Appendix 13

Collision Risk Modelling (CRM) Report

Derrynadarragh Wind Farm

Collision Risk Modelling

Prepared for:

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1 INTRODUCTION

Wind Farm Developments have the potential to impact bird species in a number of ways, including displacement, barrier effects, habitat effects, and collision risk. Collison risk can be assessed using Collision Risk Modelling (CRM). *Wetland Surveys Ireland Ltd.* were commissioned by *Dara Energy Limited Ltd.* to assess the collision risk for bird species at the proposed Derrynadarragh Wind Farm, Co. Offaly and Co. Kildare.

CRM is a method to estimate the number of birds likely to collide with turbines at a proposed wind farm site. This method uses vantage point data collected during field surveys to calculate the risk of collision. In this case, vantage point data collected over two years (two breeding seasons and two winter seasons) at the proposed Derrynadarragh Wind Farm site was used. The vantage point surveys were undertaken over a 24-month period from October 2021 to September 2023 at two vantage point locations (VP1 and VP2). A third vantage point, VP3, was established in April 2022 and was surveyed along with VP1 and VP2 from then until September 2023 (see Figure 1). For the purposes of the CRM, the parameters used to inform turbine characteristics are based on the Vestas V-162 model of turbine.

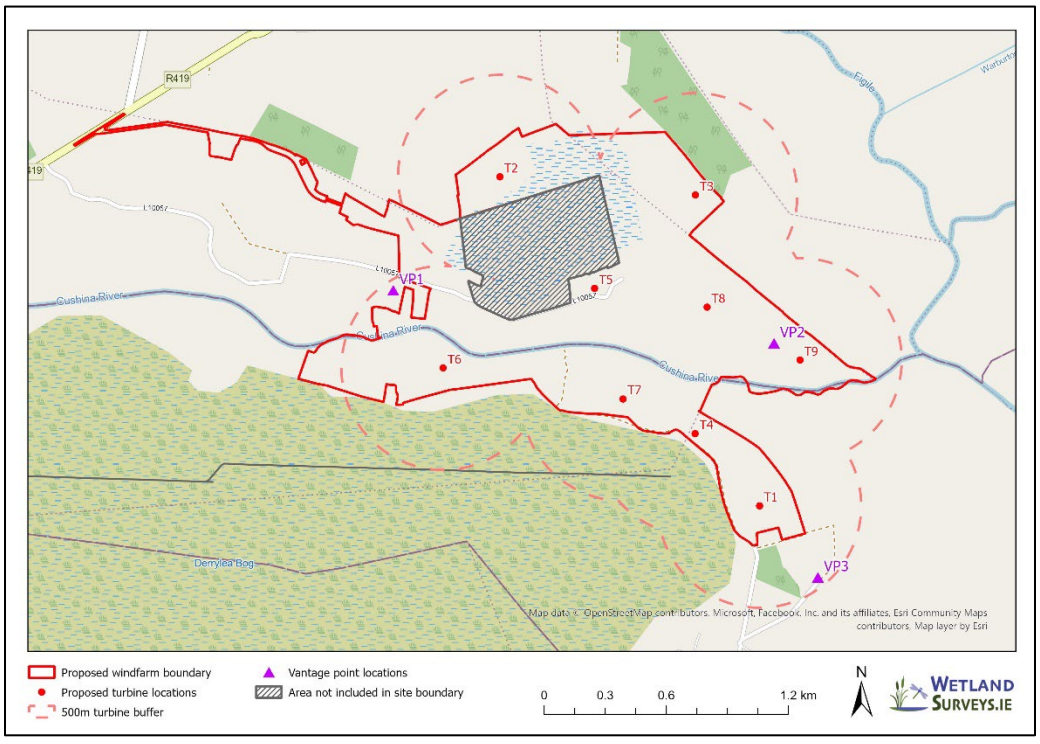

Figure 1: Layout of Derrynadarragh Windfarm showing site boundary, turbine location (No. 9), bird survey area and Vantage Point locations.

2 METHODOLOGY

The vantage point surveys were carried out following Scottish Natural Heritage guidelines (SNH 2017). CRM uses a mathematical model to estimate the number of birds of a particular species that are likely to collide with the proposed turbines. The CRM method followed here is that of Scottish Natural Heritage, which is also known as the Band Model (Band 2000, Band *et al.* 2007) as updated in 2024 (Band 2024). The excel calculation sheet available for download from the SNH website[1] was used for the current CRM and follows the updated approach of Band (2024). The Collision Risk sheet within the calculation excel requires data to be input relating to the target bird species, the wind farm, and the turbines. These data are then used within Stages A - E of the collision risk calculation, which are clearly delineated within the excel. Additional data input is also required for Stages A, D, and E within the calculation excel.

2.1 BIRD DATA

For each target species several parameters must be entered into the excel calculation sheet including bird length, wingspan, and bird flight speed. Bird biometric data were obtained from the Royal Society for the Protection of Birds[2]. It is recommended (Band 2024) that bird biometrics are obtained from standard reference works (e.g. Cramp & Simmons 1983) or from British Trust for Ornithology (BTO) Bird Facts. BTO Bird Facts[3] were consulted in February 2025, however the required biometric data was not displayed for the bird species required. This data was found on the Royal Society for the Protection of Birds website and so was used in place of BTO data (Table 1).

The calculation excel requires a nocturnal activity ranking to be selected for each target species. The ranking ranges from 1-5, where 1 represents no nocturnal activity (birds are inactive at night) and 5 represents high levels of nocturnal activity (birds are as active at night as they are during the day). A ranking of 1 was assigned to all target bird species recorded, except for Golden Plover, Snipe, and Lapwing which were given a nocturnal activity ranking of 2, which represents 25% nocturnal activity (birds are 25% as active at night as they are during the daytime).

For all target bird species it was assumed that flight speed was the same upwind and downwind. The calculations were run for both gliding and or flapping flight depending on the typical flight of each species. Where both gliding and flapping are calculated then the two values are averaged.

[1] https://www.nature.scot/doc/collision-risk-model-onshore-wind-farms-spreadsheet-2024

[2] https://www.rspb.org.uk/birds-and-wildlife

[3] https://www.bto.org/understanding-birds/welcome-birdfacts

For each target species 'normal approach' or 'birds on migration' needed to be specified in the calculation excel. All species recorded during regular vantage point watches were selected as 'normal approach'.

To account for a bird's ability to detect and avoid turbines, an avoidance factor is applied to the annual collision mortality rate. Based on empirical evidence and ongoing studies, avoidance rates for most species are typically 98-99% or higher (SNH, 2018). For Golden Plover, an avoidance rate of 99.8% was used as it was determined by Gittings (2022) to be appropriate based on a review of four onshore windfarms in the UK. The avoidance rate used for Hen Harrier was 99%, Whooper Swan was 99.5%, and Kestrel was 95%. For the other species included in this collision risk, the SNH guidance specifies a default avoidance rate of 98% (see Table 1).

Table 1: Bird biometrics and seasonal data for target species.

Species	Period	Avoidance Rates (%)	Length (m)	Wingspan (m)	Average speed (m/s)
Buzzard	All	98	0.54	1.21	11.6
Curlew	All	98	0.55	0.9	16.3
Golden Plover	Sept to Apr	99.8	0.28	0.72	17.9
Hen Harrier	All	99	0.48	1.1	9.1
Kestrel	All	95	0.34	0.76	10.1
Lapwing	All	98	0.3	0.85	12.8
Mallard	All	98	0.57	0.9	18.5
Merlin	All	98	0.28	0.56	11.2
Peregrine	All	98	0.45	1.05	12.1
Snipe	All	98	0.26	0.42	17.1
Sparrowhawk	All	98	0.33	0.63	11.3
Whooper Swan	Oct to Mar	99.5	1.5	2.2	17.3
Woodcock	All	98	0.34	0.6	17.1

Length and wingspan from RSPB. Flight speed from Alerstam et al. (2007); for Golden plover, value for grey plover was used; for woodcock, value for snipe was used

2.2 WINDFARM DATA

The latitude of Derrynadarragh windfarm is 53.2 degrees (at its most northerly point). This value was entered into the calculation excel which then automatically calculated the total daylight hours per month for the windfarm site. The number of proposed turbines for the site is 9 and this value was also entered into the calculation excel.

2.2.1 Turbine Data

The turbine model used to inform the CRM is the Vestas V-162. The turbine parameters as per the manufacturer's specifications are presented in Table 2 were used in the CRM. Blade profile

data (a separate sheet in the calculation excel) were not altered and default values were used, as the specific data for the turbine model was not available.

Table 2: Turbine parameters for the proposed turbine model at Derrynadarragh Wind Farm.

Turbine Model	V-162 (Vestas)
Number of turbines	9
Hub height	105m
Rotor radius	81m
Number of blades	3
Rotation speed[4]	12.1rpm
Maximum blade width	4.3m
Blade pitch	15 degrees[5]

2.3 STAGES OF COLLISION RISK ASESSMENT

The five stages (A to E) involved in CRM (as per Band 2024) are as follows:

Stage A Flight Activity:

Vantage point survey data of birds flying in the study area are used to determine the density of birds flying in the vicinity of the proposed turbines and the proportion flying at risk height (between the lowest and highest points of the rotors).

Bird Density

Two years of survey data (October 2021 – September 2023) were used for this CRM analysis. Data was collected at dedicated vantage point (VP) locations overlooking the proposed windfarm site as illustrated in Figure 1 above. A total of 162 hours of survey effort was carried out at VP1 and VP2 individually over the entire survey period. The total survey effort at VP3 was 120 hours. The survey effort at VP3 was lower than that at VP1 and VP2 as VP3 was only established in Summer 2022. Survey effort per season is summarised in Table 3.

The three VP locations afforded views over the proposed wind farm site and a 500 m buffer around each proposed turbine. The viewshed from each VP is illustrated in Figure 2 - Figure 4 below. The viewsheds were determined by surveyors and confirmed using spatial analyst GIS software tools. Both a 0m (ground level) and 20m (above ground level) viewshed were established for each VP. The viewsheds were used to calculate the area visible from each VP. The cumulative coverage of the survey area by the 20m elevation viewshed from all VPs is illustrated in Figure 5 below.

[4] *The dynamic operation range (the rate at which the blades rotate) of the turbines is approximately 4-12.1 revolutions per minute (rpm) which is influenced by wind speed. Taking a precautionary approach the higher rate of 12.1 is used in the CRM.*

[5] *A pitch value of 15 degrees was used as this is accepted as a recognised average when a turbine is operating at around its mean rotational speed (Band 2024).*

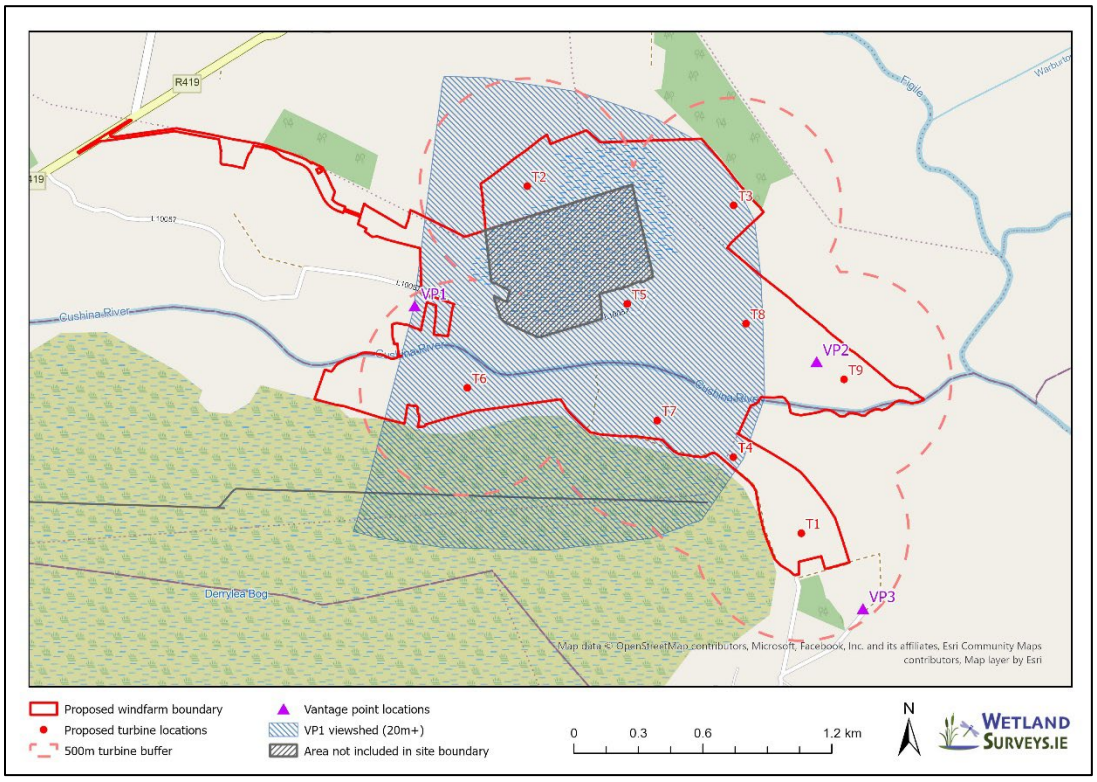

Figure 2: Viewshed from VP1 (20m height).

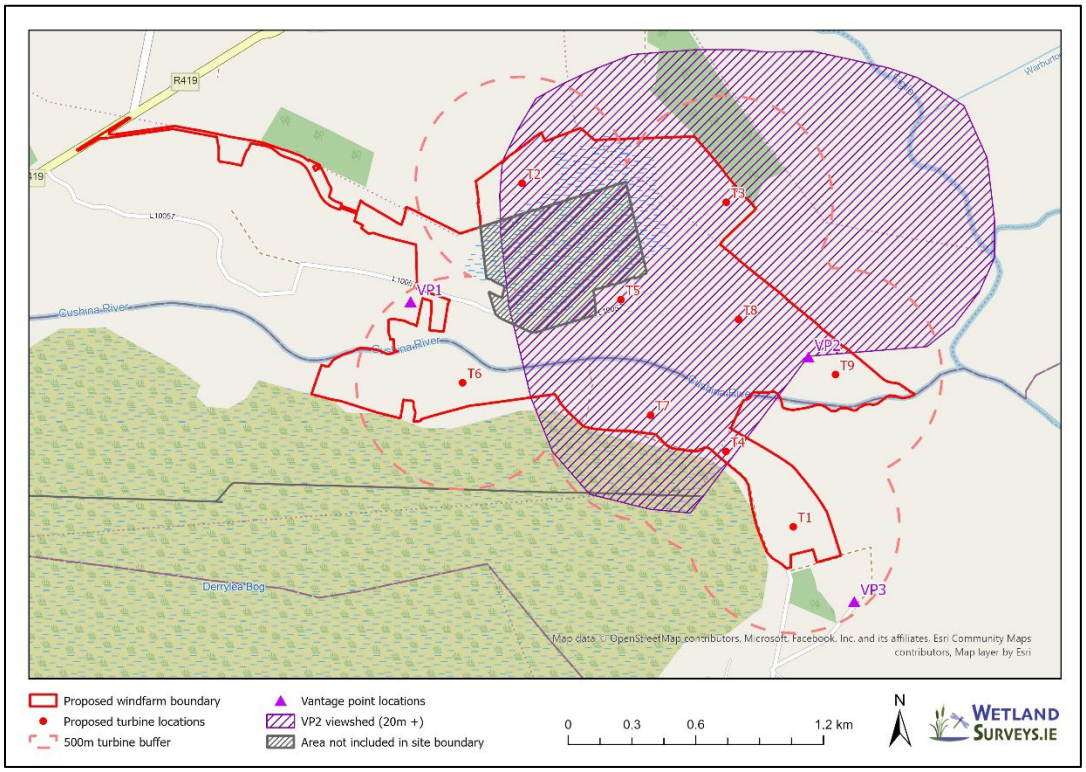

Figure 3: Viewshed from VP2 (20m height).

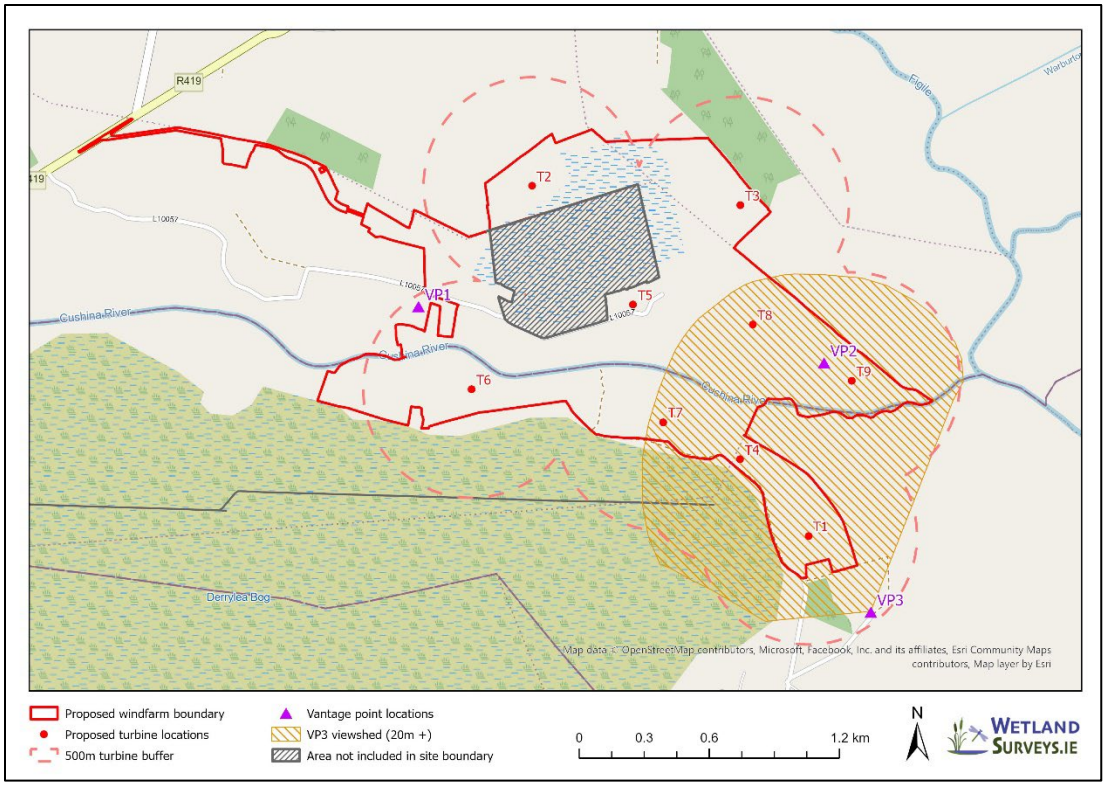

Figure 4: Viewshed from VP3 (20m height).

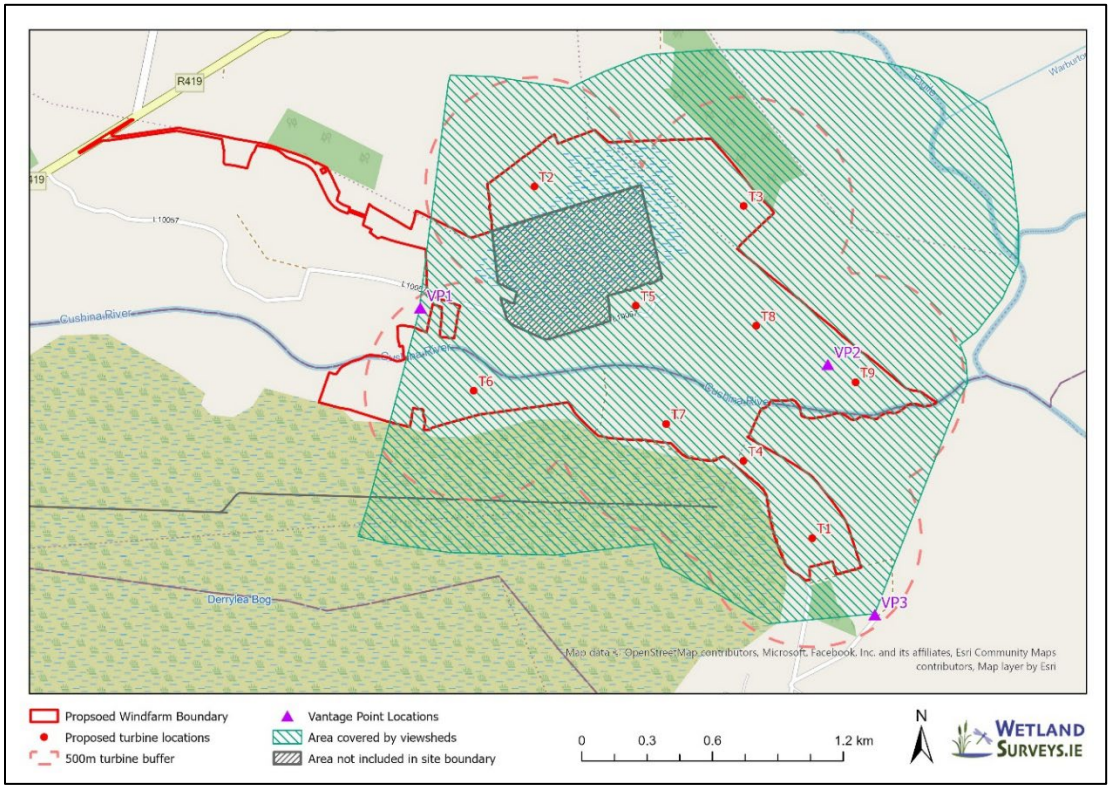

Figure 5: Overall coverage of study area by three VP viewsheds (20m height).

Table 3: Details of vantage point watches carried out at Derrynadarragh Wind Farm

	Viewshed area (km^2)	Seasonal surveys	Total survey effort (hrs)	VP Location
VP1	3.24	Winter (Oct 21 – Mar 22): 36hrs Summer (Apr – Sep 22): 36hrs Winter (Oct 22 – Mar 23): 54hrs Summer (Apr – Sep 23): 36hrs	162	658138, 716055
VP2	3.65	Winter (Oct 21 – Mar 22): 36hrs Summer (Apr – Sep 22): 36hrs Winter (Oct 22 – Mar 23): 48hrs Summer (Apr – Sep 23): 42hrs	162	660008, 715795
VP3	1.79	Winter (Oct 21 – Mar 22): na Summer (Apr – Sep 22): 36hrs Winter (Oct 22 – Mar 23): 42hrs Summer (Apr – Sep 23): 42hrs	120	660224, 714647

** VP3 has a lower survey effort compared to VP1 and VP2 as it was not established until April 2022*

** A number of additional watches were undertaken during winter 2022-23 and summer 2023 to increase coverage of the Spring and Autumn migration periods.*

Flightlines were recorded during each VP survey, noting the species of bird, number of individuals and time spent flying at various height bands[6]. Any flightlines that occurred entirely outside of the relevant viewshed were excluded from the analysis. Flightlines that partly occurred within the relevant viewshed were clipped to the viewshed and the duration of the flight was recalculated using the proportion of the original flightline occurring within the viewshed. This recalculation assumes that flight height distribution and flight speed were similar in the segments inside and outside of the viewshed.

Multiplying the number of birds by the time recorded flying for each species of interest provided the total flying time for that species during a given season in bird-seconds. This total flying time was then divided by the total watch time (s) and the area surveyed (viewshed) (km^2) to calculate the average density of birds in flight per km^2.

Vantage Point data was aggregated into two periods: winter season (October - March) and breeding season (April – September) for each year following the approach used in Band (2024). In the case of Golden Plover and Whooper Swan, which are present only during winter, the relevant periods which correspond with their presence in the study area are September to April and October to March respectively, and these periods have been used for the purposes of CRM. As there is no major difference in habitat covered by each of the VP locations, the data for all VPs were also aggregated. There were variations in the level of flight activity recorded for individual species between years, however activity was not consistently higher in one year for all

[6] Three flight bands were used to record flightlines during bird surveys at Derrynadarragh: 0-25m, 25-180m, and >180m

species. Therefore, data for the two years at all VPs was aggregated, resulting in mean bird density values for the winter season and the breeding season. These average values were used to populate daytime bird density values in the calculation excel for their corresponding months. Calculations for bird density are presented in Appendix I.

Proportion flying at risk height

In order to determine the proportion of birds flying at risk height the proportion of flight time recorded within each of the flight height bands is calculated using the height range of the proposed turbine model.

The risk height range of the selected turbine is 24-186m above ground. The following flight bands were used to record flightlines during VP surveys: Band A: 0-25m, Band B: 25-180m, and Band C >180m. These bands were established in advance of knowing the turbine dimensions and hence the risk height range differs slightly from Band B. In order to determine the proportion of birds within B and A and Band C that may be at height risk, a proportion of flights in each band were assigned as occurring within the flight risk height.

It is assumed that flight heights were distributed uniformly within each of the height bands that were used to record flightline data.

An upper ceiling of 400m was applied to Band C as this is likely to represent the upper height that most birds were observed. The risk height range for the proposed turbine models is 24-186m (hub height = 105m and rotor radius = 81m). For the flight height bands used, 1m of the rotor height span falls within the 0-25m band, 155m falls within the 25-180m band, and 6m falls within the 180-400m band. The flight time recorded within each flight height band for each species was expressed as a percentage of the total flight time for each species to determine the proportion of time spent within each flight height band for each species. This value was then multiplied by the proportion of the rotor height within the flight band, and this value for each flight band was summed to obtain the total proportion of flights falling within rotor risk height. The outcome of these calculations are presented in Table 6.

Stage B Number of flights through rotors: *Using bird density and proportion of birds at risk height (Stage A), an estimate is made of the number of bird passages through the turbine rotors over a given time period. At this stage it is assumed that birds will continue to make flights within the windfarm area at the same intensity as prior to the establishment of the windfarm.*

The potential number of flights through turbine rotors depends on turbine size. The rotor radius for turbines is 81m and nine turbines are proposed for the site. Bird flight speed is also required for this calculation. Values for each species were obtained from Alerstam *et al.* (2007).

The result of this calculation at stage B as produced by the excel spreadsheet is the projected number of rotor transits per month and per year. Projected number of transits per year are presented in Table 7.

Stage C Probability of collision for a single transit: *The probability of a collision during a single rotor transit by a bird is calculated.*

In this stage, the projected number of rotor transits calculated in Stage B are used to determine the single transit collision risk for each target species as presented in Table 7.

Stage D Expected collisions per year: *The outputs of Stage B and Stage C are multiplied to give the potential collision rate for each bird species. Current levels of bird usage at the site are still assumed at this stage, but an adjustment is made to allow for the amount of time that the turbines are operational.*

In this case a value of 85% was used as the actual percentage of operational time for the proposed windfarm site is unknown. It is known that wind turbines are not active 100% of the time and 85% is seen as an upper limit for time that a wind turbine is typically active (Wind Europe).

Stage E Allowing for avoidance and attraction: *This stage takes into account the proportion of birds likely to avoid the windfarm or turbines, either due to displacement, evasive action, or attraction to the windfarm site.*

For this part of the CRM analysis avoidance rates as presented in SNH (2018) were used (see Table 1). An exception however is in relation to Golden Plover, rather than applying the default 98% avoidance rate, a species specific rate of 99.8% was used. This approach is informed by a study by Gittings (2022) based on a review of collision data relating to four onshore wind farms.

In the case of all target bird species it was assumed that there is no reason for the proposed windfarm site to attract a higher number of species than that already present.

As the proposed windfarm comprises nine turbines, the large array correction was not applied (required for sites with 50 turbines or more).

Birds on Migration

There were peak counts of Golden Plover recorded around the Autumn migration period in both years with a flock of 4,000 birds observed in Autumn 2022. It was determined that the flights did not represent migration flights but represent staging behaviour. The migration approach was therefore not applied to the bird observations at the site.

3 RESULTS

A total of 13 target bird species were recorded during VP watches (Table 4).

Table 4: Bird species recorded during VP watches at the proposed Derrynadarragh Wind Farm. Annex I refers to whether the species is listed in Annex I of the EU Birds Directive.

Species	Conservation Status	Annex I
Buzzard	Green Listed	No
Curlew	Red Listed	No
Golden Plover	Red Listed	Yes
Hen Harrier	Amber Listed	Yes
Kestrel	Red Listed	No
Mallard	Amber Listed	No
Lapwing	Red Listed	No
Merlin	Amber Listed	Yes
Peregrine	Green Listed	Yes
Snipe	Red Listed	No
Sparrowhawk	Green Listed	No
Whooper Swan	Amber Listed	Yes
Woodcock	Red Listed	No

The average bird density value calculated for each species recorded during VP watches is presented in Table 5 below.

Table 5: Average bird density (birds / km^2) of bird species recorded during VP watches at the proposed Derrynadarragh Wind Farm

Species	*Winter average*	*Breeding average*	Birds / km^2 (all year)
Buzzard	0.00165	0.0027	0.00431
Curlew	0.00000	0.0002	0.00019
Golden Plover (winter only)	5.01733	*n/a*	5.01733
Hen Harrier	0.00006	0.0000	0.00006
Kestrel	0.00125	0.0002	0.00147
Lapwing	0.00719	0.0000	0.00719
Mallard	0.00001	0.0000	0.00001
Merlin	0.00002	0.0000	0.00002
Peregrine	0.00002	0.0000	0.00002
Snipe	0.00020	0.0000	0.00022
Sparrowhawk	0.00017	0.0001	0.00030
Whooper Swan	0.00017	*n/a*	0.00017
Woodcock	0.00001	0.0000	0.00001

Summary results for the calculation of proportion of birds at risk height are presented in Table 6 below (for more details see Appendix III) and were input as Proportion at risk height (Q_{2R}) for each species in the excel spreadsheet.

Table 6: Proportion of birds flying at risk height

Species	Proportion at risk height (24-186m)
Buzzard	57.0
Curlew	59.7
Golden Plover (winter only)	59.8
Hen Harrier	54.0
Kestrel	50.6
Lapwing	29.5
Mallard	100.0
Merlin	20.7
Peregrine	71.9
Snipe	76.1
Sparrowhawk	4.9
Whooper Swan	68.6
Woodcock	36.0

The outcome of the collision risk modelling (number of expected collisions per year with avoidance behaviour) is presented in Table 7. All input data and calculations are presented in Appendix I-III.

Table 7: Expected number of collisions per year (assuming avoidance behaviour) for bird species at the proposed Derrynadarragh Wind Farm.

Species	Projected number of rotor transits per year	Collision Risk (single transit risk)			Annual Collision Rate			Estimated collisions over a 30-year period
		Flapping	Gliding	Average	Without avoidance	Avoidance rate	With avoidance	
Buzzard	281	6.87	6.8	6.84	16	98	0.3	9
Curlew	22	5.53	5.47	5.5	1.03	98	0.021	0.63
Golden Plover (Sep - Apr)	566,588	4.96	N/A	N/A	23878	98.6	47.8	1,434
Hen Harrier	2	7.85	7.8	7.83	0.14	99	0.001	0.03
Kestrel	57	6.37	6.32	6.35	3	95	0.2	6
Lapwing	267	5.28	N/A	N/A	12	98	0.2	6
Mallard	1	5.26	N/a	N/A	0.06	98	0.001	0.03
Merlin	0	0	0	0	0.02	98	0.0003	0.0009
Peregrine	1	6.21	6.14	6.18	0.06	98	0.001	0.03
Snipe	26	4.3	4.27	4.29	0.93	98	0.019	0.57
Sparrowhawk	1	5.8	5.76	5.78	0.06	98	0.001	0.03
Whooper Swan (Oct - Mar)	14	8.82	n/a	N/A	1.07	99.5	0.005	0.15
Woodcock	0	4.62	4.57	4.6	0.02	98	0.0003	0.0009

3.1 OVERVIEW OF UNCERTAINTIES

It should be noted that CRM makes the following assumptions:

- That a bird can be modelled by a simple cruciform shape
- That a turbine blade has a width and pitch, but no thickness
- That birds fly through turbines in straight lines
- That a bird's flight will be unaffected by a near miss, despite the slipstream around a turbine blade
- That no action is taken by a bird to avoid collision and so the figures represent worst case scenarios.

It is also accepted that there are uncertainties with the input data which should be considered to give an overall level of uncertainty regarding the estimated collision risk. Following Band (2024) there are five error sources within collision risk modelling:

1. **Uncertainty in bird density (e_1)**

Survey data shows that there are variations in bird density between surveys.

The standard deviation of survey results has been calculated for the winter and breeding seasons. The square root of the sum of these values was then determined to allow for the fact that errors in one season may be offset by errors in the other direction in the other period. This standard deviation value was then applied to the sum of the average bird density values for the winter and breeding seasons to determine the associated percentage value and e value as presented in Table 8.

Table 8: Uncertainty value associated with bird density for each target species.

Species	e_1 value
Buzzard	0.07
Curlew	0.01
Golden Plover	1.59
Hen Harrier	0.01
Kestrel	0.04
Lapwing	0.06
Mallard	0.00
Merlin	0.00
Peregrine	0.00
Snipe	0.01
Sparrowhawk	0.02
Whooper Swan	0.01
Woodcock	0.00

2. Uncertainty in level of nocturnal activity (e_2)

The actual nocturnal activity of bird species is unknown due to the absence of nighttime survey data.

The number of daylight hours used in the calculation is assumed to be accurate. However there is uncertainty regarding nocturnal activity. It was assumed that none of the target species were active at night, with the exception of Golden Plover, Snipe, and Lapwing, which were assumed to be 25% as active at night as during the day (nocturnal activity factor = 2 in the excel spreadsheet). While it cannot be entirely ruled out due to the absence of data, it is not seen that it would be greater than 5%. Therefore the level of uncertainty for all species is e_2=0.05, with the exception of Golden Plover, Lapwing and Snipe where e_2=0 (as nocturnal activity is already accounted for in the calculations for this species.

3. Uncertainty in proportion flying at risk height (e_3)

Despite bird surveyors being fully trained and very experienced, it is possible that bird flights can be recorded within the wrong flight height bands.

In particular, it is possible that birds recorded in the 0-25m flight band may actually have been in the 25-180m flight band and vice versa. If the visual estimate was out by ±5m at the two lowest flight bands this would have implications for the proportion of birds flying at risk height for the proposed turbine model. The flight patterns of raptors and Whooper Swan make it unlikely that there would be errors in recording flight heights, so a low uncertainty level (e_3 = 0.05) has been assigned to these species, with a slightly higher uncertainty level (e_3 = 0.1) being assigned to the remaining species (Curlew, Golden Plover, Lapwing, Snipe).

4. Uncertainty in estimating numbers of individuals in large flocks (e_4)

Some species of birds often fly in large flocks, making an accurate estimation of the number of individuals present in the flock difficult.

Golden Plover was the only species recorded in large flocks during vantage point watches with a maximum of 4,000 birds recorded in one flock. Given the large size and mobile nature of these flocks it is likely that under or overestimates regarding the number of birds were made. Lapwing was the only other bird species recorded in significant flocks (maximum of 150 birds). Given the smaller size of the flocks there is less chance of uncertainty regarding the estimate, however a small level of uncertainty does remain.

For all other target bird species an uncertainty value of e_4 = 0 was assigned as these species typically occur singly or in very low numbers, eliminating the chance of making an incorrect estimate of numbers. For Lapwing, an uncertainty of 5% (e_4 = 0.05) was assigned due to the occurrence of some smaller flocks. The very large numbers of Golden Plover increases the

uncertainty of making accurate estimates of numbers, therefore an uncertainty of 20% (e_4 = 0.20) is assigned to Golden Plover.

5. **Uncertainty due to distance effects (e_5)**

It has been found that higher densities of flightlines are recorded in proximity to vantage point locations, while very few flightlines are recorded in the more distant parts of viewsheds.

Analysis of vantage point data has revealed that there are very strong distance effects on bird detection rates with very low detection rates at distances over 1km from the vantage point location. It has been suggested that correcting for under-detection due to distance could increase collision risk by a factor of 1.6 – 6.3 times (Gittings 2024). Three vantage points were used to gain comprehensive views over the proposed wind farm site, with some overlap in viewshed areas. In addition, the furthest limit of the 500m turbine buffer from each vantage point location is not greater than 1.5km, increasing the likelihood of all birds being recorded. The underestimation of bird activity at the outer limits of the viewsheds is estimated to be approximately 15% (reduced from the estimates provided by Gittings (2024)) due to the presence of three vantage points with some overlap in viewsheds and the proximity of the vantage points to the outer limits of the 500m turbine buffers. Therefore, e_5 = 0.15 for all target species, with the exception of Whooper Swan and Golden Plover. The large size of Whooper Swan and the large flock size of Golden Plover reduce the chance of under recording these species, even at the outer limits of a viewshed. Therefore the uncertainty for this species is reduced to 5% (e_5 = 0.05) for these two species.

6. **Uncertainty in operational time (e_6)**

An estimate of the operational time of the turbines is used as the actual operational time is unknown

A value of 85% was used in the calculation as an upper limit of operational time as provided by Wind Energy Europe. Although this value is subject to some variation it is reasonably precise and so no uncertainty is assigned (e_6=0 for all species).

7. **Uncertainty due to simplifications in the model (e_7)**

The collision risk model involves a number of simplifications such as assuming that a bird can be modelled by a simple cruciform shape, that birds fly through turbines in straight lines, and the use of an average pitch for turbine blades.

Following the worked example presented in Band (2024) an uncertainty of ± 20% is assumed (e_7=0.20 for all species).

The combined uncertainty values for each target species and each proposed turbine model is presented in Table 9 below. These uncertainty values can be applied to the relevant calculated collision risk values presented in Table 10.

Table 9: Combined uncertainty values for each target species.

Species	1	2	3	4	5	6	7	Combined uncertainty value (factor)
Buzzard	0.07	0.05	0.05	0	0.15	0	0.2	0.52
Curlew	0.01	0.05	0.1	0	0.15	0	0.2	0.51
Golden Plover	1.59	0	0.1	0.2	0.05	0	0.2	2.14
Hen Harrier	0.01	0.05	0.05	0	0.15	0	0.2	0.46
Kestrel	0.04	0.05	0.05	0	0.15	0	0.2	0.49
Lapwing	0.06	0	0.1	0	0.15	0	0.2	0.51
Mallard	0.00	0.05	0.05	0	0.15	0	0.2	0.45
Merlin	0.00	0.05	0.1	0	0.15	0	0.2	0.5
Peregrine	0.00	0.05	0.05	0	0.15	0	0.2	0.45
Snipe	0.01	0	0.1	0	0.15	0	0.2	0.46
Sparrowhawk	0.02	0.05	0.1	0	0.15	0	0.2	0.52
Whooper Swan	0.01	0.05	0.05	0	0.05	0	0.2	0.36
Woodcock	0.00	0.05	0.1	0	0.15	0	0.2	0.5

Table 10: Estimated number of collisions per year with uncertainty values

Species	Estimated number of collisions per year with avoidance and associated uncertainty values	
Buzzard	0.3 +/-	0.1560
Curlew	0.021 +/-	0.0107
Golden Plover	47.8 +/-	102.2920
Hen Harrier	0.001 +/-	0.0005
Kestrel	0.2 +/-	0.0980
Lapwing	0.2 +/-	0.1020
Mallard	0.001 +/-	0.0005
Merlin	0.0003 +/-	0.0002
Peregrine	0.001 +/-	0.0005
Snipe	0.019 +/-	0.0087
Sparrowhawk	0.001 +/-	0.0005
Whooper Swan	0.005 +/-	0.0018
Woodcock	0.0003 +/-	0.0002

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Appendix I

Calculating bird density for use in Stage A calculations

1. Total time in flight (bird seconds) for each target species recorded at each VP during the four surveys seasons

	Year 1						Year 2					
	Winter 1			Breeding 1			Winter 2			Breeding 2		
	VP1	VP2	VP3	VP1	VP2	VP3	VP1	VP2	VP3	VP1	VP2	VP3
Buzzard	1588	1325	0	2441	14	159	518	318	96	1299	2614	432
Curlew	0	0	0	0	0	264	0	0	0	0	0	0
Golden Plover (Sep to Apr)	17036	94800	0	0	0	0	17480	1624847	7936621	0	0	0
Hen Harrier	0	87	0	0	0	3	0	60	0	0	0	0
Kestrel	576	630	0	0	0	0	225	1664	155	159	456	17
Lapwing	14679	0	0	0	0	0	610	16	0	0	0	0
Mallard	0	0	0	0	0	0	38	0	0	0	0	0
Merlin	0	46	0	0	0	0	0	0	0	0	0	0
Peregrine	0	41	0	0	0	0	0	0	0	0	0	0
Snipe	91	44	0	0	0	0	427	0	0	0	7	41
Sparrowhawk	86	23	0	7	0	141	151	158	27	13	0	31
Whooper Swan (Oct to Mar)	0	204	0	0	0	0	253	0	0	0	0	0
Woodcock	0	15	0	0	0	0	7	0	0	0	0	0

2. Time in flight (total watch time divided by total watch time)

	Year 1						Year 2					
	Winter 1			Breeding 1			Winter 2			Breeding 2		
	VP1	VP2	VP3	VP1	VP2	VP3	VP1	VP2	VP3	VP1	VP2	VP3
Buzzard	0.0123	0.0102		0.0188	0.0001	0.0012	0.0027	0.0018	0.0006	0.0100	0.0173	0.0029
Curlew	0.0000	0.0000		0.0000	0.0000	0.0020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Golden Plover (Sep to Apr)	0.1052	0.5852		0.0000	0.0000	0.0000	0.0809	7.5224	40.8262	0.0000	0.0000	0.0000
Hen Harrier	0.0000	0.0007		0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000
Kestrel	0.0044	0.0049		0.0000	0.0000	0.0000	0.0012	0.0096	0.0010	0.0012	0.0030	0.0001
Lapwing	0.1133	0.0000		0.0000	0.0000	0.0000	0.0031	0.0001	0.0000	0.0000	0.0000	0.0000
Mallard	0.0000	0.0000		0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
Merlin	0.0000	0.0004		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Peregrine	0.0000	0.0003		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Snipe	0.0007	0.0003		0.0000	0.0000	0.0000	0.0022	0.0000	0.0000	0.0000	0.0000	0.0003
Sparrowhawk	0.0007	0.0002		0.0001	0.0000	0.0011	0.0008	0.0009	0.0002	0.0001	0.0000	0.0002
Whooper Swan (Oct to Mar)	0.0000	0.0016		0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000
Woodcock	0.0000	0.0001		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

3. Bird Density (time in flight divided by area)

	Year 1						Year 2					
	Winter 1			Breeding 1			Winter 2			Breeding 2		
	VP1	VP2	VP3	VP1	VP2	VP3	VP1	VP2	VP3	VP1	VP2	VP3
Buzzard	0.0038	0.0028		0.0058	0.0000	0.0007	0.0008	0.0005	0.0004	0.0031	0.0047	0.0016
Curlew	0.0000	0.0000		0.0000	0.0000	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Golden Plover (Sep to Apr)	0.0325	0.1603		0.0000	0.0000	0.0000	0.0250	2.0609	22.8080	0.0000	0.0000	0.0000
Hen Harrier	0.0000	0.0002		0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
Kestrel	0.0014	0.0013		0.0000	0.0000	0.0000	0.0004	0.0026	0.0006	0.0004	0.0008	0.0001
Lapwing	0.0350	0.0000		0.0000	0.0000	0.0000	0.0010	0.0000	0.0000	0.0000	0.0000	0.0000
Mallard	0.0000	0.0000		0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
Merlin	0.0000	0.0001		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Peregrine	0.0000	0.0001		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Snipe	0.0002	0.0001		0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0002
Sparrowhawk	0.0002	0.0000		0.0000	0.0000	0.0006	0.0002	0.0003	0.0001	0.0000	0.0000	0.0001
Whooper Swan (Oct to Mar)	0.0000	0.0004		0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000
Woodcock	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

4. Mean bird density according to season for birds recorded during Vantage Point watches

	Winter season		Breeding Season	
	Average	Standard Deviation	Average	Standard Deviation
Buzzard	0.00165	0.00154	0.0027	0.00230
Curlew	0.00000	0.00000	0.0002	0.00046
Kestrel	5.01733	9.98261	0.0000	0.00000
Golden Plover	0.00006	0.00008	0.0000	0.00001
Hen Harrier	0.00125	0.00090	0.0002	0.00034
Lapwing	0.00719	0.01553	0.0000	0.00000
Mallard	0.00001	0.00003	0.0000	0.00000
Merlin	0.00002	0.00004	0.0000	0.00000
Peregrine	0.00002	0.00004	0.0000	0.00000
Snipe	0.00020	0.00028	0.0000	0.00006
Sparrowhawk	0.00017	0.00009	0.0001	0.00024
Whooper Swan	0.00017	0.00023	0.0000	0.00000
Woodcock	0.00001	0.00001	0.0000	0.00000

Appendix II

Calculations for proportion of birds flying at risk height for use in Stage A calculations

Species	Proportion observed 0-25m	Proportion observed 25-180m	Proportion observed 180-200m	At Rotor Height			Proportion between 24-186m (based on proportion of flight time in risk zone) as percentage
				Proportion of birds at >24 in Band A	Proportion in flight band B (25-180)	Proportion of birds at <185 in Band C	
Buzzard	6	57	37	0.3	55.7	1.0	57.0
Curlew	0	59	41	0.0	58.6	1.1	59.7
Golden Plover	0	55	45	0.0	58.7	1.1	59.8
Hen Harrier	48	52	0	1.9	52.1	0.0	54.0
Kestrel	42	51	7	1.8	48.6	0.2	50.6
Lapwing	0.5	5	94.5	0.1	27.5	1.9	29.5
Mallard	0	100	0	0.0	100.0	0.0	100.0
Merlin	83	17	0	3.3	17.4	0.0	20.7
Peregrine	19	71	10	0.8	70.9	0.3	71.9
Snipe	33	65	2	0.9	75.1	0.0	76.1
Sparrowhawk	34	2	64	1.6	1.7	1.6	4.9
Whooper Swan	21	79	0	1.3	67.3	0.0	68.6
Woodcock	67	33	0	2.7	33.3	0.0	36.0

Appendix III

Collision probability

Outcome of Stage A – Stage E in collision risk model

Species	Projected number of rotor transits per year	Collision Risk (single transit risk)			Annual Collision Rate			Estimated collisions over a 30-year period
		Flapping	Gliding	Average	Without avoidance	Avoidance rate %	With avoidance	
Buzzard	281	6.87	6.8	6.84	16	98	0.3 ± 0.1560	9 ± 4.68
Curlew	22	5.53	5.47	5.5	1.03	98	0.021 ± 0.0107	0.63 ± 0.32
Golden Plover	566,588	4.96	N/A	N/A	23878	98.6	47.8 ± 102	1,434 ± 3068
Hen Harrier	2	7.85	7.8	7.83	0.14	99	0.001 ± 0.0005	0.03 ± 0.01
Kestrel	57	6.37	6.32	6.35	3	95	0.2 ± 0.0980	6 ± 2.94
Lapwing	267	5.28	N/A	N/A	12	98	0.2 ± 0.1020	6 ± 3.06
Mallard	1	5.26	N/a	N/A	0.06	98	0.001 ± 0.0005	0.03 ± 0.01
Merlin	0	0	0	0	0.02	98	0.0003 ± 0.0002	0.001 ± 0.00
Peregrine	1	6.21	6.14	6.18	0.06	98	0.001 ± 0.0005	0.03 ± 0.01
Snipe	26	4.3	4.27	4.29	0.93	98	0.019 ± 0.0087	0.57 ± 0.26
Sparrowhawk	1	5.8	5.76	5.78	0.06	98	0.001 ± 0.0005	0.03 ± 0.02
Whooper Swan	14	8.82	n/a	N/A	1.07	99.5	0.005 ± 0.0018	0.15 ± 0.05
Woodcock	0	4.62	4.57	4.6	0.02	98	0.0003 ± 0.0002	0.0009 ± 0.00