ScottishPower Renewables

Hare Hill Windfarm Repowering and Extension

Technical Appendix 8.2: Collision Risk Modelling Report

November 2025

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Abbreviations

Abbreviation	Description
CRM	Collision Risk Model
CRZ	Collision Risk Zone
DGC	Dumfries and Galloway Council
EAC	East Ayrshire Council
HHE	Hare Hill Windfarm Extension
PCH	Potential Collision Height
VPs	Viewpoints

1. Introduction

1. This Technical Appendix was commissioned by ScottishPower Renewables (UK) Limited (the Applicant) and has been prepared to accompany **Chapter 8: Ornithology** of the Hare Hill Windfarm Repowering and Extension (hereafter, the 'proposed Development') Environmental Impact Assessment (EIA) Report. This Technical Appendix references data from **Technical Appendix 8.1: Ornithology Baseline**.

2. The proposed Development is located on the border of East Ayrshire and Dumfries and Galloway: Hare Hill Windfarm (HH) and Hare Hill Windfarm Extension (HHE) sit south east of New Cumnock, East Ayrshire, straddling the administrative boundaries of East Ayrshire Council (EAC) and Dumfries and Galloway Council (DGC) (hereafter, the 'Site'). The proposed Development will decommission and remove all 55 existing turbines, replacing them with 23 turbines of higher generating capacity.

3. Bird flight activity surveys were conducted from April 2022 to August 2024 using eight Vantage Point (VP) locations (VP 1–8). However, due to design changes, only data from VPs 1–7 remained relevant to the final layout and was used to assess the theoretical collision risk for the proposed Development. The VP locations and their viewsheds are shown on Figure 8.1.2 accompanying Technical Appendix 8.1: Ornithology Baseline.

4. The existing windfarm covers approximately 4.07 km². In the final layout, the new turbines will be more widely spaced, extending across approximately 13.33 km² (calculated by connecting the outermost turbine rotors). While there is some overlap between the existing and proposed windfarms, survey data for collision risk calculations excludes flight activity from the existing windfarm area. Therefore, the total study area used for calculations is approximately 9.33 km², which includes the final layout excluding the existing windfarm area. With an additional 500 m buffer[1], the total area is approximately 17.3 km².

5. Among the bird species present/recorded on Site, golden plover (*Pluvialis apricaria*) and red kite (*Milvus milvus*) were identified as particularly sensitive to collision risk. The survey data for these species was incorporated into a Collision Risk Model (CRM) (Band et al., 2007), referred to as 'the Band model', as detailed in this Technical Appendix.

6. **Annex A** contains the flight data used in the CRM, whilst **Annex B** presents CRM calculations.

[1] *A 500m buffer is added to allow for observer inaccuracies when mapping flights during surveys (NatureScot, 2018).*

2. CRM Methodology

2.1. Introduction

7. The risk of birds colliding with turbine rotors has been assessed using a model developed by William Band, which estimates the number of bird collisions with the turbine rotors during a specified time period (Band *et al.,* 2007; Band, 2024; NatureScot, 2024a). The model requires input data based on species biometrics and flight characteristics, turbine specification and flights observed within the Study Area (defined as the Collision Risk Zone (CRZ)[2]). The amount of time that a species may be active within the Study Area in any given season is also required for the model and must therefore be estimated.

8. The original 'Band model' used a two-stage approach, whereby the number of birds or flights passing through the air space swept by the rotors is determined at Stage 1 and the probability of a bird strike occurring is calculated at Stage 2. The product of Stage 1 and Stage 2 gives a theoretical annual collision mortality rate on the assumption that birds make no attempt to avoid collision.

9. An updated guidance released by NatureScot in 2024 (Band, 2024; NatureScot, 2024a) builds on the original 'Band model' and standardises all stages of the CRM calculations with an updated CRM spreadsheet for running the analysis. The updated model estimates the number of potential collisions through a five-stage process:

   Stage A uses bird survey data to establish the density of flying birds in the vicinity of the turbines, and the proportion flying at risk height, between the lowest and highest points of the rotors.

   Stage B provides an estimate of the potential number of bird passages through rotors in the period in question, based on the bird density and proportion at risk height.

   Stage C calculates the probability of collision during a single bird rotor transit.

   Stage D estimates the potential collision rate for a bird species, assuming current levels of bird use of the site, allowing for the proportion of time that turbines are not operational.

   Stage E takes account of the proportion of birds likely to avoid the windfarm or its turbines, either because they have been displaced from the site, take evasive action or are attracted to the windfarm, e.g. in response to changing habitats.

10. This Technical Appendix uses the updated NatureScot guidance and CRM spreadsheet for its calculations.

11. The results of the modelling provide an estimate of the number of collisions that can be expected over a specific season, year, or for the lifetime of the proposed Development.

[2] *The Collision Risk Zone (CRZ) is defined as the perimeter of the proposed Development (measured by connecting the outermost turbine rotors) plus a 500m buffer (NatureScot, 2017). The CRZ for this development excludes the area covered by the existing windfarm.*

2.2. Selection of flights

12. All flights observed at Potential Collision Height (PCH) falling within the CRZ are typically included in modelling. Those flights that extended beyond the CRZ were clipped to the CRZ boundary (i.e., only the time spent within the CRZ was included in the collision risk model). Where flights at PCH originated or ended outside of the CRZ, the amount of time for the clipped flight in the relevant height bands within CRZ was calculated as a proportion of the clipped flight length to the total flight length in that height band. Where a flight represented the activity of more than one bird, total flight time was calculated based on number of birds multiplied by the time at PCH within the CRZ.

13. As outlined earlier, data from VP 8 was not included in the analysis as its viewshed did not fall within the CRZ.

14. Annex A provides details of all flights included in the CRM, including the length of clipped flights.

2.3. Stage A: Flight activity

2.3.1. Choice of Model: Directional or Non-Directional

15. The Stage A calculation varies depending on whether flight activity follows a regular directional pattern or is non-directional.

16. The modelling method for birds with directional flight activity is used for birds such as geese following a regular migration route or travelling from a winter roost to a regular feeding area.

17. The modelling method for birds with non-directional ('normal') flight activity, such as raptors and waders, requires the calculation of the amount of time birds were observed flying per unit of area surveyed. This level of flight activity is then applied to the proposed Development in subsequent calculations of the collision risk.

18. The flight activity surveys undertaken primarily recorded golden plovers in circling flocks and landing within the Site, indicative of foraging behaviour rather than directed migratory movements. Hence, the non-directional ('normal') approach was used for assessment of collision risk for this species.

19. Similarly, red kites were noted exhibiting hunting and foraging behaviour. Hence, the non-directional ('normal') approach was also used for their collision risk assessment.

2.3.2. Areal bird density

20. Areal bird density is defined as the number of birds per unit area, in flight at any height at a given point in time.

21. Vantage point watch bird survey was undertaken for 2.5 years from VPs 1-7, covering the entire site plus a buffer area of 500m outside the proposed Development boundary. All areas were watched for 36 hours per season (breeding and non-breeding season) gathering data for three breeding seasons and two non-breeding seasons. The watches were divided into three-hour sessions and the sessions were spread to be representative sample of daylight hours. Flights of golden plover and red kite were recorded for the

entire duration of each watch period, yielding total flying time in bird-seconds over the duration of the watch.

22. For both species (following non-directional/'normal' flight pattern), flying time was divided by the period of the watch (in seconds) and the area watched (in km^2) to give the average density of birds in flight per square kilometre.

2.3.3. Golden Plover

23. Survey results for golden plover are shown in Table 2.1. The bird data was combined per month rather than aggregated into seasons because the Site is used as a migration stopover during autumn and spring, resulting in large flock sizes that provide sufficient data per month (although no data was recorded in months of June, July, and December). The monthly data were aggregated across all survey efforts per VP and entered into Stage A of the CRM spreadsheet accordingly.

24. Watch times were taken as follows to calculate the areal bird densities:

- Breeding season: April to August inclusive, 36 hours per VP per season for three seasons = 388,800s
- Non-breeding season: September to March inclusive, 36 hours per VP per season for two seasons = 259,200s

Table 2.1 Survey results and areal bird density for Golden Plover

VP	Area (km^2)	Jan	Feb	Mar	April	May	Aug	Sept	Oct	Nov
		Time in flight (bird-seconds) Areal bird density (birds/km^2)								
VP 1	0.98	16108 0.0637	0 0.0000	9417 0.0373	0 0.0000	0 0.0000	0 0.0000	0 0.0000	4618 0.0183	0 0.0000
VP 2	2.79	0 0.0000	0 0.0000	674 0.0009	0 0.0000	0 0.0000	0 0.0000	330 0.0003	6060 0.0084	357447 0.4946
VP 3	4.34	0 0.0000	0 0.0000	0 0.0000	0 0.0000	0 0.0000	0 0.0000	0 0.0000	0 0.0000	840 0.0007
VP 4	3.87	0 0.0000	360 0.0004	6522 0.0065	0 0.0000	0 0.0000	0 0.0000	2376 0.0016	810 0.0008	0 0.0000
VP 5	2.98	0 0.0000	0 0.0000	0 0.0000	793 0.0007	4352 0.0038	239 0.0002	3232 0.0028	34885 0.0451	237574 0.3071
VP 6	1.37	0 0.0000	0 0.0000	0 0.0000	0 0.0000	0 0.0000	0 0.0000	0 0.0000	0 0.0000	0 0.0000
VP 7	1.64	0 0.0000	0 0.0000	0 0.000	0 0.0000	0 0.0000	0 0.0000	750 0.0012	0 0.0000	0 0.0000

VP	Area (km^2)	Jan	Feb	Mar	April	May	Aug	Sept	Oct	Nov
Mean bird density		**0.0091**	**0.0001**	**0.0064**	**0.0001**	**0.0005**	**0.0000**	**0.0008**	**0.0104**	**0.1146**
Standard deviation		0.0241	0.0001	0.0138	0.0003	0.0014	0.0001	0.0011	0.0168	0.2029

** No flight activity was recorded in the months of June, July, and December.*

25. For Stage A, the mean bird density per month was entered into the CRM spreadsheet.

2.3.4. Red Kite

26. Survey results for Red Kite are shown in Table 2.2. The data for both years were combined into two periods: breeding (April to August) and non-breeding (September to March). The data for both the years is aggregated and a mean and standard deviation calculated for each season.

Table 2.2 Survey results and areal bird density for Red Kite

		Breeding season **Watch time over 3 seasons = 388,800s**		**Non-Breeding season** **Watch time over 2 seasons = 259,200s**	
	Area (km2)	**Time in flight (bird-seconds)**	**Areal bird density (birds/km2)**	**Time in flight (bird-seconds)**	**Areal bird density (birds/km2)**
VP 1	0.98	149	0.0004	371	0.0015
VP 2	2.79	374	0.0003	500	0.0007
VP 3	4.34	401	0.0002	1240	0.0011
VP 4	3.87	0	0.0000	101	0.0001
VP 5	2.98	0	0.0000	186	0.0002
VP 6	1.37	0	0.0000	233	0.0007
VP 7	1.64	0	0.0000	254	0.0006
Mean bird density			0.0001		0.0007
Standard Deviation			0.0002		0.0005

27. The bird densities used in the CRM spreadsheet are as below:

- Breeding season: mean density 0.0001 birds/km2 with standard deviation 0.0002; and
- Non-breeding season: mean density 0.0007 birds/km2 with standard deviation 0.0005.

28. The mean bird density for the red kites was entered as below:

- April to August inclusive – 0.0001 for each month; and
- September to March inclusive – 0.0007 for each month.

2.3.5. Proportion flying at risk height

29. The proposed Development will have turbines of three different models (detailed in **Section 2.4.1: Windfarm specifications** below). For the purpose of CRM, PCH is calculated by using the lowest blade sweep height and highest blade sweep height for each individual model, resulting in the following PCH values:

    - Model 1: PCH 14-150m;
    - Model 2: PCH 30-180m; and
    - Model 3: PCH 38-200m.

30. The flight activity surveys recorded the flight heights of birds, using bands of 0-50m, 50-200m, and >200m. To calculate the proportion of birds flying at PCH for each turbine model being installed, it was assumed that in each of the height ranges within which flight height was classified, flight heights were distributed uniformly. Thus, the proportion of flights within each of the relevant height ranges (0-50m and 50-200m) could be calculated for each of the rotor height ranges, as detailed in **Table 2.3**.

Table 2.3 Proportion of birds flying at PCH

Species	Proportion observed 0-50m height	Proportion observed 50-200m height	Model 1: Proportion at PCH 14-150m	Model 2: Proportion at PCH 30-180m	Model 3: Proportion at PCH 38-200m
Golden Plover	12%	58%	(36/50)*12% + (100/150)*58% = 47.31%	(20/50)*12% + (130/150)*58% = 55.06%	(12/50)*12% + (150/150)*58% = 60.88%
Red Kite	46%	48%	(36/50)*46% + (100/150)*48% = 65.12%	(20/50)*46% + (130/150)*48% = 60.00%	(12/50)*46% + (150/150)*48% = 59.04%

2.3.6. Windfarm latitude

31. The windfarm's latitude is 55°21′. This is expressed in decimals as 55.35° in Sheet 3 of the CRM workbook ('Daylight and night hours') to determine the total daylight hours for which the previously calculated bird densities are predicted.

2.3.7. Nocturnal activity factor

32. No night-time surveys of the Site were conducted. Likely levels of nocturnal activity for both species have been established based on expert assessment and literature review. Nocturnal activity was entered as a ranking on a scale of one to five, from 1 = hardly any night activity (0%) to 5 = as active at night as by day (100%).

    - Golden Plover - levels of nocturnal activity by golden plovers are believed to be between 25% to 100% of daytime activity depending on the season/activity of the birds (Gillings, 2003; Stodola, 2014; Whittingham, 2001). Accordingly, this has been averaged out to a score of three to be used in CRM spreadsheet.
    - Red Kite – levels of nocturnal activity by Red Kite are believed to be very low. A score of one on the scale has therefore been attributed.

2.4. Stage B: Estimating number of flights through rotors

2.4.1. Windfarm specifications

33. Ten of the 23 proposed turbines are to be located within the existing windfarm area. These have accordingly been excluded from initial calculations (i.e., only 13 turbines are included in the CRM).

34. A scaling adjustment is later made (after Stage F; see **paragraph 59**) to capture an estimated worst-case collision risk scenario across 23 turbines. The presence of other turbines may mean that birds are in fact subjected to reduced impact levels from the 10 turbines inside the existing windfarm's boundaries.

35. The allocation of turbine models to the 13 specific locations included in the CRM is currently unknown. The assessment has therefore been undertaken using three scenarios. Each scenario assumes that all 13 turbines are of a single model type (details given in

36. **Table** *2.4* below) to represent the full range of possible outcomes. Collision risk has been calculated for each turbine model individually.

Table 2.4 Windfarm specifications

Parameter	Model 1 - Vestas V136	Model 2 - Vestas V150	Model 3 - Vestas V162
Number of blades	3	3	3
Hub height (m)	82	105	119
Rotor radius (m)	68	75	81
Maximum height to blade tip (m)	150	180	200
Minimum height to blade tip (m)	14	30	38
PCH (m)	14-150	30-180	38-200
Mean rotor speed (rpm)	8.75	8.75	8.2
Mean pitch (degrees)	45°	45°	45°
Maximum chord (m)	4.2	4.3	4.3

2.4.2. Bird biometrics

37. Morphometric measurements for bird species (**Table 2.5**) were taken from BTO Bird Facts (BTO, *n.d.*) with flight speeds from Alerstam *et al.* (2007) or, where required, from Bruderer and Boldt (2001).

Table 2.5 Bird biometrics

Species	Bird length (m)	Wingspan length (m)	Flight speed (m/s)
Golden Plover	0.28	0.72	13.7

Species	Bird length (m)	Wingspan length (m)	Flight speed (m/s)
Red Kite	0.63	1.85	12

38. Stage B requires only input of flight speed. Other parameters are used in Stages C and E.

2.4.3. Output from Stage B

39. The output from Stage B is shown in the 'Collision risk' sheet as the potential number of bird transits through the rotors, per month and per annum. The output from this stage for all three turbine models is given in
40. Table *2.6*.

Table 2.6 Output from Stage B

	Species	Model 1	Model 2	Model 3
Total rotor frontal area (m^2)		188,847	229,729	267,956
Projected number of rotor transits per annum	Golden plover	2275	2920	3486
	Red kite	66	67	71

41. It is worth noting that at this stage, non-operational time for the turbines has not yet been factored in.

2.5. Stage C: Probability of collision for a single rotor transit

42. This stage uses information on the size and speed of the turbines (given in Table 2.4) and physical details on the size and speed of the bird (Table 2.5) to compute the risk of collision for a bird flying through a rotating rotor.

43. Typical golden plover flight is predominantly flapping; hence, flapping flight was used in the modelling.

44. Typical red kite flight in Scotland and England is a mix of flapping and gliding (with slightly more time considered likely to be spent gliding). However, in this case, flapping flight has been used, which gives a slightly more precautionary estimate than for gliding flight (NatureScot, 2024b).

45. The orientation of the wind turbines is expected to be distributed across many directions, according to the wind rose for the Site. It has been assumed that golden plover and red kite flights are equally split as between upwind and downwind.

2.5.1. Output from Stage C

46. The CRM spreadsheet calculated the risk of collision during a single transit. The result is expressed as a percentage risk for upwind and downwind flight respectively, with the weighted mean value being used in calculating collision risk. The outputs are detailed in

47. **Table** *2.7* below.

Table 2.7 Output from Stage C - Single transit risk

	Golden plover			Red kite		
	Model 1	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
Single transit risk upwind (%)	8.95	8.83	8.24	11.48	11.31	10.55
Single transit risk downwind (%)	4.14	4.29	4.03	6.57	6.70	6.28
Single transit risk weighted mean (%)	**6.54**	**6.56**	**6.14**	**9.03**	**9.00**	**8.42**

2.6. Stage D: Multiplying to yield expected collisions per year

48. This stage multiplies the outputs from Stage B and Stage C to yield the projected number of bird collisions per month or year. This includes a factor to allow for proportion of time that rotors are not operational.

49. It has been assumed that turbines will be non-operational for 15 % of the time (e.g., during periods when wind speed is too low or too high to operate, or during maintenance).

2.6.1. Output from Stage D

50. The output from Stage D, given in Table 2.8, is the expected number of collisions assuming no avoidance by birds.

Table 2.8 Output from Stage D - Expected collisions per annum assuming no avoidance

Species	Model 1	Model 2	Model 3
Golden plover	127	163	182
Red kite	5	5	5

2.7. Stage E: Applying the avoidance rate

2.7.1.Avoidance rates and attraction

51. The avoidance rate for golden plover, based on current NatureScot guidance, is 98%. Survey data indicates that golden plovers frequently flew close to or within the existing windfarm. CRM results for the Hare Hill Windfarm Extension (See Chapter 8 Ornithology) estimated between 6.8 and 10.4 potential collisions per year, yet no recorded fatalities have been found during carcass searches since 2011. Given this site-specific evidence, an avoidance rate of 99% has been assessed as reasonable.

52. For red kite, the NatureScot guidance specifies an avoidance rate of 99%. Survey data shows that red kites also frequently flew near or within the windfarm. Carcass searches conducted since 2011 recorded one red kite fatality in 2023, indicating some level of

collision risk. Considering this evidence, an avoidance rate of 98% has been assessed as appropriate.

53. Collision risks have been calculated for avoidance rates of 95%, 98%, 99% and 99.5%. The central result is taken to be that for **99% for golden plover** and **98% for red kite**.

2.7.2. Large array correction

54. The 'Large array correction factor' sheet has calculated the correction factor which should be applied to take account of any depletion of bird density because of collisions. A figure close to 100% means little to no correction is required. For all three turbine models, the factor is insignificant; hence the setting 'Allow for large array correction?' in the Collision risk sheet was set to 'No' to avoid unnecessary complications.

2.7.3. Output from Stage E: CRM results

Golden Plover

55. The results of the CRM for golden plover are summarised in **Table 2.9**. Full model calculations are provided in **Annex B**.

Table 2.9 CRM results for Golden Plover - Potential collisions per annum (assessed for 13 turbines of each turbine model)

Avoidance rates	Model 1: V136 (82m hub)	Model 2: V150 (105m hub)	Model 3: V162 (119m hub)
95%	6.3	8.1	9.1
98%	2.5	3.3	3.6
99%	**1.3**	**1.6**	**1.8**
99.5%	0.6	0.8	0.9

** Potential collision estimates are rounded to the nearest decimal place*

56. Assuming a 99% avoidance rate, potential collisions for golden plovers over 50 years (assumed lifespan of the proposed windfarm) are as below:

- Model 1: 65;
- Model 2: 80; and
- Model 3: 90.

2.7.4. Red Kite

57. The results of the CRM for red kite are summarised in

58. Table *2.10*. Full model calculations are provided in Annex B.

Table 2.10 CRM results for Red Kite - Potential collisions per annum (assessed for 13 turbines of each turbine model)

Avoidance rates	Model 1: V136 (82m hub)	Model 2: V162 (99m hub)	Model 3: V162 (119m hub)
95%	0.3	0.3	0.3
98%	**0.1**	**0.1**	**0.1**
99%	0.1	0.1	0.1
99.5%	0.0	0.0	0.0

** Potential collision estimates are rounded to the nearest decimal place*

59. Assuming a 99% avoidance rate, potential collisions for red kites over 50 years (assumed lifespan of the proposed windfarm) are as below:

    - Model 1: 5;
    - Model 2: 5; and
    - Model 3: 5.

2.8. Stage F: Expressing uncertainty

60. In a collision risk estimate, there are many sources of variability or uncertainty at multiple stages. These must be combined to give an understanding of the uncertainty (and hence the likely accuracy) of the estimated collision risk.

61. Each error or uncertainty is first expressed as a relative error, i.e. expressed as a percentage of the value to which it refers. All the errors here are based on seeking 95% certainty.

62. The errors are assessed as detailed in **Table 2.11** below:

Table 2.11 Sources of uncertainty

	Golden Plover		Red Kite	
Source of error	**Description**	**Error estimate**	**Description**	**Error estimate**
Bird density (E1)	Bird density measures showed variability between months. Error is estimated by calculating 1.96 * annual standard deviation (SD) from the mean.	SD_{year} = √(sum of SD_{month}^2) = √(0.042) = 0.205 E1 = 1.96 * 0.205 = 0.403	Bird density measures showed variability between survey seasons. Error is estimated by calculating 1.96 * annual standard deviation (SD) from the mean.	SD_{year} = √($SD_{breeding}^2$ + $SD_{non\text{-}breeding}^2$) = 0.000 E1= 1.96 * 0.000 = 0.001
Nocturnal flight activity (E2)	Nocturnal flight activity can vary between 25 and 100% of the daytime activity. This results in an uncertainty of ±37.5%	E2 = 0.375	Nocturnal activity has been assumed as 0% of the daytime activity, but it has been judged it might be in the range of 0-10%. This results in an uncertainty of 0 ±5%.	E2 = 0.05
Proportion at risk height (E3)	If the visual estimate of flight height is out by ±5m, it is estimated that the proportion of birds	E3 = 0.1	If the visual estimate of height is out by ±5m, it is estimated that the proportion of birds flying	E3 = 0.1

	Golden Plover		Red Kite	
Source of error	**Description**	**Error estimate**	**Description**	**Error estimate**
	flying above 50m would vary by around ±10%		above 50m would vary by around ±10%	
Collision model (E4)	The model involves a number of simplifications, such as shape of bird, use of average pitch, etc. Based on the NatureScot guidelines, ±20% is considered a reasonable estimate of this uncertainty.	E4 = 0.20	The model involves a number of simplifications, such as shape of bird, use of average pitch, etc. Based on the NatureScot guidelines, ±20% is considered a reasonable estimate of this uncertainty.	E4 = 0.20

63. These errors arise independently so in combining errors, the root mean square is taken to allow for the likelihood that some errors will offset others, i.e.

- $E = \sqrt{(E1^2 + E2^2 + E3^2 + E4^2)}$, which calculates combined uncertainty as
- $E = \pm 0.5942$ (i.e. ±59%) for golden plover, and
- $E = \pm 0.2291$ (i.e. ±23%) for red kite.

3. CRM Results

64. The best estimate of annual collision risk, considering avoidance rates outlined in **Section 2.7: Stage E: Applying the avoidance rate** and uncertainties outlined in **Section 2.8: Stage F: Expressing uncertainty**, is given below in **Table 3.1** for golden plover and red kite.

Table 3.1 Best estimate of annual collision risk for Golden Plover and Red Kite (assessed for the same set of 13 turbines under each model)

	Golden Plover Avoidance rate = 99%			**Red Kite Avoidance rate = 98%**		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Annual collision estimate	1.3 ± 59%	1.6 ± 59%	1.8 ± 59%	0.1 ± 23%	0.1 ± 23%	0.1 ± 23%
Best estimate range	0 - 2	1 - 2	1 – 2.5	0	0	0

65. As the proposed Development incorporates 23 turbines, but only 13 are outside the existing windfarm, a simple adjustment is suggested to help interpret these data. This scales up the results from 13 turbines to 23, as shown in **Table 3.2**. However, it should be noted that this is likely to represent a worst-case scenario.

Table 3.2 Worst-case collision risk estimates for Golden Plover and Red Kite (scaled to account for 23 turbines)

	Golden Plover Avoidance rate = 99%			**Red Kite* Avoidance rate = 98%**		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Annual collision estimate	2.3	2.8	3.2	0.1	0.1	0.1
Potential collisions over 50 years	115	140	159	5	5	5

** Due to rounding and the small numbers involved, estimates for red kite do not materially differ from the 13-turbine scenarios.*

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Annex A: Flight Data Used In CRM

Table A- 1 Flight data for Golden Plover used for CRM

VP	Date	Total flight time (s)	Time at Height Band 1: 0-50m (s)	Time at Height Band 2: 50-200m (s)	Time at Height Band 3: >200m (s)	Original length (m)	Clipped length (m)	Clip length (%)	Clipped flight time (s)	Flock size	Clipped (bird-seconds)	Clipped flight time at Height Band 1	Clipped flight time at Height Band 2	Clipped flight time at Height Band 3
VP1	03-01-2023	240	75	120	45	2731	2105	77%	185	32	5919	58	92	35
VP1	03-01-2023	330	135	120	75	3350	3232	96%	318	32	10189	130	116	72
VP1	04-03-2023	420	210	120	90	3797	1419	37%	157	60	9417	78	45	34
VP1	18-10-2023	90	90	0	0	1319	667	51%	46	100	4552	46	0	0
VP1	18-10-2023	30	30	0	0	579	44	8%	2	29	67	2	0	0
VP2	03-10-2022	60	30	30	0	2896	2896	100%	60	17	1020	30	30	0
VP2	03-10-2022	105	60	45	0	3926	3926	100%	105	24	2520	60	45	0
VP2	03-11-2022	225	60	165	0	2830	2830	100%	225	27	6075	60	165	0
VP2	03-11-2022	900	30	450	420	1888	1098	58%	523	670	350533	17	262	244
VP2	26-09-2022	45	15	30	0	537.6	538	100%	45	2	90	15	30	0
VP2	26-09-2022	30	0	30	0	376.1	376	100%	30	8	240	0	30	0
VP2	16-10-2023	105	0	75	30	2049	2049	100%	105	24	2520	0	75	30
VP2	11-03-2023	300	120	120	60	10390	7786	75%	225	3	674	90	90	45
VP2	03-11-2022	90	0	90	0	3563	1788	50%	45	9	406	0	45	0
VP2	03-11-2022	300	0	120	180	7028	34	0%	1	300	433	0	1	1
VP3	09-11-2023	60	45	15	0	3056	3056	100%	60	14	840	45	15	0
VP4	21-02-2023	45	30	15	0	1939	1939	100%	45	8	360	30	15	0
VP4	21-03-2023	15	15	0	0	161.2	161	100%	15	20	300	15	0	0
VP4	21-03-2023	120	0	60	60	1521	1521	100%	120	20	2400	0	60	60

VP	Date	Total flight time (s)	Time at Height Band 1: 0-50m (s)	Time at Height Band 2: 50-200m (s)	Time at Height Band 3: >200m (s)	Original length (m)	Clipped length (m)	Clip length (%)	Clipped flight time (s)	Flock size	Clipped (bird-seconds)	Clipped flight time at Height Band 1	Clipped flight time at Height Band 2	Clipped flight time at Height Band 3
VP4	21-03-2023	90	15	75	0	1725	1725	100%	90	5	450	15	75	0
VP4	21-03-2023	15	15	0	0	166.6	167	100%	15	8	120	15	0	0
VP4	22-09-2023	255	120	135	0	3360	2846	85%	216	11	2376	102	114	0
VP4	23-10-2023	30	30	0	0	419.2	419	100%	30	9	270	30	0	0
VP4	23-10-2023	60	60	0	0	1275	1275	100%	60	9	540	60	0	0
VP4	01-03-2024	150	30	120	0	8066	8066	100%	150	15	2250	30	120	0
VP4	01-03-2024	120	45	75	0	5104	3279	64%	77	13	1002	29	48	0
VP5	26-04-2022	75	15	30	30	1763	1035	59%	44	18	793	9	18	18
VP5	03-10-2022	30	30	0	0	437.3	413	94%	28	133	3770	28	0	0
VP5	03-10-2022	75	60	15	0	1244	802	64%	48	55	2660	39	10	0
VP5	03-10-2022	15	15	0	0	699.1	699	100%	15	55	825	15	0	0
VP5	03-10-2022	45	45	0	0	1212	1212	100%	45	25	1125	45	0	0
VP5	03-11-2022	840	60	660	120	10320	7297	71%	594	400	237574	42	467	85
VP5	26-09-2022	75	30	45	0	1078	588	55%	41	30	1228	16	25	0
VP5	26-09-2022	15	15	0	0	255.4	255	100%	15	3	45	15	0	0
VP5	03-08-2023	30	30	0	0	715	438	61%	18	13	239	18	0	0
VP5	09-05-2023	120	30	90	0	1688	1083	64%	77	35	2694	19	58	0
VP5	16-10-2023	60	30	30	0	1199	772	64%	39	2	77	19	19	0
VP5	16-10-2023	30	30	0	0	571.1	571	100%	30	90	2700	30	0	0
VP5	03-10-2022	300	210	90	0	3866	2299	59%	178	133	23728	125	54	0
VP5	26-09-2022	75	30	45	0	1673	430	26%	19	50	963	8	12	0
VP5	26-09-2022	75	30	45	0	1025	475	46%	35	10	347	14	21	0
VP5	26-09-2022	75	75	0	0	1272	463	36%	27	20	546	27	0	0

VP	Date	Total flight time (s)	Time at Height Band 1: 0-50m (s)	Time at Height Band 2: 50-200m (s)	Time at Height Band 3: >200m (s)	Original length (m)	Clipped length (m)	Clip length (%)	Clipped flight time (s)	Flock size	Clipped (bird-seconds)	Clipped flight time at Height Band 1	Clipped flight time at Height Band 2	Clipped flight time at Height Band 3
VP5	26-09-2022	45	45	0	0	1051	601	57%	26	4	103	26	0	0
VP5	09-05-2023	120	45	75	0	1441	796	55%	66	25	1658	25	41	0
VP7	29-09-2022	15	15	0	0	186.7	187	100%	15	50	750	15	0	0

Table A- 2 Flight data for Red Kite used for CRM

VP	Date	Total flight time (s)	Time at Height Band 1: 0-50m (s)	Time at Height Band 2: 50-200m (s)	Time at Height Band 3: >200m (s)	Original length (m)	Clipped length (m)	Clip length (%)	Clipped flight time (s)	Flock size	Clipped (bird-seconds)	Clipped flight time at Height Band 1	Clipped flight time at Height Band 2	Clipped flight time at Height Band 3
VP1	02-06-2023	285	150	135	0	5345	2803	52%	149	1	149	79	71	0
VP1	01-11-2023	60	60	0	0	1223	112	9%	6	1	6	6	0	0
VP1	01-11-2023	120	120	0	0	2785	1535	55%	66	1	66	66	0	0
VP1	06-01-2023	240	15	165	60	1901	1369	72%	173	1	173	11	119	43
VP1	06-01-2023	330	30	240	60	2607	1003	38%	127	1	127	12	92	23
VP2	05-11-2022	30	30	0	0	2353	2227	95%	28	1	28	28	0	0
VP2	15-06-2022	30	30	0	0	1045	947	91%	27	1	27	27	0	0
VP2	15-06-2022	150	75	75	0	3885	1983	51%	77	1	77	38	38	0
VP2	29-07-2022	270	180	90	0	849.8	850	100%	270	1	270	180	90	0
VP2	06-02-2023	180	0	135	45	5032	4653	92%	166	1	166	0	125	42
VP2	06-02-2023	30	0	30	0	566.3	566	100%	30	1	30	0	30	0
VP2	06-02-2023	95	60	45	0	3508	3508	100%	95	1	95	60	45	0
VP2	01-02-2024	210	30	120	60	4435	3801	86%	180	1	180	26	103	51

VP	Date	Total flight time (s)	Time at Height Band 1: 0-50m (s)	Time at Height Band 2: 50-200m (s)	Time at Height Band 3: >200m (s)	Original length (m)	Clipped length (m)	Clip length (%)	Clipped flight time (s)	Flock size	Clipped (bird-seconds)	Clipped flight time at Height Band 1	Clipped flight time at Height Band 2	Clipped flight time at Height Band 3
VP3	05-12-2022	255	255	0	0	1782	1543	87%	221	1	221	221	0	0
VP3	15-05-2023	150	90	60	0	3529	3083	87%	131	1	131	79	52	0
VP3	19-05-2023	225	120	105	0	4035	4035	100%	225	1	225	120	105	0
VP3	06-12-2023	690	435	255	0	7954	7954	100%	690	1	690	435	255	0
VP3	06-12-2023	75	45	30	0	2073	1772	85%	64	1	64	38	26	0
VP3	17-07-2023	45	45	0	0	1403	1401	100%	45	1	45	45	0	0
VP3	17-10-2023	150	45	105	0	3735	3735	100%	150	1	150	45	105	0
VP3	08-03-2024	120	60	60	0	3666	3533	96%	116	1	116	58	58	0
VP4	23-10-2023	30	30	0	0	825.2	825	100%	30	1	30	30	0	0
VP4	23-10-2023	270	270	0	0	1538	405	26%	71	1	71	71	0	0
VP5	03-11-2022	240	15	225	0	2659	2064	78%	186	1	186	12	175	0
VP6	15-05-2024	330	75	180	75	5629	2228	40%	131	1	131	30	71	30
VP6	15-05-2024	250	30	150	90	3876	1595	41%	103	1	103	12	62	37
VP7	17-10-2023	135	0	105	30	2266	1418	63%	84	1	84	0	66	19
VP7	07-02-2024	210	15	195	0	2418	1874	78%	163	1	163	12	151	0
VP7	06-12-2023	30	30	0	0	575.1	121	21%	6	1	6	6	0	0

Annex B: CRM Calculations

Golden Plover – Turbine model 1

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

		Value	Units			Value	Units			Value	Units
Bird data				**Windfarm data**				**Turbine data**			
Species name		Golden Plover		Site name		Hare Hill		Model		Model 1 V136	
Bird length	L	0.28	m	Latitude		55.35	degrees	Hub height		82	m
Wingspan	W	0.72	m	No of turbines	T	13		Rotor radius	R	68	m
Bird flight speed	v	13.7	m s^{-1}	Width of windfarm	w	3.9	km	No of blades	b	3	
Flight type, flapping or gliding		flapping						Rotation speed	Ω	8.75	rpm
% of flights upwind/downwind		50%	50%					Max blade width	C	4.2	m
Nocturnal activity ranking 1-5		3						Blade pitch	λ	45	degrees
Nocturnal activity factor	f_{night}	50%						Risk height range		14-150	m

normal approach	Set to 'normal approach' to use survey data on bird density
	Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A		birds/km^2	0.0091	0.0001	0.0064	0.0001	0.0005	0	0	0	0.0008	0.0104	0.1146	0	0.0118
Proportion at rotor risk height	Q_{2R}	47.31%														
At latitude 55.4		Daylight hours per month		241.3	268.7	365.8	423.0	501.2	520.2	522.0	465.7	384.2	326.3	252.8	223.8	4494.9
		Nighttime hours per month		502.7	403.3	378.2	297.0	242.8	199.8	222.0	278.3	335.8	417.7	467.2	520.2	4265.1

Stage B					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	13															
Rotor radius	R	68	m														
		Total rotor frontal area m^2		188847													
Nocturnal activity factor	f_{night}	50%															
Bird flight speed	v	13.7	m s^{-1}														
		Projected number of rotor transits			145.3	1.5	115.1	1.9	10.1	0.0	0.0	0.0	14.3	180.3	1806.1	0.0	**2275**

Stage C								
No of blades	b	3			Bird length	l	0.28	m
Rotation speed	Ω	8.75	rpm		Wingspan	w	0.72	m
Rotor radius	R	68	m		Bird flight speed	v	13.7	m s^{-1}
Max blade width	C	4.2	m		Flight type		flapping	
Pitch	λ	45	degrees	% of flights upwind/downwind			50%	50%
Blade profile		see Blade profile sheet						
		Single transit risk		upwind	8.95%			
				downwind	4.14%			
				weighted mean	**6.54%**			

Stage D			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}		85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance													year total
			8.08	0.08	6.40	0.10	0.56	0.00	0.00	0.00	0.80	10.03	100.47	0.00	**127**

Stage E															
Allow for large array correction?		No													
Width of windfarm	w	3.9	km												
			large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
				Collision rates allowing for avoidance												
Avoidance rates modelled		95.00%	100.00%	0.40	0.00	0.32	0.01	0.03	0.00	0.00	0.00	0.04	0.50	5.02	0.00	**6.3**
		98.00%	100.00%	0.16	0.00	0.13	0.00	0.01	0.00	0.00	0.00	0.02	0.20	2.01	0.00	**2.5**
		99.00%	100.00%	0.08	0.00	0.06	0.00	0.01	0.00	0.00	0.00	0.01	0.10	1.00	0.00	**1.3**
		99.50%	100.00%	0.04	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.50	0.00	**0.6**

ScottishPower Renewables

Golden Plover – Turbine model 2

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

		Value	Units			Value	Units			Value	Units
Bird data				**Windfarm data**				**Turbine data**			
Species name		**Golden Plover**		Site name		**Hare Hill**		Model		**Model 2 V162**	
Bird length	L	0.28	m	Latitude		55.35	degrees	Hub height		105	m
Wingspan	W	0.72	m	No of turbines	T	13		Rotor radius	R	75	m
Bird flight speed	v	13.7	m s^{-1}	Width of windfarm	w	3.9	km	No of blades	b	3	
Flight type, flapping or gliding		flapping						Rotation speed	Ω	8.75	rpm
% of flights upwind/downwind		50%	50%					Max blade width	C	4.3	m
Nocturnal activity ranking 1-5		3						Blade pitch	λ	45	degrees
Nocturnal activity factor	f_{night}	50%						Risk height range		30-180	m

normal approach	Set to 'normal approach' to use survey data on bird density
	Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A		birds/km^2	0.0091	0.0001	0.0064	0.0001	0.0005	0	0	0	0.0008	0.0104	0.1146	0	0.0118
Proportion at rotor risk height	Q_{ER}	55.06%														
At latitude 55.4		**Daylight hours per month**		241.3	268.7	365.8	423.0	501.2	520.2	522.0	465.7	384.2	326.3	252.8	223.8	4494.9
		Nighttime hours per month		502.7	403.3	378.2	297.0	242.8	199.8	222.0	278.3	335.8	417.7	467.2	520.2	4265.1

Stage B					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	13															
Rotor radius	R	75	m														
		Total rotor frontal ar		229729													
Nocturnal activity factor	f_{night}	50%															
Bird flight speed	v	13.7	m s^{-1}														
		Projected number of rotor transits			186.5	2.0	147.7	2.4	12.9	0.0	0.0	0.0	18.4	231.5	2318.4	0.0	**2920**

Stage C								
No of blades	b	3			Bird length	l	0.28	m
Rotation speed	Ω	8.75	rpm		Wingspan	w	0.72	m
Rotor radius	R	75	m		Bird flight speed	v	13.7	m s^{-1}
Max blade width	C	4.3	m		Flight type		flapping	
Pitch	λ	45	degrees	% of flights upwind/downwind			50%	50%
Blade profile		see Blade profile sheet						
		Single transit risk	**upwind**	8.83%				
			downwind	4.29%				
			weighted mean	**6.56%**				

Stage D			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}		85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance													year total
			10.39	0.11	8.23	0.13	0.72	0.00	0.00	0.00	1.02	12.90	129.24	0.00	**163**

Stage E															
Allow for large array correction?		No													
Width of windfarm	w	3.9	km												
			large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
				Collision rates allowing for avoidance												
Avoidance rates modelled		95.00%	100.00%	0.52	0.01	0.41	0.01	0.04	0.00	0.00	0.00	0.05	0.65	6.46	0.00	**8.1**
		98.00%	100.00%	0.21	0.00	0.16	0.00	0.01	0.00	0.00	0.00	0.02	0.26	2.58	0.00	**3.3**
		99.00%	100.00%	0.10	0.00	0.08	0.00	0.01	0.00	0.00	0.00	0.01	0.13	1.29	0.00	**1.6**
		99.50%	100.00%	0.05	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.65	0.00	**0.8**

Golden Plover – Turbine model 3

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

Bird data		Value	Units
Species name		Golden Plover	
Bird length	L	0.28	m
Wingspan	W	0.72	m
Bird flight speed	v	13.7	m s^{-1}
Flight type, flapping or gliding		flapping	
% of flights upwind/downwind		50%	50%
Nocturnal activity ranking 1-5		3	
Nocturnal activity factor	f_{night}	50%	

Windfarm data		Value	Units
Site name		Hare Hill	
Latitude		55.35	degrees
No of turbines	T	13	
Width of windfarm	w	3.9	km

Turbine data		Value	Units
Model		Model 3 V162	
Hub height		119	m
Rotor radius	R	81	m
No of blades	b	3	
Rotation speed	Ω	8.2	rpm
Max blade width	C	4.3	m
Blade pitch	λ	45	degrees
Risk height range		38-200	m

normal approach	Set to 'normal approach' to use survey data on bird density
	Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R		birds/km^2	0.0091	0.0001	0.0064	0.0001	0.0005	0	0	0	0.0008	0.0104	0.1146	0	0.0118
Proportion at rotor risk height	Q_{RR}	60.88%														
At latitude 55.4		Daylight hours per month		241.3	268.7	365.8	423.0	501.2	520.2	522.0	465.7	384.2	326.3	252.8	223.8	4494.9
		Nighttime hours per month		502.7	403.3	378.2	297.0	242.8	199.8	222.0	278.3	335.8	417.7	467.2	520.2	4265.1

Stage B																
No of turbines	T	13														
Rotor radius	R	81	m													
		Total rotor frontal ar	267956													
Nocturnal activity factor	f_{night}	50%														
Bird flight speed	v	13.7	m s^{-1}	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
		Projected number of rotor transits		222.7	2.3	176.4	2.8	15.5	0.0	0.0	0.0	21.9	276.4	2768.5	0.0	**3486**

Stage C							
No of blades	b	3		Bird length	l	0.28	m
Rotation speed	Ω	8.2	rpm	Wingspan	w	0.72	m
Rotor radius	R	81	m	Bird flight speed	v	13.7	m s^{-1}
Max blade width	C	4.3	m	Flight type		flapping	
Pitch	λ	45	degrees	% of flights upwind/downwind		50%	50%
Blade profile		see Blade profile sheet					
		Single transit risk	upwind	8.24%			
			downwind	4.03%			
			weighted mean	**6.14%**			

Stage D		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		11.61	0.12	9.20	0.15	0.81	0.00	0.00	0.00	1.14	14.42	144.38	0.00	**182**

Stage E																
Allow for large array correction?		No														
Width of windfarm	w	3.9	km													
			large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
				Collision rates allowing for avoidance												
Avoidance rates modelled	95.00%	100.00%		0.58	0.01	0.46	0.01	0.04	0.00	0.00	0.00	0.06	0.72	7.22	0.00	**9.1**
	98.00%	100.00%		0.23	0.00	0.18	0.00	0.02	0.00	0.00	0.00	0.02	0.29	2.89	0.00	**3.6**
	99.00%	100.00%		0.12	0.00	0.09	0.00	0.01	0.00	0.00	0.00	0.01	0.14	1.44	0.00	**1.8**
	99.50%	100.00%		0.06	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.72	0.00	**0.9**

Red Kite – Turbine model 1

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

Bird data		Value	Units
Species name		Red Kite	
Bird length	L	0.63	m
Wingspan	W	1.85	m
Bird flight speed	v	12	m s^{-1}
Flight type, flapping or gliding		flapping	
% of flights upwind/downwind		50%	50%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

Windfarm data		Value	Units
Site name		Hare Hill	
Latitude		55.35	degrees
No of turbines	T	13	
Width of windfarm	w	3.9	km

Turbine data		Value	Units
Model		Model 1 V136	
Hub height		82	m
Rotor radius	R	68	m
No of blades	b	3	
Rotation speed	Ω	8.75	rpm
Max blade width	C	4.2	m
Blade pitch	λ	45	degrees
Risk height range		14-150	m

normal approach	Set to 'normal approach' to use survey data on bird density
	Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R		birds/km^2	0.0007	0.0007	0.0007	0.0001	0.0001	0.0001	0.0001	0.0001	0.0007	0.0007	0.0007	0.0007	0.0005
Proportion at rotor risk height	Q_{zR}	65.12%														
At latitude 55.4		Daylight hours per month		241.3	268.7	365.8	423.0	501.2	520.2	522.0	465.7	384.2	326.3	252.8	223.8	4494.9
		Nighttime hours per month		502.7	403.3	378.2	297.0	242.8	199.8	222.0	278.3	335.8	417.7	467.2	520.2	4265.1

Stage B																
No of turbines	T	13														
Rotor radius	R	68	m													
		Total rotor frontal ar	188847													
Nocturnal activity factor	f_{night}	0%														
Bird flight speed	v	12	m s^{-1}	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
		Projected number of rotor transits		6.6	7.3	10.0	1.7	2.0	2.0	2.0	1.8	10.5	8.9	6.9	6.1	**66**

Stage C								
No of blades	b	3		Bird length	l	0.63	m	
Rotation speed	Ω	8.75	rpm	Wingspan	w	1.85	m	
Rotor radius	R	68	m	Bird flight speed	v	12	m s^{-1}	
Max blade width	C	4.2	m	Flight type		flapping		
Pitch	λ	45	degrees	% of flights upwind/downwind		50%	50%	
Blade profile		see Blade profile sheet						
		Single transit risk	upwind	11.48%				
			downwind	6.57%				
			weighted mean	**9.03%**				

Stage D		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.51	0.56	0.77	0.13	0.15	0.16	0.16	0.14	0.81	0.68	0.53	0.47	**5**

Stage E																
Allow for large array correction?		No														
Width of windfarm	w	3.9	km													
			large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
				Collision rates allowing for avoidance												
Avoidance rates modelled		95.00%	100.00%	0.03	0.03	0.04	0.01	0.01	0.01	0.01	0.01	0.04	0.03	0.03	0.02	**0.3**
		98.00%	100.00%	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.01	**0.1**
		99.00%	100.00%	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	**0.1**
		99.50%	100.00%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

Red Kite – Turbine model 2

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

Bird data		Value	Units
Species name		Red Kite	
Bird length	L	0.63	m
Wingspan	W	1.85	m
Bird flight speed	v	12	m s^{-1}
Flight type, flapping or gliding		flapping	
% of flights upwind/downwind		50%	50%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

Windfarm data		Value	Units
Site name		Hare Hill	
Latitude		55.35	degrees
No of turbines	T	13	
Width of windfarm	w	3.9	km

Turbine data		Value	Units
Model		Model 2 V162	
Hub height		105	m
Rotor radius	R	75	m
No of blades	b	3	
Rotation speed	Ω	8.75	rpm
Max blade width	C	4.3	m
Blade pitch	λ	45	degrees
Risk height range		30-180	m

normal approach	Set to 'normal approach' to use survey data on bird density
	Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_a		birds/km^2	0.0007	0.0007	0.0007	0.0001	0.0001	0.0001	0.0001	0.0001	0.0007	0.0007	0.0007	0.0007	0.0005
Proportion at rotor risk height	Q_{ar}	60.00%														
At latitude 55.4		Daylight hours per month		241.3	268.7	365.8	423.0	501.2	520.2	522.0	465.7	384.2	326.3	252.8	223.8	4494.9
		Nighttime hours per month		502.7	403.3	378.2	297.0	242.8	199.8	222.0	278.3	335.8	417.7	467.2	520.2	4265.1

Stage B																
No of turbines	T	13														
Rotor radius	R	75	m													
		Total rotor frontal ar	229729													
Nocturnal activity factor	f_{night}	0%														
Bird flight speed	v	12	m s^{-1}	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
		Projected number of rotor transits		6.7	7.5	10.2	1.7	2.0	2.1	2.1	1.8	10.7	9.1	7.0	6.2	**67**

Stage C								
No of blades	b	3		Bird length	l	0.63	m	
Rotation speed	Ω	8.75	rpm	Wingspan	w	1.85	m	
Rotor radius	R	75	m	Bird flight speed	v	12	m s^{-1}	
Max blade width	C	4.3	m	Flight type		flapping		
Pitch	λ	45	degrees	% of flights upwind/downwind		50%	50%	
Blade profile		see Blade profile sheet						
		Single transit risk	upwind	11.31%				
			downwind	6.70%				
			weighted mean	**9.00%**				

Stage D																
Proportion of time operational	Q_{op}			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
				85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
				Collision rates before avoidance												year total
				0.51	0.57	0.78	0.13	0.15	0.16	0.16	0.14	0.82	0.69	0.54	0.48	**5**

Stage E																
Allow for large array correction?		No														
Width of windfarm	w	3.9	km													
			large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
				Collision rates allowing for avoidance												
Avoidance rates modelled		95.00%	100.00%	0.03	0.03	0.04	0.01	0.01	0.01	0.01	0.01	0.04	0.03	0.03	0.02	**0.3**
		98.00%	100.00%	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.01	**0.1**
		99.00%	100.00%	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	**0.1**
		99.50%	100.00%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

Red Kite – Turbine Model 3

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

		Value	Units			Value	Units			Value	Units
Bird data				**Windfarm data**				**Turbine data**			
Species name		**Red Kite**		Site name		**Hare Hill**		Model		**Model 3 V162**	
Bird length	L	0.63	m	Latitude		55.35	degrees	Hub height		119	m
Wingspan	W	1.85	m	No of turbines	T	13		Rotor radius	R	81	m
Bird flight speed	v	12	m s^{-1}	Width of windfarm	w	3.9	km	No of blades	b	3	
Flight type, flapping or gliding		flapping						Rotation speed	Ω	8.2	rpm
% of flights upwind/downwind		50%	50%					Max blade width	C	4.3	m
Nocturnal activity ranking 1-5		1						Blade pitch	λ	45	degrees
Nocturnal activity factor	f_{night}	0%						Risk height range		38-200	m

normal approach	Set to 'normal approach' to use survey data on bird density
	Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A		birds/km^2	0.0007	0.0007	0.0007	0.0001	0.0001	0.0001	0.0001	0.0001	0.0007	0.0007	0.0007	0.0007	0.0005
Proportion at rotor risk height	Q_{ER}	59.04%														
At latitude 55.4		**Daylight hours per month**		241.3	268.7	365.8	423.0	501.2	520.2	522.0	465.7	384.2	326.3	252.8	223.8	4494.9
		Nighttime hours per month		502.7	403.3	378.2	297.0	242.8	199.8	222.0	278.3	335.8	417.7	467.2	520.2	4265.1

Stage B					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	13															
Rotor radius	R	81	m														
		Total rotor frontal ar		267956													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	12	m s^{-1}														
		Projected number of rotor transits			7.1	7.9	10.8	1.8	2.1	2.2	2.2	2.0	11.3	9.6	7.5	6.6	**71**

Stage C								
No of blades	b	3			Bird length	l	0.63	m
Rotation speed	Ω	8.2	rpm		Wingspan	w	1.85	m
Rotor radius	R	81	m		Bird flight speed	v	12	m s^{-1}
Max blade width	C	4.3	m		Flight type		flapping	
Pitch	λ	45	degrees	% of flights upwind/downwind			50%	50%
Blade profile		see Blade profile sheet						
		Single transit risk	**upwind**	10.55%				
			downwind	6.28%				
			weighted mean	**8.42%**				

Stage D			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}		85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance													year total
			0.51	0.57	0.77	0.13	0.15	0.16	0.16	0.14	0.81	0.69	0.53	0.47	**5**

Stage E																
Allow for large array correction?		No														
Width of windfarm	w	3.9	km													
			large array correction		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
				Collision rates allowing for avoidance													
Avoidance rates modelled		95.00%	100.00%		0.03	0.03	0.04	0.01	0.01	0.01	0.01	0.01	0.04	0.03	0.03	0.02	**0.3**
		98.00%	100.00%		0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.01	**0.1**
		99.00%	100.00%		0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	**0.1**
		99.50%	100.00%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**