/s) (Cochran & Applegate, 1986)	12.7
Avoidance rate (%) (SNH, 2018)	98
Flight type	Flapping

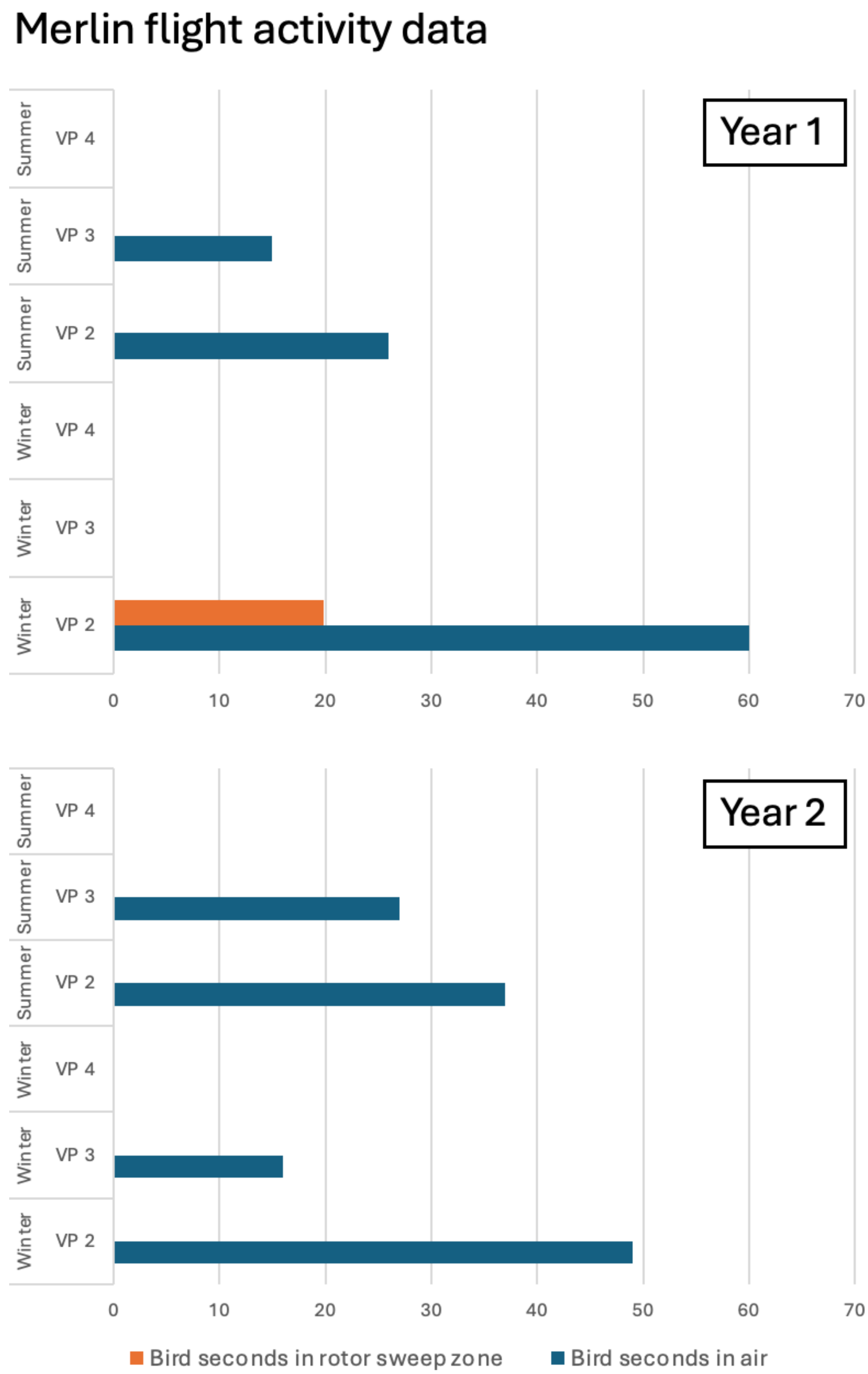

Figure 17. Flight activity of merlin across years, seasons, and vantage point (VP) locations. Blue bars show the total flight activity in bird seconds (time spent in the air), and orange bars show the subset of seconds birds spent at risk height.

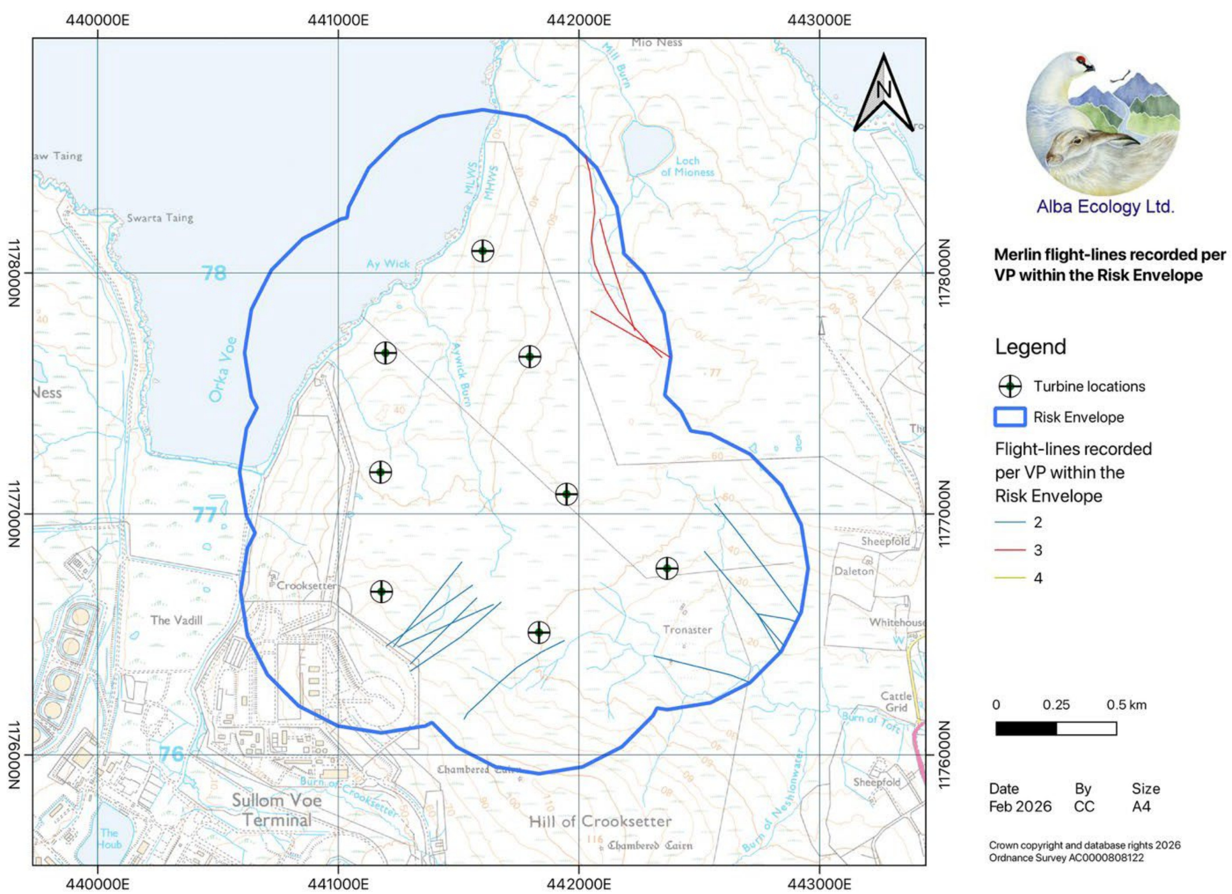

Figure 18. Merlin flight-line data collected in Year One and Year Two.

The CRA for merlin with two years combined data is shown in Table 26-Table 29. Table 26 provides a summary of merlin flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 27 gives the survey results for merlin across seasons and VPs. Table 28 estimates the uncertainty for the merlin CRA and Table 29 presents the estimated number of collisions per year.

Table 26. A summary of merlin flight activity in bird seconds, including Q2r which is the proportion of flight activity that occurred in the risk height range (rotor sweep area).

Total bird seconds in air (s)	230
Total bird seconds in rotor sweep area (s)	20
Q_{2r} – Proportion of time in rotor sweep area	8.6%

Table 27. Survey results for merlin across seasons and VPs. Time shows the seconds birds were in the air, and D_A shows the areal density (bird seconds per km^2).

			Summer		Winter	
Year	**VP**	**Area (km^2)**	**Time (bird seconds)**	**D_A**	**Time (bird seconds)**	**D_A**
1	VP 2	3.61	26	0.0000556	60	0.000128
1	VP 3	0.22	15	0.000519	0	0
1	VP 4	0.52	0	0	0	0
2	VP 2	3.61	37	0.0000791	49	0.000105
2	VP 3	0.22	27	0.000934	16	0.000554
2	VP 4	0.52	0	0	0	0
			Weighted Mean	0.000152	**Weighted Mean**	0.000152
			Weighted SD	0.000259	**Weighted SD**	0.000259

Table 28. Sources of uncertainty for the merlin CRA.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	2.35
Survey flight height error	0.05
Simplifications in the collision model	0.2
Combined uncertainty	+/- 236%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Merlin were assessed using 98% avoidance as recommended by NatureScot as a precautionary measure (SNH, 2018). Assuming an avoidance factor of 98% by which merlin may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions (Table 29):

Table 29. CRA outputs for merlin

Potential annual bird transits through rotors	3
Collisions assuming no avoidance	0.00

Collisions assuming 95% avoidance	0.00
Collisions assuming 98% avoidance	**0.00 (No collisions expected)**
Collisions assuming 99% avoidance	0.00
Collisions assuming 99.5% avoidance	0.00

Due to over 90% of merlin flights occurring below rotor height, there is no expected collision risk to merlin in the Study Area.

Red-throated Diver

Red-throated diver were recorded in the Study Area during the summer over both years (Figure 19). No red-throated divers were observed during the winter months. A total of 27 flights were observed in the Study Area over two years (Figure 20).

The biological parameters used within the CRA for red-throated diver are in **Table 30**.

Table 30. Biological parameters for red-throated diver CRA.

Bird length (m) (Snow *et al*., 1998)	0.61
Wingspan (m) (Snow *et al*., 1998)	1.11
Assumed bird speed (m/s) (Alerstam *et al*., 2007)	18.6
Avoidance rate (%) (SNH, 2018)	99.5
Flight type	Flapping

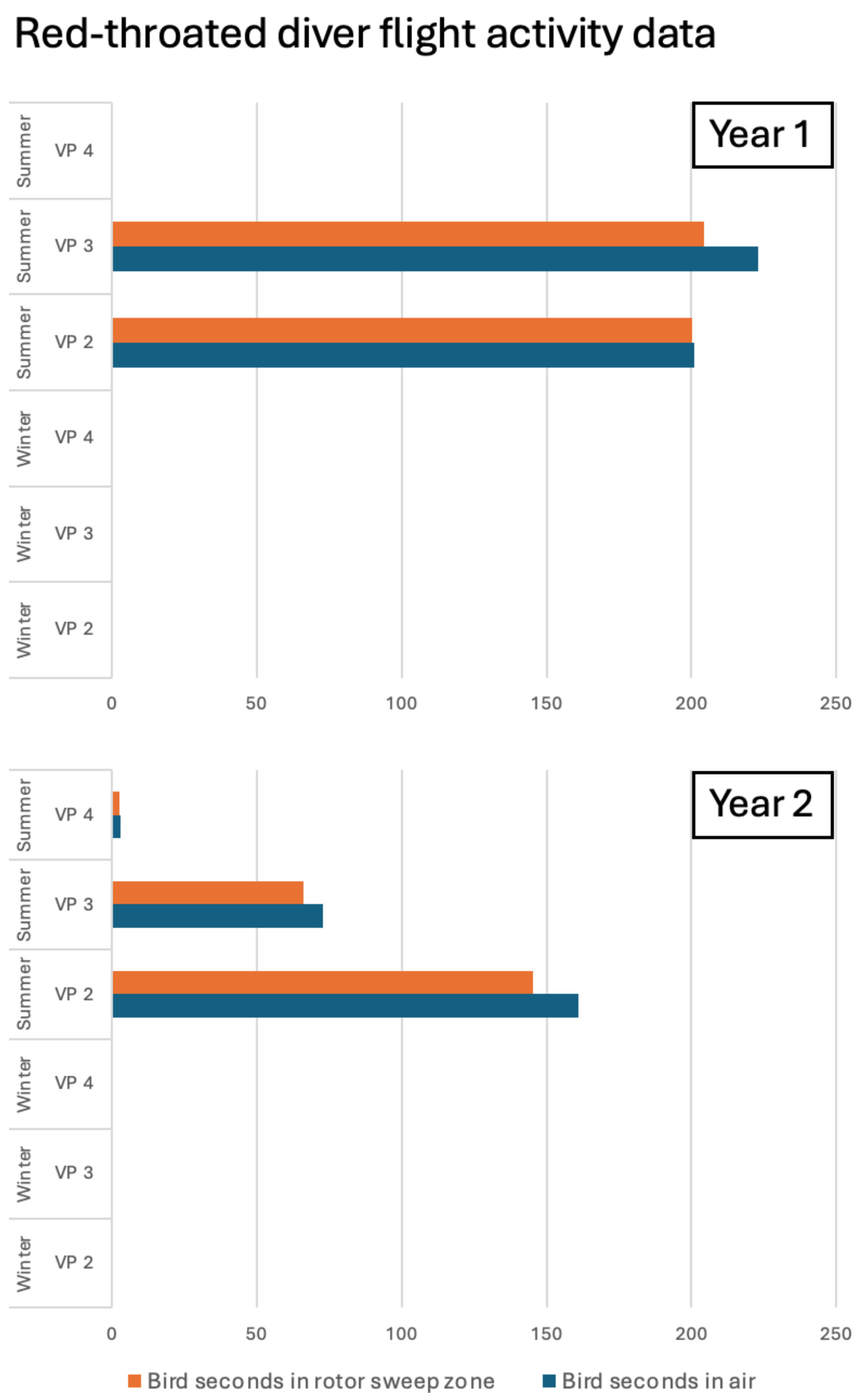

Figure 19. Flight activity of red-throated diver across years, seasons, and vantage point (VP) locations. Blue bars show the total flight activity in bird seconds (time spent in the air), and orange bars show the subset of seconds birds spent at risk height.

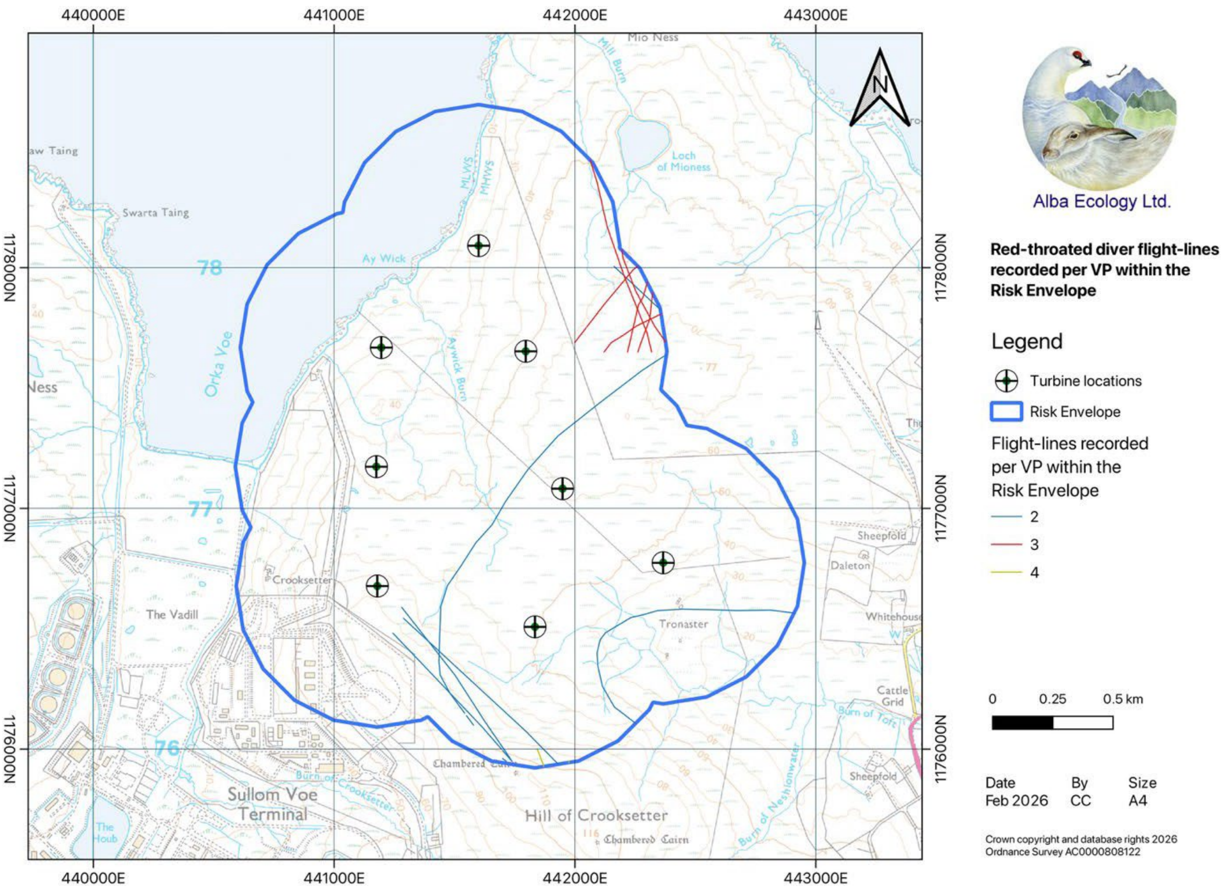

Figure 20. Red-throated diver flight-line data collected in Year One and Year Two.

The CRA for red-throated diver with two years combined data is shown in Table 31-Table 34. Table 31 provides a summary of red-throated diver flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 32 gives the survey results for red-throated diver across seasons and VPs. Table 33 estimates the uncertainty for the red-throated diver CRA and Table 34 presents the estimated number of collisions per year.

Table 31. A summary of red-throated diver flight activity in bird seconds, including Q2r which is the proportion of flight activity that occurred in the risk height range (rotor sweep area).

Total bird seconds in air (s)	661
Total bird seconds in rotor sweep area (s)	619
Q_{2r} – Proportion of time in rotor sweep area	93.6%

Table 32. Survey results for red-throated diver across seasons and VPs. Time shows the seconds birds were in the air, and D_A shows the areal density (bird seconds per km²).

			Summer		Winter	
Year	**VP**	**Area (km²)**	**Time (bird seconds)**	**D_A**	**Time (bird seconds)**	**D_A**
1	VP 2	3.61	201	0.00043	0	0
1	VP 3	0.22	223	0.00772	0	0
1	VP 4	0.52	0	0	0	0
2	VP 2	3.61	161	0.000344	0	0
2	VP 3	0.22	73	0.00253	0	0
2	VP 4	0.52	3	0.0000442	0	0
			Weighted Mean	0.00102	**Weighted Mean**	0
			Weighted SD	0.00202	**Weighted SD**	0

Table 33. Sources of uncertainty for the red-throated diver CRA.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	3.86
Survey flight height error	0.05
Simplifications in the collision model	0.2
Combined uncertainty	+/- 387%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Red-throated diver were assessed using 99.5% avoidance as recommended by NatureScot (SNH, 2018). Assuming an avoidance factor of 99.5% by which red-throated diver may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions (Table 34):

Table 34. CRA outputs for red-throated diver

Potential annual bird transits through rotors	206
Collisions assuming no avoidance	10

Collisions assuming 95% avoidance	0.5
Collisions assuming 98% avoidance	0.21
Collisions assuming 99% avoidance	0.1
Collisions assuming 99.5% avoidance	**0.06 (One collision every 16.7 years)**

At a 99.5% avoidance rate, the estimated collision rate was 0.06 collisions per year, equivalent to one bird strike every 16.7 years. The associated uncertainty ranged from 0 to 0.29 collisions per year (one bird strike every 3.4 years), reflecting a 95% confidence interval with an uncertainty range of 387% (truncated at zero to maintain biological realism).

The estimated collision risk (excluding avoidance assumptions) exhibited a very large uncertainty range of 387%. This large spread of values primarily stems from the diversity of areal flight density estimates (D_A) presented in Table 32, which result from real heterogeneity in red-throated diver flight activity, such as many true absences, rather than from measurement errors or insufficient sampling.

Herring Gull

Herring gulls were observed in the Study Area throughout the summer and winter period both years. A total of 354 flights were observed in the Study Area (Figure 21). 246 flights were deemed directional and 108 were deemed non-directional. (Figure 22). The following CRA section presents the outputs from the directional and non-directional analysis, then presents the combined collision estimate.

The biological parameters used for both the directional and non-directional CRAs for herring gull are in Table 35:

Table 35. Biological parameters for herring gull CRA.

Bird length (m) (Snow et al., 1998)	0.6
Wingspan (m) (Snow et al., 1998)	1.44
Assumed bird speed (m/s) (Alerstam *et al.*, 2007)	12.8
Avoidance rate (%) (SNH, 2018)	99.5
Flight type	Glide

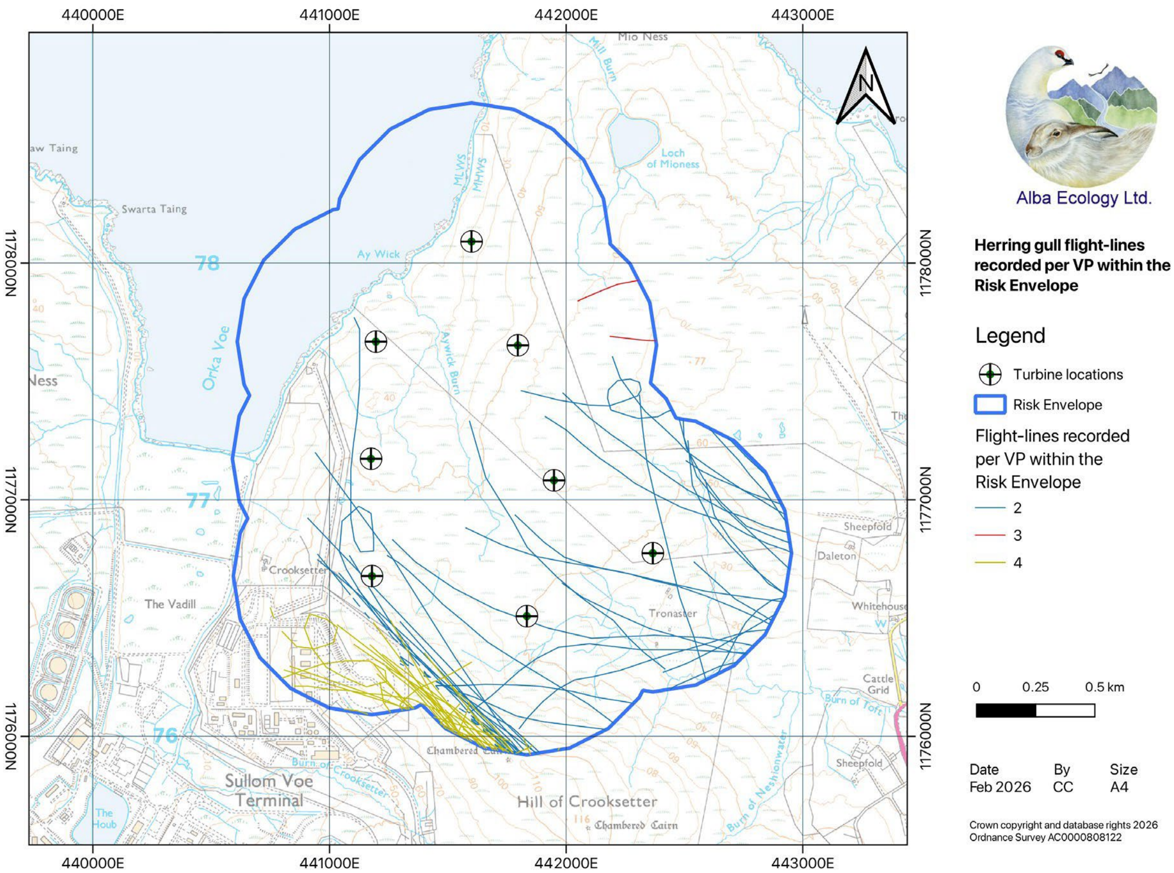

Figure 21. Herring gull flight-lines recorded per VP within the Risk Envelope.

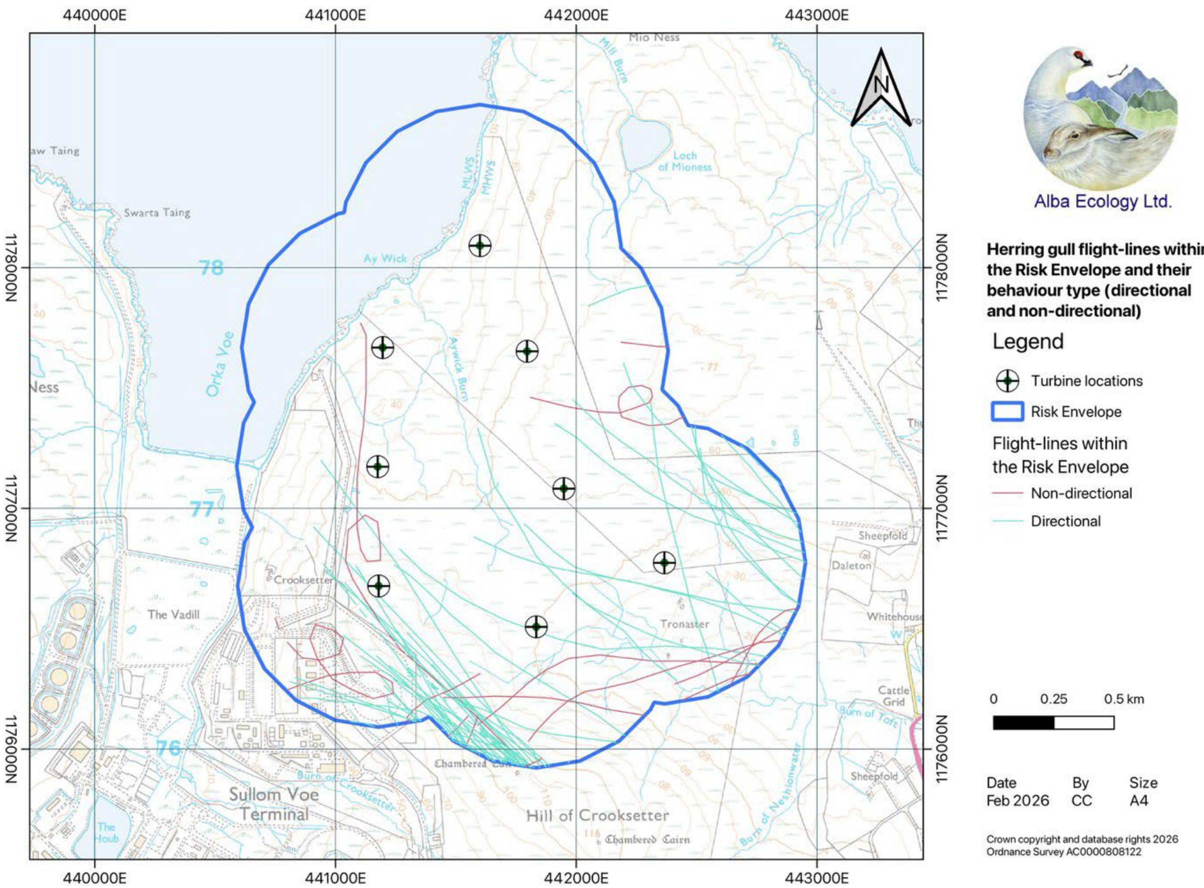

Figure 22. Herring gull flight-line data collected in Year One and Year Two showing which flights were deemed directional and non-directional.

Directional Analysis

Directional flight-lines of herring gull were observed throughout both summer and winter periods over both years (Figure 23). 163 flights directly crossed the baselines in each VP, and 83 were assumed to cross if birds continued along their bearing. Both direct and assumed crosses were used to calculate collision risk.

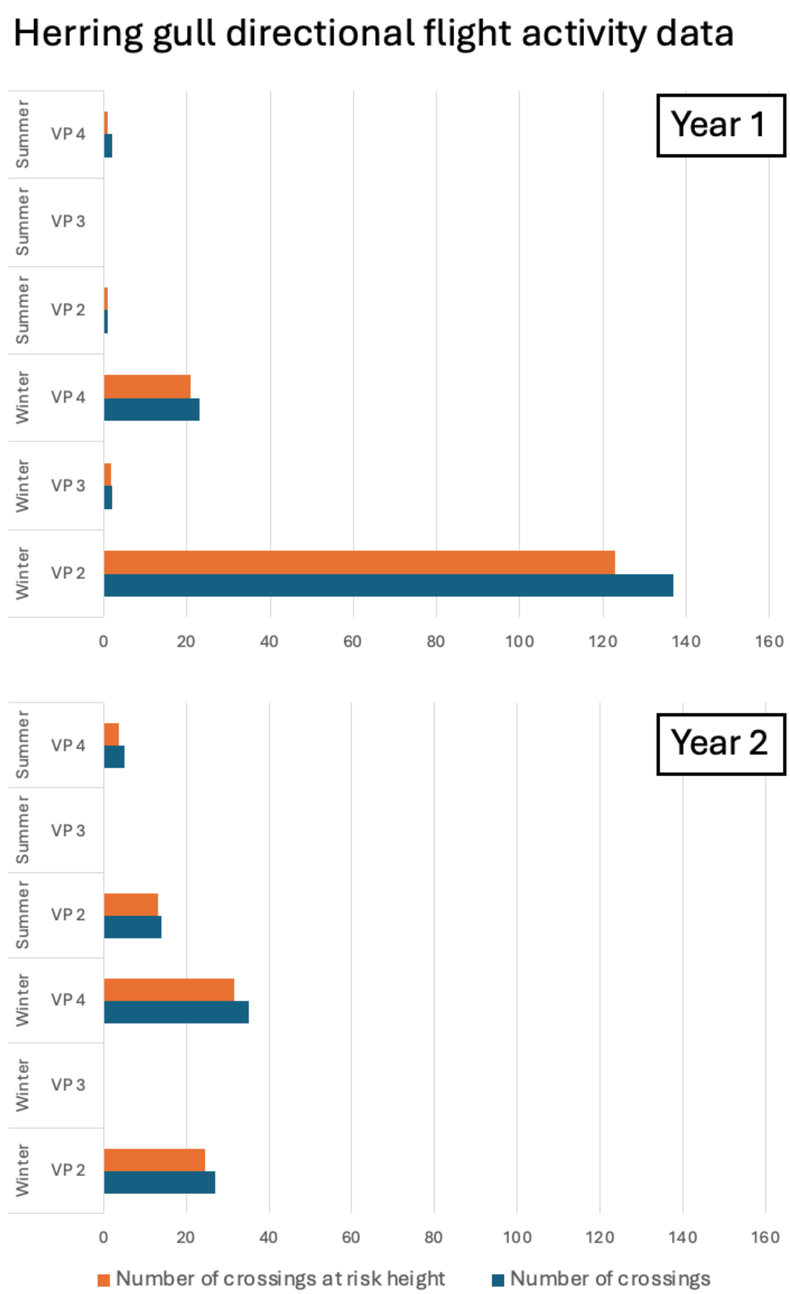

Figure 23. Flight activity of directional herring gull flights across years, seasons, and vantage point (VP) locations. Blue bars show the total number of crossings through the Study Area, and orange bars show the subset of seconds birds spent at risk height.

The CRA for directional herring gull flights with two years combined data is shown in Table 36-Table 39. Table 36 provides a summary of directional herring gull flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 37 gives the survey results for directional herring gull flights across seasons and VPs. Table 38 estimates the uncertainty for the directional herring gull CRA and Table 39 presents the estimated number of collisions per year. The data highlighted in red in this table and subsequent tables may be incorrect due to errors in NatureScot's directional flightline guidance.

Table 36. A summary of directional herring gull flight activity represented by the number of crossings across a baseline perpendicular to the dominant flight direction, including Q2r which is the proportion of flights that occurred in the risk height range (rotor sweep area).

Number of crossings	246
Number of crossing at risk height	220
Q_{2r} – Proportion of time in rotor sweep area	89.5

Table 37. Survey results for directional herring gull flights across seasons and VPs. MTR shows number of birds per km per hour that crossed a 1 km baseline, and D_A shows the areal density (bird seconds per km^2).

			Summer		**Winter**	
Year	**VP**	**Baseline length (km)**	**MTR**	**D_A**	**MTR**	**D_A**
1	VP 2	1.634	0.016999864	1.0431E-05	2.328981368	0.001429045
1	VP 3	1.07	0	0	0.05192108	3.18584E-05
1	VP 4	0.513	0.10829543	6.64492E-05	1.245397444	0.000764166
2	VP 2	1.634	0.237998096	0.000146034	0.458996328	0.000281637
2	VP 3	1.07	0	0	0	0
2	VP 4	0.513	0.270738575	0.000166123	1.895170024	0.001162862
			Weighted Mean	7.29745E-05	**Weighted Mean**	0.000716619
			Weighted SD	6.85081E-05	**Weighted SD**	0.000550061

Table 38. Sources of uncertainty for the directional herring gull CRA.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	1.38
Survey flight height error	0.05
Simplifications in the collision model	0.2
Combined uncertainty	+/-139%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Herring gulls were assessed using 99.5% avoidance as recommended by NatureScot (SNH, 2018). Assuming an avoidance factor of 99.5% by which herring gulls may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions (Table 39):

Table 39. CRA outputs for directional herring gull flights

Potential annual bird transits through rotors	59
Collisions assuming no avoidance	3
Collisions assuming 95% avoidance	0.17
Collisions assuming 98% avoidance	0.06
Collisions assuming 99% avoidance	0.02
Collisions assuming 99.5% avoidance	**0 (No collisions expected)**

Non-directional Analysis

Non-directional flights were recorded over both the summer and winter periods both years, with more flights recorded in Year One (Figure 24).

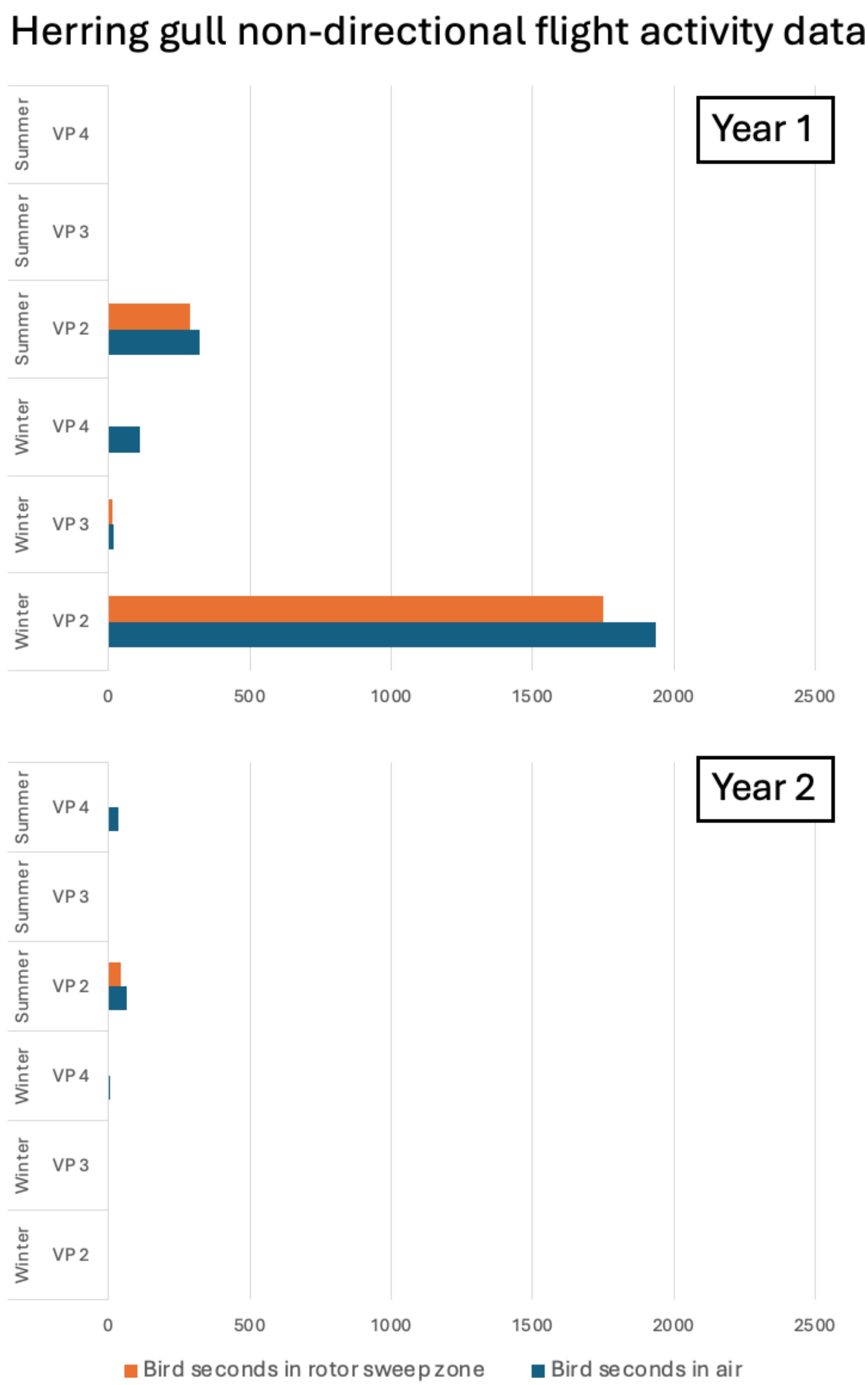

Figure 24. Flight activity of non-directional herring gull flights across years, seasons, and vantage point (VP) locations. Blue bars show the total flight activity in bird seconds (time spent in the air), and orange bars show the subset of seconds birds spent at risk height.

The CRA for non-directional herring gull flights with two years combined data is shown in Table 40-Table 43. Table 40 provides a summary of herring gull flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 41 gives the survey results for herring gull across seasons and VPs. Table 42 estimates the uncertainty for the herring gull non-directional CRA and Table 43 presents the estimated number of collisions per year.

Table 40. A summary of non-directional herring gull flight activity in bird seconds, including Q2r which is the proportion of flight activity that occurred in the risk height range (rotor sweep area).

Total bird seconds in air (s)	2491
Total bird seconds in rotor sweep area (s)	2097
Q_{2r} – Proportion of time in rotor sweep area	84.2%

Table 41. Survey results for non-directional herring gull flights across seasons and VPs. Time shows the seconds birds were in the air, and D_A shows the areal density (bird seconds per km^2).

			Summer		**Winter**	
Year	**VP**	**Area (km^2)**	**Time (bird seconds)**	**D_A**	**Time (bird seconds)**	**D_A**
1	VP 2	3.61	321	0.000686	1936	0.00414
1	VP 3	0.22	0	0	17	0.000588
1	VP 4	0.52	0	0	111	0.00163
2	VP 2	3.61	66	0.000141	0	0
2	VP 3	0.22	0	0	0	0
2	VP 4	0.52	34	0.000501	6	0.0000884
			Weighted Mean	0.000312	**Weighted Mean**	0.00152
			Weighted SD	0.000287	**Weighted SD**	0.00182

Table 42. Sources of uncertainty for the herring gull non-directional CRA.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	1.97
Survey flight height error	0.05
Simplifications in the collision model	0.2

Source of uncertainty	Estimated range
Combined uncertainty	+/- 198%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Herring gull were assessed using 99.5% avoidance as recommended by NatureScot as a precautionary measure (SNH, 2018). Assuming an avoidance factor of 99.5% by which herring gull may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions (Table 43):

Table 43. Non-directional CRA outputs for herring gull

Potential annual bird transits through rotors	148
Collisions assuming no avoidance	9
Collisions assuming 95% avoidance	0.42
Collisions assuming 98% avoidance	0.18
Collisions assuming 99% avoidance	0.06
Collisions assuming 99.5% avoidance	**0.02 (One collision every 50 years)**

The estimated collision risk is 0.02 in the '*Collision Risk Model for Onshore Wind Farm*' spreadsheet provided by NatureScot. Applying an uncertainty range of +/- 198% to this upper-bound worse-case estimate results in a maximum collision risk of 0.06 collisions per year, equating to one bird every 16.6 years. This figure represents the upper limit of a hypothetical worse-case scenario of collision risk. A likely collision risk should be assumed to be less than this.

The estimated collision risk (excluding avoidance assumptions) exhibited a substantial uncertainty range of 198%. This large spread of values primarily stems from the diversity of areal flight density estimates (D_A) presented in Table 41, which result from real heterogeneity in non-directional herring gull flight activity.

Combined Collision Risk

There are no expected collisions at 99.5% avoidance for directional flights of herring gulls. Therefore, the overall collision risk is driven only by non-directional flights. This equates to one collision every 50 years.

Common Gull

Common gulls were observed in the Study Area throughout the summer and winter period both years. A total of 442 flights were observed in the Study Area (Figure 25). 270 flights were deemed directional and 172 were deemed non-directional (Figure 26). The following CRA section presents the outputs from the directional and non-directional analysis, then presents the combined collision estimate.

The biological parameters used for both the directional and non-directional CRAs for common gull are in Table 44:

Table 44. Biological parameters for common gull CRA.

Bird length (m) (Snow *et al.*, 1998)	0.44
Wingspan (m) (Snow *et al.*, 1998)	1.2
Assumed bird speed (m/s) (Alerstam *et al.*, 2007)	13.4
Avoidance rate (%) (SNH, 2018)	99.5
Flight type	Glide

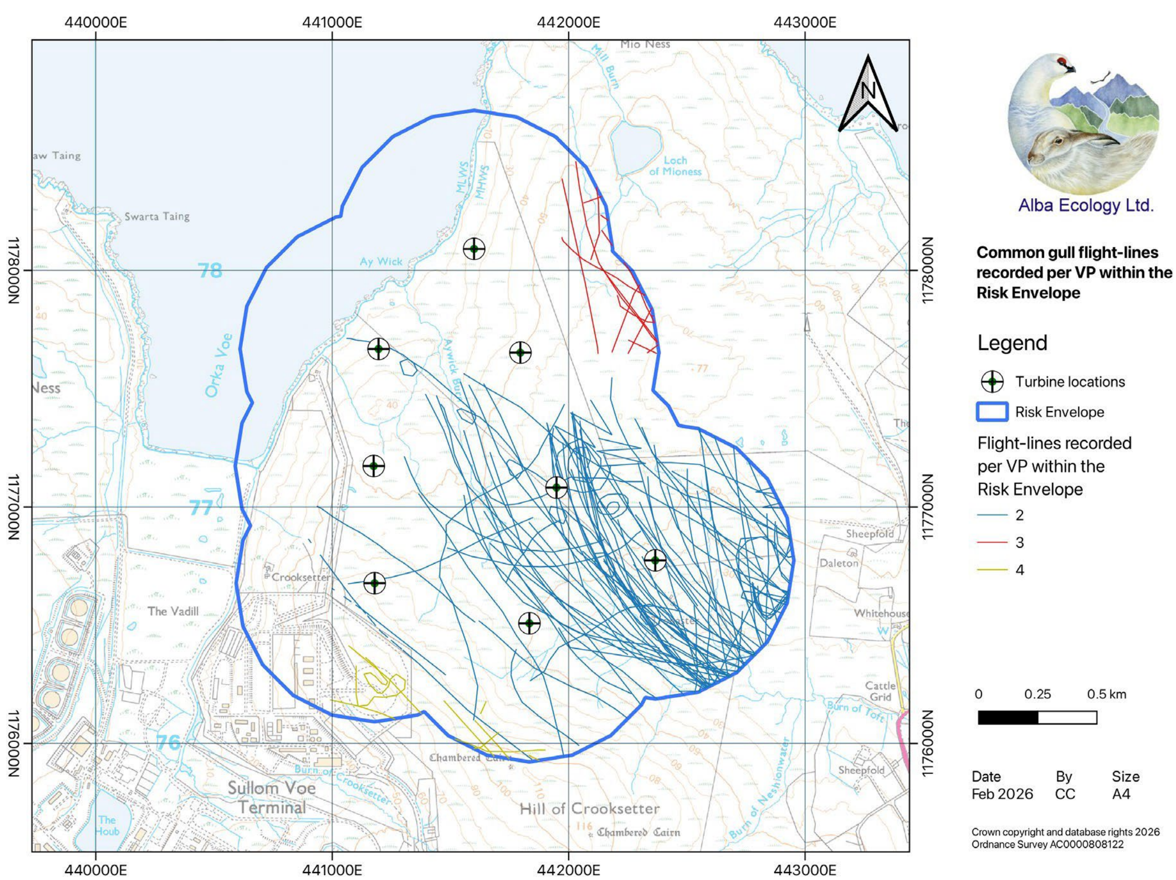

Figure 25.Common gull flight-lines recorded per VP within the Risk Envelope.

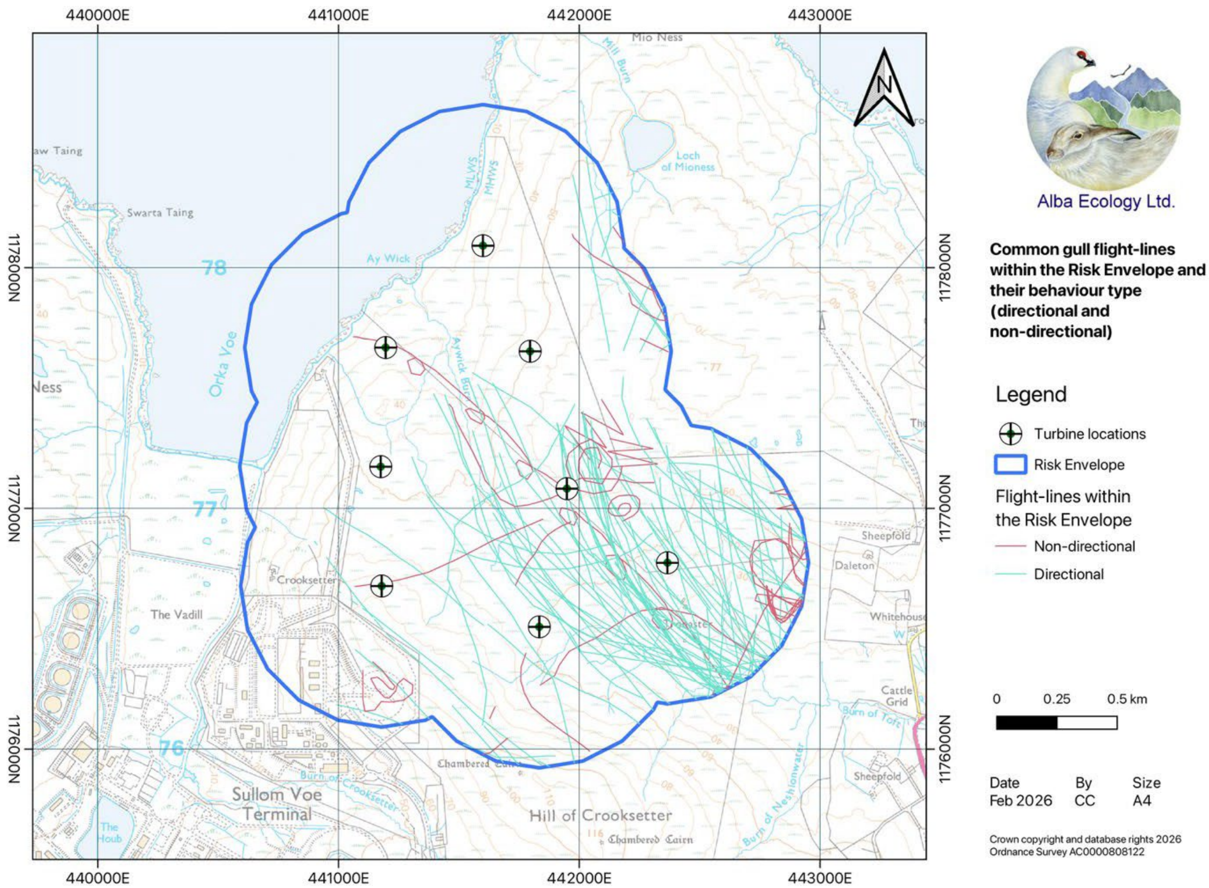

Figure 26. Common gull flight-line data collected in Year One and Year Two showing which flights were deemed directional and non-directional.

Directional Analysis

Directional flight-lines of common gull were observed throughout both summer and winter periods over both years (Figure 27). 218 flights directly crossed the baselines in each VP, and 52 were assumed to cross if birds continued along their bearing. Both direct and assumed crosses are used to calculate collision risk.

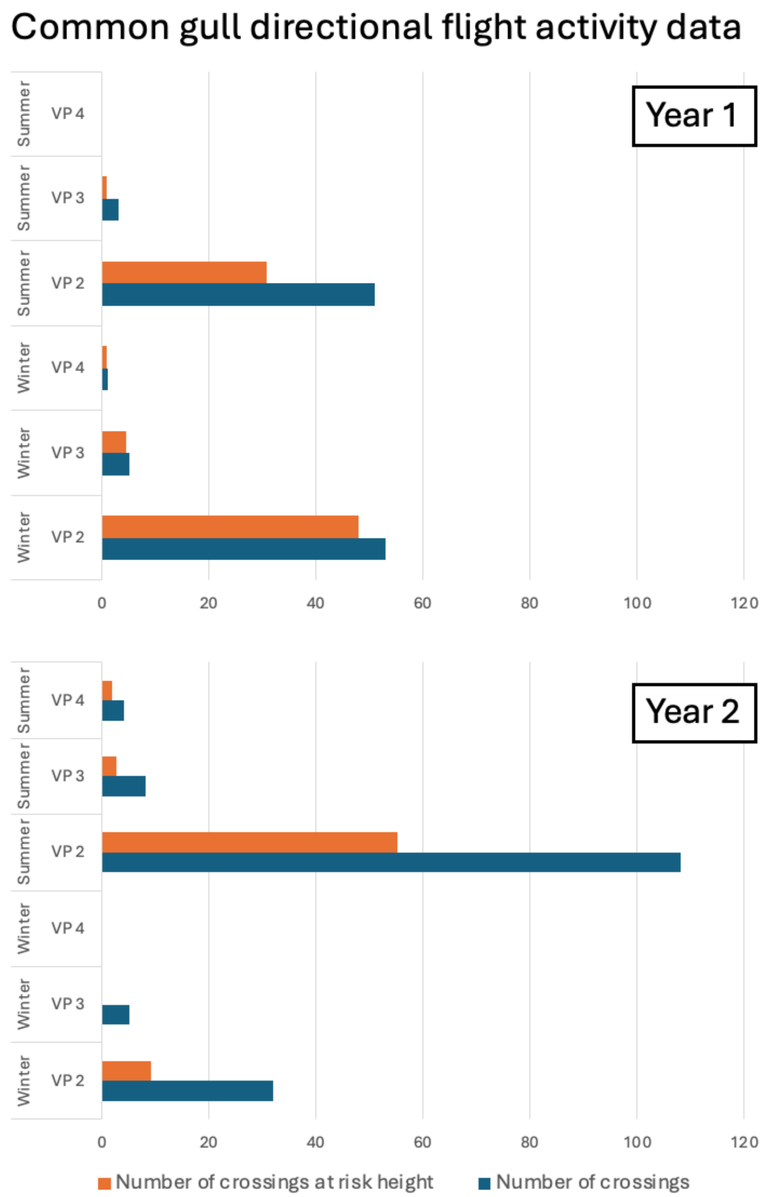

Figure 27. Flight activity of directional common gull flights across years, seasons, and vantage point (VP) locations. Blue bars show the total number of crossings through the Study Area, and orange bars show the subset of seconds birds spent at risk height.

The CRA for directional common gull flights with two years combined data is shown in Table 45 - Table 48. Table 45 provides a summary of common gull directional flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 46 gives the survey results for directional common gull flights across seasons and VPs. Table 47 estimates the uncertainty for the directional common gull CRA and Table 48 presents the estimated number of collisions per year.

Table 45. A summary of directional common gull flight activity represented by the number of crossings across a baseline perpendicular to the dominant flight direction, including Q2r which is the proportion of flights that occurred in the risk height range (rotor sweep area).

Number of crossings	270
Number of crossing at risk height	154
Q_{2r} – Proportion of time in rotor sweep area	56.9

Table 46. Survey results for directional common gull flights across seasons and VPs. MTR shows number of birds per km per hour that crossed a 1 km baseline, and D_A shows the areal density (bird seconds per km²).

			Summer		**Winter**	
Year	**VP**	**Baseline length (km)**	**MTR**	**D_A**	**MTR**	**D_A**
1	VP 2	1.634	0.867	0.000508	0.901	0.000528
1	VP 3	1.07	0.0779	0.0000456	0.130	0.0000761
1	VP 4	0.513		0	0.0541	0.0000317
2	VP 2	1.634	1.836	0.00108	0.544	0.000319
2	VP 3	1.07	0.208	0.000122	0.130	0.0000761
2	VP 4	0.513	0.217	0.000127	0	0
			Weighted Mean	0.000378	**Weighted Mean**	0.000208
			Weighted SD	0.000401	**Weighted SD**	0.000197

Table 47. Sources of uncertainty for the directional common gull CRA.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	1.49
Survey flight height error	0.05
Simplifications in the collision model	0.2
Combined uncertainty	+/-151%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Common gulls were assessed using 99.5% avoidance as recommended by

NatureScot (SNH, 2018). Assuming an avoidance factor of 99.5% by which common gulls may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions (Table 48):

Table 48. CRA outputs for common gulls

Potential annual bird transits through rotors	43
Collisions assuming no avoidance	2
Collisions assuming 95% avoidance	0.1
Collisions assuming 98% avoidance	0.04
Collisions assuming 99% avoidance	0.
Collisions assuming 99.5% avoidance	**0 (No collisions expected)**

Non-directional Analysis

Non-directional flights were recorded over both the summer and winter periods both years (Figure 28). Substantially more flight activity was recorded in the summer in Year One at VP 2 which is due to two separate flocks of circling gulls (both composed of 30 gulls) over the Study Area.

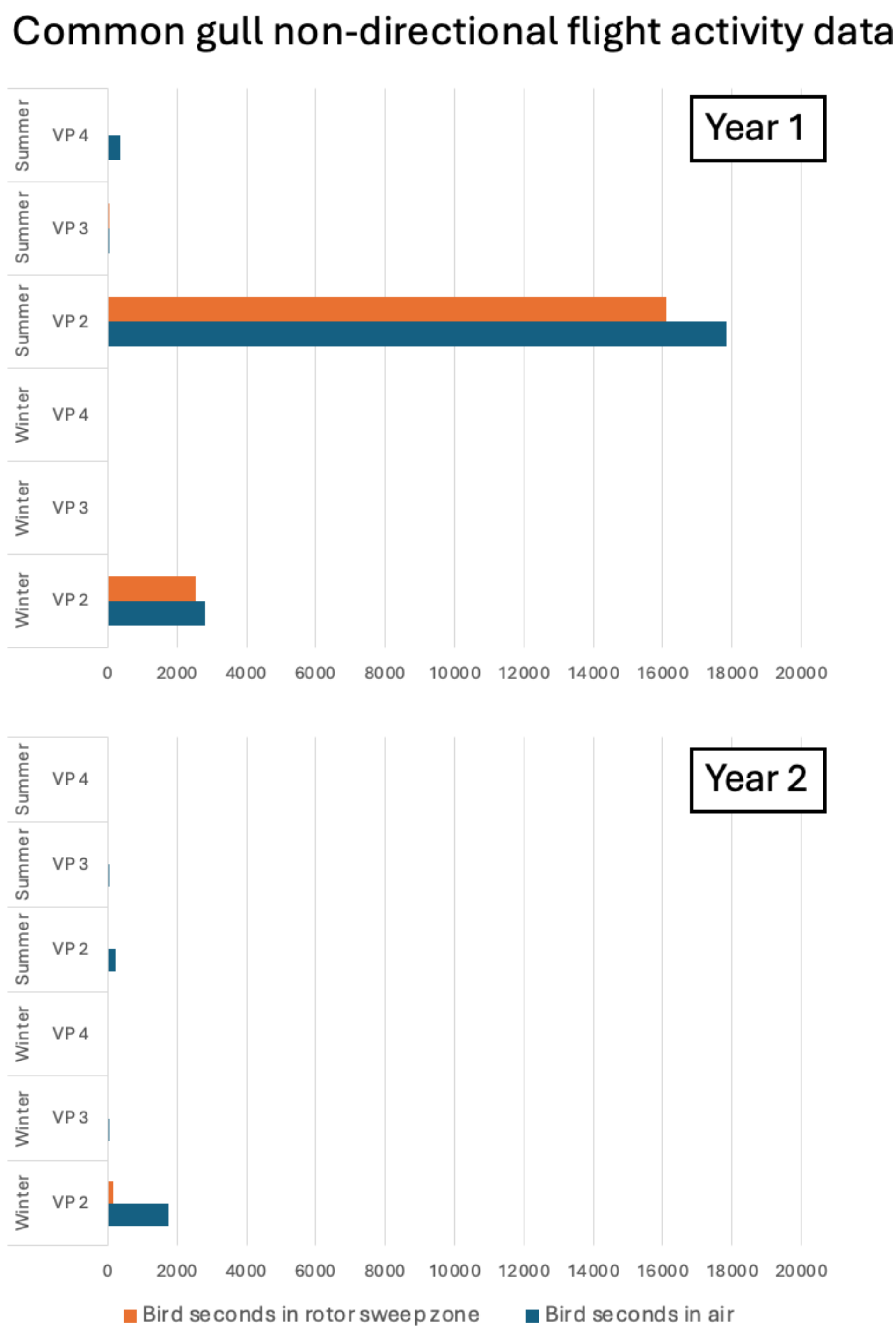

Figure 28. Flight activity of non-directional common gull flights across years, seasons, and vantage point (VP) locations. Blue bars show the total flight activity in bird seconds (time spent in the air), and orange bars show the subset of seconds birds spent at risk height.

The CRA for non-directional common gull flights with two years combined data is shown in Table 49 - Table 52. Table 49 provides a summary of common gull flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 50 gives the survey results for common gull across seasons and VPs. Table 51 estimates the uncertainty for the common gull non-directional CRA and Table 52 presents the estimated number of collisions per year.

Table 49. A summary of non-directional common gull flight activity in bird seconds, including Q2r which is the proportion of flight activity that occurred in the risk height range (rotor sweep area).

Total bird seconds in air (s)	23021
Total bird seconds in rotor sweep area (s)	18767
Q_{2r} – Proportion of time in rotor sweep area	81.5%

Table 50. Survey results for non-directional common gull across seasons and VPs. Time shows the seconds birds were in the air, and D_A shows the areal density (bird seconds per km^2).

			Summer		**Winter**	
Year	**VP**	**Area (km^2)**	**Time (bird seconds)**	**D_A**	**Time (bird seconds)**	**D_A**
1	VP 2	3.61	17848	0.0382	2792	0.00600
1	VP 3	0.22	43	0.00149	0	0
1	VP 4	0.52	373	0.00550	0	0
2	VP 2	3.61	205	0.000438	1740	0.00372
2	VP 3	0.22	9	0.000311	11	0.000380
2	VP 4	0.52	0	0	0	0
			Weighted Mean	0.0126	**Weighted Mean**	0.00300
			Weighted SD	0.0171	**Weighted SD**	0.00249

Table 51. Sources of uncertainty for the common gull non-directional CRA.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	2.16
Survey flight height error	0.05

Source of uncertainty	Estimated range
Simplifications in the collision model	0.2
Combined uncertainty	+/- 217%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Common gull were assessed using 99.5% avoidance as recommended by NatureScot as a precautionary measure (SNH, 2018). Assuming an avoidance factor of 99.5% by which common gull may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions (Table 52):

Table 52. Non-directional CRA outputs for common gull

Potential annual bird transits through rotors	1795
Collisions assuming no avoidance	91
Collisions assuming 95% avoidance	4.6
Collisions assuming 98% avoidance	1.8
Collisions assuming 99% avoidance	0.9
Collisions assuming 99.5% avoidance	**0.47 (One collision every 2.1 years)**

The estimated collision risk is 0.47 in the '*Collision Risk Model for Onshore Wind Farm*' spreadsheet provided by NatureScot. Applying an uncertainty range of +/- 217% to this upper-bound worse-case estimate results in a maximum collision risk of 1.49 collisions per year, equating to one bird every 0.67 years. This figure represents the upper limit of a hypothetical worse-case scenario of collision risk. A likely collision risk should be assumed to be less than this.

The estimated collision risk (excluding avoidance assumptions) exhibited a substantial uncertainty range of 217%. This large spread of values primarily stems from the diversity of areal flight density estimates (D_A) presented in Table 50, which result from real heterogeneity in non-directional common gull flight activity.

Combined Collision Risk

There are no expected collisions at 99.5% avoidance for directional flights of common gulls. Therefore, the overall collision risk is driven only by non-directional flights. This equates to one collision every 2.1 years.

Great Black-backed Gull

Great black-backed gulls were observed in the Study Area throughout the summer and winter period both years. A total of 242 flights were observed in the Study Area (Figure 29). 203 flights were deemed directional and 39 were deemed non-directional. (Figure 30). The following CRA section presents the outputs from the directional and non-directional analysis, then presents the combined collision estimate.

The biological parameters used for both the directional and non-directional CRAs for great black-backed gull are in Table 53:

Table 53. Biological parameters for great black-backed gull CRA.

Bird length (m) (Snow *et al*., 1998)	0.71
Wingspan (m) (Snow *et al*., 1998)	1.58
Assumed bird speed (m/s) (Alerstam *et al*., 2007)	13.7
Avoidance rate (%) (SNH, 2018)	99.5
Flight type	Glide

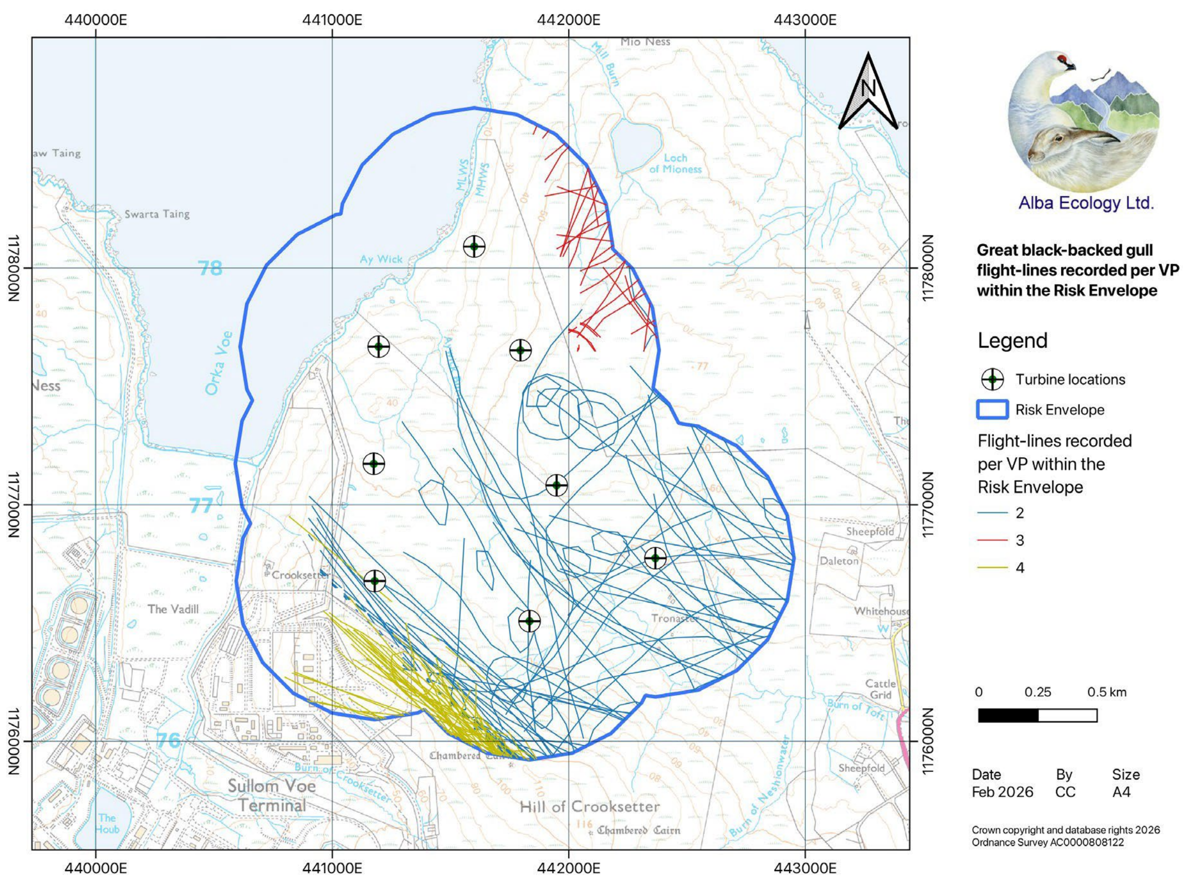

Figure 29. Great black-backed gull flight-lines recorded per VP within the Risk Envelope.

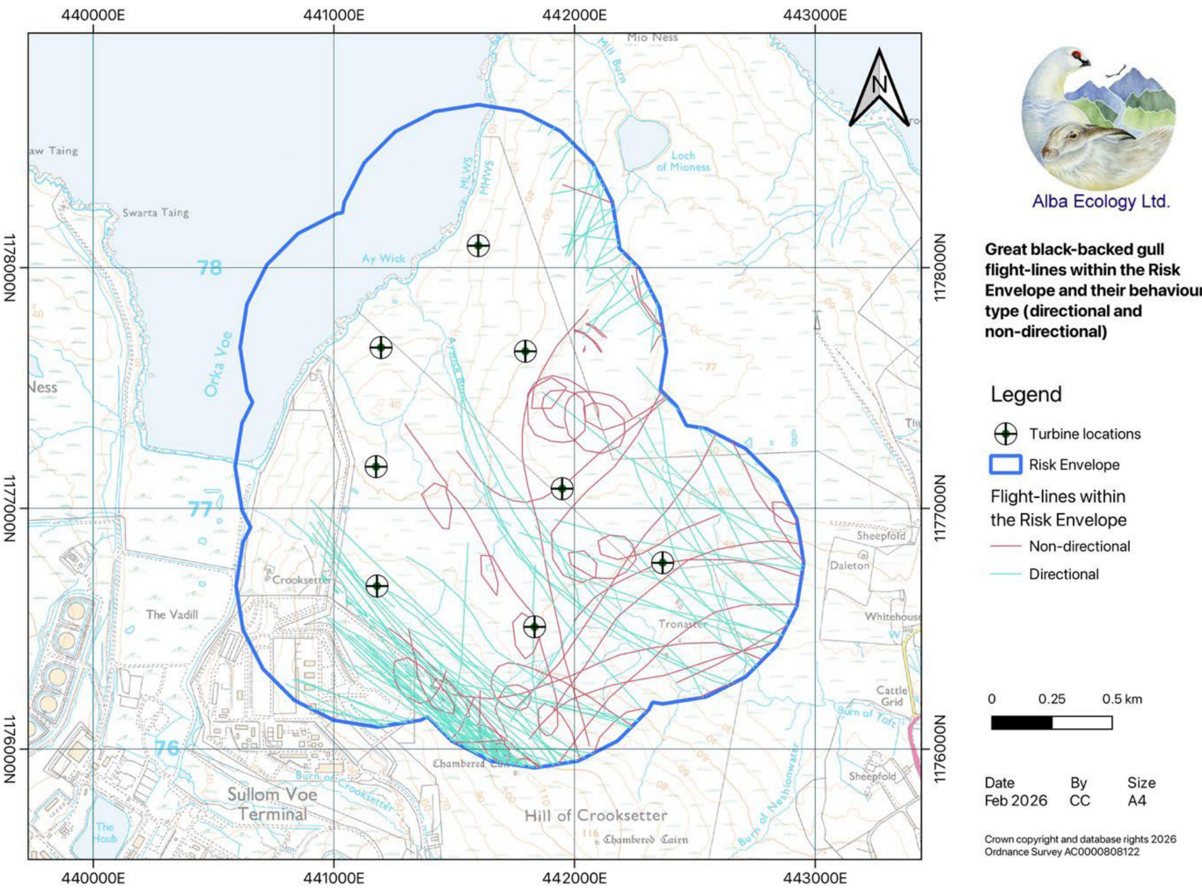

Figure 30. Great black-backed gull flight-line data collected in Year One and Year Two showing which flights were deemed directional and non-directional.

Directional Analysis

Directional flight-lines of great black-backed gull were observed throughout both summer and winter periods over both years (Figure 31). 111 flights directly crossed the baselines in each VP, and 92 were assumed to cross if birds continued along their bearing. Both direct and assumed crosses are used to calculate collision risk.

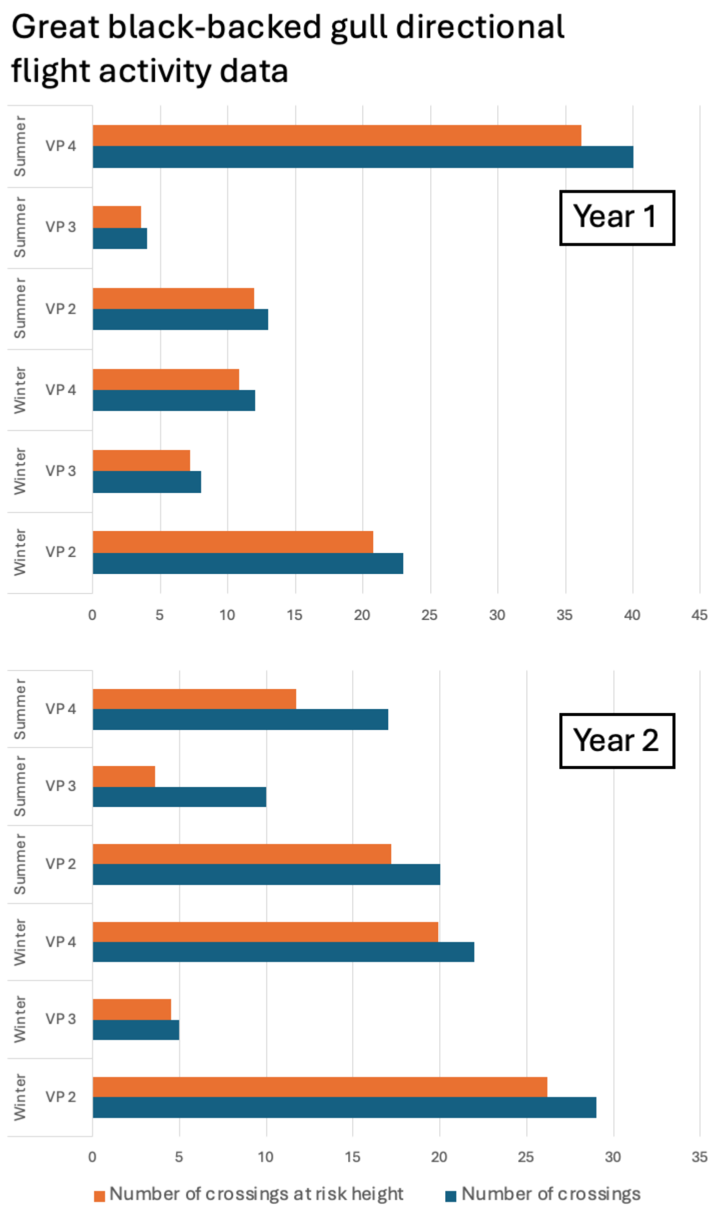

Figure 31. Flight activity of directional great black-backed gull flights across years, seasons, and vantage point (VP) locations. Blue bars show the total number of crossings through the Study Area, and orange bars show the subset of seconds birds spent at risk height.

The CRA for great black-backed gull with two years combined data is shown in Table 54 -Table 57. Table 54 provides a summary of great black-backed gull flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 55 gives the survey results for great black-backed gull across seasons and VPs. Table 56 estimates the uncertainty for the great black-backed gull CRA and Table 57 presents the estimated number of collisions per year.

Table 54. A summary of directional great black-backed gull flight activity represented by the number of crossings across a baseline perpendicular to the dominant flight direction, including Q2r which is the proportion of flights that occurred in the risk height range (rotor sweep area).

Number of crossings	202
Number of crossing at risk height	174
Q_{2r} – Proportion of time in rotor sweep area	85.6

Table 55. Survey results for directional great black-backed gull flights across seasons and VPs. MTR shows number of birds per km per hour that crossed a 1 km baseline, and D_A shows the areal density (bird seconds per km^2).

			Summer		Winter	
Year	**VP**	**Baseline length (km)**	**MTR**	**D_A**	**MTR**	**D_A**
1	VP 2	1.634	0.221	0.000127	0.397	0.000224
1	VP 3	1.07	0.104	0.00006	0.208	0.000119
1	VP 4	0.513	2.17	0.00124	0.65	0.000373
2	VP 2	1.634	0.34	0.000195	0.493	0.000283
2	VP 3	1.07	0.26	0.000149	0.123	0.0000744
2	VP 4	0.513	0.921	0.000528	1.19	0.000683
			Weighted Mean	0.000313	**Weighted Mean**	0.000265
			Weighted SD	0.000365	**Weighted SD**	0.00018

Table 56. Sources of uncertainty for the directional great black-backed gull CRA.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	1.38
Survey flight height error	0.05
Simplifications in the collision model	0.2
Combined uncertainty	+/-140%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Great black-backed gulls were assessed using 99.5% avoidance as recommended by

NatureScot (SNH, 2018). Assuming an avoidance factor of 99.5% by which great black-backed gulls may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions (Table 57):

Table 57. Directional CRA outputs for great black-backed gulls

Potential annual bird transits through rotors	61
Collisions assuming no avoidance	4
Collisions assuming 95% avoidance	0.2
Collisions assuming 98% avoidance	0.1
Collisions assuming 99% avoidance	0
Collisions assuming 99.5% avoidance	**0 (No collisions expected)**

Non-directional Analysis

Non-directional great black-backed gull flights were recorded over both the summer and winter in Year One, but only during the summer months for Year Two (Figure 32).

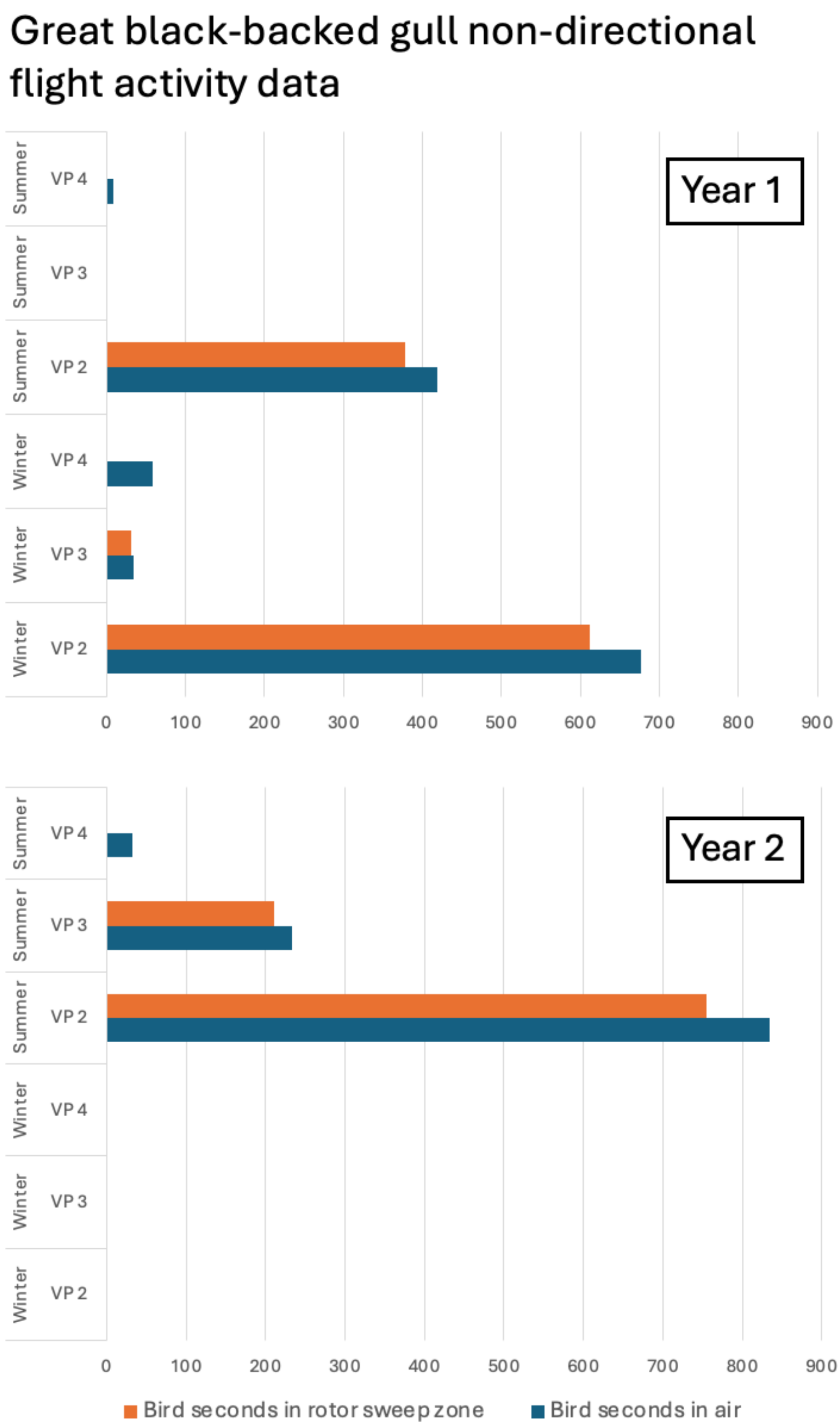

Figure 32. Flight activity of non-directional great black-backed flights gull across years, seasons, and vantage point (VP) locations. Blue bars show the total flight activity in bird seconds (time spent in the air), and orange bars show the subset of seconds birds spent at risk height.

The CRA for non-directional great black-backed gull flights with two years combined data is shown in Table 58-Table 61. Table 58 provides a summary of great black-backed gull flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 59 gives the survey results for great black-backed gull across seasons and VPs. Table 60 estimates the uncertainty for the great black-backed gull non-directional CRA and Table 61 presents the estimated number of collisions per year.

Table 58. A summary of non-directional great black-backed gull flight activity in bird seconds, including Q2r which is the proportion of flight activity that occurred in the risk height range (rotor sweep area).

Total bird seconds in air (s)	2299
Total bird seconds in rotor sweep area (s)	1987
Q_{2r} – Proportion of time in rotor sweep area	86.4%

Table 59. Survey results for non-directional great black-backed gull across seasons and VPs. Time shows the seconds birds were in the air, and D_A shows the areal density (bird seconds per km^2).

			Summer		**Winter**	
Year	**VP**	**Area (km^2)**	**Time (bird seconds)**	**D_A**	**Time (bird seconds)**	**D_A**
1	VP 2	3.61	419	0.000896	677	0.00145
1	VP 3	0.22	0	0	34	0.00118
1	VP 4	0.52	8	0.000118	59	0.000869
2	VP 2	3.61	835	0.00179	0	0
2	VP 3	0.22	234	0.0081	0	0
2	VP 4	0.52	33	0.000486	0	0
			Weighted Mean	0.00151	**Weighted Mean**	0.000635
			Weighted SD	0.00199	**Weighted SD**	0.000658

Table 60. Sources of uncertainty for the non-directional great black-backed gull non-directional CRA.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	1.92
Survey flight height error	0.05
Simplifications in the collision model	0.2

Source of uncertainty	**Estimated range**
Combined uncertainty	+/- 193%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Great black-backed gull were assessed using 99.5% avoidance as recommended by NatureScot as a precautionary measure (SNH, 2018). Assuming an avoidance factor of 99.5% by which great black-backed gull may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions (Table 61):

Table 61.Non-directional CRA outputs for great black-backed gull

Potential annual bird transits through rotors	253
Collisions assuming no avoidance	15
Collisions assuming 95% avoidance	0.7
Collisions assuming 98% avoidance	0.3
Collisions assuming 99% avoidance	0.14
Collisions assuming 99.5% avoidance	**0.06 (One collision every 16.7 years)**

The estimated collision risk is 0.06 in the '*Collision Risk Model for Onshore Wind Farm*' spreadsheet provided by NatureScot. Applying an uncertainty range of +/- 193% to this upper-bound worse-case estimate results in a maximum collision risk of 0.18 collisions per year, equating to one bird every 5.6 years. This figure represents the upper limit of a hypothetical worse-case scenario of collision risk. A likely collision risk should be assumed to be less than this.

The estimated collision risk (excluding avoidance assumptions) exhibited a substantial uncertainty range of 193%. This large spread of values primarily stems from the diversity of areal flight density estimates (D_A) presented in Table 59, which result from real heterogeneity in non-directional great black-backed gull flight activity.

Combined Collision Risk

There are no expected collisions at 99.5% avoidance for directional flights of great black-backed gulls. Therefore, the overall collision risk is driven only by non-directional flights. This equates to one collision every 16.7 years.

Curlew

As described in the Methods section, for curlew, the CRA was disaggregated into two turbine clusters to reflect the substantial spatial variation in curlew flight activity across the Study Area. One cluster consists of three turbines located within an area of higher curlew activity in the south-east of the Study Area, while the second cluster comprises five turbines situated within an area characterised by comparatively lower levels of activity.

To derive an overall collision estimate for the Proposed Development, the predicted collision totals from each cluster were summed, and associated uncertainty was propagated accordingly. The following sections present the CRA results for each turbine cluster, followed by the combined site-wide collision estimate.

The biological parameters used for all curlew CRA are in Table 62.

Table 62. Biological parameters for curlew CRA.

Bird length (m) (Snow *et al*., 1998)	0.55
Wingspan (m) (Snow *et al*., 1998)	0.9
Assumed bird speed (m/s) (Alerstam *et al*., 2007)	16.3
Avoidance rate (%) (SNH, 2018)	98
Flight type	Flapping

Higher-Use Turbine Cluster

Curlew were recorded in the Higher-Use Area during the summer over both years (Figure 33). A total of 300 flights were observed in the Higher-Use Area over two years (Figure 34).

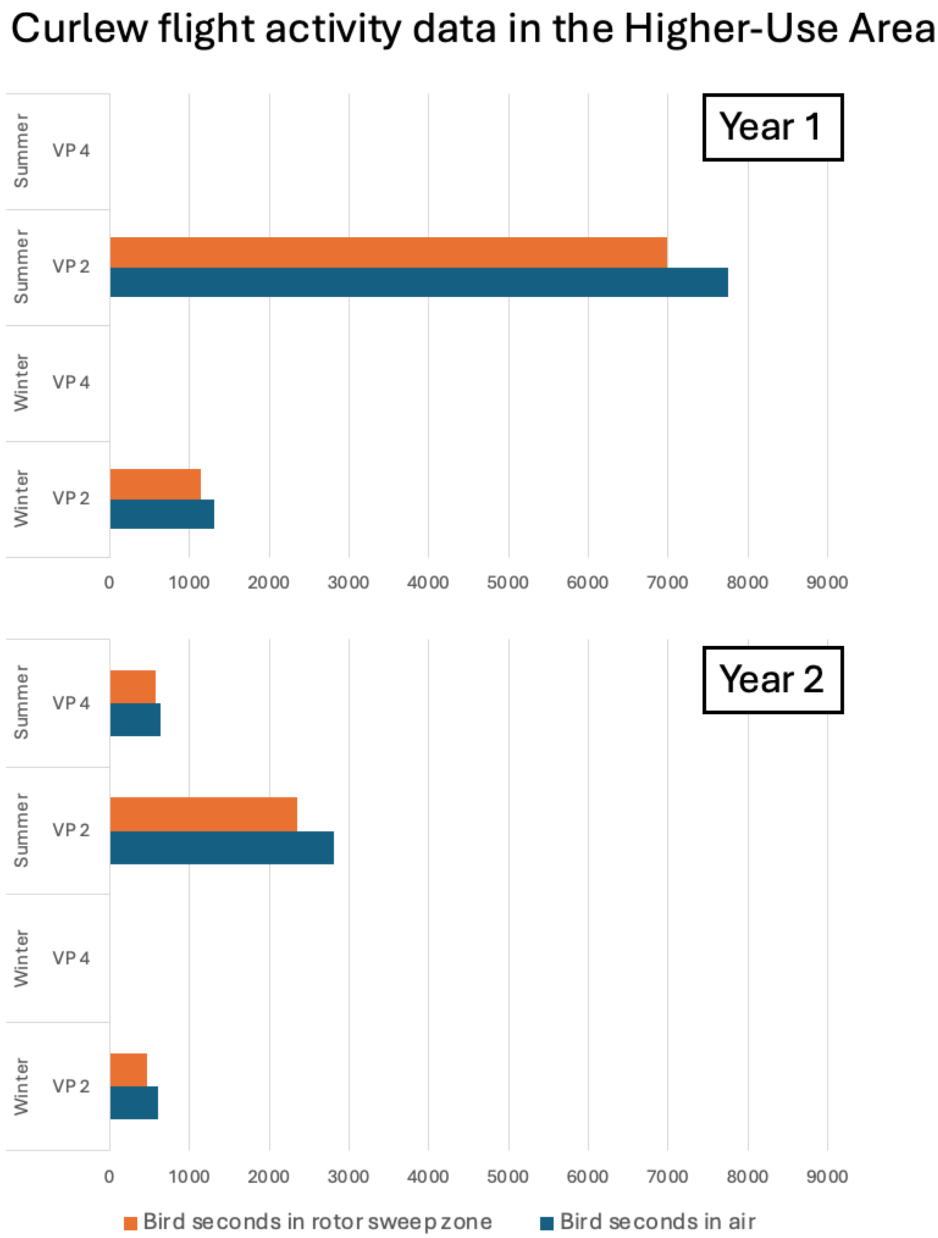

Figure 33. Flight activity of curlew across years, seasons, and vantage point (VP) locations in the Higher-Use Area. Blue bars show the total flight activity in bird seconds (time spent in the air), and orange bars show the subset of seconds birds spent at risk height.

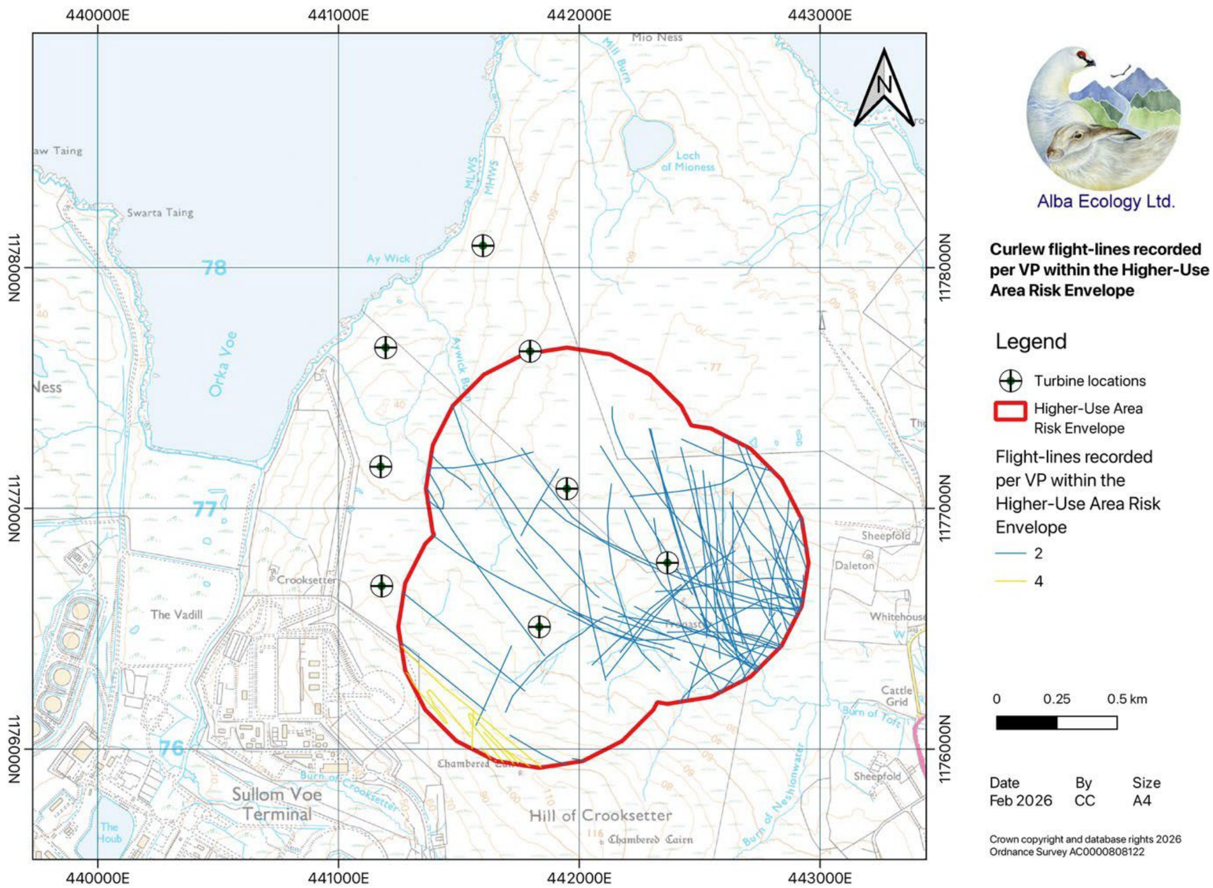

Figure 34. Curlew flight-line data collected in Year One and Year Two in the Higher-Use Area.

The CRA for curlew in the Higher-Use Area with two years combined data is shown in Table 63-Table 66. Table 63 provides a summary of curlew flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 64 gives the survey results for curlew across seasons and VPs. Table 65 estimates the uncertainty for the curlew CRA and Table 66 presents the estimated number of collisions per year.

Table 63. A summary of curlew flight activity in bird seconds for the Higher-Use Area, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range (rotor sweep area).

Total bird seconds in air (s)	13123
Total bird seconds in rotor sweep area (s)	11527
Q_{2r} – Proportion of time in rotor sweep area	87.8%

Table 64. Survey results for curlew across seasons and VPs in the Higher-Use Area. Time shows the seconds birds were in the air, and D_A shows the areal density (bird seconds per km^2).

			Summer		Winter	
Year	**VP**	**Area (km^2)**	**Time (bird seconds)**	**D_A**	**Time (bird seconds)**	**D_A**
1	VP 2	2.1	7755	0.0285	1314	0.00483
1	VP 4	0.16	0	0	0	0
2	VP 2	2.1	2807	0.0103	606	0.00223
2	VP 4	0.16	641	0.0316	0	0
			Weighted Mean	0.0186	**Weighted Mean**	0.00277
			Weighted SD	0.011	**Weighted SD**	0.00185

Table 65. Sources of uncertainty for the curlew CRA in the Higher-Use Area.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	1.02
Survey flight height error	0.05
Simplifications in the collision model	0.2
Combined uncertainty	+/- 104%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Curlew were assessed using 98% avoidance as recommended by NatureScot as a precautionary measure (SNH, 2018). Assuming an avoidance factor of 98% by which curlew may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions (Table 66):

Table 66. CRA outputs for curlew in the Higher-Use Area

Potential annual bird transits through rotors	1263
Collisions assuming no avoidance	66
Collisions assuming 95% avoidance	3.3
Collisions assuming 98% avoidance	**1.31 (One collision expected every 0.76 years)**

Collisions assuming 99% avoidance	0.68
Collisions assuming 99.5% avoidance	0.31

At a 98% avoidance rate, the estimated collision rate was 1.31 collisions per year, equivalent to one bird strike every 0.76 years. The associated uncertainty ranged from 0 to 2.67 collisions per year (one bird strike every 0.37 years), reflecting a 95% confidence interval with an uncertainty range of 104% (truncated at zero to maintain biological realism).

Lower-Use Turbine Cluster

Curlew were recorded in the Lower-Use Area during the summer and winter periods over both years, although substantially more activity was recorded in summer months (Figure 35). A total of 114 flights were observed in the Lower-Use Area over two years (Figure 36).

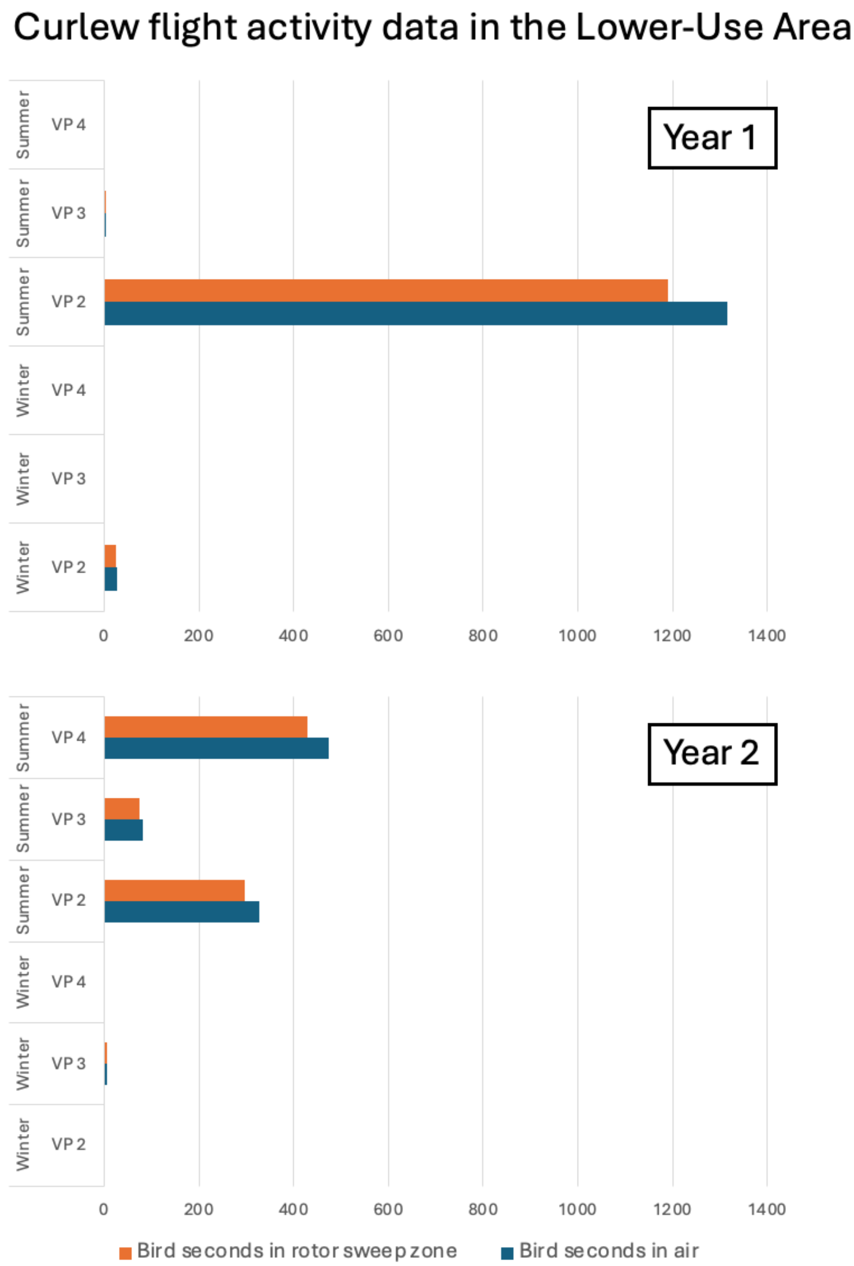

Figure 35. Flight activity of curlew across years, seasons, and vantage point (VP) locations in the Lower-Use Area. Blue bars show the total flight activity in bird seconds (time spent in the air), and orange bars show the subset of seconds birds spent at risk height.

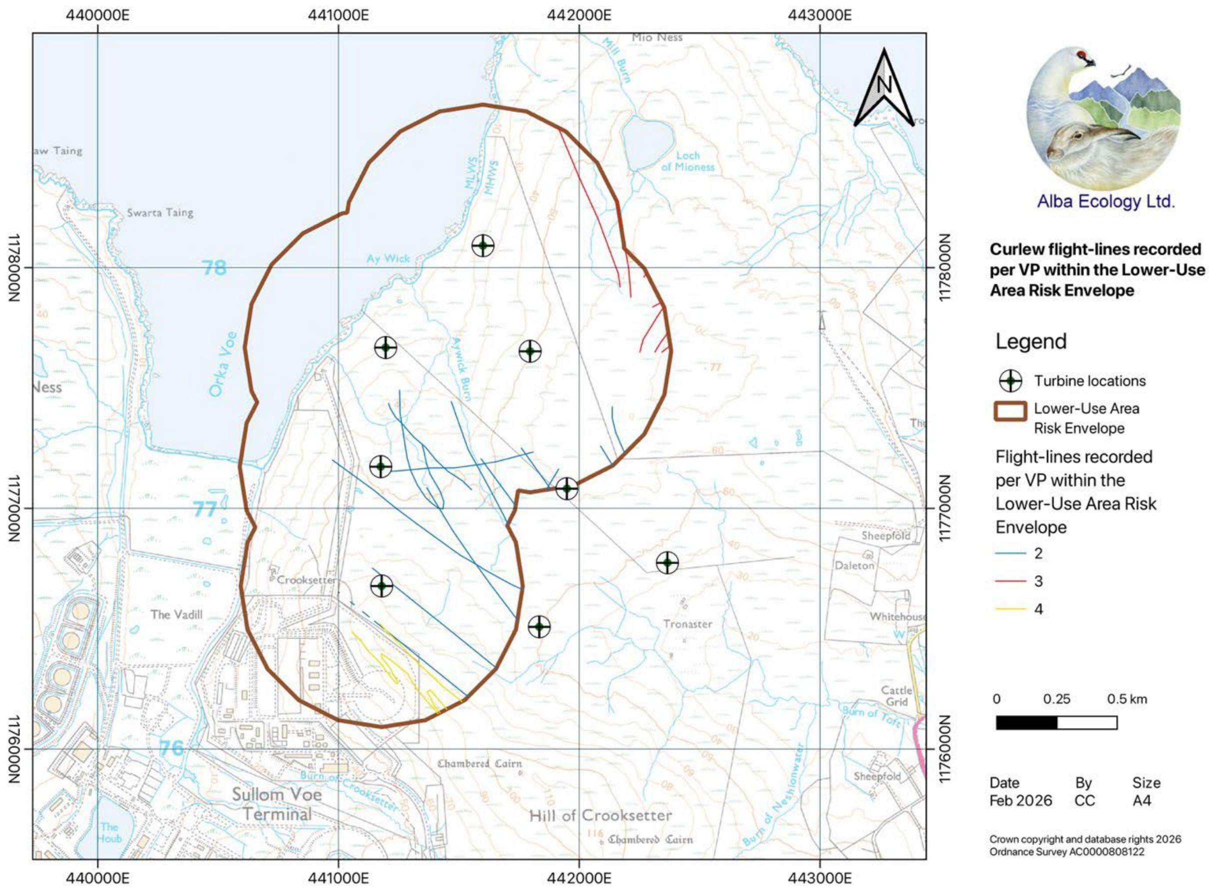

Figure 36. Curlew flight-line data collected in Year One and Year Two in the Lower-Use Area.

The CRA for curlew in the Lower-Use Area with two years combined data is shown in Table 67 - Table 70. Table 67 provides a summary of curlew flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 68 gives the survey results for curlew across seasons and VPs. Table 69 estimates the uncertainty for the curlew CRA and Table 70 presents the estimated number of collisions per year.

Table 67. A summary of curlew flight activity in bird seconds for the Lower-Use Area, including Q2r which is the proportion of flight activity that occurred in the risk height range (rotor sweep area).

Total bird seconds in air (s)	2239
Total bird seconds in rotor sweep area (s)	2022
Q_{2r} – Proportion of time in rotor sweep area	90.3%

Table 68. Survey results for curlew across seasons and VPs in the Lower-Use Area. Time shows the seconds birds were in the air, and D_A shows the areal density (bird seconds per km^2).

			Summer		Winter	
Year	**VP**	**Area (km^2)**	**Time (bird seconds)**	**D_A**	**Time (bird seconds)**	**D_A**
1	VP 2	2.3	1316	0.00446	27	0.0000916
1	VP 3	0.22	3	0.000104	0	0
1	VP 4	0.45	0	0	0	0
2	VP 2	2.3	328	0.00111	0	0
2	VP 3	0.22	83	0.00287	7	0.000242
2	VP 4	0.45	475	0.00823	0	0
			Weighted Mean	0.00289	**Weighted Mean**	0.0000477
			Weighted SD	0.00263	**Weighted SD**	0.0000731

Table 69. Sources of uncertainty for the curlew CRA in the Lower-Use Area.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	1.76
Survey flight height error	0.05
Simplifications in the collision model	0.2
Combined uncertainty	+/- 177%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Curlew were assessed using 98% avoidance as recommended by NatureScot as a precautionary measure (SNH, 2018). Assuming an avoidance factor of 98% by which curlew may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions (Table 70):

Table 70. CRA outputs for curlew in the Lower-Use Area

Potential annual bird transits through rotors	315
Collisions assuming no avoidance	16

Collisions assuming 95% avoidance	0.8
Collisions assuming 98% avoidance	**0.32 (One collision expected every 3.1 years)**
Collisions assuming 99% avoidance	0.16
Collisions assuming 99.5% avoidance	0.08

At a 98% avoidance rate, the estimated collision rate was 0.32 collisions per year, equivalent to one bird strike every 3.1 years. The associated uncertainty ranged from 0 to 0.89 collisions per year (one bird strike every 1.1 years), reflecting a 95% confidence interval with an uncertainty range of 177% (truncated at zero to maintain biological realism).

Combined Collision Risk

Combining the collision estimates from both the Lower-Use and Higher-Use Area estimates (and propagating their uncertainties) gives an overall collision risk for curlew in the Proposed Development of 1.63 (+/- 91%) collisions a year (one bird strike expected every 0.61 years). The associated uncertainty ranges from 0.15 to 3.11 collisions per year.

Lapwing

As described in the Methods section, for lapwing, the CRA was disaggregated into two turbine clusters to reflect the substantial spatial variation in lapwing flight activity across the Study Area. One cluster consists of three turbines located within an area of higher lapwing activity in the south-east of the Study Area, while the second cluster comprises five turbines situated within an area characterised by comparatively lower levels of activity.

To derive an overall collision estimate for the Proposed Development, the predicted collision totals from each cluster were summed, and associated uncertainty was propagated accordingly. The following sections present the CRA results for each turbine cluster, followed by the combined site-wide collision estimate.

The biological parameters used for all lapwing CRA are in Table 71.

Table 71. Biological parameters for lapwing CRA.

Bird length (m) (Snow *et al*., 1998)	0.3
Wingspan (m) (Snow *et al*., 1998)	0.85
Assumed bird speed (m/s) (Alerstam *et al*., 2007)	12.4
Avoidance rate (%) (SNH, 2018)	98
Flight type	Flapping

Higher-Use Turbine Cluster

Lapwing were recorded in the Higher-Use Area during the summer and winter over both years (Figure 37). A total of 190 flights were observed in the Higher-Use Area over two years (Figure 38).

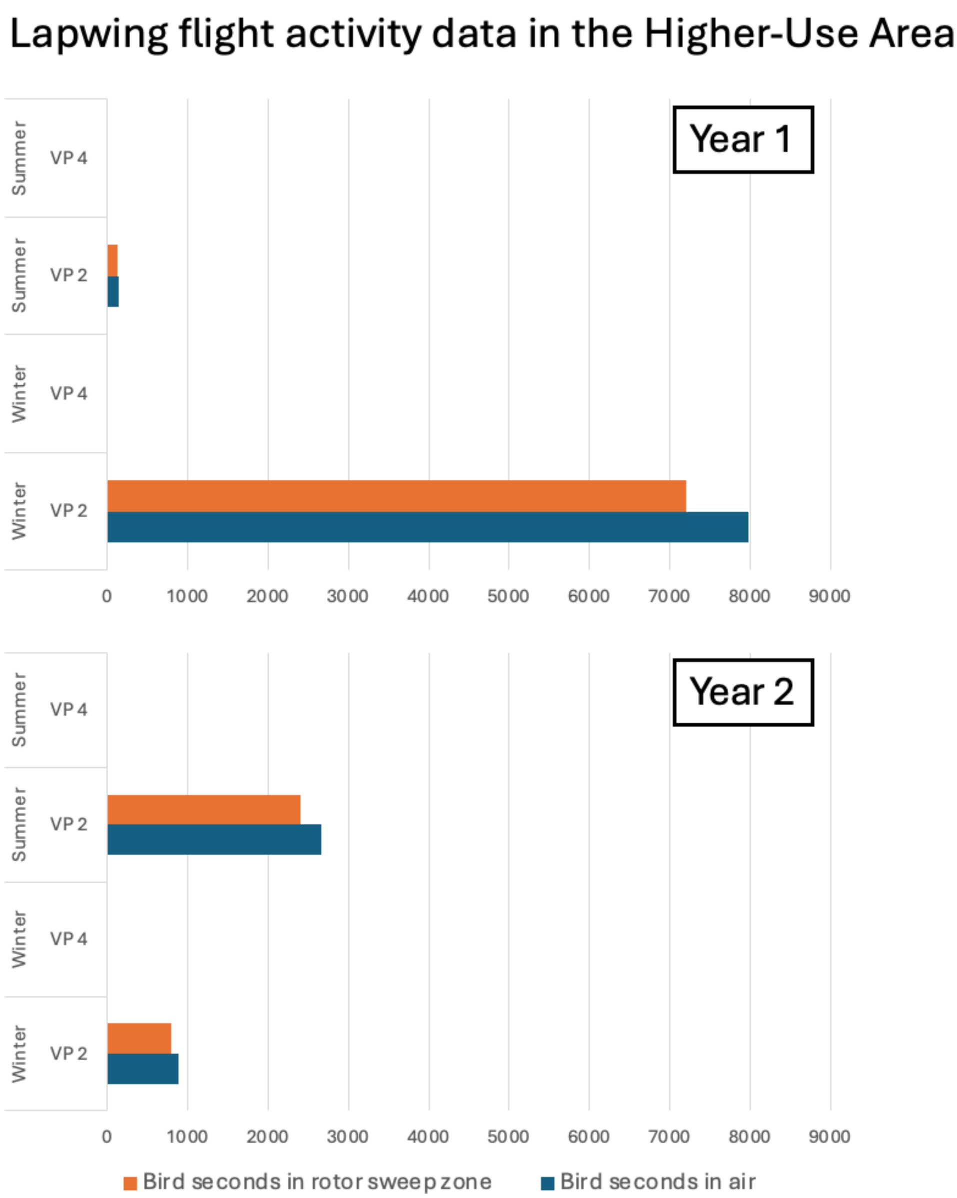

Figure 37. Flight activity of lapwing across years, seasons, and vantage point (VP) locations in the Higher-Use Area. Blue bars show the total flight activity in bird seconds (time spent in the air), and orange bars show the subset of seconds birds spent at risk height.

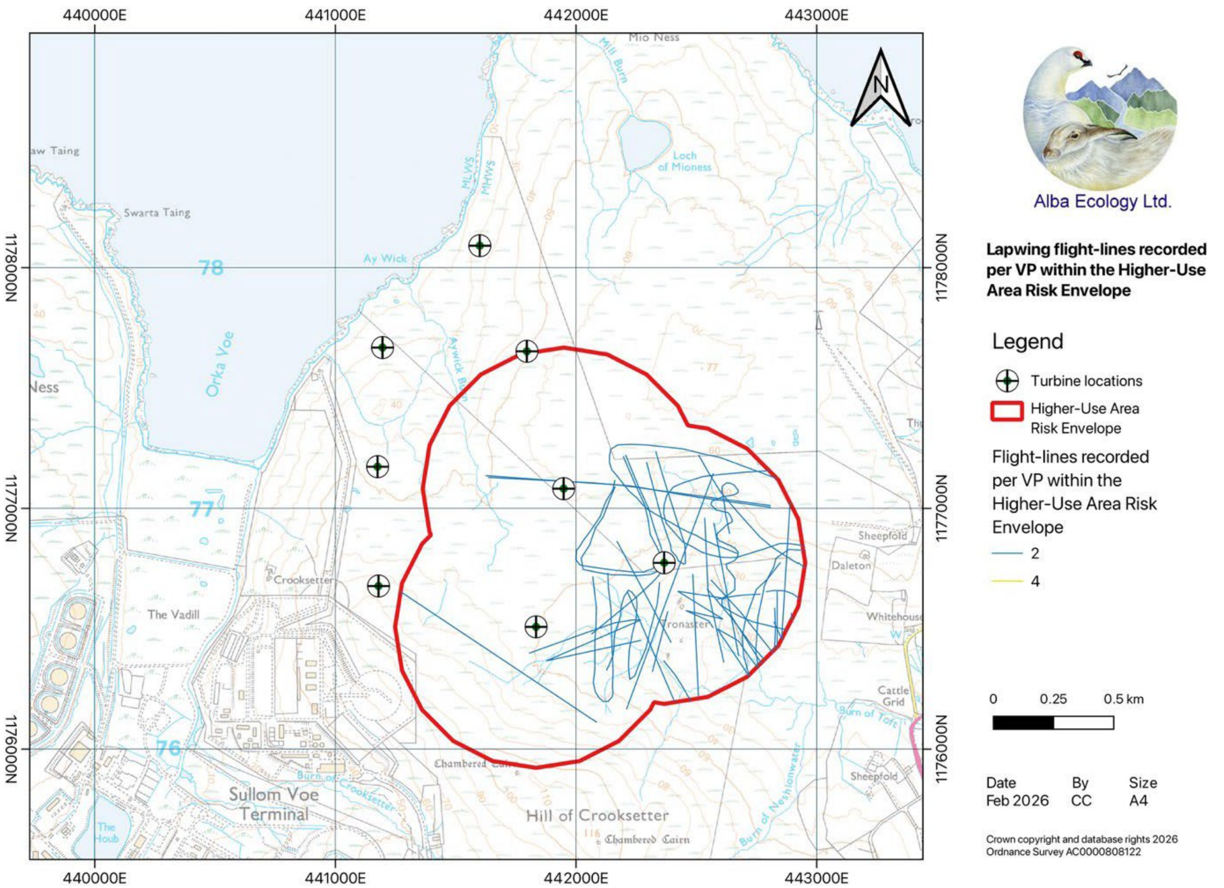

Figure 38. Lapwing flight-line data collected in Year One and Year Two in the Higher-Use Area.

The CRA for lapwing in the Higher-Use Area with two years combined data is shown in Table 72 - Table 75. Table 72 provides a summary of lapwing flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 73 gives the survey results for lapwing across seasons and VPs. Table 74 estimates the uncertainty for the lapwing CRA and Table 75 presents the estimated number of collisions per year.

Table 72. A summary of lapwing flight activity in bird seconds for the Higher-Use Area, including Q2r which is the proportion of flight activity that occurred in the risk height range (rotor sweep area).

Total bird seconds in air (s)	11673
Total bird seconds in rotor sweep area (s)	10540
Q_{2r} – Proportion of time in rotor sweep area	90.3%

Table 73. Survey results for lapwing across seasons and VPs in the Higher-Use Area. Time shows the seconds birds were in the air, and D_A shows the areal density (bird seconds per km²).

			Summer		Winter	
Year	**VP**	**Area (km²)**	**Time (bird seconds)**	**D_A**	**Time (bird seconds)**	**D_A**
1	VP 2	2.1	144	0.00053	7978	0.0293
1	VP 4	0.16	0	0	0	0
2	VP 2	2.1	2662	0.00979	889	0.00327
2	VP 4	0.16	0	0	0	0
			Weighted Mean	0.00404	**Weighted Mean**	0.0128
			Weighted SD	0.00462	**Weighted SD**	0.0133

Table 74. Sources of uncertainty for the lapwing CRA in the Higher-Use Area.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	1.64
Survey flight height error	0.05
Simplifications in the collision model	0.2
Combined uncertainty	+/- 166%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Lapwing were assessed using 98% avoidance as recommended by NatureScot as a precautionary measure (SNH, 2018). Assuming an avoidance factor of 98% by which lapwing may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions (Table 75):

Table 75. CRA outputs for lapwing in the Higher-Use Area.

Potential annual bird transits through rotors	517
Collisions assuming no avoidance	25
Collisions assuming 95% avoidance	1.3
Collisions assuming 98% avoidance	**0.5 (One collision expected every 2 years)**

Collisions assuming 99% avoidance	0.26
Collisions assuming 99.5% avoidance	0.1

At a 98% avoidance rate, the estimated collision rate was 0.5 collisions per year, equivalent to one bird strike every 2 years. The associated uncertainty ranged from 0 to 1.33 collisions per year (one bird strike every 0.75 years), reflecting a 95% confidence interval with an uncertainty range of 166% (truncated at zero to maintain biological realism).

Lower-Use Turbine Cluster

Lapwing were recorded in the Lower-Use Area only during the winter of Year One (Figure 39). A total of 75 flights were observed in the Lower-Use Area over two years (Figure 40).

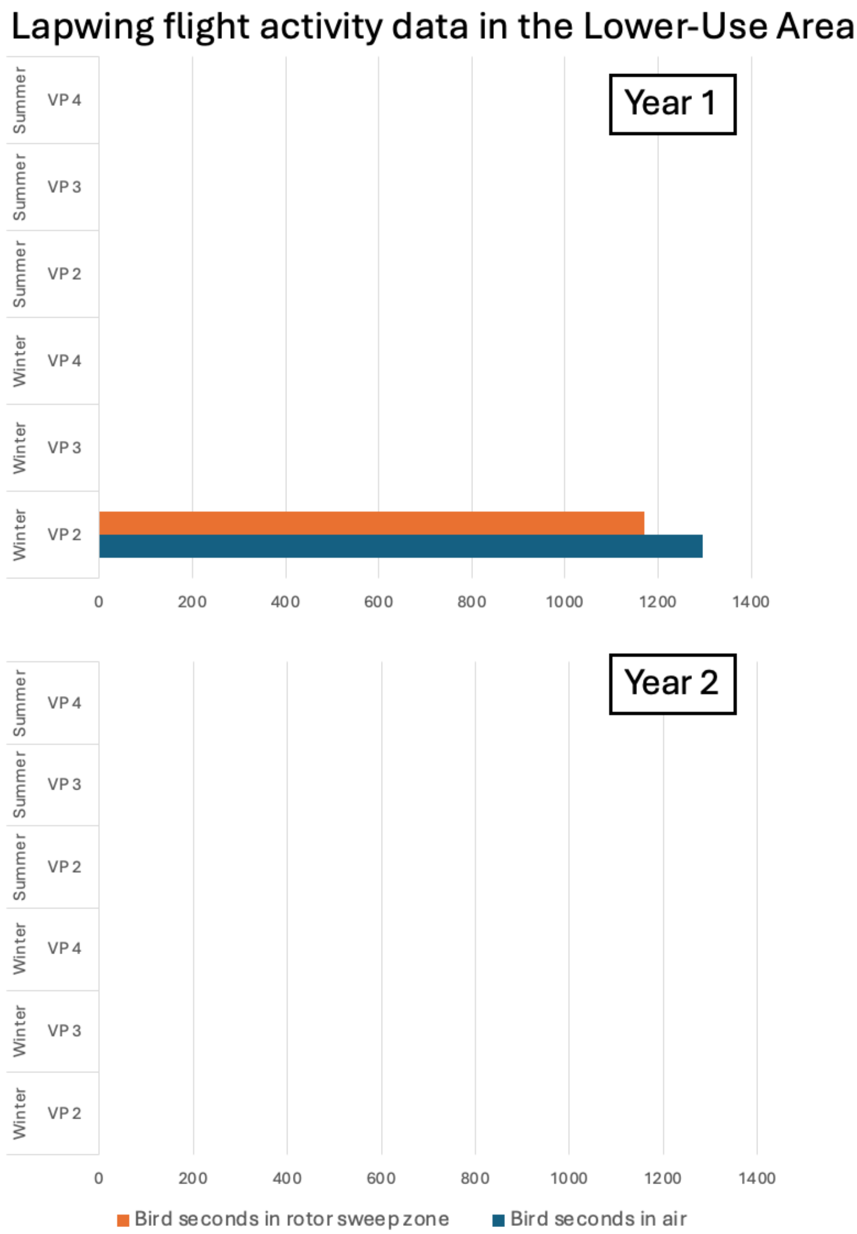

Figure 39. Flight activity of lapwing across years, seasons, and vantage point (VP) locations in the Lower-Use Area. Blue bars show the total flight activity in bird seconds (time spent in the air), and orange bars show the subset of seconds birds spent at risk height.

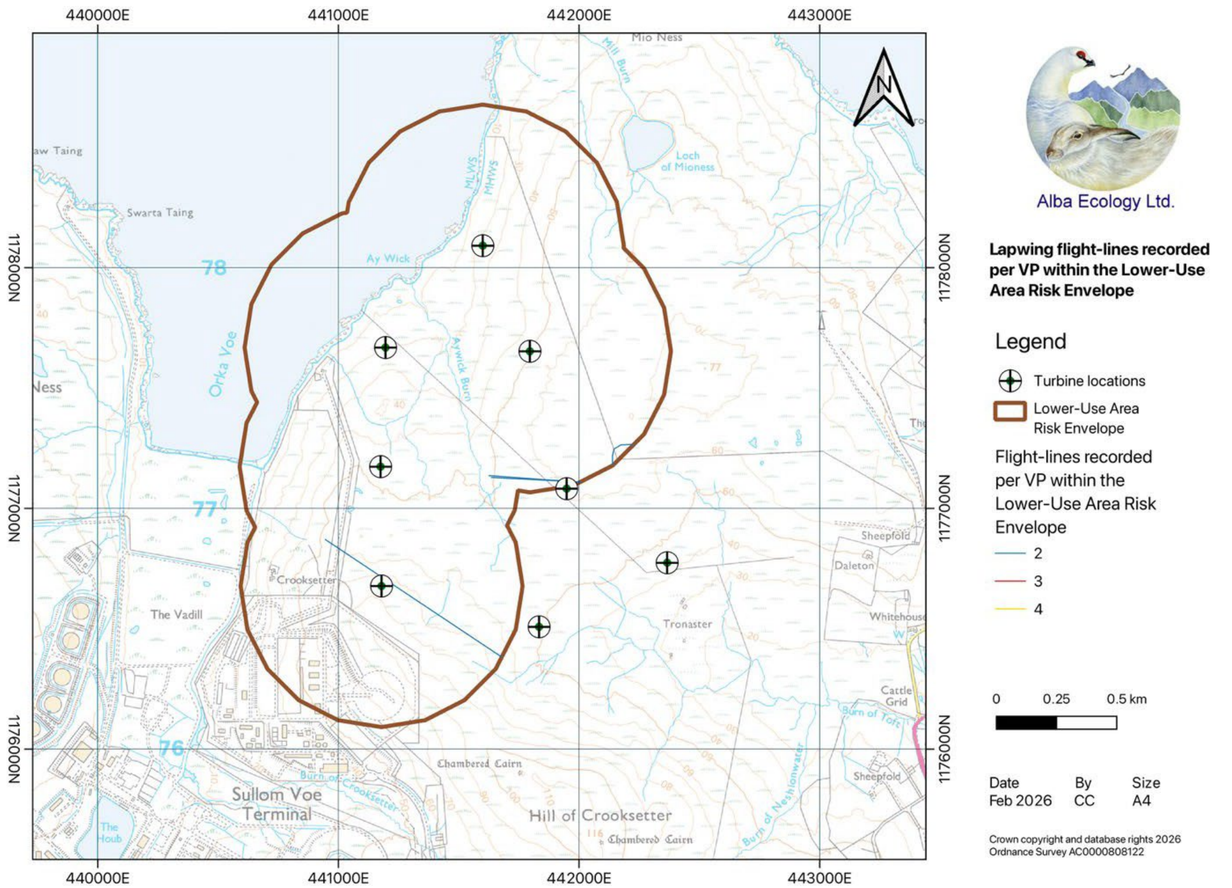

Figure 40. Lapwing flight-line data collected in Year One and Year Two in the Lower-Use Area.

The CRA for lapwing in the Lower-Use Area with two years combined data is shown in Table 76-Table 79. Table 76 provides a summary of lapwing flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 77 gives the survey results for lapwing across seasons and VPs. Table 78 estimates the uncertainty for the lapwing CRA and Table 79 presents the estimated number of collisions per year.

Table 76. A summary of lapwing flight activity in bird seconds for the Lower-Use Area, including Q2r which is the proportion of flight activity that occurred in the risk height range (rotor sweep area).

Total bird seconds in air (s)	1296
Total bird seconds in rotor sweep area (s)	1171
Q_{2r} – Proportion of time in rotor sweep area	90.4%

Table 77. Survey results for lapwing across seasons and VPs in the Lower-Use Area. Time shows the seconds birds were in the air, and D_A shows the areal density (bird seconds per km^2).

			Summer		Winter	
Year	**VP**	**Area (km^2)**	**Time (bird seconds)**	**D_A**	**Time (bird seconds)**	**D_A**
1	VP 2	2.3	0	0	1296	0.00440
1	VP 3	0.22	0	0	0	0
1	VP 4	0.45	0	0	0	0
2	VP 2	2.3	0	0	0	0
2	VP 3	0.22	0	0	0	0
2	VP 4	0.45	0	0	0	0
			Weighted Mean	0	**Weighted Mean**	0.00125
			Weighted SD	0	**Weighted SD**	0.00198

Table 78. Sources of uncertainty for the lapwing CRA in the Lower-Use Area.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	3.1
Survey flight height error	0.05
Simplifications in the collision model	0.2
Combined uncertainty	+/- 311%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Lapwing were assessed using 98% avoidance as recommended by NatureScot as a precautionary measure (SNH, 2018). Assuming an avoidance factor of 98% by which lapwing may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions (Table 79):

Table 79. CRA outputs for lapwing in the Lower-Use Area

Potential annual bird transits through rotors	53
Collisions assuming no avoidance	3

Collisions assuming 95% avoidance	0.1
Collisions assuming 98% avoidance	**0.06 (One collision expected every 16.7 years)**
Collisions assuming 99% avoidance	0
Collisions assuming 99.5% avoidance	0

At a 98% avoidance rate, the estimated collision rate was 0.06 collisions per year, equivalent to one bird strike every 16.7 years. The associated uncertainty ranged from 0 to 0.25 collisions per year (one bird strike every 1.1 years), reflecting a 95% confidence interval with an uncertainty range of 311% (truncated at zero to maintain biological realism).

Combined Collision Risk

Combining the collision estimates from both the Lower-Use and Higher-Use Area estimates (and propagating their uncertainties) gives an overall collision risk for lapwing in the Proposed Development of 0.56 (+/- 152%) collisions a year (one bird strike expected every 1.78 years). The associated uncertainty ranges from 0 to 1.41 collisions per year.

Redshank

For redshank, the CRA was disaggregated into two turbine clusters to reflect the substantial spatial variation in redshank flight activity across the Study Area. One cluster consists of three turbines located within an area of higher redshank activity in the south-east of the Study Area, while the second cluster comprises five turbines situated within an area characterised by comparatively lower levels of activity.

To derive an overall collision estimate for the Proposed Development, the predicted collision totals from each cluster were summed, and associated uncertainty was propagated accordingly. The following sections present the CRA results for each turbine cluster, followed by the combined site-wide collision estimate.

The biological parameters used for all redshank CRA are in Table 80. The flight speed of greenshank (*Tringa nebularia*) was used in the absence of a stated redshank flight speed.

Table 80. Biological parameters for redshank CRA.

Bird length (m) (Snow *et al*., 1998)	0.23
Wingspan (m) (Snow *et al*., 1998)	0.63
Assumed bird speed (m/s) (Alerstam *et al*., 2007) ****Tringa nebularia* **proxy used**	12.3
Avoidance rate (%) (SNH, 2018)	98
Flight type	Flapping

Higher-Use Turbine Cluster

Redshank were recorded in the Higher-Use Area during the summer and winter in Year One, but only in the summer in Year Two (Figure 41). A total of 26 flights were observed in the Higher-Use Area over two years (Figure 42).

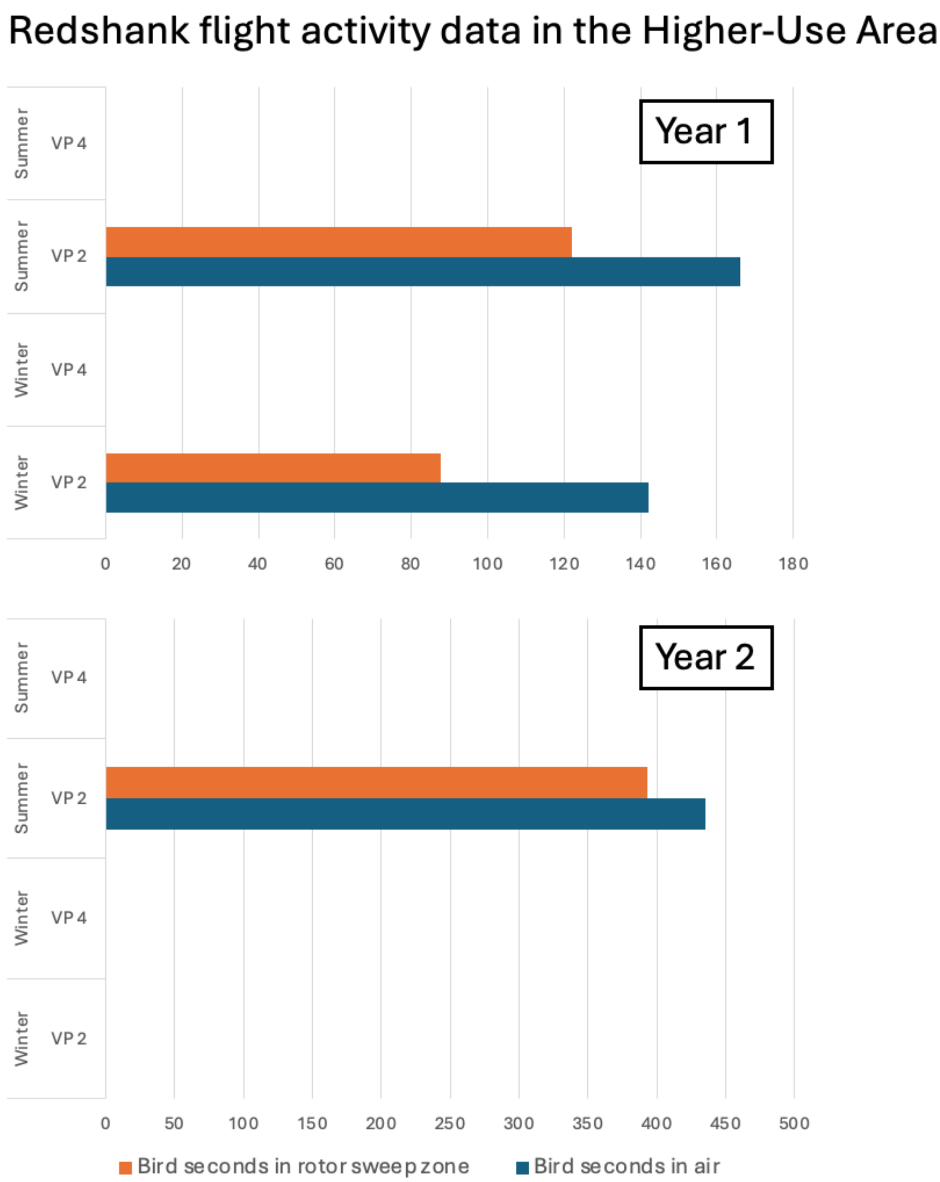

Figure 41. Flight activity of redshank across years, seasons, and vantage point (VP) locations in the Higher-Use Area. Blue bars show the total flight activity in bird seconds (time spent in the air), and orange bars show the subset of seconds birds spent at risk height.

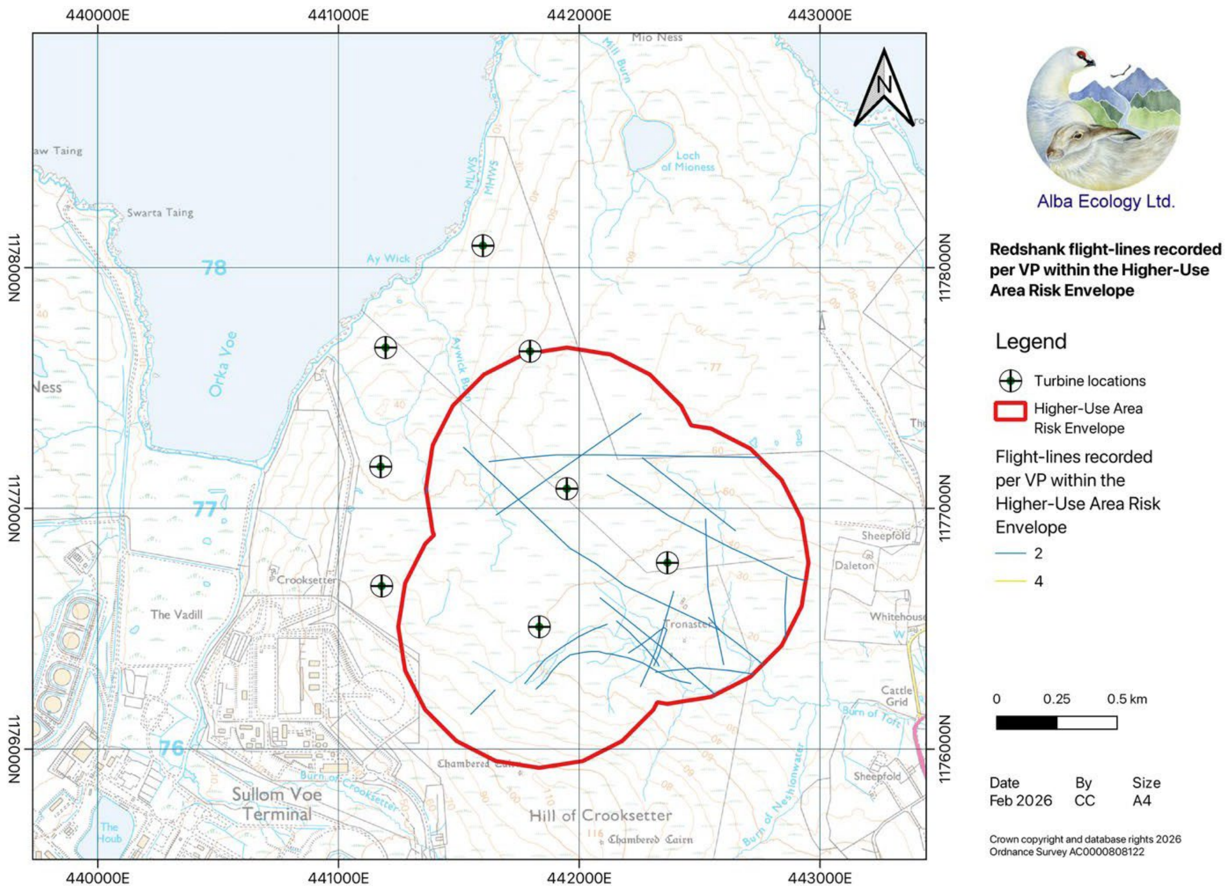

Figure 42. Redshank flight-line data collected in Year One and Year Two in the Higher-Use Area.

The CRA for redshank in the Higher-Use Area with two years combined data is shown in Table 81-Table 84. Table 81 provides a summary of redshank flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 82 gives the survey results for redshank across seasons and VPs. Table 83 estimates the uncertainty for the redshank CRA and Table 84 presents the estimated number of collisions per year.

Table 81. A summary of redshank flight activity in bird seconds for the Higher-Use Area, including Q2r which is the proportion of flight activity that occurred in the risk height range (rotor sweep area).

Total bird seconds in air (s)	743
Total bird seconds in rotor sweep area (s)	603
Q_{2r} – Proportion of time in rotor sweep area	81.1%

Table 82. Survey results for redshank across seasons and VPs in the Higher-Use Area. Time shows the seconds birds were in the air, and D_A shows the areal density (bird seconds per km^2).

			Summer		Winter	
Year	**VP**	**Area (km^2)**	**Time (bird seconds)**	**D_A**	**Time (bird seconds)**	**D_A**
1	VP 2	2.1	166	0.00061	142	0.000522
1	VP 4	0.16	0	0	0	0
2	VP 2	2.1	435	0.0016	0	0
2	VP 4	0.16	0	0	0	0
			Weighted Mean	0.000866	**Weighted Mean**	0.000205
			Weighted SD	0.000631	**Weighted SD**	0.000255

Table 83. Sources of uncertainty for the redshank CRA in the Higher-Use Area.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	1.25
Survey flight height error	0.05
Simplifications in the collision model	0.2
Combined uncertainty	+/- 126%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Redshank were assessed using 98% avoidance as recommended by NatureScot as a precautionary measure (SNH, 2018). Assuming an avoidance factor of 98% by which redshank may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions (Table 84):

Table 84. CRA outputs for redshank in the Higher-Use Area.

Potential annual bird transits through rotors	42
Collisions assuming no avoidance	2
Collisions assuming 95% avoidance	0.09
Collisions assuming 98% avoidance	**0.05 (One collision expected every 20 years)**

Collisions assuming 99% avoidance	0
Collisions assuming 99.5% avoidance	0

At a 98% avoidance rate, the estimated collision rate was 0.05 collisions per year, equivalent to one bird strike every 20 years. The associated uncertainty ranged from 0 to 0.11 collisions per year (one bird strike every 9.1 years), reflecting a 95% confidence interval with an uncertainty range of 126% (truncated at zero to maintain biological realism).

Lower-Use Turbine Cluster

Redshank were recorded in the Lower-Use during the summer and winter in Year One, but only in the summer in Year Two (Figure 43). A total of 9 flights were observed in the Lower-Use Area over two years (Figure 44).

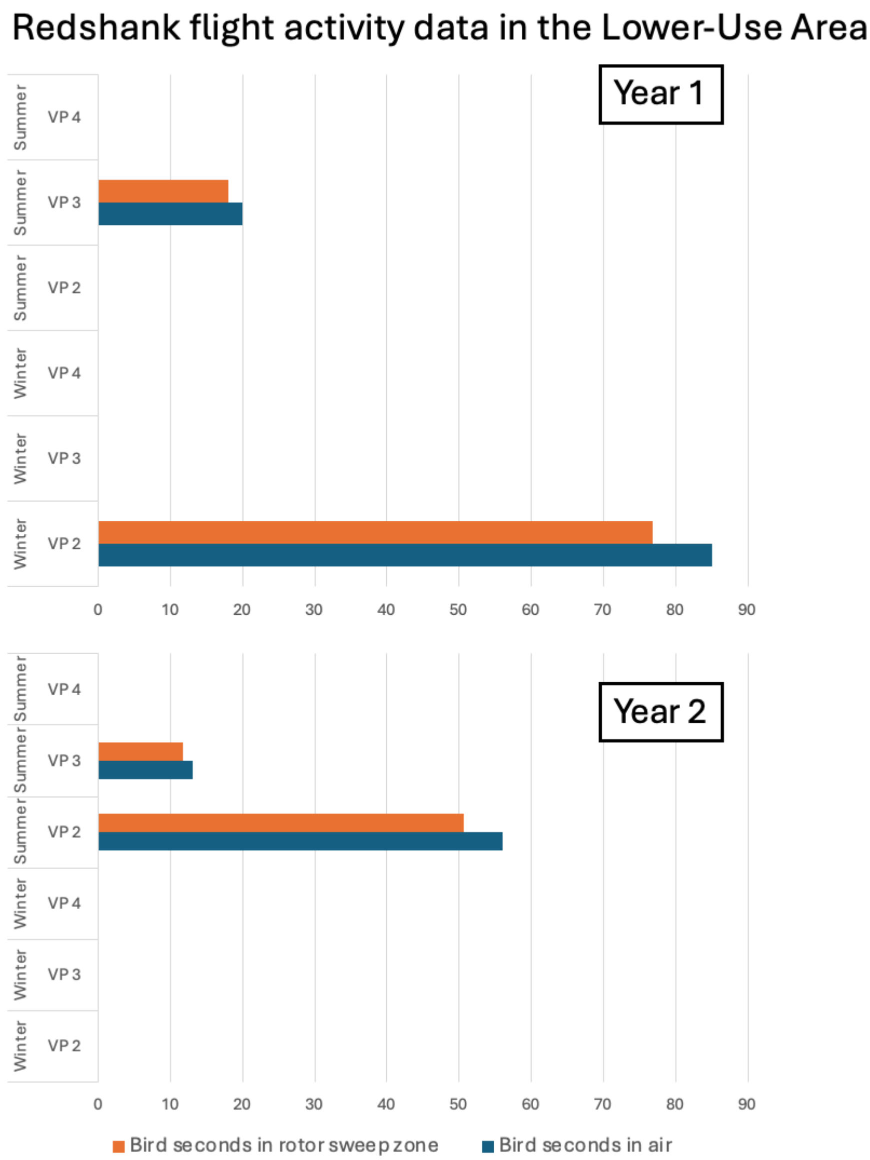

Figure 43. Flight activity of redshank across years, seasons, and vantage point (VP) locations in the Lower-Use Area. Blue bars show the total flight activity in bird seconds (time spent in the air), and orange bars show the subset of seconds birds spent at risk height.

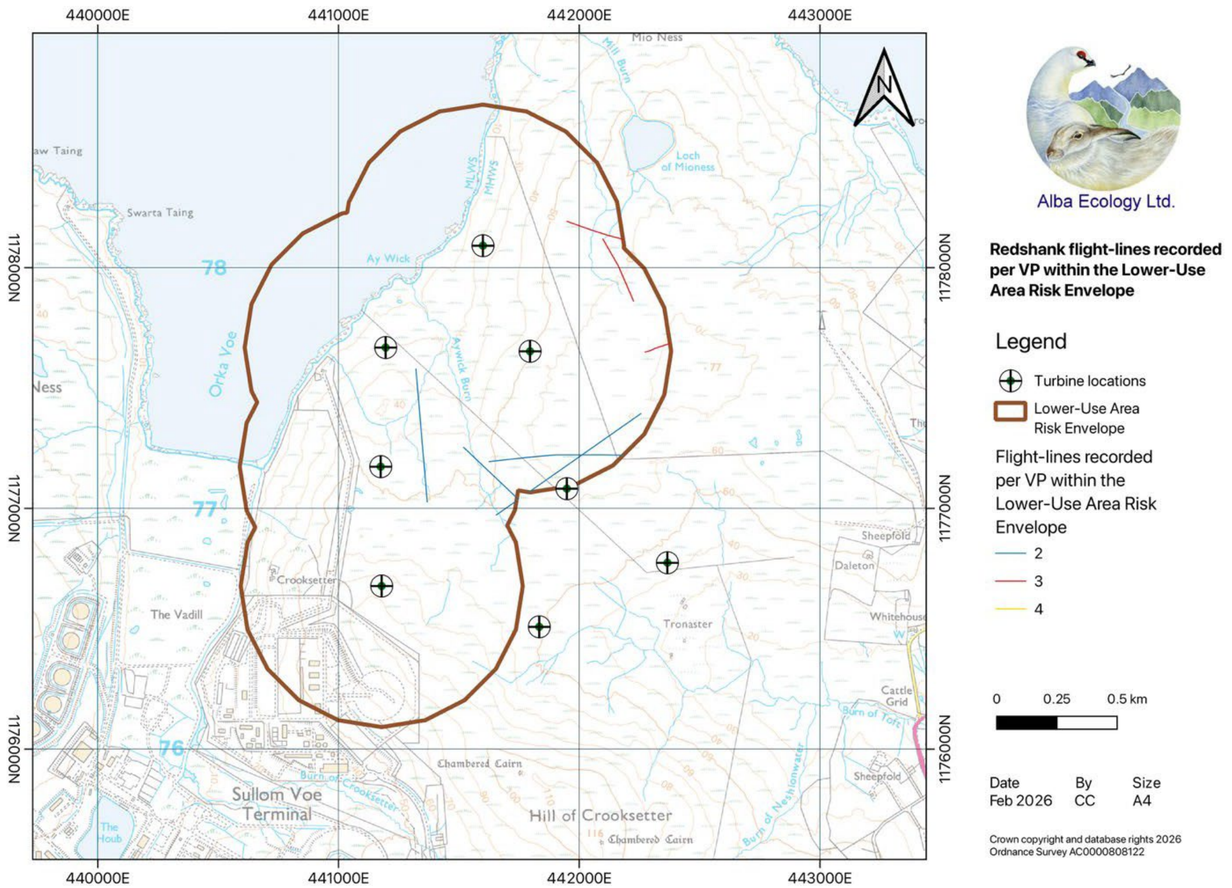

Figure 44. Redshank flight-line data collected in Year One and Year Two in the Lower-Use Area.

The CRA for redshank in the Lower-Use Area with two years combined data is shown in Table 85-Table 88. Table 85 provides a summary of lapwing flight activity in bird seconds, including Q_{2r} which is the proportion of flight activity that occurred in the risk height range. Table 86 gives the survey results for redshank across seasons and VPs. Table 87 estimates the uncertainty for the redshank CRA and Table 88 presents the estimated number of collisions per year.

Table 85. A summary of redshank flight activity in bird seconds for the Lower-Use Area, including Q2r which is the proportion of flight activity that occurred in the risk height range (rotor sweep area).

Total bird seconds in air (s)	174
Total bird seconds in rotor sweep area (s)	157
Q_{2r} – Proportion of time in rotor sweep area	90.4%

Table 86. Survey results for redshank across seasons and VPs in the Lower-Use Area. Time shows the seconds birds were in the air, and D_A shows the areal density (bird seconds per km^2).

			Summer		Winter	
Year	**VP**	**Area (km^2)**	**Time (bird seconds)**	**D_A**	**Time (bird seconds)**	**D_A**
1	VP 2	2.3	0	0	85	0.000288
1	VP 3	0.22	20	0.000692	0	0
1	VP 4	0.45	0	0	0	0
2	VP 2	2.3	56	0.00019	0	0
2	VP 3	0.22	13	0.00045	0	0
2	VP 4	0.45	0	0	0	0
			Weighted Mean	0.000156	**Weighted Mean**	0.0000821
			Weighted SD	0.000211	**Weighted SD**	0.000130

Table 87. Sources of uncertainty for the redshank CRA in the Lower-Use Area.

Source of uncertainty	**Estimated range**
Uncertainty in areal flight density (D_A)	2.04
Survey flight height error	0.05
Simplifications in the collision model	0.2
Combined uncertainty	+/- 205%

Accounting for birds taking evasive action before colliding with turbine blades is challenging to parameterise in collision modelling and represents a dominant source of error in collision estimates. Redshank were assessed using 98% avoidance as recommended by NatureScot as a precautionary measure (SNH, 2018). Assuming an avoidance factor of 98% by which redshank may be able to take evasive action to avoid colliding with a turbine blade, gives the following number of predicted collisions (Table 88):

Table 88. CRA outputs for redshank in the Lower-Use Area.

Potential annual bird transits through rotors	16
Collisions assuming no avoidance	1

Collisions assuming 95% avoidance	0.03
Collisions assuming 98% avoidance	**0 (No collisions expected)**
Collisions assuming 99% avoidance	0
Collisions assuming 99.5% avoidance	0

At a 98% avoidance rate, no collisions are estimated for redshank in the Lower-Use Area.

Combined Collision Risk

Given no collisions are expected from the Lower-Use Area, the combined collision risk is posed only from the Higher-Use Area. The overall collision risk for redshank in the Proposed Development of 0.05 collisions per year (+/- 126%), equivalent to one bird strike every 20 years. The associated uncertainty ranged from 0 to 0.11 collisions per year (one bird strike every 9.1 years), reflecting a 95% confidence interval with an uncertainty range of 126% (truncated at zero to maintain biological realism).

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