Pennant Walters

GLANLLYNFI GARTH WIND FARM

Draft Environmental Statement

Appendix 9B - Bird Collision Risk Modelling Report

JULY 2026

PUBLIC

Pennant Walters

GLANLLYNFI GARTH WIND FARM

Bird Collision Risk Modelling Report

TYPE OF DOCUMENT (VERSION) PUBLIC

PROJECT NO. UK0039180.3591

OUR REF. NO. CRM

DATE: JULY 2026

WSP

WSP in the UK
Kings Orchard
1 Queens Street
Bristol

Phone: +36 30 846 91 52

WSP.com

CONTENTS

TABLES

APPENDICES

1 INTRODUCTION

1.1.1. This Technical Note was commissioned by Pennant Walters (hereafter, the 'Applicant') and has been prepared to accompany **Chapter 9: Ornithology** of the Glanllynfi Garth Wind Farm (hereafter, the 'Proposed Development') Environmental Statement (ES).

1.1.2. The Proposed Development comprises two neighbouring land parcels, the Northern Array (Pwll yr Lwrch) and Southern Array (Moel Cynhordy), with associated forestry access tracks from the public highway to each array. These are collectively referred to as the 'Development Site'.

1.2 THE COLLISION RISK MODEL

1.2.1. The risk of birds colliding with turbine rotors has been assessed using a model ('Band model') developed by William Band, which estimates the number of bird collisions with the turbine rotors during a specified time period[1,2,3]. The model requires input data based on species biometrics and flight characteristics, turbine specification and flights observed within the Development Site. The amount of time that a species may be active within the Development Site in any given season is also required for the model and must therefore be estimated.

1.2.2. 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.

1.2.3. An updated guidance released by NatureScot in 2024[2,3] builds on the original 'Band model' and standardises all stages of these Collision Risk Model (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 wind farm or its turbines, either because they have been displaced from the site, take evasive action or are attracted to the wind farm, e.g. in response to changing habitats.

[1] Band, W., Madders, M. & Whitfield, D.P. (2007). Developing field and analytical methods to assess avian collision risk at wind farms. In: Birds and Wind Farms: Risk Assessment and Mitigation. de Lucas, M., Janss, G., and Ferrer, M. (eds). Lynx Edicions, Barcelona.

[2] Band, W. (2024). Using a collision risk model to assess bird collision risks for onshore wind farms. NatureScot Research Report 909.

[3] NatureScot (2024). Guidance on using an updated collision risk model to assess bird collision risk at onshore wind farms. NatureScot guidance note.

1.2.4. The CRM analysis in this report uses the updated NatureScot guidance and CRM spreadsheet for its calculations.

1.2.5. 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 wind farm.

1.3 SURVEY DESIGN (OCTOBER 2024 TO MARCH 2026)

1.3.1. WSP has undertaken vantage point (VP) surveys across the Northern and Southern Arrays since October 2024 to assess baseline bird biodiversity, including bird density and flight activity.

1.3.2. During the first survey year (October 2024 to September 2025), two VPs were used for each array. Survey effort for the non-breeding season (October to March) and breeding season (April to September) is summarised in **Table 1-1** and **Table 1-2** respectively.

Table 1-1 – Hours surveyed during non-breeding season 2024/2025 surveys

	VP	Oct	Nov	Dec	Jan	Feb	Mar	Total
Northern Array - 2024/2025 Non-Breeding Season	VP1	6	0	6	12	6	6	**36**
	VP2	3.5	2	3	15	9	5	**37.5**
Southern Array - 2024/2025 Non-Breeding Season	VP1	6	0	3	15	6	6	**36**
	VP2	0	8	0	15	3	12	**38**

Table 1-2 – Hours surveyed during breeding season 2025 surveys

	VP	Apr	May	Jun	Jul	Aug	Sep	Total
Northern Array - 2025 Breeding Season	VP1	0	12	6	6	6	6	**36**
	VP2	0	12	6	6	6	6	**36**
Southern Array - 2025 Breeding Season	VP1	0	12	6	6	6	6	**36**
	VP2	0	12	6	6	6	6	**36**

1.3.3. For the second survey year (October 2025 to September 2026), Northern Array VP1 and Southern Array VP2 were replaced with new VP locations in response to the updated turbine layout across the two arrays. The second-year VP survey effort for the 2025–2026 non-breeding season is summarised in **Table 1-3**. Breeding season surveys for 2026 are ongoing, and the data will be analysed for CRM once the surveys are complete, with the results presented in the final ES document.

Table 1-3 – Hours surveyed during non-breeding season 2025/2026 surveys

	VP	Oct	Nov	Dec	Jan	Feb	Mar	Total
Norther Array - 2025/2026 Non-Breeding Season	VP1*	6	6	6	3	9	6	**36**
	VP2	6	6	6	4.5	5	8.5	**36**
Southern Array - 2025/2026 Non-Breeding Season	VP1	6	6	6	1.5	11	5.5	**36**
	VP2*	0	12	6	6	3	9	**36**

* Modified VP location

1.4 BIRD SPECIES SELECTED FOR CRM

1.4.1. Eight species were observed flying at Potential Collision Height (PCH) (defined further in **paragraph 2.4.4**) within the Development Site. For CRM, only species of conservation concern with at least five flights recorded at PCH across the entire survey effort were considered. Based on this, five species were taken forward for the assessment, as follows:

- Red kite *Milvus milvus*;
- Kestrel *Falco tinnunculus*;
- Eurasian goshawk *Accipiter gentilis*;
- Golden plover *Pluvialis apricaria*; and
- Peregrine *Falco peregrinus*.

1.4.2. Where survey flightlines for the above species extended beyond the Development Site boundary, they were clipped to the boundary, and the associated flight time was reduced proportionally based on the clipped flightline length. This adjustment ensures that CRM calculations are based only on flight activity within the Development Site, avoiding overestimation of time spent at collision risk.

2 CRM METHODOLOGY

2.1 WIND FARM SPECIFICS

2.1.1. The Proposed Development would consist of eight turbines of model Vestas V150 4.2MW. Turbine details as used for the assessment are given in **Table 2-1** below.

Table 2-1 – Turbine specifications

Parameter	Model – Vestas V150 4.2MW
Number of turbines	8 (4 in each array)
Number of blades	3
Hub height (m)	105
Rotor radius (m)	75
Maximum height to blade tip (m)	180
Minimum height to blade tip (m)	30
PCH (m)	30-180
Mean rotor speed (rpm)	7.65
Mean pitch (degrees)	45
Maximum chord (m)	4.2

2.2 BIRD BIOMETRICS

2.2.1. Morphometric measurements for bird species (**Table 2-2**) were taken from credible peer-reviewed sources[4,5,6,7]. Flight type for each species was decided based on expert judgement.

Table 2-2 – Bird biometrics

Species	Bird length (m)	Wingspan length (m)	Flight speed (m/s)	Flight type
Red kite	0.66	1.85	15.0	Gliding
Common kestrel	0.35	0.75	8.0	Flapping

[4] NatureScot (2024). Wind farm impacts on birds – Flight speeds and biometrics for Collision Risk Modelling. NatureScot guidance note.
[5] BTO (2024). Bird facts https://www.bto.org/about-birds/birdfacts. Accessed February 2025.
[6] Alerstam T., Rosén M., Bäckman J., Ericson P.G.P. & Hellgren, O. (2007). Flight Speeds among Bird Species: Allometric and Phylogenetic Effects. PLoS Biol 5(8): e197. DOI:10.1371/journal.pbio.0050197.
[7] Bruderer, B., & Boldt, A. (2001). Flight characteristics of birds: I. Radar measurements of speeds. Ibis, 143(2), 178-204.

Species	Bird length (m)	Wingspan length (m)	Flight speed (m/s)	Flight type
Eurasian goshawk	0.54	1.12	10.1	Gliding
Golden plover	0.28	0.72	15.5	Flapping
Peregrine falcon	0.47	1.03	12.3	Flapping

2.3 DIRECTIONAL OR NON-DIRECTIONAL MODEL

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

2.3.2. 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. The directional or 'birds on migration' approach requires input of the number of birds that cross a baseline perpendicular to the main flight direction.

2.3.3. The modelling method for birds with non-directional or 'normal' flight activity, such as most 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.

2.3.4. The flight activity surveys indicated non-directional flight activity for all species taken forward for CRM. Hence, the non-directional or 'normal' approach to modelling was used.

2.4 STAGE A: FLIGHT ACTIVITY

NON-DIRECTIONAL FLIGHT: AREAL BIRD DENSITY

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

2.4.2. Flying time was divided by the watch duration, in seconds, and the area surveyed, in km^2, to calculate the average density of birds in flight per square kilometre. For each species, this was calculated as an average seasonal areal bird density and entered in the CRM spreadsheet as follows:

- Non-breeding season density value for October to March; and
- Breeding season density value for April to September.

2.4.3. **Table 2-3** below shows the average bird density for each species, as entered in the CRM spreadsheet.

Table 2-3 – Average seasonal areal bird density for each species

Species	Non-breeding season (Oct to Mar)	Breeding season (Apr to Sept)
Red kite	0.0321	0.0189
Common kestrel	0.0058	0.0081

Species	Non-breeding season (Oct to Mar)	Breeding season (Apr to Sept)
Eurasian goshawk	0.0021	0.0007
Golden plover	0.0494	0.0145
Peregrine falcon	0.0006	0.0000

PROPORTION FLYING AT RISK HEIGHT

2.4.4. For the purpose of CRM, PCH is calculated by using the lowest blade sweep height and highest blade sweep height for the turbine model. For the selected turbine model (**Table 2-1**), PCH has been calculated as 30 - 180m.

2.4.5. The flight activity surveys recorded the flight heights of birds using height bands of 0 – 10m, 10 – 50m, 50 – 150m, and >150m. The proportion of birds flying at PCH for the turbine model was calculated and entered in the CRM spreadsheet for each species.

WINDFARM LATITUDE

2.4.6. The windfarm latitude is 55°32′. This is expressed in decimals as 55.32 in the CRM spreadsheet to determine the total daylight hours for which the previously calculated bird densities may be expected to persist.

NOCTURNAL ACTIVITY FACTOR

2.4.7. No night-time surveys of the Development Site were conducted. Instead, likely levels of nocturnal activity for all species were determined through expert assessment and literature review. Nocturnal activity is entered in the spreadsheet as a ranking on the scale of 1 – 5, from 1 = hardly any night activity to 5 = as active at night as by day.

2.4.8. 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[8,9,10]. Accordingly, this has been averaged out to a score of three to be used in the CRM spreadsheet.

2.4.9. Levels of nocturnal activity by peregrine falcons are believed to be between 10-100% of daytime activity depending on the season/activity of the birds[11,12,13]. Accordingly, this has been averaged out to a score of three to be used in the CRM spreadsheet.

---

[8] Gillings, S. (2003). Diurnal and nocturnal ecology of Golden Plovers *Pluvialis apricaria* and Lapwings *Vanellus vanellus* wintering on arable farmland (Doctoral dissertation, University of East Anglia).

[9] Stodola, K. W., et al. (2014). Stopover ecology of American Golden-Plover (*Pluvialis dominica*) in Midwestern agricultural fields. The Condor: Ornithological Applications 116(2), 162-172.

[10] Whittingham, M.J., et al. (2001). Time budgets and foraging or breeding golden plover *Pluvialis apricaria*. Journal of Applied Ecology, 37(4), 632-646.

[11] Rejt, Ł. (2001). Feeding activity and seasonal changes in prey composition of urban Peregrine Falcons *Falco peregrinus*. Acta Ornithologica, 36(2), 165-169.

[12] Drewitt, E. J., & Dixon, N. (2008). Diet and prey selection of urban-dwelling Peregrine Falcons in southwest England. British Birds, 101(2), 58.

[13] Time, B. E. (2016). Hunting activity by urban Peregrine Falcons (*Falco peregrinus*) during autumn and winter in south-west Norway. Ornis Norvegica, 39, 39-44.

2.4.10. As nocturnal activities of all other species are believed to be low and therefore, a score of one has therefore been attributed in the spreadsheet.

2.5 STAGE B: ESTIMATING NUMBER OF FLIGHTS THROUGH ROTORS

2.5.1. The total number of bird transits expected through rotors is proportional to the number and cross-sectional area of the rotors and to density of birds in the airspace at risk height (given in **Table 2-3**). Additional information is required on flight speed of the species being observed.

OUTPUT FROM STAGE B

2.5.2. 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 is given in **Table 2-4** below.

Table 2-4 – Output from Stage B

	Species	Vestas V150 4.2MW
Total rotor frontal area (m^2)		141,372
Projected number of rotor transits per annum (non-directional flights)	Red kite	2,235
	Common kestrel	327
	Eurasian goshawk	107
	Golden plover	8,271
	Peregrine falcon	36

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

2.6 STAGE C: PROBABILITY OF COLLISION FOR A SINGLE ROTOR TRANSIT

2.6.1. This stage uses information on the size and speed of the turbines and physical details on the size, speed and flight type of the bird to compute the risk of collision for a bird flying through a rotating rotor.

2.6.2. The orientation of the wind turbines is assumed to be distributed across many directions, according to the wind rose for the Development Site. It has been assumed that flights of all species are equally split between upwind and downwind.

OUTPUT FROM STAGE C

2.6.3. 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 **Table 2-5** below.

Table 2-5 – Output from Stage C - Single transit risk

Species	Single transit risk upwind (%)	Single transit risk downwind (%)	Single transit risk weighted mean (%)
Red kite	8.57	4.30	6.44
Common kestrel	11.87	7.24	9.55
Eurasian goshawk	10.64	6.12	8.38
Golden plover	7.35	3.12	5.24
Peregrine falcon	9.13	4.72	6.92

2.7 STAGE D: MULTIPLYING TO YIELD EXPECTED COLLISIONS PER YEAR

2.7.1. 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.

2.7.2. 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).

OUTPUT FROM STAGE D

2.7.3. The output from Stage D, given in **Table 2-6**, is the expected number of collisions assuming no avoidance by birds.

Table 2-6 – Output from Stage D - Expected collisions per annum assuming no avoidance

Species	Expected collisions per annum (no avoidance)
Red kite	122
Common kestrel	27
Eurasian goshawk	8
Golden plover	368
Peregrine falcon	2

2.8 STAGE E: APPLYING THE AVOIDANCE RATE

AVOIDANCE RATES AND ATTRACTION

2.8.1. The avoidance rates for all species are based on the current NatureScot guidance[14]. Collision risks have been calculated for avoidance rates of 95%, 98%, 99%, and 99.5%. However, the central result is determined according to the guidance for each species.

LARGE ARRAY CORRECTION

2.8.2. The 'Large array correction factor' sheet calculates the correction factor which should be applied to take account of any depletion of bird density because of collisions. The setting 'Allow for large array correction?' in the Collision risk sheet was set to 'No' as it is generally applied to larger scale wind farms and to keep the calculation simple.

OUTPUT FROM STAGE E: CRM RESULTS

2.8.3. The results of the CRM for all modelled species are summarised in **Table 2-7**, with the full model calculations provided in Annex B. For the purposes of **Table 2-7**, the operational life of the wind farm is assumed to be 30 years.

Table 2-7 – CRM results - Potential collisions per annum

Species	Avoidance rate	Modelled collisions per year*	Modelled collisions per 30 years (approximate)*
Red kite	99%	1.2	36
Common kestrel	95%	1.3	39
Eurasian goshawk	98%	0.2	6
Golden plover	98%	7.4	222
Peregrine falcon	98%	0.0	0

*All estimates are rounded to the nearest decimal place

2.9 STAGE F: EXPRESSING UNCERTAINTY

2.9.1. 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.

2.9.2. 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. The errors are assessed as follows:

- Survey effort (E1): NatureScot[15] recommends 72 hours of continuous survey effort over two years. The current assessment uses 1.5 years of survey data (see Section 1.3). Taking this into account, an uncertainty margin of ±15% has been used based on professional judgment;

[14] NatureScot. (2018). Avoidance Rates for the onshore NatureScot Wind Farm Collision Risk Model. NatureScot guidance. September 2018, v2.
[15] NatureScot (2025). Recommended bird survey methods to inform impact assessment of onshore windfarms.

therefore, E1 = 0.15 for all species. This error will be zero in subsequent CRM calculations that use the full two years of data.

- Bird density (E2) for species following non-directional flight pattern: Bird density measures showed variability between months. Error is estimated by calculating 1.96 * annual Standard Deviation (SD) from the mean[16]. The annual SD is obtained by taking the square root of the sum of squares of seasonal SDs. The error estimate E2 for all species is given below in Table 2-8.

Table 2-8 – Error E2 estimate

Species	Annual Standard Deviation (SD)	Standard error (E2) = SD* 1.96
Red kite	0.0209	0.0410
Common kestrel	0.0123	0.0241
Eurasian goshawk	0.0027	0.0053
Golden plover	0.1148	0.2250
Peregrine falcon	0.0008	0.0017

- Nocturnal flight activity (E3): Nocturnal activity for red kite, common kestrel and Eurasian goshawk has been assumed as 0% of the daytime activity, but as a precaution is judged to be in the range of 0-10%. This results in an uncertainty of ± 5%. Therefore E3 = 0.05 for these three species.

  For golden plover, nocturnal activity has been judged it might be in the range of 25-100%. This results in an uncertainty of ± 37.5%. Therefore, E3 = 0.375 for golden plover.

  For peregrine falcon, nocturnal activity has been judged it might be in the range of 10-100%. This results in an uncertainty of ± 45%. Therefore, E3 = 0.45 for peregrine falcon.

- Proportion at risk height (E4): If the visual estimate is out by ±5m, it is estimated that the proportion of birds flying above or below the PCH boundary would vary by around ±25%. Therefore E4 = 0.25 for all species.

- Collision model (E5): The model involves a number of simplifications, such as shape of bird, use of average pitch, etc. Based on the NatureScot guidelines, an uncertainty of ±20% is considered a reasonable estimate. Therefore, E6 = 0.20 for all species.

2.9.3. All these errors (E1 to E5) 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.

$$E = \sqrt{\{(E1)^2 + (E2)^2 + E3^2 + E4^2 + E5^2)\}}$$

calculates combined uncertainty. Combined uncertainty for each species as shown in **Table 2-9** below.

[16] 1.96 is the standard multiplier used when calculating a 95% confidence interval.

Table 2-9 – Combined error estimate (%)

Species	Error (%)
Red kite	36%
Common kestrel	36%
Eurasian goshawk	36%
Golden plover	56%
Peregrine falcon	57%

3 CRM RESULTS

3.1.1. The best estimate of annual collision risk, with considering avoidance rates outlined in **Section 2.8** and uncertainties outlined in **Section 2.9**, is given below in **Table 3-1** for all species for which collision risk was modelled.

Table 3-1 – Best estimate of annual collision risk

Species	Avoidance rate (%)	Annual collision estimate	Best estimate range
Red kite	99%	1.2 ± 37%	0.8 – 1.6
Common kestrel	95%	1.3 ± 36%	0.8 – 1.8
Eurasian goshawk	98%	0.2 ± 36%	0.1 – 0.3
Golden plover	98%	7.4 ± 57%	3.2 – 11.6
Peregrine falcon	98%	0 ± 57%	0*

*zero mortality predicted with low confidence

3.1.2. The model predicts zero mortality for peregrine falcon, but the error percentage indicate that the result should be seen as an approximate value rather than an absolute zero. A small amount of undetected mortality may still be possible.

3.1.3. The model predicts the highest mortality for golden plover, followed by common kestrel and red kite. The CRM calculations will be updated for the final ES, assuming the full two-year survey dataset is available, and the results reviewed to confirm whether the predicted collision risks require any species-specific mitigation or monitoring.

Annex A

CRM CALCULATIONS

RED KITE – NON-DIRECTIONAL APPROACH

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	Windfarm data		Value	Units	Turbine data		Value	Units
Species name		**Red kite**		Site name		**Glanllynfi Garth**		Model		**stas V150 4.2MW**	
Bird length	L	0.66	m	Latitude		55.32	degrees	Hub height		105	m
Wingspan	W	1.85	m	No of turbines	T	8		Rotor radius	R	75	m
Bird flight speed	v	15	m s^{-1}	Width of windfarm	w		km	No of blades	b	3	
Flight type, flapping or gliding		gliding						Rotation speed	Ω	7.65	rpm
% of flights upwind/downwind		50%	50%					Max blade width	C	4.2	m
Nocturnal activity ranking 1-5		1						Blade pitch	λ	45	degrees
Nocturnal activity factor	f_{night}	0%						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	0.0321	0.0321	0.0321	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0321	0.0321	0.0321	0.0255
Proportion at rotor risk height	Q_{2R}	41.00%														
At latitude 55.3		**Daylight hours per month**		241.5	268.8	365.8	422.9	501.0	520.0	521.8	465.6	384.1	326.4	253.0	224.0	4494.8
		Nighttime hours per month		502.5	403.2	378.2	297.1	243.0	200.0	222.2	278.4	335.9	417.6	467.0	520.0	4265.2

Stage B

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	8														
Rotor radius	R	75	m													
		Total rotor frontal ar	141372													
Nocturnal activity factor	f_{night}	0%														
Bird flight speed	v	15	m s^{-1}													
		Projected number of rotor transits		161.8	180.0	245.0	166.8	197.6	205.1	205.8	183.6	151.5	218.6	169.4	150.0	**2235**

Stage C

No of blades	b	3		Bird length	l	0.66	m
Rotation speed	Ω	7.65	rpm	Wingspan	w	1.85	m
Rotor radius	R	75	m	Bird flight speed	v	15	m s^{-1}
Max blade width	C	4.2	m	Flight type		gliding	
Pitch	λ	45	degrees	% of flights upwind/downwind		50%	50%
Blade profile		see Blade profile sheet					
		Single transit risk	**upwind**	8.57%			
			downwind	4.30%			
			weighted mean	**6.44%**			

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
		8.85	9.85	13.41	9.13	10.81	11.22	11.26	10.05	8.29	11.96	9.27	8.21	**122**

Stage E

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
Allow for large array correction?		No														
Width of windfarm	w	0	km													
			large array correction	**Collision rates allowing for avoidance**												
Avoidance rates modelled		95.00%	100.00%	0.44	0.49	0.67	0.46	0.54	0.56	0.56	0.50	0.41	0.60	0.46	0.41	**6.1**
		98.00%	100.00%	0.18	0.20	0.27	0.18	0.22	0.22	0.23	0.20	0.17	0.24	0.19	0.16	**2.4**
		99.00%	100.00%	0.09	0.10	0.13	0.09	0.11	0.11	0.11	0.10	0.08	0.12	0.09	0.08	**1.2**
		99.50%	100.00%	0.04	0.05	0.07	0.05	0.05	0.06	0.06	0.05	0.04	0.06	0.05	0.04	**0.6**

COMMON KESTREL – NON-DIRECTIONAL APPROACH

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	Windfarm data		Value	Units	Turbine data		Value	Units
Species name		Common kestrel		Site name		Glanllynfi Garth		Model		Vestas V150 4.2MW	
Bird length	L	0.35	m	Latitude		55.32	degrees	Hub height		105	m
Wingspan	W	0.75	m	No of turbines	T	8		Rotor radius	R	75	m
Bird flight speed	v	8	$m\,s^{-1}$	Width of windfarm	w		km	No of blades	b	3	
Flight type, flapping or gliding		flapping						Rotation speed	Ω	7.65	rpm
% of flights upwind/downwind		50%	50%					Max blade width	C	4.2	m
Nocturnal activity ranking 1-5		1						Blade pitch	λ	45	degrees
Nocturnal activity factor	f_{night}	0%						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	0.0058	0.0058	0.0058	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	0.0058	0.0058	0.0058	0.0070
Proportion at rotor risk height	Q_{2R}	37.00%														
At latitude 55.3		Daylight hours per month		241.5	268.8	365.8	422.9	501.0	520.0	521.8	465.6	384.1	326.4	253.0	224.0	4494.8
		Nighttime hours per month		502.5	403.2	378.2	297.1	243.0	200.0	222.2	278.4	335.9	417.6	467.0	520.0	4265.2

Stage B				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	8														
Rotor radius	R	75	m													
		Total rotor frontal area m^2	141372													
Nocturnal activity factor	f_{night}	0%														
Bird flight speed	v	8	$m\,s^{-1}$													
		Projected number of rotor transits		14.1	15.7	21.3	34.4	40.8	42.3	42.4	37.9	31.2	19.0	14.7	13.0	327

Stage C							
No of blades	b	3		Bird length	l	0.35	m
Rotation speed	Ω	7.65	rpm	Wingspan	w	0.75	m
Rotor radius	R	75	m	Bird flight speed	v	8	$m\,s^{-1}$
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	11.87%			
			downwind	7.24%			
			weighted mean	9.55%			

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
		1.14	1.27	1.73	2.79	3.31	3.44	3.45	3.08	2.54	1.54	1.20	1.06	27

Stage E				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
Allow for large array correction?		No														
Width of windfarm	w	0	km													
			large array correction	Collision rates allowing for avoidance												
Avoidance rates modelled		95.00%	100.00%	0.06	0.06	0.09	0.14	0.17	0.17	0.17	0.15	0.13	0.08	0.06	0.05	1.3
		98.00%	100.00%	0.02	0.03	0.03	0.06	0.07	0.07	0.07	0.06	0.05	0.03	0.02	0.02	0.5
		99.00%	100.00%	0.01	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.01	0.01	0.3
		99.50%	100.00%	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.1

EURASIAN GOSHAWK – NON-DIRECTIONAL APPROACH

OLLISION 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

d data		Value	Units	Windfarm data		Value	Units	Turbine data		Value	Units
Species name		Eurasian goshawk		Site name		Glanllynfi Garth		Model		Vestas V150 4.2MW	
Bird length	L	0.54	m	Latitude		55.32	degrees	Hub height		105	m
Wingspan	W	1.12	m	No of turbines	T	8		Rotor radius	R	75	m
Bird flight speed	v	10.1	m s^{-1}	Width of windfarm	w		km	No of blades	b	3	
Flight type, flapping or gliding		gliding						Rotation speed	Ω	7.65	rpm
% of flights upwind/downwind		50%	50%					Max blade width	C	4.2	m
Nocturnal activity ranking 1-5		1						Blade pitch	λ	45	degrees
Nocturnal activity factor	f_{night}	0%						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

ge A				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A		birds/km^2	0.0021	0.0021	0.0021	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0021	0.0021	0.0021	0.0014
Proportion at rotor risk height	Q_{2R}	57.00%														
At latitude 55.3		Daylight hours per month		241.5	268.8	365.8	422.9	501.0	520.0	521.8	465.6	384.1	326.4	253.0	224.0	4494.8
		Nighttime hours per month		502.5	403.2	378.2	297.1	243.0	200.0	222.2	278.4	335.9	417.6	467.0	520.0	4265.2

ge B					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	8															
Rotor radius	R	75	m														
		Total rotor frontal area m^2		141372													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	10.1	m s^{-1}														
		Projected number of rotor transits			9.9	11.0	15.0	5.8	6.9	7.1	7.1	6.4	5.3	13.4	10.4	9.2	107

ge C							
No of blades	b	3		Bird length	l	0.54	m
Rotation speed	Ω	7.65	rpm	Wingspan	w	1.12	m
Rotor radius	R	75	m	Bird flight speed	v	10.1	m s^{-1}
Max blade width	C	4.2	m	Flight type		gliding	
Pitch	λ	45	degrees	% of flights upwind/downwind		50%	50%
Blade profile		see Blade profile sheet					
		Single transit risk	upwind	10.64%			
			downwind	6.12%			
			weighted mean	8.38%			

ge D		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
portion 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
		0.71	0.79	1.07	0.41	0.49	0.51	0.51	0.45	0.37	0.95	0.74	0.65	8

ge E				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
ow for large array correction?		No														
Width of windfarm	w	0	km													
			large array correction	Collision rates allowing for avoidance												
idance rates modelled		95.00%	100.00%	0.04	0.04	0.05	0.02	0.02	0.03	0.03	0.02	0.02	0.05	0.04	0.03	0.4
		98.00%	100.00%	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.2
		99.00%	100.00%	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.1
		99.50%	100.00%	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0

wsp

GOLDEN PLOVER – NON-DIRECTIONAL APPROACH

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	15.5	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		Glanllynfi Garth	
Latitude		55.32	degrees
No of turbines	T	8	
Width of windfarm	w		km

Turbine data		Value	Units
Model		stas V150 4.2MW	
Hub height		105	m
Rotor radius	R	75	m
No of blades	b	3	
Rotation speed	Ω	7.65	rpm
Max blade width	C	4.2	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/km²		0.0494	0.0494	0.0494	0.0145	0.0145	0.0145	0.0145	0.0145	0.0145	0.0494	0.0494	0.0494	0.0320
Proportion at rotor risk height	Q_{2R}	78.00%															
At latitude 55.3		Daylight hours per month			241.5	268.8	365.8	422.9	501.0	520.0	521.8	465.6	384.1	326.4	253.0	224.0	4494.8
		Nighttime hours per month			502.5	403.2	378.2	297.1	243.0	200.0	222.2	278.4	335.9	417.6	467.0	520.0	4265.2

Stage B					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	8															
Rotor radius	R	75	m														
		Total rotor frontal ar		141372													
Nocturnal activity factor	f_{night}	50%															
Bird flight speed	v	15.5	m s^{-1}														
		Projected number of rotor transits			998.5	953.2	1124.4	339.9	370.3	368.8	376.4	359.7	328.4	1084.5	985.8	980.7	**8271**

Stage C							
No of blades	b	3		Bird length	l	0.28	m
Rotation speed	Ω	7.65	rpm	Wingspan	w	0.72	m
Rotor radius	R	75	m	Bird flight speed	v	15.5	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	7.35%			
			downwind	3.12%			
			weighted mean	**5.24%**			

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
					44.45	42.43	50.05	15.13	16.48	16.42	16.76	16.01	14.62	48.28	43.88	43.66	**368**

Stage E					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
Allow for large array correction?		No															
Width of windfarm	w	0	km														
			large array correction		Collision rates allowing for avoidance												
Avoidance rates modelled		95.00%	100.00%		2.22	2.12	2.50	0.76	0.82	0.82	0.84	0.80	0.73	2.41	2.19	2.18	**18.4**
		98.00%	100.00%		0.89	0.85	1.00	0.30	0.33	0.33	0.34	0.32	0.29	0.97	0.88	0.87	**7.4**
		99.00%	100.00%		0.44	0.42	0.50	0.15	0.16	0.16	0.17	0.16	0.15	0.48	0.44	0.44	**3.7**
		99.50%	100.00%		0.22	0.21	0.25	0.08	0.08	0.08	0.08	0.08	0.07	0.24	0.22	0.22	**1.8**

PEREGRINE FALCON – NON-DIRECTIONAL APPROACH

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		Peregrine falcon	
Bird length	L	0.47	m
Wingspan	W	1.03	m
Bird flight speed	v	12.3	$m\ s^{-1}$
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		Glanllynfi Garth	
Latitude		55.32	degrees
No of turbines	T	8	
Width of windfarm	w		km

Turbine data

		Value	Units
Model		Vestas V150 4.2MW	
Hub height		105	m
Rotor radius	R	75	m
No of blades	b	3	
Rotation speed	Ω	7.65	rpm
Max blade width	C	4.2	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	0.0006	0.0006	0.0006	0	0	0	0	0	0	0.0006	0.0006	0.0006	0.0003
Proportion at rotor risk height	Q_{2R}	47.00%														
At latitude 55.3		Daylight hours per month		241.5	268.8	365.8	422.9	501.0	520.0	521.8	465.6	384.1	326.4	253.0	224.0	4494.8
		Nighttime hours per month		502.5	403.2	378.2	297.1	243.0	200.0	222.2	278.4	335.9	417.6	467.0	520.0	4265.2

Stage B

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	8														
Rotor radius	R	75	m													
		Total rotor frontal area m^2	141372													
Nocturnal activity factor	f_{night}	50%														
Bird flight speed	v	12.3	$m\ s^{-1}$													
		Projected number of rotor transits		5.8	5.5	6.5	0.0	0.0	0.0	0.0	0.0	0.0	6.3	5.7	5.7	36

Stage C

No of blades	b	3		Bird length	l	0.47	m
Rotation speed	Ω	7.65	rpm	Wingspan	w	1.03	m
Rotor radius	R	75	m	Bird flight speed	v	12.3	$m\ s^{-1}$
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	9.13%			
			downwind	4.72%			
			weighted mean	**6.92%**			

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
		0.34	0.33	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.34	0.34	**2**

Stage E

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
Allow for large array correction?		No														
Width of windfarm	w	0	km													
			large array correction	Collision rates allowing for avoidance												
Avoidance rates modelled		95.00%	100.00%	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	**0.1**
		98.00%	100.00%	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	**0.0**
		99.00%	100.00%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		99.50%	100.00%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

WSP in the UK
Kings Orchard
1 Queens Street
Bristol

wsp.com